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W227 Tree Growth Characteristics

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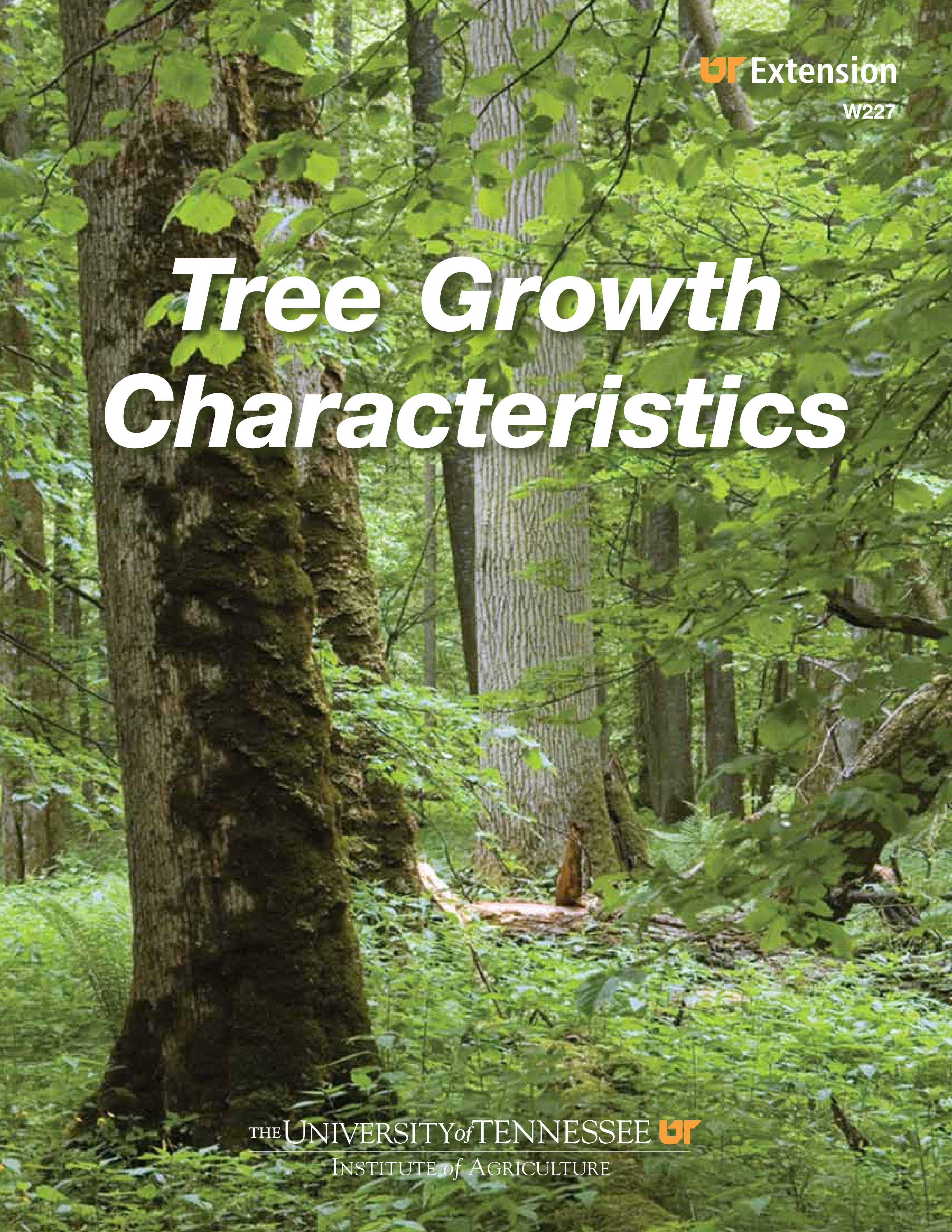

Tree Growth Characteristics

THE UNIVERSITY of TENNESSEE UT
INSTITUTE of AGRICULTURE

Tree Growth Characteristics

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Introduction

Trees are fascinating. The largest of all woody plants, they have well-defined stems that support a crown of leaves. The growth form varies by species and can be categorized. This publication has been created to provide professional foresters, arborists, students, Extension personnel, advanced homeowners and others a general understanding of how trees grow. Specifics will include primary vs. secondary growth, allocation of photosynthate, shoot growth patterns and crown shape.

