Chapter 14

Pruning

OBJECTIVES

- The training and pruning of broad-leaved and coniferous trees, shrubs, palms, and vines are explained and demonstrated.
- The reasons for pruning and plant responses to pruning are discussed.
- The types, terminology, and location of pruning cuts and plant responses are described.
- Characteristics of and ways to develop strong tree structure are presented.
- Prepruning preparation in order to work safely and efficiently in mature trees is given.
- Pruning to maintain healthy, strong, attractive, mature trees is discussed.
- Creating and maintaining artificial tree and shrub forms are described.
- Efforts are made to reconcile differing pruning terminology, practices, and their influences on trees.

Pruning is the removal of plant parts—usually shoots and branches, but sometimes buds, roots, and even flowers and fruit. By pruning, one can direct the growth of plants to enhance their performance and function in the landscape. Pruning can increase the structural strength of trees, the productive capacity of fruit trees, the trunk quality of timber trees, the quality and size of flowers and fruit, and the esthetic appeal of many plants. **Most important, pruning as part of the training of young trees can best ensure structurally strong mature trees that will be safer and require less corrective pruning to fulfill their functions in the landscape.**

GENERAL PRINCIPLES OF PRUNING

PURPOSES OF PRUNING

Plants grow in many shapes and sizes. Some have central leaders with tall, straight trunks (an excurrent growth habit) (see Fig. 2-10). Others have several main branches with spreading crowns (a decurrent, deliquescent, or diffuse growth habit) (see Fig. 2-11). Between these extremes, intermediate forms occur. The natural characteristics of different plants can be exploited through landscape use and maintenance practices. Pruning can enhance plant appearance and safeguard plant health and well-being. Depending on its extent, pruning can affect a plant from root to crown. Arborists should be familiar with pruning techniques and plant responses to pruning. They should be able to determine the growth habit of a plant by observing its growth and its response to previous pruning and thereby be able to properly prune even unfamiliar species. This discussion covers pruning techniques and plant responses in general but offers little advice on pruning particular species.

REASONS FOR PRUNING

TRAINING YOUNG PLANTS The arrangement, attachment, and size of scaffold branches can be controlled to produce vigorous and mechanically strong plants. Pruning should take advantage of the plant's growth habit, accentuating its natural tendencies and seldom modifying them greatly. Unusual plant forms can be created by pruning, including topiary, espalier, bonsai, pleach, and pollard forms (discussed later), but to do so effectively you must be familiar with the plant's responses to pruning.

MAINTENANCE OF HEALTH AND APPEARANCE Pruning can remove dead, diseased, injured, broken, crossing, interfering, and crowded limbs. A dense top may be thinned to allow the passage of light and air. Light is needed by interior foliage of a plant and by other plants beneath it; air circulation reduces the incidence of certain diseases and allows sprays to penetrate more effectively.

Proper pruning encourages tapered trunk and branches that reduce wind resistance. Wind can create deformities and uproot trees; however, unless they are well attached, an occasional branch may break because of greater exposure.

CONTROL OF PLANT SIZE Pruning can reduce shade, the danger of windthrow, and interference with structures and/or utility wires; simplify pest-control spraying; and prevent the obstruction of views and traffic. Choosing plants that will be of appropriate size at maturity minimizes the need for pruning when plants mature. If a plant in a landscape must be pruned more often than every 3 to 5 years to control its size, it is the wrong plant for the particular location or use. Withholding nitrogen fertilizer and growing turf under trees will slow growth and reduce the frequency of pruning as a plant reaches the desired size.

INFLUENCING FLOWERING, FRUITING, AND VIGOR Pruning influences the balance between vegetative growth and flower bud formation. If young plants that flower on 1-year-old wood are pruned severely, the initiation of flower buds may be delayed. On mature plants, pruning helps maintain vigor, minimize overcropping (which results in small blossoms and fruit and broken limbs), and encourages annual flowering and fruiting throughout the plant. Pruning plants that flower on the current season's growth stimulates shoots, producing fewer but larger flowers, particularly those that flower only from terminal buds (e.g., roses *(Rosa)* and crape myrtle *(Lagerstroema indica)*.

COMPENSATION FOR ROOT LOSS This is often given as a reason for pruning back the tops of newly planted plants. Considerable root loss occurs between the nursery field and landscape planting. A 100-mm (4-in.) caliper tree may lose 95% of its absorbing roots when mechanically transplanted (Watson and Himelick, 1982). But, if water is not limiting, removing a large portion of the top may not necessarily improve a plant's ability to survive and grow (Whitcomb, 1987). Such pruning may instead delay the initiation of root growth (see the next section).

INVIGORATION OF STAGNATING PLANTS When plants are doing poorly but show no symptoms other than extreme lack of vigor, they should be pruned more severely than in previous years.

INCREASING THE VALUE OF CONIFERS Nursery stock and Christmas trees may be sheared to control their shape, density of foliage, and appearance.

PRUNING RESPONSES

Pruning removes leaves and buds that would develop into leaves. Two seemingly opposite effects occur when young plants and more mature plants that have few flower buds are pruned.

Invigoration of the remaining individual shoots is the universal response to pruning (Fig. 14-1). Pruning off foliage and buds that would develop into leaves allows the root system (which is not immediately affected) to supply each remaining shoot, leaf, and bud with more water

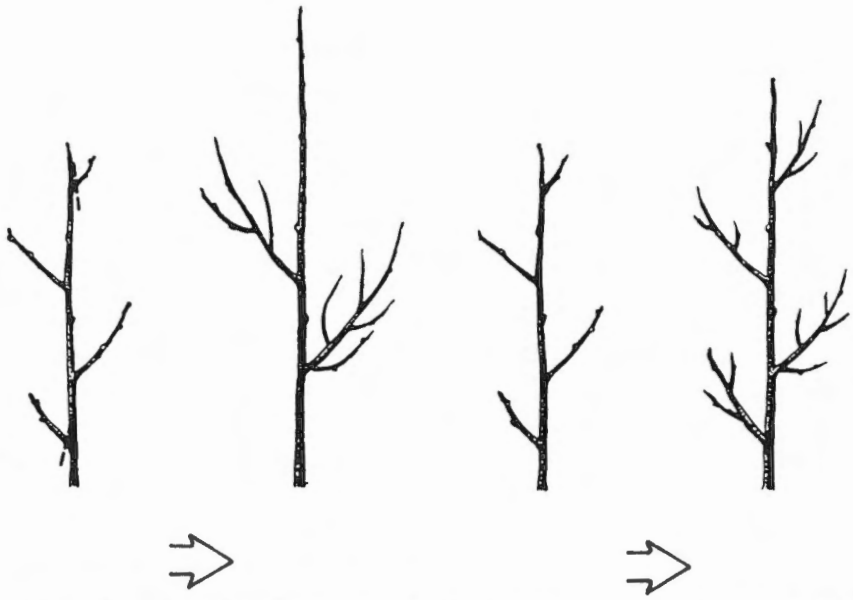


FIGURE 14-1 The effects of pruning. The trees to the left of each arrow were exactly the same before two of four lateral branches were pruned off the tree on the left. The two remaining laterals and the terminal of the pruned tree grew more than the corresponding laterals on the unpruned tree, but by the next dormant season the unpruned tree (extreme right) will have made more total growth.

and nutrients than before. Individual shoots grow more rapidly and later into the season; leaves become larger and greener (more chlorophyll).

Dwarfing of the total plant results when young plants and those that have few flower buds are severely pruned. Even with more and larger leaves on longer individual shoots, there are fewer shoots with less total leaf area and fewer buds. These shoots grow later in the season, using foods produced by less leaf surface. After shoot growth stops, the pruned plant has less time to produce food to store for the next season. Less total growth is the result. This can be observed and even measured by the relative sizes of trunks or branches on plants that have been pruned more and those less severely.

A plant with few or no flower buds that has been properly dormant pruned will usually exhibit the following characteristics at the end of a growing season.

- The top and root systems are in balance.
- The top and roots will be smaller than if the plant had not been pruned.
- There will be less stored food because the plant had a smaller leaf area for photosynthesis and its leaves were active for a shorter time.
- If properly pruned, the structure should be stronger and more attractive.

The extent of invigoration and dwarfing depends on the severity of pruning. A branch that needs subduing should be pruned more severely to reduce its total growth. Remaining shoots will be more vigorous but the total leaf area of the plant will be less. A branch that needs encouraging, however, should be pruned lightly or not at all; branches that shade or compete with the branch to be encouraged should be pruned more severely. Removing dead, weak, and heavily shaded branches has little or no effect compared to removing healthy, well-exposed branches.

Pruning does not always result in dwarfing. Mature plants, such as peach *(Prunus persica)* and *pyracantha*, that produce flowers and fruit heavily on 1-year-old wood can attain a greater leaf area by the end of the growing season if they are pruned when dormant. Both leaf and flower buds are removed by pruning. No new flower buds will form and bloom in the spring following pruning, but individual shoots from leaf buds that remain can form more leaves than they would have without pruning. Thus, shoots and leaves will form in greater quantities relative to flowers and fruit. It is possible to prune severely enough that the leaf area developed will not only increase fruit size but also enhance total growth of the plant. Pruning a stagnated plant may stimulate it to grow more vigorously and also more in volume.

TOP PRUNING Removing branches of a young plant reduces not only the food supply to the roots but also the flow of auxin formed in developing buds and leaves. The spring root growth of deciduous plants may be delayed by the removal of shoot terminals, which provide the first auxin needed to stimulate root initiation. Richardson (1958) found a close correlation between the initiation of spring root growth in sugar maple *(Acer saccharum)* and the presence of at least one physiologically active bud. The roots of sugar maple whips began to grow just before the terminal bud began to expand; when the terminal bud was removed, however, root growth slowed to zero in 3 days and did not resume for another 5 days, when the two uppermost lateral buds began to swell. This response may explain Whitcomb's (1987) finding that pruning bare-root trees at planting (designed to balance the top with a reduced root system) improved neither survival nor growth. On unpruned trees, expanding buds and new leaves may stimulate enough additional root growth to more than compensate for any increased transpiration due to a larger leaf surface. The best established reasons for pruning plants at planting are to remove damaged branches and to begin to develop tree structure. It may be desirable, however, if there will be sufficient water, to leave as many terminals and leaves as possible in order to stimulate root growth.

INFLUENCE OF PRUNING ON FLOWERING AND FRUITING In most young plants, particularly those that produce flowers on 1-year-old wood (Fig. 14-2a), pruning will delay flowering. It will invigorate the growth of individual shoots, so less food and fewer hormones will be available during the early summer, when the buds for the next season are differentiating into leaf or flower buds. If pruning is kept to a minimum and nitrogen fertilization withheld, plants will be more floriferous and will flower at a younger age. However, plants of low vigor may produce few flowers because of a lack of nitrogen and associated compounds; pruning channels available nutrients into fewer shoots, thereby increasing the nitrogen supply of each. Plants that flower laterally on growth of the current season will produce more flower buds along invigorated shoots. Plants that flower terminally will have larger flowers or flower clusters (Fig. 14-2b). Measures that increase flowering will usually increase fruiting. If a tree must be pruned annually to reduce undesirable fruiting, it is the wrong tree or in the wrong location.

ROOT PRUNING As would be expected, root pruning has essentially the opposite effect of top pruning. It decreases the supply of nutrients and water to the top, though usually not in proportion

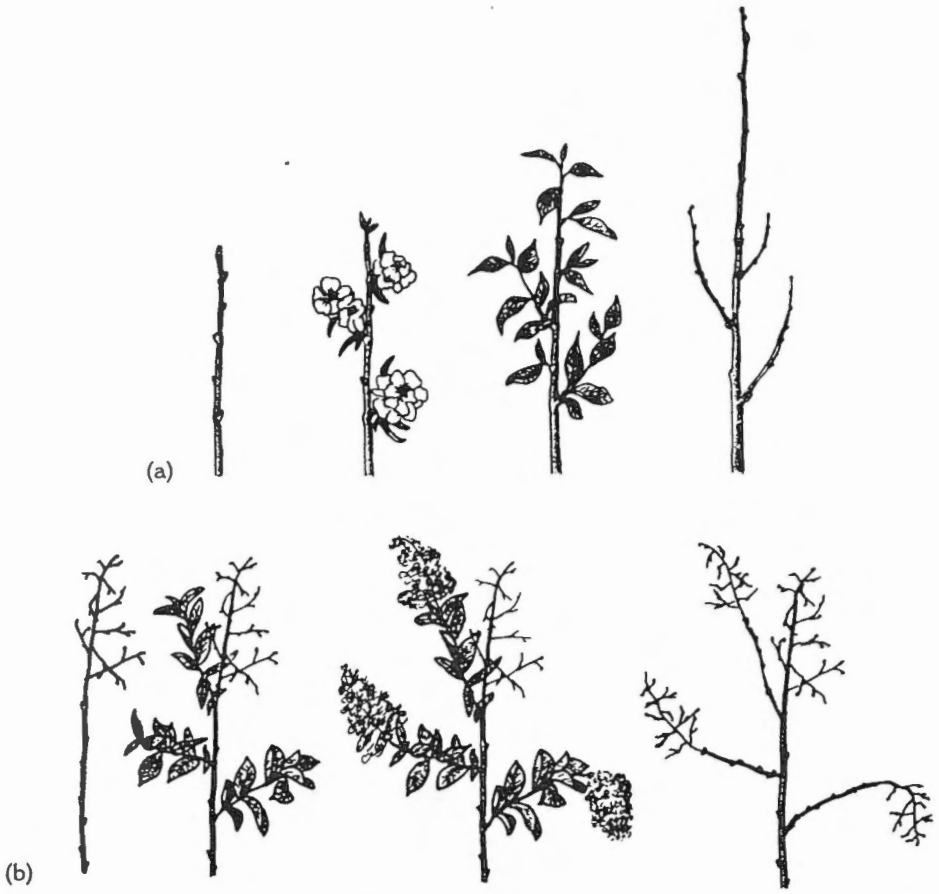


FIGURE 14-2 (a) Spring-flowering plants bloom from buds formed the year before (extreme left). Flowers usually open before new shoot growth is extensive (left center). New shoots grow after the setting of fruit and fading of bloom (right center). Dormant buds on newly formed shoots overwinter to bloom the next spring (extreme right). (b) Summer-flowering plants bloom from buds on the current season's shoots. Overwintering twigs have dormant vegetative buds and often remnants of the previous summer's blossoms (extreme left). New shoots grow from lateral buds in the spring (left center), and flowers or flower clusters form on current shoots, often terminally (right center). The following winter, flower stalks may remain on the previous season's shoots (extreme right).

to the roots pruned off. Thus, less vigorous growth of individual shoots and less total growth are produced. On a young, vigorous plant that flowers on 1-year-old wood, root pruning will usually encourage flowering and fruiting at a younger age. The roots of established trees to be transplanted are sometimes severely pruned to obtain more fibrous rooting within the future root ball (see Chapter 9); this is thought to enhance transplanting success. When surface roots threaten walks, streets, paving, and foundations, they are commonly pruned back mechanically close to the endangered hardscape, and efforts are made to stop or divert their growth. Exposing the threatening roots may make it possible to prune them back to laterals growing in more desirable directions (see Locating Roots, Chapter 11). Root pruning can be used to decrease the vigor of severely top-pruned, vigorous shrubs. Root pruning is hard, dirty work, and the results are not always obvious, so it is usually discussed more than it is practiced.

TIME OF PRUNING The appropriate time to prune depends on the plant species, its condition, and the desired results. Light pruning can usually be done any time. Unwanted growth is most easily removed while it is small, and early removal will have a less dwarfing effect. Broken, dead, weak, or heavily shaded branches of most species can be removed almost any time with little or no effect on plant vigor.

Most deciduous plants can be pruned during the dormant period between leaf fall to the end of winter with similar growth results. The growth of young plants can be directed effectively during the growing season. Branches in desired positions can be encouraged by pinching back or removing competing laterals or shoots. Otherwise, avoid pruning broad-leaved trees in early to late spring.

Evergreens will be set back the least if they are pruned in the late winter; this timing also minimizes bark beetle attack on conifers (if bark beetles are a problem, take pine prunings to a landfill or stack and cover with a sealed plastic tarp) (Barrie Coate, Los Gatos, CA, 1997, pers. comm.). A few broad-leaved evergreen species grow most rapidly after the weather warms up later in the season. If these plants are pruned just before the period of most rapid growth, leaves will be kept productive for the longest time and pruning cuts will be concealed more quickly by new growth.

Plant development can be slowed and plant size maintained if pruning takes place soon after growth is complete for the season. Such pruning should not be so severe or so early as to encourage new shoot growth. If maximum dwarfing is desired, most plants should be pruned in the period from early to midsummer. This reduces leaf area for the longest period. Pruning cuts should be discretely placed for minimum visibility (see Fig. 14-12).

Corrective pruning may be easier during the growing season. Branches that hang too low from the weight of leaves or fruit can be thinned. Dead and weak limbs can be more easily spotted for removal. If concerned about bird life, do not disturb tree-nesting birds until usually late autumn and early winter.

To maximize flowering, timing will depend on the growth habit of the plant (Fig. 14-2). Those that flower in summer or fall on the current season's growth, such as crape myrtle *(Lagerstroemia indica)*, Jacaranda, and rose *(Rosa)*, should be pruned during winter before growth begins. Moderate-to-severe pruning will favor the growth of fewer but larger blossoms or blossom clusters. Plants that flower in the spring from buds on 1-year-old wood, particularly flowering fruit trees, should be pruned near the end of their blooming period. For species from which little or no fruit is wanted, the blossoms can be enjoyed and then removed before many set fruit that compete with new shoot growth. Pruning at the end of spring bloom will have little or no debilitating effect on growth. Blossoming utilizes food in the bud and its immediate shoot and makes little or no demand on other food reserves. This is demonstrated by branches that bloom and initiate shoot growth after they are cut in the spring and brought indoors to flower.

