The Tree stands in triumph with its roots deep in the Earth, its branches touching the Sky, its leaves capturing the Sun and breathing the breath of life for animals and Man—the keystone of our natural environment and the symbol of man's life and consciousness.

—Marion T. Hall, The Morton Arboretum

CHAPTER ONE TREE BASICS

What do you think of when you hear the word *tree?*

Did you think of a sprawling oak or a newly planted ash that grew outside your grade-school classroom? Maybe your image is one of pines towering above your head on a needle-padded hike, or of fresh green aspen lining the shore of a northern lake, or a glowing maple whose changing colors mark the coming of frost and football. Your thoughts might even turn to trees transformed—to the chair in which you sit, the crisp apples of autumn, the floor beneath your feet, the paper on which these words rest.

Whatever specific images come to your own mind, one point is common to all Minnesotans: the trees of our state hold a treasured place in our memories, in the moments we are living today, and in our futures. Rooted to the ground, they provide a sense of beauty and timelessness. Sensibly harvested, they provide a natural, renewable source of goods for everyday living. Managed with wisdom and a sense of stewardship, trees are the ultimate gifts that keep on giving.

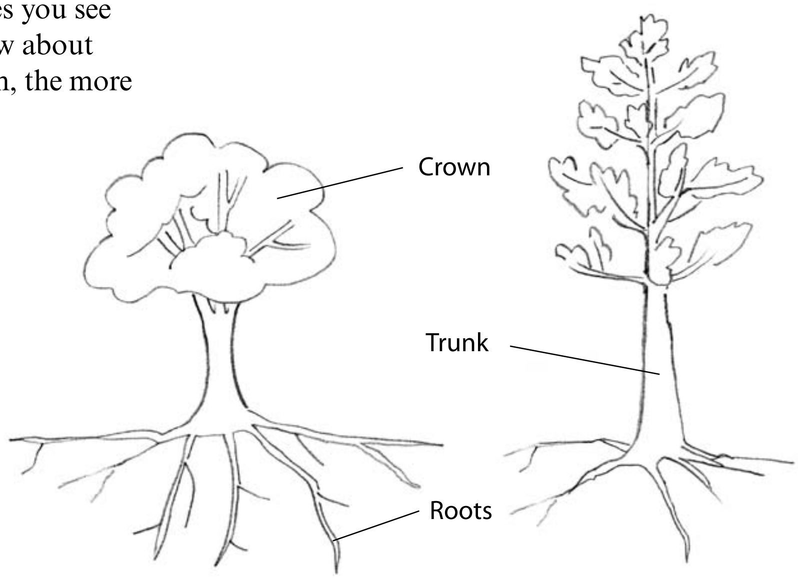
The more you learn to appreciate the trees you see around you, the more you'll want to know about them. And the more you know about them, the more you'll appreciate them!

Anatomy of a Tree

Trees are defined as woody plants that can reach a height of 15 feet (4.6 meters) or more at maturity, are usually single stemmed, and have a branched-out area at the top. This distinguishes trees from shrubs, which are woody but short and multistemmed, and from vines, which may be long and woody, but cannot support themselves and lack a branching top.

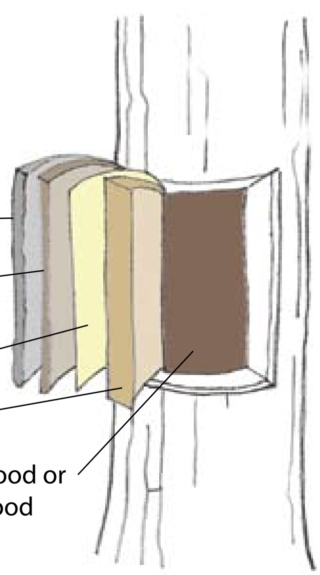
Trees have three major parts: crown, trunk, and roots.

The ***crown*** consists of branches and leaves. Cells in the leaves convert sunlight, water, and carbon dioxide into sugar ***(glucose)*** in a process called ***photosynthesis***. Trees use the glucose to make wood, leaves, seeds, and other plant parts. Trees with large crowns have more leaves and generally grow faster than trees with small crowns. In some trees, such as box elders, cells in the twigs and branches also photosynthesize. These twigs usually appear greenish. The tree's crown also is home to flowers, fruits, and seeds, all of which play a part in reproduction.