Primary Growth

Tree growth occurs in two ways. Growth from the root and shoot tips resulting in increases in height and length is called primary growth. Growth that increases the thickness of stems and branches is called secondary growth. Primary growth occurs in small areas called apical meristems. All leaves, height growth and increases in the length of branches and roots are the result of growth at the apical meristems. Here one or more leaves are produced at a region called a node, followed by a section of stem that is called the internode.

For most species, the number of leaves produced in a season is determined by the environmental growth conditions, with ample light and nutrients resulting in a greater number of leaves. However, the size of a leaf and length of the internode are influenced more by water availability during the time they are maturing. A spring drought or damage to the roots results in less water availability, and the resulting smaller leaves may make the canopy appear sparse.

Each tree species produces leaves in a particular pattern on the stem that help in tree identification, and this pattern plays a large part in determining the mature form of the tree. Leaves develop in one of two arrangements: alternate or opposite (Fig. 1). Alternate leaves are produced one at a time, with one leaf at each node. Alternate leaves may occur on two sides of the stem, giving the branch a "flat" appearance as black cherry (Prunus serotina), or they may be produced one after another in a spiral pattern, so are found on all sides of the stem as in Southern magnolia (Magnolia grandiflora). Opposite leaves are typically produced two at each node, on opposite sides of the meristem. These leaves may also occur on just two sides of the stem, as in ash (Fraxinus spp.), or on all sides of the stem, as in dogwood (Cornus spp.). When three or more leaves are produced at one node we say they are whorled. A whorled leaf arrangement is seen in white pine, but is otherwise uncommon in trees. A few species, such as pines, apple and maple, produce short shoots with a cluster of leaves at the tip. These look similar to a whorl, and for these species it is important to look at the youngest stems, on which the leaf arrangement is easily distinguished.

The apical meristem, along with the tiny developing leaves around it, is referred to as the terminal bud. The terminal bud is found at the end of each branch. In most young trees, normally one of the terminal buds grows straight up, and this is called the leader. At the base of each leaf, where the leaf joins the stem, is a small region of tissue that can become a new apical meristem. You can often see a small bud on the stem, just above where the leaf is attached (Fig.2). These are called lateral buds, and can grow to become a branch. Many of these buds will not expand, but lie dormant in the stem, ready to grow if new branches are needed.

Because the buds grow from leaf bases, the pattern of leaf production at the apical meristem ultimately determines the pattern of branches in the mature crown. The alternate branching pattern of Eastern redbud (Cercis canadensis) is a good example (Fig. 3). The largest branches off the main stem are called the first order lateral branches. Branches growing from the first order laterals are referred to as second order laterals, and so on. The smallest woody branches, often fourth order branches in a mature tree, may be referred to as twigs.

