Anatomy of Flowering Plants

Objectives

After going through this lesson, the learners will be able to understand the following:

- Meristematic Tissue
- Permanent Tissues

Content Outline

- Introduction
- Meristematic Tissue
    - Apical meristems
    - Lateral meristems
    - Intercalary meristems
- Permanent Tissues
    - Simple Tissues
    - Complex Tissues
- Summary

Introduction

All living organisms are made of cells. The organisms which evolved first were the unicellular organisms. The single cell body of these organisms is able perform quite successfully, all the important functions of an organism, such as obtaining nutrition, carryout metabolism, reproduction, respond to external stimuli and defend itself from dangers etc. Today, almost half the biomass on earth is made of unicellular organisms. However, evolution of multicellularity (generally, in eukaryotes) enabled the organisms to function more efficiently. There was a division of labour amongst the cells; groups of cells became structurally specialized to perform a particular function. This led to first the evolution of tissues and then organs. A **tissue** is made up of cells of similar structure performing a common function. Different types of tissues associate to form an **organ** which performs a specialized function, e.g., a limb or stomach of an animal or stem or leaf of a plant. Major groups of multicellular organisms, such as plants, fungi and animals acquired body plans with characteristic tissues.

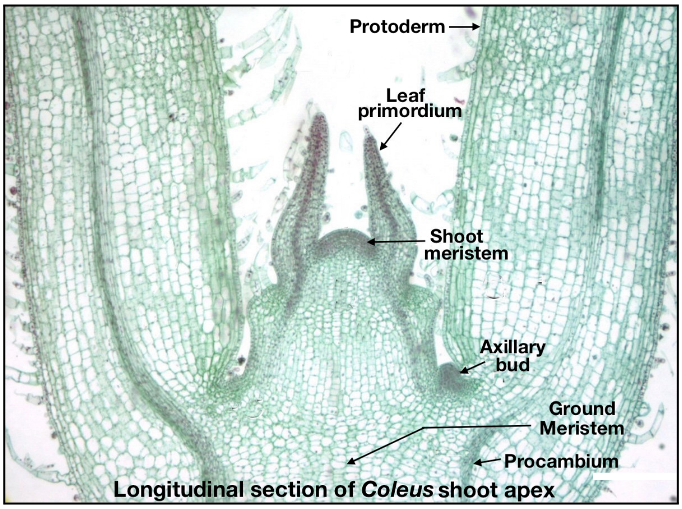
Modifications in the structure of the tissues, generally with increased functional efficiency, lead to manifestation of structural differences in organisms within the groups, and to the diversification and evolution of species. Therefore, it is important to understand the structure of various tissues and organs in order to understand their function/s. This knowledge can be used to increase the efficiency and productivity of communities and ecosystems.

Anatomy is the study of the internal structure of organisms. Flowering plants are considered the most evolved group of plants. Their body is made up of a number of tissues. These tissues are produced by the embryo. The embryo at an early stage of development, differentiates shoot and root apices which produce most of the tissues of the plant. The apices contain meristematic cells which divide continuously and give rise to new cells. The new cells may divide a few times more and the resultant cells convert or differentiate into adult cells comprising the permanent tissues.

Therefore, there are essentially two types of tissues in a plant body, the meristematic tissues or the meristems and the permanent tissues.

Meristematic Tissue

The **meristems** (derived from the Greek, *merismos* meaning division) are tissues concerned primarily with the growth of plant. They contain cells capable of dividing mitotically and giving rise to new cells. The meristematic activity of these tissues is generally maintained indefinitely as a few of the new cells do not develop into mature cells but continue to be meristematic. The cells which retain their meristematic activity are called the **initials** while their products, which subsequently **differentiate** into mature cells, may be after a few divisions, are called the **derivatives**. The meristematic cells may be dense or vacuolated but are generally characterized by thin walls and lack of storage materials. The meristems are most often classified according to their position in the plant body.



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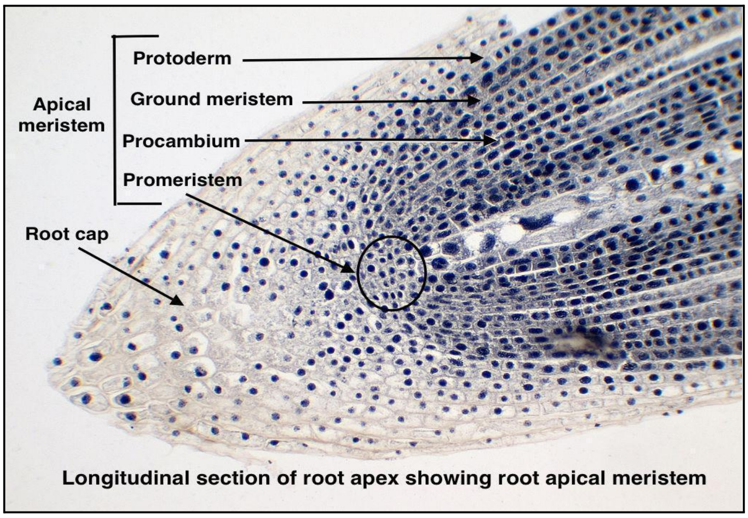
Apical meristems

Apical meristems are located at the apices or ends of the plant body, i.e., at the end of main and lateral roots known as the root meristem and at the end of main stem and branches, known as the shoot meristem. They are responsible for the growth of the plant in length in a process known as the **primary growth** and produce mostly the **primary tissues** of the plant.



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Meristematic activity of the **shoot apical meristem** gives rise to the aerial parts, such as stem, branches, leaves and flowers of the plant. Shoot apical meristem and the surrounding very young developing leaves present at the terminus or tip of main stem and branches constitute a **terminal bud**. Branches arise from the meristematic tissue of **axillary buds** which are present at the axils of leaves. The meristematic cells of axillary bud are part of the shoot apical meristem left behind during the formation of leaves and the subsequent elongation of stem. During flowering, usually axillary buds or rarely, terminal buds get modified into flower buds and produce flowers.