Callusing and woundwood formation should be more rapid if a wound is made between a few weeks before and after growth begins, assuming that bleeding is not a problem. In Illinois, Neely (1970) found that wounds on ash *(Fraxinus)*, honey locust *(Gleditsia triacanthos)*, and pin oak *(Quercus palustris)* closed as rapidly in the next growing season whether cuts were made in the spring, summer, or winter, but about 20% more slowly when they were made in the autumn. Summer wounds, however, closed much less than spring wounds during the current growing season because they had less time to do so. This difference in closing did not carry over into the following season.

Shigo (1989) recommends not pruning during the spring flush of growth when the cambium is active and bark particularly vulnerable to being torn loose. Even though decay of proper pruning wounds is seldom a threat, he suggests that autumn, when most decay fungi are sporulating, is not a good time for pruning. This, along with Neely's (1970) findings, make it wise not to prune in the autumn without good reason.

However, oozing sap *(bleeding)* can be minimized if predisposed species are pruned in autumn and early winter instead of late winter and early spring. Wounds on mature trees, particularly deciduous trees, such as birch *(Betula)*, elm *(Ulmus)*, and maple *(Acer)*, can bleed heavily (Brown, 1972). On susceptible trees, this can be minimized if only small cuts (less than 75 mm or 3 in.) are made. Bleeding is usually not harmful to plants, but if it is heavy and persistent, it can cause bark injury below the pruning cut and can retard callusing in the lower portion of the wound. Brown (1972) describes a procedure for tightly binding small wounds to stop bleeding.

Cold injury may be increased if substantial pruning takes place before growth begins in the spring. Some plants, such as roses and subtropicals, can be stimulated into new growth if pruned in the fall and early winter, only to be injured when the weather turns cold. When winter temperatures go below −18°C (0°F), the hardiness of tissue near pruning cuts may be reduced even though growth is not stimulated by pruning. This is particularly true of some conifers (Brown, 1972). If cold injury is a danger, it is best to delay pruning until just before growth begins in the spring.

The incidence of some diseases or their eradication can be affected by the season of pruning. Check the influence of timing on infection and development of diseases before pruning species susceptible to serious vascular and foliage diseases and to boring insects that may be attracted to pruned plants (see Eradicative Pruning in Chapter 19).

Solar heating capacities can be enhanced by pruning in the early autumn to open up trees and allow more sunlight to reach exposed windows, solar collectors, and patios (see Chapter 5). Even so, bare branches of some deciduous trees can block up to 70% of incoming radiation.

PRUNING TECHNIQUES

The International Society of Arboriculture (ISA) published *Best Management Practices—Tree Pruning* (Gilman and Lilly, 2002) to aid in the interpretation and implementation of *The American National Standard for Tree Care Operations—Standard Practices (Pruning)* (ANSI A300 (Part 1), 2001 *Pruning*). The *Best Management Practices* publication is intended as a guide for practicing arborists, treeworkers, their supervisors, and the people who employ their services to effectively follow the ANSI A300 standards.

TYPES OF PRUNING CUTS Three types of pruning cuts differ in how and where they are made and the plant responses to each. The commonly used terms for two of the three types of pruning cuts in *Best Management Practices: Tree Pruning* (2002) differ from those in *Tree Pruning Guidelines* (International Society of Arboriculture, 1995) and in *Arboriculture: Integrated Management of Landscape Trees, Shrubs, and Vines*, third edition (Harris, Clark, and Matheny, 1999). The terms on the left below are used in *Best Management Practices* and those on the right in the other two publications:

Types of pruning cuts[a]

Heading cut	**Heading cut**
Branch removal cut	**Thinning cut**
(Thinning cut)	(To thin)
Reduction cut	**Thin to a lateral**
(Cutting to a lateral)	(Thin to a lateral cut)
(Lateral cut)	(Drop-crotch cut)
(Drop-crotch cut)	

[a]Names in bold are preferred for each pruning procedure. Those in parentheses are terms with the same meaning that are or have been used.

Each of the three pruning cuts is defined, described, and illustrated in ISA (1995); Harris, Clark, and Matheny (1999); and Gilman and Lilly (2002). The ANSI A300 (2001) standard defines and describes heading (5.3.6) as a pruning cut but without an illustration. The ANSI standard illustrates a thinning cut (branch removal cut) (Fig. 5.3.2 and 5.3.7) and a thin to a lateral cut (reduction cut, lateral cut, thin to a lateral) (Fig. 5.3.3) but does not define or describe them.

A *heading* or *heading back cut (to head* or *head back)* removes a currently growing or 1-year-old shoot back to a bud, or cuts a branch or leader back to a stub or to a lateral not large enough to assume the terminal role (Fig. 14-3).

A thinning cut (removal cut, to thin) removes a lateral branch at its point of origin (Fig. 14-4). A *thin to a lateral cut (reduction cut, lateral cut, thin to a lateral)* shortens a branch or leader by cutting it to a lateral large enough to assume the terminal role (Fig. 14-4).

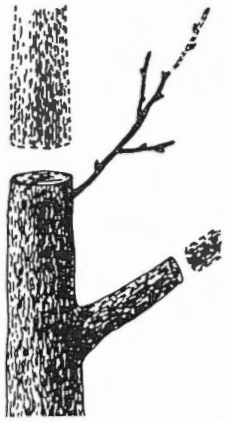


FIGURE 14-3 Heading or heading back is pruning to a stub (lower branch), a small lateral (trunk), or a bud (terminal on small lateral).

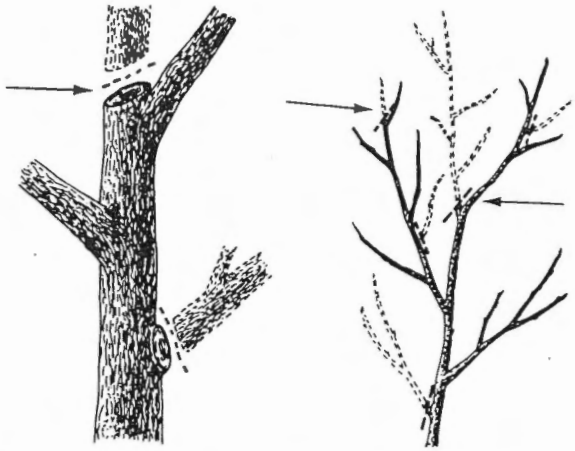


FIGURE 14-4 Thinning (removing) cuts remove branches at their points of origin (dashed lines, no arrow) or thinning to a lateral (reduction) cuts prune to a lateral large enough to assume the terminal role of the leader or to a branch (dashed lines with arrows). This applies to mature (left) as well as young (right) trees. The vegetative responses of trees to these two cuts are similar.

Reducing the height or spread of a large tree or branch by pruning a terminal or a branch to a lateral commonly was referred to as drop-crotching. Heading is another term that has been used in some regions to denote cutting back to a large lateral. However, thin to a lateral or reduction cut seem to be more appropriate terms, because little or no stub should be left and the plant responds as it would to other thinning cuts.

The lateral to which a branch or trunk is cut should be at least one-third the diameter of the cut being made in order to assume the terminal

role (*apical dominance* as used in ANSI A300 (2001) sections 4.20 and 5.5.4 is not an appropriate term; see the definition of apical dominance in ANSI Section 4.2 or in the Glossary). The branch to which a trunk or lateral is properly cut does not suppress the laterals below but has enough foliage (energy) to outgrow them (see Responses to Pruning Cuts next).

Deciding how severe (where) to make a thin to a lateral cut (reduction cut) should be easier to do based on the relative terminal and lateral branch sizes (diameters near where the cut is to be made) than on the relative amounts of foliage even when present. When an experienced pruner tried to thin newly planted trees by 30% foliage removal, reductions of the branch systems of the trees ranged from 20 to 50% (Evans and Klett, 1985). It would be even more difficult in a mature tree. Fraedrich and Smiley (1996) caution that when thinning to a lateral much smaller than one-third the diameter of the parent limb that the limb will either die back or sprout profusely. If the lateral is considerably larger than the 1/3 guideline there is the risk of storm damage unless the lateral is growing fairly upright and the lateral is thinned to reduce its weight.

RESPONSES TO PRUNING CUTS A healthy plant's response to a specific type of pruning cut is universal. A pruning cut not only affects the initial appearance of a branch and/or plant but also determines where future growth will most likely take place and influences its vigor. Based on plant response, pruning cuts can result in one of two distinctly different responses.

Heading (heading back) young branches and leaders usually results in vigorous, upright growth from one or more buds just below the cut; lower buds may not grow unless the plant has been severely pruned (Fig. 14-5). Shoots (epicormic) that grow from the trunk or large branches after stubbing come from latent buds. Vigorous new growth from large heading cuts is attached only by the thin layer of new wood formed after pruning (Fig. 14-6). It is weakly attached and can break out easily. If the heading is severe, such shoots may be so numerous and thick that lower leaves and plants underneath are severely shaded.

The invigoration from thinning (branch removal) cuts and thin to a lateral (reduction) cuts are more widely dispersed throughout the plant and individual shoots are less vigorous than those from equally severe heading cuts. The responses to these two types of thinning cuts, however, are similar. Unless severe, invigoration is not concentrated near the cuts but is spread into the lateral left and throughout the plant. Plants that have been pruned by thinning cuts become more open and retain their natural form. More sunlight penetrates the plant and foliage grows more deeply within its canopy, thereby increasing branch taper.

LOCATION OF PRUNING CUT The type of pruning cut not only influences subsequent growth but also its location in relation to the branch attachment determines the size of wound, and affects callusing and woundwood formation, exposure to decay, and the possibility of ring shakes (circumferential separation of xylem along

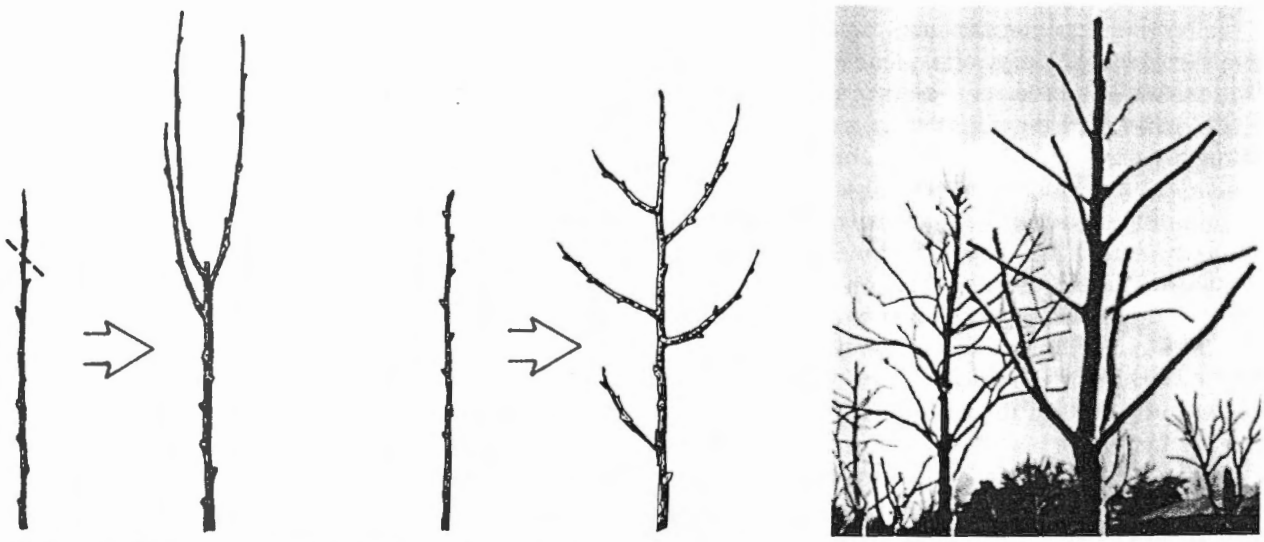


FIGURE 14-5 Heading a 1-year-old shoot (left pair above) will force two to four buds just below the cut into vigorous upright growth. Growth from a similar but unpruned shoot usually will be more uniformly distributed along the shoot and will be less vigorous (right center). The London plane *(Platanus* x *acerifolia)* tree in the foreground of the photograph (right) was headed back (stubbed) shortly before the photograph was taken; the tree immediately to its left was headed back the winter before. Note the vigorous upright shoots stimulated below the pruning cuts.

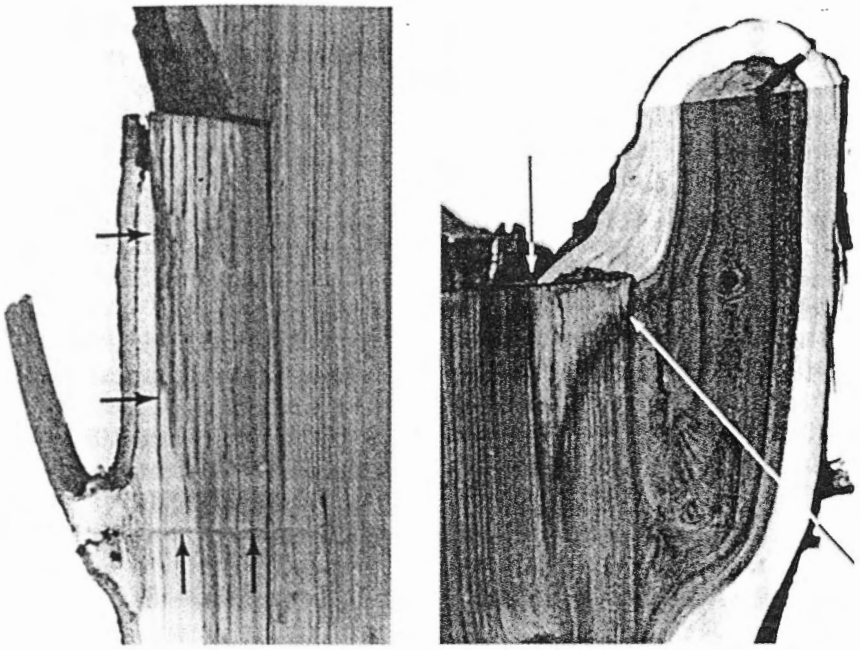


FIGURE 14-6 A latent red oak *(Quercus rubur)* bud (note the bud trace, lower arrows; the bud was formed the first year that the branch grew as a shoot) was stimulated to grow by the wound inflicted above it the year before (left). The epicormic branch formed is attached only by the current year's xylem. The barrier zone (upper arrows) formed after wounding further physically weakening the branch attachment. Vigorous sprouts forced to grow after heading cuts are similarly attached (right). Note the lack of union (between arrows) of the lateral branch that grew after this coast redwood *(Sequoia sempervirens)* was headed back (right); even though at least 10 years old, the branch is weakly attached. *(Left photo courtesy Alex Shigo and Kenneth Dudzik, U.S. Forestry Service.)*

annual rings) (Shigo and others, 1979). The closeness of a cut may reduce the number of watersprouts from the base of a cut or the strength of a lateral attachment when a branch is thinned to that lateral.

Before 1979, several authors recommended that the final cut be flush with or as close as possible to the trunk or mother branch. Flush cuts are unnecessarily large and expose trunk tissue to the possibility of decay. Shigo and co-workers (1979) observed that flush cuts on black walnut *(Juglans nigra)* often resulted in multiple ring shakes. A flush cut removes trunk cambium and severs phloem and xylem pathways for food and water in trunk tissue that was near the branch removed. Trunk tissue above and below is exposed to dehydration, with less moisture moving upward to keep the tissue moist and cool. Canker and/or death of the tissue is likely. **If possible, flush cuts should not be made.**

Since 1983, *natural target pruning* (NTP) has become the goal of most informed arborists. An NTP cut is to be made close to but beyond (1) the branch bark ridge in the branch crotch and (2) the collar at the base of the branch (Fig. 14-7) (Shigo, 1989). Such a cut retains the natural protection zone within the branch collar; should a pruning cut begin to decay, depending on the species and health of the tree, the infection would most likely be confined to branch tissue within the trunk and not spread farther.

Neely (1988c, 1991) questioned the desirability of natural target pruning (NTP) as described by Shigo in 1983, compared to what Neely called conventional pruning (CP): cutting with an downstroke the same as an NTP cut but cutting through the branch collar instead of outside it. It was thought an NTP cut frequently would have to be an upstroke so as to not injure the trunk with the chain saw (Neely, 1991). Neely maintained that a CP cut was easier and safer to make with less possibility of injury to the tree than an NTP cut. Even though CP wounds initially were 30 to 50% larger than NTP wounds, Neely (1988c) concluded that "A CP cut through the shoulder (collar) would result in a more aesthetically pleasing and faster growing callus. An (NTP) cut outside the shoulder (collar) would possibly reduce discoloration and decay in the stem or trunk from which the branch was removed. Both objectives are desirable, but only one is obtainable."

In response to a 1997 questionnaire concerning pruning cuts, callusing, and decay of mature broad-leaved trees, the authors received responses from 40 experienced arborists, well representing the continental United States.

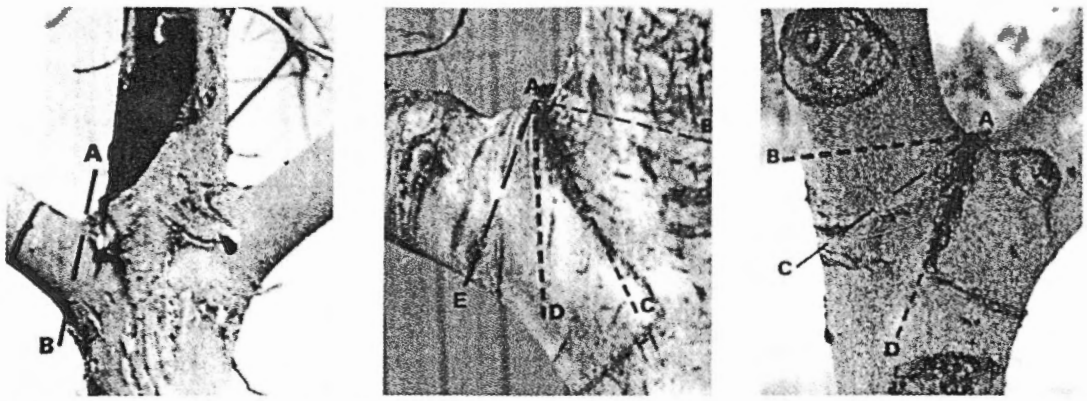


FIGURE 14-7 When the branch bark ridge (A) and the branch collar (B) can be located, remove the limb by making the final cut (A–B) just to the outside of the branch bark ridge and the collar (left).
When the branch collar is not visible or you wish to check its location (center), two estimates will help locate the proper final pruning cut: (1) the angle between an imaginary line parallel to the branch to be cut (A–B) and the branch bark ridge (A–C) should equal the angle between the branch bark ridge (A–C) and the line of the pruning cut (A–E), or (2) the angle between the branch bark ridge (A–C) and an imaginary vertical line downward from the branch bark ridge (A–D) should equal the angle between the imaginary line A–D and the line of the pruning cut (A–E). (Line A–D is often parallel to the upper portion of the branch being cut to.) Both methods indicate practically the same pruning cut (A–E) and the possible location of the branch collar (note that the line of rough bark below D is not the branch collar).

