INTRODUCTION TO PLANT ANATOMY

Plant anatomy or phytotomy is the general study of the internal structure of plants (shape, structure, and size). Originally it included plant morphology, the description of the physical form and external structure of plants, but since the mid-20th century plant anatomy has been considered a separate field referring only to internal plant structure. Plant anatomy is now frequently investigated at the cellular level, and often involves the sectioning of tissues and microscopy.

Some studies of plant anatomy use a systems approach, organized on the basis of the plant's activities, such as nutrient transport, flowering, pollination, embryogenesis or seed development. Others are more classically divided into the following structural categories:

A- Flower anatomy : including study of the Calyx, Corolla, Androecium, and Gynoecium.

B- Leaf anatomy : including study of the Epidermis, stomata and Palisade cells.

C- Stem anatomy : including stem structure and vascular tissues buds and shoot apex.

D- Fruit/Seed anatomy : including structure of the ovule, seed, Pericarp and Accessory fruit.

E- Wood anatomy : including structure of the Bark, Cork, Xylem, Phloem, Vascular cambium, Heartwood and sapwood and branch collar,

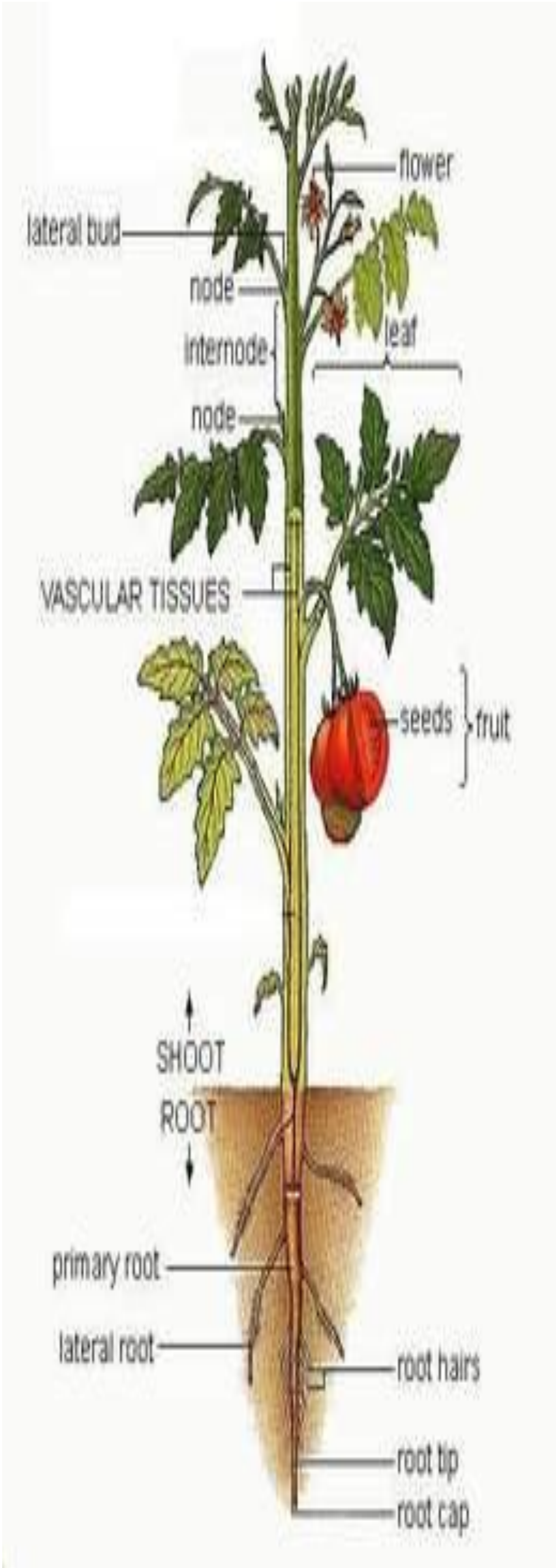
F- Root anatomy : including Structure of the root, Root tip, Endodermis.

Because of plant anatomy as a part of botany (the study of plants), and It is focuses on the structural or body parts and systems that make up a plant, thus a typical plant body consists of three major vegetative organs: the root, the stem, and the leaf, as well as a set of reproductive parts of that include flowers, fruits, and seeds.

1- THE ROOTS

A plant's roots, like the foundation of a skyscraper, help it to stay upright. They also absorb water and dissolved minerals from the ground and give the plant what it needs to make its own food. Most roots grow underground and move downward because of the influence of gravity, although the roots of some water plants float. Other root systems, like that of the English ivy, actually attach themselves to a vertical surface and allow the plant to climb. There are two main types of root systems: taproot and fibrous. Plants that have taproots grow a single, long root that penetrates straight down and firmly anchors the plant.

Trees and dandelions have taproots that serve this function. Fibrous roots are shorter and more shallow and form a branching network. Grass has a fibrous root system that grows at a shallow level and in all directions. Inside a root are pipelines or veins that carry water and minerals to the rest of the plant. These pipes are concentrated in the center of the root, like the lead in the center of a pencil. At the end of each root is a cap that protects it as it pushes farther into the soil. Extending from the sides of the root, but further back from the root cap are root hairs. These hairs are the main water and oxygen absorbing parts of a plant. Materials enter and leave roots by two main processes: diffusion and osmosis. When molecules are distributed unequally, nature always seeks a balance and molecules will move from an area of high concentration to one of low concentration. When the cells of a root hair have little oxygen and the soil around the root hair has a lot, oxygen will move from the soil to the root automatically without the plant having to expend any energy. Osmosis is a similar situation (from high to low concentration), but it occurs when molecules, like those of water, move across a membrane that will not allow other materials to pass. Like diffusion, osmosis does not require the plant to use any energy.



2- THE STEMS

Plant stems perform two functions. They support the parts of the plant aboveground (usually the buds, leaves, and flowers), and they carry water and food from place to place within the plant itself. A stem is made up of an outer layer, the epidermis; an inner layer, the cortex; and a central zone called the pith. The stem of a green plant holds itself up by having thousands of cells lined up next to and on top of each other. As the cells take in water, they expand like a full balloon, and since their walls are elastic, they stretch very tight against each other and against the stem wall. It is their pressure that holds the stem up. A plant droops when its cells lack water and have begun to shrink. Woody plants, like trees, also contain a material called lignin that strengthen cell walls and make them more rigid. A plant's stem also functions as its circulatory system and uses what is called vascular tissue to form long tubes through which materials move from the roots to the leaves and from the leaves to the roots.

3- THE LEAVES

A leaf (plural leaves) is the principal lateral appendage of the vascular plant stem usually borne above ground and specialized for photosynthesis. The leaves and stem together form the shoot. Leaves are collectively referred to as foliage, as in "autumn foliage". In most leaves, the primary photosynthetic tissue, the palisade mesophyll, is located on the upper side of the blade or lamina of the leaf but in some species, including the mature foliage of *Eucalyptus*, palisade mesophyll is present on both sides and the leaves are said to be isobilateral. Most leaves are flattened and have distinct upper (*adaxial*) and lower (*abaxial*) surfaces that differ in color, hairiness, the number of stomata (pores that intake and output gases), the amount and structure of epicuticular wax and other features. Leaves are mostly green in color due to the presence of a compound called chlorophyll that is essential for photosynthesis as it absorbs light energy from the sun. A leaf with white patches or edges is called a variegated leaf.

Leaves can have many different shapes, sizes, and textures. The broad, flat leaves with complex venation of flowering plants are known as *megaphylls* and the species that bear them, the majority, as broad-leaved or megaphyllous plants. In the clubmosses, with different evolutionary origins, the leaves are simple (with only a single vein) and are known as microphylls. Some leaves, such as bulb scales, are not above ground. In many aquatic species, the leaves are submerged in water. Succulent plants often have thick juicy leaves, but some leaves are without major photosynthetic function and may be dead at maturity, as in some cataphylls and spines. Furthermore, several kinds of leaf-like structures found in vascular plants are not totally homologous with them. Examples include flattened plant stems called phylloclades and cladodes, and flattened leaf stems called phyllodes which differ from leaves both in their structure and origin. Some structures of non-vascular plants look and function much like leaves. Examples include the phyllids of mosses and liverworts.

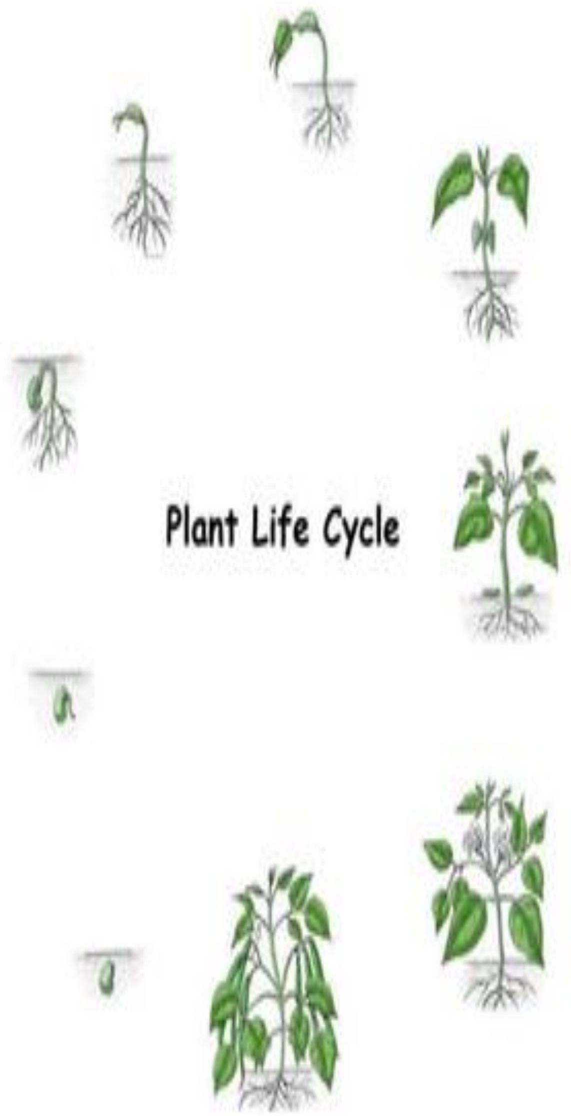
4- FLOWERS AND SEEDS

The reproductive part of a seed-producing plant is called the flower. Flowers have male and female cells that produce a seed when they unite. The stamen is the male reproductive organ in a flower and contains the male cells (pollen) in its anther that grows at the tip of its long, narrow stalk. The pistil is the female reproductive organ and looks like a long-necked bottle. It has a round base containing the ovary, a slender tube or long neck called the style, and a flattened, sticky top called the stigma. Once a flower opens, its petals (which are a type of leaf) protect the sex organs and serve to help pollination (the transfer of pollen to the female parts) by attracting animals like bees and birds. When this happens, fertilization occurs and the ovaries become seeds.

Seeds have three main parts: the coat, the embryo, and the food storage tissue. The coat protects the embryo, which is the beginning of a plant and grows by using food stored in the seed. Most seeds are enclosed in fruit that can be dry like a ripe bean pod, or fleshy like an apple or a peach. Other plants, like fir trees, have naked or uncovered seeds that form on the upper side of the scales that make up a pine cone. All are designed to be scattered as far as possible from the parent plant to ensure the further survival of the species.

Plant life cycle

Germination Depending on the type of seed, it may or may not require soil or light to germinate. However, most all plants need water in order for this process to occur. As water is absorbed by the seed, it begins to expand or swell, eventually cracking or splitting the seed coat. Once germination occurs, the new plant will gradually begin to emerge. The root, which anchors the plant to the soil, grows downward. This also enables the plant to take up water and nutrients required for growth. The shoot then grows upward as it reaches for light. Once the shoot reaches the surface, it becomes a sprout. The sprout will eventually take on a green color (chlorophyll) upon developing its first leaves, at which time the plant becomes a seedling.



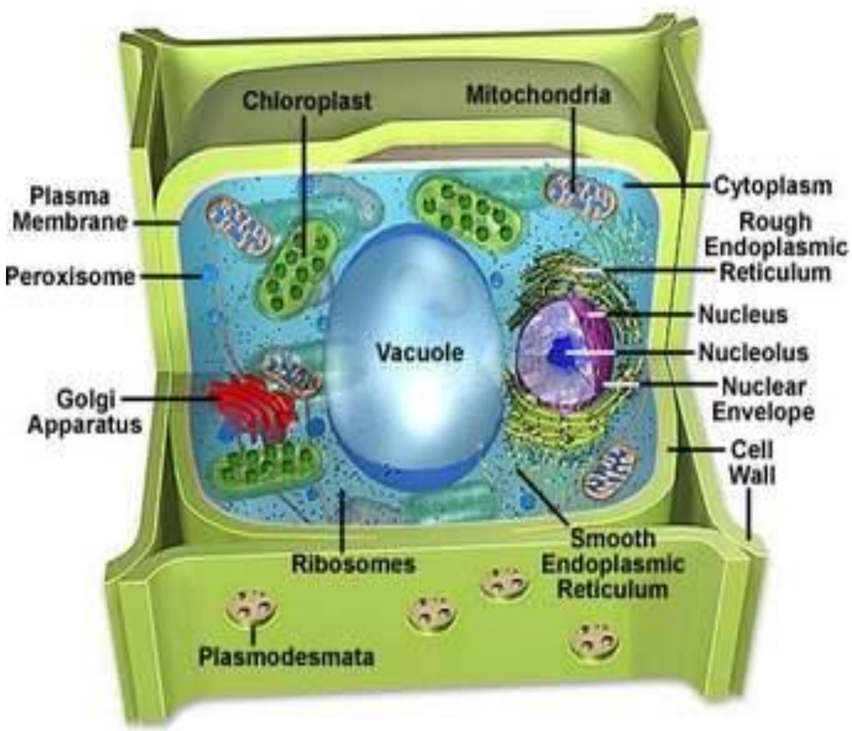
Basic Plant Life Cycle: Seedlings, Flowers, & Pollination Once the seedling develops these first leaves, it is able to make its own food through photosynthesis. Light is important for this process to occur, as this is where the plant gets its energy. As it grows and becomes stronger, the seedling changes into a young adult plant, with many leaves. Over time, the young plant will begin to produce buds at the growing tips. These will eventually open up into flowers. Pollination must occur in order for fertilization to happen, which creates new seeds.

The flowers transform into fruiting bodies, which protect the numerous seeds that are inside. As the seeds mature or ripen, the flowers will eventually fade away or drop. Once the seeds have dried, they are ready to be planted (or stored), repeating the life cycle of a flowering plant all over again.

PLANT CELL STRUCTURE

Plant cell is the structural and functional unit in plant. The cell consist of two main parts :

1- Cell wall
2- Protoplast



Protoplasts are spherical naked plant cells produced by the removal of the cell wall with digestive enzymes. They are usually derived from either leaf tissue or from cell suspension cultures and have been isolated from a wide variety of plant species.

The cytoplasm along with the cellular organelles is called protoplasm i.e., protoplasm = Cytoplasm + nucleus. It does not include cell membrane or cell wall. Protoplast is the living part of cell and does not include the cell wall. Protoplast = cell membrane + cytoplasm + nucleus.

I- Cell Membrane Function and Structure

The cell membrane (plasma membrane) is a thin semi-permeable membrane that surrounds the cytoplasm of a cell. Its function is to protect the integrity of the interior of the cell by allowing certain substances into the cell while keeping other substances out. It also serves as a base of attachment for the cytoskeleton in some organisms and the cell wall in others. Thus the cell membrane also serves to help support the cell and help maintain its shape.

Another function of the membrane is to regulate cell growth through the balance of endocytosis and exocytosis. In endocytosis, lipids and proteins are removed from the cell membrane as substances are internalized. In exocytosis, vesicles containing lipids and proteins fuse with the cell membrane increasing cell size. Animal cells, plant cells, prokaryotic cells, and fungal cells have plasma membranes. Internal organelles are also encased by membranes.

The cell membrane is primarily composed of a mix of proteins and lipids. Depending on the membrane's location and role in the body, lipids can make up anywhere from 20 to 80 percent of the membrane, with the remainder being proteins. While lipids help to give membranes their flexibility, proteins monitor and maintain the cell's chemical climate and assist in the transfer of molecules across the membrane.

II- Living Components of plant cell

The substance except nucleus surrounded by the plasma lemma of cell is known as cytoplasm. Its contains :

1- Endoplasmic reticulum

Cytoplasm contains an extensive network of membrane enclosed spaces; these spaces along with the membranes enclosing them are known as endoplasmic reticulum (ER).

2- Ribosomes

Ribosomes are particles of about 200 A° diameter; they are composed of RNA and protein. Generally ribosomes are attached to the outer surfaces of ER membranes. This converts smooth ER elements into rough ER.

3- Golgi body

It consists of 2-7 flat cisternae stacked close to each other. Golgi bodies originate from ER elements.

4- Lysosomes

Lysosomes are vesicles of 400-800 μm formed by budding of Golgi bodies and they contain hydrolytic enzymes.

The main enzyme present in lysosomes is acid phosphatase, other enzymes are acid DNAase, acid RNAase and β galactosidase etc.

5- **Mitochondria**

These are cylindrical bodies with an average diameter of 0.2 to 1 μ and ordinarily 3-10 μ in length.

6- Nucleus:

It is a denser, rounded or spherical protoplasmic body enclosed in the protoplasm. Its shape and size differs greatly according to size of cell. It is composed of following organelles:

a- Nuclear Membrane: Nucleus is bounded by a membrane on the outside called nuclear membrane, which is double walled and having numerous minute pores.
b- Nucleoplasm: It is viscous, non-staining, granular, colorless fluid inside the nuclear membrane. It is also known as nuclear sap or karyolymph.
c- Chromatin network: The threads like bodies forming a reticulum are suspended in nucleoplasm, which are network of chromosomes.
d- Nucleolus: A spherical round body usually single but may be double. It plays important role in protein synthesis. It is associated with a particular nuclear organizing chromosome.

7- Plastids

Plastids are the organelles which are peculiar to plant cells. Plastids that contain high concentration of carotenoid pigments are called 'chromoplasts'. They give yellow, orange and red colors to many fruits (tomato), roots (carrot) and flower petals.

Nonpigmented plastids are called 'leucoplasts'. An important type of leucoplast is 'amyoplast' which is a starch-storing plastid.

Chloroplasts are the plastids that contain green pigment, chlorophyll. They are found in green tissues of plant, especially leaf. They are absent in roots. The chloroplast is surrounded by the inner and outer membranes.

Chloroplasts also contain third system of membrane called thylakoid. All the chlorophyll is contained within this membrane, which is the site of light reactions of photosynthesis. Thylakoid membranes are highly folded and appear like stacked coins. These stacked membranes are known as grana lamellae (or grana thylakoid). The membranes without stacking are known as stroma lamellae (or stroma thylakoid). Each stack is called granum, the inner space within a thylakoid is known as lumen, the region of the chloroplast that is inside the inner membrane and surrounds thylakoids is known as stroma. The carbon reactions take place in stroma. Chloroplasts contain their own DNA and protein-synthesizing machinery. Chloroplast genome is smaller (145 kb) than mitochondrial genome (200 kb). Chloroplast DNA is circular and histone-free. Ribosomes occur free in stroma or bound to the outer surface of thylakoid membrane. As is mitochondria, most of the chloroplast's proteins are encoded by nuclear genes, synthesized in cytosol and transported to organelle.

III- Non-living components of plant cell

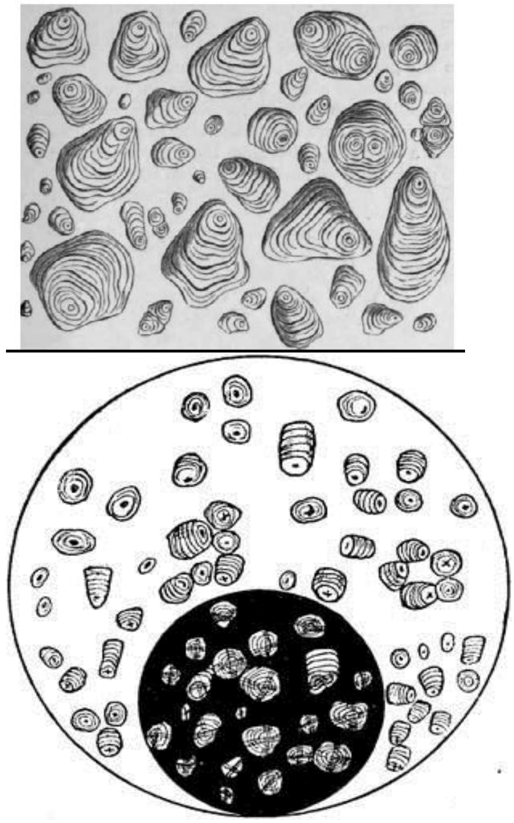
1-Vacuoles

Vacuoles are organelles bounded by a single membrane, the tonoplast, or vacuolar membrane. They are multifunctional organelles and are widely diverse in form, size, content, and functional dynamics. A single cell may contain more than one kind of vacuole. Some vacuoles function primarily as storage organelles, others as lytic compartments, vacuoles are involved with the breakdown of macromolecules and the recycling of components within the cell. Entire organelles, such as senescent plastids and mitochondria, may be engulfed and subsequently degraded by Vacuoles are organelles bounded by a single membrane vacuoles containing large numbers of hydrolytic and oxidizing enzymes. Many meristematic plant cells contain numerous small vacuoles. In the mature cell as much as 90% of the volume may be taken up by the vacuole, with the rest of the cytoplasm consisting of a thin peripheral layer closely pressed against the cell wall. Being a selectively permeable membrane, the tonoplast is involved with the regulation of osmotic phenomena associated with the vacuoles.

The principal component of the non–protein-storing vacuoles is water, with other components varying according to the type of plant, organ, and cell and their developmental and physiological state. In addition to inorganic ions such as Ca2+, Cl−, K+, Na+, NO3, such vacuoles commonly contain sugars, organic acids, and amino acids, and the aqueous solution commonly is called cell sap.

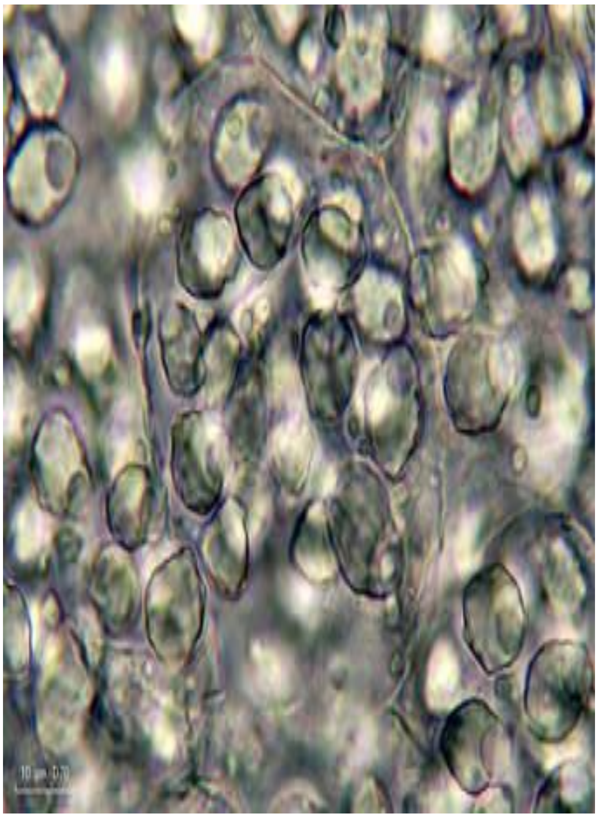
2- Starch grains

A starch is the most abundant carbohydrate in the plant world. Moreover it is the principal storage polysaccharide in plants. During photosynthesis assimilatory starch is formed in chloroplasts. Later it is broken down into sugars, transported to storage cells, a re-synthesized as storage starch in amyloplasts. As mentioned previously, an amyloplast may contain one (simple) or more (compound) starch grains. If several starch grains develop together, they may become enclosed in common outer layers, forming a complex starch grain. Starch grains, or granules, are varied in shape and size and commonly show layering around a point, the hilum, which may be the center of the grain or to one side. The layering of starch grains is attributed to an alternation of these two polysaccharide molecules.



The layering is accentuated when the starch grain is placed in water because of differential swelling of the two substances: amylose is soluble in water, and amylopectin is not. Storage starch occurs widely in the plant body. It is found in parenchyma cells of the cortex, pith, and vascular tissues of roots and stems; in parenchyma cells of fleshy leaves (bulb scales), rhizomes, tubers, corms, fruits, and cotyledons; and in the endosperm of seeds.

3- Aleurone grains



It is storage proteins that found in wheat, which considerable part of the prolamins aggregate directly into it within the rough ER and then are transported in distinct vesicles to the vacuoles without Golgi involvement. Structurally consist of an amorphous proteinaceous matrix surrounded by a bounding membrane. Other protein bodies may contain one or more non-proteinaceous globoids or one or more globoids and one or more protein crystalloids, in addition to the proteinaceous matrix.

3- Oil bodies

Are more or less spherical structures that impart a granular appearance to the cytoplasm of a plant cell when viewed with the light microscope. Oil bodies are widely distributed throughout the plant body but are most abundant in fruits and seeds. Approximately 45% of the weight of sun flower, peanut, and sesame seed is composed of oil. The oil provides energy and a source of carbon to the developing seedling.

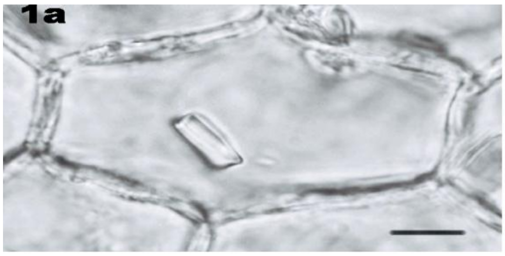
4- Crystals

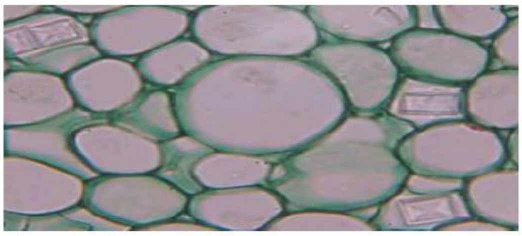
Inorganic deposits in plants consist mostly of calcium salts and anhydrides of silica. Among the calcium salts, the most common is calcium oxalate.

a- Calcium oxalate:

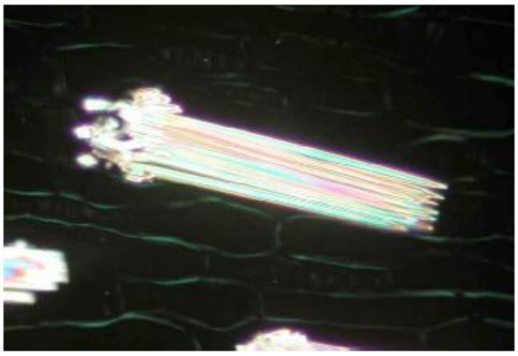
It occurs in the majority of plant families, notable exceptions being the Cucurbitaceae and some families of Liliales, Poales, and all Alismatidae . Calcium oxalate occurs as mono- and dihydrate salts in many crystalline forms. The monohydrate is the more stable and is more commonly found in plants than is the dihydrate. The most common forms of calcium oxalate crystals are:

(1) **Prismatic crystals**, variously shaped prisms, usually one per cell. Occur **Prismatic crystals** in *Allium cepa*.

