Anatomical structure of the herbaceous and woody stem. Morphology of the stem.

Plan

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The structure of wood

The shoot - this is an organ that arises from the apical meristem and is differentiated an early stage of morphogenesis into specialized parts: stem, leaves, buds.

Its main function is photosynthesis. Parts of the shoot can also serve for vegetative reproduction, accumulation of reserves nutritional products, water. The vegetative non-modified shoot consists of a stem, leaves and buds. Stems and leaves are structural elements of the shoot (often considered as its organs).

It is parts of the shoot. The section of the stem at the level articulation with the leaf is called a node, and the section of the stem between two nodes is called an internode. An axillary bud forms above the node in the leaf axil. The stem is the axial part of the shoot, which usually has a cylindrical shape, the leaves are flat lateral organs of the shoot which are on the stem, the buds are the german of new shoots that provide branching of the plant (forming a system of shoots).Along with the root, the shoot is the main organ of the vascular plants.

Metamerism. Usually the shoot has several nodes and internodes. Such a repetition of shoot segments having the same organs is called a metamerism. Each metamere (phytomere) of a typical shoot consists of a node with a leaf and an axillary bud and an underlying internode.

The shoot is called long shoot if the nodes and internodes are well expressed. If the nodes are close together and the internodes are almost invisible, then this is a short shoot (rosette).

According to the position in space, the shoots can be erect, creeping, creeping, rising, curling, clinging (with hooks and suckers), climbing (entwining supports with tendrils).

There is no unified classification of shoots depending on the position of shoots in space, but practically all textbooks have these basic types of shoots.

The erect stems rise vertically. They do not need support as they have well-developed mechanical tissue.

Prostrate (recumbent) stems have little mechanical tissue and lie prostrate on the soil without forming adventitious roots. Such stems are found in bird's-foot mountaineer (Polygonum aviculare).

Decumbent (rising): A stem that lies flat on the ground and turns upwards at the ends.

Creeping stems have adventitious roots at each node. Each node of such a stem can give rise to a new plant. Such stems are found in the creeping buttercup (Ranunculus repens).

Twiners Morning glories, pole beans, honeysuckle and clematis are some of the many plants that twine. There are two important differences among twining plants: they either have twining leaves or twining stems.

Adhesive pads. Boston ivy (Parthenosissus tricuspidata) and Virginia creeper (P. quinquefolia) have stem tendrils with touch-sensitive adhesive pads that allow them to stick to almost any surface. Climbers with adhesive pads can attach themselves to the face of a building or the trunk of a tree. If not provided with a vertical support, they will just as happily crawl sideways, attaching themselves to anything in their path.

Climbing: Stems that cling or wrap around other plants or structures.

The last group of climbers use clinging stem roots to attach themselves. The stems of these plants produce a cluster of short, stout roots that cling to surfaces of almost any kind. Examples of plants with clinging stem roots include climbing hydrangea (Hydrangea petiolaris), most ivies such as English ivy (Hedera helix) and Irish ivy (Hedera hibernica), and also euonymus. These plants can damage paint work and mortar if you try to remove the stem roots from a structure.

Depending on the location and function, the shoots may modified. Metamorphoses of shoots:

1. **Rhizome** – This is seen in ginger, turmeric, alocasia, banana, and dryopteris. It lacks chlorophyll, is not green in color, is fleshy, and bears the presence of axillary buds, dry scale leaves, and adventitious roots around the nodes.

2. A **bulb -** like structure is seen in the case of onion, garlic, and lily. There are a lot of scaly leaves surrounding the bulbs and a clutch of roots arising from the base of the bulb. It has a terminal bud in its upper region and is a discoid stem that is highly condensed.

3. **Corm** is a modification seen in Gladiolus and Colocasia. It looks like a compressed rhizome that is spherical and has a flat base. Scale leaves and axillary buds are seen in regions around the nodes and a cluster of roots can grow around its entire body.

4. **Tuber** is a common swollen underground stem, seen in the case of potatoes. It has eyes all over its body in very small depressions, which represent the nodes and it lacks adventitious roots.

