ANATOMY AND TYPES OF TREES

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The study of **anatomy** is a study of the structure of an organism. This includes the arrangement and relationships of individual organs to each of the other organs. **Physiology** is the branch of biology that deals with the life functions and processes of living organisms. Studied together, the sciences of anatomy and physiology deal with the relationships between the parts of a tree and the biological processes that nourish it and allow it to grow and reproduce itself.

OBJECTIVES

After completing this chapter, you should be able to

- distinguish between the anatomy and the physiology of a tree
- name the basic structures of a plant cell
- describe different tissue systems of a tree
- identify the external parts of a tree leaf
- explain the importance of xylem tissue in a tree
- compare the methods of seed production between angiosperms and gymnosperms
- describe the importance of meristem tissue as it relates to growth of trees
- illustrate the basic structure of a tree root
- name the basic parts of a flower
- list and describe the most common tree groups found in North America

TERMS FOR UNDERSTANDING

anatomy	epidermis	petal	secondary tissue
angiosperm	filament	petiole	semipermeable
annual ring	gene	phloem	sepal
anther	gymnosperm	physiology	sieve element
apical meristem	heartwood	pinnately compound	sieve tube
bipinnately compound	lobed simple leaf	pistil	spines
blade	margin	pith	stamen
cambium	meristem	primary growth	stigma
cell	midrib	primary tissue	style
cell membrane	needle-leaf	protoplasm	tissue
cell wall	nucleoplasm	receptacle	tracheid
chloroplast	nucleus	reproductive organ	vacuole
collenchyma	organ	resin	vascular cambium
cork	ovary	root cap	vascular cylinder
cork cambium	ovule	root hair	vascular ray
cortex	palmately compound	sapwood	vegetative organ
cuticle	parenchyma	scale-leaf	vein
cytoplasm	pericycle	sclerenchyma	vessel
endodermis	permeable	secondary growth	vessel element
			xylem

PLANT STRUCTURES

The most basic unit of life is the cell. Each living cell contains specialized structures used to perform life sustaining functions. The **cell wall** is a rigid outer covering of the cell that contains high amounts of fiber. The cell wall makes it possible for plants to maintain their shapes. A **cell membrane** is found inside the cell wall. It is permeable, meaning that body and plant fluids can pass through it to deliver nutrients and to remove waste materials.

Each cell has an oval-shaped **nucleus**. This structure contains the hereditary material through which a living organism passes its traits to its offspring. The chromosome is a structure found within the nucleus. It is a long strand of material on which many smaller structures called **genes** are located. Chromosomes are found in pairs, and each male and female parent furnishes one of the chromosomes of each pair that is present in the offspring. The genes contain the information that determines the characteristics an organism inherits from the parents.

Protoplasm is made up of all of the structures and substances located within the cell. It consists of a thick liquid composed of salts, water, proteins, fats and carbohydrates. Two kinds of protoplasm are found in cells. **Cytoplasm** includes all the cell contents except for the nucleus. The other kind of protoplasm includes the material found in the nucleus of a cell. This material is called **nucleoplasm**. The **vacuole** is a round structure that collects excess water and wastes within the cell and discharges them through the cell wall. The **chloroplast** is a cell structure that contains materials capable of capturing energy from the sun as the plant produces sugars and starches.

Plant Tissue Systems

Groups of plant cells that contribute to a single function are called plant **tissues**. The **anatomy** of a tree is very much like the anatomy of other seed plants. Plant tissue systems perform a number of specialized functions in a tree. The different types of plant tissue systems are the ground tissue system, the vascular tissue system, and the dermal tissue system. They strengthen the stem or trunk, they provide structures through which water and nutrients can flow within the tree, and they protect the internal tissues and prevent water loss from the plant.

The ground tissue system consists of the following kinds of specialized cells: parenchyma, collenchyma and sclerenchyma. **Parenchyma** cells are thin-walled living cells loosely packed together to form spongy tissues with air spaces interspersed between the cells. These cells make up much of the material in plant leaves, roots, stems and fruits. They perform functions in photosynthesis and other plant processes.

