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Mechanical tissues

Mechanical (reinforcement/ supporting) tissues are tissues that provide the strength of plant organs, the ability to withstand loads. They fulfill their purpose only when combined with other tissues.

The roots of the plant perform the function of anchoring. They must resist tearing and pulling the plant out of the soil. Therefore, in the roots of plants, mechanical tissues are concentrated in their center. The stems of the plant resist the effects of wind and gravity, they must be elastic and strong and resist bending. Therefore, the mechanical tissues in the stems are concentrated on the periphery and form a strong, light and elastic frame (sceleton). In leaves, mechanical tissues strengthen the veins that make up their skeleton and prevent their break.

There are two types of mechanical tissues: **collenchyma** and **sclerenchyma**.

Collenchyma is a living tissue consisting of parenchymal or prosenchymal living cells. Their cell walls are unevenly thickened.

An important feature of collenchyma is that it is extremely plastic—the cells can extend and thus adjust to increased growth of the organ. It occurs early in young shoots (but not in the roots) when stretching in length is still continuing. If rigid tissues had appeared at this time, stretching would have been impossible. Collenchyma, on the one site, provides the strength of young organs, on the other site, it is able to stretch itself as the surrounding tissues stretch due to uneven thickening. Plastic stretching is possible only with the active participation of the protoplast. One of the features of the collenchyma is that it performs its functions only in the state of turgor. If the leaves or young stems lose water, thin area of the collenchyma shells form an accordion and the plant withers. At the same time, the collenchyma is a photosynthetic parenchymal tissue and, along with the assimilating parenchyma, also performs the function of photosynthesis.

By origin, the collenchyma is always the primary tissue and is formed in the axial organs (in the stems) from the pericycle, and in the lateral organs (in the leaves) from the intercalary meristems.

Depending on the nature of the thickening of the cell walls, angular, lamellar, annular and lacunar collenchyma are distinguished. In the angular collenchyma, the thickenings are located in the corners of the cell. The lamellar one has uniform thickening, or broad parallel areas of the cell wall are thickened. In lacunar collenchyma, intercellular places are well developed, and parts of the walls bordering them are thickened. Finally, annular collenchyma (collenchyme annulaire) is distinguished by having uniformly thickened walls. Collenchyma can fulfill its purpose of reinforcing tissue only in the state of turgor. Collenchyma develops, as a rule, in the aboveground organs of dicotyledonous plants, monocotyledons usually do not have it. The main purpose of collenchyma is to maintain the shape and provide support for young growing plant organs until their internal structure and other mechanical tissues are fully formed. The tissue is found chiefly in the cortex of stems and in leaves and is the primary supporting tissue for many herbaceous plants. In plants with secondary growth, the collenchyma tissue is only temporarily functional and becomes crushed as woody tissue develops. It often constitutes the ridges and angles of stems and commonly borders the veins in eudicot leaves. The “strings” in stalks of celery are a notable example of collenchyma tissue.

Sclerenchyma is a dead mechanical tissue consisting of cells with uniformly thickened lignified cell walls. Sclerenchyma performs a supporting function after the death of cell protoplasts. The cell walls of sclerenchymal cells have a high strength, close to the strength of steel. They are superior to steel in their ability to withstand dynamic loads without experiencing residual deformation. Sclerenchyma cells possess two types of cell walls: primary and secondary walls. The secondary wall is very thick and highly lignified (15%–35%) and imparts a great rigidity and hardness to the cell and tissue. The deposition of lignin in the cell wall (lignification) increases the strength of the shells and their ability to resist crushing. However, this makes them more fragile. Therefore, there are rare exceptions when the elements of the sclerenchyma remain not lignification (flax fibers)

There are two main types of sclerenchyma cells: fibers and sclereids. Fibers are very elongated cells that can be found in stems, roots, and vascular bundles in leaves. Fibers impart fibrousness as in the case of asparagus. Sclereids are found in different shapes (spherical, oval, or cylindrical) and are present in various plant tissues such as the periderm, cortex, pith, xylem, phloem, leaves, and fruits. The hardness of the shell of nuts, the coat of many seeds, and the stone of drupes (cherries and plums) is due to this type of cell. Sclereids may impart a grainy texture to some fruits when found scattered in their parenchymal tissue, that is, in pears and quinces. Support sclerenchyma is comprised of sclereids and fibers. This tissue reduces wilting, but it is energetically costly for the plant to create. Sclerenchyma matures with the surrounding tissues and provides more permanent support than collenchyma, maintaining the established morphology of the plant.