5. **Runner** is a type of modification seen in lawn grasses and Oxalis, which is a wood sorrel. It is a type of horizontal creeper that runs parallel to the soil sur-

face and they Branch out and grow from the axillary buds in several directions. There is the presence of adventitious roots and scale leaves from the nodes.

6. **Sucker** is a modification seen in Chrysanthemum, strawberry, and pineapple. It arises from below the main stem, grows horizontally underground, then arises above the soil upward and proceeds to separate itself from the mother plant.

7. **Stolon** is a subaerial modification that is seen in jasmine and colocasia. When a weak branch from the main stem bends downward in the soil, new adventitious roots and shoots are developed and a few days later, it can grow as a separate plant.

8. **Offset** is a modification seen in plants that are in water plants like Pistia and water hyacinth. A rosette of leaves is produced above the water, and adventitious roots are produced below the water. Given below are a few types of stem modifications that are seen in the stems that are completely above the ground:

9. The stem is modified into stem **tendrils**, which are green thread-like structures to aid the plants in climbing. It is seen in grapevine and cucurbita.

10. **Thorns** are modifications that serve to protect and defend the plants and there are a variety of different types of thorns, as seen in Bougainvillea.

11. **Phylloclades** and **Cladophylls** are seen in stems which are flattened to reduce the water lost in transpiration. Examples of plants where this modification can be seen are Opuntia, Ruscus, and Cocoloba.

12. **Cabbage** is a condensed leafy shoot. The venation in outermost leaf is indicating the leafy nature of the crumpled appendages. a number of leaves compacted over the condensed axis (stem). The shoot apex (vegetative) is covered by many younger leaf primordia. So cabbage is a vegetative bud.

The Stem

In typical cases, it is an axial shoot organ with radial symmetry, negative geotropism, having unlimited growth in length, having leaves and buds; the increase in length occurs by apex and insertion growth.

The stem provides a connection between the leaves and the roots, determines the formation of a powerful assimilation surface of the leaves and their best placement in relation to light, serves as a container for spare products. Stems (as well as roots) of woody plants can reach the age of 4-6 thousand years (mammoth and dragon trees). In some herbs, the stem age is limited to only 30-45 days (ephemeral plants). In grasses, stems usually live only 1 year, in trees, the stem has existed for many years.

The stem is the main structural part of the shoot. It consists of nodes and internodes and has a number of important functions: 1) conductive - ascending (transpirational) and descending (assimilational) currents of substances between the roots and leaves move in the stem; 2) mechanical, or supporting, - the stem ensures the position of the body in space and brings the leaves to the light, withstanding significant mechanical loads (the weight of its own branches, leaves, flowers, fruits, wind action, mechanical damage, etc.); 3) storage - in some storage tissues of the stem, organic substances are deposited in reserve; 4) assimilation — this function is characteristic of young green plant stems, perennial stems of many succulents (cacti, euphorbias), as well as stems of some plant species of arid regions (species of ruscus, etc.).

In cross-section, the stem has radial symmetry. The shape of the cross-section of the stem is most often cylindrical, but in herbaceous plants there are triangular stems (sedges), tetrahedral (Lamiaceae), winged (Fabaceae), flat (Potamogeton).

The length of the stems varies widely: from 280-300 m (climbing stems of rattan palms) to 1.5 mm (water plant wolfia).

The primary structure of the stem

The primary structure of the stem, both in monocotyledonous plants and dicotyledons, is formed as the cells of the apical stem of the shoot differentiate (see meristematic tissues). Thus, the primary dermal tissue, the epidermis, is formed from the outer layers of the formation tissue; the primary cortex is formed from the cells of the apical meristem located to the periphery, at the level of the first primordia of the leaves; the central axial cylinder is formed in the central part.

There are three main parts in the anatomical structure of the stem of herbaceous plants:

1. The dermal tissue.
2. Primary cortex.
3. Central axial cylinder.

The dermal tissue of the stems of herbaceous plants is usually represented by the epidermis.

The primary cortex is a complex of mechanical and parenchymal tissues. In most herbaceous plants, it is represented by collenchyma, assimilating parenchyma and endoderm.

The collenchyma is located in a solid ring or sections opposite the vascular bundles. In very young stems, collenchyma may not be expressed.