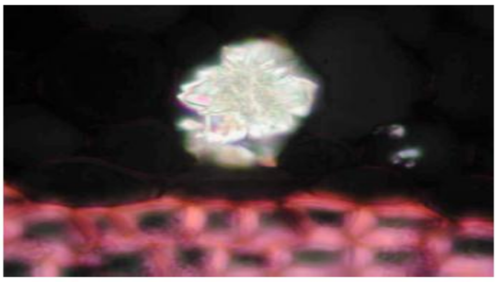




(2) **Raphide**, needle-shaped crystals that occur in bundles of *Lemna* sp.



(3) **Druses**, spherical aggregates of prismatic crystals.



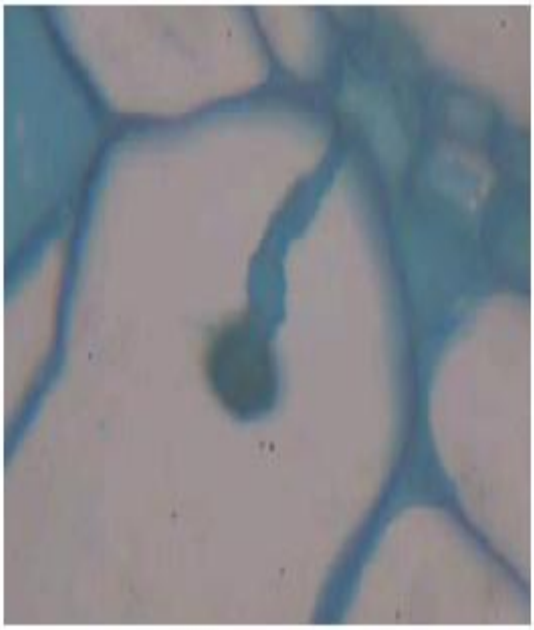
(4**) Styloids**, elongated crystals with pointed or ridged ends, one or two to a cell.

(5) **Crystal sand**

Very small crystals, usually in masses. In some tissues calcium oxalate crystals arise in cells that resemble adjacent, crystal-free cells. In others, the crystals are formed in cells called crystal idioblasts specialized to produce crystals. Crystal idioblasts contain an abundance of ER and Golgi bodies. Most crystal cells are probably alive at maturity. The location and type of calcium oxalate crystals within a given taxon may be very consistent and, hence, useful in taxonomic classification. Calcium oxalate crystals usually develop in vacuoles.

2- Calcium carbonate crystals

They are not common in seed plants. The best known calcium carbonate formations are cystoliths, which are formed in specialized enlarged cells called lithocysts of the ground parenchyma and epidermis. The cystolith develops outside the plasma membrane in association with the cell wall of the lithocyst. Callose, cellulose, silica, and pectic substances also enter into the composition of cystoliths, which are confined to a limited number (14) of plant families. Found in *Fucus elastic*.



Plant Cell Structure

CELL WALL

One of the most distinctive characteristics of plant cells with respect to those of animals is the cell wall, which some authors consider as the extracellular matrix of plants. It is the structure that R. Hook saw and drew when he gave name to the cell. The cell wall is located externally to the plasma membrane, is synthetized by the cell itself and consists mainly of cellulose, in addition to other polysaccharides and glycoproteins. Different cell types present differences in composition and organization in their cell wall, depending on the function they are developing. In fact, the different cell types of plants can be identified by the characteristics of their cell wall.

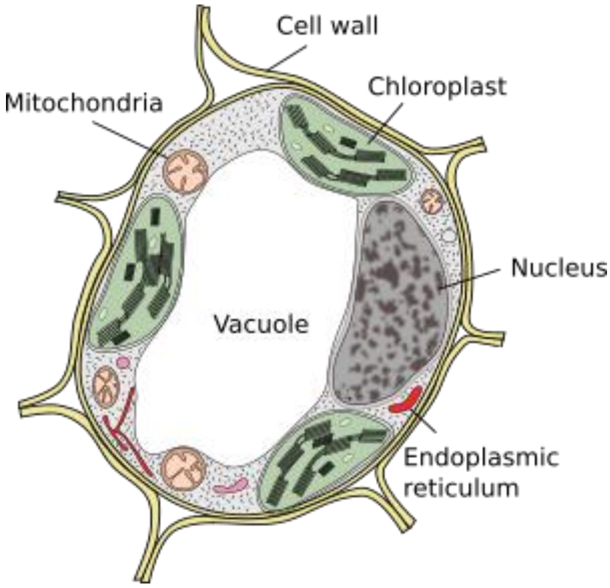
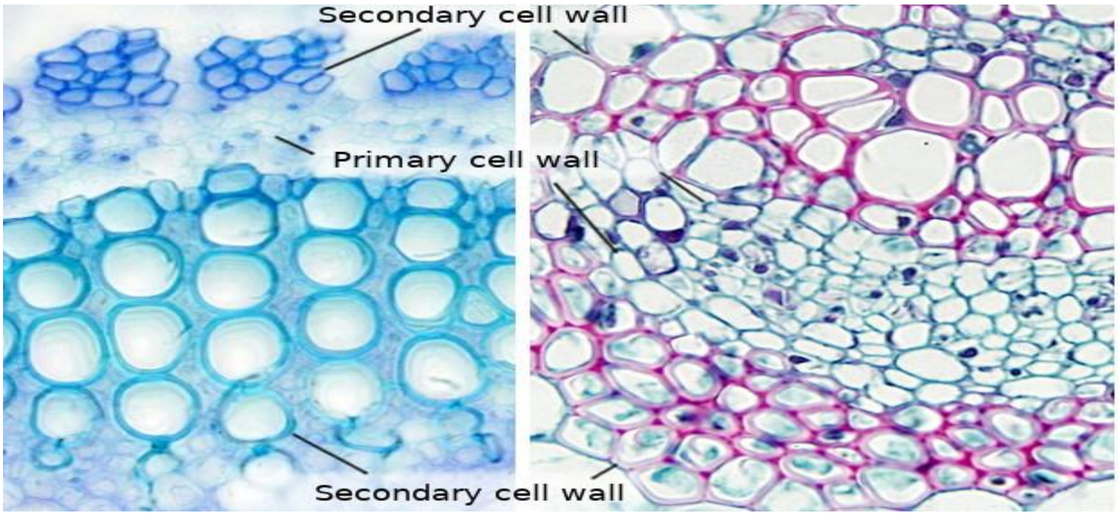


Diagram of a typical parenchymatic cell with its primary cell wall.

The cell wall has a mechanical function. It is responsible for the shape and size of plant cells and provides them with both structural support and protection as an exoskeleton. As a result, it is also responsible for the rigidity of the plant and for keeping its aerial structures and the organs that form it upright. Another of its main functions is to be a means of communication and transport of molecules and water between cells, both between nearby and distant cells. It also participates in the fight against pathogens being able to trigger defense responses, or give texture to the tissues of the fruits. Morphologically, the cell wall is formed by layers or sheets. All cells have at least two: middle lamella and primary wall. The middle lamella is synthetized and shared by cells that are contiguous with each other, while the primary cell wall is synthetized and belongs to each cell. In some plant cells, a third thicker layer called secondary cell wall is deposited. Most of the wood in the trees correspond to the secondary cell wall.



Images of cells with primary cell wall and with secondary cell wall (the latter also have primary cell wall, although it is not visible). All of them have middle lamella, which is not distinguished in the images. They correspond to conductive vessels: the one on the left stained with toluidine blue and the one on the right with safranin - fast green.

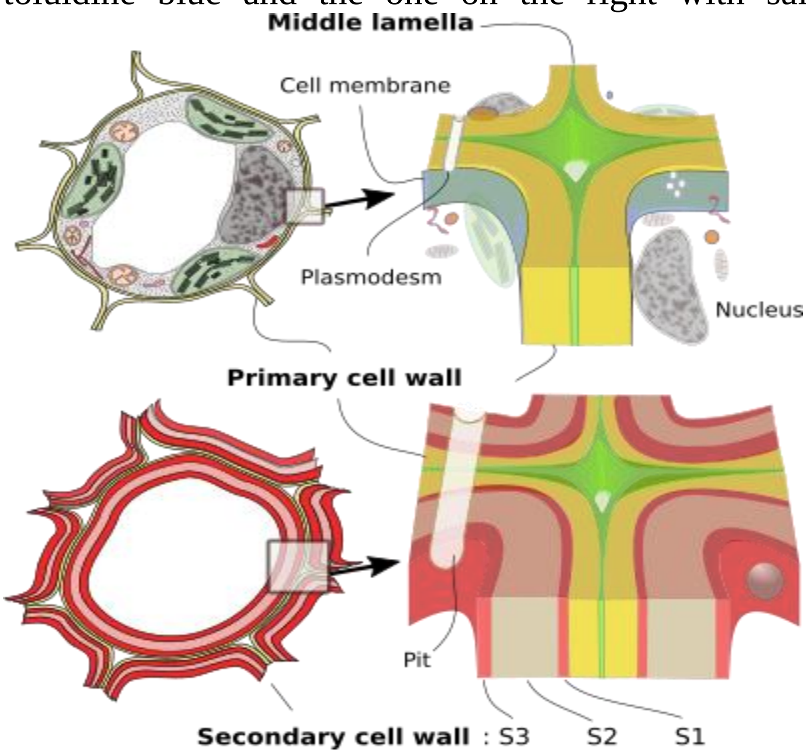


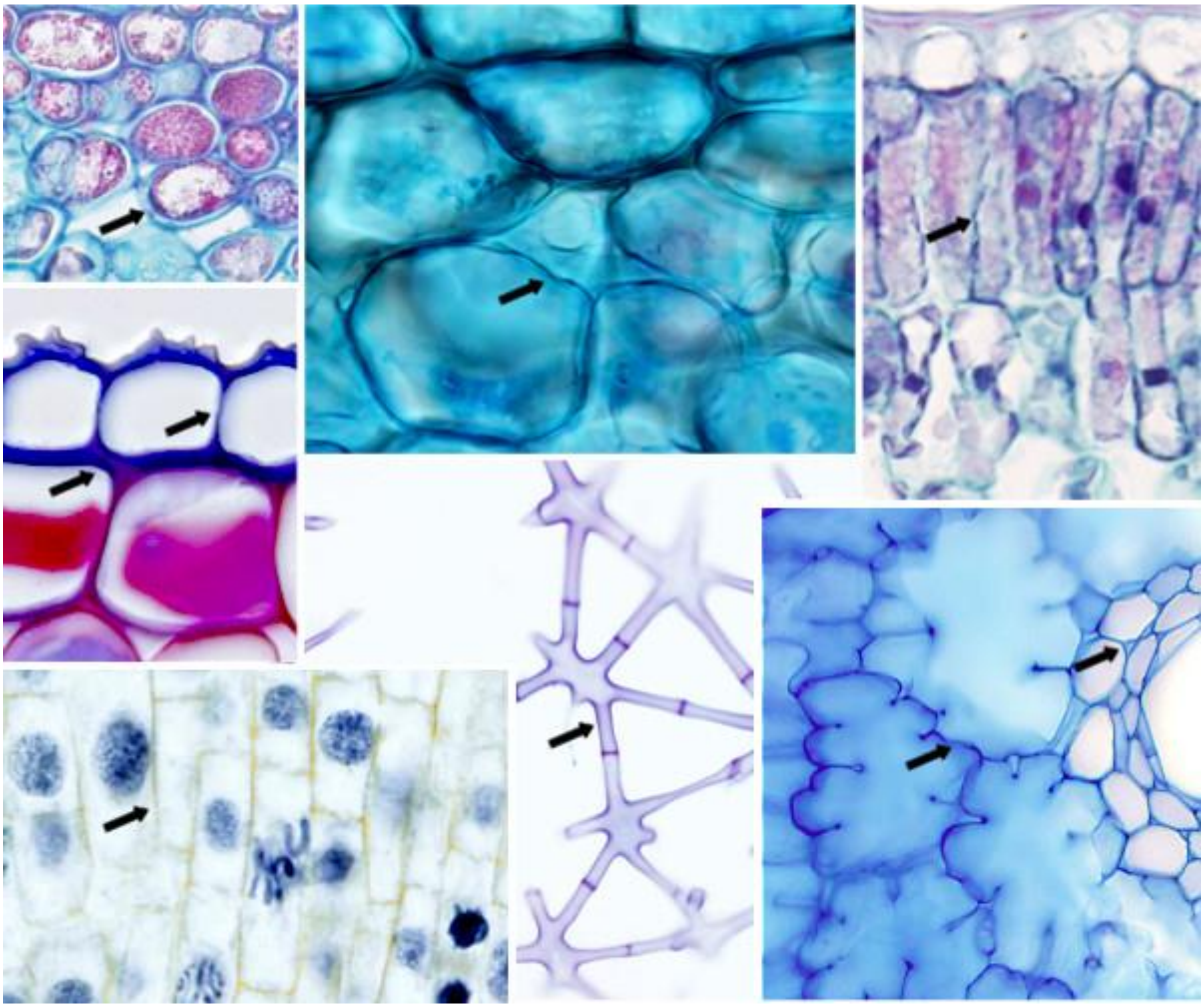
Diagram of the primary and secondary cell walls. S1, S2, and S3 are layers of the secondary cell wall.

MIDDLE LAMELLA

The outermost layer of the cell wall and the first to form is the middle lamella. It acts as a glue that binds neighboring cells. It is the only layer synthetized and shared by two contiguous cells. It has an amorphous appearance and is very thin; its thickness is close to the resolution limit of the light microscope. Nevertheless, it does not appear as a well-defined layer even with the electron microscope. In some tissues, there are intercellular spaces and, therefore, the middle lamella has one of their surfaces free. The middle lamella consists mainly of pectins, although it can be lignified in those cells that have a secondary cell wall.

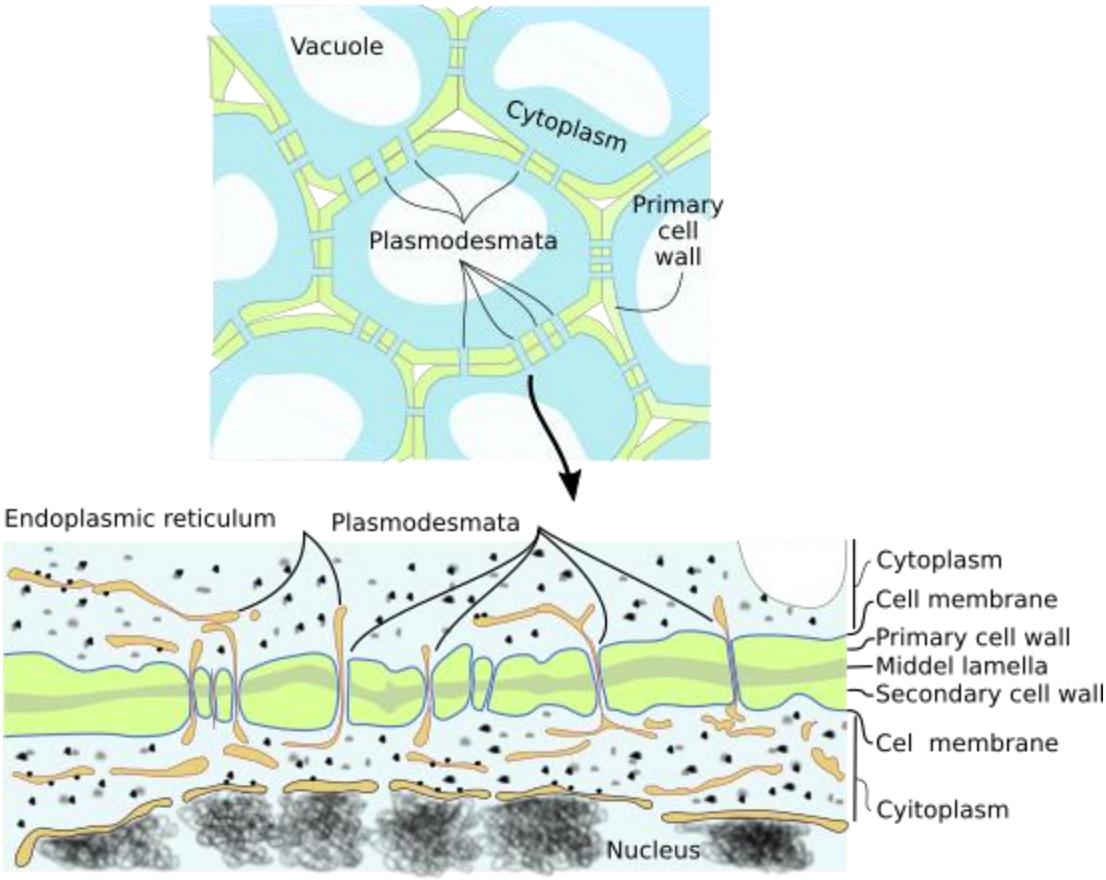
PRIMARY CELL WALL

The primary cell wall is the first clearly visible layer of the cell wall and it is located between the plasma membrane and the middle lamella or, in some cells, between the secondary wall and the middle lamella. It is responsible for the initial shape and size of the plant cell, and determines its subsequent changes in shape and size. It appears in all plant cells and originates during cell division, but the primary cell wall is also synthetized during growth in cell size. In addition, through the life of the cell there is a recycling with degradation and new synthesis of the components of the primary cell wall. In cells that are metabolically active, secretory, or capable of dividing, it remains the only component of the cell wall, in addition to the middle lamella. Plant cells stop growing when the primary cell wall become rigid, which may be due to a change in their composition.



Primary cell walls (arrows) in different tissues. The shape and size of the cells are conditioned by their cell wall.

The cell wall is a barrier to the free diffusion of molecules between cells; of course, it is much less permissive than the extracellular matrix of animals. However, cells need to communicate with each other. To do this, plant cells create channels that cross the cell walls and allow direct communication between adjacent cytoplasms. These channels are called plasmodesmata. With very few exceptions, all cells in a plant are connected with their neighbors by plasmodesmata. This connection is literal, that is, the plasma membranes of neighboring cells are continuous with each other, so we could say that a plant is a large syncytium. Plasmodesmata can appear concentrated in certain areas of the cell wall forming what are called primary pore fields, which form depressions in the cell wall since its thickness is smaller.



Plasmodesmata in the primary cell wall. In the lower part of the figure, there is a drawing of an electron microphotography.

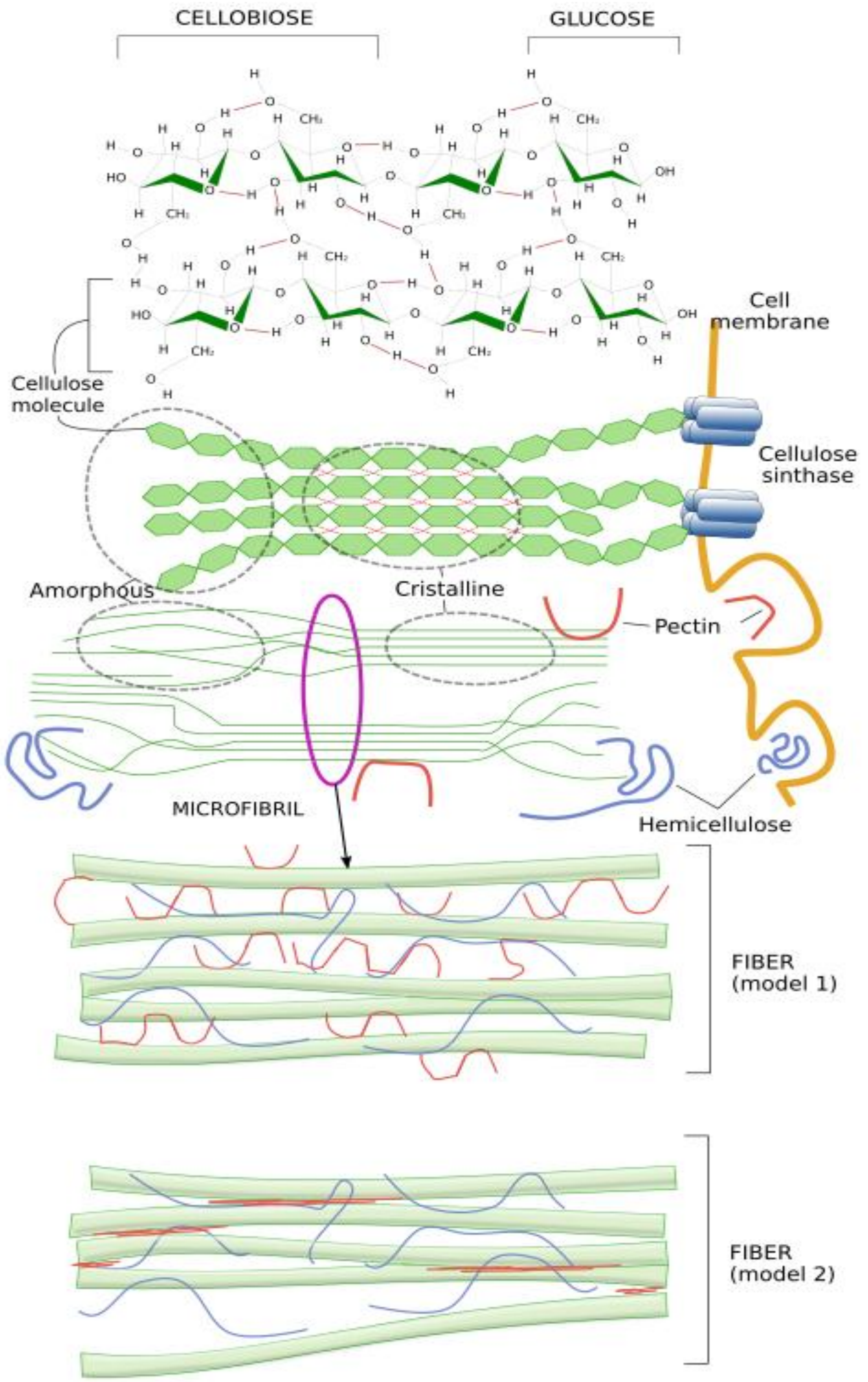
In the primary cell wall there are also areas with a greater thinness, although they do not produce interruptions in it, called primary pits; these structures may appear isolated or grouped in areas called primary pit fields. Plasmodesmata are usually concentrated in primary pit fields.

Composition

The primary cell wall is composed, considering the dry weight, by 25-30% of cellulose, 30% of hemicellulose, 35% of pectins and 1-5% of glycoproteins. The proportion and types of components that constitute the primary cell walls varies between cell types. It has been estimated that more than 2000 genes are required for the synthesis and remodeling of the primary cell wall.

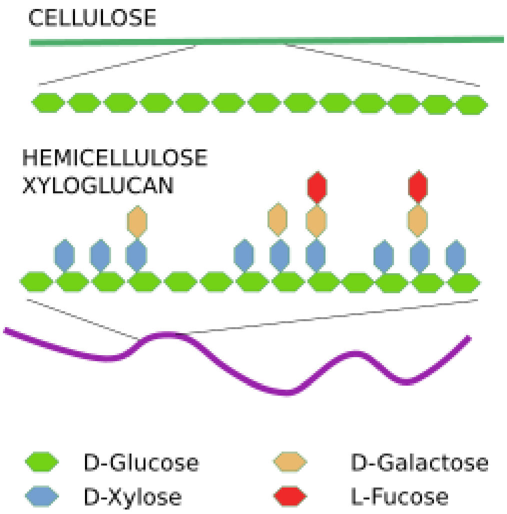
Cells with primary cell wall are usually metabolically active. Usually the primary cell wall is thin, around 0.1 µm thick. In addition, the cells that develop secondary cell wall usually have thin primary cell wall. Only a few cells achieve thick primary cell walls, such as some endosperm and collenchyma cells. In any case, the thickness can change according to the conditions in which the cell is located. In the primary cell wall there are pores (not to be confuse with plasmodesmata) with a diameter ranging from 4 to 8 nm, which allow the passage of water, ions and small molecules such as sugars and amino acids, and hormones.

Cellulose. Cellulose is the main component of plant walls. It is a linear polysaccharide formed by glucose. The formula is $(C_6H_{10}O_5)n$, where n can be greater to 500 per polysaccharide chain. The long cellulose molecules associate with each other through hydrogen bonds and Van der Waals forces to form structures called cellulose microfibrills, formed by 50 cellulose molecules oriented with the same polarity. Microfibrills are associated with each other through bonds formed between them and other carbohydrates, mainly hemicellulose and pectins, which result in fibrils and cellulose fibers, visible under the light microscope. The cellulose fibers can measure about 0.5 µm in diameter and 4 to 7 µm in length. The strength of cellulose fibers is similar to that of steel and the bonds between cellulose molecules by hydrogen bonds make the cellulose microfibrills have crystalline properties in some regions, while the rest acquires paracrystalline properties.



Organization of cellulose molecules. The glycoproteins have not been represented. The detailed organization of the cellulose microfibrills has not been solved yet and two models were proposed. In one of them (model 2) pectins play a predominant role.

As with hyaluronate (hyaluronic acid), cellulose is synthetized in the plasma membrane thanks to the action of cellulose synthase, a transmembrane protein with an amino acid sequence that crosses 8 times the plasma membrane. Up to 36 cellulose synthase enzymes bind at a point on the plasma membrane to form the so-called cellulose synthase complex that is rosette-shaped, and is so large that it can be observed with the electron microscope. Each rosette can synthetize up to 36 molecules of glucose simultaneously. The cellulose molecules that polymerize nearby are joined laterally by hydrogen bonds. These new cellulose molecules are also associated with the microfibrills that had previously formed piles of these microfibrills, fibrils and cellulose fibers.



Molecular composition of the xyloglucan, the most common hemicellulose.

Hemicellulose is actually a family of polysaccharides of 200 to 500 monosaccharides. The type of hemicellulose that appears in the cell wall varies greatly between tissues and cell types. <u>It is synthetized in the Golgi apparatus</u> and is transported to the plasma membrane in vesicles, where it is released by exocytosis. Xyloglucan is the most frequent molecule of hemicellulose. Structurally, hemicellulose is similar to cellulose so it can establish hydrogen bonds with it. As the hemicellulose molecules are synthetized, they coat the cellulose microfibrills, helping to the cohesion to form cellulose fibers.

Pectins : form a very diverse group of acidic polysaccharides <u>synthetized in the Golgi apparatus</u> and secreted into the cell wall. Together they form a gel-like structure that is located between the cellulose microfibrills. They seem the main responsible for the formation of pores that allow the diffusion of small molecules through the primary wall. Pectins are more abundant in the dicotyledons that in the monocotyledons. For example, grasses contain only traces of pectins. Pectins appear absent in the secondary cell wall (see below).

Glycoproteins of the cell wall are usually rich in proline, hydroxyproline and glycine, amino acids that are found in much repeated sequences. The type of glycoprotein usually varies a lot between cell types. One of the most common family of glycoproteins are extensins, which are rich in prolines. The glycoproteins have an apparent structural function, although there are also enzymes such as peroxidases, laccases, phosphatases, cellulases, pectidases, among others.