Fibers have tapered ends, can be many centimeters long, and comprise the bundle caps and sheaths characteristic of vascular bundles, especially in monocotyledonous plants. Fibers function in mechanical support of various organs and tissues, sometimes making up the bulk of the tissue. Fibers often occur in groups or bundles. They may be components of the xylem and/or phloem or may occur independently of vascular tissue. Sclereids may also function in structural support, but their role in some plant organs is unclear; they may possibly help to deter herbivory in some plants. The evolution of sclerenchyma, especially fibers, with lignified secondary cell walls, constitutes a major plant adaptation permitting the structural support needed to attain greater stem height.

There are two types of sclerenchyma: **fibers** and **sclereids**.

The **fibers** are prosenchymal cells, pointed at the ends, have thick walls and a very narrow cavity.

Depending on the location of the fibers, there are:

a) **wood (xylem) fibers (libriform)** — strengthen the conductive elements of vessels,

b) **bark fibers** — are located in the primary bark of plant stems, c

) perivascular (pericyclic) fibers — strengthen the central axial cylinder,

d) **bast (phloem) fibers (cambiform)** — protect the living tissues of the phloem (sieve tubes).

The fibers act as the internal skeleton of the plant. They are found in all parts of the plant and protect the plants from mechanical damage.

Sclereids are roughly isodiametric, and clumps of these “stone cells” (brachysclereids) give the Bartlett pear (Pyrus communis) its distinctive grittiness. Testas (seed coats) of many plants, especially legumes, are made of two layers of sclereids while sclereids comprise the thick dense layer forming the shell (endocarp) of the coconut. Star-shaped or branched astrosclereids make water lily leaves (Nymphaea sp.) tough but pliable, allowing them to withstand the tearing forces of waves and currents.

Various types of sclereids:

Brachysclereids or Stone Cells - These are unbranched, short and isodiametric with ramiform pits. For example: grit of Guava, Sapota, Apple and Pear.

Macrosclereids - These are elongated and columnar or rod-like. For example: epidermal covering of legume seeds.

Osteosclereids - These are bone-like or columnar with swollen ends. For example: sub-epidermal covering of legume seeds.

Astrosclereids - These are branched as star. For example: petiole of lotus, tea leaves.

Filiform Sclereids - These are fibre like, sparingly branched. For example: Olea.

Trichosclereids - These are elongated hair-like. These branch once and extend into intercellular spaces.

Vascular (conducting) tissue.

Vascular (conducting) tissues is tissues on which substances move in the plant. They arose as a result of adaptation to life on land. The body of the higher plant was divided into two parts, live in two environments air and soil nutrition. As a result, two specialized tissues have emerged, through which substances move in two directions: from the roots to the leaves and from the leaves to the roots. The first direction is called the ascending current of substances. The ascending current of substances carries water and dissolved minerals in it, absorbed by the roots. The second direction is called the downward flow of substances. This current carries the products of photosynthesis from the leaves to all other parts of the plant.

Vascular tissue are tissue that perform the function of conducting water and organic and mineral substances dissolved in it through the plant. All conductive tissues are complex. Any vascular tissue consists of three types of elements: conductive, mechanical and basic. Conducting elements perform the main functions of conducting tissues. Mechanical elements maintain the integrity of the conductive elements and protect them from compression and breaking. The parenchymal elements carry out the transfer and distribution of substances in the radial direction.

The vascular tissues include **phloem** and **xylem.**

Xylem and phloem have a number of common features:

1. they form a continuous branched system in the plant body, connecting all the organs of the plant from the thinnest roots to the youngest shoots.
2. xylem and phloem are complex tissues, i.e. they are composed of heterogeneous elements: vascular, mechanical, storage, excretory
3. The vascular elements both in the xylem and in the phloem are elongated in the direction of the current of substances, sometimes very significantly.
4. The walls of the vascular elements contain pores or perforations (through holes) that facilitate the passage of the current of substances.

Xylem.

Xylem, or wood is the main water-conducting tissue of vascular plants.