The activity of root apical meristem located at the growing end of main and lateral roots results in the elongation of roots.

In some plants, the shoot and root meristems may form at regions other than the apices and produce adventitious shoots or roots at unusual positions, e.g., roots and shoots from leaf margins in Kalanchoe, roots from stems of grasses and dicot plants, shoots from roots in Citrus plants.

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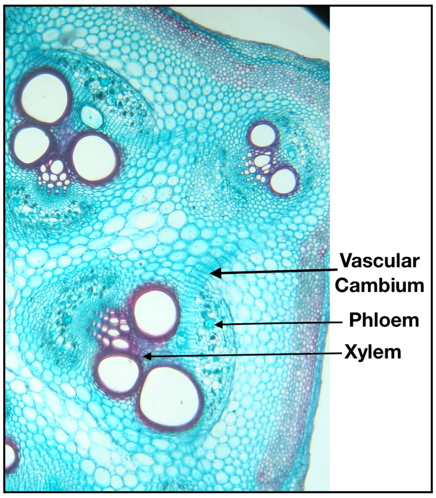
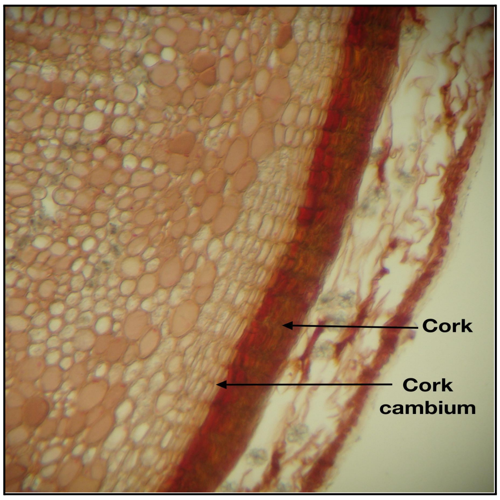


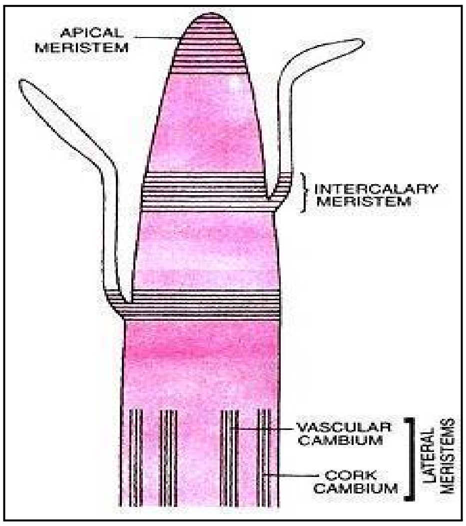


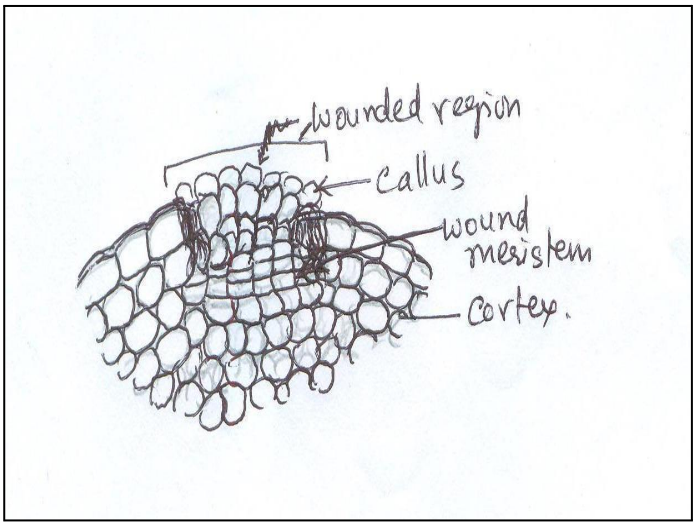
Lateral meristems

Meristems positioned lateral or parallel to the long axis of the plant body are the **lateral meristems** which are involved in the **secondary growth** of the plant. They produce the **secondary tissues** of the plant. Vascular and cork cambium which form secondary vascular and secondary cortex and cork tissues, respectively, are examples of lateral meristems. They increase the girth of the plant.

Intercalary meristems

In a few plants such as grasses and some dicots, meristematic cells are present in the internodes and leaf sheaths. Such meristems are called intercalary meristems. These meristems are responsible for the growth of mature plant parts such as internodes of stems, leaves, flower stalks, etc.





Wound meristem is formed below a damaged region or wound to repair it. Parenchyma cells below the wound differentiate into meristematic cells and divide to replace the damaged cells. Meristems may also be categorized according to their origin, i.e. the type of cells from which they have arisen.

Primary meristems comprise of cells which are remnant embryonal cells and have retained their meristematic activity in the adult plant. The apical meristems at the end of main stem and root, the intercalary meristems, and the fascicular part of vascular cambium in dicot stems are examples of primary meristem.

Secondary meristems arise from mature differentiated cells which revert back to their meristematic state due to some stimulus. For example, cork cambium, vascular cambium of roots, the interfascicular part of vascular cambium of stems, the wound meristem and meristems giving rise to adventitious buds, all differentiate from mature parenchyma cells.

Permanent Tissues

P**ermanent tissues** are formed from the derivatives of meristems that have stopped dividing and have become specialized structurally and functionally. The permanent tissues form the structure of the plant. The cells of these tissues have structures which are specialized to perform certain specific functions such as storage, photosynthesis, reproduction or transportation of water and food. Depending on their structure and the function they perform, there are various types of tissues. These tissues can be broadly classified into two categories, the simple and complex tissues.