Callose is a substance that is deposited between the plasma membrane and the cell wall; then, it cannot be considered strictly as a component of the primary cell wall. It is mainly located around the openings of the plasmodesmata . The callose is synthetized, released and deposited in response to cellular stress, either by wounds or by pathogens, and its mission is to obliterate the plasmodesma channel and cut or decrease the communication between neighboring cells. It also appears in other places with less clear functions, such as in the pollen tubes or in the cell plate during cytokinesis.

Some specialized cells have other particular molecules. For example, **cutine** and other waxy polymers are deposited in the free surface of the epidermal cells forming a structure called cuticle. This layer, which can be very thick, prevents the loss of water and protects against pathogens. The **suberin** is deposited in the cell wall of other cells such as those of the suber or cork of the periderm, in the root endodermis and in cells that surround some nerves of the leaves. Suberin has two domains, one is inserted into the primary wall and the other is between the primary wall and the plasma membrane.

It can be said that the primary cell wall is a framework of cellulose microfibrills, connected by hemicellulose molecules and embedded in a pectin matrix. The three-dimensional organization of cellulose, hemicellulose and pectins is not clear yet. Several models have been proposed and the most cited assumes that hemicellulose molecules bind tightly to cellulose molecules by hydrogen bonds. However, recently it has been seen that hemicellulose does not have as many connections with the cellulose as was thought and that pectins seem to play a more important role in the compaction of the cell wall. For example, it seems that pectins have more links with cellulose than hemicellulose with cellulose. Pectins help to hydrate the primary cell wall.

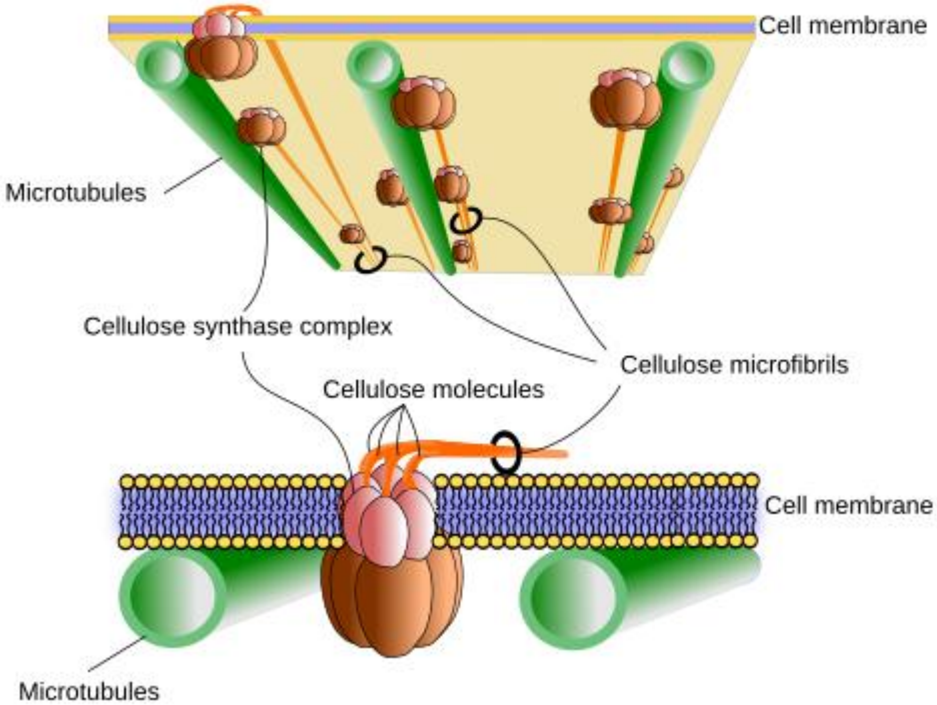
Cell growth

When the cell wall grows, it is necessary to distinguish between growth in thickness (deposition of successive layers) and increase in length, when the cell wall increases its surface and the cell increases in size. The growth of the plants is mainly due to cell size growth, which is produced by the force of the hydrostatic pressure, that is, by the force exerted by the water from inside the cell outwards on the primary cell wall. Although it depends on the cell type, cells can grow up to 10 times their size. In some cases up to 100 times.

The cells can grow homotrophically, the entire surface of the cell wall expands although it can be at different rates, or heterotropic, only a part of the surface of the cell wall expands (for example in the pollen tubes, or in the trichomes). A cell grows where there is less resistance, which depends on the resistance opposed by the cell wall. This conditions where the cell of the plant will grow, which will determine, for example, the shape of the stems and leaves, or that they will grow towards a light source or not. The resistance of the primary cell wall is determined by the orientation of the fibers of cellulose and by the consistency of the primary cell wall assembly.

The primary cell wall is anisotropic, a consequence of the irregular orientation of the fibers of cellulose. These fibers are shorter and more irregular that in the secondary cell wall (see below). Usually this irregular orientation occurs in cells that grow or have grown in all directions. When a cell expands in a preferred direction, the microfibrills of cellulose are oriented perpendicular, in the manner of rings, with respect to the growth axis, and the external ones, which were already there, are arranged longitudinally to that axis. It is normal to find layers in the primary cell wall where the microfibrills are oriented helically and with a certain rotation of angle with respect to the next layers.

An interesting aspect of the primary cell wall synthesis is how the cell manages to orient the molecules and microfibrills of cellulose, since this will determine the orientation of the fibrils and fibers of cellulose. The orientation of the molecules of cellulose is conditioned by their synthesis and by how they are deposited on the plasma membrane, which is determined by the spaces through which the enzymatic complex that synthetizes it can move through the plasma membrane: the rosette of cellulose synthase. One theory suggests that this movement depends on the orientation of the cortical microtubules that are located just under the plasma membrane, in the cytosol. These microtubules act like barriers that cannot be crossed by the rosettes of cellulose synthase. The enzymes move through the membrane, driven by the polymers of cellulose that are synthetized but only where microtubules allow them. In this way, by depolymerizing and polymerizing microtubules again, the cell can control the orientation of the fibers of cellulose. It has been shown that microtubules can rearrange in a matter of minutes to accommodate these changes of orientation. Other extracellular and intracellular factors can also condition the direction of movement of these enzymatic complexes.



Synthesis and orientation of cellulose fibrils guided by microtubules. Cellulose synthesizer complexes move as they synthetize cellulose following the pathways marked by microtubules (Modified from McFarlane et al., 2014)

The consistency of the cell wall also determines how the cell will grow. A softening or relaxation of the cell wall must be produced by secretion of substances to certain areas of the wall. It has been observed that it becomes softer in certain places through the chemical modification of the pectins and by acidification; it is in these places where there is also less resistance and, therefore, where the cell grows.

Pectins play an important role in the relaxation of the cell wall for growth. They can be hydrated a lot by adding plasticity to the wall. In particular, during growth, enzymes are released that change the molecular form of the pectins initially released or different types of pectins are released directly. All this leads to a relaxation of the cell wall and promotes cell growth. Calcium is important for pectins since it favors the union between them, and is released after the elongation of the cell. For example, the walls of meristematic cells are poor in calcium.

Auxins, a class of plant hormones (or plant growth regulators), cause acidification of the cell wall and its relaxation by activating the expansins, the methyl-esterase of pectin and the endoglucanases. The expansins do not have enzymatic activity and their effect seems to hinder hydrogen bonds, while the endoglucanases decrease the number of bonds between cellulose-cellulose and cellulose-hemicellulose.

Although microtubules seem involved in determining how a cell grows, it has been found that non-uniform (anisotropic) growth begins to be detected even before cellulose fiber orientation occurs. Prior to the organization of the microtubules and the orientation of the cellulose fibers, a local or irregular alteration of the pectins takes place. Therefore, the initiation of heterotropic growth would not begin with the reorientation of the microtubules, but with the modification of the pectins. It is even suggested that the orientation of the microtubules would be a consequence of the alteration of the pectins and, therefore, a secondary response.

SECONDARY CELL WALL

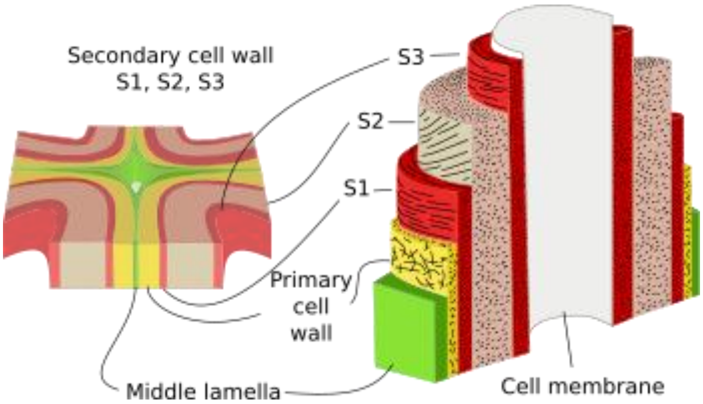
Those cells that have the mission of support and those conductors that are part of the xylem develop an additional wall layer called secondary cell wall. It is deposited between the plasma membrane and the primary cell wall and the process involves the synthesis of numerous layers of cellulose fibers that are added one after the other by a mechanism called apposition. The synthesis of the secondary cell wall begins during the final phase of the growth and extension of the primary cell wall. Once the cell wall is synthetized, the cells die by apoptosis. They are probably one of the few cell types whose function, mechanical resistance and sap transport, is performed when they die. Plants that grow in thickness and height need a great support and develop what we call wood. The secondary wall is the main component of the wood.

Composition

The secondary cell wall is composed mainly of cellulose (40-60% of the dry weight), hemicellulose (10-40% of the dry weight, especially the xylan) and lignin (10 to the 35% of the dry weight). It has very few pectins and lacks glycoproteins as structural proteins and enzymes, or at least they are not abundant. The proportion of cellulose in the secondary wall is greater that in the primary wall and it also has hemicellulose in lower proportion.

A typical substance of the secondary cell wall is lignin, which is the most abundant biopolymer in plants after cellulose. The lignin is deposited between the microfibrills of cellulose to give consistency.

This molecule allowed the plants gain a consistency and resistance hitherto unknown. When lignification of the secondary wall occurs, part of these molecules can also be deposited in the primary cell wall and in the middle lamella. Even in conifers, the largest amount of lignin is found in the middle lamella of the conductive cells. The cross-linked framework that these molecules form seems to favor the elimination of water from the wall and, therefore, the access of hydrolytic enzymes.



Orientation of the fibers of cellulose in the different layers of the cell wall.

The secondary wall have a thickness of 2 to 10 µm, is poorly hydrated and is rigid. Its thickness is greater than that of the primary wall, sometimes so thick that it obliterates the interior of the cell. In some cells, three layers can be distinguished in the secondary cell wall: S1, S2, and S3, each with a different orientation of its fibers of cellulose. Usually layer S2 varies in thickness between cell types. Cellulose fibers are usually arranged helically. When the secondary wall develops, the rest of the cytoplasm adhere the layer S3 forming a layer called the warty layer, due to the irregularity of its surface. The secondary cell wall deposition is not very regular so there are interruptions in it. Sometimes, it is possible to find cells with a part of their wall that is secondary and another part that is primary.

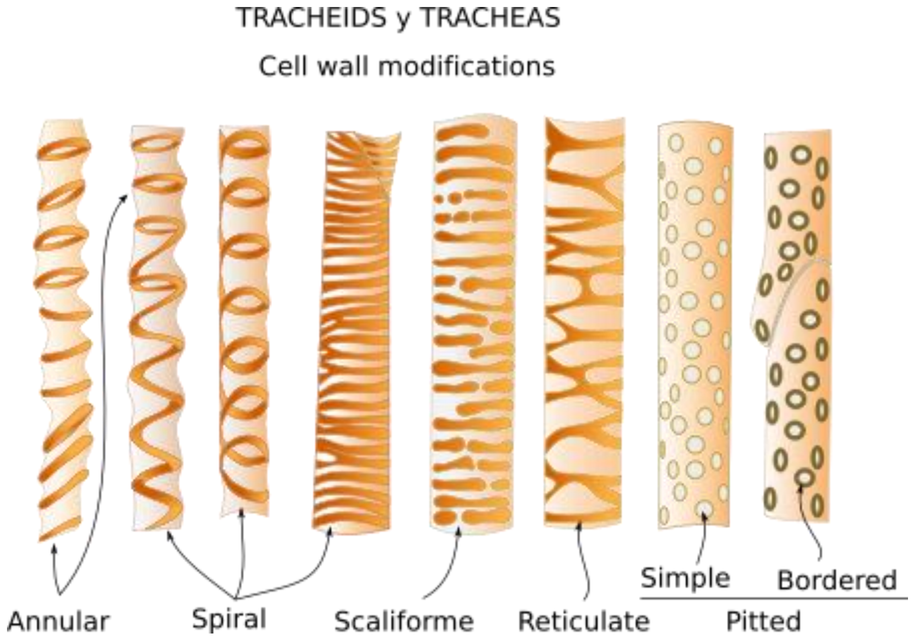


Diagram showing various forms of thickening in the cell walls of the conductive cells of the xylem.

The irregular deposition of secondary cell wall on the cell surface creates irregular structures that are characteristic of some cell types. For example, the cells of the protoxylem and of the metaxylem present a thickening of the secondary wall that is arranged helically along the cell. This arrangement resembles the tracheae of the insects and thus the conductive cells of the xylem are called tracheal elements. While in the secondary xylem, cells there have other types of irregularities.

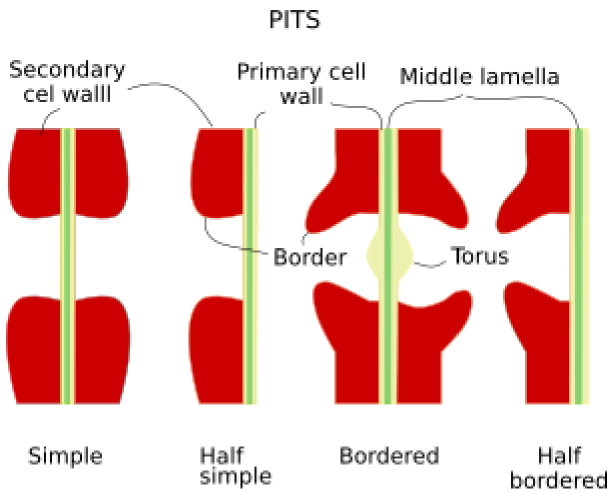
Pits

Although the entire cell may be surrounded by a secondary cell wall, there are always interruptions or channels in it that are called pores or pits, which originate when the secondary cell wall is being deposited. These pits are created simultaneously in the two neighboring cells, leaving a channel that allows to communicate the interior of both cells. A thin membrane, which is called membrane of the pit, separates the two aligned pits of neighboring cells; this membrane is formed by the middle lamella and the primary walls of the two cells. The pits, one or more, are formed where there were primary pits in the primary cell wall.

Types of pits

Though pits are usually simple and complementary, a few more pit variations can be formed:

- **Simple pits**: A pit pair in which the diameter of the pit chamber and the diameter of the pit aperture are equal.
- **Bordered pits**: A pit pair in which the pit chamber is over-arched by the cell wall, creating a larger pit chamber and smaller pit aperture.
- **Half bordered pits**: A pit pair in which a bordered pit has a complementary simple pit. Such a pit pair is called half bordered pit pair.
- **Blind pits**: A pit pair in which a simple pit has no complementary pit.
- **Compound pits**: A pit pair in which one cell wall has a large pit and the adjacent cell wall has numerous, small pits.

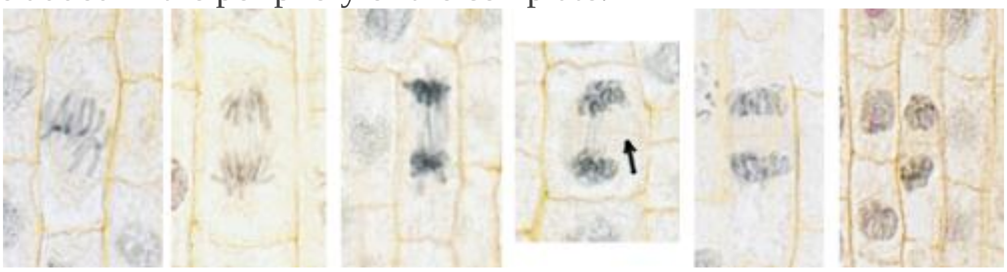


Main morphologies of pits.

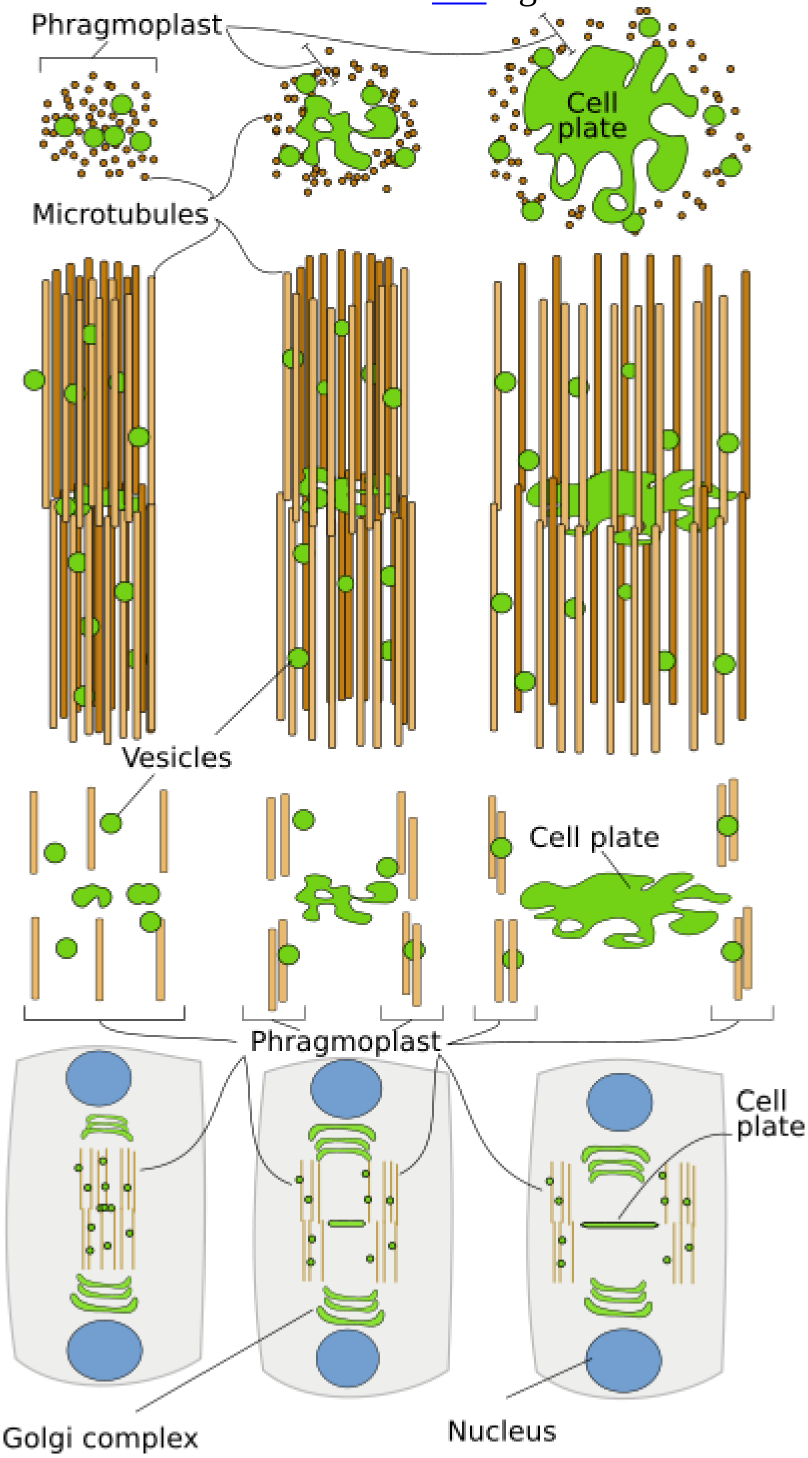
The pits have different morphology. In the simple pits, the pit chamber or hollow area that crosses the cell wall has a similar diameter over its entire length or a little wider in the pit apertures. These pits are found in parenchyma cells, extraxilar fibers and sclereids. The bordered pits are those in which a ridge is formed in the apertures, half bordered pits when only an aperture shows the ridge (typically established between conductive and accompanying cells) and bordered with "torus" are those in which in the middle lamella there is a thickening of the primary wall called a bull, which acts as a valve. The bordered pits with "torus" are absent in flowering plants (angiosperms). On the other hand, there are pits called blind when the pit opens to the intercellular space; that is, it has no complementary pit.

CELL WALL FORMATION DURING CELL DIVISION

A new plant cell does not generate its entire cell wall completely from scratch, that is, it is not born naked. When a cell is going to divide, its two daughters cells inherit all the cell wall that produced its progenitor except in the area where the cytoplasms will separate. The formation of this cell wall from scratch begins at the late anaphase of the mitosis, beginning with this the cytokinesis or division of the cytoplasms. The first thing observed during the cytokinesis of plant cells is the transport of vesicles from the Golgi apparatus with content to build the new wall, mainly polysaccharides and glycoproteins. This transport is given from the two zones close to the nuclei to the intermediate zone where the new wall will be formed. The vesicles are transported by motor proteins along bundles of microtubules remaining from the mitotic spindle. There is a bundle for each nucleus and both bundles overlap in the intermediate zone. In this division zone, there are also actin filaments oriented perpendicularly to the microtubules. The set of microtubules, actin filaments, and vesicles is called phragmoplast. The phragmoplast is the structure that is responsible for forming the new cell wall. When the vesicles reach the intermediate zone of division, where the new cell wall will form, they fuse together to form a plate-like structure that will separate the two cells and that is oriented perpendicular to the mitotic spindle. This plate is called a cell plate. The cell plate grows in a centrifugal manner, that is, the center of the plate is formed first and then more material is added to the edges so that it grows in extension, but not in thickness. The phragmoplast then adopts, by depolymerization and polymerization of new microtubules, an annular form and the vesicles are added in the periphery of the cell plate.



Different phases of mitosis from prophase (left) to telophase (right). It can be observed how a new cell wall is gradually created that separates both groups of chromosomes, which will form the nuclei of the daughter cells. This structure under construction is called phragmoplast (arrow). It is also seen in this figure.



Formation of the new cell wall thanks to the activity of the phragmoplast, which is formed by microtubules belonging to the two daughter cells; they transport vesicles from the Golgi apparatus to the central plate. The phragmoplast becomes increasingly peripheral until it touches the original wall of the stem cell and the central plate merges with that wall.

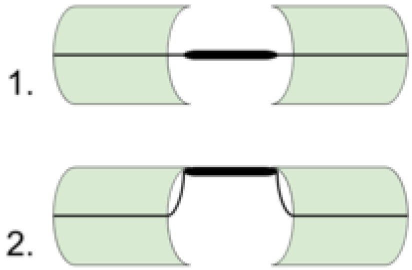
The cell plate edges will be extended, making the cell plate grow, until they come into contact and merge with the cell walls parallel to the mitotic spindle that the mother cell already had. In this way, each daughter cell is completely surrounded by a cell wall. The cell plate, with the arrival of more substances from the Golgi apparatus, especially pectic substances, will be transformed into the middle lamella. It seems that once the contact of the edge of the cell plate with the middle lamella of the mother cell has occurred, it is when there is a transformation of the cell plate in the middle lamella. The growth of the middle lamella is mainly centripetal, that is, it will form from the edges to the interior, where the cell plate began to form. The middle lamella is the layer of the cell wall that is shared between the two daughter cells and both contribute to its formation. It is a very fine layer to which later the others will be added to form a mature cell wall. Regardless of whether the cell wall is synthetized again or new layers are added during maturation, the process is always from the outside in, that is, the more recent parts are always closer to the plasma membrane.

An interesting aspect of the formation of a new cell wall during cytokinesis is where and how the division plane will be oriented. For example, if it will be periclinal or anticlinal, or any other orientation. The position and orientation of the dividing plane, and therefore of the cell plate, is established even before the formation of the mitotic spindle. In the majority of the cells, before the formation of the mitotic spindle, a network of microtubules, actin filaments and endoplasmic reticulum cisterns appear in the cortical region of the cytoplasm near the plasma membrane, forming a belt or ring called the preprophase band. This ring disappears when the mitotic spindle begins to form. However, the cell plate will be formed where this preprophase band was located. In such a way that this initial band conditions the formation and orientation of the mitotic spindle.

During cytokinesis, intercellular spaces are also formed; they are important for the diffusion of gases and store secretion substances. Most of these spaces are formed when the growth edge of the new middle lamella reaches to the proximities of the primary cell wall of the mother cell. This growing middle lamella branches out and then two growth fronts are created that will cross the primary cell wall of the mother cell. When these fronts reach the middle lamella of the mother cell, a space surrounded by middle lamella is created. This space will become an intercellular space. During the maturation of tissues, the intercellular spaces increase, being greater in adult tissues. The normal form is by schizogenesis, that is, by a physical separation between cells produced first by degradation of the middle lamella that allows physical separation, and by a subsequent cell differential growth. These spaces are very evident in the spongy parenchyma of the leaves.

During the formation of the cell wall, cisterns of endoplasmic reticulum are trapped; these cisterns inhibit cell wall formation and remain as discontinuities, which will later become plasmodesmata.

Torus and margo



A simplified diagram of a bordered pit-pair with a torus and margo. The top shows an unobstructed pit and the bottom shows an aspirated pit, with the margo flexing under stress.

The torus and margo are characteristic features of bordered pit-pairs in gymnosperms. In other vascular plants, the torus is rare. The pit membrane is separated into two parts: a thick impermeable torus at the center of the pit membrane, and the permeable margo surrounding it. The torus regulates the functions of the bordered pit, and the margo is a cell wall-derived porous membrane that supports the torus. The margo is composed of bundles of microfibrils that radiate from the torus.

The margo is flexible and can move towards either side of the pit while under stress. This allows the thick, impermeable torus to block the pit aperture. When the torus is displaced so that it blocks the pit aperture, the pit is said to be aspirated.

Plasmodesmata

Plasmodesmata are thin sections of the endoplasmic reticulum that traverse pits and connect adjacent cells. These sections provide an avenue of transport through the pits and facilitate communication. Plasmodesmata are not restricted to pits however, as plasmodesmata often cross a cell wall of constant width and occasionally the cell wall is even wider in areas where plasmodesmata traverse it.

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PLANT TISSUES

Introduction

Growth takes place in two stages in plants: first there is the division of cells of an undifferentiated type (simple, thin-walled parenchyma) adding to the number of cells; then there is the enlargement of some of the cells produced by these divisions.

Dividing cells of the undifferentiated type are not present throughout the plant, but are concentrated in particular places. In addition to these, certain cells in most organs remain relatively undifferentiated and may begin to divide if the appropriate conditions arise and after they have undergone a process known as dedifferentiation. Such cells give rise to adventitious roots and buds, or to the callus tissue which forms during wound healing. They are of great importance to the horticulturalist. The ability of such cells to divide is a basic requirement for the success of many forms of vegetative propagation and grafting.