The vascular (conducting) elements of the xylem carry out an "ascending current" of substances. These include **vessels** and **tracheids**, which are dead cells with lignified and often unevenly thickened walls. Therefore, they can also perform a mechanical function. A vessel (trachea) is a tube made up of a chain of closed cells (segments) with perforated common walls. Tracheids are single-celled formations of a fusiform shape with pointed ends. Sometimes wood fibers are also referred to as tracheal elements, because there is no sharp border between them and the tracheids. From the point of view of evolution, vessels are younger and more progressive conducting elements than tracheids and perform their function better.

Xylem vessels transport water and mineral ions from the roots to the rest of the plant. They are made up of dead, hollow cells with no end cell walls. This forms one continuous tube when the xylem cells are stacked on top of each other. The cells have no organelles or cytoplasm, which creates more space inside the vessel for transporting water. The cell walls contain pits which allows water and mineral ions to move into and out of the vessel. The cell wall also contains a tough, woody substance called lignin, which strengthens the xylem vessel and provides structure and support to the plant.

The tracheid is a highly elongated water-conducting cell with undisturbed primary walls. The penetration of solutions from one tracheid into another occurs by filtration through these walls, more precisely through the bordered pits in the lateral (oblique walls) that are in contact with each other.

The vessel consists of many cells called segments of the vessel. The segments are located on top of each other, forming a tube. Between the adjacent segments of the same vessel, through holes – perforations appear by dissolving the transverse walls. Solutions move much more easily through the vessel than through the tracheids. In the mature state, the tracheal elements consist only of shells, since their protoplasts die off. Vessels and tracheids transmit solutions not only in the longitudinal, but also in the radial direction to neighboring tracheal elements and living cells. The lateral walls of the tracheal elements are kept thin on a larger or smaller area. At the same time, they have various thickenings that give the walls strength.

Secondary thickening of the walls of vessels and tracheids can be annular, spiral (helical), reticulate, scalariform and pitted. In these cases, they speak respectively of annular, spiral, stair and porous vessels and tracheids.

Various thickenings can be considered as an evolutionary series, but the same sequence of occurrence of first annular and spiral, and then the rest is observed in the histogenesis of the same bundle. The presence of various elements in one bundle is explained by the fact that the first of them are formed before the end of growth in the length of the plant (annular and spiral vessels do not prevent this growth), when growth stops, reticulated ones appear, stair and porous tracheal elements.

Almost all angiosperms have vessels. Ferns and gymnosperms are usually devoid of vessels and have only tracheids.

The first xylem that appears in the plant during its development is called the primary xylem; it is laid at the tip of the root and at the top of the shoots. Differentiated segments of the xylem vessels appear in rows at the ends of the procambial strands. A vessel occurs when adjacent segments in a given row merge as a result of the destruction of the partitions between them. Inside the vessel, the remnants of the destroyed end walls are preserved in the form of rims.

The first vessels — the protoxylem — are formed at the top of the axial organs, directly under the apical meristem, where the surrounding cells still continue to stretch. Mature vessels of the protoxylem are able to stretch simultaneously with the stretching of the surrounding cells, since their cellulose walls are not yet completely lignified —lignin is deposited in them only in rings or in a spiral. These lignin deposits allow the tubes to maintain sufficient strength during the growth of the stem or root. With the growth of the organ, new xylem vessels appear, which undergo more intensive lignification and complete their development in the mature parts of the organ; this is how the metaxylem is formed. Meanwhile, the very first vessels of the protoxylem are stretched, and then destroyed. Mature vessels of the metaxylem are not able to stretch and grow. These are dead, rigid, completely lignified tubes. If their development was completed before the pulling of the surrounding living cells ended, they would greatly interfere with this process.

Three main types of thickenings are found in the vessels of the metaxilema: ladder, mesh and point.

The xylem also performs its second function - mechanical - due to the fact that it consists of a number of lignified tubes. In the primary structure body of the plant, the xylem in the roots occupies a central position, helping the root to resist the pulling force of the aboveground parts bending under wind gusts, In the stem, the conducting bundles either form a ring around the periphery, like in dicotyledons, or are arranged randomly, like in monocotyledons; in both cases, the stem is penetrated by separate xylem strands, providing it with a certain support. The supporting function of the xylem becomes especially important where secondary growth takes place. During this process, the amount of secondary xylem rapidly increases; the role of the main mechanical tissue passes from the collenchyma and sclerenchyma to it, and it is it that serves as a support for large tree and shrub species. The growth of trunks in thickness is determined to a certain extent by the loads to which the plant is subjected, so that sometimes there is additional growth, the meaning of which is to strengthen the structure and provide it with maximum support.