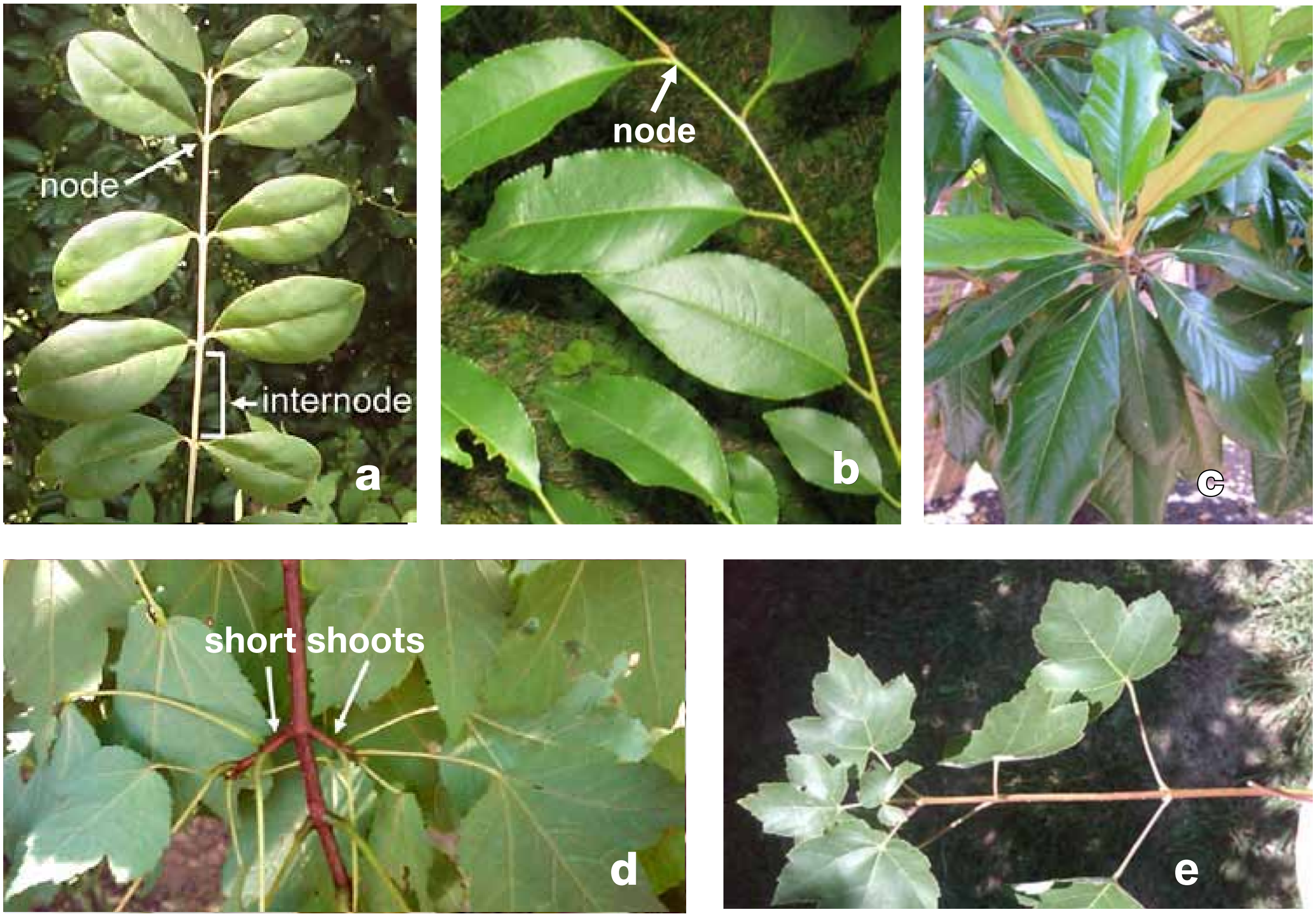

Fig. 1. (a) Opposite leaf arrangement in privet; (b) alternate leaves in cherry are attached on two sides of the stem; (c) alternate leaves of magnolia are attached on all sides of the stem, which has short internodes; (d) short shoots in maple are on opposite sides of the stem; and (e) the youngest shoot in maple clearly shows opposite leaf arrangement.

Fig. 2. When leaves fall off they leave a scar on the stem. Above each scar is a lateral bud that can grow into a branch. Rings around the stem are scars from the terminal bud, and are seen in species with preformed growth.

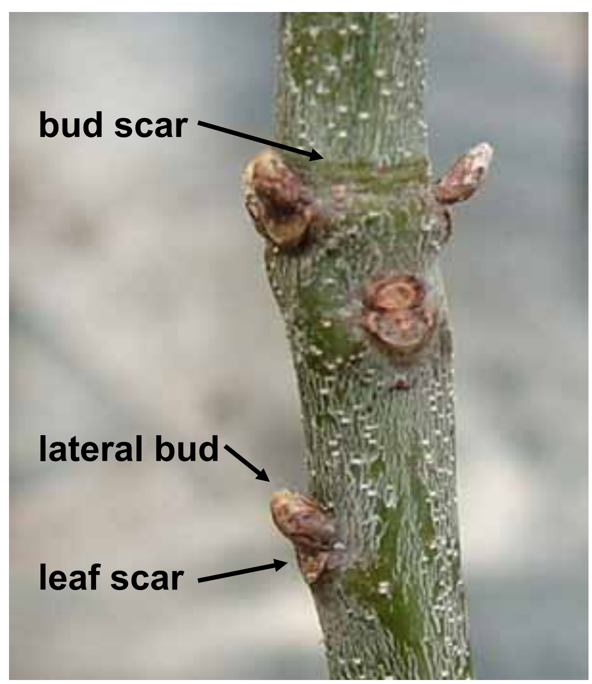

Fig. 3. Trees with sustained growth, like this redbud, have small leaves at the branch tip rather than a bud. Lateral buds at the base of each leaf can grow into branches, so the pattern of leaves determines the mature branching pattern, as is seen on the right. The growth of redbud can also be described as having alternate leaves on two sides of the stem, and zig-zag growth.