Simple Tissues

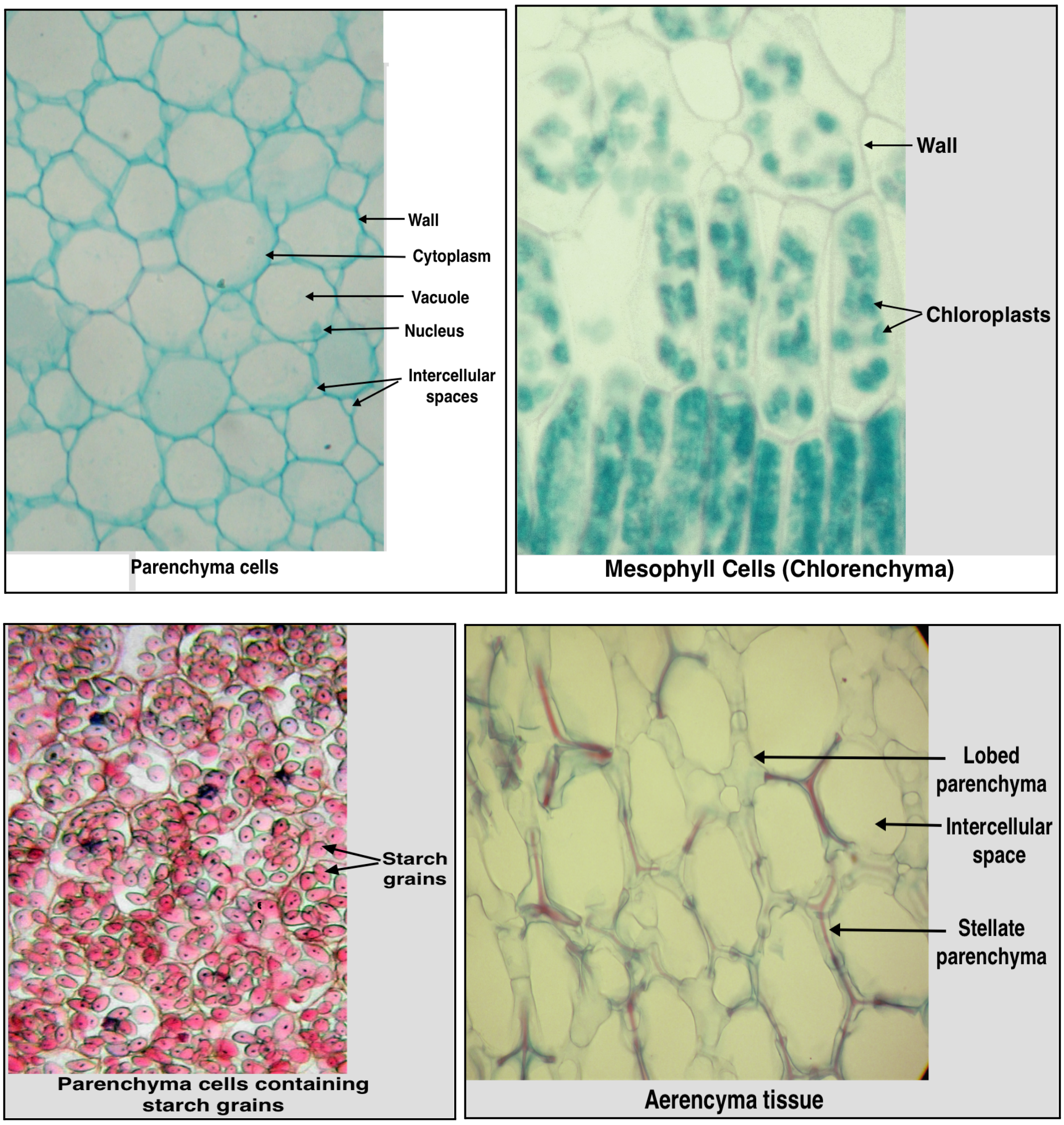
The simple tissues are homogeneous or are composed of structurally similar cells. Simple tissues are classified into three types, parenchyma, collenchyma and sclerenchyma, based on the structure of their cells.

Parenchyma

Parenchyma is the fundamental or ground tissue which fills up the space between the other tissues. The word is derived from the Greek, para, meaning “beside”, and en-chein, meaning “to pour”, referring to the presence of parenchyma filling the spaces (as a fluid) around most other tissues in almost all plant parts such as root, stem, leaf, flower, fruit and seed. Since this tissue occurs in the lowermost plant forms (algae) to the most advanced angiosperms, it is considered as the precursor of most of the other tissues; i.e., most of the other tissues are thought to have evolved from parenchyma through modifications in structure of cells.

- Parenchyma cells are comparatively the least specialized cells and therefore, have the flexibility to adapt structures suited to different functions. As a result, parenchyma cells are also structurally the most diverse.
- The features common to all the diverse types of parenchyma cells are the presence of thin walls and living protoplasts.
- The cells are generally polygonal and isodiametric (diameter of same length in any direction) in cross-section but can also be of other shapes such as lobed, elongated, stellate, etc.

- They are usually surrounded by intercellular spaces but sometimes may be closely packed.
- The contents of the cells vary depending on the type of function they perform.
- The cells are mostly vacuolate but some, like the secretary or glandular cells and the reproductive cells are densely cytoplasmic, while the storage cells are filled with stored materials such as starch, sugar, proteins, lipids, crystals, etc. The photosynthesizing cells of leaves are parenchyma cells containing chloroplasts, also called chlorenchyma.



Source: https://upload.wikimedia.org/wikipedia/commons/a/ad/Parenchima_amilifero.JPG

- Synthesis of special substances such as resins, tannins, phenols, glycosides, essential oils, mucilage, sugars, alkaloids, steroids etc, are carried out by parenchyma cells rich in cytoplasm.

- Parenchyma cells are also involved in secretion (of the above substances) and transfer of substances, and such cells have wall in growths to help in efficient transport.
- In succulent plants, parenchyma cells store large amounts of water.
- Aquatic plants and plants growing under submerged conditions generally possess aerenchyma tissue made up of parenchyma cells with wide intercellular spaces between them. These spaces trap air to provide vital gases such as carbon dioxide and oxygen as well as buoyancy to the plant.