The pruning cuts (left and right photos) are made just outside the branch bark ridge and the branch collar (Shigo, 1986a). If a left stub is longer than wanted and/or the final pruning cut with a chain saw must be upward because of the angle of the cut, the pruning cut can be made just outside the branch bark ridge through the branch collar (Neely, 1988c).

The final thinning to a lateral (reduction) cut (right) should be made on a line (A–C) that bisects the angle formed by an imaginary line perpendicular to the leader or branch being removed (A–B) and the branch bark ridge (A–D). A cut closer to A–D might weaken the attachment of the limb remaining; it could split out more easily.

- Sixty percent observed or were aware that more decay occurred from cutting through a branch shoulder (collar) than cutting outside it, especially with fast-growing and/or decay-susceptible species or when wounds were larger than 200 mm (8 in.) in diameter. Forty percent of the arborists were not aware of differences in decay between the two types of cuts.
- When "above-average" arborists remove a narrow angle of attached branch, 58% of the arborists responding thought that NTP cuts were made, whereas 42% thought that CP cuts usually resulted.
- Disregarding flush cuts, 19% of the arborists thought that decay was a "serious" possibility following the removal of a lateral branch, depending on species and wound size. Thirty-one percent thought that decay was "moderately serious"; the same percentage thought that there was "slight danger," whereas 19% responded "none."
- Fifty-four percent of the arborists recommend that the callus collar around a dead branch never be violated; 29% thought that cutting into the callus was sometimes appropriate; and 17% thought that there was seldom a problem cutting into the callus collar. In fact, one usually cut into the collar on a dead branch to hasten callusing.

Some additional comments may be of interest.

- Many thought that decay was more of a problem on fast-growing species (e.g., birch [*Betula*], alder [*Alnus*], willow [*Salix*], soft maples [*Acer*], ash [*Fraxinus*], poplar [*Populus*], and Siberian elm [*Ulmus pumila*]), low vigor trees, and large pruning wounds.
- When a branch shoulder is cut, callus may not be complete at the bottom of the wound, sometimes resulting in ring shakes; some desert trees weep and the bark dies below a shoulder cut.
- The likelihood of decay of a wound is not related to the rate of callus closure.
- Several thought that, in relation to pruning, decay is overemphasized, whereas infectious vascular diseases and certain boring insects are more serious in some areas.

Some individual comments are worthy of note.

- A thinning cut on a lateral branch may weaken the branch and is more apt to decay than a similar cut on the trunk.
- Decay of pruning cuts is less likely the higher in the tree that they are.
- Instead of removing a large limb, it would be better to lighten up the end of the limb and/or cable the limb.

- An upward cut takes more time and skill but should not be more hazardous for a competent arborist.
- The quality of pruning has improved, but too many trees are still overpruned.
- "Penetration of live tissue requires justification."

NTP appears to be the goal, as are the concerns as to which branches are cut, their size, and the species involved. The mark of a satisfactory pruning cut is a decay-free result with uniform callus closure.

A summary of 315 branch failures of hardwood trees reported to the California Tree Failure Report Program supports the recommended types of pruning cuts (Alison Berry, University of California, Davis, 1998, pers. comm.). A higher percentage of branch failures (about 40%) was associated with decay on branches from which laterals had been removed by flush cuts or moderate heading, compared to branches (about 20% associated with decay) that had no laterals removed or had laterals removed by thinning cuts. In contrast, less than 5% of conifer branch failures that had been flush cut were associated with decay.

Although the foregoing remarks pertain primarily to large pruning cuts, Shigo and co-workers (1979) indicate that branch bark ridges should not be violated even in young trees. An exception might be made with vigorous, young trunks on which a close cut would reduce protruding buds and thereby reduce the number of shoots that might be stimulated to grow. Shigo (1989) disagrees, even though such wounds would be small and close quickly. Some species in cold-winter areas might be subject to radial shakes even from small flush cuts that could lead to frost cracks (see Chapter 3).

MAKING THE PRUNING CUT

Pruning shears come in a variety of sizes and shapes but are essentially of two types. One has a curved blade that cuts by passing close to a curved or hooked anvil (Fig. 14-8). The other has a straight blade that cuts against a flat anvil. The curved shears make closer cuts and are less likely to crush stem tissue, particularly if the shears are dull.

Hand (Fig. 14-9) and power saws are used to cut branches that are usually too large for pruning shears. Chain saws are used to remove large branches. They have greatly eased the effort needed in pruning, but often the chain saw blade is dropped into a branch crotch with little regard for the location of the branch bark ridge. The resulting large flush cut opens trunk tissue to the possibility of decay (cut A–D, Fig. 14-7). Some ar-

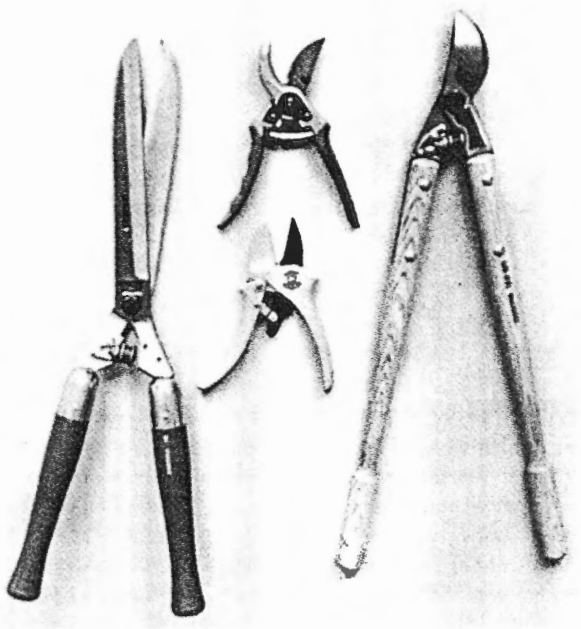


FIGURE 14-8 One-hand shears (secateurs) may be of the hook-and-blade (top center) or the anvil (bottom center) type. The anvil type bruises the bark on both sides of the cut; the hook-and-blade type bruises only on the hook side. Long-handled shears also come in varying lengths and are of both types, though the hook-and-blade is more common (right). Hedge shears have two blades of similar design (left).

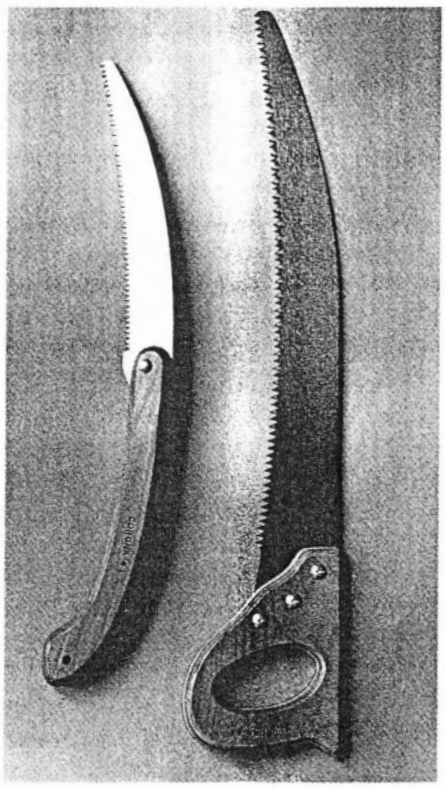


FIGURE 14-9 A hand saw that folds (left) is convenient when working with young trees because the saw can be folded and put in a pocket when not in use. A larger saw with larger teeth is more effective for more frequent sawing of larger limbs (right).

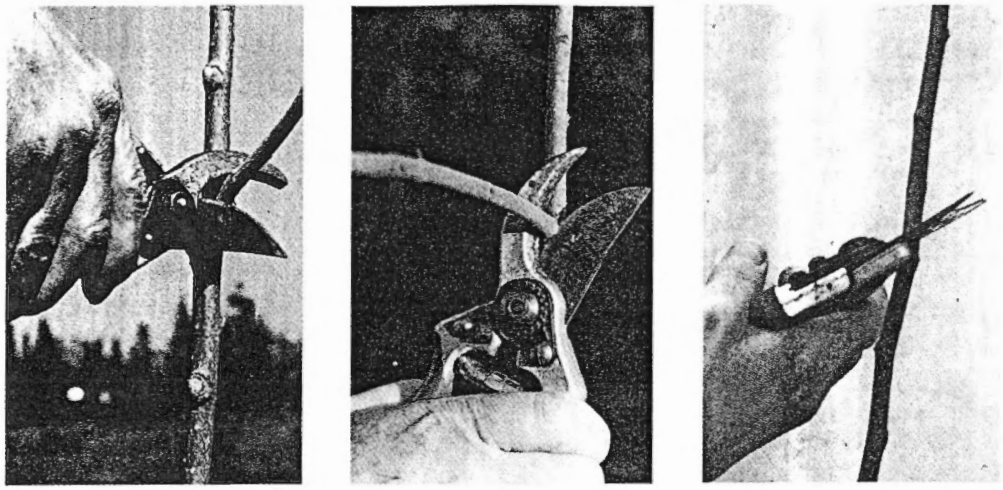


FIGURE 14-10 Make a close cut by placing the blade of hook-and-blade shears just to the outside of the branch bark ridge of the branch to be removed (left). Less effort will be required if the blade cuts up (left) or diagonally (center), instead of down. Similarly, less effort is needed to make a diagonal heading cut (right); the branch is less likely to be crushed with a diagonal cut with the sharp blade nearer the branch base than is the anvil. The top of the diagonal cut should be about 5 mm (0.25 in.) above the topmost bud left.

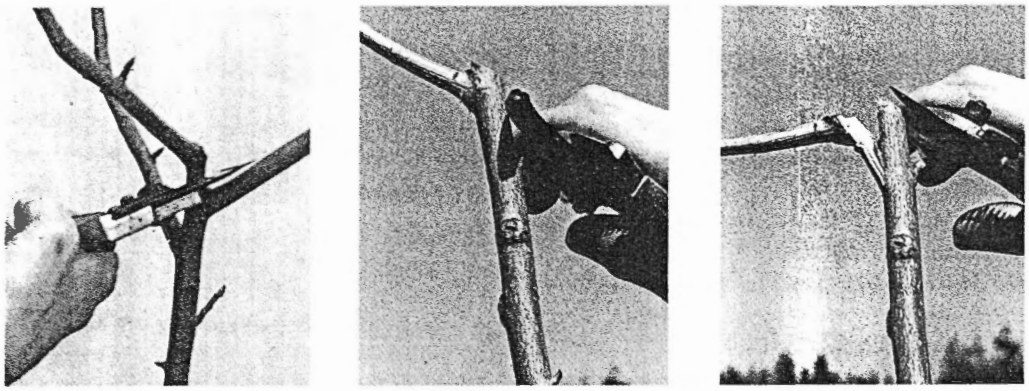


FIGURE 14-11 When thinning to a lateral (reducing), hold the shears so that the sharp blade will be closer to the branch to remain than will the anvil (left). Hold the shears so that the blade cuts up parallel to the direction of the lateral. Leave a short stub so that the branch bark ridge of the lateral is not cut (center). If the blade is placed in the crotch and the cut is downward, the branch bark ridge may be violated and often the selected lateral will split out (right).

borists prefer to use handsaws for quality work when removing limbs less than 75 mm (3 in.) in diameter.

Other mechanically powered pruning tools, particularly those on poles, greatly increase the versatility of the arborist. Even though most pruning cuts will not be accurately placed, the cuts cause few or no problems because they are usually made in smaller branches. These tools can be powered by pneumatic, hydraulic, electric, and gasoline-driven equipment adapted to be used with aerial-lift equipment. A boom-mounted power saw with a limb clamp now available can cut limbs up to 170 mm (6.75 in.) in diameter, hold the cut portion, and remove it from the tree. This equipment is particularly adapted for utility-line clearance and other situations in which limbs would be difficult to remove and lower safely.

SMALL BRANCHES A proper smooth cut can be made when removing a small branch by placing the curved blade just outside a branch collar of the branch to be removed so that the blade will cut up or from the side to the outside of the branch bark ridge (Fig. 14-10). A cut from the side with a curved blade is similar to cutting from below. A heading cut should be made diagonally instead of at right angles to the branch to be cut (Fig. 14-10). Such cuts usually take less energy because the blade will be cutting more with the grain than into or against it. The shear hook will be against the portion to be removed, so injury to tissue remaining will be minimal.

Leaving a short stub and cutting upward, instead of down, when thinning to a lateral will lessen the chance of the new terminal splitting out (Fig. 14-11). Again, have the shear hook against the portion removed. It is also easier to cut a limb

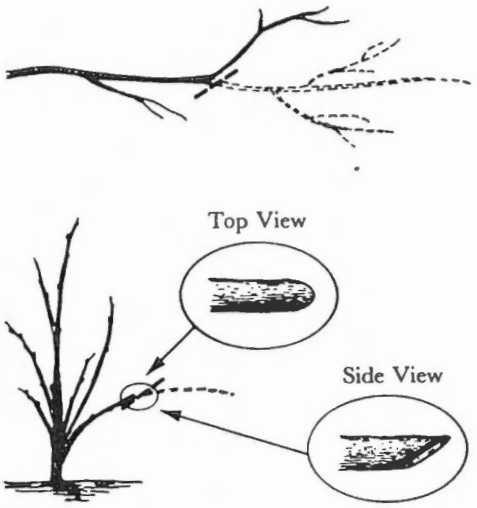


FIGURE 14-12 On low-growing shrubs, you can often hide pruning cuts by cutting back to a horizontal lateral growing from the top of the branch (top) or cutting to a bud so that the cut surface is toward the ground and away from a viewer's angle of vision (bottom).

when a deep bite is taken and the fulcrum of the shears is placed near the limb to be cut. Cutting through a limb too large for the shears or twisting them while cutting can strain and permanently damage the shears.

Where appearance is important, pruning cuts can be hidden on shrubs and low-branched trees somewhat by angling cuts away from the direction of most frequent viewing (Fig. 14-12). The plants will appear more natural if cut to a lateral arising on the top of the branch; if the pruning cuts are horizontal, or parallel to the ground, they will be hidden from view. If pruned just before growth begins, the cuts will be covered by new growth most quickly.

LARGE BRANCHES Branches larger than 25 mm (1 in.) in diameter will usually need to be cut with a saw. Branches much larger than 50 mm (2 in.) should be cut in three steps to avoid splitting back the branch and tearing the bark (Fig. 14-13). Make the first cut on the underside of the branch about 300 mm (12 in.) from the crotch. Cut the branch about one-fourth of the way through. Begin the second cut on top of the limb at or within 25 mm (1 in.) of the first cut and saw until the limb breaks off. The split is less likely to tear if the top cut is beyond the first (farther from the crotch) (Fred Roth, Pomona, CA, 1990, pers. comm.). However, when using a chain saw, it may be safer to make the top cut closer to the crotch (Capel, 1987).

Make the third cut at the crotch as described earlier; this is best done by cutting outside the branch bark ridge to just beyond the branch collar. Observations of old pruning cuts usually reveal that the most uniform closure is on those that were cut just beyond the branch collar.

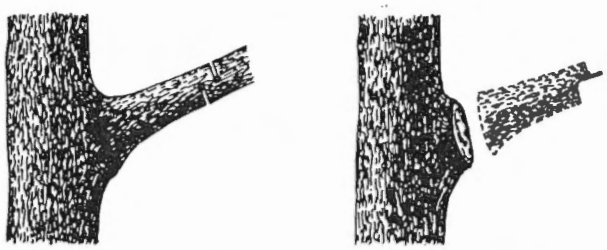


FIGURE 14-13 Remove a large limb by making three cuts. Make the first cut on the bottom of the branch about 300 mm (12 in.) from the branch attachment (left). Make the second cut on the top of the branch within 25 mm (1 in.) of the undercut. Make the final cut just beyond the outer portion of the shoulder and the branch bark ridge (right).

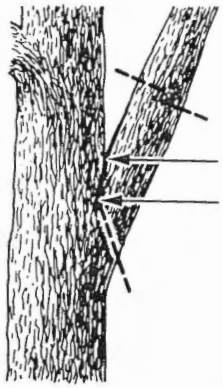


FIGURE 14-14 When removing a large branch with a sharp branch attachment, angle the third cut upward to just above the top of the actual union of the branch with the trunk. Although they touch, the branch and trunk are not united between the two arrows and the trunk does not encircle the branch.

If the branch stub is heavy, it should be removed with two cuts: the first from the bottom and the second from the top. Until cut, a heavy stub should be supported by a rope sling, which can later be used to lower the stub safely (Bridgeman, 1976). Beranek (1996) describes five basic cuts when removing branches with a chain saw.

Remove a branch with a sharp V crotch in a similar three-step process (Fig. 14-14), being aware that the actual union of the two branches is often much lower than the apparent junction. The cut should slope upward to the point of attachment at a 40° to 50° angle from the horizontal.