ANATOMY OF A TREE

External Leaf Structure

The external parts of a leaf include several specialized structures organized into two main parts, the blade and the petiole. The petiole or leaf stalk is the point of attachment to the tree. The **petiole** consists of vascular tissues for transporting water, minerals and nutrients to the leaf cells. They also transport sugars from the leaf cells to the stem and roots of the plant. In addition to vascular tissues, the petiole contains collenchyma cells that strengthen the leaf stalk. The flat part of the leaf is usually green or red in color. This part of the leaf is the **blade**. The remaining leaf structures are found within the blade. The **midrib** is composed of the same materials as the petiole. It gives shape to the leaf and distributes dissolved nutrients within the leaf. The **spines** of a leaf function in the same manner as the midrib. Leaf **veins** connect to the vascular tissues in the leaf spines, and they distribute materials to and from the cells of a leaf. The leaf **margin** differs greatly among tree species. It is useful for tree identification purposes.

The **collenchyma** cells have extra thick cell walls that add strength to plant stems and stalks. Another kind of plant cells called sclerenchyma cells strengthen tissue by adding fibers. Examples of material added to plant tissues by these cells include the long, stringy material found in the bark of some kinds of trees. These cells also provide the hard material for the shells of nuts.

The vascular tissue system is responsible for movement of nutrients and plant food between locations in the plant. This is accomplished by the **xylem**, a water-conducting woody tissue through which dissolved nutrients are carried from the roots to stems and leaves. Specialized plant cells called tracheids and vessel elements become important components of xylem after they have died and become hollow. **Tracheids** are long tapered cells that have pits in their cell walls through which water is able to flow from one cell to another. Many tracheids growing side by side in the stem of a plant create passages through which water and dissolved nutrients can move to other locations in the plant.

A **vessel element** functions in a similar manner to a tracheid cell. After it has died, it becomes a hollow tube through which dissolved nutrients can pass. Several vessel elements that have grown together end-to-end form long tubes inside stems, roots and leaves. These are called **vessels**, and they are capable of conducting large volumes of plant fluids. They function much more efficiently than tracheids.

Plant food consisting of sugars manufactured in the leaves is carried to stems and roots through a vascular tissue called **phloem**. This is a specialized tissue consisting mostly of **sieve elements** that join together to form long **sieve tubes**. These structures are located in the bark and outer protective coverings of stems and roots. Sugar solutions flow both directions in the phloem from areas of high concentration to areas of low concentration.

Trees that bear seeds in cones as the conifers do are called **gymnosperms**. Some of the most common trees classed as gymnosperms include the pines, spruces, and cedars. Trees that produce seeds inside an ovary or fruit are called **angiosperms**. All the flowering trees fall into this class. The vascular tissue in the xylem of gymnosperms, such as the pines, spruces and cedars, contains only tracheid cells. Movement of dissolved plant materials is quite slow in conifers. Vascular tissue in angiosperms contains both tracheid cells and vessel elements making it possible for plant materials to be transported rapidly within these trees.

The dermal tissue system in plants performs some important functions. One of these is protection of the soft material found inside plant cells from losing the plant fluids. Another function is to keep harmful microorganisms out of the cells. The leaves, stems, flowers, seeds and roots of plants are protected by an outer layer of cells known as the **epidermis** and a covering of waxy material called the **cuticle**. Woody stems and roots are covered with a different kind of cells. A layer of these cells containing waxy material in their cell walls is deposited over the surfaces of root and stem tissues. These cells mature and die, and the material that remains is called **cork**. This cork covering prevents water loss from the plants. Some plant structures such as leaves and roots consist of several plant tissues that function in a coordinated manner.

Another group of specialized plant tissues are the **meristems**. A meristem is a rapidly dividing mass of cells that causes plants to grow. When it is located on the ends of branches, twigs or roots, it is known as an **apical meristem**. When these cells divide, roots and twigs grow longer, and trees get taller. Meristem tissue is also located between the phloem and xylem layers of roots and stems. In this location it is part of a layer of cells known as the **cambium** layer.

When a cell in the cambium layer divides, one cell remains as a cambial cell until it divides again. The other cell becomes part of either the xylem or the phloem tissue. Each cell division in the cambium layer increases the diameter of the stem or root. This accounts for the increased thickness that occurs each growing season in the trunk of a live tree. Each growing season deposits a new layer of xylem in the woody portion of a tree trunk or stem. Each new layer is distinct from the one before, and we call it an **annual ring**. This difference occurs because the vessels that form in the spring season are larger and the tracheids have thinner walls than those formed during the dryer summer season. When water is less plentiful to the plant, the cell walls of the tracheids become thicker, and the vessels that form are smaller.