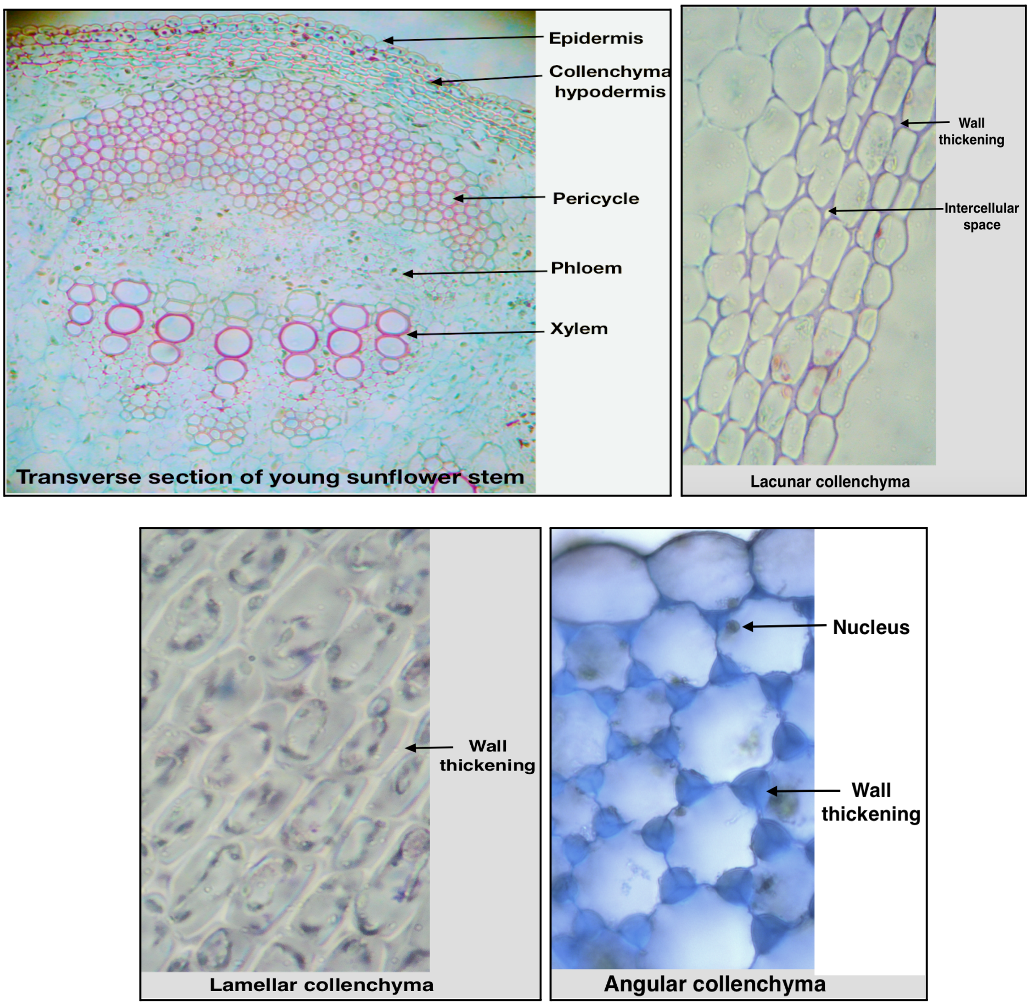
Parenchyma cells have retained the ability to divide; they can dedifferentiate to a meristematic state and divide under special circumstances, e.g., during secondary growth, healing of wounds etc.

Collenchyma

Collenchyma is a tissue involved primarily in providing flexible support to the plant. This tissue is often considered as a special type of parenchyma with thick-walled cells. The term has been derived from the Greek colla, meaning glue, which refers to the thick glistening walls of the cells.

- Collenchyma is composed of elongated cells with living protoplast.
- The cells posses thickened primary walls rich in cellulose, hemicelluloses and pectin but the thickening is unevenly distributed.
- They may be closely packed or contain small intercellular spaces.
- Often, these cells contain chloroplasts and carry out photosynthesis.
- Like parenchyma cells, collenchyma cells too, can dedifferentiate to a meristematic state under special conditions.
- Collenchyma characteristically has a peripheral location, occurring just below (hypodermal position) or a few layers below (sub-hypodermal) the epidermis, in the cortex. The tissue may be present as a continuous layer or in small patches.
- It is generally found as a supporting tissue in young and growing organs, and in mature organs that do not show much secondary growth as in petiole and midrib of leaves, stalks of flowers and fruits, and in herbaceous stems; it is rarely found in roots and is absent in many monocots.
- The function of collenchyma is to provide mechanical support to plant parts, especially to young and developing organs because of the thick walls of the cells. The wall thickenings are plastic and extendable, enabling the elongation of young stems and leaves.

- Collenchyma is classified into different types depending on the pattern of distribution of wall thickening. Angular collenchyma has cells with prominently thickened corners. In lamellar or plate collenchyma, the inner and outer tangential walls of the cells are more thickened. Wall thickening predominantly around the intercellular spaces is found in lacunar collenchyma