Some books and articles on pruning give directions for paring the edges of large pruning wounds with a sharp knife or chisel. Paring means cutting the thick bark around a wound to give a smoother, more even edge. The process is thought to speed wound closure. However, although the wound will look neater, paring does

not seem to be worth the effort. Cambium may be damaged by a mallet and chisel and will be subject to greater desiccation if much bark is cut. If bark is pared around a wound, pare only thick bark and cut no more than one-half its thickness at the wound edge. Feather out the pared bark to the bark surface around the wound (Keith Davey, Belmont, California, 1981, pers. comm.).

Trunk xylem may not completely enclose a branch on the underside so that the branch shoulder is incomplete; the trunk below such a branch will be indented or sunken. If the branch is removed, the tissue in the sunken area usually dies because of inadequate sap flow. Such results from removing a branch probably led to the recommendation by Thompson (1961), Bernatzky (1978), and Pirone (1978a) to trace (remove bark) around pruning wounds. This practice, however, is not recommended by Davey (1967), Brown (1972), Bridgeman (1976), or Shigo (1989). If the cambium dies below a pruning wound and the tree is fairly healthy, callus growth will eventually cover the exposed surface. Regardless of whether the bare wood is covered, the dead bark can be removed to live tissue. No live tissue should be cut.

DEAD BRANCH STUBS Advice has conflicted on how to remove a dead branch stub on which a collar has formed. Bartlett (1958) states that the wound will close more quickly if the cut is made into the collar of woundwood. Shigo and co-workers (1979) dissected the trunks of seven 36-year-old black walnut trees from which dead branch stubs had been pruned 11 years earlier. Ring shakes (tangential and longitudinal separation in the wood) were associated with 14 of 17 stubs that had been flush cut (more severe than leaving the branch collar base). Ring shakes were not associated with four stubs whose branch collars had not been removed from the tree. In addition, more discolored wood was associated with the flush cuts and was more subject to decay. The authors recommended that, when pruning is done late in the life of a tree, care must be taken to preserve branch collars that form around the bases of dying and dead branches (Fig. 14-15). When collar tissue on a branch stub is cut, the wound may close more quickly, but it may be more vulnerable to decay.

PROTECTING PRUNING CUTS

It is doubtful that pruning cuts can be protected from decay by an asphalt emulsion or other materials (Harris and others, 1969; Neely, 1970; Shigo and Wilson, 1977). The purpose of these coverings is to protect the cut surface from wood-rotting organisms and to reduce surface checking caused by drying. On exposure to the sun, however, most coverings may crack. Moisture from rain, sprinklers, or dew can then enter the cracks and accumulate in pockets between the wood and the wound covering. These circumstances are even more favorable for wood-rotting organisms than an uncovered wound.

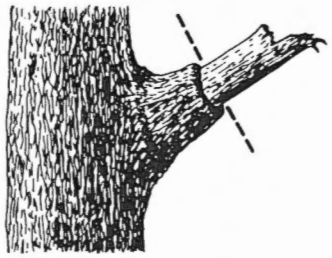


FIGURE 14-15 A dead branch stub that has a collar of live wood should be cut just at the outer edge of the collar. Some arborists think that cutting the end of the collar will hasten closure.

Reduction of dieback and drying of pruning and bark wounds by application of a lanolin paste promoted wound closure (McQuilkin, 1950). This was the main conclusion from a series of 11 studies involving several substances tested on wounds on 646 mature trees of 10 species in a second-growth woodland near Beltsville, MD. Lanolin slowed drying of wounds so that there was less cambium dieback than on control wounds, particularly around bark wounds. This hastened initiation of callus growth. Compared to the controls, the rate of closure of lanolin-treated wounds averaged 14% more per year. Lanolin was less effective on rate of closure of pruning than of bark wounds.

In a 2-year test in Michigan on three species of trees, Kielbaso and Hart (1998) compared the rate of closure of pruning and bark wounds treated with either Fongisil™, Lac-Balsam™, Ortho Pruning Sealer™, or nothing (control). Branch pruning wounds did not callus as quickly as bark wounds. Pruning wounds treated with any of the three products closed at least 50% more rapidly on white ash *(Fraxinus americana)* than the controls. There was no difference between any of the treatments and the check on red maple *(Acer rubrum)*. Pruning wound closure was 19% percent faster on Ortho Pruning Sealer-treated wounds than closure on the control or the other two treatments.

Because decay does not appear to be a problem on thinning-type cuts on most species, little justification can be given to treat pruning wounds with a sealer. If pruning or bark wounds are to be painted for the sake of appearance, bonding of the paint will be strongest if the wound is allowed to dry before applying a thin coating. Examine the wound several times in the first year and retreat it if the coating cracks.

A growth retardant, *naphthalene acetic acid (NAA),* has been added to some asphalt emulsion and aerosol paints for application to pruning cuts. This will reduce the number of watersprouts, as well as the vigor of those that grow, by about 50% (Ashbaugh, 1968). For NAA to be effective, it must be applied to the bark around the pruning wound. It is ineffective if it is placed only on the cut xylem surface (see Chapter 15).

Fresh pruning wounds attract female boring insects ready to *oviposit* and are vulnerable to infection when canker-forming fungi are sporulating. Asphalt paints applied to pruning cuts reduce borer attacks, and fungicidal paint or sprays can protect pruning wounds from certain canker fungi. Chapter 17 discusses these treatments, as well as the treatment of wounds and cavities.

PRUNING TREES

Most mature solitary trees grow quite well with little or no pruning; they have done so for centuries. But if trees are taken from their natural settings or if their natural settings, such as a grove, woodland, or forest, are changed, a number of new requirements for growth, size, and form are imposed. Many trees are no longer protected by other trees in a grove or forest but are exposed to the elements. Low branches may hamper activities. Trees may grow into utility lines, block views, obstruct the sun's rays, grow too close to buildings, become deformed or destroyed by strong winds, grow too large, or assume an unattractive shape. Growth patterns started in the nursery may be undesirable; structure may be weak. These are some of the reasons for pruning.

Many tree species naturally develop a crown with desirable branch spacing and characteristic structure. Many more branches initially grow than survive; competition and shading allow some branches to develop more rapidly than others. Smaller, weaker branches die, and many are shed in a natural pruning process. Trees allowed to develop with minimal pruning will often require only correction of obvious structural faults, such as poorly positioned or strongly competing limbs, weak branch attachments, or limbs that are damaged or dead.

STRUCTURAL STRENGTH

Certain features contribute to the structural strength of the trunk and main branches of a tree and are important to almost all trees regardless of their age or eventual size or shape.

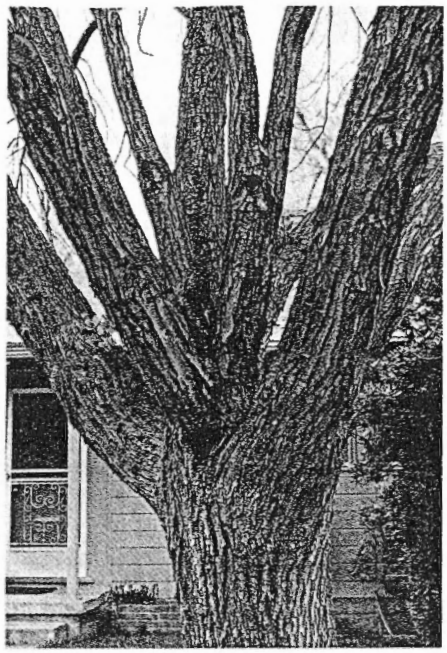


FIGURE 14-16 This Modesto ash (*Fraxinus velutina* var. *glabra* 'Modesto') was headed in the nursery or at planting; the many shoots that grew from below the heading cut were not thinned. Most of these branches have sharp angles of attachment and included bark so they are weakly attached and in danger of splitting out as the tree grows larger and continues to spread.

BRANCH SPACING When the branches of broad-leaved trees are well spaced on the trunk, both vertically and around the circumference, they are more likely to have strong attachments than when several branches arise at about the same level (Fig. 14-16). Vertical branch spacing is more critical in large-growing trees than in smaller ones. If the main leader has been headed in the nursery or at planting, close branch spacing usually develops just below a heading cut. Trees of some species with terminal-bud clusters usually form several branches close together at the base or near the tip of last season's growth (see Fig. 14-19).

BRANCH ATTACHMENTS For a strong attachment, a branch should be smaller in diameter than the trunk or limb from which it arises. Relative branch size is equally if not more important than the angle of attachment unless the angle of attachment is sharp and/or has included bark (see Chapter 2). The growth of a branch that competes with the terminal should be slowed to ensure strong attachment and to reduce competition with the leader. If there is a choice among permanent branches, usually those with wide angles of attachment and less than vertical growth should be selected; their less vigorous growth and smaller size will ensure a strong attachment.

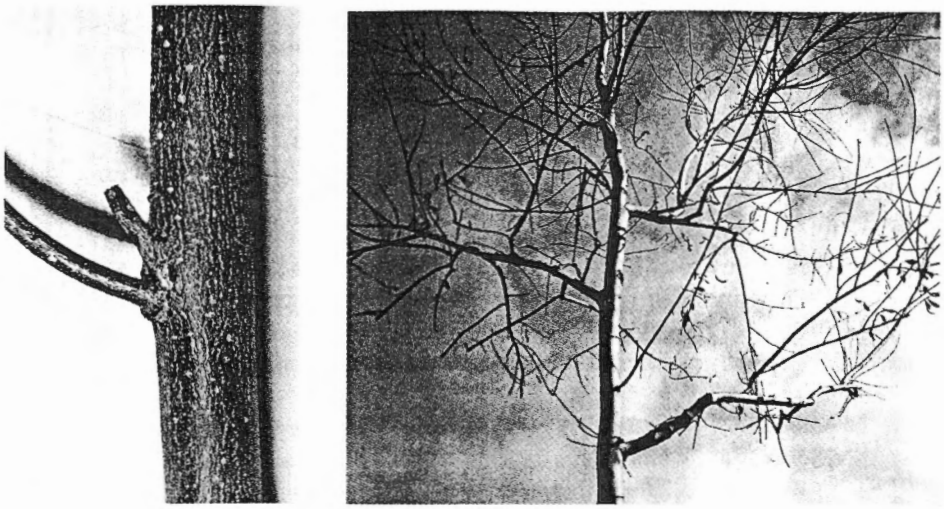


FIGURE 14-17 On young trees, shoots with sharp angles of attachment or included bark should be pruned off when they are about 150 to 200 mm (6 to 8 in.) long. A second bud will usually form a shoot with less vigor than the more upright shoots and will grow at a wider angle free of included bark; in the photograph, a short stub indicates the position of the removed shoot (left). A 7-year-old Modesto ash (*Fraxinus velutina* var. *glabra* 'Modesto') whose first laterals were removed during its first year in the landscape and later laterals thinned for vertical spacing is pictured on the right. (Compare with Fig. 14-16.)

ATTACHMENTS WITH INCLUDED BARK Included bark often occurs in sharp-angled branch attachments and between double leaders (codominant stems). Branch attachments with included bark (see Figs. 2-34b, 14-16, and 16-7) are inherently weak. The trunk is not able to grow around the branch or the other stem. Limbs or stems with included bark usually are quite upright and can grow to large size before their tops begin to spread and increase the stress on weak attachments. It is usually only a matter of time before failure occurs. Branches with included bark should be removed in young trees. In older trees, pruning to reduce the weight and spread of the branch and even rodding and cabling may be necessary to reduce stress at a branch attachment (see Chapter 17).

Attachments with included bark often occur at the height at which permanent branches are wanted. On young trees, if only weakly attached branches are at the desired height for a scaffold, prune them off. A second shoot will usually grow free of included bark and be smaller in size than the trunk (Fig. 14-17). Another alternative for a young tree with a sharp-angled branch attachment in a desirable location is to thin out up to half the leaf area of the branch to slow its growth in diameter. Usually the trunk (or larger branch) will grow around the base of the smaller branch with less likelihood of the bark becoming embedded (Brian Kempf, Visalia, CA, 2002, pers. comm.).

Some tree species have branches with extremely narrow angles of attachment, acute enough to form indentations in the trunk. Certain of these species, such as Lombardy poplar (*Populus nigra* 'Italia'), have been selected for their erect branching (fastigiate) habit. These branches remain relatively small in relation to the trunk, and there is little or no structural reason to remove them.

TAPERED TRUNKS Trees with tapered trunks can withstand stronger winds and more damage from vandals (Leiser and Kemper, 1973). A tapered trunk decreases in diameter with height. A tapered trunk free to move will more easily bend with the wind providing a fairly "uniform distribution of surface-bending stresses" along the trunk (Mattheck and Kubler, 1995). If the stress is not uniform, the trunk will grow attempting to make it so. The tops of trees with well-tapered trunks and branches bend more in a wind than those with less taper. This reduces the danger of a broken trunk and branches or an uprooted tree. Exposed to periodic winds during the growing season, the tip of a leader may bend far enough to be nearly parallel to the wind, relieving almost all stress on the immature wood of the tip. Unless the wind is persistent, terminals of most species will return to vertical when the wind subsides. Temporary branches on the trunk of a young tree will increase trunk taper, improve flexibility, and protect it from the sun and vandals.

Using computer modeling and experimental tree tests, Leiser and Kemper (1973) found that stress is more uniformly distributed along the trunk and branches of a tree that has at least one-half of

its foliage on branches originating in the lower two-thirds of the tree.

The 2001 ANSI A300 standard (Section 5.6.2.1) states "Thinning should result in an even distribution of branches on individual limbs and throughout the crown." The left tree in Figure 2-15 and the right one in Figure 6-10 meet both the 1995 and the 2001 A300 standards, but in a storm would fall short of being able to uniformly distribute stress along their trunks and would be more subject to damage. More important than *"even distribution of branches on individual limbs through out the crown"* is to have a proper *"live crown ratio. Best Management Practices* recommends that the *"live crown ratio"* should be no less that 66% (2/3) the height of a tree (Gilman and Lilly, 2002). Such a live crown ratio agrees fairly close to the findings of Leiser and Kemper (1973).

LONG AND SHORT PRUNING

Trees can be trained to different forms and styles. Most forms, however, are created and maintained by pruning primarily in one of two fundamentally different ways. They are distinguished by their cultural origins, the techniques used, and their effects on the physiology of the plant. *Short pruning*, which is of Mediterranean origin (14th century), is used to shape and maintain trees in artificial geometric forms [*architectural pruning* which includes: *rideau* (screen pruning), *pollard, espalier, pleach,* and *topiary* described later in this chapter]. *Long pruning*, although practiced for centuries, was so labeled more recently (18th century) at least in central Europe. It is used to maintain trees in their natural shape under artificial conditions (Raimbault, 1998).

Different styles of pruning affect the distribution of carbohydrate reserves, photosynthetic activity, and growth. Working primarily with the commonly used plane tree *(Platanus* x *acerfolia),* lime *(Tilia platyphyllos),* and horse chestnut *(Aesculus hippocastanum)* species in Europe, Bory and others (1996) report that in long-pruned *(freeform or natural form)* trees, the root collar and lower trunk are the main storage zones for starch-type products. The amount of starch in the trunk decreases with increasing height. In like manner, starch content is greatest at branch bases and decreases toward their tips. These starch gradients persist throughout the year.

In contrast, short pruning or shearing led to important seasonal variations in starch content in the roots and trunk as well as seriously upset the compartmentalization process (Bory and others, 1996). Branch attachments and bases were no longer important storage sites. The richest areas in starch were in the small woundwood calluses in the crown of a tree resulting from the repeated prunings each year.

The main starch storage sites for pollarded (short-pruned) trees were in the heads (knobs at branch ends from which shoots usually are pruned annually; also known as *tetes de chat* and cat heads). Seasonal movement of starch products occurred in the main roots, but only low amounts accumulated in the trunk, main branches, and attachments. However, pollard heads contained 30 to 60% of all storage carbohydrates in the aerial parts of the three species studied.

These findings provide evidence that, for long-pruned trees, wounds made by thinning and thinning to lateral cuts (removal and reduction cuts) would be well supplied with energy for protection and callusing, but heading cuts would be more vulnerable. Likewise, current and 1-year growth could be safely headed from short- and pollard-trained trees, but removing larger branches from these trees would create more vulnerable wounds because of lower-than-normal carbohydrate levels. In plane trees where pollarding was done only at 4-year or longer intervals or stopped altogether, the starch reserves in the knobs slowly moved into the new shoots. The knobs had reduced carbohydrates, which might slow callus growth and be more vulnerable to pathogens. These results led to the recommendation that with mature trees it would be unwise to change from short- to long-pruning styles, or vice versa, without good reason. Also, more serious carbohydrate storage problems with mature trees would occur if short-pruning were abandoned compared to stopping pruning of long-pruned trees.

SUMMER PRUNING Bory and others (1996) observed in mature lime (linden, *Tilia platyphyllos*), plane tree *(Platanus* x *acerifolia),* and wild cherry *(Prunus)* species that heading currently growing shoots 50% in early summer (end of June in France) 'triggered a reactivation of basal leaves (on shoots pruned) that had already gone into senescence.' Leaf carbohydrate storage decreased, chlorophyll increased, and photosynthesis was stimulated in the remaining basal leaves. An increase of 35 to 45% in carbohydrates was observed in the crowns and trunks of trees so pruned.

This may explain why trees and shrubs sheared in the summer are not noticeably weakened by the practice. In fact, it supports the practice that summer pruning of current growth of temporary branches and those competing with the leader or potential permanent branches on

young trees will increase trunk caliper and taper, and root growth.

LONG PRUNING: NATURAL

Long-pruning techniques probably were not given much thought until large, mature trees were growing in parks, along streets and roads, around public buildings, and in estate and home yards. Most trees needed more than lower limbs removed for clearance.

Raimbault (1996) and associates at the National Engineers School, Paysage, France, analyzed growth responses and the resulting architecture of broad-leaved, decurrent trees to long pruning at different stages of a tree's life. Unfortunately, at least in the United States, many newly planted trees had already been nursery pruned with little thought as to their mature structure.

TRAINING YOUNG TREES (PRUNING PRIMARILY FOR STRUCTURE)

Training young trees, particularly those with decurrent crown form, provides the greatest impact of any cultural practice on their future structure, appearance, and maintenance costs. The few minutes of time spent with small shears involves little cost but returns significant benefits.