Behind it are the assimilative parenchyma, whose cells contain chloroplasts, and endoderm. In some herbal plants, the endoderm is represented by a containing starch sheath, where starch is acumulated. In others, there is little difference from the chlorophyll-bearing parenchyma.

In monocotyledonous herbaceous plants, the primary cortex, as a rule, does not have collenchyma, and is often poorly expressed or practically absent. In the latter case, the assimilating function is performed by the outer layers of the main parenchyma of the central axial cylinder. In Gymnosperms, the primary cortex is represented by a homogeneous parenchymal assimilating tissue, often having resin ducts. Dicotyledons may also have resin ducts in the assimilating parenchyma (for example, sunflower).

The boundary between the stele (central axial cylinder) and the cortex in the stems is much less clearly expressed than in the roots, since the inner boundary layer of the primary cortex - the endoderm - does not have such characteristic features as in the root. The primary cortex may include chlorenchyma (assimilative parenchyma), non-specialized parenchyma, excretory, mechanical (more often collenchyma), as well as some other tissues.

The totality tissues of stem located inwards from the cortex is called **the central axial cylinder (stele)**. It occupies the central part of the stem inwards from the endoderm, which is bordered by the outermost layer of the central cylinder - the pericycle. Vascular tissues are located under it. In the very center is the pith. The whole system of vascular tissues in the axial organs, considered as a whole, is a stele. The composition of the stele includes, in addition to xylem and phloem, pericycle, pith rays and pith. Thus, the central axial cylinder is a complex of tissues consisting of a pericycle, the pith parenchyma and vascular tissues, which, as a rule, are located in vascular-fibrous bundles.

During the development of the shoot, the pericycle turns into a sclerenchyma, or (much less often) into the parenchyma, consisting of several rows of cells, and is visible on the slice as a continuous or intermittent ring. Very often it is preserved in the form of mechanical tissue only in the area of the bundles, and in this case forms part of their sclerenchymal sheaths.

Vascular tissues, as a rule, are located in vascular-fibrous bundles, represented in monocotyledonous plants by closed—type bundles, in dicotyledonous - open-type.

The pith is located in the center of the stem and consists parenchyma, the cell size of which increases towards the center. The pith of many plants is partially destroyed, and then the stem becomes hollow. In the stem, the pith communicates with the primary cortex with the help of parenchymal tissue arranged in radial rows and called the pith rays. The outer part of the pith may differ slightly from its main mass, for example, by smaller cell sizes and thicker cell walls. This morphologically distinct zone is called the perimedullary zone.

In the stem of most monocotyledonous plants, the pith is not pronounced, since the vascular bundles are located along the entire cross-section of the stem.

In the stems of monocotyledonous plants, the bundle structure is well expressed. Vascular-fibrous bundles of a closed type (without cambium) are distributed throughout the entire thickness of the stem. From the surface, the stem is covered with a single-layer epidermis, which forming a cuticle layer. Located directly under the epidermis, the primary cortex consists of a thin layer of living parenchymal cells with chloroplasts. There is a central axial cylinder located inside frome the primary cortex. It is starting from the outside with a mechanical tissue of sclerenchyma of pericyclic origin. The sclerenchyma gives the stem strength. The main part of the central cylinder consists of large parenchymal cells with intercellular places and randomly spaced vascular-fibrous bundles. The shape of the bundles on the cross-section of the stem is oval; all parts of xylem tend closer to the center, and the phloem parts - to the surface of the stem. There is no cambium in the vascular-fibrous bundle, and the stem cannot thicken. Each bundle is surrounded by a mechanical tissue from the outside. The maximum amount of mechanical tissue is concentrated around the bundles near the stem surface.

Those, for the stems of monocotyledonous herbaceous plants, the following is characteristic:

1) the primary structure is preserved throughout life;

2) the covering tissue is the epidermis;

3) the primary cortex is weakly expressed and usually consists of chlorophyll-bearing parenchyma;

4) the central cylinder has a bundle structure;

5) vascular-fibrous bundles are collateral (or concentric, or incomplete bundles, or their mixtures) arranged randomly;

6) vascular-fibrous bundles of a closed type,

7) vascular-fibrous bundles is located randomly.