Three types of cells make up the ***trunk.*** In turn, the trunk is made up of several layers, each with a specific function.

1. ***Xylem*** cells make up the bulk of the trunk and the annual rings. Xylem cells move water and nutrients between the roots and the leaves.
   - ***Inner wood*** or ***Heartwood*** consists of dead xylem cells and leftover darker chemical compounds that are the products of decomposition. It is found in the center of a tree. It functions to provide strength and support as the tree grows.
   - ***Sapwood*** consists of layers of living xylem cells. As these cells age and die, they become inner wood.
2. ***Cambium*** cells reside in a very thin layer between the xylem and phloem. Each year, cambium makes a new layer of xylem cells inward and a thin layer of phloem cells outward. The cambium layer is only a few cells thick and can only be seen with a microscope.
3. ***Phloem*** cells move sugar and other substances between the leaves and the roots.
   - ***Inner bark*** is made of live phloem cells and is rich with nutrients. Inner bark stays alive and active for only one year, and then becomes outer bark.
   - ***Outer bark*** is made up of dead phloem cells. It protects the tree.



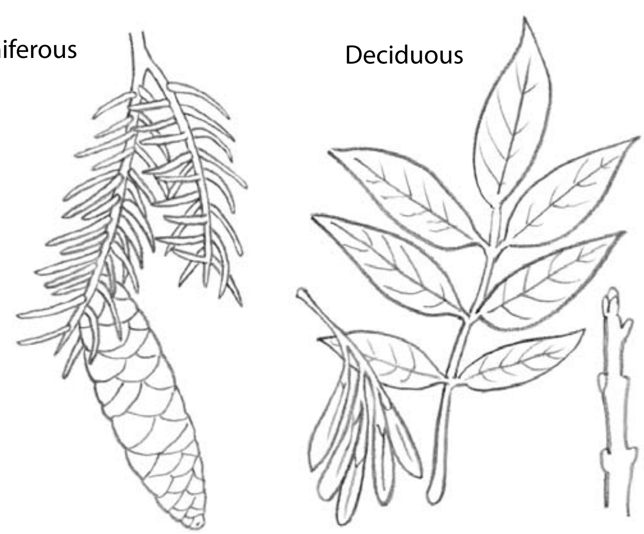
The ***roots*** anchor a tree in the soil. Roots also take up water and nutrients, such as phosphorus and nitrogen, which a tree needs to grow. In some species, such as aspen, roots play a part in making new trees. Shapes and locations of tree roots vary by species and growing conditions. Roots may be thinner than a human hair or as big around as a telephone pole. Some trees, such as some oaks, have a large ***taproot*** that extends straight down from the trunk, from which smaller roots extend. In other species, roots fan out broadly and stay closer to the surface of the soil. Aspen roots, for instance, may stretch 60 feet (18 meters) or more from the base of the tree. Roots may take up four to seven times the amount of space covered by the crown of the tree. Ninety-nine percent of the roots of most trees are in the top three feet (0.9 meters) of the soil.

Two Types of Trees

Trees are often divided into two groups: ***coniferous*** and ***deciduous***.

Coniferous trees ***(conifers)*** protect their seeds in cones and do not produce fruit. Coniferous trees have needlelike or scaly leaves that are shed as the leaves age and not all at once. Because most coniferous trees retain some green leaves all year, they are also known as "evergreens." Conifers may also be referred to as needleleaf trees, or softwoods.

Deciduous trees shed their leaves each fall and grow new leaves each spring from buds created in the previous year's growing season. Their seeds are covered and come in several forms, such as winged maple seeds, nuts, and berries. Deciduous trees are also called ***broadleaf*** trees, or hardwoods.



Trees Through the Seasons

Spring, summer, fall, winter … each season provides trees with unique challenges and opportunities.

Spring

As the air warms in spring, sap rises from the roots, carrying nourishment to the branches. Coniferous trees develop new shoots that expand to form new stems and needles. On deciduous trees, buds swell and open into new shoots and leaves. Conifer buds also swell and flush out in the spring.