Secondary Growth

Tree stems, branches and roots also increase in diameter, through secondary growth. Upon peeling the bark off a branch, the soft inner layer of bark next to the wood is revealed. This is the vascular cambium, and every year it creates xylem (new wood) on the inside, and phloem (new inner bark) on the outside. The xylem carries water and nutrients from the roots upward, while the phloem carries sugars from the leaves downward (Fig. 4). In temperate climates, the cambium does not grow during the winter and a dark line can be seen in the wood where cambial growth slowed at year's end. These are the annual growth rings that are visible in many species. In tropical climates, growth may occur year-round, and annual rings may not be visible. In some species, the rings are very pronounced (Fig. 5), because wood produced in the spring (earlywood) is less dense that wood produced in the summer and fall (latewood). Deciduous species (hardwoods) that have distinctly different earlywood and latewood are described as 'ring-porous,' while those with similar early and latewood are described as 'diffuse porous.' These terms are not applied to coniferous species (softwoods).

A certain amount of diameter growth also occurs through growth of the cork cambium, which produces cork, the outer layer of bark. New cork is produced each year; however, the outermost layer is shed so that the bark thickness of a mature tree remains nearly the same from year to year. Therefore, while growth of the cork cambium may contribute greatly to diameter growth as a sapling develops a thick bark, diameter growth of a mature tree is mainly due to the production of wood by the vascular cambium.

The Energy for Growth

Leaves and young stems contain a green pigment called chlorophyll. Any part of the tree that is green performs photosynthesis, using sunlight, water and carbon dioxide to produce sugar. The sugar can either be used to provide energy to the leaves, or it can be transported to the stem and roots, where it is either used or converted to starch for storage. Sugar and starch are sometimes called photosynthate, or carbohydrates. Trees use the energy from photosynthate for maintenance and growth.

Approximately half of all photosynthate produced is used for respiration, e.g., maintenance of the trees'