Cells that divide actively to produce the primary plant body are associated together in meristems.

From the above it is clear that the plant tissues :

A tissue is a group of cells having a common origin and usually performing a common function. A plant is made up of different kinds of tissues. Tissues are classified into two main groups, namely, meristematic and permanent tissues based on whether the cells being formed are capable of dividing or not.

MERISTEMATIC TISSUES (MERISTEMS)

Growth in plants is largely restricted to specialized regions of active cell division called meristems (Gk. meristos: divided). Plants have different kinds of meristems. The meristems which occur at the tips of roots and shoots and produce primary tissues are called apical meristems.

Characterization

- Meristematic tissue is a group of cells that has power of continuous division.
- Cells are immature and young
- Meristematic tissue is commonly called as meristems.
- Shape of cell: each cell is oval, rounded, polygonal or rectangular
- Size: small
- Intercellular space: Absent
- Cell wall: thin walled made up of cellulose
- Nucleus: single large and prominent
- Reserved food: cell do not store food
- Cell division: high capacity and continuous
- Metabolic activity: very high

TYPES OF MERISTEMATIC TISSUE

1. Based on origin
2. Based on position
3. Based on function

Types of meristematic tissue on the basis of origin

i- promeristem (primodial meristem)

- Origin: embryonic origin
- It is earliest and youngest meristematic tissue
- It is present in growing root and shoot tip.
- It give rises to primary meristem,

ii- Primary meristem:

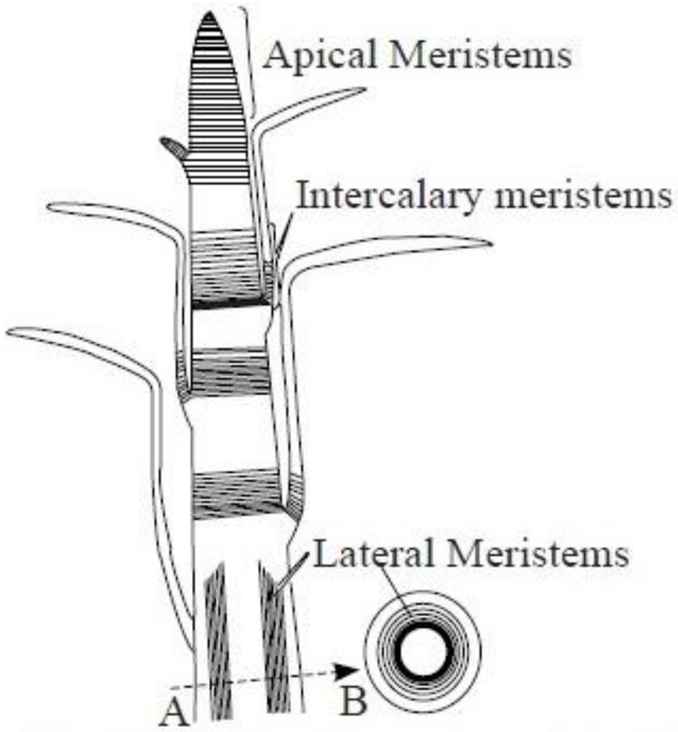
- Origin: from Promeristem
- Cell are always active and dividing
- Present below promeristem in the shoot and root tip, and also in intercalary position
- It give rises to secondary meristem, and primary permanent tissue.

iii- Secondary meristem:

- Origin: from primary meristem
- It is developed later on life
- It give rises to secondary permanent tissue

Types of meristematic tissue on the basis of Position

i. Apical meristem
ii. Intercalary meristem
iii. Lateral meristem



i- **Apical Meristems**

Apical meristems are located at the shoot apex, where primary stem, leaves and flowers differentiate, and at the root apex (Fig. below), where primary root tissue is produced. Subsequent elongation of the shoot axis may occur by random cell divisions and growth throughout the youngest internodes. This region of diffuse cell division is termed an uninterrupted meristem, and is continuous with the apical meristem. However, in some plant stems, particularly in grasses, most cell divisions contributing to stem elongation occur in a limited region, usually at the base of the internode, which is then termed an intercalary meristem. Both intercalary and uninterrupted meristems represent growth in regions of already differentiated tissues.

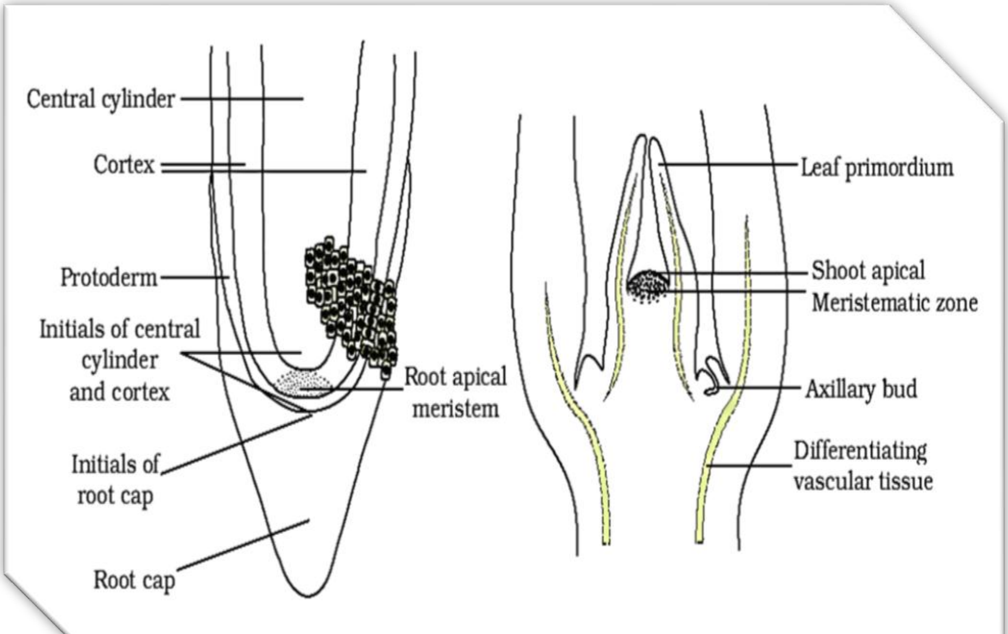


Figure 6.1 Apical meristem: (a) Root (b) Shoot

ii- **Lateral Meristems**

Lateral meristems are located parallel to the long axis of a shoot or root, most commonly in the pericyclic region, at the junction between vascular tissue and cortex. Examples of lateral meristems include primary and secondary thickening meristems (PTM and STM) and vascular cambium. Primary and secondary thickening meristems produce both ground tissue and vascular bundles . Vascular cambium produces secondary xylem and phloem. Adventitious roots are typically formed in the root pericycle; in these cases the pericycle could be termed a lateral meristem. The phellogen (cork cambium) is a lateral meristem that occurs in the stem or root cortex, where it forms a protective corky layer. A phellogen may also develop in the region of a wound, or at the point of leaf abscission.

ii- Intercalary meristem

A meristem developing between regions of mature or permanent tissue (as at the base of the grass leaf) compare apical meristem, lateral meristem.

Intercalary meristems are capable of cell division, and they allow for rapid growth and regrowth of many monocots. Intercalary meristems at the nodes of bamboo allow for rapid stem elongation, while those at the base of most grass leaf blades allow damaged leaves to rapidly regrow.

Meristems are classified by their location in the plant as apical (located at root and shoot tips), lateral (in the vascular and cork cambia), and intercalary (at internodes, or stem regions between the places at which leaves attach, and leaf bases, especially of certain monocotyledons—e.g., grasses).

Monocots, like grasses, have intercalary meristems which allow the leaves to grow back after mowing. In addition to the apical meristems located in the shoot and root tips, plants in the DICOT class have lateral meristems.

Intercalary Meristems – The intercalary meristems are located at the internodes or the base of the leaves. The intercalary meristems help in increasing the length of the internode. This is usually seen in monocotyledonous plants.

Intercalary Growth. a lengthwise growth in plants as a result of cell division in the formative tissue (meristem), located below the top of the organ—for example, in the internodes of the stalks of grasses and at the base of the leaves.

Types of meristematic tissue on the basis of function:

i. Protoderm

- Function: protection from mechanical injury
- It gives rise to epidermis layer.
- It is the outermost meristematic tissue

ii. Procambium

- Function: transport of water and nutrition
- It gives rise to vascular tissue (xylem and phloem)
- It is the innermost meristematic tissue

iii. Ground meristem

- Function: various functions
- It gives rise to cortex, endodermis, pericycle and pith in dicot and hypodermis, ground tissue in monocot.

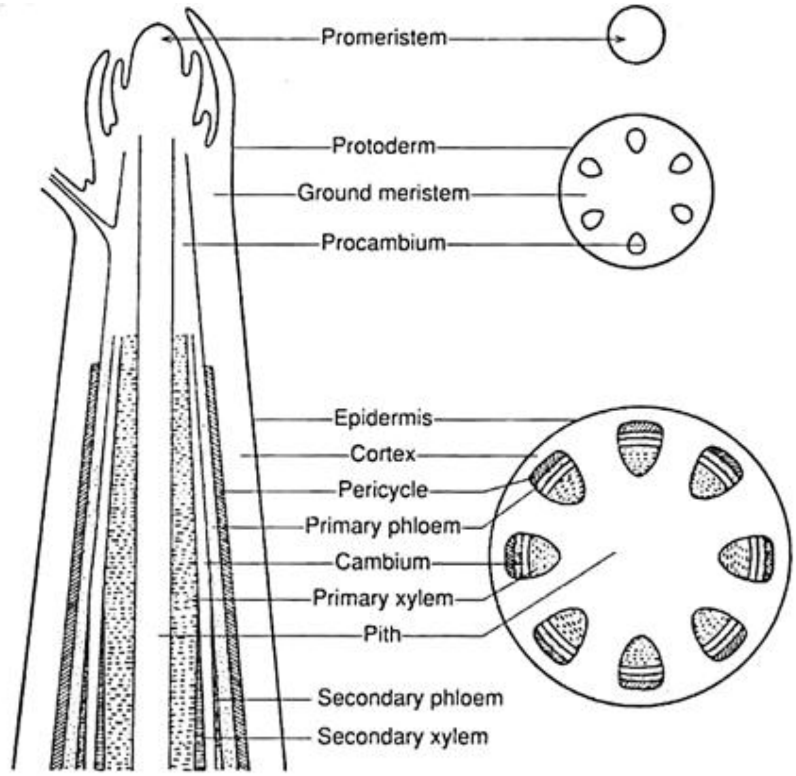


Fig. 5.40 : Diagrammatic representations of meristems in plant body and their gradual differentiation in L.S. with corresponding transverse views in T.S.

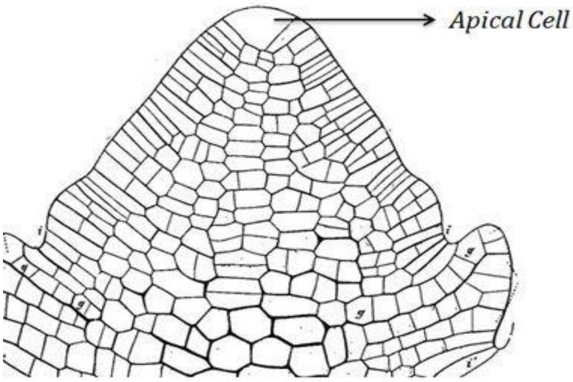
MERISTEMOIDS AND ASYMMETRIC CELL DIVISION

Meristemoids are individual cells that are responsible for the differentiation of distinct structures. In many cases meristemoids represent the smaller, densely cytoplasmic, daughter cell that results from an unequal (asymmetric) cell division; the larger daughter cell is less active. Asymmetric divisions are caused by cell polarization resulting from organized arrays of actin filaments in the dense cytoplasm during determination of cell plate alignment42. Examples of unequal cell divisions include cleavage of the microspore into a larger vegetative cell and smaller generative cell, formation of a root hair initial (trichoblast), a protophloem division to form a larger sieve tube element and smaller companion cell, and division of an epidermal cell into two cells of unequal sizes, the smaller of which is the meristemoid that will divide to form the guard cells of a stoma.

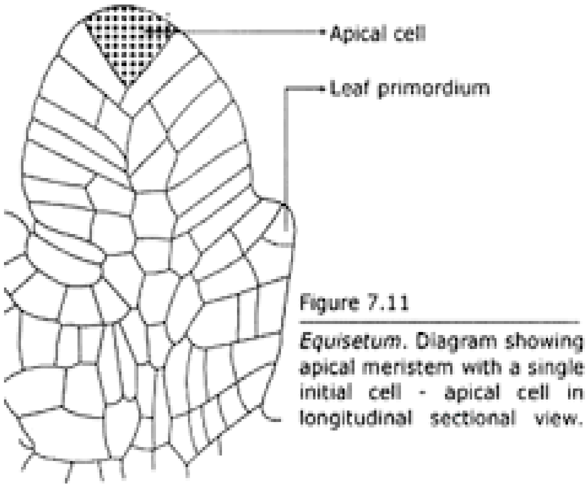
Several theories have been to explain the mode of growth found in shoot apical meristem

1- **APICAL CELL THEORY**

This theory proposed by Nagli 1878. According this theory, a single apical cell is the structural and functional unit apical meristem which governs the entire process of apical growth. Such organization has been found only in lower plants like algae, ferns.



Apical Meristem Organization in Shoot
Apical Cell Theory



2- <u>HISTOGEN THEORY</u>

Hanstein postulated this theory revealing that three distinct meristematic zone (layer) are found in apical region. Each zone consists of a variable number of layers called histogen or tissue builder.

i- Dermatogen

The outermost uniseriate layer. Dermatogen cells divide anticlinally and develop into unilayerd epidermis.

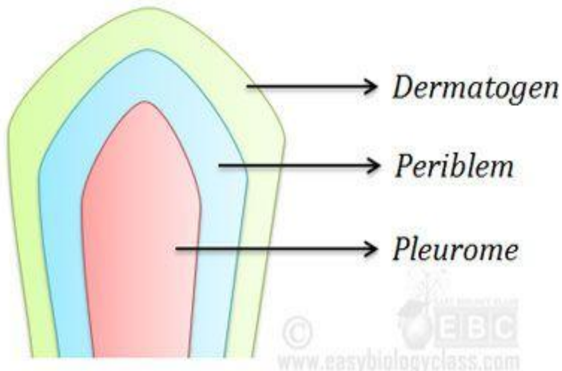
ii- Periblem

The middle region composed of isodiametric cell, forms the cortex.

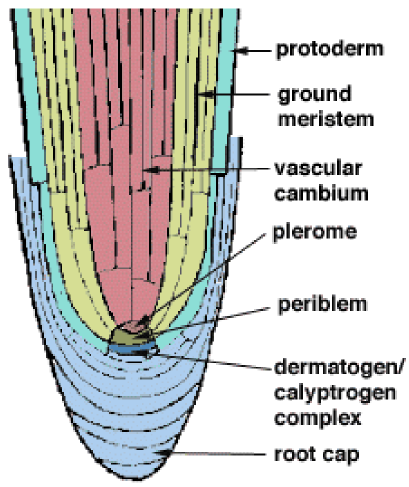
iii- Plerome

The central or inner mass, forms the stele (vascular tissues, pericycle, pith, rays). Disadvantage of this theory:

It is not possible to distinguish these three histogen layers in gymnosperms and angiosperms. Hence this theory was rejected for shoot apical meristem.



Apical Meristem Organization in Shoot
Histogen Theory



3- **TUNICA-CORPUS THEORY**

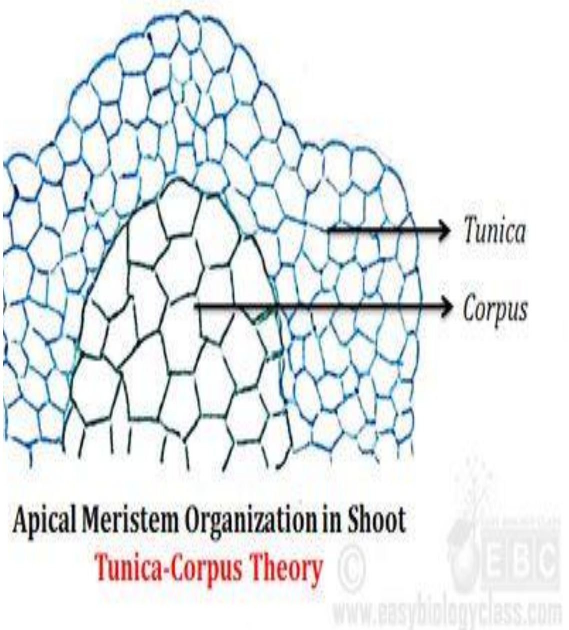
Schmidt 1924 proposed tunica – corpus theory to explain shoot apex organization. According to this theory, there are two zone in apical meristem.

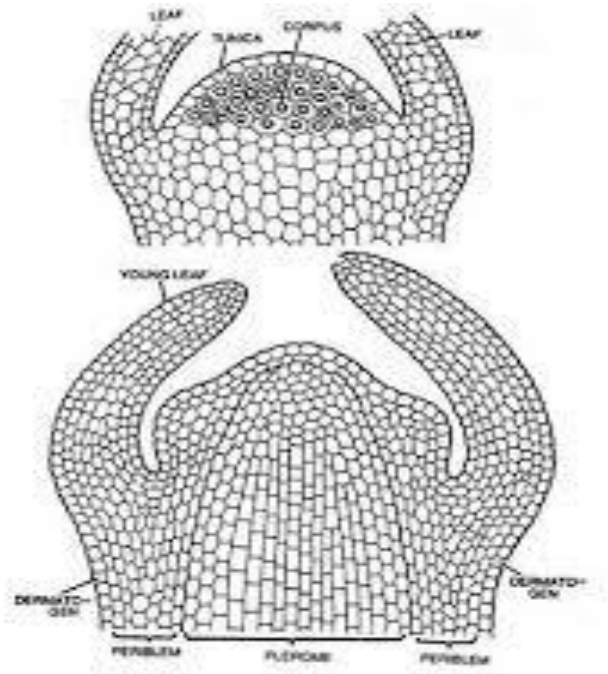
i- Tunica: the outer zone consisting of one or more peripheral layers of cells, forming

the outer region by anticlinal divisions.

ii- Corpus: the central undifferentiated multilayered mass of cells surrounded by tunica which forms the central part of shoot by irregular divisions.

The tunica cells are smaller and corpus cells are larger. The number of tunica layers may vary even in same species due to influence of seasonal growth changes.





4- **CYTOHISTOLOGICAL ZONATION**

It was found that in gymnosperms, tunica like layer is not found which led foster 1939 to divide shoot apex organization of ginkgo biloba on basis of cytohistological zonation, which react differently to staining. He recognized four inter related zones.

i- Apical initial zone

The outermost layer of the apical meristem undergoes periclinal and anticlinal divisions and contributes cells to the peripheral and interior tissues of the shoot.

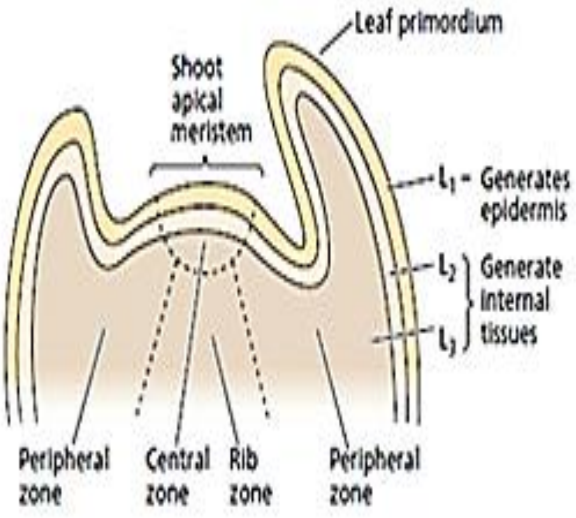
ii- Peripheral layer

Encircles the other zones. The peripheral zone typically is the most meristematic of all three zones and has the densest protoplasts and the smallest cell dimensions. It may be described as a eumeristem. Leaf primordia and the procambium arise here, as well as the cortical ground Tissue.

iii- Central mother cell

iv- Rib meristem

Appears directly below the central zone and is centrally located in the apex. It usually becomes the pith after additional meristematic activity has occurred.



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2. Permanent tissues

Tissues that stopped active division & differentiate to functions. It may be living cells contain cytoplasm & nucleus, keep in division ability depending on conditions, some of the permanent tissues lose it's nucleus but keep cytoplasm and still active like sieve tube, some of the permanent tissues lose activity because of thickening with Lignin, suberin & die as like as fibers, tracheid.

Permanent tissues on the base of Topographic continuity

Tissues forming plant body classified into systems which located certain parts in plant body, therefore three types of systems forming plants body

1- Dermal tissue system

All tissues which covered plant body such as Epidermis in primary growth parts and Periderm in roots and stems with secondary growth

2- Vascular tissue system

Consist of xylem and phloem in primary and secondary growth of plant body.

3- Ground tissue system (Fundamental)

Consist of all tissues between two systems above such as Cortex, pith, Medullary rays in roots and stems and Ground tissue in stems of monocot. and Mesophyll in leaves , Paranchyma, Collanchyma and Sclerenchyma are the most important forming of this system.

1- Dermal tissue system

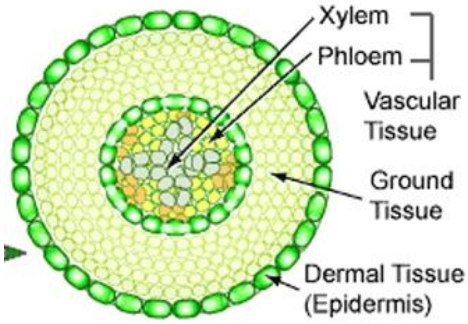
This term refers to all peripheral tissues envelop all plant body organs in primary and secondary growth, dermal tissue is a protective layer. Separate plant from the outer environment & mechanical protection, gaseous exchange through stomata & keeping water & metabolic products, it is represent in:

1- **Epidermis**: primary growth.

2- Periderm: secondary growth.

1- Epidermis

The term epidermis designates the outermost layer of all parts of on the primary plant body. It is derived from the (Greek epi, for upon, and derma, for skin). Including roots, stems, leaves, flowers, fruits, and seeds. An epidermis is considered to be absent, however, on the root cap and not differentiated as such on the apical meristems.



EPIDERMIS CELLS CHARACTERISTICS

1. Leaving cells, clear nucleus contain cytoplasm, vacuoles, chloroplasts are absent inspect of guard cells, hydrophytes, shadow plants.
2. Primary cell wall and some time secondary cell walls like in *Pinus*. containing primary pit-fields and plasmodesmata generally occur in the anticlinal and inner periclinal walls of the epidermis, although the frequency of plasmodesmata between the epidermis and mesophyll of leaves is relatively low. For a time plasmodesmata were thought to occur in the outer epidermal walls and were called ectodesmata.
3. Intercellular spaces absent so that block water & gases passage inspect of stomata.
4. In roots the epidermis may have a common origin with cells of the root cap or differentiate from the outermost cell layer of the cortex.
5. The difference in origin of the epidermis in shoots and roots has convinced some investigators that the surface layer of the root should have its own name, **rhizodermis**, or **epiblem**.
6. Aerial parts epidermis walls saturated from the outer side with cutien, which is added in two ways:
   A- Cutien adding throw cells wall this way called (Cutinization)
   B- Cutien adding as continues outer layer this way called (Cuticularization) and the layer called cuticle.

7- Cuticles are formed in cortical cells and give rise to a protective tissue called cuticular epithelium.

8- The cuticle occur in the aerial part and absent in the ground part, and cuticle thickness is very important from the ecological part,
Xerophytes plant = thick cuticle
Hydrophytes plant = thin cuticle or absent

9- Epidermal cell walls vary in thickness in different plants and in different parts of the same plant. In the thinner walled epidermis, the outer periclinal walls are frequently thicker than the inner periclinal and anticlinal walls.

INITIATION OF EPIDERMIS

Plant epidermal initials varies with plant groups as following :

1- In low vascular plants there is no independent origin of the epidermis, but only one or a few cells forming of all the tissues of the plant.

2- In high vascular plants the method of epidermal initials depends on how regular structural cells in the developing apex.

a- most of gymnosperm and few of angiosperm there is no independent origin of the epidermis thus the term Protoderm is called on surface layer of the apex that will later become the epidermis.

b- In some of dicot. and most of monocot. plants which shoot apex on it Characterized into clearly coated layers, epidermis forming from outer coated layer as a result of vertical divisions (anticlinal) epidermis has an independent initials called <u>Dermatogen</u> as in Hestorgen theory.

3- In roots, epidermis rarely has an independent initials layer, in some of root apical meristem on monocot. plants there are four initials zones one of them specialized to forming epidermis

TYPES OF Epidermis

1- Simple epidermis (uniseriate)

The epidermis is usually one layer of cells in thickness

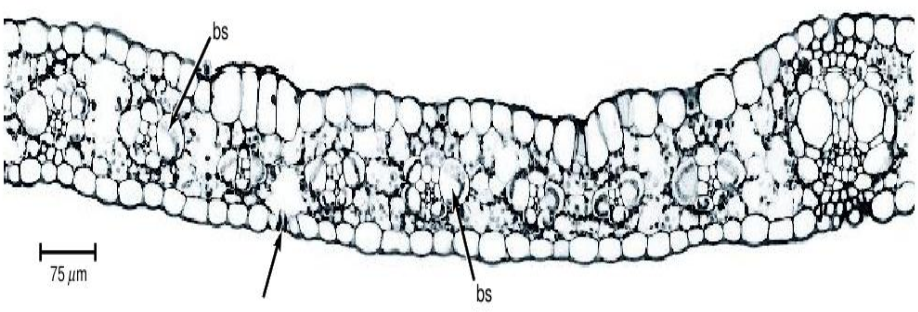


FIGURE 9.1

Transverse section of a maize (*Zea mays*) leaf showing a single-layered epidermis on both sides of the blade. A single stoma (arrow) can be seen here. The vascular bundles of various sizes are delimited from the mesophyll by prominent bundle sheaths (bs). (From Russell and Evert, 1985, Fig. 1. © 1985, Springer-Verlag.)

2- Double epidermis (double seriate)

3- Multiple epidermis (multiseriate)

In some leaves the protodermal cells and their derivatives divide periclinally (parallel with the surface), resulting in a tissue consisting of several layers of ontogenetically related cells. (Sometimes only individual cells of the epidermis undergo periclinal divisions.) such a tissue is referred to as a multiple, or multiseriate epidermis.

FUNCTIONS OF THE EPIDERMIS

The common functions of the epidermis of the aerial plant parts are :

1- considered to be reduction of water loss by transpiration.

2- mechanical protection.

3- gaseous exchange through stomata. Because of the compact arrangement of the cells and the presence of the relatively tough cuticle.

4- The epidermis also offers mechanical support and adds stiffness to the stems

5- In stems and coleoptiles the epidermis, which is under tension, has been regarded as the tissue that controls elongation of the entire organ.

6- The epidermis is also a dynamic storage compartment of various metabolic products

7- The site of light perception involved in circadian leaf movements and photoperiodic induction.