Although trees grow throughout their lives, spring is an especially rich time for fast growth.

Growing Tall

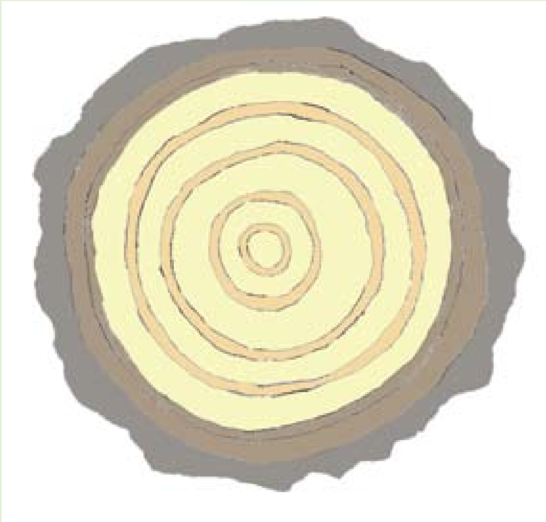
In spring, new tissue is added at ends of twigs. Leaves form as buds open and grow. Trees grow taller from the ends of their twigs, not from their trunks. If you were to drive a nail into a sapling and come back in 30 years, the nail would still be the same distance from the ground and probably completely embedded into the tree!

Growing Fat

Each year, trunks and branches grow wider and thicker. If you look at a cross section of trunk, you can see a history of the tree's growth through its annual rings. Rapid growth during springtime creates many xylem cells, which make a light-colored wood known as ***spring wood.*** As tree growth slows during the hot, dry summer, fewer new xylem cells are laid more slowly and produce a darker circle of wood. This is often called ***summer wood.*** One layer of light-colored spring wood along with one layer of darker summer wood marks the passage of a year in the tree's life.

Growing Underground

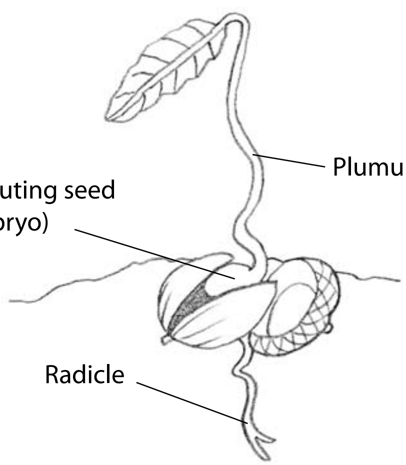
Finally, each year roots grow deeper and broader beneath the earth as root tips grow and branch.



The light rings show wood that grew in the spring, and the dark rings show wood that grew in the summer. Examining tree rings can tell a story of how that tree grew over its lifetime, recording years of vigorous or weak growth, damage from fire or insects, or competition from other trees. Appendix 3 contains drawings of common tree stories told by the trees themselves.

Summer

Many trees ***germinate*** in the summer. Sunlight and moisture send the seed signals to begin to sprout. Water softens the seed shell (coat) and expands the food, called ***endosperm,*** inside. The new plant, or ***embryo,*** uses energy from the endosperm to push a stem ***(plumule)*** up toward the sunlight and to push a root ***(radicle)*** down into the soil.



Sugar From Sunshine

Trees use a process called ***photosynthesis*** to manufacture a type of sugar called ***glucose*** from the sun. ***Chlorophyll*** and other pigments in the leaf transform carbon dioxide (CO_2) and water (H_2O) into oxygen (O_2) and sugar ($C_6H_{12}O_6$):

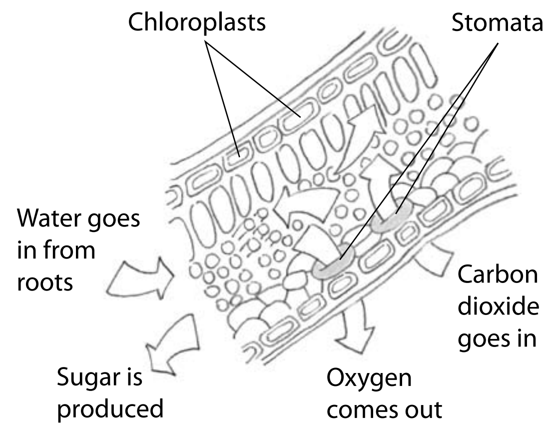
$6CO_2 + 12H_2O$ through the process of sunlight/chlorophyll turn into $6O_2 + C_6H_{12}O_6 + 6H_2O$.