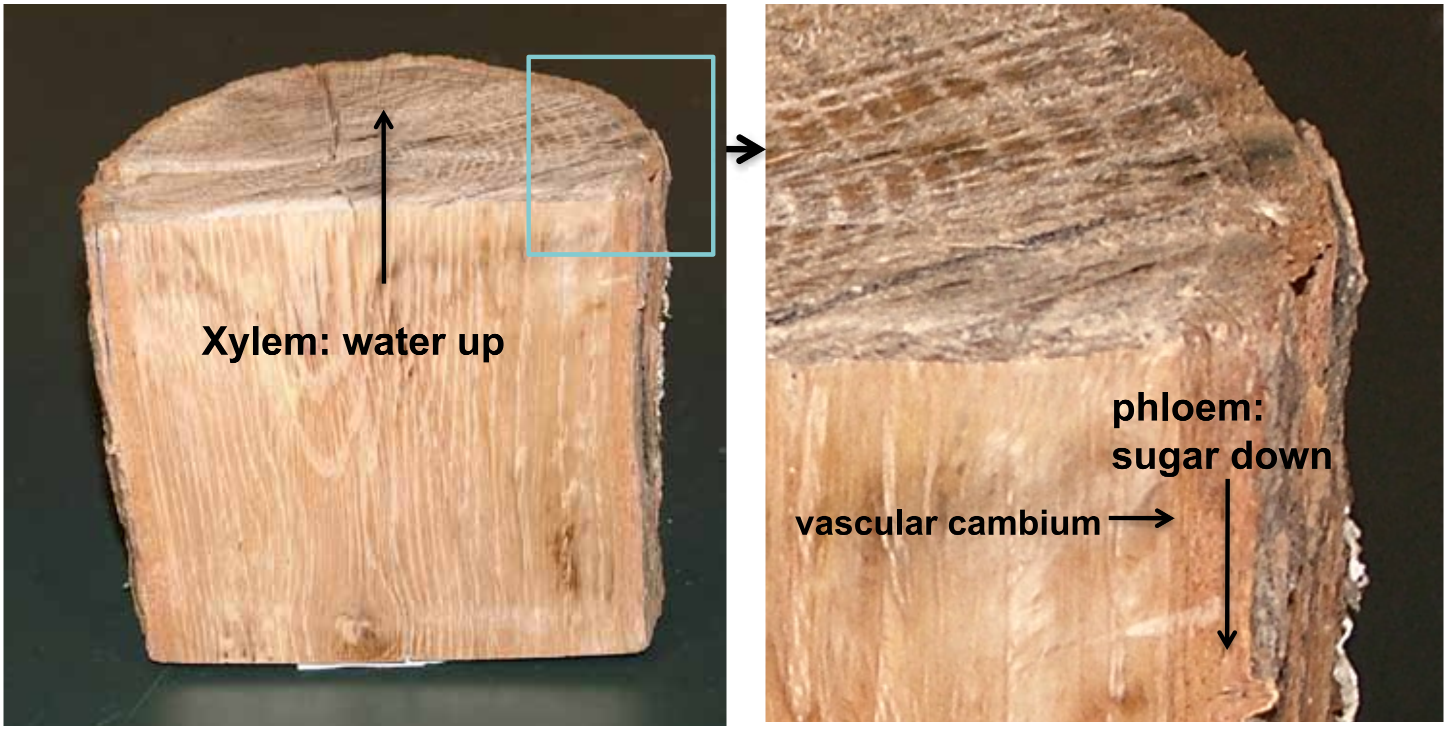

Fig. 4.

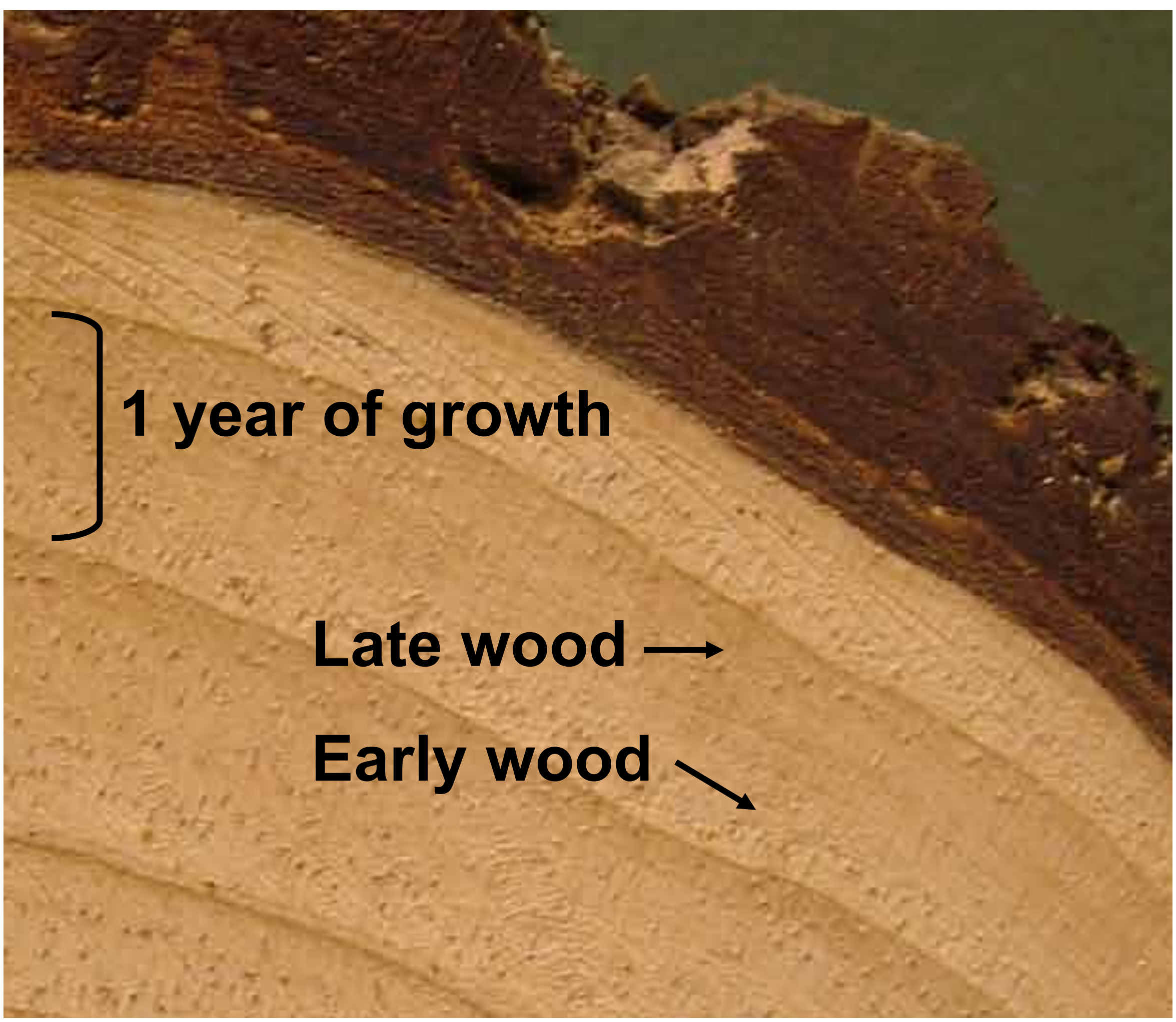

Fig. 5. Within each growth ring, early wood is toward the inside and late wood is closest to the bark and usually darker in color.