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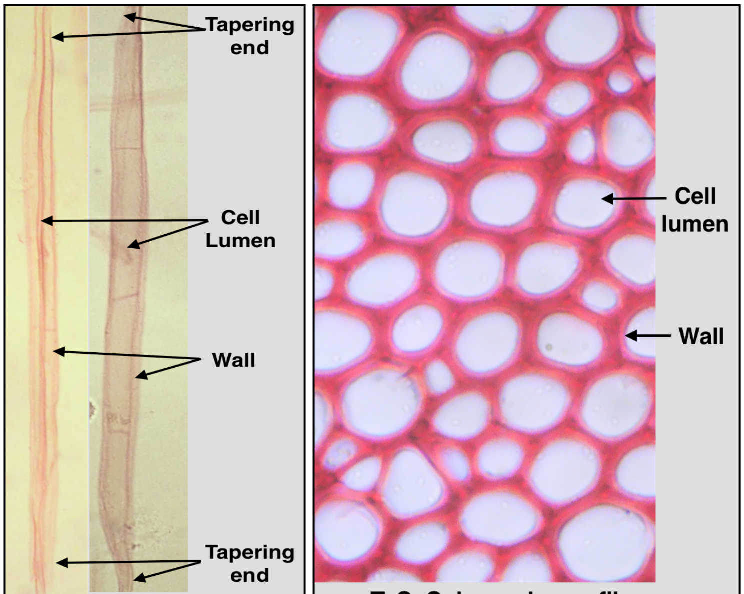
Sclerenchyma

Sclerenchyma is composed of cells with secondary walls from an early stage of development. The tissue provides mechanical support to mature parts of the plant. The term is derived from the Greek scleros, meaning "hard" and enchyma, meaning "infusion", referring to the hard walls of the sclerenchyma cells.

- Sclerenchyma cells have secondary walls which are generally lignified i.e. contain lignin, and therefore, are hard. Sometimes the secondary walls may be cellulosic as in ramie phloem fibres. Pits are generally present in the walls. Often in older parts of the plant, some parenchyma and collenchyma cells may develop secondary walls with lignin; such sclerified cells appear very similar to and often are considered as sclerenchyma cells.

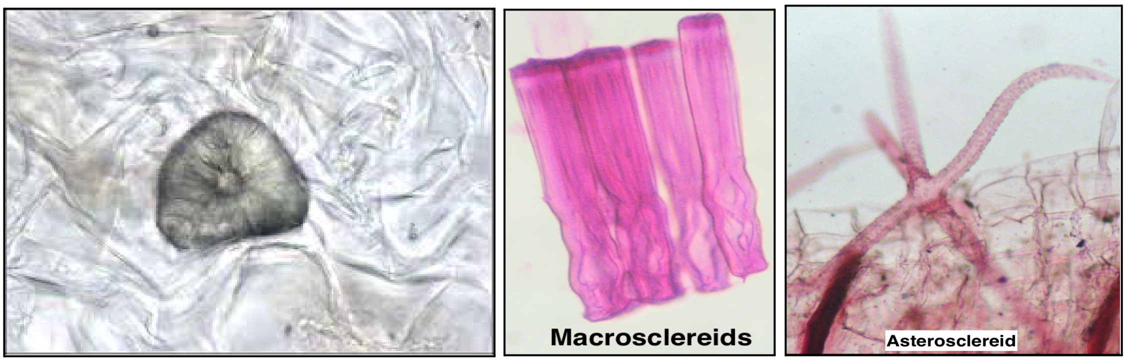
- Sclerenchyma usually is comprised of dead cells lacking living protoplasts but some cells may retain protoplasts.
- The cells may be present singly or in groups.
- They are widely distributed in plants and are found in stems, leaves, fruits, seeds and roots of both dicots as well as monocots. They are present in the cortex, pericycle, and pith and as part of xylem and phloem tissues of vascular bundles.
- Sclerenchyma cells are of two types, fibres and sclereids, based on their form and structure. Fibres are narrow elongated cells with tapering or pointed ends. They may be septated or non-sepated. The septa in the fibres form as a result of division of cells after the formation of secondary walls.



W. M. Fibres　T. S. Sclerenchyma fibres

- The fibres may be present as strands or complete cylinders in the hypodermal layers of roots and stems, in pericycle of dicot stems, as sheaths around the vascular bundles of monocot stems and leaves, and in groups or scattered in the xylem and phloem tissues of, generally, dicots.
- Fibres are broadly categorized into two groups, xylary fibres that are part of xylem tissue and extraxylary fibres that are located outside xylem tissue such as the cortical, pericyclic and phloem fibres. Most of the fibres of commerce such as those of jute, hemp, linen, bamboo, banana, coconut (coir), ramie, etc., are extraxylary fibres.

- **Sclereids** are short round cells with generally thicker walls and smaller lumens as compared to fibres. They also have more prominent pits which may be simple or branched. Sclereids are present scattered or in small groups in the flesh of gritty fruits (e.g. pear) and leaves (e.g. tea, water lily), as cylinders in stems or as sheets in the hard fruit walls (e.g. endocarp of apple, shells of nuts, seed coats of pulses).



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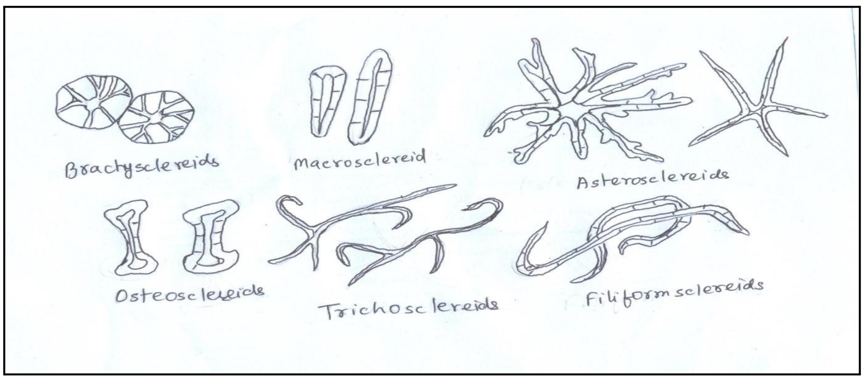
Based on their shape, sclereids have been classified into many types, the more or less rounded brachysclereids or stone cells, rod-shaped macrosclereids, star-shaped asterosclereids, bone-shaped osteosclereids, thin, branched, hair-like trichosclereids, and long fibre-like filiform sclereids.