The herbaceous stems of dicotyledonous plants are characterized by

1) the primary structure is replaced by a secondary one due to the activity of the cambium,

2) the dermal tissue is represented by the epidermis,

3) the primary cortex is well expressed and includes the collenchyma, assimilating parenchyma and endoderm,

4) the central axial cylinder can be a bundle structure or a non-bundle structure (in this case, vascular tissues form continuous layers),

5) vascular-fibrous collateral or bicollateral bundles,

6) vascular-fibrous bundles of open type (they have cambium),

7) fibrous bundles form one or two rings parallel to the surface of the stem.

Difference Between Monocot and Dicot Stem

Dicot	Monocot
The dicot stem is solid in most of the cases.	The monocot stem is usually hollow at the centre.
Primary cortex always well developed.	Primary cortex is poorly developed or not developed at all.
The internal tissues are arranged in concentric layers.	There is no concentric arrangement of tissues.
The ground tissue is differentiated as endodermis, cortex, pericycle, medullary rays, pith, etc.	The ground tissue is the same and is composed of a mass of similar cells.
The vascular bundles are formed as broken rings.	The vascular bundles are scattered irregularly around the ground tissue.
Phloem parenchyma is present.	Phloem parenchyma is absent.
Pith is well-developed.	Pith is not as well-developed in monocots (usually absent in most)

Epidermal hair may or may not exist.	Presence of epidermal hair.
Vascular bundles are less in number and are of uniform size.	There are numerous vascular bundles of different sizes.
The dicot stem does not have a bundle sheath on the outside of a vascular bundle.	The monocot stem has a sclerenchymatous bundle sheath on the outside of a vascular bundle.
The dicot stems have trichomes.	The monocot stems do not have trichomes.
The vascular bundles always remain open, due to the presence of cambium within phloem and xylem.	The vascular bundles are closed.
Dicot stem can feature secondary growth as a result of secondary vascular tissues and periderm formation.	No secondary growth is witnessed in case of monocots.
Vessels are of a polygonal shape and are arranged in rows or chains.	Vessels are rounded or oval and are arranged in a Y-shaped formation.
Usually, vascular tissues stop functioning when they get old. New vascular tissues replace the old ones.	Vascular tissues remain the same throughout the plant's life cycle.

This slide shows a cross section of a maize stem. You can see that it has no primary cortex. Just beneath the epidermis, the tissues of the central axial cylinder begin. The conductive bundles are closed, collateral. Spread throughout the entire thickness of the medullary parenchyma.

This slide shows a cross-section of a cupua (*Polygonatum officinalis*) stem. The vermilion has a pronounced primary cortex. It consists of assimilation parenchyma. The conductive bundles are closed collateral. They are located throughout the entire thickness of the medullary parenchyma. Note that the medullary parenchyma has large intercellular spaces. And some cells contain druzes of calcium oxalate.

In rhizomes of monocotyledonous plants, the cortex is usually very well developed, but is represented by the storage parenchyma. Endoderm is well expressed and has Caspari's belts and (or) horseshoe-shaped thickenings as well as in the root.   The pericycle, as in all annual stems, forms a mechanical ring at the border of the central axial cylinder. Conductive bundles are of closed type. In rhizomes they can be different: incomplete, collateral, concentric. For example, in the rhizome of lily of the valley there are two types of conductive bundles: collateral and amphivasal.

In monocotyledonous plants, the primary structure is preserved throughout the life of the plant. In dicotyledons and gymnosperms, the primary structure is replaced by a secondary structure.

The secondary structure of the stem is associated with the formation and development of cambium.

The forming of cambium can occur in different ways. Depending on this, various types of stem structure are formed.

1. The cambium is immediately formed as a solid ring and formed the phloem outside and the xylem inside. As a result, an annular non-bundles structure of the stem (for example flax) is formed. If the primary structure was non-bundles then the secondary one does not differ much from it. If the structure was a with bundles, then the secondary structure will differ significantly.

On these slides you see a cross section of a flax stem. In flax, the primary structure was not bundled and the secondary tissues were laid down in the same way.

2. Cambium is laid first inward of bundles, and then gradually expands towards neighboring bundles and eventually completely closes in continued ring. As a result, a non-bundles structure of the stem is also formed. At the junction of the vascular bundles, primary pith (medullary) rays are formed, which extend to the cortex and to the pith. This type forming of cambium observed of most trees and some of herbs (apple, linden, sunflower, hemp).