living parts. This includes energy needed to take up water and nutrients, to produce chemicals that deter herbivores, to adapt to changing temperature and water availability, and to make ongoing small repairs to cells. If the tree is stressed by insects, disease, poor weather or is growing in an environment where that species is not normally found, a greater proportion of the photosynthate will be used for maintenance. Photosynthate is also used for growth of the roots, stems and branches. Fine roots must be continuously replaced. Primary growth of shoots must occur each year to produce new leaves, even in coniferous species that retain their leaves for several years. Enough photosynthate must be stored in the roots and stem to maintain the root system over the winter months, and to support the spring growth of new leaves in deciduous species.

If growing conditions are favorable, enough photosynthate is produced for all maintenance, growth and storage requirements, and any additional photosynthate is usually used for additional growth. This excess photosynthate often goes to secondary growth, and can be measured as an increase in stem and trunk diameter. Therefore, the annual rings in wood often are wider during good growing years, and narrower during years with poor growth conditions.

Shoot Growth Patterns

Leaves can be produced by the apical meristem continuously throughout the growing season, or in discreet growth bursts termed flushes. Continuous growth, normally called sustained or indeterminate growth, ceases only when weather conditions are unfavorable. Trees with sustained growth are able to take advantage of favorable conditions by growing rapidly. To determine whether a tree has sustained growth, look at the end of the branch for leaves that get progressively smaller toward the branch tip, with tiny developing leaves at the end of the branch instead of a bud (Fig. 3).

Other species have periods of growth alternating with what appears to be a resting stage. The tree grows when the bud at the end of each branch opens and the enclosed group of leaves expands and matures. The tree then appears to stop growing, but at the tip of each branch, hidden inside a newly formed bud, a new set of leaves is being produced. In a matter of weeks, it will be ready to become the next flush of growth. This phenomenon is referred to as preformed, or fixed growth, because the number of leaves that will be produced is determined before the bud starts to expand (Kozlowski and Pallardy, 1997).

In some species, the bud will flush as soon as the tiny leaves inside are formed, as long as the growth conditions are favorable, resulting in multiple flushes each year. This growth pattern is sometimes referred to as semi-determinate, and oak species (Quercus spp.) often exhibit this type of growth. Other trees have a single flush each year, regardless of growth conditions. These are often species or individuals from a northerly climate.

Although growth rate is generally less than species with sustained growth, species with preformed growth often suffer less from weather and insect-related injury. This is because tender young leaves form inside the relative safety of the bud, then expand and mature rapidly. Note that for species with preformed growth, the extent of the first flush of the year is determined by the growing conditions in the previous year. To find out whether a tree has preformed growth, look for a bud (or buds) at the end of the branch (Fig. 6). Species with very small buds often have preformed growth at the beginning of the year, followed by sustained growth as the year progresses.

Fig. 6. Monopodial and preformed growth of oak is easily distinguished by the straight stem ending in a terminal bud. Oak can also be described as having alternate leaves occurring on all sides of the stem. Just below the terminal bud internodes are very short, making leaf arrangement indistinct.

The growth of shoots can occur either in a straight or a zigzag pattern, termed monopodial or sympodial growth, respectively (Fig. 7). In straight growth, the apical meristem produces nodes and internodes. A zigzag pattern occurs in some species with alternate leaves, where the apical meristem produces one leaf, then either dies or produces a flower. The lateral bud at the base of the leaf then begins to grow and becomes the new apical meristem, resulting in a distinctive zigzag stem.

Crown Shape

The crown of a tree or woody plant is that portion that contains live branches and foliage. The live crown ratio expresses the relationship of the portion of the tree with live branches (crown depth) to the total tree height. For example, a tree with a total height of 100 feet, having live branches in the upper 40 feet, would have a live crown ratio of 40 percent (calculated by 40/100). When trees are young and/or open-grown, they will have high live crown ratios because live branches often exist nearer the ground level. However, as trees age or experience competition from adjacent trees for sunlight, lower limbs succumb and the live crown ratios shrink.