8- In the sea grasses and other submerged aquatic angiosperms, the epidermis is the principal site of photosynthesis.

9- In some leaves the upper epidermal cells act as lenses, focusing light upon the chloroplasts of the underlying palisade parenchyma cells

10- Epidermal cells of both the shoot and root are involved with the absorption of water and solutes.

11- Although the mature epidermis is generally passive with regard to meristematic activity, it often retains the potentiality for growth for a long time.

12- Epidermal cells have living protoplasts and may store various products of metabolism.

13- They contain plastids that usually develop only few grana and are, therefore, deficient in chlorophyll. Photosynthetically active chloroplasts, however, occur in the epidermis of plants living in deep shade, as well as in the epidermis of submerged water plants. Starch and protein crystals may be present in epidermal plastids, anthocyanins in vacuoles.

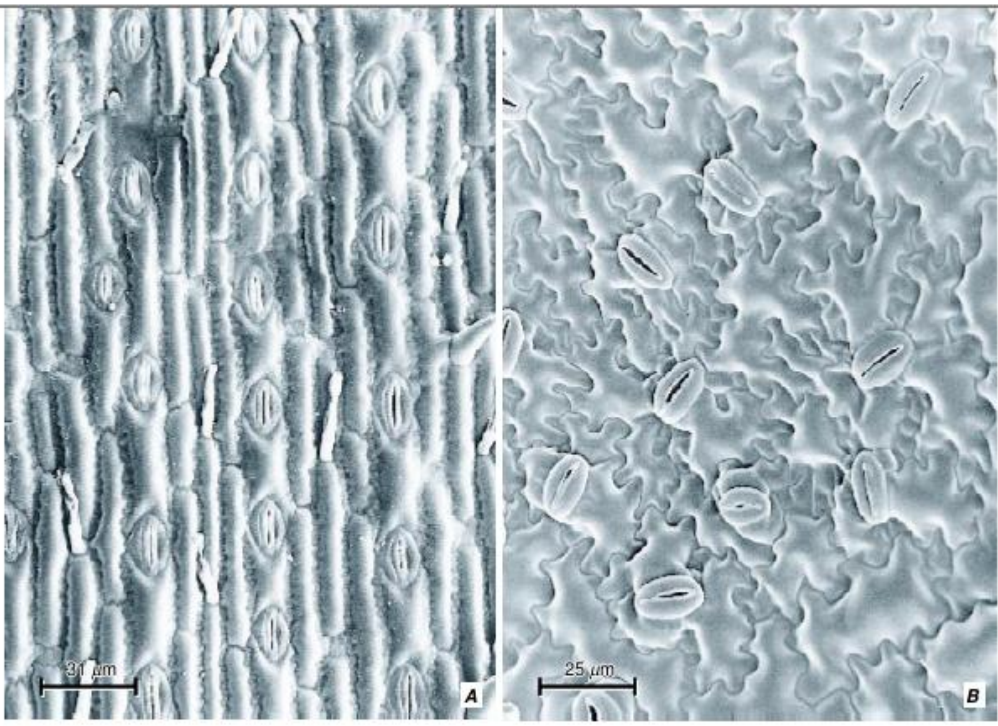


FIGURE 9.17

Surface views of stomata shown in scanning electron micrographs. **A**, maize (*Zea mays*) leaf showing the parallel arrangement of stomata typical of the leaves of monocots. In maize each pair of narrow guard cells is associated with two subsidiary cells, one on each side of the stoma. **B**, potato (*Solanum tuberosum*) leaf showing the random, or diffuse, arrangement of stomata typical of the leaves of dicots. The kidney-shaped guard cells in potato are not associated with subsidiary cells. (**B**, courtesy of M. Michelle McCauley.)

TYPES OF EPIDERMIS CELLS

1- Ordinary epidermal cells : (also called ground cells, epidermal cells proper, unspecialized epidermal cells, pavement cells), and of more specialized cells dispersed throughout the mass.

2- guard cells : more specialized cells are the guard cells of the stomata and a variety of appendages.

3- epidermal hairs or trichomes : the trichomes, including the root hairs, which develop from epidermal cells of the roots.

1- Ordinary epidermal cells

Mature ordinary epidermal cells (often simply referred to hereafter as epidermal cells) are variable in shape, but typically they are tubular, having little depth. Some, such as the palisade -like epidermal cells of many seeds, are much deeper than they are wide. In elongated plant parts, such as stems, petioles, vein ribs of leaves, and leaves of most monocots, the epidermal cells are elongated parallel with the long axis of the plant part. In many leaves, ovaries, and ovules, the epidermal cells have wavy vertical (anticlinal) walls. The pattern of waviness is controlled by local wall differentiation, which determines the pattern of wall expansion.

2- Guard cells

Cells occur like couples with a stoma between each pear leaving cells contain nucleus & chloroplasts its occur either kidney shape or dumble shape may be contact with assistant cells or may not, its function is open and close the stomata.

Stomata

Stomata are specialized pores in the epidermis through which gaseous exchange (water release and carbon dioxide uptake) takes place. They occur on most plant surfaces above ground, especially on green photosynthetic stems and leaves, but also on floral parts. Each stoma consists of two guard cells surrounding a central pore. Cuticular ridges extend over or under the pore from the outer or inner edges of the adjacent guard cell walls.

Stomata kinds:

1- Monocot – Dicot type of stomata

The normal and most common type is called the type of dicotyledon and the dicotyledon. It is found in all dicotyledons and all monocots except for Gramineae and cyperaceae family and in this type the sense cells are kidney-shaped in the surface view. In the vertical section, the guard cells appear to contain a horn-like on the outside only or the outer and inner sides of the stoma, these parts are bounded on the outside by a cavity called the front cavity, and on the inner side another cavity called the back cavity, and the latter is located between the stoma opening and the internal air chamber that lies directly inside the stoma.

2- Gramineae - cyperaceae type

In this type, the s guard cells are dum-bell-shaped in surface view and the cell appears narrow in the middle and widened and bulging at the two ends. The narrow middle part is thick in wall and the swollen ends are thin wall. Opening and closing the gap in this type depends on the shape of the guard cell and the uneven thickening in its wall. When the cell is full, the thin edges below the thick-walled midsection swell and the stoma opens. In the case of decreased osmotic pressure, the peripheral parts become less swollen, the thicker, intermediate parts of the sentinel cells converge, and the stoma closes.

3- Coniferales type

The third type is found in Coniferales plants, including *Pinus*, and it is called the gymnosperm type. Stomatal complexes in this type are sunken and equipped with subsidiary cells. The guard cells appear in the vertical section in an inclined position, as their walls are thickened in their parts and thin in other parts, and the opening and closing of the stoma depends on the type of thickening of the guard cells walls and the placement of the subsidiary cells in relation to the guard cells

subsidiary cells

The epidermal cells immediately adjacent to the guard cells are termed subsidiary cells. it they differ morphologically from surrounding epidermal cells.

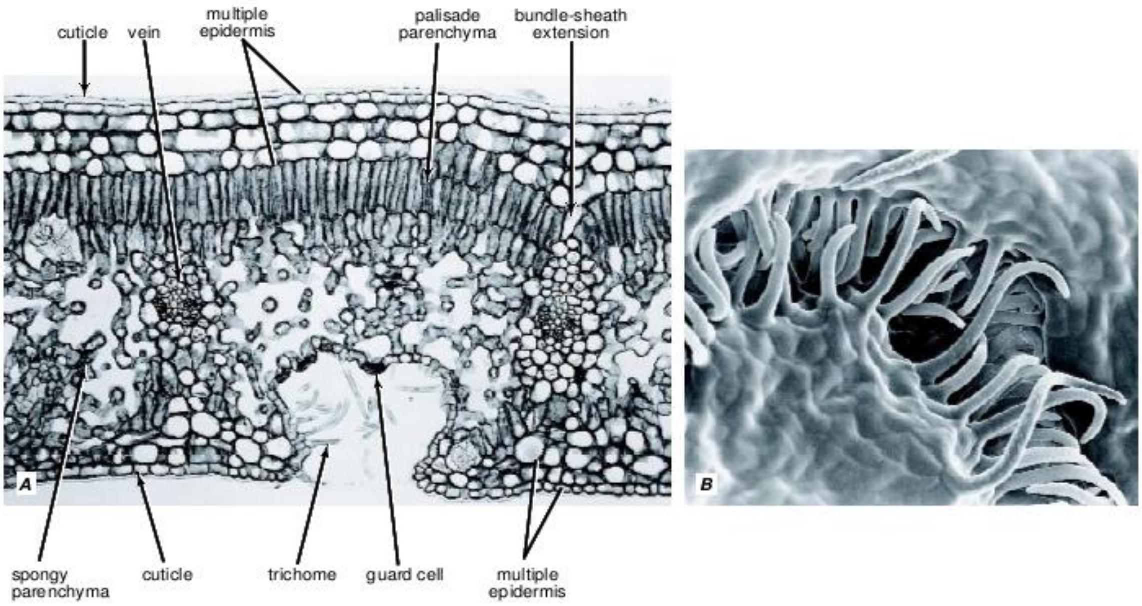


FIGURE 9.12

Oleander (*Nerium oleander*) leaf. **A**, transverse section showing a stomatal crypt on the lower side of the leaf. In oleander the stomata and trichomes are restricted to the crypts. The oleander leaf has a multiple epidermis. **B**, scanning electron micrograph of a stomatal crypt showing numerous trichomes lining the crypt. (**A**, ×177; **B**, ×725.)

Type of subsidiary cells

Classifications of stomatal types are based either on the arrangement of mature subsidiary cells, or on their patterns of development. Types of mature stomata include :

1- Anomocytic : stomata lack subsidiary cells entirely Ex. Apocynaceae, Boraginaceae, Chenopodiaceae, Cucurbita etc.

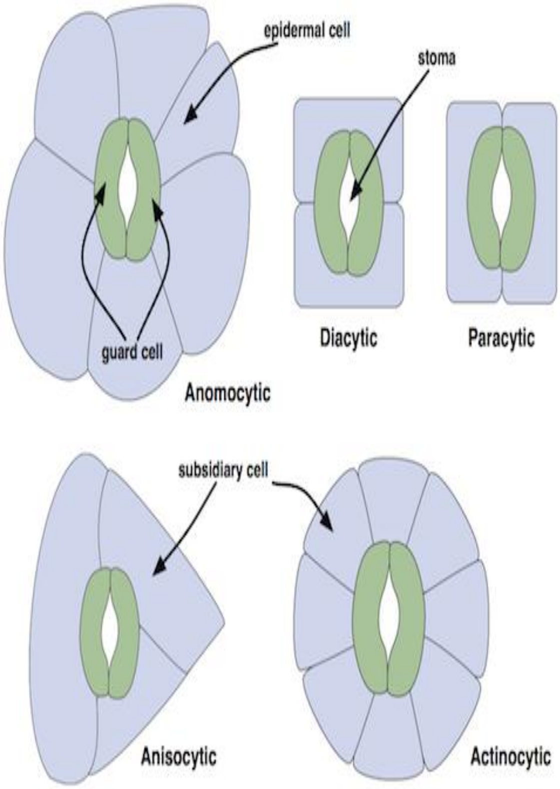
2- Anisocytic : stomata possess three unequal subsidiary cells Ex. Cruciferae, Solanum, Petunia, Sedum and Nicotiana etc.

3- Diacytic : stomata possess one or more pairs of subsidiary cells with their common walls at right angles to the guard cells Ex. , Acanthaceae, Hygrophila, Dianthus etc.

4- Paracytic : stomata possess one or more subsidiary cells at either side of the guard cells Ex. Rubiaceae, Convolvulaceae, Phaseolus, Arachis and Psoralea etc.

5- Actinocytic: stoma remains surrounded by a circle of radiating subsidiary cells Ex. Ancistrocladus and Euclea pseudebenus (Ebenaceae)

6- Gramineous: Gramineous stoma possesses two guard cells that are shaped like dumb-bells. Each guard cell has a narrow middle portion and two bulbous ends. The narrow middle portion is strongly thickened.



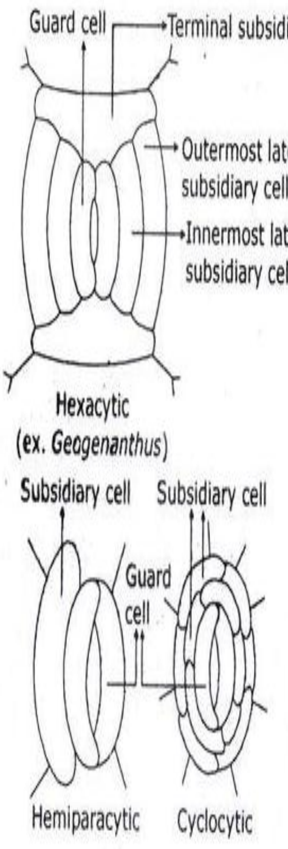


Figure 12.10
Diagrams illustrating three stomata

The subsidiary cells occur parallel to the long axis of pore. Ex. Gramineae and Cyperaceae.

7- Hemiparacytic**:** The stoma is accompanied by a single subsidiary cell, which is placed parallel to the long axis of the pore and this cell may be long or short in length in contrast to the guard cells. Example: Glinus latioides and Trianthema lancastrum etc.

8- Hexacytic**:** The stoma is surrounded by six subsidiary cells among which two are situated on the two polar sides and rest two pairs occur on the two lateral sides being parallel to the long axis of the guard cells.

Stomata occurrence

The stomata are common on green aerial parts of plants particularly the leaves, they occur either on both surfaces (amphistomatic leaf) or on one only either the upper (epistomatic leaf) or more commonly the lower (hypostomatic leaf).

Formation of Stomata

Stomata formation either by the oblique division for the protodermal cell (in dicotyledon) or by unisometric division for epidermal cell (in monocotyledon) temperature have a direct effect on division.

EPIDERMAL HAIRS OR TRICHOMES

Trichomes (from the Greek, meaning a growth of hair) are highly variable epidermal appendages. They may occur on all parts of the plant and may persist throughout the life of the plant part or may fall off early. Some of the persisting trichomes remain alive; others die and become dry. Although trichomes vary widely in structure within families and smaller groups of plants, they are sometimes remarkably uniform in a given taxon and have long been used for taxonomic purposes trichomes are usually distinguished from emer-gences, such as warts and prickles, which are formed from both epidermal and subepidermal tissue and typically are more massive than trichomes. The distinction between trichomes and emergences is not sharp, however, because some trichomes are elevated upon a base consisting of subepidermal cells. Thus a developmental study may be necessary to determine whether some outgrowths are solely epidermal in origin or both epidermal and subepidermal in origin.

They vary widely in both form and function, and include unicellular or multicellular, branched or unbranched forms, and also scales, glandular (secretory) hairs, hooked hairs and stinging hairs.

Glandular trichomes usually possess a unicellular or multi-cellular stalk and a secretory head with one to several cells. Secreted substances such as volatile oils collect between the secretory cells and a raised cuticle, which later breaks to release them. Trichomes can be classified into:

1- Unicellular:
   a. unbranched in cotton seed
   b. branched in Mathiola
2- Multicellular:
   a. uniseriate
   b. multiseriate in begonia

3- Dendroid (tree-like) in platanus
4- Stellate in Malva
5- Peltate in Olea
6- Bladders in Atriplex
7- subsurface emergence in some roses.
8- Stinging hairs in Urtica

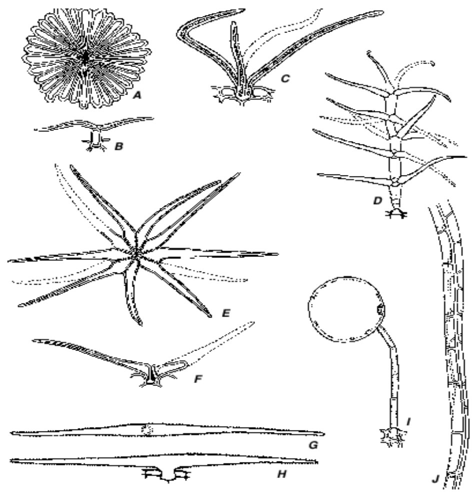


FIGURE 9.24

Trichomes. **A**, **B**, peltate scale of *Olea* in surface (**A**) and side (**B**) views. **C**, tufted, stellate hair of *Quercus*. **D**, dendritic hair of *Platanus*. **E**, **F**, stellate hair of *Sida* in surface (**E**) and side (**F**) views. **G**, **H**, two-armed, T-shaped unicellular hair of *Lobularia* in surface (**G**) and side (**H**) views. **I**, vesiculate hair of *Chenopodium*. **J**, part of multicellular shaggy hair of *Portulaca*. (A–C, I, ×210; D–H, J, ×105.)

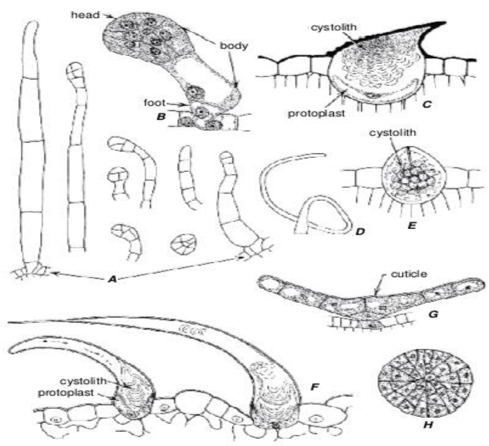


FIGURE 9.25

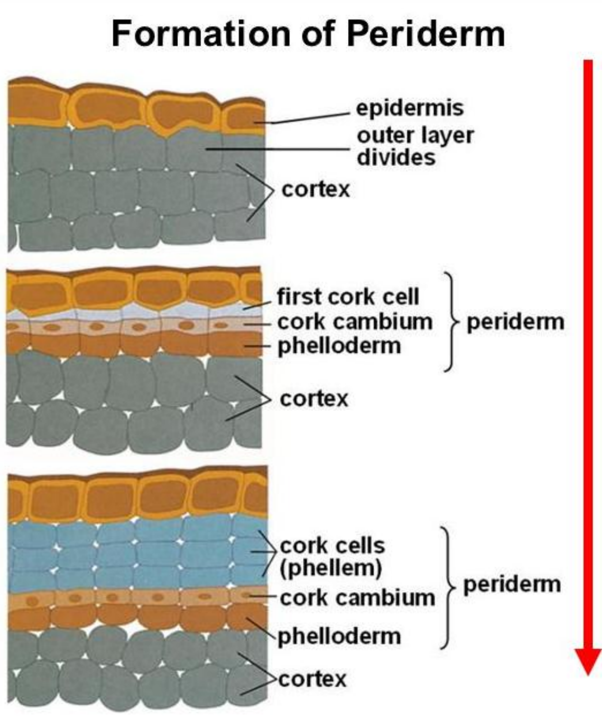
Trichomes. **A**, group of ordinary and glandular (with multicellular heads) hairs of *Nicotiana* (tobacco). **B**, enlarged view of glandular hair of tobacco, showing characteristic density of contents of glandular head. **C**, hooked hair with cystolith of *Humulus*. **D**, long coiled unicellular hair, and **E**, short bristle with cystolith of *Boehmeria*. **F**, hooked hairs with cystoliths of *Cannabis*. **G**, **H**, glandular peltate trichome of *Humulus* seen in sectional (**G**) and surface (**H**) views. (**H** from younger trichome than **G**.) (A, F, ×100; B, D, E, ×310; C–G, ×245; H, ×490.)

The Periderm

Periderm is a protective tissue of secondary origin. It replaces the epidermis when the axis increased in growth and the epidermis is destroyed. Periderm contains:

a. Cork cambium (phellogen)
b. Cork (phellem) , mostly dead cells with cell walls containing much suberin.
c. phelloderm

<u>Cork cambium (phellogen)</u>: Secondary meristem, lateral position, rectangular cells, meristematic cells which have so more vacuoles, simple tissue (one type of cells, thermoisolation, to form cork (outside) and secondary cortex (inside).



The origin:

- In the root from the pericycle.
- In the stem from the hypodermis region.

<u>Cork (phellem)</u>: permanent tissue, it cells dead in mature because of thicking its wall with (suberin) (max substance) in perviousness to water & gases exchanged & prevent temperature effect on the inner tissues.

<u>Phelloderm</u>: parenchymatic cells differ from ordinary cortex cells in its regular strips & its composed of few layers some time one layer.

The average of phellem formation is higher from the average of phelloderm formation and it may reaches to 20 strips in one season of growth.

Origin:

The first periderm from sub-epidermal layer.

Rhytidom: a term mean all the dead tissues which occur outside the phellogen when the phellogen get in deeper layers. (outer Bark) (a layer of cork alternating with a layer of tissue cut off by the cork).

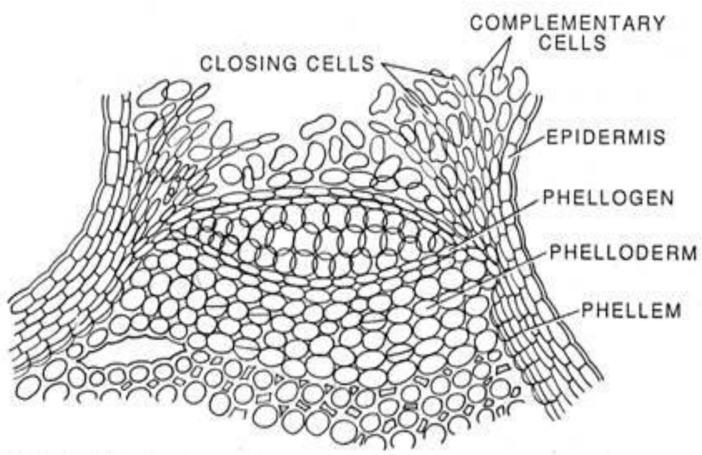
Bark: a term applied most commonly to all tissues outside the vascular cambium of the axis, in either primary or secondary state growth. (Like primary and secondary phloem, cortex, periderm and any other tissue outside the periderm, Bark contain a sclerenchymatic cells, phloem fibes&sclerides. We can see **two** kinds of Bark:

- **Cyclic Bark:** when the cork cambium occur as a complete cylinder. The Bark is formed and fall in cyclic form as like as in *vitis*.
- **Scaly Bark:** its formed when the cork cambium occur in linear shape and the Bark fall like as scales as like as in *Pinus& Oak.*

Lenticels:

Cells without subern in on its walls called complementary tissue which contain wide intercellular spaces their function is gas use exchange instead of the guard cells.

Lenticels are structurally differentiated portions of the periderm characterized by a relatively loose arrangement of the cells.



3- Ground Tissue System (Fundamental)

This system includes all the tissues excepting the epidermis and the vascular bundles. Thus it is the largest or the most exhaustive system, which begins from the layer next to epidermis and continues right up to the center of the organs in cylindrical bodies such as **Cortex, pith, Medullary rays in roots and stems and Mesophyll in leaves , Paranchyma, Collanchyma and Sclerenchyma** are the most important forming of this system.

Characterization

1- Ground tissue system is permanent tissue which is heterogeneous in nature, consisting of diverse types of cell elements adapted to carry on different functions.
2- In the axis of higher plants the vascular bundles occupy a restricted position inside the stele or central cylinder.
3- The ground tissues occurring outside the stele, and, in fact, surrounding it, form the cortex, what may be called external or extrastelar ground tissue.
4- Similarly there are internal or intrastelar ground tissues inside the stele, e.g., pith.
5- Both external and internal ground tissues are further differentiated to specialized zones.
6- These tissues are derived from the ground meristem of the embryonic region.

Types of ground tissues

A- Parenchyma
B- Collenchyma
C- Sclerenchyma

A- Parenchyma

The term parenchyma refers to a tissue composed of living cells variable in their morphology and physiology, the word parenchyma is derived from the Greek para, beside, and en-chein, to pour, a combination of words that expresses the ancient concept of parenchyma as a semiliquid substance “poured beside” other tissues that are formed earlier and are more solid.

Characterization of parenchyma cells

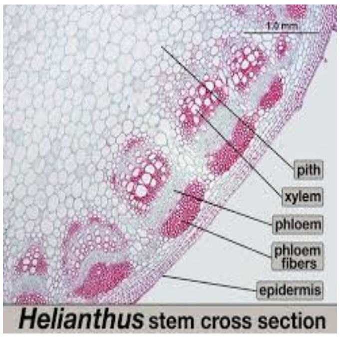
1- Parenchyma may be considered the phylogenetic precursor of all other tissues.
2- Living cells at maturity with central nucleus, cytoplasm and vacuoles surrounded by thin primary cell wall (0.2 to 2 μm in diameter), sometimes is thick in the endosperm of date palm and persimmon.
3-These cells keep their ability to divide or to resume (meristematic activity)developmentally, parenchyma cells are relatively undifferentiat

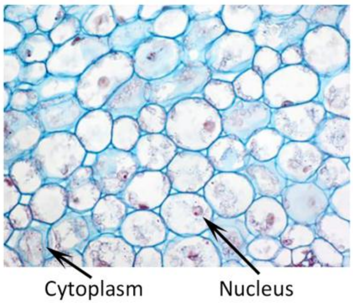
(unspecialized morphologically and physiologically) compared with such cells as sieve elements, tracheids, and fibers because, in contrast to these three examples of cell categories, on other word (**<u>parenchyma cells are able to resume meristematic activity: to dedifferentiate, divide, and redifferentiate</u>**). parenchyma cells may change functions or combine several different ones. However, parenchyma cells may also be distinctly specialized, for example, with reference to photosynthesis, storage of specific substances.

4- they are surrounded by intercellular spaces or larger cavities for effective gas exchange.

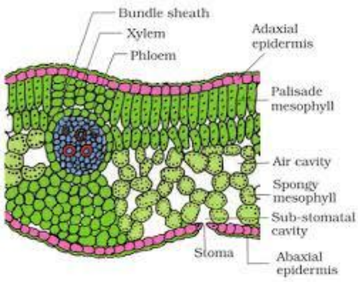
5-Shapes of cells differ with the differentiation of tissue.

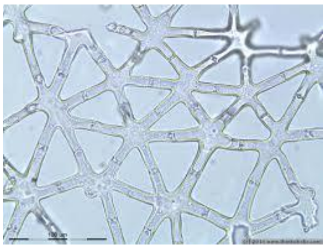
i. Isodiametric: *Helianthus annus* ii- Spherical: Geranium



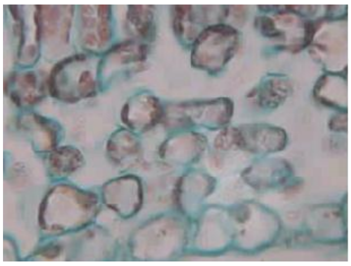


iii- Columinal: like in mesophyll in leaf iv- Stellate: like in *Alkana*





v- Lobed: like in *Pinus*



6- Middle lamellae may or not be distinguishable, plasmodesmata are common.

7- Parenchyma cells are the pith and cortex of stems and roots, the photosynthetic tissue (mesophyll) of leaves .
8- Some parenchyma cells develop secondary walls (lignified) make it difficult to distinguish from sclerenchyma.