"Both desirable qualities and flaws are amplified as trees increase in size; a small amount of extra time and money invested in purchasing and training quality trees pays for the effort many times over in reduced maintenance and repair costs, landscape effectiveness, and longer useful life-spans" (Scott Mayer, Seattle, WA, 1997, pers. comm.).

Usually little or no training is needed on young excurrent trees that have lateral branches on current growth such as sweetgum *(Liquidambar styraciflua)* (at least in the United States), pin oak *(Quercus palustris)*, tulip tree *(Liriodendron tulipifera)*, and most conifers (See Fig. 2-10).

Some young decurrent trees may have few or no laterals on current growth. Species such as mulberry (*Morus* sp.) and elm (*Ulmus* sp.) have weak apical control. Some lateral buds formed the previous year may outgrow the leader. A similar situation occurs when these species are headed in a nursery (Fig. 14-18). Species with decurrent form usually need considerable pruning while young in order to develop a central trunk and strong branch structure.

Some species, such as Chinese pistache *(Pistacia chinensis)*, may have leaders with few or no laterals on current growth except for a tuft of small twigs below the terminal bud. If left, the leader may be stunted and the twigs will not do much when growth resumes. Prune off all but one of the small twigs and the terminal bud.

Similarly, red oak *(Quercus rubra)*, green ash *(Fraxinus pennsylvanica)*, and other species have a cluster of buds (cluster buds) surrounding the terminal bud, resulting in several laterals arising near the same level and preventing the growth of laterals on the trunk below. Oleksak, Kmetz-Gonzalez, and Struve (1997) report that removing the cluster of lateral buds around the terminal and one or two buds immediately below the terminal cluster usually resulted in a vigorous leader and several well-spaced

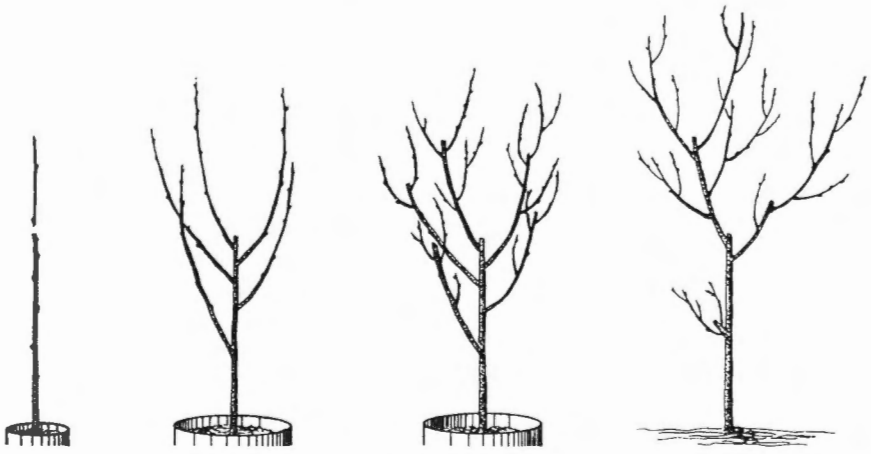


FIGURE 14-18 Container-grown trees are often headed in the nursery (extreme left) to encourage branching and to develop proportions that will be attractive at the time of sale (two center sketches). The laterals are usually headed a second time to ensure another set of branching (right center). Even for small-growing trees, most of the branches are too low; for large trees, they will also be too close together. Once the tree is in the landscape, select the top branch as the leader, prune another high branch so that it will become the lowest permanent scaffold, and remove or severely cut back the lower laterals on the trunk (extreme right).

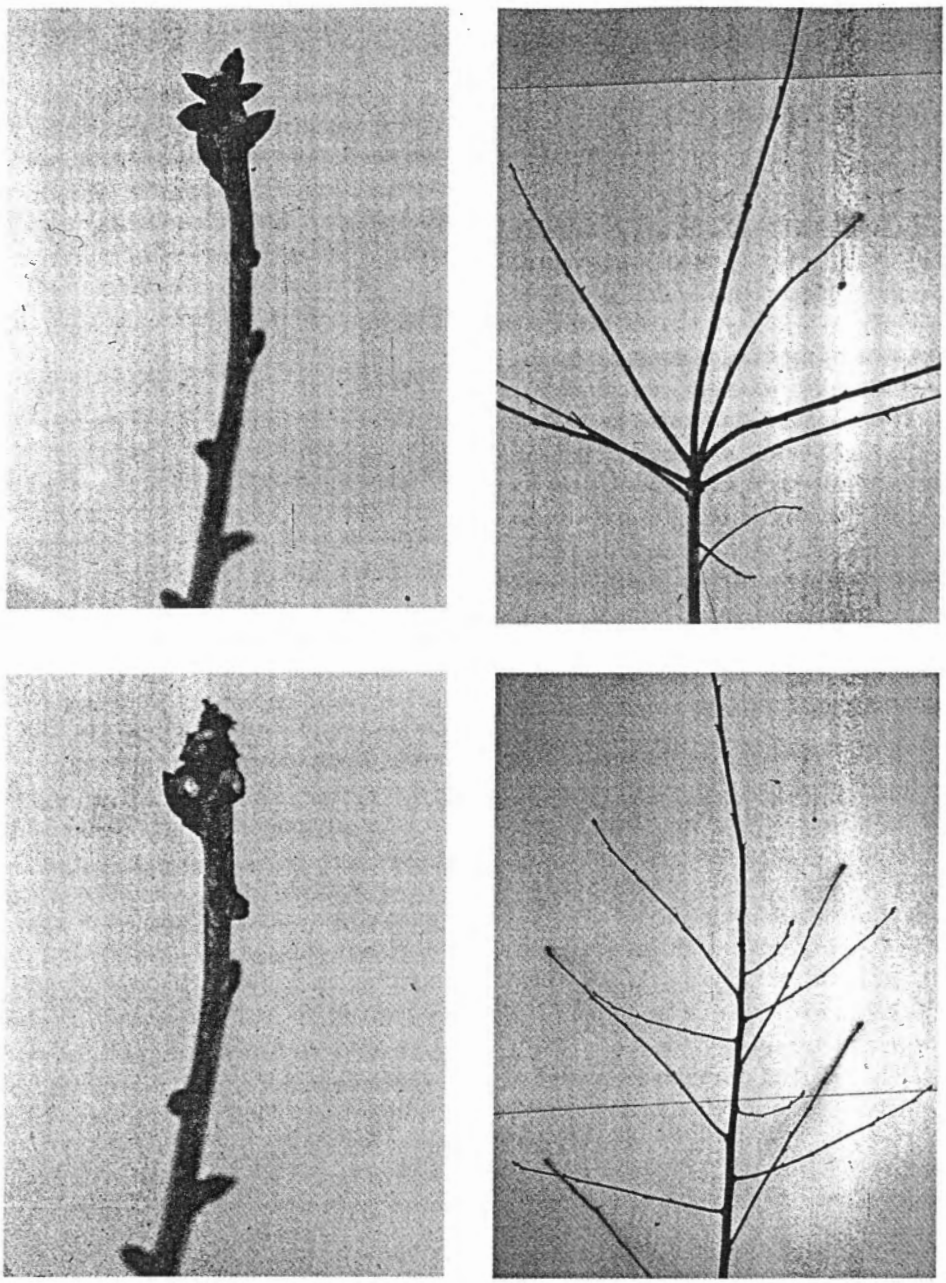
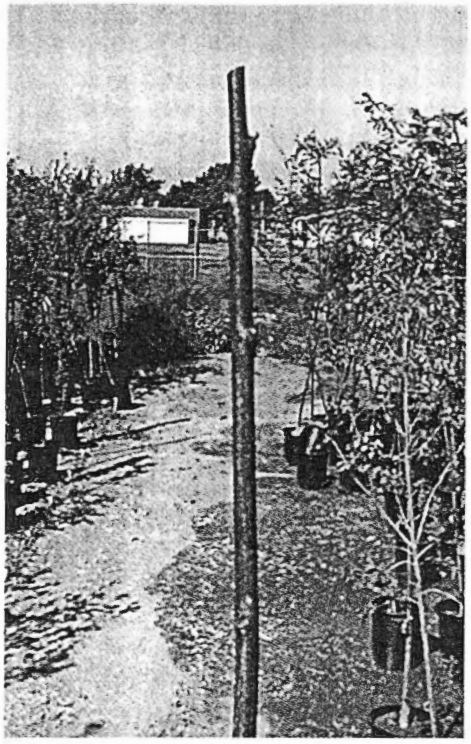
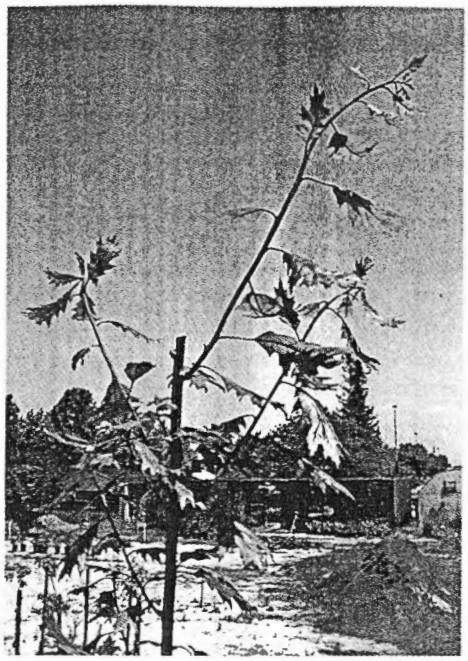


FIGURE 14-19 Red oak (*Quercus rubra*) lateral buds cluster around the terminal bud of a nursery whip (upper left); no buds were removed. The cluster buds and two or three buds below the terminal bud were removed from the leader of other nursery whips before growth started (lower left). A field-grown tree, at the end of the first growing season, from which no buds had been thinned (upper right). A field-grown cluster-bud-thinned tree the autumn after being thinned (lower right). In the spring, more lateral buds grew and were more vertically distributed along the trunk below the cluster-bud-thinned terminal (lower right) than on the leader with buds intact (upper right). The camera that photographed the two trees in the lower photographs was not the same distance from each tree. It is not easy to compare the vigor or total tree growth because of the bud-removal practice. The diameter and heights of trees in the two treatments, however, were approximately the same, with the cluster-bud-thinned trees slightly smaller, though not significantly so (Oleksak, Kmetz-Gonzalez, and Struve, 1997).

laterals on the leader below (Fig. 14-19). Barrie Coate (Los Gatos, CA, 1997, pers. comm.) did a variation of this on several oak species: Two or three of the cluster buds and the buds below the terminal are left to be shoot tipped later. "The results were similar to those reported by Oleksak and others (1997), but the laterals along the trunk and the terminal bud were good temporary branches to shade and nourish the trunk, but even at a desired height, did not appear to be potential scaffolds. Due to the laterals along the trunk, the leader made a more acceptable modest growth"





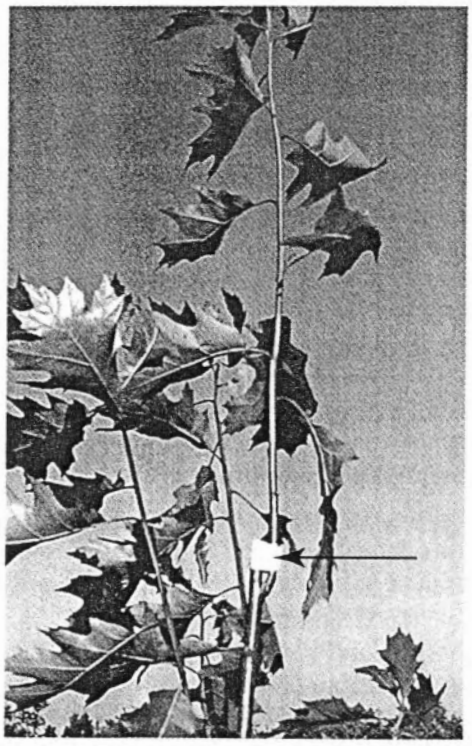


FIGURE 14-20 Vigorous red oak headed before growth begins 25–40 mm (1–1.5 in.) above a bud 300–400 mm (12–16 in.) above the height of a potential lowest scaffold (top left); vigorous shoot ready to be taped (top right); new leader taped with masking tape to the originally headed leader (bottom). Two potential lateral shoots have been stimulated to grow and could become scaffold branches. *(Photos courtesy Brian Kempf, Visalia, CA.)*

(Barrie Coate, 1997, pers. comm.). Within the height range for scaffolds, preliminary selection of scaffolds to reduce their number would improve the growth of those to be retained.

Another way to prune a tall, vigorous whip (leader with no lateral shoots) that may or may not have terminal cluster buds is to head the whip 25 to 50 mm (1–2 in.) above a bud that is 300 to 600 mm (12–24 in.) above the height of a lowest potential scaffold (Figure 14-20). Heading a vigorous whip should stimulate a good distribution of shoots from which laterals can be selected. If prevailing winds are a problem, choose a shoot heading into the wind. When this top shoot is 300 to 450 mm

(12–18 in.) long and still flexible, bend it to the vertical, parallel with the whip stub. Hold it vertically with 1.5 to 2.5 rotations of masking tape around the new leader and the headed whip. The new leader should be well attached by the time the tape disintegrates. New lower shoots should provide a good selection of potential scaffold branches (Brian Kempf, 2002, pers. comm.). If laterals are wanted on the new leader, pinch it (see Figure 14-25).

Species whose young trees have problems with several closely spaced laterals concentrated below the previous season's terminal bud should be pruned by one of the above described methods.

PRUNING AT PLANTING

Although widely recommended in the past to compensate for root loss, pruning at planting has been brought into question. ANSI A300 (Part 1, 2001) states in section 5.7.1.3 "At planting: pruning should be limited to cleaning"; which in section 5.6.1 indicates that, cleaning is "Selective pruning to remove one or more of dead, diseased, and/or broken branches." However, if properly done, pruning trees at planting not only should ensure survival but also begin to direct growth into future scaffold branches by removing or pruning back competing branches.

In experiments in Oklahoma at the planting of bare-root deciduous trees, Whitcomb (1987) removed up to 45% of the tops of seven irrigated landscape and four fruit tree species. Pruning severity had little or no deleterious influence on tree survival. At the end of the first growing season the number and weight of leaves per tree of each species were similar regardless of pruning severity.

Thinning (removal) and heading pruning at planting of 2-year-old, bare-root crab apple *(Malus sargentii)* and plum *(Prunus cerasifera)* trees in Colorado were compared to no pruning (Evans and Klett, 1984, 1985). Pruning severity of the crab apple was 50% removal of branch length and number of buds on each tree by either thinning or heading. Thinning (removal) severity of the plum trees ranged from none (check) to from 21 to 78%. Pruning reduced total leaf weights the first year only on the crab apple but not on root weights or leaf to new-root ratios of either species.

However, if water (rain or irrigation) is limiting, pruning at planting may be even more advantageous. Five bare-root, deciduous tree species in England each made more growth the more severely they were pruned after planting (presumably they were unirrigated) (Gilbertson, Kendle, and Bradshaw, 1987). Vigorous water oak *(Quercus nigra)* seedlings in Louisiana (Adams, 1984) and vigorous blue oak *(Q. douglasii)* seedlings in the California Sierra foothills (McCreary and Tecklin, 1993) pruned back at least 50% at planting made 90% and 400% more total top growth the first year, respectively, than unpruned seedlings. Growth of the pruned compared to unpruned trees the second year was slightly better in Louisiana and 12 times greater in California. These trees were not irrigated.

It is known that removing the terminal bud of a 1-year-old seedling whip (single stem) that is just beginning to grow usually will delay the initiation of root growth until another bud begins to grow (Richardson, 1958). Even so, pruning a newly planted tree, even heading a single whip, would delay rooting only a short time and have little effect on the amount of future growth as shown in numerous experiments.

If sufficient moisture is available, the pruning of bare-root, container, and B-in-B plants should be restricted to removing damaged branches and pruning back or removing branches that would compete with the leader or potential scaffold branches. Even if the trees did not make as much total growth because of the pruning, the growth would be where it was needed. Strong structure is extremely important in large-growing decurrent trees.

TRAINING IN THE LANDSCAPE

The first 3 to 5 years in the landscape are critical in the training of most decurrent trees. Pruning should be only extensive enough to direct a tree's growth and correct structural weakness. Trees that are pruned lightly or not at all usually will make the most total growth.

Costello (1999) describes and demonstrates the five essential steps in training young landscape trees. At each pruning, each step should be considered in sequence:

1. Remove broken, injured, diseased, dying, and dead branches.
2. Select or maintain a leader and remove or cut back competing branches.
3. Select and establish the lowest permanent scaffold branch with a strong attachment. Remove or cut back lower and competing branches.
4. Select scaffold branches that are well spaced vertically and radially on the trunk.
5. Select temporary branches on the trunk below the lowest scaffold and possibly between the main scaffolds. Keep them small.