Crown shape will vary according to tree species. McCurdy, et al. (1972) identified six distinct crown shapes: oblong, round, oval vase, pyramidal and weeping (Fig 8). In forested settings, the crown shape is influenced by a tree's position within the canopy. Crown shape is of interest to foresters because it indicates the amount of growing space (or stocking) that is needed to maximize lumber production. Crown shape should be considered around buildings and in urban settings, because it influences contrast, view, shading and screening. Although the basic shape is characteristic of a species, branch growth and death is modified by the environment so trees grown in close proximity to others can have vastly different crowns than those grown in an open setting.

Perhaps most influential in determining crown shape is differences in the degree of apical dominance. Apical dominance is the upward growth of the leader, at the expense of lateral shoots. Flushing and growth of lateral shoots is inhibited by hormones produced by the apical bud on the leader. As a result, crowns of trees with strong apical dominance grow in height much faster than in width. Typically, these species will have a single, dominating central trunk and leader. Lateral branches often grow outward, rather than upward. Such trees are said to have an excurrent crown that favors oblong or pyramidal shapes. Forks in the central trunk are rare, usually forming only when the leader has been damaged or destroyed. Sweet gum (Liquidambar styraciflua L.), tulip poplar (Liriodendron tulipifera L.) and many conifer species exhibit strong apical dominance.

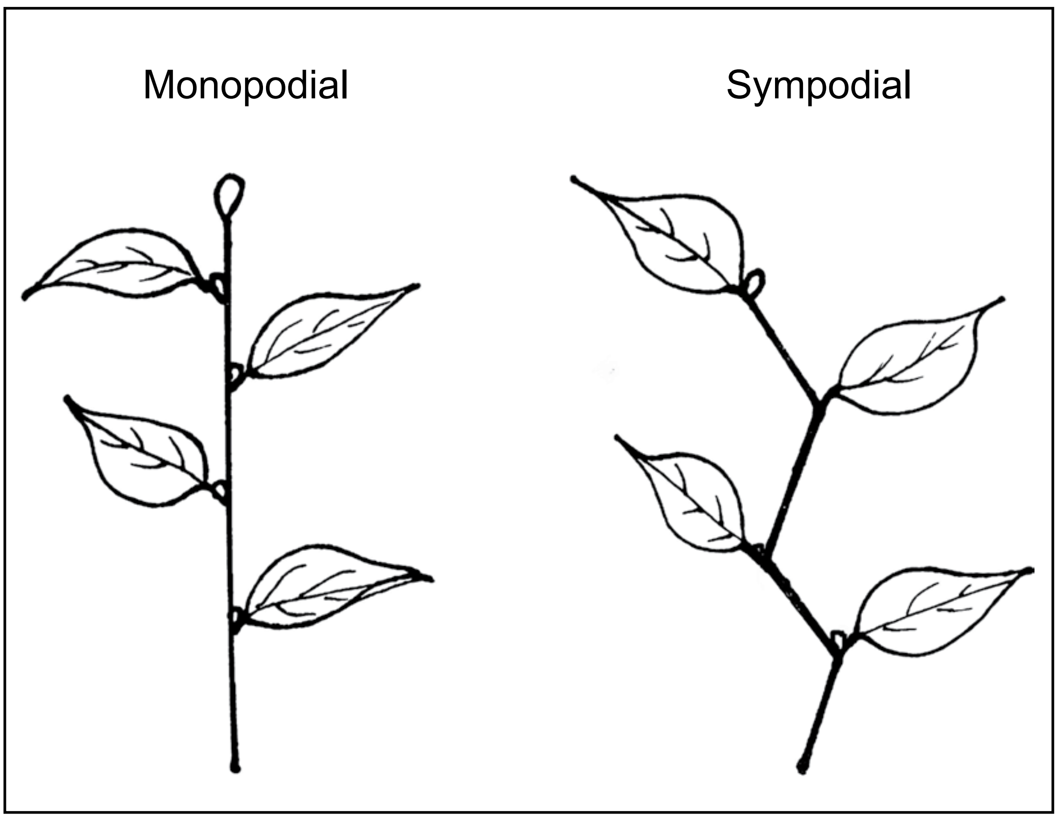

Fig. 7. Growth is monopodial when the terminal bud produces new leaves and stem, but maintains a growing point at the tip. In some species the terminal bud becomes a leaf or flower, and new growth must come from a lateral bud, resulting in a zig-zag pattern.