The principal function of sclerenchyma is to provide strength, mechanical support and protection to the softer tissues of plants. Sclerenchyma cells, with their hard walls provide mechanical support and enable plants to stand erect. They prevent plant parts from breaking or getting damaged when subjected to stretching, bending, excess pressure or weight. By forming a hard cover, sclerenchyma cells also protect softer tissues of embryos and seeds from predation, and pest and microbial infestations.



Complex Tissues

Complex tissues are heterogeneous consisting of many types of structurally dissimilar cells. Xylem and phloem tissues fall under this category. Vascular bundles which are involved in conduction of substances within the plant are primarily made up of these two tissues.

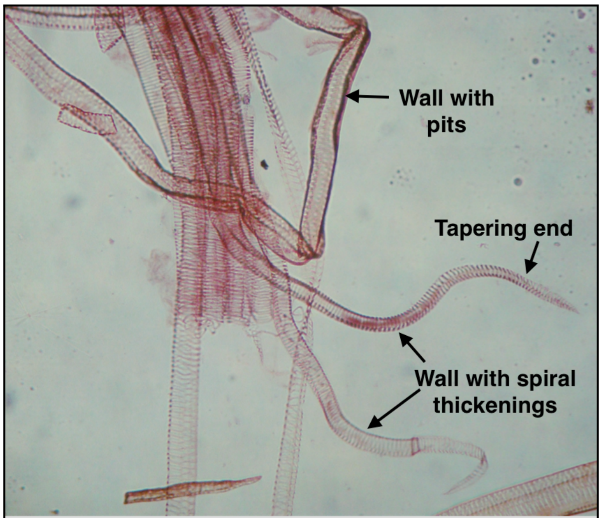
Xylem

Xylem tissue is concerned with conduction of water and minerals from roots to the aerial parts of the plant such as stem, leaves, flowers and fruits. It is comprised of four types of cells,viz. tracheids, vessels, fibres and parenchyma.

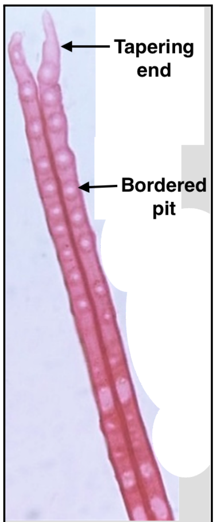
Tracheary Elements

- Tracheids and vessels, are called the tracheary elements, and are the main water transporting elements.
- Both are elongated pipe-like structures resembling insect trachea. The functional elements are hollow as their protoplast degenerates during maturation.
- Tracheary elements are present in bundles forming a continuous xylem column oriented parallel to the long axis of the organ in which they are present.
- They possess lignified secondary walls deposited in various patterns such as annular, spiral, reticulate, scalariform, and pitted. The early formed xylem (protoxylem) elements generally have narrow elements with annular, spiral, reticulate or scalariform thickenings whereas the later formed primary xylem (metaxylem) and the secondary xylem elements are broad and mostly pitted.
- Water can pass only through the cellulosic and non-lignified parts of the wall of the elements. In the pitted elements, water is transferred only through the pit pairs connecting two neighbouring elements as the rest of the wall of the elements is lignified and is impermeable to water. The pit pairs are separated by a cellulosic primary wall which is thinner at this region and is called the pit membrane.
- The hard lignified secondary walls provide strength to the elements and prevent their collapse when water is pulled up with a high tension generated by transpiration at leaf surfaces.

Tracheids are elongated angular cells with tapering ends that overlap with the neighbouring element. They have thick lignified secondary walls and narrow lumen. These evolved first as conducting cells and are found in all the vascular plants including pteridophytes, gymnosperms and angiosperms. Because of their narrow lumen and pits being the only openings for transfer of water, tracheids conduct water with much less efficiency. But their thick, lignified, hard walls provide mechanical support to the plants, especially to pteridophytes and gymnosperms which possess very few fibres.



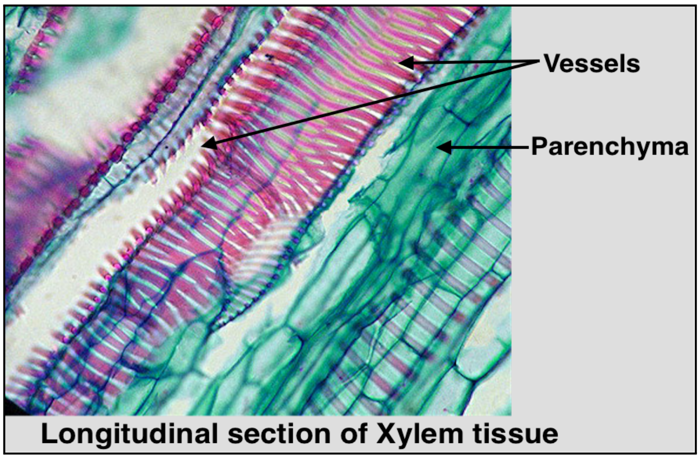
Whole mount of Tracheids



W. M. Tracheids

Vessels

Vessels evolved later and are found mostly in angiosperms; few advanced genera of pteridophytes and gymnosperms also have evolved vessels. Vessels are long, tube-like structures formed by two to hundreds or even thousands of elements placed one above the other in the form of long columns. The vessel elements are wider and have thinner walls as compared to tracheids. The end-walls of these elements are transverse or slightly oblique unlike the long tapering end-walls of tracheids. In addition to pits, vessel elements bear perforation plates on their lateral and end-walls. The perforation may contain a single perforation or many perforations or pores which are areas without any wall material. Vessels with elements having perforation plates with single pore at their end walls, resemble hollow tubes through which water can flow unhindered. Because of this and the wider lumen of elements, vessels conduct water much more efficiently than tracheids. Water can also pass from one vessel to another through the perforation plates present on the lateral walls.