Let's look at the sunflower stalk again. It has a well-defined cortex with collenchyma, assimilation parenchyma and endoderm. Above each conductive bundle is sclerenchyma of pericyclic origin. On this slide we see that over time the bundles grow and interlock into continuous layers of phloem, cambium and xylem.

3. Cambium is formed in a solid ring, but in the bundles it forms a xylem and phloem (fascicular cambium) and between the bundles (interfascicular cambium) - a pith parenchyma. As a result, the bundles structure persists throughout life of stem, but the stem may thicken (herbaceous plants: tomato, aristolochia, annual pepper).

This is the type of cambium embedding in Aristolochia. You can see well-defined cambium and conductive bundles, which are isolated from each other by rays of medullary parenchyma.

4. Cambium is formed only inward of bundles and finishes their formation. The interfascicular cambium is not formed (pumpkin, cucumber).

The structure of the stem of woody plants.

In the stems of woody dicotyledonous plants, there are:

1. Dermal tissue,
2. Secondary cortex
3. Cambium,
4. The wood,
5. The pith.

The covering (dermal) tissue of the stem of a perennial woody plant is represented by the remains of the epidermis, which is gradually replaced by the periderm. With age, the plant becomes covered with a bark that replaces the periderm.

The secondary cortex consists of the remains of the primary cortex (relatively young woody stems retain all its components: collenchyma, assimilative parenchyma and endoderm), primary and secondary phloem (or bast). In the secondary phloem (or bast) Dicotyledons usually have bast fibers. In Gymnosperms, there are no mechanical tissues in the secondary cortex usually.

Cambium is the boundary of secondary cortex and wood. In woody plants, it presents in the form of a solid ring, so the secondary xylem and phloem have an annular structure, although the primary structure of the stems of these plants could be a bundle. In the latter case, this is clearly noticeable, since the primary vascular tissues are located not in a solid ring, but in segments.

The wood consists of xylem and pith rays. The main elements of wood: vessels and tracheids, mechanical fibers (libriform), woody parenchyma, parenchyma of the pith rays.

Wood is formed by dividing cambium cells. The seasonal rhythm of the cambium is expressed in the formation of zones of wood - annual rings (annual growth). In spring, thin-walled, broad vessels and tracheids are formed. It is early wood. In summer and autumn - thick-walled narrow vessels and tracheids are formed. It is late wood. In the wood of Gymnosperms there are only tracheids, mechanical and parenchymal tissues (with the exception of the pith rays) are absent.

The pith rays remain alive for a very long time. They carry out radial transport of substances. They are divided into primary and secondary. Primary rays are formed due to the activity of the procambium, and after the formation of the cambium grow at its expense. Secondary pith rays are formed by cambium, and can be laid throughout the life of the plant. Therefore, the main difference between primary and secondary rays will be that the former penetrate all the vascular tissues of the stem along the radius (both primary and secondary phloem and xylem). The secondary pith rays passage only secondary vascular tissues. The part of the pith ray penetrating the phloem (bast) is called the bast ray, the xylem (wood) is called the wood ray.

The pith is represented by parenchymal cells. There are large, often dead cells in the center of the pith and small living cells in its peripheral part. This is the perimedular zone of the pith. With age (especially in heartwood species tree), the pith can accumulate various substances and die off**.**

Let's consider it on the example of a linden stem. Annual linden shoots are covered with epidermis. By autumn, they become lignified and the epidermis is replaced by a periderm. During the growing season, a cork cambium is laid under the epidermis, which forms a cork (phellem) externally, and phelloderm cells inside. These three tissues form the covering complex of the periderm. The cells of the epidermis gradually peel off and die within 2-3 years. The primary cortex is located under the periderm. The outer layers are represented by cells of lamellar collenchyma, followed by assimilation parenchyma and weakly expressed endoderm.

The pericycle is represented by sections of sclerenchyma protecting the phloem from the outside.