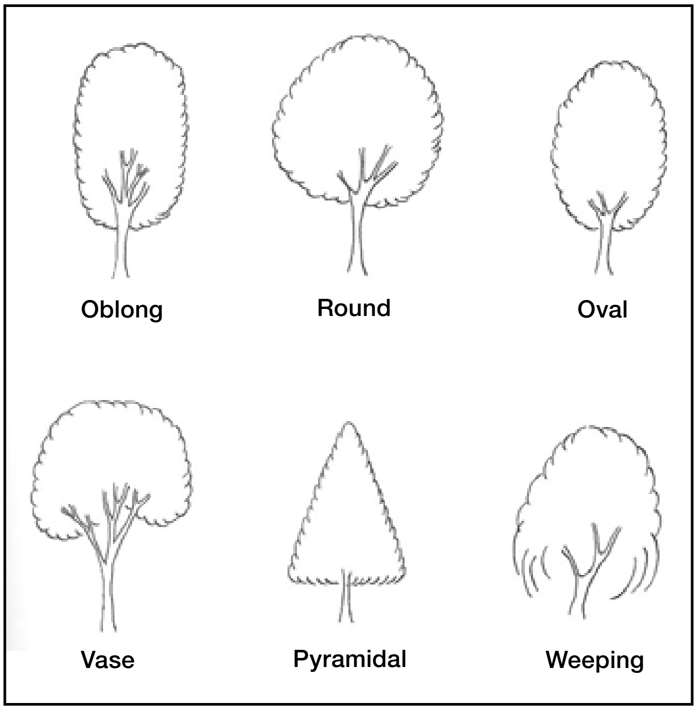

Fig. 8. Tree crown shapes

In contrast, in tree species with weak apical dominance, crown width grows nearly as fast as crown height (especially when open-grown). Such species have no particular prevailing leader, but rather multiple ones. The leader with the most access to sunlight normally prevails, and sometimes compromises tree form (Oliver, 1996). Such trees are said to have a decurrent crown that favors round or oval shapes. Forks in the central trunk are common, even exacerbated when the leader(s) have been damaged. Oaks (Quercus spp.) and maples (Acer spp.) are examples.

Conclusion

An understanding of tree growth characteristics is beneficial for the management of trees in both forested and urban settings. This knowledge can aid in maintaining proper forest stocking, in pruning and limb manipulation, in making aesthetic choices, and in selecting appropriate growth measurements to monitor individual tree growth and forest health. Table 1 summarizes tree growth characteristics for many of the more common tree species found in the eastern United States.

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Oliver, C. and B. Larson. 1996. Forest Stand Dynamics. John Wiley & Sons, Inc. New York.

Table 1.
Summary of Tree Growth Characteristics for Select Species - Eastern U.S.

Species	Crown Shape	Apical Dominance	Shoot Growth	Leaf Scars	Branching
American beech	round, oval	decurrent	preformed	alternate	zig-zag
Ash	oval	decurrent	preformed	opposite	monopodial
Birch species	weeping	decurrent	sustained	alternate	zig-zag
Black cherry	round, oblong	decurrent	preformed	alternate	monopodial
Cottonwood	round, vase	decurrent	sustained	alternate	zig-zag
Eastern red cedar	pyramidal	excurrent	sustained	whorl/opposite	monopodial
Elm	vase	decurrent	sustained	alternate	zig-zag
Flowering dogwood	oval	decurrent	sustained	opposite	monopodial
Hackberry	round, vase	decurrent	sustained	alternate	monopodial
Hickories	oblong	decurrent	preformed	alternate	monopodial
Holly	pyramidal	excurrent	sustained	alternate	monopodial
Oaks, red and white	round, oval	decurrent	preformed	alternate	monopodial
Pine, white	pyramidal	excurrent	preformed	alternate	monopodial
Pine, loblolly	pyramidal	excurrent	preformed	alternate	monopodial
Red maple	oval,	decurrent	both types	opposite	monopodial
Redbud	round, vase	decurrent	sustained	alternate	zig-zag
Sugar maple	round, oval	decurrent	both types	opposite	monopodial
Sweetgum	oblong, pyramidal	excurrent	both types	alternate	monopodial
Sycamore	round, oval	decurrent	sustained	alternate	zig-zag
Tulip poplar	oblong	excurrent	sustained	alternate	monopodial
Willow	round, weeping	decurrent	sustained	alternate	zig-zag

Note:
Trees with sustained growth produce less definitive growth rings (diffuse porous) because there is little difference between wood formed early in the season and wood formed late in the growing season.

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