The cambium also forms rows of parenchyma cells that radiate to the center of the stem. They become the **vascular rays**, and transport dissolved materials across the woody section of a stem between the phloem and the **pith** that is located at the center of the stem. The pith consists of parenchyma cells that have the primary function of storing plant food. As a plant matures, the pith is surrounded by xylem. When a tree matures, the xylem of the tree becomes old, and it begins to fill with such materials as tannins, gums and resins. When this happens, it becomes darker in color, and it no longer conducts water. This wood is now known as **heartwood**. Once the heartwood has formed, the pith can no longer function. The lighter colored wood through which water still moves is called **sapwood**. In a very old tree, the heartwood tends to rot away causing the tree to become hollow. It can continue to live, however, as long as enough sapwood remains to transport plant nutrients.

An **organ** is a group of several tissues that function together as a single unit. Roots, stems and leaves are the **vegetative**

organs of a plant, and the flowers are the **reproductive organs**.

The Root Tip

Plant roots are specialized organs that anchor the trees in the soil and transport water and plant nutrients into the plant from the soil. There are several different types of roots, but the anatomy of each type is similar. A growing root contains meristem tissue located near its tip. As it divides, some of the cells develop toward the root tip. These cells will become the **root cap**, consisting of a group of specialized cells that deposit slimy material in the soil to help the root pass through as it grows. The cells of the root cap protect the tender root tissue. As the root grows in length, the cells of the root cap wear off. They are continually being replaced by new cells.

As meristem cells divide, some of the new cells become phloem, but most develop into xylem. This part of the root is called the region of cell division. The portion of the root in which the new cells are deposited is known as the region of elongation. These cells double or triple in length and become a little wider during this period of development. This elongation of root cells accounts for the lengthwise growth of the root, and we call it **primary growth**.

When root cells have stopped growing, they mature. During this period they develop or differentiate into specialized tissues such as root hairs or cortex. This part of the young root is called the region of maturation. The first specialized root tissues of a new plant that form in the area of maturation are the epidermis, cortex and vascular cylinder. These three tissues compose the primary tissue of the root.

The phloem area in the root merges with the phloem region in the stem, and it performs the same functions in both locations. This tissue is deposited throughout the length of the root and the stem to facilitate the flow of plant nutrients. Plant nutrients are transported through the phloem tissue to nourish the cells of the stem and roots. In the same manner, the xylem located in the plant root merges with the xylem tissue in the stem to facilitate the flow of minerals, nutrients and dissolved gases from the roots to the cells of the leaves and stems. Xylem and phloem are located in the **vascular cylinder** in the innermost part of the root.

The anatomy of a root is very similar in many ways to that of a stem. The outer layer of cells is called the epidermis. This tissue protects the root and absorbs water and dissolved plant nutrients. Epidermal cells develop long, thin, thread-like projections called **root hairs** that extend out into the soil. Root hairs increase the amount of surface area of the root and make it possible for the root to absorb large amounts of water and minerals. Root hairs only live for a short time before they die and are replaced by new root hairs. The cells of the epidermis and the root cap also slough off the root, and they are replaced with new cells.

Young roots contain a large amount of tissue called **cortex**. This tissue is composed of parenchyma cells that are organized in a loose arrangement in the interior of the root. Plant foods such as sugars and starches are stored in the parenchyma cells of the cortex. Water and dissolved materials move easily through this area until they get to the inner boundary of the cortex. Movement of fluids is stopped there by the endodermis. The **endodermis** is a single layer of cells that are surrounded by a waxy waterproof material. The wax prevents water from flowing through the spaces between cells. The membranes of the endodermal cells are **semipermeable** allowing only certain materials to pass through. In this way, plant roots have some control over the kinds of materials that enter plants.

Just inside the row of cells that form the endodermis is another row of parenchyma cells called the **pericycle**. The pericycle is the outer layer of the vascular cylinder. Lateral roots develop from the pericycle, growing out through the cortex and epidermis of the primary root. It becomes an extension of the tissue of the primary root increasing, the ability of the root system to absorb water and nutrients from the surrounding soil.

Once the primary tissues of the root have formed (epidermis, cortex and vascular cylinder), all of the root tissues produced are called **secondary tissues**. All of the secondary tissues develop from the meristem tissue or vascular **cambium** that forms in a continuous ring between the xylem and phloem layers of the vascular cylinder. Secondary xylem and secondary phloem are formed from the vascular cambium. They add to the thickness of the root causing pressure to develop between the epidermis tissue and the soil in which the root is growing.