Most of the stem is made up of tissues formed by the activity of the cambium. The boundary of secondary cortex and wood runs along the cambium. All tissues lying outside of the cambium are called cortex. The cortex is primary and secondary. The secondary cortex consists of the phloem, or bast, and the pith rays. The phloem is trapezoidal in shape, and the pith rays are represented in the form of triangles, the tops of which converge to the center of the stem to the core on the transverse slices.

The pith rays penetrate through the wood. These are the primary pith rays, along which water and organic substances move in a radial direction. The pith rays are represented by parenchymal cells, inside of which spare nutrients (starch) are deposited by autumn, which are consumed in the spring for the growth of young shoots. Cambium also forms secondary pith rays, but they do not reach the core, remaining in the wood.

Layers of hard bast (bast fibers) and soft bast (live thin-walled elements) alternate in the phloem. Bast (sclerenchymal) fibers are represented by dead prosenchymal cells with thick lignified walls. Soft bast consists of sieve-tubes with companion cells (conductive tissue) and bast parenchyma, in which nutrients (carbohydrates, fatty oils, etc.) are accumulated. In spring, these substances are spent on the growth of shoots. Organic substances formed as a result of photosynthesis move along the sieve tubes. In the spring, when the bark is cut, the juice flows out. Younger sections of the bast are located closer to the cambium. The younger and wider cells of the bast are superimposed on the older peripheral narrow cells, thereby creating a trapezoidal appearance of the bast. The cambium is represented by one dense ring of thin-walled rectangular cells with a large nucleus and cytoplasm. In autumn, the cells of the cambium become thick-walled, and its activity ceases.

Towards the center of the stem, wood is formed inward from the cambium, consisting of vessels (trachea), tracheids, woody parenchyma and woody sclerenchyma (libriform). Libriform is a collection of narrow thick-walled and lignified cells of mechanical tissue. Wood is deposited in the form of annual rings (a combination of spring and autumn wood elements) wider in spring and summer and narrower in autumn, as well as in dry summers. On the transverse slice of a tree, the relative age of the tree can be determined by the number of annual rings. In spring, during the sap flow, water with dissolved mineral salts rises through the vessels of the wood.

In the central part of the stem there is a pith consisting of parenchymal cells and surrounded by small vessels of primary xylem.

Anatomical structure of stems of gymnosperms. The anatomical structure is very similar to the anatomical structure of dicotyledonous tree plants, however, there are some differences. Resin ducts are formed in the cortex part and coniferous wood (spruce, fir, pine, etc.). In cypress trees, resin accumulates in large cells of the cortex parenchyma or in the pith rays. The pine phloem consists of sieve cells and bast parenchyma; the sieve cells of the phloem are without companion cells and bast fibers. The wood of the vessels does not have and consists of only tracheids, arranged in even rows and having numerous bordered pits. Wood parenchyma and mechanical fibers, as a rule, are absent. The boundaries between of early and late wood growth are clearly expressed and the annual rings are clearly visible. Thanks to the communication of vertical and horizontal resin ducts, conifers have a single resin-separating system. The resin ducts of pine are laid out from the inside with thin-walled parenchymal cells that make up the epithelium that secretes resin into the resin duct.

Differences in the anatomical structure of woody stems of Gymnosperms and Dicotyledonous Angiosperms

Anatomical structures and tissues	**Gymnosperms Dicotyledonous Angiosperms**	**Dicotyledonous Angiosperms**
Primary cortex	It is represented by a homogeneous assimilating parenchyma, often with resin ducts.	It is represented by assimilating parenchyma, collenchyma and endoderm.
Mechanical tissue	As a rule, they are not developed. The supporting function is performed by tracheids.	Well expresed.
a) collenchyma	Absent.	There is, in woody stems, more often lamellar.
б) sklerenchyma	Absent.	Have. Fibers and sclereids. Fibers can be in phloem (bast), xylem (woody), pericycle (perivascular).
Vascular tissue	Do not contain mechanical elements.	They must contain mechanical elements.
a) phloem	Vascular elements are represented by sieve cells	Conducting elements are represented by sieve-shaped tubes with companion cells.
б) xylem	Vascular elements are represented by tracheids	Conducting elements are represented by vessels and tracheids.
Secretory cavities (their type and location in the stem)	There are resin ducts that are located in the cortex and in the wood.	Of various types, they are located in parenchymal tissues (cortex and pith), but not in wood.