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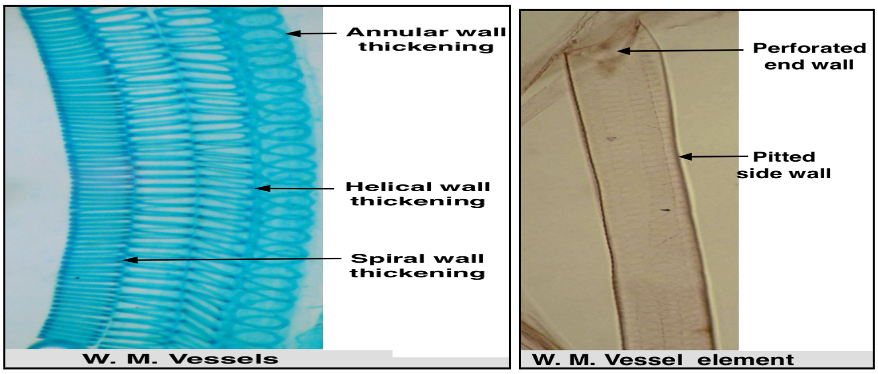
Xylem Fibres

- These are sclerenchymatous fibres present along with the tracheary elements in the xylem tissue.
- The cells are long with thick lignified secondary walls. They may be septate or non-septate. Pits are present in the walls. They are mostly dead cells but some may contain living protoplast and store starch grains.



Source:https://upload.wikimedia.org/wikipedia/commons/4/4e/Xylem_rays_%28Tilia_Americana%29.jpg

- The principal function of xylary fibres is to provide mechanical support to plants, especially angiosperms, which have fewer tracheids. Fibres also store starch.

Xylem Parenchyma

- These are the living cells present among the generally dead tracheary elements and fibres.

- In the primary xylem, parenchyma cells are elongated with their long axis positioned parallel to the tracheary elements. Two types of parenchyma are found in secondary xylem, axial and ray parenchyma. Axial parenchyma are elongated cells like those of primary xylem parenchyma. Ray parenchyma cells are shorter and are radially placed with their long axis oriented perpendicular to the axial cells.
- These parenchyma cells have thin cellulosic walls but may develop lignified secondary walls.
- They are involved in storage of food reserves in the form of starch and lipids. They also synthesize and store a variety of substances such as tannins, resins and crystals. Ray parenchyma helps in radial conduction of water.

Phloem

- Phloem is the second type of complex tissue present in the vascular bundles along with xylem. It is the principle food-conducting tissue of vascular plants and is responsible for transport of food or the photo-assimilate from sources such as leaves and storage organs to the regions where it is required (sink) such as the growing meristems and other parts of the plant. Apart from photo assimilates, substances such as amino acids, lipids, proteins, RNA, hormones and micro-nutrients are also transported in phloem. Interestingly, phloem is also involved in long distance signalling, communication between organs, and coordination of growth processes.
- Phloem tissue in angiosperms is comprised of four types of cells, sieve tubes, companion cells, parenchyma and sclerenchyma (including both fibres and sclereids). Laticifers (containing latex) and resin ducts are found in phloem of some plants.

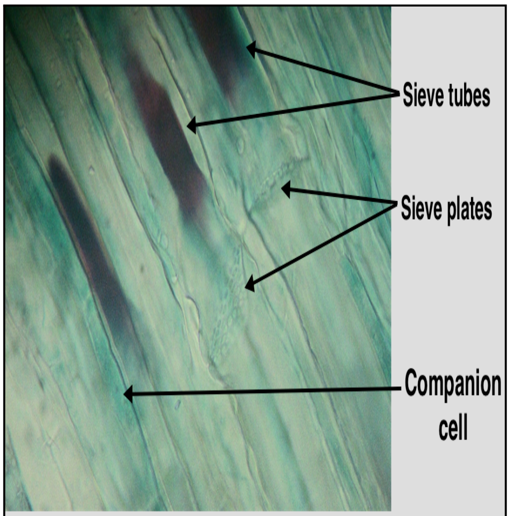
Sieve tubes

- Sieve tubes are the principal elements through which food materials are transported in angiosperms. In lower vascular plants such as pteridophytes and gymnosperms, sieve tubes are absent and the conduction of food materials is carried out by less specialized sieve cells.
- Sieve tubes, like vessels, are long tubes formed by elements (also called as members) placed one above the other. The end walls of the sieve tube elements are transverse, perpendicular to the long axis of the tube and perforated. The elements of one tube are connected with adjacent tube forming a longitudinal network of sieve tubes within a vascular bundle. Sieve tubes also form lateral connections or anastomoses with sieve tubes of other vascular bundles interconnecting them. If sieve tubes of a vascular

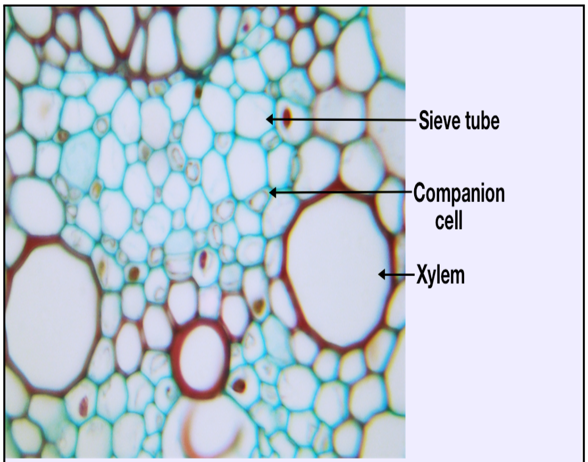
bundle become non-functional due to any reason, then food is transferred to sieve tubes of other vascular bundles via these phloem anastomoses.