Chlorophyll and other pigments absorb energy from the sun. They are found in green, microscopic structures called ***chloroplasts,*** which are within cells.

The tree takes in carbon dioxide through small holes in its leaves called stomata (singular: ***stoma)***.

Using the energy from the sun, trees combine carbon dioxide with water, drawn up from the roots, to make sugar and oxygen. The tree uses sugar to grow. It releases oxygen, a byproduct, to the air.

Cross section of a leaf

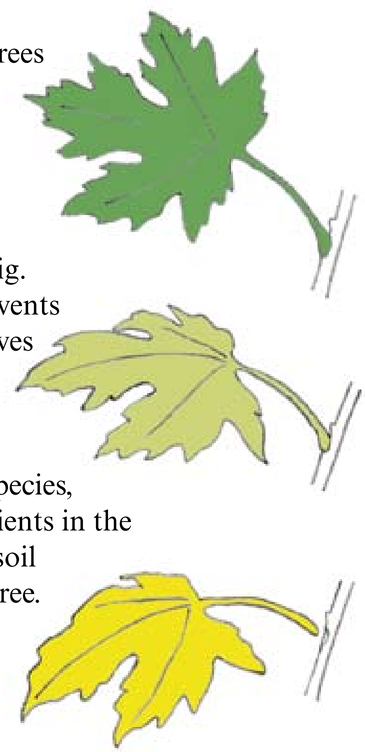


All of Earth's oxygen is produced by photosynthesis.

Fall

The cool nights and shorter days of autumn signal deciduous trees to shut down the process of photosynthesis. When photosynthesis stops, the green chlorophyll pigments become less vibrant. Then, yellow, orange, and brown pigments called ***carotenoids*** that were hidden by summer's green chlorophyll begin to show. Red, purple, and crimson ***anthocyanin*** pigments also appear. The leaves of most coniferous trees stay green, because their hard, waxy needles prevent them from drying out and the chlorophyll within can continue to photosynthesize all winter long. However, less sugar is created in the winter because of shorter periods of and less intense sunlight due to the lower angle of the sun.

Carotenoids give color to carrots, corn, canaries, daffodils, egg yolks, rutabagas, buttercups, and bananas, as well as tree leaves.



Also in fall, deciduous trees produce a hormone called ***abscisic acid,*** which forms a corky membrane called an ***abscission layer*** between the leaf and twig. The abscission layer prevents sugars created in the leaves from entering the woody parts of the tree. The leaf then separates from the tree. In some species, much of the stored nutrients in the leaf are dropped to the soil around the base of the tree. In other species, leaves move nutrients from the leaf into the stem before abscission.

Ever notice how some dried oak leaves seem to persist on twigs through the winter? That's because in oak leaves, the abscission layer fails to form all the way through the leaf stem in the fall. Instead, oaks undergo a second phase of leaf drop (abscission) in the spring just before bud-break. No one knows why oak trees keep tight hold of dead leaves through winter, but it's an interesting observation.

Weather and Fall Colors

Fall colors are related to temperature and moisture conditions before and during the time when chlorophyll in the leaves dwindles away. Sunny, warm days cause leaves to produce a lot of sugar, and cool evenings prevent the sugars from moving into the trunk and roots. As a result, a succession of warm, sunny days and cool, but not freezing, nights seems to contribute to a good fall color season. These kinds of fall days produce the most anthocyanin pigments—red, purple, and crimson. Carotenoids are always present in leaves, so yellow and gold colors are fairly constant each year.

Late springs and severe summer droughts can delay the onset of fall color by a few weeks. A warm, wet spring, followed by a summer of adequate moisture, then warm fall days with cool nights, seems to bring on the best colors.