Occasionally, a tree will be so vigorous that the pruning needed to retard growth of less desirable branches would excessively stimulate scaffold

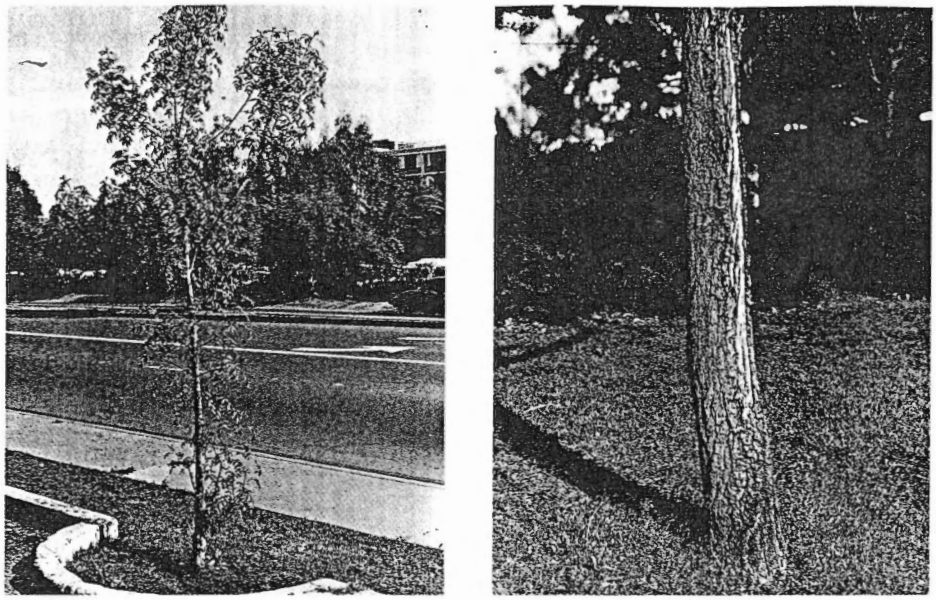


FIGURE 14-21 Temporary branches, particularly on the side exposed to the afternoon sun, can shade and nourish a trunk (left); unprotected bark, particularly on young trees of low vigor, is often killed by the sun (right).

branches. Extremely vigorous young branches may bend below a desired angle of growth and are more susceptible to breakage, particularly in windy sites. In such cases, even on future scaffold branches current growth should be headed to return the branch to a more desired angle of growth. Head to a bud pointing in the desired direction of future growth. Start modestly and increase the severity until it is seen how much is needed. Only one or two shoots from headed prospective scaffold branches should be retained; if two are retained, the lower one should be smaller or be kept smaller. If needed, delay fertilization and, in extreme situations, reduce irrigation to slow growth.

TEMPORARY BRANCHES Branches to be retained as temporaries on young trees during the first 3 to 5 years in the landscape are those too low to be permanent and those between potential scaffolds that ultimately would be removed. Temporary branches strengthen and protect the trunk (Fig. 14-21). When young trees have not yet reached the desired height for the lowest scaffold, treat the laterals as temporary branches. At planting, during the growing season, and at each dormant pruning select laterals of weak to moderate vigor to remain as temporary branches. Remove vigorous low-growing laterals if less vigorous ones can be selected. Short, horizontal laterals can be left unpruned. If there are not enough low-vigor laterals to shade the trunk, more vigorous ones can be selected but kept pruned back.

Studies in France (Bory and others, 1996) indicate that heading currently-growing temporary shoots stimulates basal leaves to supply more carbohydrates to the remaining portion of the shoots, the branch to which they are attached, the trunk, and possibly the roots. Head back shoots 50% when they reach 250 to 350 mm (10 to 14 in.) or less in length. This will keep them in bounds and reduce competition with the leader. Examine young trees at least two to four times during the growing season. Pinch off or back new shoots from the previously headed laterals. This requires little time and provides an opportunity to observe and correct other problems that may arise.

Although the angle of attachment and spacing along the trunk of temporary branches are not important, they should be 150 to 300 mm (6 to 12 in.) apart. Closer spacing may unduly retard overall increase in tree height. Temporary branches on the west side of the trunk, which is exposed to the afternoon sun, reduce the possibility of sunburn.

As a young tree develops a sturdy trunk and upper growth shades the trunk, temporary branches can be reduced in number and eventually eliminated. Two or three years after planting, when the trunks of small trees (such as crape myrtle [*Lagerstroemia indica*] and Japanese maple [*Acer palmatum*]) are 50 to 75 mm (2 to 3 in.) in caliper and those of large trees (such as elm [*Ulmus*] and sycamore [*Platanus*]) are 75 to 100 mm (3 to 4 in.) in caliper, the number of temporary branches can be reduced over a 2- to 3-year period. Remove the largest temporary branches first to ease the transition and to keep the pruning wounds small.

Unfortunately, many young trees come from nurseries with no laterals along the lower trunk. Thus, any shoots that do begin growth in this region

should be encouraged. If a trunk is spindly and could benefit from the nourishment and protection of temporary branches, it may be possible to stimulate their growth by notching the trunk. With a sharp knife remove a slit of bark 1 to 2 mm (0.06 in.) wide around 15 to 25% of the trunk circumference just above each bud a month before expected growth to help ensure the growth of the bud. The notch reduces the flow of bud-inhibiting substances (auxins) from the terminal bud and developing leaves higher on the stem (apical dominance).

A less precise method of encouraging shoot growth is to bend the trunk so that the side where the shoots are wanted is uppermost. The terminal portion of the leader is held nearly parallel to the ground. This should take place about 2 weeks before buds are expected to grow and should continue until buds break, possibly within 3 to 6 weeks. The trunk must be protected from sunburn with shade or white latex paint. After the buds break, the tree can be returned upright. Container-grown trees can be laid on their side before planting to encourage new shoots along the upper side of the trunk; again, the plant must be protected from the sun. Inclining the trunk from the vertical decreases bud-inhibiting substances on the upper portion, thereby releasing the buds but primarily on the top of side of the trunk.

Notching and bending are not so much recommended here as used to exemplify the manner in which a basic knowledge of plant responses might be used to improve growing techniques. Temporary branches often have been pruned off by uninformed people for a variety of misguided reasons. More education is needed.

HEIGHT OF THE LOWEST PERMANENT BRANCH Height of the lowest branch is usually prescribed by the function of the tree in the landscape. The lowest permanent branch can be only several centimeters (or inches) to more than 4 m (12 ft) from the ground, depending on how the tree is to be used. A certain clearance is needed over streets or patios, but limbs may be lower if they will not interfere with traffic or the use of ground underneath the tree. The position of a limb on a trunk remains essentially the same throughout the life of the tree. In fact, as a branch increases in diameter, the distance between it and the ground actually decreases (Fig. 14-22).

VERTICAL BRANCH SPACING In many decurrent species, branch spacing is important for future leader dominance, structural strength, and appearance of the tree. Two or more vigorous branches arising at or near the same level on the trunk are apt to choke the leader and limbs above. This is especially true in fast-growing trees whose laterals grow from buds formed during the previous season, such as flowering fruit trees, mulberry *(Morus)*, and callery pears *(Pyrus calleryana)*. On mature trees, closely spaced scaffolds break out more easily than those with greater spacing (Fig. 14-16). Closely spaced scaffolds usually have fewer laterals and thus develop as long, thin branches with little or no taper and poor structural strength (Fig. 14-23). These branches are particularly susceptible to snow and ice breakage; if one branch is lost, others are more likely to fail.

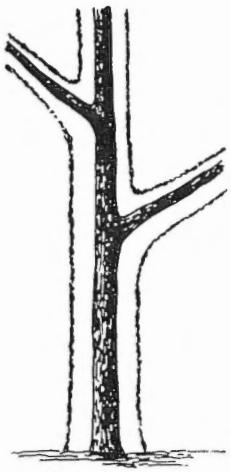


FIGURE 14-22 As a tree grows, branches retain their position on the trunk and at the same time increase in diameter, becoming closer to the ground.

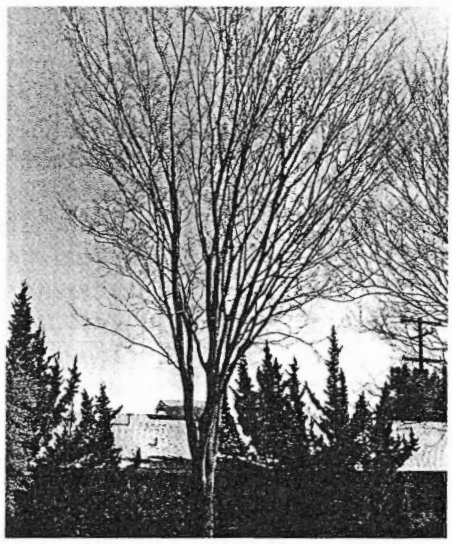


FIGURE 14-23 The three scaffold branches closely spaced vertically on the trunk are out growing and choking the original leader of this tree. In addition to the tree's increasingly dangerous structure, the leader is being outgrown as can be seen by its reduced top growth. Five or six pruning cuts when the tree was young could have prevented this (see Fig. 14-24).

Vertical spacing between permanent branches should be greater on a large-growing tree with large-diameter branches than on a tree of smaller mature size. For deciduous shade trees that will reach or exceed 12 m (40 ft) in height at maturity, the commonly recommended spacing between major scaffold branches is at least 45 cm (18 in.) vertically, and preferably 60 cm (24 in.) or more. Many attractive and safe mature trees have branches 1 to 4 m (3 to 12 ft) apart. Vertical branch spacing can be less on smaller trees (Britton, 1995), "15 to 20 cm (6 to 8 in.)" (ANSI A300, 1995).

On excurrent trees, vertical spacing is less critical because the branches usually are only moderately vigorous and more horizontal and seldom compete with the leader. Little or no pruning is needed except when an occasional limb becomes overly vigorous and competes with the leader (Fig. 14-24a).

RADIAL BRANCH DISTRIBUTION Select five to seven scaffolds to fill the circle around a trunk without undue crowding (Fig. 14-24b). This can be done in one or two rotations around the circumference. Although an ascending spiral may appear more symmetrical and pleasing to the eye, branches seem to grow equally well even though they do not arise from the trunk in a spiral. In large-growing trees, avoid allowing one limb to grow directly over another if they are less than 4 m (12 ft) apart; otherwise, neither can develop properly (Fig. 14-24b): The lower branch will be shaded and develop few or no ascending branches; the upper one will be less vigorous in the presence of the lower, which competes with it for water and nutrients.

SELECTING SCAFFOLD BRANCHES Examine the vertical and especially the radial distribution of potential scaffold branches. **If one sector of a tree has few branches from which to choose, it may be wise to select the scaffold in that sector first and then the others in relation to it.** This ensures the best radial symmetry and selection. Depending on the tree's growth rate, scaffold branch selection may take 2 to 3 years to complete.

PRUNING DURING THE GROWING SEASON If growth is vigorous, do not wait 2 to 4 years after planting, as is often suggested, but direct growth when the tree is active as well as when dormant. Pinching the growing point (heading) or complete removal of a shoot (thinning) will direct growth into the leader and remaining shoots. Pruning during the growing season is usually confined to temporary shoots and branches. On a young tree, the leader or a scaffold will only occasionally need substantial pruning. Shoots that are too low, too close, or too vigorous in relation to the leader or selected scaffolds should be pinched or removed. This only takes a few minutes for a young tree, and the health and well-being of the tree also can be checked.

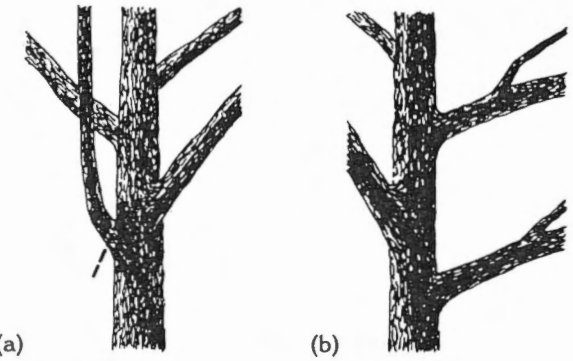


FIGURE 14-24 (a) Occasionally, a young vigorous branch (watersprout) will grow more upright than the others and compete with the leader. Unless the sector in which it grows is devoid of limbs, the upright branch should have been removed earlier (broken line). (b) On large-growing trees, the permanent scaffold branches should be well-spaced vertically and radially. Proper vertical and radial distribution allows limbs adequate space for development, which is important for strong structure and appearance.

In many species, few or no laterals may form on a currently growing leader. Even in the second year, some trees may develop few or no laterals, except near the previous season's terminal. On vigorous leaders, it is possible to obtain branches during the growing season by pinching the growing point when it has grown a little above the desired height of a lateral (Fig. 14-25). Remove about 50 mm (2 in.) of the tip, and buds below the pinch will begin to grow. One will usually be more vigorous and upright than the other shoots. It can become the leader, although it may need encouragement. Choose a second developing shoot below the leader as a lateral by pinching the tips of the other shoots that were forced. On a vigorous tree, the new leader may in turn be pinched when it reaches a height that is suitable for another lateral branch. On a vigorous tree it may be possible to force as many as three well-spaced laterals in one season. Without such pinching, the leader might require severe heading during the dormant season in order to get one lateral the next year at the height at which the lowest lateral is desired.

Some species may develop a vigorous stem with few or no laterals. In order to obtain lateral branches where wanted, the year-old stem should be headed before growth begins to encourage laterals to form below the heading cut.

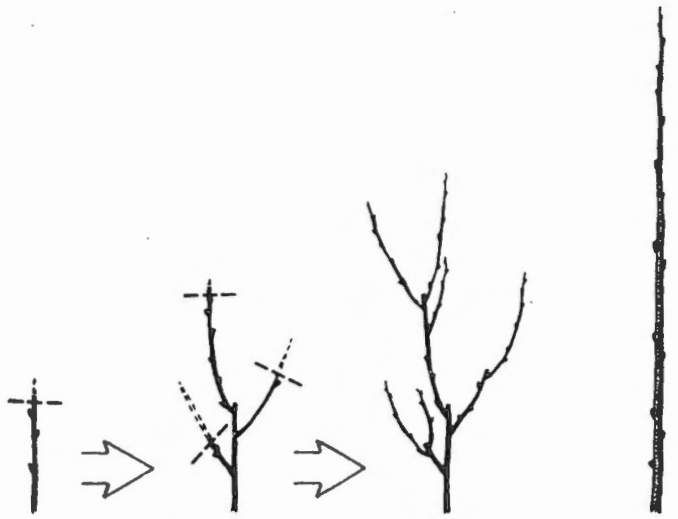


FIGURE 14-25 Vigorous young trees with strong apical dominance may grow 2 m (6 to 7 ft) with no lateral branches the first year (extreme right). However, if the leader is pinched during the growing season when the terminal is 25 to 50 mm (1 to 2 in.) above the height desired for the first scaffold (extreme left), two or more shoots usually can be encouraged to grow. Select the most vigorous and upright shoot as the leader; select a second one below the leader as a lateral and head it lightly if necessary; head the others more severely (left center). Repeat this process as long as a vigorously growing leader can be selected (right center).

A young tree should be left with a few more branches than will ultimately be wanted above the height of the lowest permanent scaffold; some will grow more and begin to dominate the others. If the leader has not been headed, dominant branches are usually fairly well spaced. Severe pruning of young trees may remove potentially dominant limbs, leaving some that will not develop as readily. For this reason, it is best to remove or prune back those branches that are clearly unwanted and those that compete with the leader or other more desirable branches. The growth of these branches can be slowed by pruning to keep them in balance. Remove or cut back competing branches that

- Grow from the same node or within 100 to 150 mm (4 to 6 in.) of a more desirable branch(es)
- May outgrow the leader or other potential scaffolds
- Have sharp angles of attachment, particularly with included bark in the crotch (see Figs. 14-16 and 14-17).

Developing scaffold branches can be kept in balance with a new leader and the rest of the tree either by thinning laterals or by pinching the tips of the most vigorous laterals during the growing season. Growth can be channeled where it will be most effective. For a tall, upright trunk, keep the leader in control by preventing laterals from outgrowing it. Uncontrolled laterals can outstrip the leader in decurrent species and occasionally even in excurrent species.

LOW BRANCHES Nursery trees with low, large laterals close together can be a problem in the landscape. Such branching may be satisfactory for small trees in areas with little activity but not for large trees or in active areas. At planting, it may be possible to select the most upright and vigorous branch to become the leader. A second branch may be chosen as the first scaffold if it is high enough above the ground for the site. In some cases, only a leader can be selected. Some branches may need to be thinned and those remaining treated as temporary branches.

The sooner corrective pruning is done, the less dwarfing it will cause in the long run. In some cases, however, the pruning needed may be so severe that it should be done over at least 2 years. This happens more often with older nursery trees than with young ones.

UPRIGHT VERSUS HORIZONTAL BRANCHES An upright branch will usually be more vigorous than one that is less upright, and it may be wanted as a permanent branch if its position is desirable. Because the branch may, however, compete with the leader, a more horizontal branch should usually be selected or the upright one headed above a bud headed in the desired direction of future growth. Whenever a potential scaffold is headed because of its vigor, it should be watched and the number and direction of new shoots controlled.

In contrast to upright branches, those growing more horizontally are usually of lower vigor. Horizontal branches will seldom compete with the leader and are desirable as temporary branches to protect and nourish the trunk. Unless they become too long, the smaller ones can be left unpruned. Horizontal or drooping limbs may become a problem as a tree matures, however. If they droop because of excessively vigorous growth, buds behind the top of the bend often grow. The new shoots usually will be more upright. Select the well-placed shoots from among these by thinning the lateral back to the selected shoot (Fig. 14-26). Thin out other new shoots that

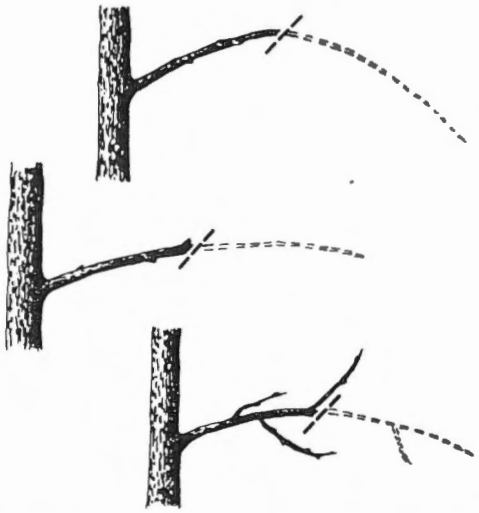


FIGURE 14-26 To cause a horizontal branch to grow more upright, prune it back to an upright lateral (bottom), cut it back to an upward facing bud (center), or cut it back near the top of an arch (top).

might compete or interfere with the one selected. If the horizontal or drooping limb has no well-placed upright laterals, head the branch to an upward-growing bud slightly behind the top of the bend or to a point where you wish a lateral to form. Certain trees (such as weeping willow [*Salix babylonica*] and Chile mayten [*Maytenus boaria*]) are chosen for their drooping branches, and the characteristic can be exploited.