As a root grows larger, the epidermis sloughs off, and it is replaced by cork. This material is waterproof. It does not absorb materials from the soil, but the root continues to perform all other root functions. Cork tissue is produced from meristem tissue called **cork-cambium**. Growth in the diameter of a root is **secondary growth**.

Reproduction occurs in trees in much the same manner as it does in other plants. Seeds are produced from flowers which are specialized organs.

The Flower

The female flower parts include the stigma, style and ovary. These three parts constitute the **pistil** of the flower. The **stigma** is an organ located on the female structure of a flower where it functions as a pollen receptor.

The **ovary** is the flower part that produces the egg cell. A small chamber inside the ovary known as the **ovule** is the site where the seed eventually forms. The **style** is the structure that connects the stigma to the ovary.

The male flower parts consist of the **anther** and the filament. These two parts together compose the **stamen** of the flower. The **anther** is the organ in which pollen grains develop and mature. It is supported and connected to the **receptacle** or base of the flower, by the **filament**. Several anthers are usually present in a flower, and each anther contains four pollen sacs in which pollen grains develop. Other flower parts are the brightly colored **petals** whose color attracts pollinators, and the leaf-like **sepals** that close over the flower to protect it.

TREE GROUPS

As you study the different kinds of trees, it is often convenient to organize them into groups that have similar characteristics. Many different groupings are possible, and a particular species of trees may move from one group to another depending on the characteristics that are used.

For convenience in identification, the trees of North America are grouped according to their leaf structure. This system is used by the National Audubon Society in their field guides to North American trees.

Needle-leaf Conifers

Conifers have leaves of two basic types, although there are many distinctly different leaf arrangements. The **needle-leaf** is unique in that the leaves are narrow in width, and quite long in length. These leaves are called needles, and each leaf tends to resemble a sewing needle in its proportion of length to width.

The leaf length differs greatly among tree species and even on an individual tree. The Black Spruce, for example, has needles that are as short as 1/4-5/8", and the Longleaf Pine has needles up to 15" long. Some trees, such as the redwoods, have needles that extend along the smaller branches as well as on the tips. In contrast, the needles of the larch trees are grouped, and single needles are not evident along the stem.

Needle shape is another distinguishing feature in tree identification. Seen in cross-section, some needles are relatively flat; others are 3-angled or 4-angled. Some needles have rounded points while others are sharp or blunt. Some needles are flexible and others are stiff; some are thick and others are slender; some are wide and others are narrow. Some needles emerge from the stem in bundles; others are single.

Needle-leaf conifers include the Douglas-firs, firs, hemlocks, larches, pines, Redwood/ Cryptomeria, spruces and true cedars.

Scale-leaf Conifers

Three kinds of trees are included in the **scale-leaf** Conifer group: the cedars, cypresses, and junipers. In each instance, the leaves are shaped like tiny overlapping scales. From a distance, these leaves appear to be quite dry, but under magnification they appear to be quite succulent. Leaves that make up the new growth of a tree frequently ooze small amounts of resin or sticky sap on the leaf surfaces.

The cedars, junipers and some cypresses are evergreen trees that grow well in environments where water is so scarce that most other trees cannot survive. The small scale-leaf surfaces are generally smooth and shiny like the surface of a cactus plant. This characteristic is an indicator that this kind of leaf structure is capable of conserving water.

Untoothed Simple Leaves

A simple leaf is one that has only one set of leaf parts. It has a single blade and only one petiole. An untoothed leaf has a smooth leaf margin. Several North American trees display untoothed simple leaves. Among them are the catalpas, dogwoods, eucalyptus, magnolias, oaks, redbuds, sumacs and willows.

Toothed Simple Leaves

Many broadleaf trees have simple leaves with teeth on the edges. The leaf margin may have teeth that are uniform and point forward. These leaves are described as saw-toothed. Doubly saw-toothed leaves have alternating large and small teeth. Many variations occur among the toothed simple leaves, but all have some kind of serrated leaf margins. Trees in this group include alders, birches, cercocarpuses, cherries, cottonwoods (also aspens and poplars), crabapples (also apples), elms, hawthorns, hophornbeams, mulberries, oaks and willows.