<u>Origin</u>

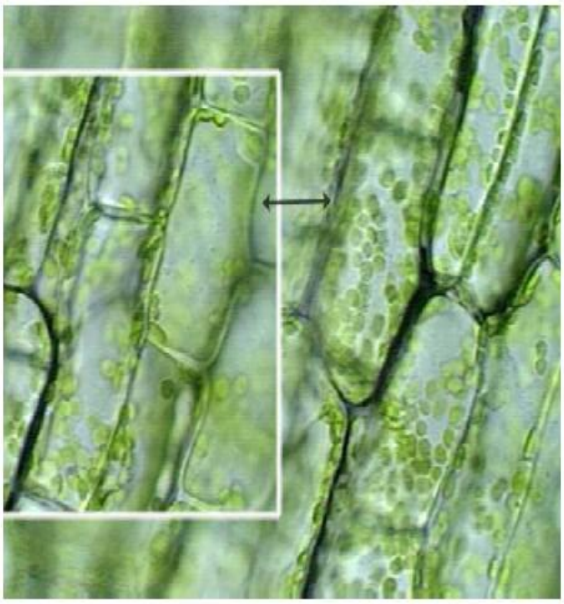
a- The parenchyma of the cortex and pith, of the mesophyll of leaves, and of flower parts, **<u>differentiates from the ground meristem</u>**.
b- The parenchyma cells associated with the primary and secondary vascular tissues are **<u>formed by the procambium and the vascular cambium</u>** respectively.

Classification of parenchyma tissues according to function

1- Ordinary parenchyma : not differentiated to any function.

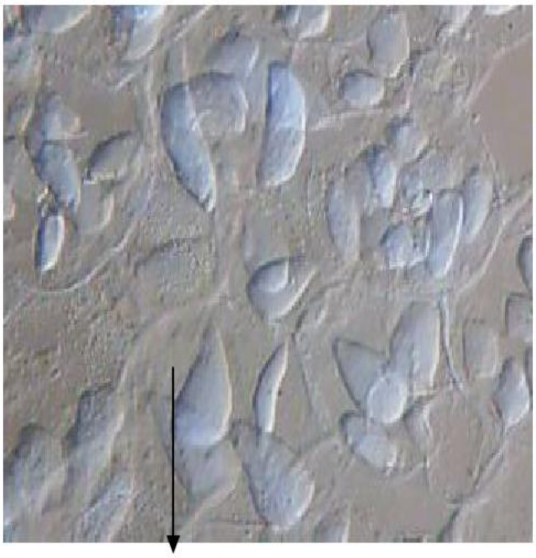
2- **Chlorenchyma**:

It is specialized parenchyma tissue specialized for photosynthesis contains numerous chloroplasts. The greatest expression of chlorenchyma is <u>represented by the mesophyll of leaves</u>, but chloroplasts may be abundant also in the cortex of a stem. Chloroplasts may occur in deeper stem tissues, including the secondary xylem and even the pith. Typically photosynthesizing cells are conspicuously vacuolated, and the tissue is permeated by an extensive system of intercellular spaces.



3- Storage parenchyma

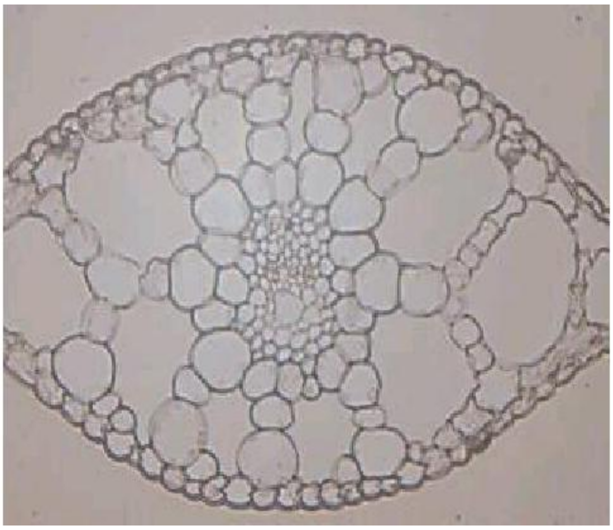
It is characterized by accumulating specific kinds of substances like starch-storing cells such as those of the potato tuber, the endosperm of cereals, and the cotyledons of many embryos, the abundant starch-containing amyloplasts may virtually obscure all other cytoplasmic components. In many seeds the storage parenchyma cells are characterized by an abundance of protein and/or oil bodies. In various parts of the plant, parenchyma cells may become conspicuous by accumulating anthocyanins or tannins in their vacuoles.



Starch grains in Potato stem

4- **Aernchyma**

It is type of parenchyma which found in the leaves, stems and roots of some plants like aquatic, the cells are characterized by small size, thin cell wall and air filled large cavities which provide low resistance internal pathway for the exchange of gases between plant organs above the water and submerged tissues.



5- **Water storage parenchyma**

Parenchyma cells in the tissue system, parenchyma may be rather specialized as a waterstorage tissue. Many succulent plants, such as the Cactaceae, *Aloe, Agave*, contain in their photosynthetic organs chlorophyll free parenchyma cells full of water. This water tissue consists of living cells of particularly large size and usually with thin walls. The cells are often in rows Transfer cell, a specialized form of parenchyma cell, is readily identified by elaborate ingrowths of the primary cell wall. The increase in the area of the plasma membrane beneath these walls facilitates the rapid transport of solutes to and from cells of the vascular system. The ingrowths develop relatively late in cell maturation and are deposited on the original primary wall; hence they may be considered a specialized form of secondary wall.

6- Secretory parenchyma

In contrast, secretory types of parenchyma cells have dense protoplasts, especially rich in ribosomes, and have either numerous Golgi bodies or a massively developed endoplasmic reticulum, depending on the type of secretory product formed.

B- **Collenchyma tissues**

The terms parenchyma and collenchyma are also related, but in the latter the first part of the word, derived from the Greek colla, glue, refers to the thick glistening wall characteristic of collenchyma.

Collenchyma cells and parenchyma cells are similar to one another both physiologically and structurally. Both have complete protoplasts capable of resuming meristematic activity, and their cell walls are typically primary and nonlignified. The difference between the two lies chiefly in the thicker walls of collenchyma cells; in addition the more highly specialized collenchyma cells are longer than most kinds of parenchyma cells.

Characterization of collenchyma

1- It is a living simple permanent tissue composed of more or less elongated cells, with thickened primary walls. for it consists of a single cell type.
2- Its cells contain nuclei, cytoplasm and chloroplasts.
3- It occurs in the peripheral regions of stem and leaf, directly beneath epidermis or a few layers removed from it.
4- Frequently forms a continuous layer around circumference of axis (stem and leaf petiole), may occur in strands
5- In leaf blade occurs in ribs especially the larger one, occurs on both sides or one side of ribs.
6- Roots rarely have collenchyma.
7- Collenchyma may or may not contain intercellular spaces. If spaces are present in the angular type of collenchyma, the thickened walls occur next to the intercellular spaces.
8- Cell Walls of Collenchyma are thick and glistening in fresh sections, and often the thickening is unevenly distributed. They contain, in addition to cellulose, large amounts of pectin and hemicelluloses and no lignin, so it is nonlignified primary walls.

9- Its function is supporting in living organs

Origin

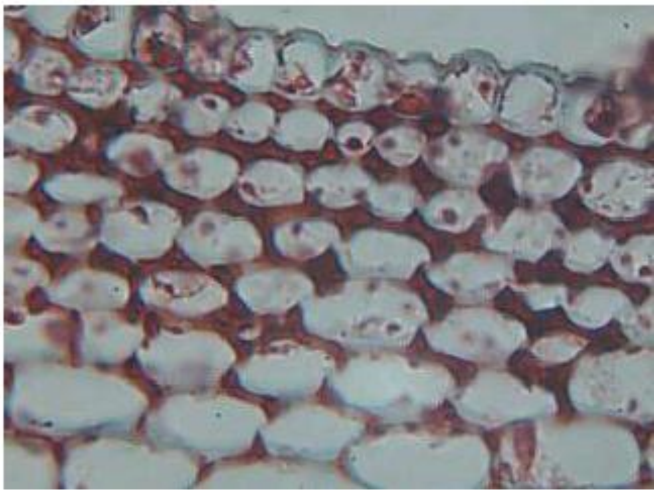
a- Procambium
b- Ground meristems

TYPES OF COLLENCHYMA ACCORDING TO WALL THICKENED NATURE

The distribution of wall thickening in collenchyma shows several patterns, these are :

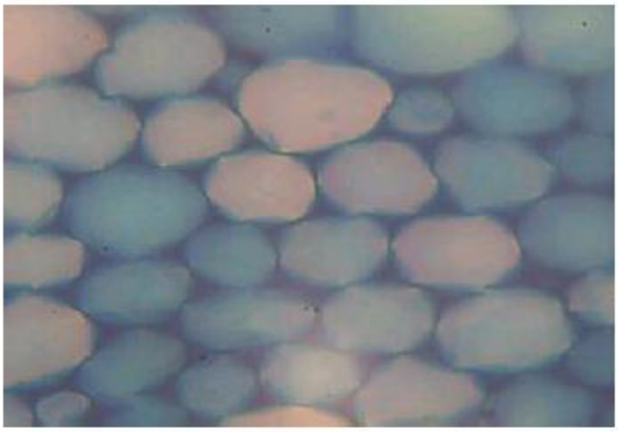
1- Lamellar Collenchyma or plate parenchyma

Collenchyma with the thickenings on two opposite sites of the tangential walls. And radial walls still thin, These thicknesses are in the form of layers or overlapping sheets lying on top of each other, cells without intercellular spaces completely. Lamellar collenchyma is especially well developed in the stem cortex of *Sambucus nigra* and *Helinthus annuus* stem.



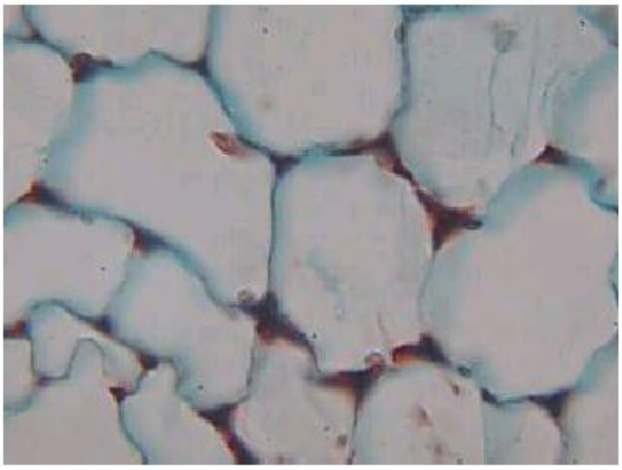
2- Angular collenchyma

It is with wall thickenings localized in the corners commonly, angular collenchyma are found in the stems of *Cucurbita*. and *Vitis*. It is the most common type, cells without intercellular spaces completely.



3- <u>Lacunar, or lacunate, collenchyma</u>

It is characterized by the presence of intercellular spaces between cells, and the thickness is concentrated on the parts of the walls facing these voids, Cells of this type may contain chloroplasts and have the capacity of dedifferentiation, It is the least common type. Occur in *Lactuce* plant.



C- Sclerenchyma

The word is derived from the Greek skleros, meaning “hard” and enchyma, an infusion; it emphasizes the hardness of sclerenchyma walls. The individual cells of sclerenchyma are termed sclerenchyma cells. In addition to comprising sclerenchyma tissue, sclerenchyma cells like parenchyma cells may occur singly or in groups in other tissues. both parenchyma cells and collenchyma cells may become sclerified.

Characterization of Sclerenchyma

1- Simple permanent tissues
2- Thick walled cells, often lignified dead when get mature.
3- Principal function is mechanical (Supporting), so the cells are supposed to enable plant organs to withstand various stress, such as bending, weight & pressure, without damage to the thin-walled softer cells.
4- The elastic, highly hydrated primary walls of collenchyma, distinguish this tissue from sclerenchyma with its hard elastic secondary walls.
5- Sclerenchyma cells are usually divided into two categories, fibers and sclereids.

<u>Origin</u>
1- Procambium
2- Vascular cambium
3- Differentiation of parenchyma cells.

TYPES OF SCLERENCHYMA CELLS
1- FIBERS **2- SCLEREIDS**

<u>1- FIBERS</u>

Fibers typically are long, spindle-shaped cells, with more or less thick secondary walls, and they usually occur in strands, the fiber walls are not highly hydrated. They are therefore harder than collenchyma walls and are elastic rather than plastic. Fibers serve as supporting elements in plant parts that are no longer elongating. The degree of lignification varies, and typically the simple or slightly bordered pits are relatively scarce and slit-like. Many fibers retain their protoplasts at maturity.

Origin: Procambium or vascular cambium

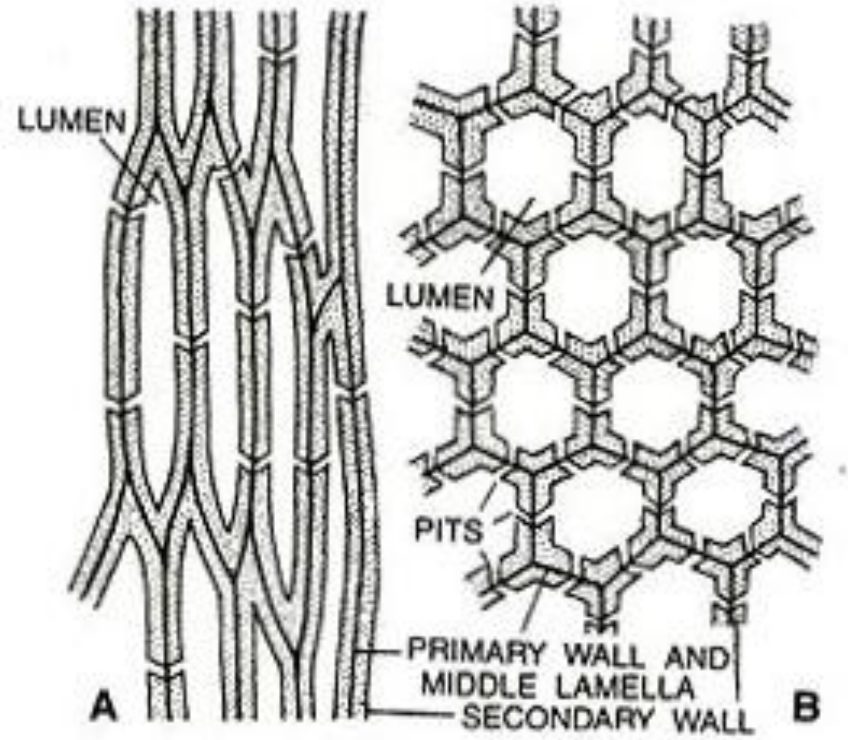
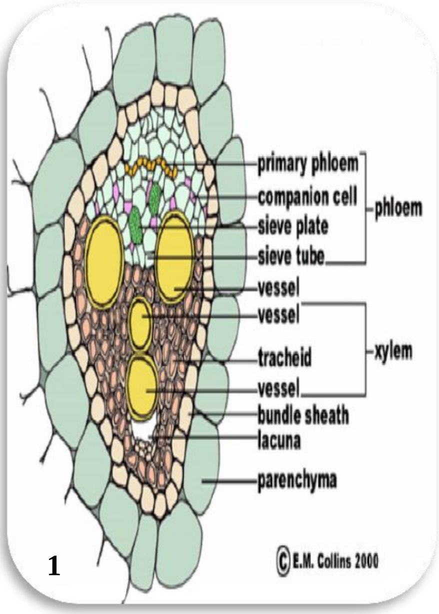


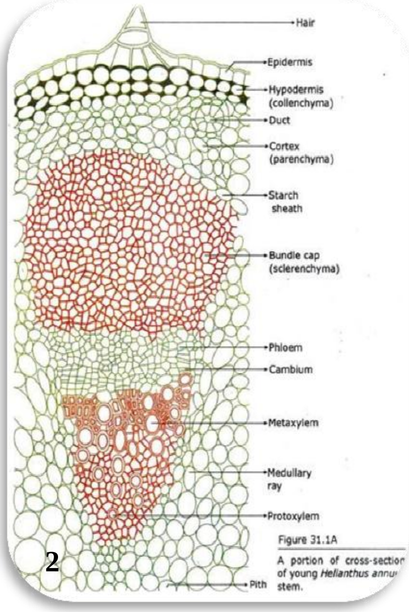
Fig. 6.9. Sclerenchyma Fibres. A, longitudinal section; B, transverse section.

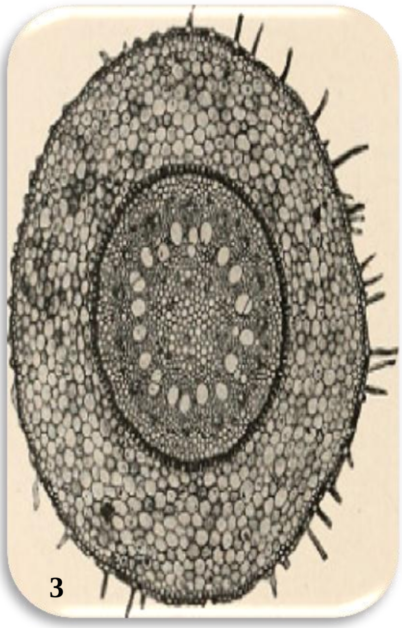
Distribution of fibers in the plant body

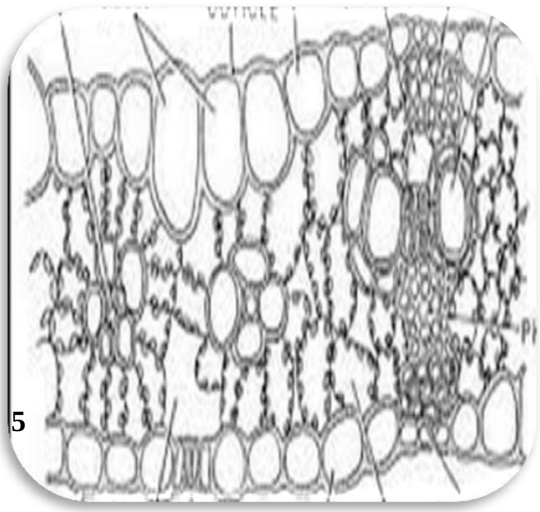
1- Bundle sheath in Gramineae stems such as *Zea mays* stem.
2- Bundle cap which is part of pericycle in *Helianthus annuus* stem.

3- Fibers as continues ring in pericycle of *Ruscus* sp. and *Cucurita* .
4- Fibers are separated bundles in *Yucca* leaf.
5- Fibers as Tapes Opposite of vascular bundles in *Zea mays* leaf.









There are two kinds of fibers:

<u>1- Hard fiber:</u> occur in monocotyledone& leaves up and down vascular bundle and usually its not pure fibers mixed with other tissues, heavily lignified walls.

<u>2- Soft fiber:</u> (Phloem, Pericycle, Cortex fibers) found in dicotyledonae plants, this kind of fibers utilized economically since ancient times in plant like (Flax, hemp, ramie, jute). The epidermal hairs of cotton seed and the kapok seed pod are also termed fibers.

Fibers may be divided into two large groups depending on its position:

1- Xylary (Xylem fibers or Wood fibers).

2- Extraxylary : fibers located outside the xylem

1- Xylary (Xylem fibers or Wood fibers) : Wood fibers are commonly divided into two main groups :

a- The libriform fibers

b- The fiber-tracheids

both of which typically have lignified cell walls. The libriform fibers resemble phloem fibers. Libriform is derived from the Latin liber, meaning "inner bark," that is, phloem. Although the distinction between the two groups of wood fibers has long been based primarily on the presence of simple pits in libriform fibers and of bordered pits in fiber-tracheids, truly simple pits in fiber walls are extremely uncommon. The extremes of the two types of wood fiber are easy to distinguish, but imperceptible gradations occur between them. Fiber-tracheids also intergrade with tracheids, which have distinctly bordered pits. Commonly the thickness of the wall increases in the sequence of tracheid, fiber-tracheid, and libriform fiber. In addition, in a given sample of wood, the tracheids are usually shorter and the fibers longer, with the libriform fibers attaining the greatest length.

Although commonly regarded as dead cells at maturity, living protoplasts are retained in the libriform fibers and fiber-tracheids in many woody plants (Fibers with living protoplasts have been found in bamboo culms over nine years of age) These fibers often contain numerous starch grains; hence, in addition to support, they function in the storage of carbohydrates. The secondary walls of wood fibers differ from those of phloem fibers in that they consist of three layers designated S1, S2, and S3 for outer, middle, and inner, respectively. In addition the walls of wood fibers typically are lignified.

2- Extraxylary : fibers located outside the xylem

i. The cell walls of the extraxylary fibers are often very thick. In the phloem fibers of flax, the secondary wall may amount to 90% of the cross-sectional area of the cell.
ii. The secondary walls of extraxylary fibers have a distinct polylamellate structure, the individual lamellae varying in thickness from 0.1 to 0.2 µm.
iii. Not all extraxylary fibers have such wall structure. In mature bamboo culms, some fiber walls show a high degree of polylamellation, whereas others have no clearly visible lamellae.
iv. Some extraxylary fibers have lignified walls; the walls of others contain little or no lignin (flax, hemp, ramie). Some extraxylary fibers, notably those of the monocots, are strongly lignified.

Extraxylary consist of :

a- the phloem fibers :

Phloem fibers occur in many stems. The flax (Linum usitatissimum) stem has only one band of fibers, several layers in depth, located on the outer periphery of the vascular cylinder. These fibers originate in the earliest part of the primary phloem (the protophloem) but mature as fibers after this part of the phloem ceases to function in conduction. Flax fibers are, therefore, primary phloem fibers, or protophloem fibers. The stems of, Tilia (basswood), Vitis (grapevine), and many others, have both primary phloem fibers and secondary phloem fibers, which are located within the secondary phloem , In addition the secondary walls of the secondary phloem fibers of most woody angiosperms and conifers consist of only two layers, a thin outer (S1) layer and a thick inner (S2) layer .

b- Cortical fibers

Cortical fibers, as the name implies, originate in the cortex, do not originate as part of the phloem tissue but outside it. Perivascular fibers are commonly referred to as pericyclic fibers. However, the designation pericyclic is often used with reference to the primary phloem fibers as well

C- Perivascular fibers

Perivascular fibers are located on the periphery of the vascular cylinder inside the innermost cortical layer. do not originate as part of the phloem tissue but outside it.

d- Extraxylary fibers also include the fibers of the monocots, whether or not associated with the vascular bundles.

2- SCLEREIDS

The distribution of sclereids among other cells is of special interest with regard to problems of cell differentiation in plants. They may occur in more or less extensive layers or clusters, but frequently they appear isolated among other types of cells from which they may differ sharply by their thick walls and often bizarre shapes.

Sclereids typically are short cells with thick secondary walls, strongly lignified, and provided with numerous simple pits. Some sclereids have relatively thin secondary walls, however, and may be difficult to distinguish from sclerified parenchyma cells. The thick-walled forms, on the other hand, may strongly contrast with parenchyma cells: their walls may be so massive as almost to occlude the lumina, and their prominent pits often are ramiform. The secondary wall typically appears multilayered, reflecting its helicoidal construction. Crystals are embedded in the secondary walls of certain species. Many sclereids retain living protoplasts at maturity. Based on Shape and Size.

Sclereids occur in the epidermis, the ground tissue, and the vascular tissues.

Origin: Parenchyma cells differentiate into sclereids.

Sclereids May be Classified into a number of types :

1- Brachysclereids (or stone cells) : The most commonly recognized categories of sclereids, roughly isodiametric or somewhat elongated cells, widely distributed in cortex, phloem, and pith of stems, and in the flesh of fruit.

2- Macrosclereids : elongated and columnar (rod-like) cells, exemplified by sclereids forming the palisade-like epidermal layer of leguminous seed coats .

3- Osteosclereids (bone cells) : also columnar but with enlarged ends as in the subepidermal layer of some seed coats .

4- Astrosclereids, star-cells, with lobes or arms diverging from a central body, often found in the leaves of eudicots.

5- Trichosclereids : less commonly recognized types, thin-walled sclereids resembling hairs, with branches projecting into intercellular spaces.

6- Fliform sclereids : long slender cells resembling fibers .

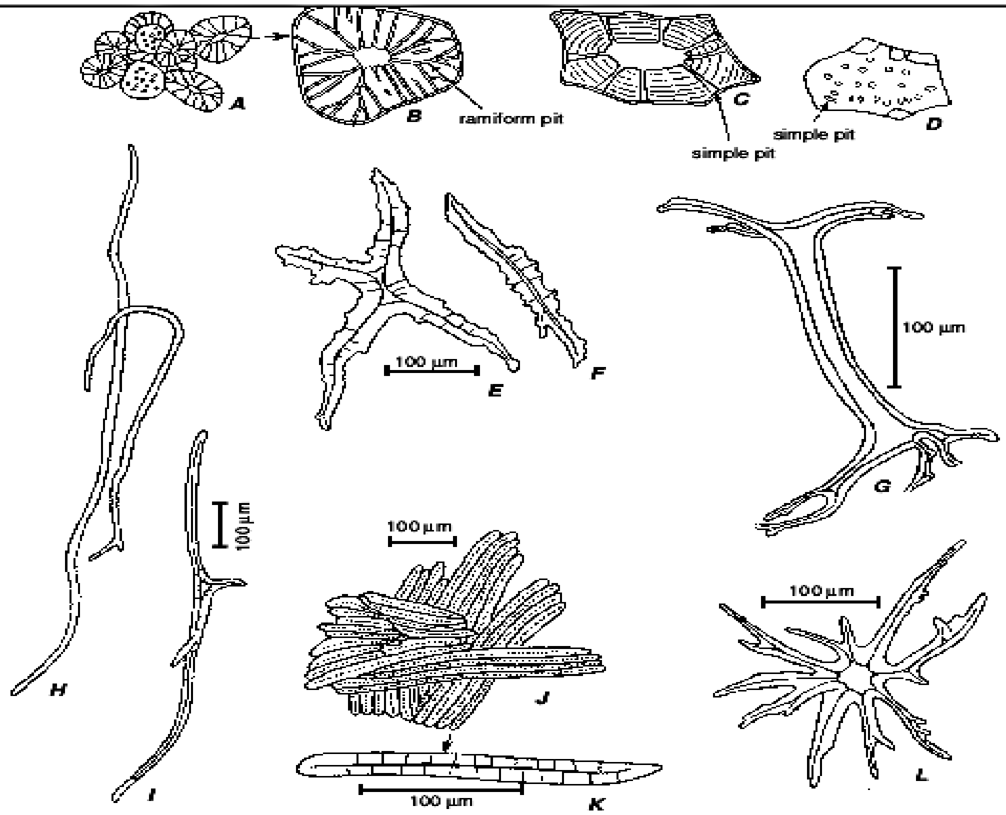


Fig. : Sclereids. A, B, stone cells from fruit flesh of pear (Pyrus). C, D, sclereids from stem cortex of wax plant (Hoya), in sectional (C) and surface (D) views. E, F, sclereids from petiole of Camellia. G, columnar sclereid with ramified ends from palisade mesophyll of Hakea. H, I, filiform sclereids from leaf mesophyll of olive (Olea). J, K, sclereids from endocarp of fruit of apple (Malus). L, astrosclereid from stem cortex of Trochodendron. (From Esau, 1977.)