Leaves to Life
The health of a forest depends on the nutrients that come from the leaves and needles that fall to the forest floor. The leaves decay to create ***humus,*** a spongy, nutrient-rich material. Humus (similar to ***duff***) becomes an important part of the soil that holds in moisture and provides food for living things, such as microorganisms, herbs, grasses, ferns, shrubs, trees, and insects.

Fall is also the time when the living tissues in the tree's trunk and branches begin a process called ***hardening,*** a gradual acclimatization to cold conditions, which prepares them for winter. Triggered by cooler and shorter days, hardening enables a tree to survive cold weather. If a tree were suddenly exposed to winter temperatures in July, it would be injured or die. But after it's gone through hardening, a tree can survive temperatures far below freezing.

Winter

In the winter, trees continue to harden. To understand hardening, it helps to know what frostbite is. Whether in people or in pines, it is the damage caused when the liquid within individual living cells freezes. As the liquid freezes, it expands, destroying the cells in the same way freezing soda will demolish the bottle or can it's sealed in.

Trees avoid frostbite in two ways. One is called ***supercooling.*** Some trees count on supercooling to survive, which relies on the fact that liquids can form crystals if they have a starting place, called a nucleus, for crystals to grow. If there is no nucleus, the liquid inside tree cells will continue to cool below its normal freezing point but will not actually turn into a solid—at least down to about –40°F (–40°C). Some trees, such as red oaks, keep their cellular liquids free of crystal-forming nuclei and so are able to survive to these low temperatures without tissue damage.

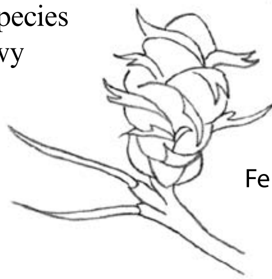
In some places, it gets colder than –40°F (–40°C). Trees that live in these conditions are able to use a technique called ***extracellular freezing.*** Here, liquids within cells seep out into the spaces between the cells, where they can freeze without harming plant tissue. This is why trees like black spruce, balsam fir, and quaking aspen can survive in temperatures as low as –100°F (–73°C)!

How Trees Reproduce

Trees reproduce in a variety of ways. Most deciduous trees form flowers in spring. In ***monoecious*** species like maples and birches, each flower has both male and female parts or, separate male and female flowers appear on the same tree. ***Dioecious*** trees like aspens develop male and female flowers on separate trees. Coniferous trees do not produce true flowers but have male and female cones that are sometimes called flowers. Male cones fall off after they release their pollen; female cones persist to develop seeds. Depending on the species, the male and female cones may be on the same (monecious) or on different (dioecious) trees.

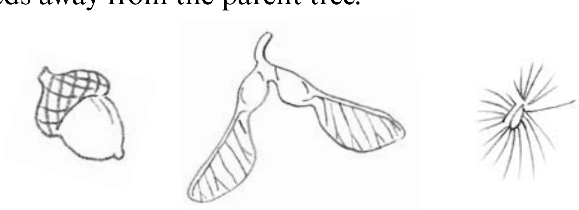
Male

For seeds to form, pollen from the male cones, ***catkins,*** or ***staminate*** flowers must come into contact with the female cones or ***pistillate*** flowers that contain tiny egg-like ***ovules.*** In many species, pollen is carried by wind. In species with fragrant or showy flowers, pollen may be carried by insects. The pollen and ovules join to make a new seed.



Female

Tree seeds are distributed in various ways. Wind carries seeds that are small, fluffy, lightweight, or have wings (samaras). Birds, mammals, and people spread seeds hidden in fruits, nuts, and cones. Water and gravity also carry seeds away from the parent tree.