Wood of forest species is usually painted in a light color. At the same time, in some species the entire mass of wood is painted in one color (alder, birch, hornbeam), in others the central part has a darker color (oak, larch, pine). The dark-colored part of the trunk is called the heartwood (duramen), and the light peripheral part is called the sapwood. The heartwood of wood consists of dead, sapwood consists of living cells. Heartwoods cells is usually contain tannins or other substances that make it dark in colour and sometimes aromatic. Heartwood is mechanically strong, resistant to decay, and less easily penetrated by wood-preservative chemicals than other types of wood.

Sapwood is the living, outermost portion of a woody stem or branch, while heartwood is the dead, inner wood, which often comprises the majority of a stem's cross-section. You can usually distinguish sapwood from heartwood by its lighter color.

But, color in wood can be very misleading; not all heartwood is dark and not all dark-colored wood is heartwood. And, the relative amounts of sapwood and heartwood in any stem can vary greatly among individuals, species, and growing conditions. So, for a more accurate – and less specious – distinction, we need a more complete understanding of what wood is and how both sapwood and heartwood form. This won't hurt.

All wood starts as sapwood. It is formed just under the bark by a thin layer of living cells known as the cambium, which produces bark cells to the outside and wood cells to the inside. Tree stems increase in girth during each year of growth because a new layer of wood cells is added inside the cambium. In good growing years, this new layer of wood can be many cells thick, and in poor years, it is relatively thin. Regardless of thickness, when any such growth occurs, the cambium moves outward to accommodate the new layers of wood forming inside. Sapwood – this newly formed, outermost region of wood – contains a variety of cell types, most of which are living and physiologically active. This sapwood is where water and dissolved minerals are transported between the roots and the crown of the tree and, to a lesser extent, where energy reserves are stored.

In young trees and young parts of older trees, all of the wood in the stem is sapwood. But as the tree gets older and its trunk increases in diameter, things change. No longer is the entire cross-section of the trunk needed for conducting sap. This, combined with an increased need for structural support, causes significant changes in the wood. The cells nearest the center of the trunk die, but they remain mostly intact. As these older sapwood cells age and die, they become heartwood. That is, they are altered to accommodate a shift in function. As residues of the once-living cells and additional chemical compounds from elsewhere in the plant accumulate in the heartwood, those cells cease to transport water or store energy reserves.

These compounds (including resins, phenols, and terpenes, sometimes referred to as extractives) not only help make heartwood more resistant to attack by insects and decay organisms but also tend to give this inner portion of the stem a distinctive darker color. For example, the famous dark brown of black walnut lumber and the striking red hues of black cherry boards occur only in the heartwoods of these trees, and both owe their characteristic colors to these chemicals.

Such woods are highly prized largely because of their colored heartwoods, but it is important to remember that color alone is not the sole distinction between sapwood and heartwood, regardless of species. Indeed, wood can be colored for reasons unrelated to heartwood. There are many discolorations associated with injury or fungal infection of wood, for example, and some heartwoods – including that in most spruces, fir, cottonwood, and basswood – are naturally very light colored. Then again, if these light-colored heartwoods are injured, they often do become darkened by discoloration. So, in summary, sapwood, which is nearly always light colored, results from new wood formation. Heartwood, which is often – but not always – dark colored, results from the natural aging process of the tree. But both can be discolored by many other causes.

Typically, there is less sapwood than heartwood in any given stem. The exception, of course, is in young trees and the youngest portions of stems and branches on older trees which – because they are young – are naturally dominated by sapwood. The proportion of heartwood to sapwood in the main stem does vary with species. Black locust, for example, usually has a very narrow band – often less than an inch – of functioning sapwood, whereas maple stems often can have many inches of sapwood and relatively narrow cores of heartwood. In general, more vigorously growing trees tend to have wider bands of sapwood.

This sapwood-heartwood distinction has important implications for woodworkers beyond the obvious implications of color. Because sapwood contains the sap-conducting cells of the tree, it tends to have a relatively high moisture content. This is good for the living tree but it is not so good for the woodworker, because sapwood tends to shrink and move considerably when dried, and it is much more susceptible to decay and staining by fungi.

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