VASCULAR TISSUES SYSTEM

Introduction

Vascular system occur in higher plants therefor it is called vascular plants and absent in lower plants, therefor it is called non-vascular plants . The vascular tissues system in plants carries out two essential functions, namely the delivery of resources (water, essential mineral nutrients, sugars and amino acids) to the various plant organs, and provision of mechanical support. There are two types of vascular tissues system :

1- xylem

2- phloem

1- Xylem

The term xylem was introduced by Nägeli (1858) and is derived from the Greek xylon, wood. The xylem is a complex permanent tissues, it is the principal water-conducting tissue in a vascular plant. It is also involved in the transport of solutes, in support, and in food storage. Together with the phloem, the principal food-conducting tissue, the xylem forms a continuous vascular system extending throughout the plant body.

The origin of xylem in primary growth stage in procambium, the resulting xylem elements at first called protoxylem, & the xylem elements mature after that called metaxylem which large in diameter than the protoxylem. Plant which get in secondary growth such as dicotyledonous & gymnosperms have secondary xylem initiated from vascular cambium.

Xylem elements:

In most of Angiosperms xylem consist of vessels, tracheid, Fibers and xylem parenchyma.

1. The vessels:

A series of vessel members joined end to end, length about 2-15 ft, thickened with lignin differ in length, thickening way, diameter depending on spaces, age, time of vessel formation in plant. Because of Functional similarities between vessels and tracheid, the two structures together are called tracheary elements. The secondary thickening of tracheary elements are pitted , scalariform , reticulate , spiral , annular.

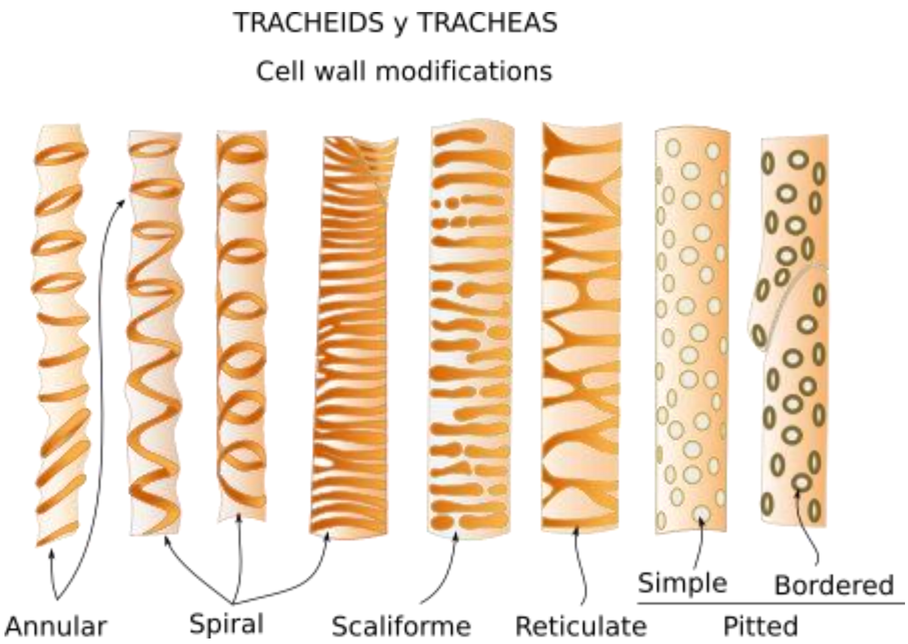


Diagram showing various forms of thickening in the cell walls of the conductive cells of the xylem.

There are two types of vessels end :

a. Non-perforated: in this kind the ends of the vessels solute.

b. Perforated:

1- Simple perforation plates (uniperforate) : continent one perforate only

2- Compound perforation plates (multiperforation) : continent more than one perforate in different shapes that are :

- Foraminate or Ephedronal
- Reticulate
- Scalariform

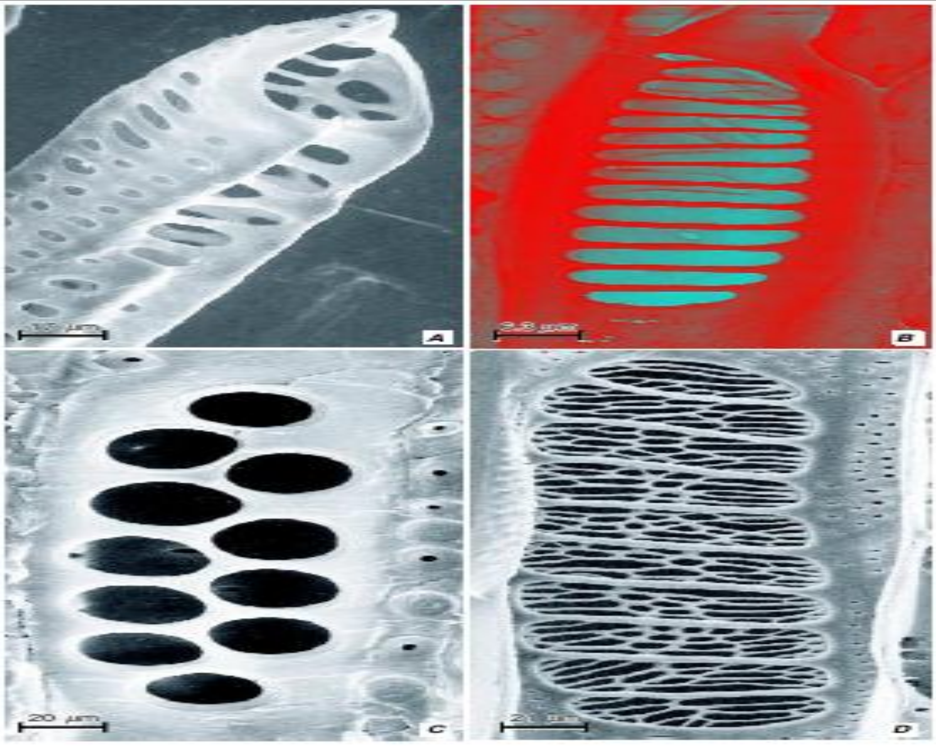


FIGURE : Perforation plates. Scanning electron micrographs of the perforated end walls of vessel elements from secondary xylem. A, a simple perforation plate, with its single large opening, in Pelargonium vessel element. B, the ladder-like bars of a scalariform perforation plate between vessel elements in Rhododendron. C, foraminate perforation plate, with its circular perforations, in Ephedra. D, contiguous scalariform and reticulate perforation plates in Knema fur-furacea. (A–C, courtesy of P. Dayanandan; D, from Ohtani et al., 1992.)

2- The Tracheid

Dead cells at maturation more narrow than the vessels with a thickened wall with the lignin, imporforated, ends attenuated, contain so many border pits, tracheids similar to vessels but it have thin cell wall & wide inner cavity. Vessels occurrence is characteristic of Angiospermae in contrast tracheid is the transportation element in Gymnospermae & lower plants xylem.

3- Xylem fibers

Any of the fibers made up of dead sclerenchyma cells in between the xylem vessels and tracheids of the xylem tissue, and chiefly provide mechanical support.

The xylem fibers are non-living sclerenchyma cells as they lose their protoplast at maturity. These cells are found in between the tracheids and xylem vessels of the xylem tissue. Sclerenchyma cells are narrow and elongated cells with tapering ends. They are former parenchyma cells that developed secondary cell walls. Their cell walls become lignified. Their elasticity and great tensile strength make them an essential component in the xylem as they protect and provide mechanical support to the major water conducting tissues of the xylem.

There are two major types of xylem fibers
(1) fiber tracheids
(2) libriform fibers. Fiber tracheids are rather involved in providing mechanical support than in conduction.

4- Xylem parenchyma:

Parenchyma cells associated with xylem are called **"xylem parenchyma"**.

- Only living cells of xylem.
- The cell wall is cellulosic and thin.
- They have prominent nucleus and protoplast.
- Cells are colorless and have large vacuoles.
- Living parenchyma cells are found in both primary and secondary xylem.
- Storage of food material in the form of starch, fats, tannins and crystals.

There are two major types of parenchyma cells in secondary xylem :

1. Axial parenchyma (Vertical): derived from fisiform cambial initials, living tall cells divided into shorter cells.
2. Radial parenchyma (Horizontal): derived from ray initials of the cambium tall with thickened wall contain simple & border & half border pits.

Tylosis

A tylosis (plural: tyloses) in many plants, the axial and the ray parenchyma cells develop protrusions that enter tracheary cells when these become inactive or the xylem tissue is injured, such outgrowth from parenchyma cells, Tyloses development occur through the pit – pairs connecting the parenchyma cells with the tracheary elements. Tyloses have bladder shape &completely fill the lumen of the tracheid or vessel element, the nucleus of the originating parenchyma cell & part of the cytoplasm appear in the cytoplasm.

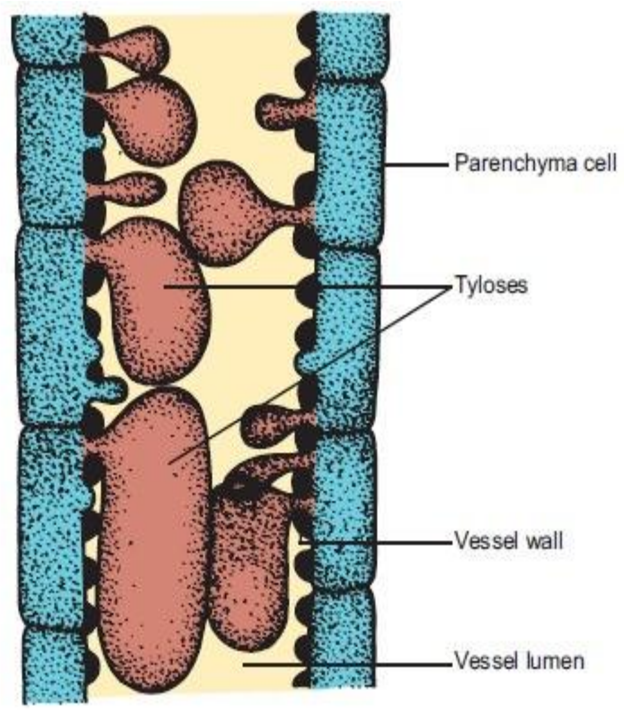
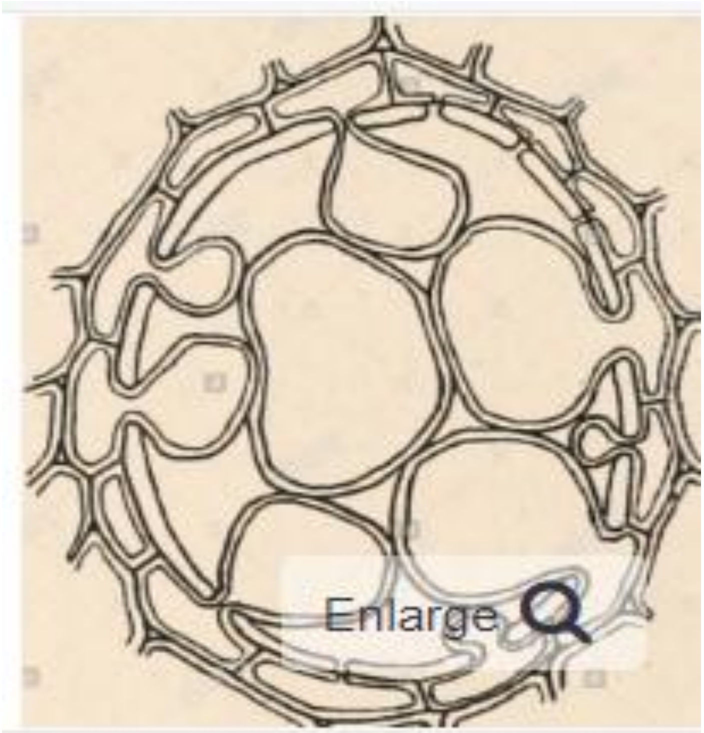


Figure 10.9: Structure of tyloses



Primary & secondary xylem

Primary xylem originate from procambium during the primary growth period, and differentiate to protoxylem and metaxylem, while the secondary xylem originate from vascular cambium and composed of vessels, tracheids, fibers, parenchyma xylem, & contain vertical system & horizontal system.

Annual Rings (Growth Rings)

Cambium activity in plants is seasonally because of the weather change therefore growth cycle appear and consist of :

i- Spring wood / Early wood: wide elements, thin cell wall, most of them are vessels.

ii- Summer wood/ Late wood: narrow elements thickened cell wall most of them are fibers, few vessels.

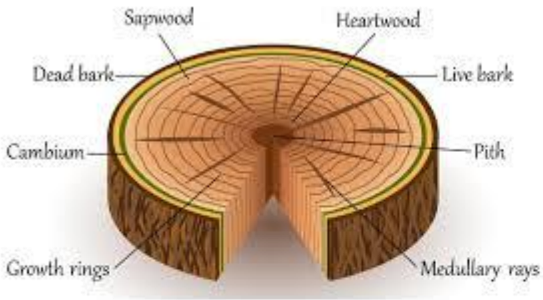
Heart wood and Sapwood

Heart wood

no active cells, cell walls thickened Low water ratio, color dark, cells saturated with oils, gums resin, pigments. important, economical.

Sap wood

leaving cells, high water ratio, thin cell walls, light colour, function is transportation and mechanical.



Secondary Xylem in Gymnospermae

1) Simpler than Angiosperm xylem composed of tracheids, fibers, parenchyma. Vessels only occur in one order (Gnelales).
2) In some of gemnospermae contain (Grassulae) up and down border pit.
3) Xylem ray contain homocellular ray composed of parenchyma and Heterocellular ray composed of parenchyma + tracheids.

Resin Ducts

Occur in gemnospermae xylem, derived in schizogenous intercellular space among parenchyma cells which produce resin after that convert to epithelium cells. Sometimes resin duct may become closed by enlarging epithelial cells. These tylosis – like intrusions are called tylosoids they differ from tyloses in that they do not grow through pits.

2- The Phloem

Phloem is the living tissue in vascular plants that transports the soluble organic compounds made during photosynthesis to parts of the plant where needed. This transport process is called translocation.

Phloem can be classified into:
1. Primary phloem : It is origin from Procambium

a- Protophloem

b- Metaphloem

	Protophloem	**Metaphloem**
1.	initiate at early stage of growth	initiate at latest age of growth
2.	external position of the vascular bundle & occur pressed	occur in determined position of the vascular bundle of larger
3.	sieve elements are thin	sieve elements are more and enlargement
4.	sieve tube may be conjugated with companion cell	sieve tube conjugated with companion cell
5.	Fibers present	Fibers absent & some sclerides

2. Secondary phloem : It is origin from vascular cambium, It is assorted as :

a- Axial or vertical system

b- Radial or horizontal system

Vascular rays = Phloem rays + Xylem rays

It is an important characteristic of the secondary xylem & phloem.

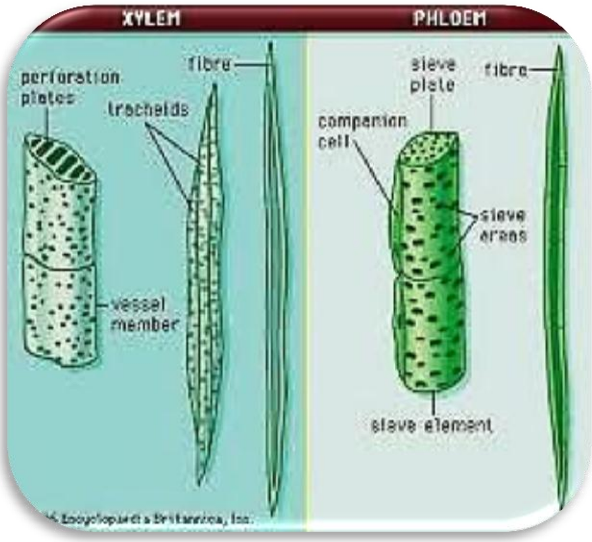
In Angiosperms Phloem consist of :

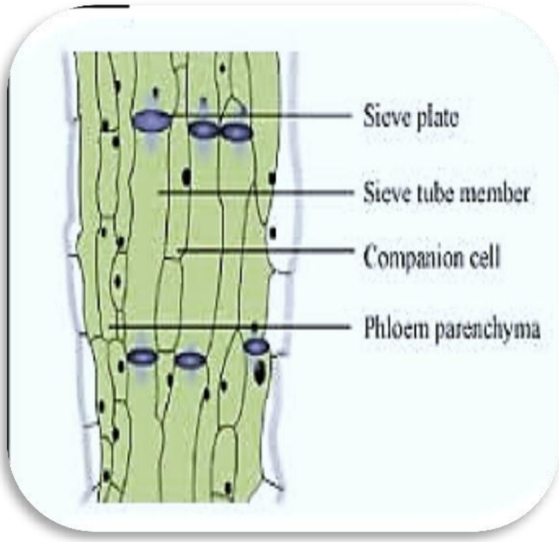
1- sieve tubes, 2- companion cells, 3- fibers, 4- parenchyma cells.

In Gymnosperms Phloem consist of: 1- sieve cells, 2- fibers, 3- phloem parenchyma, 4- Albuminous cell and other cells or tissues like secretory cells.

Phloem elements:

<u>1. Sieve Elements</u>: They consist of sieve – tube & sieve cells. The term sieve tube refer to a longitudinal series of sieve tube members. In both classification, the characteristic of the wall structures – pits and perforation plates, sieve areas and sieve plates.





The sieve areas (the term refer to a sieve) are a wall areas with clusters of pores through which the adjacent sieve elements are inter-connected by strand like prolongation of their protoplast. Thus the sieve areas are comparable to the primary pit – fields with plasmodesmata that occur in primary walls of living parenchyma cells. The sieve area strand are commonly seen associated with the carbohydrate callose , a polymer of glucose residues united into spirally wound chain.

Young sieve tube contain nucleus & cytoplasm & other organs but when it mature nucleus &vacuoles membrane (Tonoplast) analyze and mix gradually as well as Slim bodies form in cytoplasm which is a small gel, protein structures, granulosis or filiform, crystal or tubular in shapes.

<u>Sieve plates:</u> a plates that separate sieve tubes units and consist of porous, its occur at the ends of sieve tube units. Sieve plates either be <u>simple sieve plates</u>, or be <u>compound sieve plates</u>.

The sieve units considered to be a life in spite of absent their nucleus because of:

1. have the ability to form callose & analyses the callose.
2. have the ability to form connecting strand.

<u>2. Companion cells</u>: Specialized parenchyma cells, arise from the same meristematic cell as the associated sieve tube member.

Companion cells & other living cell form a systematic function to transport soluble substances through plasmodesmata to the sieve tube.

Companion cells may regulate biological activity for the sieve tube, if the companion cell die, then the sieve tube function will be absent.

The companion cell is a characteristic of Angiosperms phloem while in Gymnosperms have a similar cells called Albuminous cells with the sieve cells, Albuminous cells differ than companion cells in:

1. Origin: albuminous cells does not arise from the same origin of the sieve cells while the companion cells arise from the same origin of the sieve tube.
2. Position: albuminous cells occur in the ray system while the companion cells occur within the axial system.
3. Contents: albuminous cells contain high ratio of the albumins.

The sieve cells: occur in gymnospermae phloem, connect with each other with sieve aerial, cylindrical shape & tall, keep its ability for many years because it does not lose it nucleus.

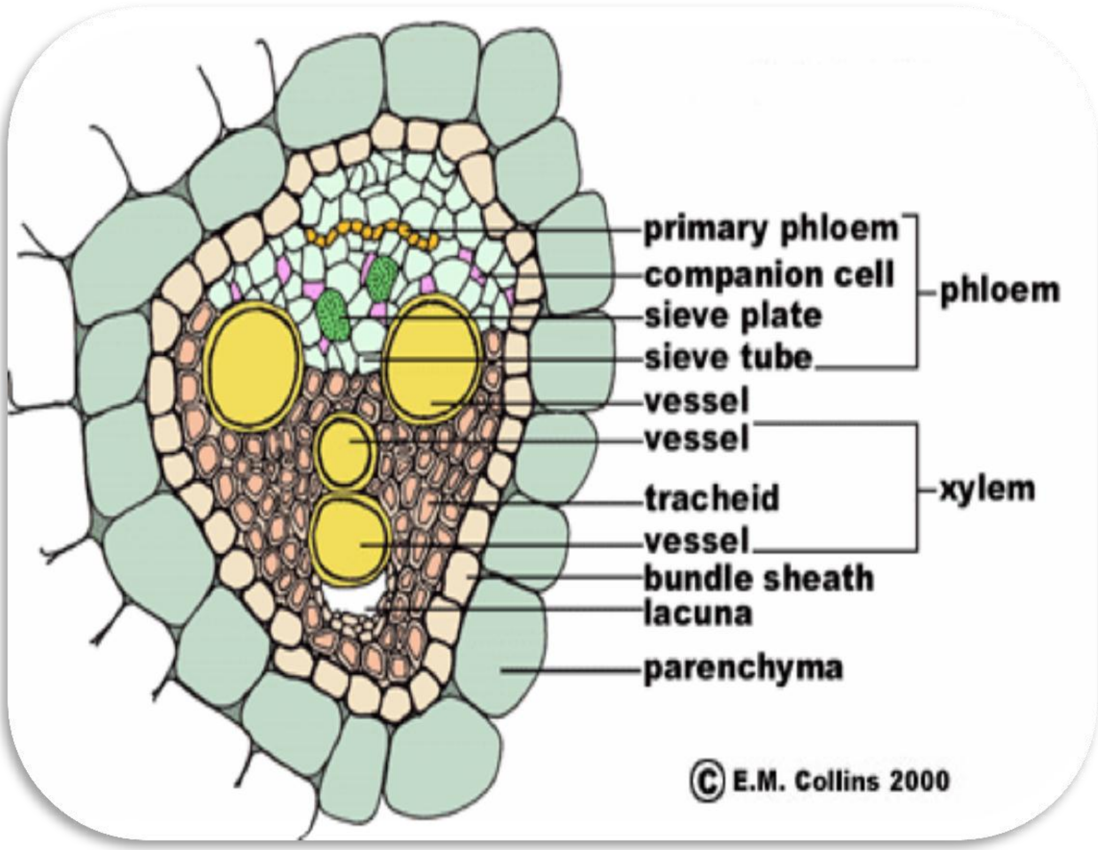
<u>3. Phloem fibers</u>: occur in both primary & secondary phloem, in primary development stage fibers still elongating so the primary fibers may be very long. It have secondary cell wall thickened with the lignin contain simple pits. Fibers may be separate as well as *Vitis*. Fibers in phloem occur as groups or layers alternate with sieve elements. Fibers in phloem is very important economical.

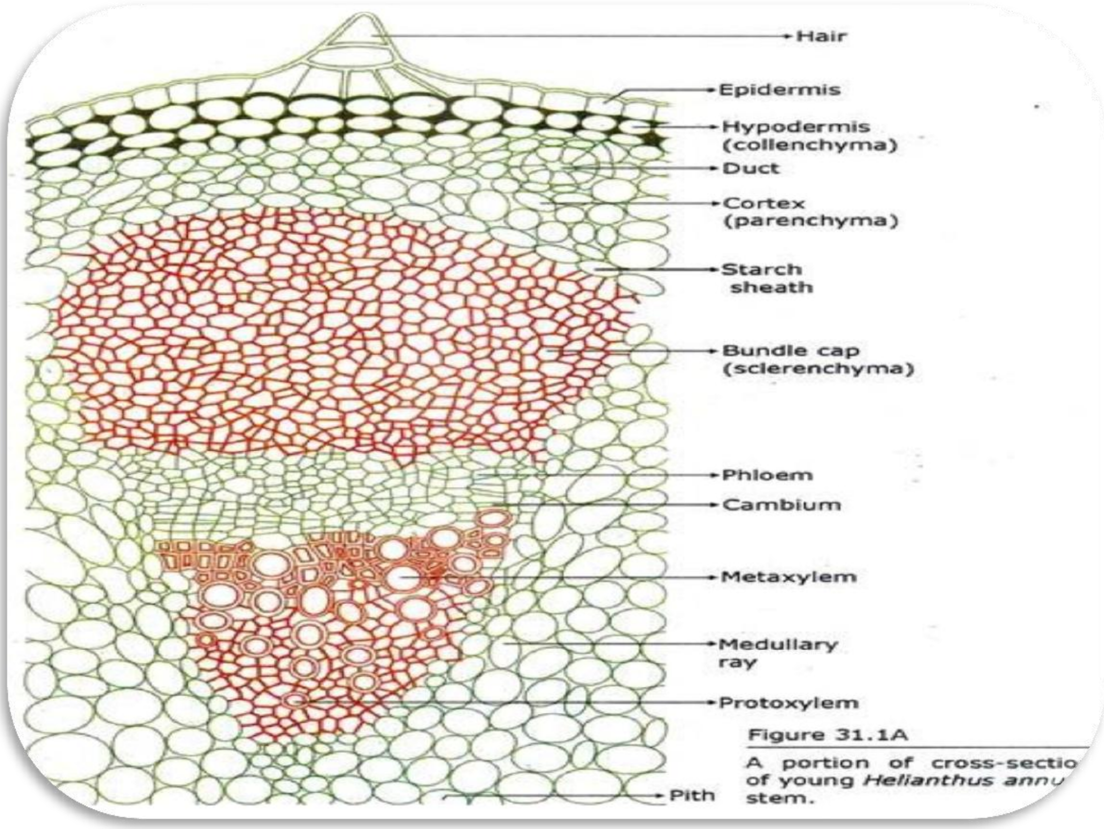
4. Phloem parenchyma: occur in primary & secondary phloem. It has primary cell wall & contain primary pit fields.

Function of phloem parenchyma is storage (store starch resin substances, crystals phloem parenchyma may die if the sieve element die, sometime became septet with cross wall as well as in xylem parenchyma.

Vascular bundles

Xylem & phloem units in monocots vascular bundle are less than in dicots, arranged as the letter(V/Y) and also contain tracheid, protoxylem have a large intercellular space called (protoxylem cavity) vascular bundle in monocots covered with a layer or more of fibers forms (bundle sheath) in some monocots plants vascular bundle as concentric bundles





Monocotyledonae	Dicotyledonae
1. Does not differentiate	1. ground tissue differentiate to cortex, pith, medullary rays.
2. Does not found	2. Pericycle found
3. diffused in ground tissue	3.Vascular bundle arranged in one – two cycles
4. Closed collateral vascular bundle does not contain vascular cambium	4. Open collateral vascular bundle contain vascular cambium
5. xylem vessels arranged in form Y or V.	5. Xylem vessels arranged in strips
6. vascular bundle covered with bundle sheath (fibers)	6. Vascular bundle does not covered with sheath
7. no secondary thickening	7. secondary thickening occur

Types of vascular bundles

The following points highlight the four main types of vascular bundle. The types are:

1. Collateral Bundle

A vascular bundle in which a strand c f phloem is present external to the strand of xylem on the same radius side by side is known as collateral bundle. Cambium may be present or absent in between xylem and phloem, and so there are the following two types of collateral bundle:

(a) Closed collateral bundle

In this type cambium is absent in between xylem and phloem. Therefore stems having this type of bundle do not have normal secondary growth. Ex. Monocotyledonous stem. Usually these bundles are enclosed within bundle sheath made up of sclerenchyma and those that lack the sheath are considered as anomalous (e.g. Asparagus stem).