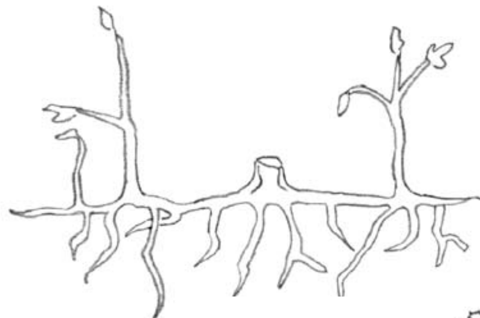


Methods of seed dispersal:

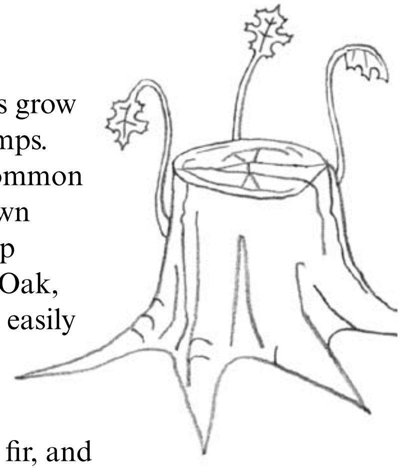
- Floats on air (cottonwood, aspen, red pine)
- Flies through air (maple, ash)
- Stored or eaten and excreted by animals (oak, cherry, pine nuts)
- Bounces or rolls (oaks, walnut)
- Released or opened by fire (jack pine)

A new tree is called a ***seedling*** if it grows from a seed. Seedlings are unique individuals because they contain a new combination of genetic material produced from the merger of pollen and eggs.

If a new tree grows from the roots of another tree, it's a ***sucker.*** Aspen often reproduce by ***suckering,*** a process by which roots send up shoots that break through the surface. As a result, aspen can cover a large area soon after trees are harvested.



Some deciduous trees grow new trunks from stumps. ***Stump sprouting*** is common when a tree is cut down or dies, and the stump remains to resprout. Oak, maple, and birch will easily stump sprout.



Some trees, such as black spruce, balsam fir, and white cedar, can reproduce through ***layering,*** a process in which a branch touching the ground takes root and forms a new plant.

Suckers, stump sprouts, and trees that grow from layering are all ***clones*** of the parent tree, which contain the same genetic material.

When a seedling, sucker, or sprout reaches a height of about 6 feet and a trunk diameter of at least 1 inch but less than 5 inches at 4½ feet from the ground, it is called a ***sapling.***

Where Trees Grow

Each species of tree has unique characteristics that allow it to grow and thrive best under a given set of conditions—sunlight, moisture, slope, temperature, soil type, and so forth.

Sunlight and Shade

Shade tolerance—the amount of shade a tree or seedling receives—affects how well it will grow. ***Shade-intolerant*** species such as aspen need direct light to thrive and are more likely to be found in an open area than growing beneath taller trees. Shade-intolerant species include aspen, black ash, paper birch, tamarack, red pine, black walnut, bitternut hickory, and jack pine. ***Shade-tolerant*** species grow readily in the shadows of other trees. Examples are red maple, balsam fir, sugar maple, black spruce, and American basswood. ***Intermediately shade-tolerant*** species can tolerate some shade and some sun. Examples include white spruce, bur oak, American elm, and white pine.

Moisture and Flooding

Trees tolerate the amount and timing of moisture differently. Some trees such as silver maples and cottonwoods have adapted to seasonal floods—periods of time when water saturates the soil and roots for more than a week. Trees with extensive root systems (such as willows) are structurally more able to withstand soils weakened by floods. Other species, such as red and sugar maples, require well-drained soils, while species such as northern white cedar prefer low and wet areas.

Slope and Landforms

Bottomlands are low areas with little or no slope and often contain more rich, moist soils than upland areas. The steeper the slope, the more well-drained the site is. Nearby landforms like hills, valleys, lakes, and mountains may funnel drying winds, or trap moisture, depending on their location.

Aspect and Temperature

South- and west-facing slopes receive more heat and sunlight. Because south- and west-facing slopes get their sunlight during the hotter parts of the day, more moisture is lost than if they received their sunlight during the cooler morning. Also, south- and west-facing slopes are windier during the growing season.

North- and east-facing slopes receive less heat, sunlight, and wind than their south- and west-facing counterparts. East-facing slopes receive sunlight during the cooler morning hours and therefore retain a little more moisture.