- The mature functional sieve tube elements are living cells characterized by the presence of sieve areas on their walls and a partially degraded protoplast.
- Sieve areas contain pores (without any wall material) which connect the neighbouring elements. In sieve tube elements of angiosperms, some sieve areas have pores that are larger. Such sieve areas with larger pores are called sieve plates. The sieve plates usually occur on the end walls. Lateral walls of the elements generally bear sieve areas as well as a few sieve plates.
- Sometimes the lateral walls of sieve elements become thick and glisten, and are referred to as nacreous walls.
- The protoplast of the elements undergoes selective degradation during maturation. The mature functional elements lack a nucleus but contain a thin layer of cytoplasm at the periphery with an intact plasma membrane. The cytoplasm has very few organelles, and is devoid of ribosomes and a distinct vacuole. Also dispersed in the peripheral cytoplasm of sieve tubes and lining the pores of sieve plates are strands or networks of special protein called the P-protein. Because of their reduced protoplasts, sieve elements are unable to carry out many of the metabolic activities and depend on adjacent companion cells for energy and other metabolites.
- During the development of vascular bundles, the first formed phloem tissue (**protophloem**)contains narrower sieve tubes as compared to the sieve tubes of later formed phloem (**metaphloem**).
- Once the materials are loaded into the sieve tubes, they act as conduits and carry the materials from source to the sink, where they are unloaded. The sieve-area pores in the walls and the reduced cytoplasm at the periphery of the sieve tubes (leaving the central part free) enable the fluid materials to pass easily from one element to the other. In case of damage to the sieve tubes, the P-protein accumulates near the pores, forms slime plugs and prevents loss of assimilates.

Companion cells



Longitudinal section of Phloem tissue



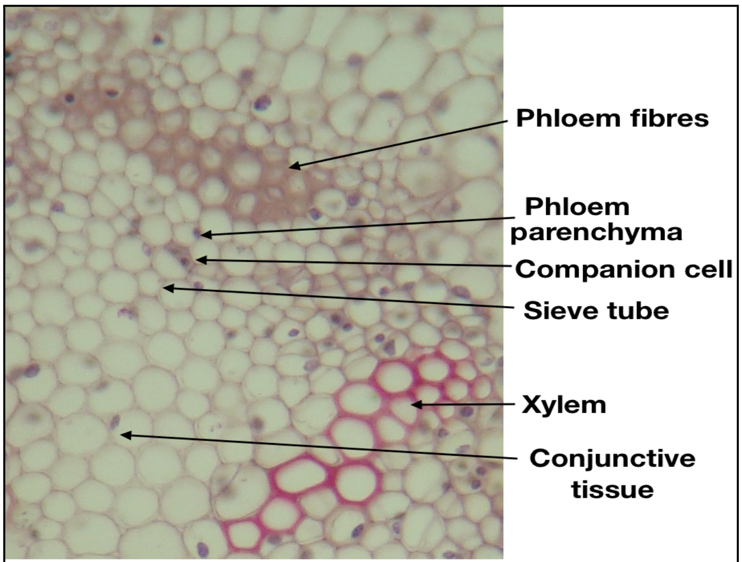
Transverse section of vascular bundle

- Companion cells are specialized parenchyma cells which are closely associated with sieve tube elements both physically as well as developmentally forming a sieve element-companion cell complex. A sieve tube element and associated companion cell/s are generally derived from the same mother cell.
- They are densely cytoplasmic and are connected to the sieve tube member by numerous plasmodesmata in their common walls.
- A sieve tube element may be associated with more than one companion cell.
- A companion cell provides the associated sieve tube element with energy, proteins and other molecules required for the survival of the element. Both the cells are interdependent on each other to such an extent that they stop functioning and die at the same time.
- The main function of transfer of food from the source into the sieve tube (phloem loading) for translocation to other regions is carried out by companion cells. They supply the energy required for active loading of food into sieve tubes.

Phloem Parenchyma

- These are parenchyma cells other than the companion cells found in the phloem tissue of dicotyledons but not of most monocotyledons.
- They are elongated cells oriented parallel to the sieve tubes in primary phloem. As in xylem, in secondary phloem too, there are two types of parenchyma, the axial and ray parenchyma. The axial parenchyma are elongated cells present parallel to the sieve tubes. The ray parenchyma are short radially oriented cells.

- The cells generally have dense cytoplasm and thin cellulosic walls. Numerous plasmodesmata in the walls interconnect the cells. Some cells may develop lignified secondary walls.
- Like xylem parenchyma, phloem parenchyma cells too, store a variety of substances such as starch, tannins, mucilage, crystals, latex, resin etc. Ray parenchyma cells carry out radial translocation of food.



Transverse section of root vascular bundle

Phloem sclerenchyma

- It is composed of fibres as well as sclereids.
- Its principal function is to provide support and protection.
- The fibres are present in both primary and secondary phloem tissue. In primary phloem, they are present at the outer regions but in the secondary phloem, they are variously distributed as bundles, in bands or continuous layers, etc. interspersed between other phloem cells.
- Phloem fibres are generally narrow and very long with sharply tapered ends. They may be living or dead at maturity. They possess thick secondary walls with simple pits. The walls may be lignified (e.g. jute) or cellulosic (e.g. ramie).
- Many of the commercially important fibres are phloem fibres (e.g. jute, ramie, hemp, linen).
- Sclereids are more often found in the secondary phloem tissue. They may be present alone or with fibres.

Summary

The flowering plant body is essentially made up of two types, the meristematic and the permanent tissues. The meristematic tissues or meristems are concerned with growth of the plant and contain cells capable of division. They are classified according to their position in the plant body. The apical meristems, comprising the root and shoot apical meristems, are located at the extreme ends of the plant, and produce the primary tissues of the plant. The lateral meristems (vascular and cork cambium) are involved in the increase in girth of plants by forming secondary tissues. Intercalary meristems help in elongation of mature stems, leaves, flower stalks, etc. Wound meristem repairs damaged tissues.

Permanent tissues contain structurally and functionally differentiated cells. They are distinguished broadly into simple tissues consisting of structurally similar cells, and complex tissues composed of different types of cells performing a special function. Parenchyma, collenchyma and sclerenchyma are simple tissues. Xylem and phloem, involved in transport of water and minerals, and food materials respectively, are complex tissues as they contain, apart from the specialized cells involved in conduction, parenchyma and sclerenchyma.