(b) Open collateral bundle

An open collateral vascular bundle has cambium called fascicular cambium between xylem and phloem. The bundles can increase in diameter by normal secondary growth with the help of fascicular cambium. Ex. Dicotyledonous stem.

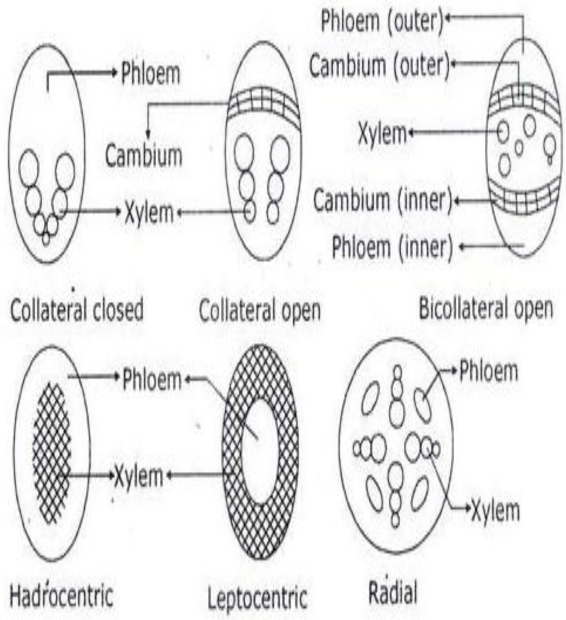


Figure 14.2

Diagram showing types of vascular bundle in t.s. (diagrammatic).

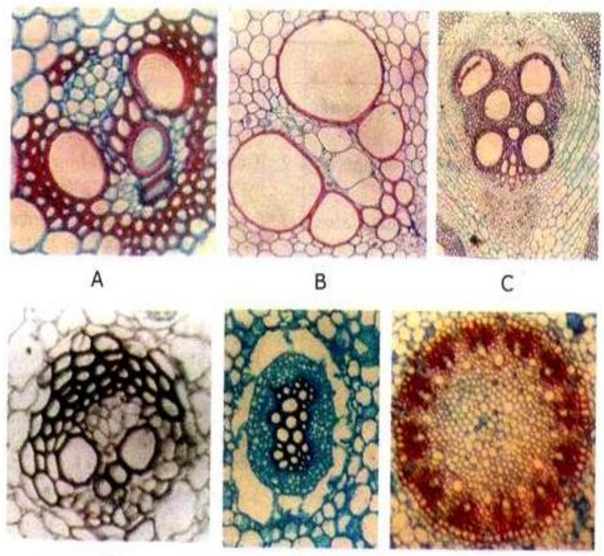


Figure 14.3

Microphotographs showing different types of vascular bundles. A. Collateral closed vascular bundle of *Zea mays* stem. B. Collateral closed vascular bundle of *Asparagus* stem without bundle sheath. C. Bicollateral open vascular bundle of *Cucurbita* stem. D. Leptocentric vascular bundle of *Dracaena* stem. E. Hadrocentric vascular bundle of *Selaginella* stem and F. Radial vascular bundle of *Vanda* root.

2. Bicollateral Bundle

A vascular bundle with phloem situated on the peripheral and inner side of xylem is known as bicollateral bundle. A strip of cambium termed outer cambium is present between the peripheral phloem and xylem; another strip of cambium, termed inner cambium, is also present between inner phloem and xylem.

The peripheral or external phloem is termed as outer phloem whereas the inner or internal phloem is called inner phloem. The sequence of vascular tissues in the bicollateral bundles from periphery toward center is outer phloem, outer cambium, xylem, inner cambium and inner phloem.

These bundles are open type as strips of cambia are present but the secondary thickening occurs only by the outer cambium, i.e. cambium present between the outer phloem and xylem. Ex. *Cucurbita* stem.

3. Concentric Bundle

A vascular bundle in which one type of vascular tissue surrounds the other is known as concentric bundle.

In this bundle xylem either encircles or is encircled by phloem and accordingly the following two types are recognized:

(a) Amphivasal bundle

A vascular bundle in which xylem encircles the central strand of phloem is known as amphivasal bundle, also called leptocentric bundle. Ex. Dracaena, Yucca.

(b) Amphicribral bundle

A vascular bundle in which phloem encircles the central strand of xylem is called as amphicribral bundle, also known as hadrocentric bundle. Ex. Selaginella.

The concentric bundles, either amphivasal or amphicribral, are closed as there is no cambium in between xylem and phloem.

4. Radial Vascular Bundle

A vascular bundle, in which the primary xylem and primary phloem strands are separated from each other by nonvascular tissues and they are situated on alternate radii of an axis, is known as radial vascular bundle or radial bundle.

Cross section of the stem
Introduction

The part of plant which grow above the ground & bear the flowers, leaves and of the organs & transport nutrients & water to other parts of plant. In some cases, stem grew underground, the most common features among stems in plants are:

1. bearing buds leaves & flowers.
2. formed from nodes & internodes.
3. Branches are externally originates & occur in early stage of growth.
4. Apex does not covered with a cap.
5. Epidermis covered with cuticle.
6. Contain collenchyma & sclerenchyma in the cuticle.
7. Vascular bundle either collateral (xylem & phloem occur on one radial) it is my be Bicollateral (External phloem then xylem then internal phloem)such as in Cucurbitaceae, or concentric: this type contain: (1) amphiversal (phloem in the center), (2) amphicribral (xylem in the center)

The primary Structure of the Stem
A. Dicotyledonae Stem

We can flow different tissues that form a mature stem in the primary growth stage from outside to inside.

1- Epidermis:

One layer of cells, covered with cuticle, may contain stomata or trichomes.

2- Cortex:

Under the epidermis directly, less thickness than the cortex in the roots, consist of parenchyma cells & collenchyma either in group forms or as continuous form its function is supporting some parenchyma contain chloroplasts. Commonly the cortex does not contain endodermis their for we can't distinguish the last layer. In few species of plant may contain casparian strip.

3- Vascular cylinder

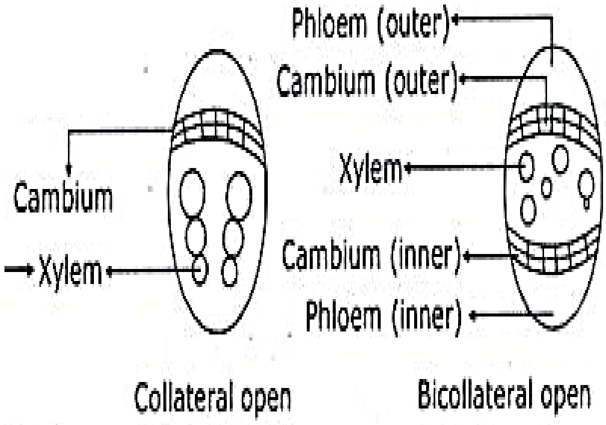
Consist of : (1) pericycle, (2) vascular bundles, (3) medullary rays, (4) pith.

1- Pericycle

If the endodermis is clear in the stem then the pericycle will be clear but almost pericycle mixed with cortex in most of Angiosperm & gymnosperm, in case of differentiate it, its composed of parenchyma & sclerenchyma as a cycles.

2- Vascular bundles

In most of Dicotyledonae, it is open collateral vascular bundles type/ or it is bicollateral vascular bundles type.



Phloem: sieve tubes, companion cells, parenchyma & fibers (phloem) and sclerides.

Xylem: occur in radial strips of xylem vessels which consist of metaxylem & (exarch) &protoxylem (endarch)

Vascular cambium: as a one strip of meristematic cells. Vascular bundle either be as a separated units or continuous like a cylinder.

Characterization

1- The vascular cambium is a layer of meristematic cells (or initials) that arises between primary xylem and phloem.
2- Although it is a single layer of cells, in actual practice it is difficult to distinguish that layer from its immediate derivatives on either side. Hence, the term cambial zone is used with few exceptions.
3- The vascular cambium is responsible for increasing the diameter of stems and roots and for forming woody tissue.
4- In dicot stems, the vascular cambium initially differentiates from procambial cells within the vascular bundles (Fig. below A).
5- Cell division by the cambium produces cells that become secondary xylem and phloem. As secondary phloem and xylem tissue accumulates, it both increases the girth of the stem and forms wood and bark. Because cambial activity is seasonal in temperate zone plants, the wood and bark are laid down in distinct annual rings (Fig. below C).

6- Monocots do not have a vascular cambium, even though some of them, such as palms and the Joshua tree, exhibit secondary growth. Instead, they have a thickening meristem that produces secondary ground tissue. This increases the girth of the stem and additional vascular bundles differentiate within the secondary ground tissue.

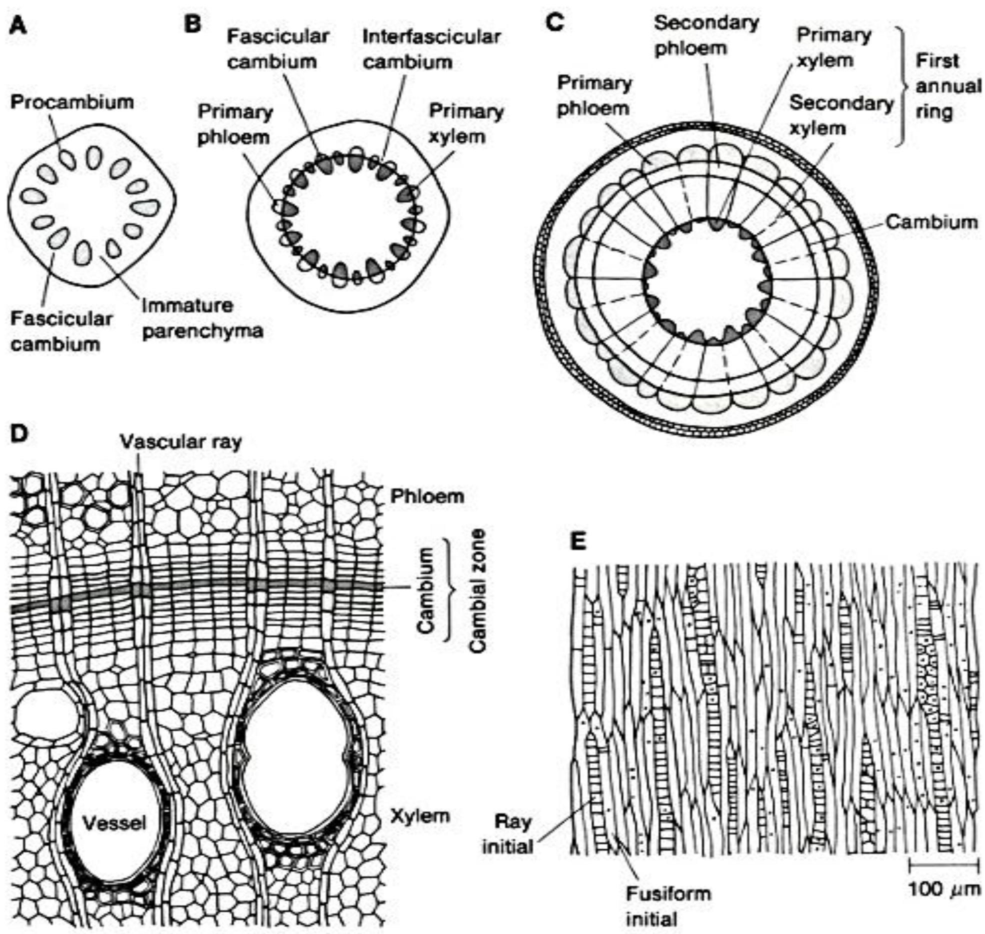
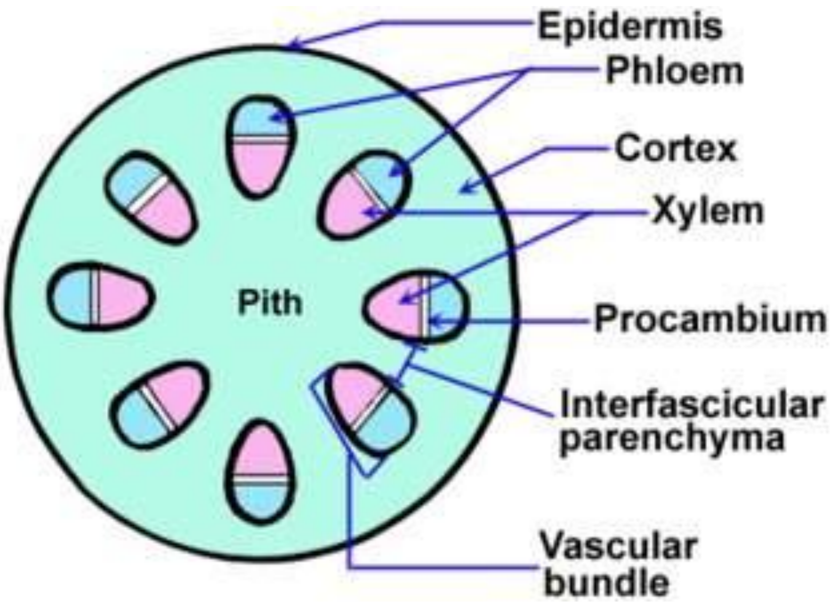


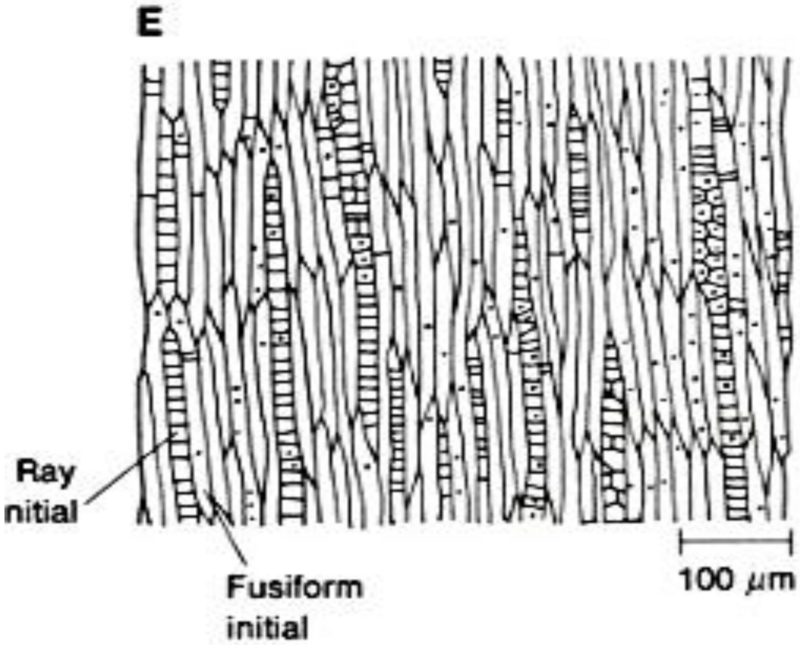
Figure : **Secondary growth: the origin and structure of vascular cambium in the stem** The vascular cambium is formed in mature dicot stems after stem elongation stops. (A) Primary xylem and phloem differentiate from procambial tissue in the vascular bundles, and a fascicular cambium is formed from procambial tissue separating these tissues. (B) Later, an interfascicular cambium appears between the vascular bundles that is continuous with the fascicular cambium. (C) The further development of the cambium results in the formation of a cylinder of vascular tissue. (D) The vascular cambium is a layer of pluripotent dividing cells whose derivatives differentiate as either xylem elements (vessel members, tracheids, fibers, or xylem parenchyma) or phloem elements (sieve tube members, companion cells, fibers, or parenchyma). (E) The dividing cells of the vascular cambium consist of long, narrow fusiform initials, from which the tracheary elements are derived, and ray initials, from which ray parenchyma is formed.

7- This **fascicular cambium** may contribute additional cells to both the xylem and the phloem of the bundle. At some point the cambium expands into the ground tissue between the vascular bundles, forming an **interfascicular cambium**, completing the ring of vascular cambium.



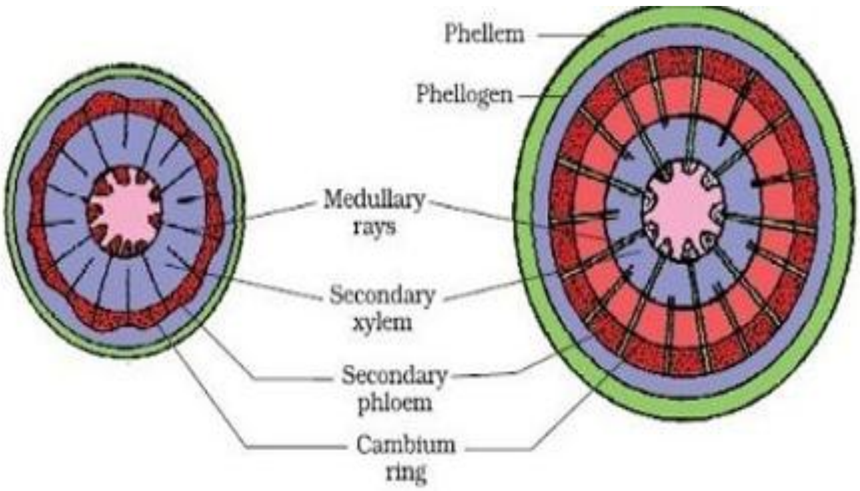
The vascular cambium is composed of two kinds of cells **:**
i- ray initials
ii- fusiform initials

In cross section these look very similar. Both are small, flattened cells with thin walls. When viewed in tangential section, however, ray initials can be seen to be relatively short, small cells, whereas fusiform initials are very long and narrow. In gymnosperms the fusiform initials often are several millimeters in length. Dicot fusiform initials are much shorter, but some still are up to 0.5 mm in length. Cell division in the fusiform initials usually is tangential and the cell is partitioned down its long axis, forming two equally long, narrow cells. Some of the cells produced by the cambial initials continue to divide, whereas others differentiate. Tracheary elements or sieve elements differentiate from derivatives of the fusiform initials, and derivatives of the ray initials differentiate as ray parenchyma. The ray parenchyma permits transport of water from the xylem into the cambium and the tissues of phloem, as well as transport of photosynthate from the phloem into the cambium and the living cells of the xylem.



3- Medullary rays

Parenchymatic cells connect the cortex with the pith. Vascular bundle among these cells, it may be wide or thin.



4- Pith:

Parenchymatic cells large in size in the center of the stem. Pith occupies large space in the stem in compare with the root, in some plants pith cells analyzed during growth.

B- Monocotyledon Stem

We can see the following tissues from the outside to inside in mature stem:

1- Epidermis:

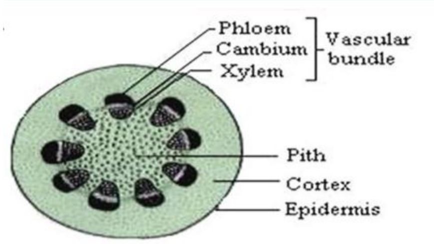
One layer of cells covered with cuticle, sometime contain chloroplasts and trichomes.

2- Ground tissue:

Cortex is not found but there is ground tissue composed of parenchymatic cells, vascular bundle diffuse within the ground meristem and the outer layers may be sclerids.

3- Vascular bundle

Occur in large number near the epidermis as well as small number in the center, vascular bundle in monocots are closed collateral vascular bundle & does not contain vascular cambium.



Dicot stem

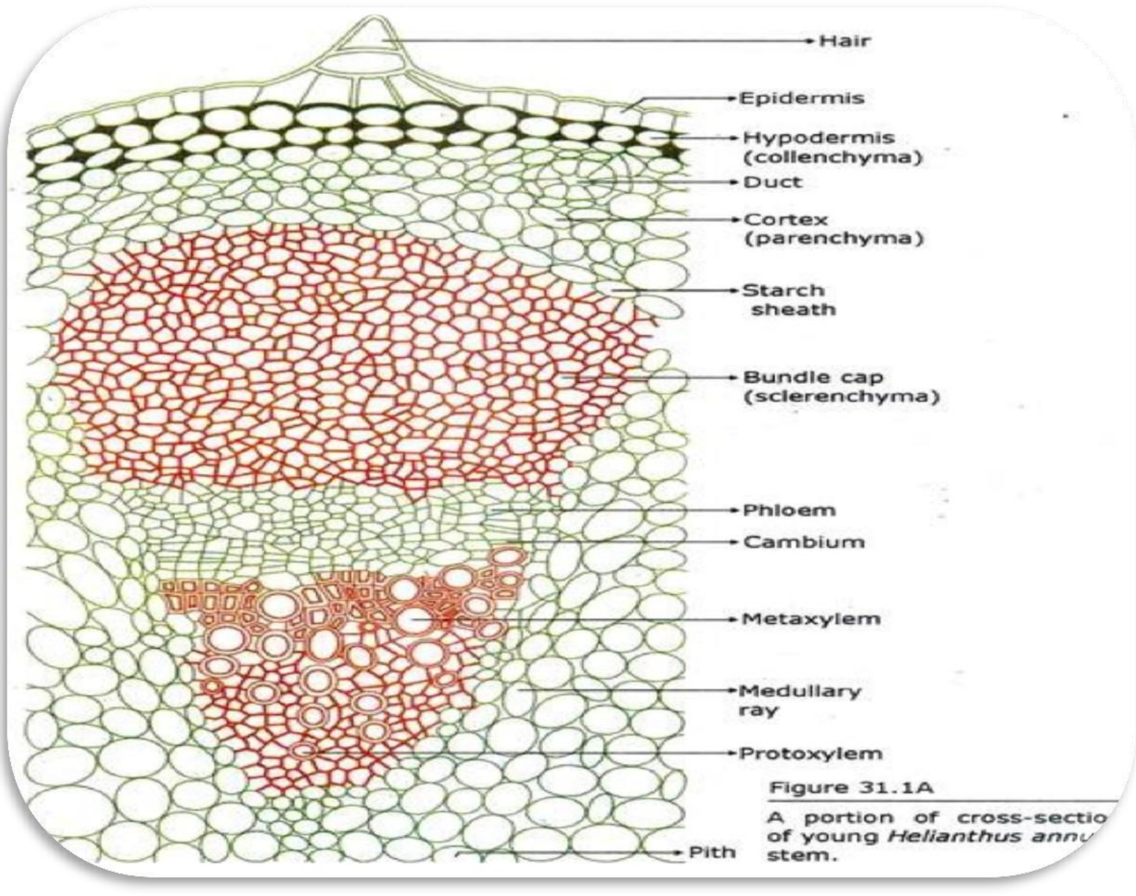
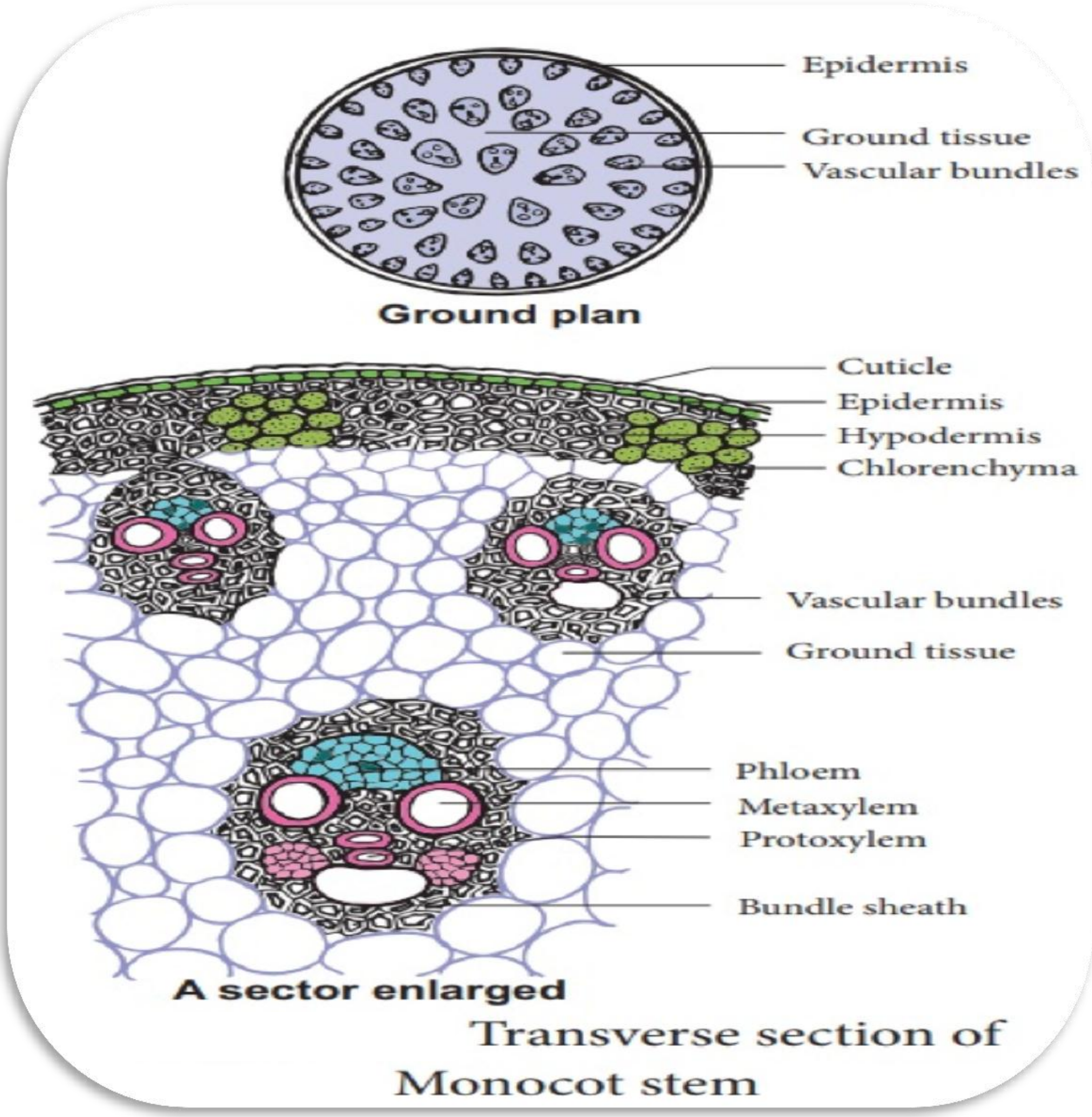


Figure 31.1A

A portion of cross-sectio of young *Helianthus ann* stem.



Dicotyledonae	Monocotyledonae
1. ground tissue differentiate to cortex, pith, medullary rays.	1. Does not differentiate
2. Pericycle found	2. Does not found
3.Vascular bundle arranged in one – two cycles	3. diffused in ground tissue
4. Open collateral vascular bundle contain vascular cambium	4. Closed collateral vascular bundle does not contain vascular cambium
5. Xylem vessels arranged in strips	5. xylem vessels arranged in form Y or V.
6. Vascular bundle does not covered with sheath	6. vascular bundle covered with bundle sheath (fibers)
7. secondary thickening occur	7. no secondary thickening

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