Lobed Simple Leaves

The leaves of many broadleaf trees have the appearance of rounded divisions along the margins of their leaves. Some of them appear to be shallow; others are deeply cut. Some leaf lobes are quite broad; others are narrow. Despite these differences, each of these is known as a **lobed simple leaf**. Among the species of trees having lobed simple leaves are cliffrose, California fremontia, ginkgo, hawthorns, maples, mulberries, oaks, poplar, sassafras, sweetgums, sycamores and yellow-poplar.

Compound Leaves

A compound leaf consists of three or more small leaflets which may be arranged on the leafstalk in a number of different configurations. Leaflets arranged along a central leafstalk are considered to be pinnately compound. Trees having leaves of this type include ashes, elders, hickories, locusts, pecans, sumacs and walnuts. Leaflets attached to sidebranches arranged along a central leafstalk are **bipinnately compound**. This group of trees includes acacias, Kentucky Coffeetree, mesquites and paloverdes. When the attachment of the leaflets is at the end of leafstock, the leaf is **palmately compound**. These trees include the buckeyes, Common Hoptree and the American Bladdernut.

LOOKING BACK

Anatomy is the study of an organism's structure, and physiology is the study of its life functions and processes. In the study of forestry, these two sciences deal with relationships between the parts of the tree and the biological processes that nourish it and allow it to grow and reproduce. Plants are organized with cells being the most basic structures, followed by tissues, tissue systems, organs, and the complete organism. Examples of tissues are epidermis, cortex and vascular bundles. Tissue systems in plants include the ground, vascular and dermal tissue systems. Organs include structures such as roots, stems, and leaves. Tree groupings based on leaf structure include needle-leaf conifers, scale-leaf conifers, toothed simple leaves, lobed simple leaves and compound leaves.

QUESTIONS FOR DISCUSSION AND REVIEW

Essay Questions

1. What is the difference between the anatomy and the physiology of a tree?
2. What are the basic structures of a plant cell?
3. Describe the different tissue systems of a tree.
4. What are the external structures of a leaf and what are their purposes?
5. How is xylem tissue adapted to its function of transporting dissolved materials within a tree?
6. In what ways is seed production different in angiosperms than in gymnosperms?
7. What role does meristem tissue play in the growth of a tree?
8. What are the basic structures of a tree root?
9. Name and describe the basic functions of the parts of male and female flowers.
10. What are the names and distinguishing characteristics of the tree groups found in North America?

Multiple Choice Questions

1. A study of the structure of an organism is called:
   a. physiology
   b. permeability
   c. anatomy
   d. taxonomy

2. A permeable structure found in plant cells that restricts the kind of materials that can enter a cell is the
   a. cell membrane
   b. nucleoplasm
   c. vacuole
   d. cell wall

3. Which of the following is not one of the basic tissue systems of a plant?
   a. vascular tissue
   b. nucleoplasm
   c. ground tissue
   d. dermal tissue

4. A plant cell that has thick cell walls that add strength to plant stalks and stems is called:
   a. parenchyma
   b. nucleoplasm
   c. collenchyma
   d. sclerenchyma

5. The petiole is a plant structure found in a:
   a. flower
   b. leaf
   c. stem
   d. root

6. Phloem is a conductive tissue that includes which of the following types of structures?
   a. sieve tube
   b. tracheid
   c. vessel element
   d. sclerenchyma

7. A plant root tissue that stores starches is:
   a. cortex
   b. cambium
   c. endodermis
   d. epidermis

8. A plant structure that transports dissolved materials across the woody section of a stem is called:
   a. apical meristem
   b. pith
   c. sieve tube
   d. vascular ray

9. A male flower part in which pollen grains develop and mature is the:
   a. filament
   b. anther
   c. stigma
   d. sepal

10. A female flower part in which the seed forms is the:
    a. ovule
    b. stamen
    c. receptacle
    d. style

LEARNING ACTIVITIES

1. Examine the scale-leaf structure of a juniper, cedar or cypress tree (ornamental shrub). Assign the students to draw what they see. Speculate with the class about how this leaf structure is able to conserve water. Name some other life forms found in desert environments that have scales, and consider whether they function in a similar way.

2. Obtain the flowers of several different types of woody plants and examine them under magnification. Sketch the flowers and identify the male and female structures of each. Assign a class member to describe the role of each of these structures.