WINDY SITUATIONS Prevailing winds can deform trees so that most of the growth is on the downwind side. (Planting in windy locations is discussed in Chapter 8.) Depending on wind conditions and the type of tree, the leader may or may not be bent by the wind. Many trees, such as conifers, *Liquidambar*, and plane tree *(Platanus)*, resist deformation by moderate prevailing winds even though they may have few limbs on the windward side (see Fig. 2-30).

In windy sites, thin the top of the tree by removing small branches, particularly near the end portion of limbs, to reduce the tree's wind resistance. Laterals develop more on the downwind side. In certain situations, such a condition may be picturesque and desirable. If it is not, thin out branches on the downwind side to laterals to keep the tree more symmetrical (Fig. 14-27). Select branches that grow into the prevailing wind. Select more upright branches and a companion in the opposite direction if they grow at right angles to the wind. A single branch at right angles to the wind is likely to twist the trunk and itself with the wind. Such a branch will be less likely to withstand a strong wind from the opposite direction (Mattheck and Breloer, 1994). A curving branch on the windward side

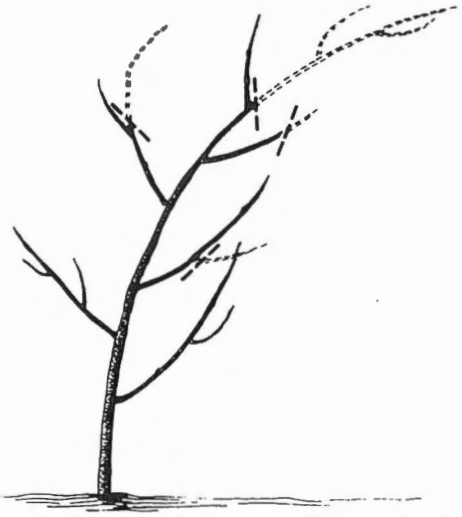


FIGURE 14-27 A tree deformed by the wind can be made more symmetrical if branches on the windward side are pruned back to a lateral or a bud pointing into the wind, if the leader is thinned to a more upright lateral, and if some of the downwind branches are shortened.

FIGURE 14-28 When a leader has been outgrown by one or more laterals, thin the leader back to one of its most vigorous and upright laterals, which in turn will become the leader.

should be headed (cut) near the point at which it begins to bend with the wind; prune to a lateral or a bud pointing into the wind. Repeat this each time the endmost new shoot starts to bend with the wind. Branches so pruned will be stockier and more resistant to bending. In some locations and for some species, windbreak protection may be needed.

MAINTAINING A LEADER Sometimes a leader may be outgrown by a vigorous lateral, which may make a better leader than the original one. If so, prune the leader back to the highest dominant upward growing lateral (Fig. 14-28). Do

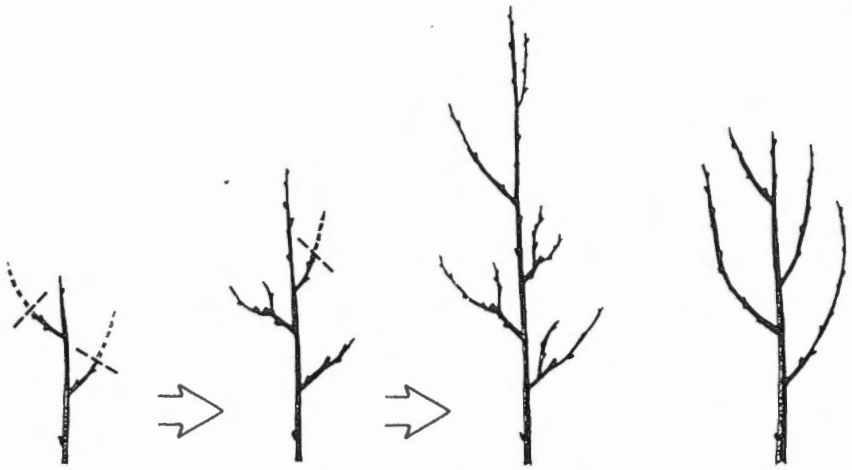


FIGURE 14-29 A leader can be retained by heading back laterals that may compete with it (extreme left); prune these laterals fairly severely if they are temporary (left center). The tree will grow taller with possible permanent branches better positioned (right center) than if it had not been pruned (extreme right).

FIGURE 14-30 A tree can be a sculpture in a landscape: The leader of this 50-year-old California sycamore *(Platanus racemosa)* was staked to the ground for the first 3 years after planting . A multitrunked tree can also be a sculpture, but be sure the trunks (low branches) have strong attachments.

not leave part of the original leader with a smaller lateral above the one selected to become the leader with the hopes that the smaller one will develop into a scaffold. It will seldom make a desirable scaffold because most of the new growth will go into the new leader and lower branches. If caught young enough, laterals can be headed to keep the leader in control (Fig. 14-29).

OTHER TREE FORMS Although the previous discussion emphasizes the development of a well-tapered single trunk with well-spaced scaffolds, this does not mean that other tree forms are not recommended. The comments focused on developing a structurally strong tree and can be applied to whatever structure is desired. Trees pruned according to these guidelines should perform well and long. Plants can become fine sculptures in the landscape either naturally or through the skill of a horticulturist (Fig. 14-30).

TRAINING IS MORE THAN PRUNING Although pruning is the primary method of training young plants, other procedures may be used. Staking may be used to encourage a straight trunk or a more upright growth habit, although support staking has limits for most species if a sturdy trunk and well-proportioned top are to develop (see Chapter 8). Branches may be tied to supports to create special forms, cover a wall, or form a screen; espalier is a prime example (see Figs. 14-40, 14-41, and 14-42).

The vigorous branches of young flowering fruit trees, particularly pear and apple, are sometimes bent and tied so that their tips are at or below the horizontal to encourage flowering and fruiting at a young age. Such a practice also increases the spread of trees that might otherwise be quite narrow. An upright limb can be made to spread if a length of a branch pruning is wedged between the trunk and the limb (Fig. 14-31). First determine that the branch attachment is strong and the limb smaller than the trunk or another branch. The spreader can be left in place for 2 or 3 years and will be more effective than pruning to an outside bud, which in turn would most likely grow upright. Spreading branches can be held more upright (see Chapter 17).

PRUNING MATURE TREES

Scaffold limbs and the main structure of a decurrent tree usually can be selected by the second to fourth year, depending on the type of tree and its growing conditions. If scaffolds are well placed, the tree may need little or no pruning for several years. Temporary branches along the trunk

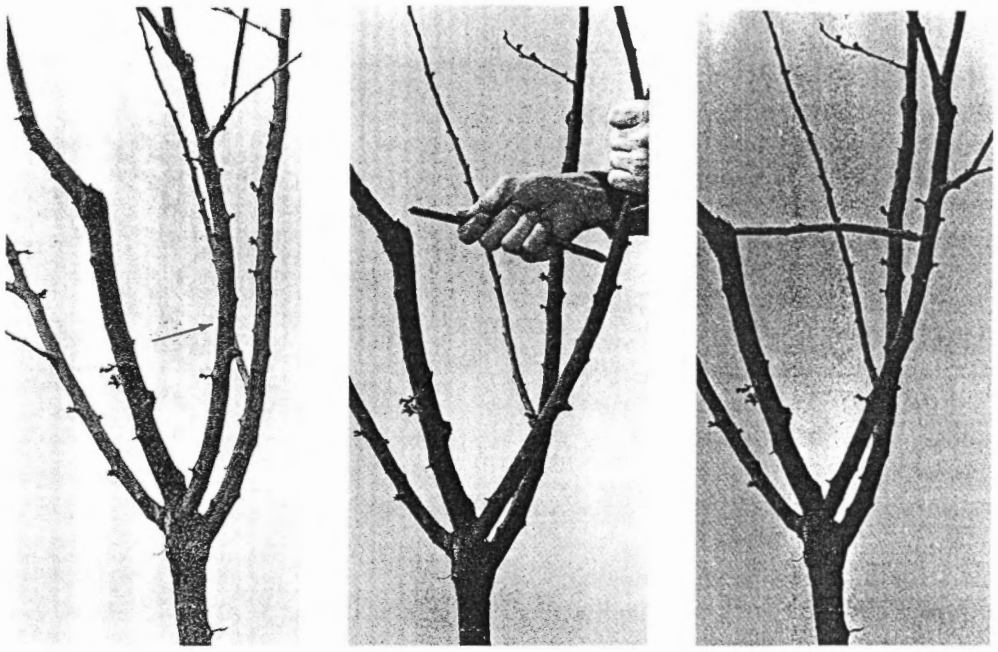


FIGURE 14-31 A lateral branch that is too upright (left arrow) can be inclined more if you insert a spreader, cut from a pruned branch of similar caliper, between the branch and the leader. The branch should be smaller than the leader and have a strong attachment. This is a flowering fruit tree, so the closely spaced scaffolds should not be a problem.

should have been thinned out or reduced in number by this time. Staking to support a tree should not be necessary, but short stakes can be used to protect the trunk from mower, auto, or other damage.

Inspect young mature trees annually to ensure that the main scaffolds are growing well and in balance with each other and the trunk. Remove low, broken, interfering, and diseased branches. A tree with dense foliage and the plants growing under it will usually benefit if the tree is thinned to allow passage of light. **Retain well-spaced inner laterals.** Depending on tree species and growing conditions, inspections can be less frequent as a tree matures.

PREPRUNING PROCEDURES In order to prune safely and efficiently, follow these guidelines before starting work:

- All equipment and tools should be checked, serviced, and in top operating condition, preferably the night before use.
- Public arborists (Hudson, 1981) and private companies (McCarthy, 1991) have found that 10 to 30 minutes of stretching and calisthenics before work begins improves performance, reduces accidents and injuries, and reduces insurance costs.
- Each tree site should be checked for possible electrical and insect hazards and appropriate action taken.
- Each tree, particularly the root collar area (see Chapter 16), should be examined for structural soundness.

The responsibilities of each person from owner to grounds worker involved in the maintenance and removal of trees are summarized in the section "Safety vs. Accident Prevention" in *Arborist Equipment* (Blair, 1995). Blair specifies the responsibilities of buyers, users, and employers with regard to tools and equipment used in tree work:

- Select proper equipment for the job to be undertaken.
- All employers covered by the Occupational Safety and Health Act (OSHA) of 1970 (USA) are responsible for the inspection and maintenance of all tools and equipment used by their employees whether the equipment is owned by the employer, the employee, or is rented for the job.
- OSHA stipulates that all personnel support equipment shall be inspected by a competent person daily before use. If any equipment shows signs of excessive wear or damage, it shall be removed from service and either repaired or destroyed.
- Any equipment or portion thereof that has been drop tested or otherwise subjected to fall, arrest, or impact shall be removed from service and destroyed to prevent further use.
- Equipment should be used only for the purpose for which it was designed and manufactured, and then only by adequately trained persons.
- When inspecting personnel support equipment, consider these important facts:

The inspector should be able to recognize danger points. These include worn, scarred, cracked, or deformed hardware; pulled stitching; strained rivets; and, of course, the condition of the belt or strap itself.

Any sign of unusual wear or damage signals the need for repair or replacement of the unit. *Pretty good* condition is not acceptable.

There is no precise useful life expectancy for tools or equipment because of age, the conditions under which they are used, the conditions to which they are subjected, and the degree of care they are given to help determine useful life.

PRUNING GUIDELINES The British Standards Institution (BSI, 1966, 1989b) in Great Britain presents standards for various pruning operations. The International Society of Arboriculture (ISA) published *Tree Pruning Guidelines* in 1994 (Britton, 1995) incorporating categories of the National Arborist Association Pruning Standards (NAA, 1987), the 1966 BSI standards, plus information on training young trees, utility pruning, and view restoration from *Pruning Standards* of the ISA Western Chapter (Perry, 1988). The American National Standards Institute (ANSI) published ANSI A300-2001, *Tree, Shrub and Other Woody Plant Maintenance-Standard Practices.* The various pruning tasks that may be necessary to properly care for mature trees follow fairly closely the *Best Management Practices* (Gilman and Lily, 2002). Appendix II presents suggested pruning specifications.

CROWN CLEANING Crown cleaning is the removal of dead, dying, diseased, broken, and weakly attached branches and watersprouts from a tree's crown. Except for some watersprouts, the aforementioned are specific branches that should be removed. Watersprouts may be needed to begin to fill voids where one or more branches have broken out (see the section on crown restoration later in the chapter). Watersprouts and suckers can be quite a problem on some species, particularly trees that have been severely pruned. Those to be removed should be cut as close to their bases as possible in order to minimize resprouting. Treating these cut surfaces with a growth retardant also minimizes new sprouts (see Chapter 15). Vines, wire, rope, nails, and other foreign material also should be removed.

A tree can also be examined for defects that might require additional attention. Pruning can quite effectively reduce insect infestation and infection and stop or slow the spread of infection within a plant (Brown, 1972; Svihra, 1994) (see Eradicative Pruning, Chapter 19).

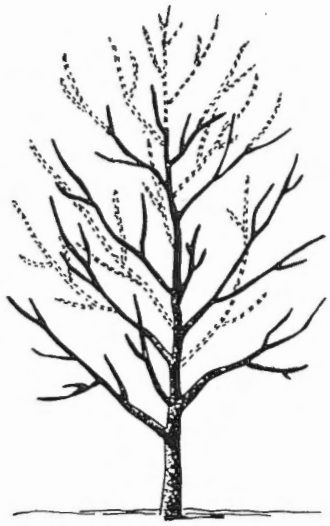


FIGURE 14-32 The height and spread of a tree can be reduced and yet maintain its natural shape. Branches that have been thinned are outlined by broken lines.

CROWN THINNING Crown thinning is the selective removal of branches to increase light penetration and air movement, and to decrease branch end weight. Moderate to high light intensity is needed for active and productive interior foliage. If branches arise close together along the trunk, they become long and slender with few laterals and little or no taper. Crossing branches and those of low vigor may need to be removed. Thinning out (removing) some of these branches gives the remaining ones more room, helps to initiate new laterals, and increases the taper of remaining branches. On remaining branches, thin out laterals near branch ends as needed in preference to removing interior branches (Fig. 14-32). Wind resistance, length of branch lever arm, and weight near branch ends can be reduced by crown thinning, which can be especially important for trees with weak branch structure, or insecure roots or trees subject to summer-branch drop (see Chapters 16 and 17).

The structural features of a tree can be emphasized by moderate thinning that opens the trunk and branches to view. *Pittosporum,* dogwood *(Cornus),* olive *(Olea europaea),* and *Ginkgo* are particularly suited to this treatment.

The first branches to remove in crown thinning are those that would normally be removed in crown cleaning. After this has been done, it is easier to see what thinning is needed to open up the crown. On a medium to large tree (12- to 18-m or 40- to 60-ft tall), removing branches less than 50 mm (2 in.) in diameter is usually desired. Smaller cuts are appropriate on smaller trees. Make these in the top and around the periphery. In large trees, limbs of up to 150 mm (6 in.) in diam-

eter may need to be removed. Such large cuts, however, should not be needed unless the tree has been neglected or improperly pruned or its use in the landscape has changed. Large cuts on lateral branches can weaken the branch and are more subject to decay.

The Tree Pruning *Guidelines* (Tree Pruning Guidelines, Britton, 1995) and *Best Management Practices* (Gilman and Lily, 2002), and the ANSI A300 standard (Part 1), 2001 (section 5.6.2.2), caution that not more than 25% of the foliage (and potential foliage) should be removed from a mature tree within a growing season. To the average person a well-pruned tree should look as if it had not been pruned.

Start pruning at the top and work down the tree. Prunings can be cleared as the work progresses downward; if falling branches damage those below, usually it is not too late to modify branch selection.

CROWN RAISING Crown raising is the removal of lower branches of a tree to provide clearance. Lower branches may block pedestrian and vehicular traffic, obstruct a view, grow too close to buildings, or reduce sunlight and breezes. As most trees increase in size, their branches bend lower because of increased length and weight. Lower branches may also tend to grow downward because light intensities may be higher under a tree canopy than within it. Lower branches should be removed only for valid reasons, however, because it is to a tree's advantage to have branches near the ground. *Low branches are a tree's best insurance in its old age* (Claus Mattheck, Forschungszentrum Karlsruhe Technik und Umwelt Institut fur Materialforschung II, Karlsruhe, Germany, 1997, pers. comm.).

Some arborists prefer to prune for clearance in late summer, when branches are heaviest with foliage and reveal the extent of any problems. Plan the height of the lowest permanent branch when training a young tree so that there will seldom be a need to remove large branches later.

When raising the crown, thin back to a more upright large lateral or remove the branch entirely. All too often, low branches are cut back to small, more upright laterals (Fig. 14-33). These low branches are usually heavily shaded and become unattractive and need further pruning. If there is a limb above, the lower one usually can be removed to provide long-term clearance and improve appearance.

The removal of low branches may increase stress on the lower trunk, immediately below the new lowest branch (Leiser and Kemper, 1973). Particularly when the crown of a young mature tree is raised, it may be wise to remove low branches over more than one season (Brown, 1972); keep in mind that at least one-half of the foliage should be on branches originating on the lower two-thirds of the tree (Leiser and Kemper, 1973). In order to leave a tree well balanced, both in appearance and stress distribution, some arborists remove branches opposite those removed in raising the head. This is primarily a matter of esthetic preference. Most trees can withstand considerable asymmetry without hazard if not created over a short period.

CROWN REDUCTION Many trees become larger than is desired or safe: They may grow into overhead wires, block views, grow into buildings or other trees, shade solar collectors or other areas where sunlight is wanted, or become hazardous because of size or condition. Size can be controlled by pruning, but it will be a continuing task. Growth can also be slowed without greatly affecting tree appearance by stopping or reducing nitrogen fertilization and irrigation (see Plant Adaptation to Low Nutrient Levels in Chapter 12). Size can be maintained most effectively if the plant is pruned as it begins to reach its acceptable size. If pruning is delayed until a tree, shrub, or vine is much larger than wanted, size control will be more difficult; wounds will be more subject to decay, harder to hide, and slower to close; and renewed growth will be encouraged. Species vary in the severity of pruning that mature trees can withstand if they are to remain healthy (Table 14-1).