The parenchymal elements of the xylem are represented by wood parenchyma. The wood parenchyma of the xylem is contained in both the primary and secondary xylem, but in the latter its quantity is greater and its role is more important. The cells of the woody parenchyma, like any other parenchymal cells, have thin cellulose walls and living contents.

There are two parenchymal systems in the secondary xylem. Both of them arise from meristematic cells, called in one case radial initials, and in the other-fusiform initials (ch. 22). The radial parenchyma is more abundant. It forms radial layers of tissue, the so-called pith rays, which, penetrating the pith, serves as a living link between the pith and the bark. Various nutrients are stored here, tannins, crystals, etc. accumulate, and radial transport of nutrients and water, as well as gas exchange through intercellular place, is also carried out here.

The mechanical elements of the xylem are represented by wood fibers and are called libriform. Wood fibers have thick shells and narrow gaps. Their presence in the wood makes the wood stronger. It is believed that wood fibers, as well as xylem vessels, originate from tracheids. They are shorter and narrower than tracheids, and their walls are much thicker, but their pores are similar to those found in tracheids, and it is sometimes difficult to distinguish fibers from tracheids on slice, since there are a number of transitional forms between them and others.

Wood fibers are very similar to the sclerenchyma fibers already described; their end walls also overlap. Unlike xylem vessels, wood fibers do not conduct water; therefore, they can have much thicker walls and narrower gaps, which means that they are also more durable, i.e. they give the xylem additional mechanical strength.

Parenchymal cells lying next to the vessels often give outgrowths inside the vascular cavity. These outgrowths are formed in those places where the shell of the vessel is thin, and they are called tills. Tiloses are formed due to the ingrowth of the closing film of the Pore into the vessel cavity. The cytoplasm, sometimes the nucleus, moves into the outgrowth, which is not separated by a partition from the mother cell. Tiloses can be filled with starch, calcium salts, resin, gum. Tiloses are most characteristic of woody plants, but they are also found in herbaceous plants (for example, in pumpkin, purslane, sorrel). Tiloses reduce the water capacity of sound wood, increase its resistance against rotting and the penetration of fungi. Sometimes the formation of tilla can be a response of the plant to damage.

https://www.youtube.com/watch?v=2j7e-zS_Ke8

Phloem.

The phloem is similar to the xylem in that it also has tubular structures modified in accordance with their conducting function. However, these tubes are made up of living cells that have a cytoplasm; they do not carry a mechanical function. There are five types of cells in the phloem: segments of the sieve tubes, companion cells, parenchymal cells, fibers and sclereids.

The conducting elements of the phloem are represented by **sieve tubes with companion cells** and **sieve cells**. They carry out a "downward current" of substances. They are called sieve because, that there are groups of small through holes (perforations) on their walls, similar to strainers. These areas of the cell wall are surrounded by thickened rollers and are called sieve fields. The sieve elements, unlike the tracheal ones, are living cells.

Sieve tubes are formed by a vertical row of cells - segments located one above the other, the transverse partitions between which are turned into sieve plates, with perforations wider than those of the sieve fields. Sieve fields are preserved on the longitudinal walls. These are living cells whose protoplast is under high turgor pressure. The walls of the sieve tubes are cellulose, there are no nuclei and leucoplasts, there is a thick layer of cytoplasm, the tonoplast disappears, and all living contents connections into a single mass (due to the activity of mucus bodies). The cytoplasm loses its semipermeability and becomes completely permeable to solutions of organic and inorganic substances. The segments of the sieve tubes are dependent on their neighboring companion cells and have a common origin with them. Companion cells presumably contribute to the movement of the assimilate (nutrients) current. There are numerous plasmodesmata between them and the segments of the sieve tubes. A characteristic feature of sieve tubes is the presence of sieve plates. This feature of them immediately catches the eye when viewed in a light microscope. The sieve plate occurs at the junction of the end walls of two adjacent segments of the sieve tubes.

Initially, plasmodesmus pass through the cell walls, but then their channels expand, turning into pores, so that the end walls take the form of a sieve through which the solution flows from one segment to another. In the sieve tube, the sieve plates are arranged at certain intervals corresponding to the individual segments of this tube.

The sieve tubes function most often for one year, after which the holes in the sieve plates are clogged with a special substance - callose, close to cellulose.