Soil

Soils consist of parent and organic material. Parent material comes from the original rock (such as limestone or basalt) that has been weathered down to make smaller particles. Organic material comes from decaying plants and animals. Soils with more organic content contain more nutrients and microorganisms. Soil texture is also categorized accordingly—fine-grained clay, medium-grained silt, and coarse-grained sand. Most of the time, soil contains a mixture of two or three categories, and is called ***loam.***

Below are examples of typical conditions in which three tree species thrive.

Species Name	Tolerance to Shade	Tolerance to Flooding	Preferred Slope and Aspect	Preferred Soil
Green ash 	High	High	Bottomlands	Medium- to coarse-textured sand and loam soils
Bur oak 	Intermediate to low	Moderate	North- and east-facing gentle slopes	Moderately deep (20 to 36 inches or 50 to 92 centimeters) sandy to loam soils
Red pine 	Low	Low	Uplands	Well-drained (but not dry) sandy to loamy soils

Minnesota Natives

A ***native*** tree is one that has evolved in and adapted to an area over several thousand years without help from humans. A ***nonnative*** tree is a tree planted or introduced by humans. Minnesota is home to 52 native species of trees (see Appendix 2).

A ***noninvasive*** tree does not spread prolifically and does not out-compete other plants. Noninvasive trees may be native, like basswood or white pine, or nonnative, such as apple trees and Scotch pine.

An ***invasive*** tree is one that spreads prolifically and may crowd out other plants, greatly reducing the diversity of plants and animals living in an area. Again, invasive trees can be native, like box elder or honeylocust, or nonnative, like Norway maple or buckthorn. Some invasive trees, like wildlife-friendly aspen, can be beneficial. In many cases, aspen took over when Minnesota's northern pinelands were extensively harvested at the turn of the last century. Other invasive trees, like buckthorn and black locust, can severely damage ecological health by crowding out species that support better habitat for wildlife. Common invasive, nonnative trees found in Minnesota include: black locust, buckthorn, Norway maple, Amur maple, Siberian elm, and Russian olive.

When determining whether a tree is native or nonnative, it helps to be able to identify the tree. The first step is learning what to look for. Here are some characteristics people use to identify trees:

- Location (country; state; proximity to rivers, wetlands, and hilltops; climate, etc.)
- Type (coniferous, deciduous)
- Leaves (shape, arrangement, size, texture)
- Bark (color, shape, texture)
- Twigs (branching patterns, bud-scale scars)
- Seeds (type, size, color)
- Flowers (number of petals, color)
- Fruit (type, color, taste)
- Shape (of trunk and crown)
- Size (height and girth)

Tree identification guides often use ***dichotomous keys*** to help you identify trees. The key asks questions about the tree you are looking at, and leads you down an ever-narrowing path of possible tree types that match the tree's features. With the help of a good tree identification guide, you can become an expert at identifying Minnesota trees. Identification guides for trees in Minnesota are listed on page 51.

Minnesota's Biggest Trees

Minnesota's biggest 52 native tree species are listed in the Big Tree Registry. Nominees are judged on three measurements: the circumference of its trunk 4½ feet above the ground, its height, and one-quarter of its crown spread. The total of these measurements is the points awarded to that particular tree. A champion is one that has accumulated the most points. If two trees of the same species have identical scores, the tree with the largest trunk circumference becomes champion.


Paul Sunberg, Minnesota DNR

Everyone is invited to join the search for Minnesota's champion big trees. Learn how to measure trees in Appendix 4.

To sum up

Chapter One: Tree Basics

- Trees have three parts: crown, trunk, and roots.
- The trunk is made of three types of cells: xylem (inner wood, sapwood), cambium, and phloem (inner bark, outer bark).
- There are two types of trees: coniferous and deciduous.
- Trees grow up, out, and down (through the roots).
- Trees make energy through the process of photosynthesis.
- Deciduous trees prepare for winter by shedding their leaves.
- In winter, trees undergo the processes of hardening and supercooling to prevent freezing to death.
- Trees reproduce through seeds, suckers, stump sprouts, and layering.
- Different tree species thrive in different growing conditions: sunlight, moisture, slope, aspect, temperature, and soil type.
- Consider whether a tree is native or nonnative when identifying trees.