In gymnosperms, conducting elements are represented by sieve cells with a nucleus and vacuoles, there are no companion cells. Their sieve fields are located on the side walls.

The sieve cells are older and more primitive conducting elements of the phloem than the sieve tubes. Through the sieve tubes, the currents of substances move more actively and freely due to the more liquid consistency of their protoplasts.

The first emerging phloem, called the protofloem, appears, as well as the protoxylem, in the zone of growth and stretching of the root or stem. As the surrounding tissues grow, the protofloem stretches and a significant part of it dies, i.e. ceases to function. At the same time, a new phloem is formed. This phloem, which has matured after the stretching ends, is called a metafloem.

The secondary phloem, which develops, like the secondary xylem, from the vascular cambium, is similar in structure to the primary phloem, differing from it only in that it shows strands of lignified fibers and the pith rays of the parenchyma. However, the secondary phloem is not as pronounced as the secondary xylem, and besides, it is constantly being updated.

In addition to conducting elements, the phloem may include mechanical and parenchymal elements. The mechanical elements are represented by sclerenchyma (bast fibers). Bast fibers remain alive for a relatively long time, unlike wood fibers. The main elements are represented by the bast parenchyma.

Bast parenchyma and **bast fibers** are present only in dicotyledons, they are absent in monocots. The structure of the bast parenchyma is similar to any other, but its cells are usually elongated. In the secondary phloem, the parenchyma is present in the form of pith rays and vertical rows as well as the wood parenchyma described above. The functions of the bast and wood parenchyma are the same.

Bast fibers do not differ in any way from the sclerenchyma fibers described above. Sometimes they are found in the primary phloem, but more often they can be found in the secondary phloem of dicotyledons. Here, these cells form vertical strands. As is known, the secondary phloem experiences stretching during growth; it is possible that the sclerenchyma helps it to resist this effect.

Sclereids in the phloem, especially in the older one, are quite common.

Vascular tissues are located in the axial organs either in rings (annular structure), or in vascular bundles. In leaves and flowers, the vascular tissues are always arranged in bundles.

Xylem and phloem usually accompany each other, forming Conductive, or **Vascular - fibrous bundles**.

A vascular-fibrous bundles is a set of elements of vascular tissues (vessels, tracheids, sieve tube with companions cells), mechanical tissues, cells of the living parenchyma, meristems. Different plants have different types of vascular-fibrous bundles, which can be a systematic and diagnostic sign.

Vascular-fibrous bundles formed by procambium that do not have cambium are called closed. Bundles with cambium are called open, since they can increase in size for a long time.

The xylem typically lies towards the axis (adaxial) with phloem positioned away from the axis (abaxial). In a stem or root this means that the xylem is closer to the centre of the stem or root while the phloem is closer to the exterior. In a leaf, the adaxial surface of the leaf will usually be the upper side, with the abaxial surface the lower side.

The four main types of vascular bundles: **Collateral bundle, Bicollateral bundle, Concentric bundle, Simple (Radial) bundle.**

1. **Collateral bundle**: It is a type of vascular bundle in which phloem strands are present externally to the xylem strands on the same radius side by side is called a collateral bundle. There are further two types of collateral vascular bundles: closed and open collateral bundle.

a. Closed collateral bundle: Cambium is absent in between phloem and xylem. They do not have normal secondary growth. Example: monocotyledonous stem.

b. Open collateral bundle: Cambium is present in between phloem and xylem. They have secondary growth by the increase in the diameter. Example: dicotyledonous stem.

2. Bicollateral bundle: It is a type of vascular bundle in which phloem situated on the peripheral and inner side of the xylem is called a bicollateral vascular bundle. Cambium is present between the peripheral xylem and phloem.

3. Concentric bundle: In this type, one type of the vascular tissue surrounds the other vascular tissue. On the basis of encircling, further divided into two types.

a. Amphivasal bundle: Xylem encircles the central strand of phloem is known as amphivasal bundle. Example: yucca, dracaena.

b. Amphicribral bundle: Phloem encircles the central strand of xylem. Example: selaginella.

4. Radial (Simple) vascular bundle: Xylem and phloem strands are separated from each other by non-vascular tissue. They are situated on other axis of radii and are known as radial vascular bundles.

5. Incomplete bundles — bundles containing only one type of vascular tissue: either phloem or xylem.

Concentric, radial and incomplete bundles are always of a closed type.