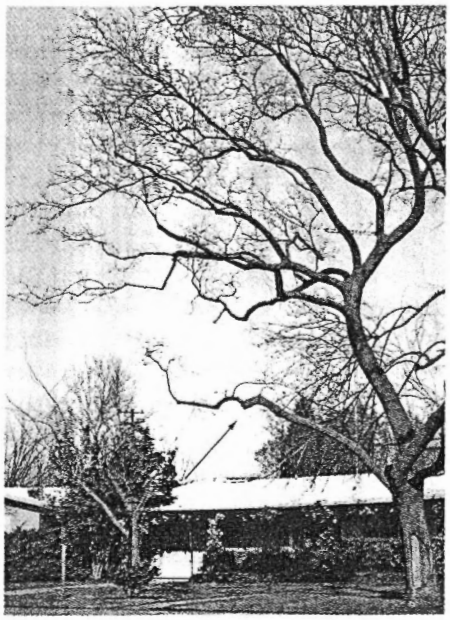


FIGURE 14-33 If there is a suitable branch above, completely remove a low, spreading branch (arrow) instead of pruning it back to less drooping laterals.

TABLE 14-1

Relative tolerance of trees to severe pruning in England[a]

Severe: Young and Old	*Severe: Young Light: Old*	*Light Only: Young and Old*
Alder, *Alnus*[b]	Beech, *Fagus*	Apple, *Malus*
Ash, *Fraxinus*[b]	Birch, *Betula*	Pear, *Pyrus*
Elder, *Acer negundo*	Honey locust, *Gleditsia triacanathos*	Prunus species
Elm, *Ulmus*[b]	Japanese pagoda, *Sophora japonica*	
Hawthorn, *Crataegus*	*Laburnum*	
Holly, *Ilex*[b]	Lilac, *Syringa*	
Horse chestnut, *Aesculus hippocastanum*[b]	Walnut, *Juglans*	
Linden (lime), *Tilia*[b]		
Mountain ash, *Sorbus*[b]		
Oak, *Quercus*[b]		
Plane, *Platanus*[b]		
Poplar, *Populus*[b]		
Maple, *Acer*[b]		
Tree of heaven, *Ailanthus*		
Yew, *Taxus*[b]		
Willow, *Salix*[b]		

Observational information by Derek Patch in Cutler and Richardson, 1989. Adapted from Cutler and Richardson. 1989. *Tree Roots and Buildings,* 2nd ed., with permission of Longman Scientific and Technical, Harlow, England.

[a]If the species name is given, the observation is primarily for that species.

[b]Including crown reduction. Severe pruning often stimulates watersprouts (Fred Roth, California State University, Pomona, California, 1989 pers. comm.).

Thinning and thinning-to-lateral cuts (removal and reduction cuts), as means of crown reduction, can reduce the height and/or spread of a tree while retaining its natural shape (see Fig. 14-32). Prune branches back to lower or inner laterals that are at least one-third the diameter of the portion removed (Britton, 1995). If the lateral cut is large in relation to the parent branch, the possibility of breakage is increased (Fraedrich and Smiley, 1996). A suggestion is, if the branch cut is more than two-thirds the diameter of the portion remaining, the angle of growth of the lateral should be fairly upright (more than 60° from the horizontal). Reduction (thinning-to-lateral) cuts will be less obvious and the tree less subject to watersprouts than if the branches are headed (lopped). Observation indicates that a tree reduced in size by thinning or thinning-to-lateral cuts takes longer to grow back to the critical height or density than a headed tree. *The finest compliment an arborist can receive after materially reducing the size or density of a tree is when observers fail to notice that it has been pruned.* Thinning and thinning-to-lateral (removal and reduction) cuts require greater skill and time than heading, but in most situations it is worth the effort: It will retain a tree's characteristic form, minimize the problems of decay and regrowth, let more light in to retain interior foliage, and extend the time until the tree needs to be pruned again.

Even when severe pruning is needed, thinning cuts and thinning-to-lateral cuts can usually accomplish the task more satisfactorily than heading. Thinning to a large lateral is sometimes called drop-crotching. Tall, decurrent trees, such as elm *(Ulmus),* hackberry *(Celtis),* and eucalyptus, occasionally branch in a pattern that provides a natural lower top to which the tree can be pruned (Fig. 14-34) (Keith Davey, Belmont, CA, 1980, pers. comm.). This second, lower top usually occurs from two-thirds to three-fourths up the tree. Except for the large thinning-to-lateral (reduction) cuts on branches that form the lower head, the tree reduced to a lower head could appear unpruned. When the height of a tree must be reduced even though a natural lower top is not readily apparent, appropriate lower branches usually can be found to accomplish the same results. Treating the large cuts with NAA should keep regrowth to a minimum (see Chapter 15).

Although most excurrent trees can be reduced in width and still retain an unpruned natural form, it is difficult to reduce height without hastening development of a round head. Bridgeman (1976) cautions that mature beech *(Fagus)*

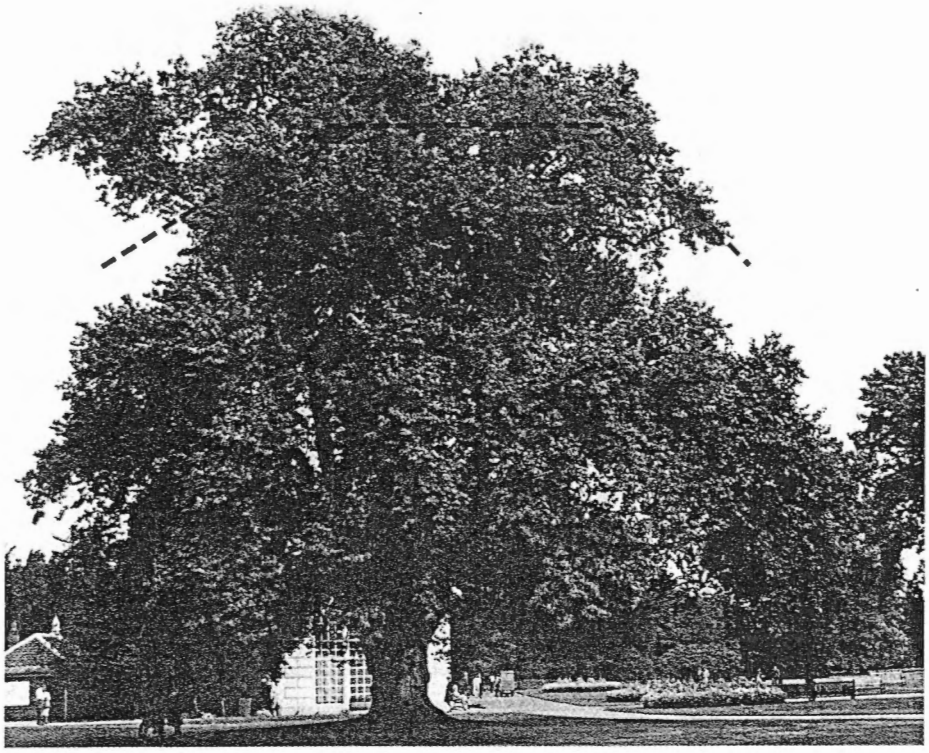


FIGURE 14-34 This London plane *(Platanus* x *acerifolia),* in the Royal Botanic Garden at Kew, England, has a natural lower crown (broken line) to which the tree could be pruned should one want to lower the height of the tree.

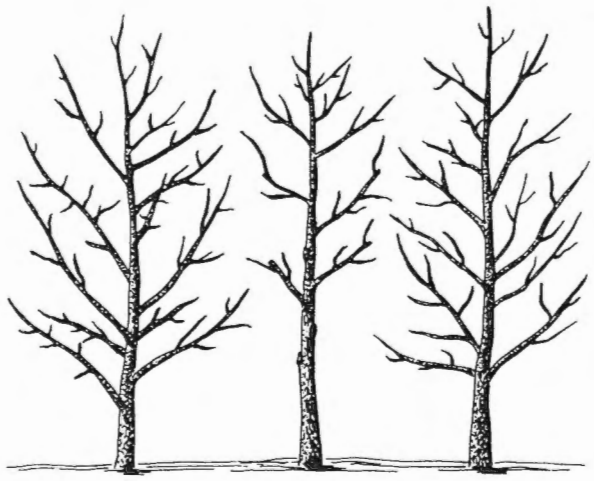


FIGURE 14-35 The center tree has been pruned back every few years to allow more room for adjacent trees and can soon be removed with little or no loss.

and birch *(Betula)* do not respond well to crown reduction and may die back from cuts (Table 14-1).

Crowded trees can become misshapen and their branches weakened by shading and rubbing. In many situations, the smaller, more deformed, or less desirably located trees should be removed. The remaining trees usually will grow into the new space with improved health and appearance. Trees are often planted closer together than will be desired when they reach mature size. As these trees begin to crowd, the less desirable ones should be pruned back more severely each year until they are removed (Fig. 14-35). This will allow proper development of the more permanent trees, while retaining the value of the temporary trees. Tree removal decisions can be difficult, and many people oppose the practice, but its delay is usually to the detriment of the landscape.

Old trees that are of low vigor and have failing branches can often be kept healthy and attractive for additional years by removing the weak-growing and dying limbs in their extremities, particularly their tops. Remove weak and failing branches after most of their leaves of deciduous trees have fallen; this will allow carbohydrates and nutrients to migrate from leaves and weak branches back into live storage areas (Weinbaum, Johnson, and DeJong, 1992). Wise fertilization, irrigation, and pest control also may be needed.

Heading (sometimes called stubbing, dehorning, or lopping on older trees), unfortunately, is often used by well-intentioned but ill-informed people to reduce tree size. In such pruning, main branches are cut to stubs with little regard for their location. Regrowth from below the cuts is dense, vigorous, and upright. New shoots form a compact head, cast dense shade, and are weakly attached to older branches (see Fig. 14-6). They are held only by the surface layers (rings) of wood formed after the shoots begin to grow; these layers are similar in thickness to the outer layer of a sheet of plywood, but are not attached as securely. Shoots usually

develop more rapidly than the strength of their attachment to the older wood. Branches from such regrowth are weakly attached, particularly if the heading cuts are large, and can be hazardous throughout the rest of their life. Regrowth near a heading cut on a vigorous small branch (less than 50 mm or 2 in.) may, however, cover over the cut surface and unite around the wound to form an intact cylinder of new wood. In some cases little or no weakness remains and the lopping line may disappear (Brown, 1972); however, Shigo (1989) states that such wounds remain points of weakness.

The unprotected surfaces of large heading cuts, particularly of mature trees of certain species, are vulnerable to decay. Newly exposed branches may sunburn and also be vulnerable to decay. If a branch has already begun to decay, cutting into it usually speeds the process. Large stub cuts seldom cover. Some arborists recommend that, if a large heading cut is to be made, cut at a slant (about 30° from the horizontal), with the upper edge above a small branch, in the direction in which regrowth is most desired or in the direction of the afternoon sun. Observations, though not verified by research, indicate that a slanted surface will remain drier, be less subject to decay, and may cover more quickly.

CROWN RESTORATION, CROWN RENEWAL, AND CORRECTIVE PRUNING These terms refer to the practice of reshaping to a more natural form a tree that has been storm damaged, vandalized, or improperly pruned. Crown restoration should improve health and structural strength (Bridgeman, 1976). A tree is probably worth saving if the main scaffolds and the trunk are sound or can be cut back to sound wood. Sprouts that grow from headed scaffolds should be thinned to two or three on each scaffold.

Selecting less vigorous sprouts will slow growth somewhat and favor more secondary laterals along the sprouts next season. Even though thinning out branches opens the top so that the tree has less wind resistance, the remaining individual limbs may be more exposed to wind damage. Therefore, the remaining branches may need to be thinned back to lower laterals. The reduction in number and size of the branches helps to develop their attachment to the main scaffolds, particularly in relation to their size.

Such severe pruning might best be done over 2 to 4 years to minimize its side effects, particularly the vigorous regrowth. Pruning during the growing season should reduce excessively long growth, strengthen branch attachment to the scaffolds, and slow total growth. In areas subject to fall frosts or winter cold, pruning should not be done so as to prolong growth and the beginning of cold hardening. Fertilization, irrigation, and other practices should be adjusted to minimize excessive growth on healthy trees. Pruned trees should be examined at least annually for structural development, presence of decay in framework branches, and general health. The safety of pedestrians and property is paramount.

PRUNING TREES SUFFERING ROOT LOSS OR DAMAGE Opinions differ as to how much, if at all, to prune large trees that are being transplanted or have had severe root loss or damage. The following discussion assumes that the trees are in good condition and will be supplied with adequate water.

Common practice has been to prune the top of root-damaged trees rather severely. One company specializing in moving large trees thins about 30% of the leaf area before boxing the roots (John Mote, Sylmar, CA, 1990, pers. comm.). The rationale for pruning is to reduce the leaf area to help to compensate for root loss, to favor branches that one wants to remain, and to minimize subsequent leaf drop and limb dieback (Watson and Himelick, 1997). As much as 50 to 75% of the leaf area has been removed from some broad-leaved trees transplanted in the heat of summer.

Others hold the view that, when mature trees have suffered severe root loss, little or no pruning should be done. This opinion is reasoned from research findings on the effects of different pruning severities on newly planted young trees. Retaining as many leaves as possible is thought to supply maximum carbohydrates for root growth and compartmentalization. Also, because failure-prone limbs can seldom be identified at the time that root damage occurs, it is thought best to wait and let the tree indicate which limbs to remove.

How a mature tree responds to a given severity of root loss depends on its health and its energy reserves. Trees have great redundancy in their tops and roots. Even though leaves, current shoots, and absorbing roots are lost, there are many others to carry on with little effect on the tree. Sinclair, Lyon, and Johnson (1987) state that a tree can lose half of its roots and still survive. Using field observations and partial excavations, Watson and Himelick (1982) estimated that only 2% of the root-occupied soil volume of a 100-mm (4-in.) diameter nursery tree was moved when dug with a 1.12-m (44-in.) tree spade.

When a tree is properly and moderately pruned, leaves within its canopy are exposed to more sunlight and to slightly more carbon dioxide than before. Photosynthesis of the remaining leaves increases and offsets some of the carbohydrate loss that would have been supplied by the leaves removed. Just as transpiration is little af-

fected by pruning until considerable foliage is removed, photosynthesis also is little affected unless pruning is severe. For a given plant, the rates of transpiration and photosynthesis are closely related (Farquhar, 1979).

As with most things, moderation would appear to be wise in caring for root-damaged trees. Thinning weak and crowded branches, which contribute little to a tree's energy reserves, exposes leaves within the canopy so they are more productive. The well-being of limbs important for the structure and beauty of a tree can be better ensured. A pruned tree should be more stable. Another advantage is that the owner of the tree will interpret the arborist's efforts as being in the best interest of the tree.

Whatever the pruning practice and severity, wise watering at least through the first growing season is paramount. Initial misting of the foliage may be wise. The water should be low in salt or the leaves could soon be coated with salt.

VISTA PRUNING View enhancement is the selective thinning of limbs or specific areas within a tree crown to provide a specific view of an object or scene from a predetermined location (ANSI, 2001). Residential, vacation home, restaurant, and roadside sites are often selected and developed to exploit pleasing and interesting vistas. Skill is needed to create, enhance, and maintain such views. Mature trees are most commonly involved, but with new tree plantings future view encroachment and enhancement also need to be taken into consideration.

A number of cities have ordinances that allow a person to prune offending plants on another person's property in order to restore a previous view. Some arborists predict that in time there will be few or no tall trees in these vista areas as the old trees die and the young ones are kept cut back. Guidelines or ordinances may help delay or prevent this from happening.

Properly pruned, well-placed trees can frame and enhance scenic views through strategically selected branches and foliage. Pruning established trees calls for variations of several of the pruning categories already discussed, particularly crown thinning. Large limbs may need to be removed to open the canopy, followed by selective thinning of some of the laterals along remaining branches that intrude into the vista. A person at the viewing spot can best direct the operation. A friendly relationship with and a concern for the landscape of the trees' owner will make the task more pleasant and effective. **Clear understanding by all parties of what is to be done is imperative. It would be wise to have this in writing.**

When a site is initially developed, some trees may need to be removed. Young trees may need to grow up through the view, partially blocking some of the view for a time, so that branches can develop above the view. Some selective branch removal can then begin without opening obvious viewing holes. Views can be quite intriguing when seen through sparsely leafed branches.

UTILITY PRUNING The objective of utility pruning is to provide safe facilities and reliable delivery of electricity. The electric utilities in the United States and Canada spent an estimated $2.5 billion to $3 billion in 2001 to keep power lines and rights-of-way free of trees and shrubs (Stephen Ciesleqicz, CN Utility Consulting, Inc., Petaluma, CA, 2002, pers. comm.). Many utilities have switched from so-called rounding over (heading to a predetermined size and shape) to directional or lateral pruning.

Directional or lateral pruning involves pruning the leader or scaffold(s) to lower outward-growing limbs (Blair, 1940; Holewinski, Orr, and Gillon, 1983; Johnstone, 1988). For a tree growing directly under a distribution line, the leader is removed or drop-crotched to a lower lateral (Fig. 14-36). The top laterals are further pruned to direct subsequent growth away from conductors.

The same method can be used for a tree not directly under utility wires. The tree is pruned by making thinning (reduction) cuts on those branches that threaten conductors (Fig. 14-36). Branches growing above the conductors are directed up and away from the wire, whereas those below are directed down and back. In both situations, subsequent growth should be moderate and directed away from the conductors.

A 5-year study by Delmarva Power along the U.S. mideastern coast involving thousands of mature trees demonstrates the value of directional pruning (Johnstone, 1988). Initially, directional pruning may take longer, although the difference is not great when arborists gain experience. The real benefit for Delmarva Power was that **electrical service reliability was improved with 56% fewer tree-related outages in 1986 than in 1980.**

Even if all cuts are thinning (reduction) cuts, the severity of the initial pruning needs to be modest so as to not stimulate excessive upright and lateral growth from the remaining branches. Follow-up pruning should be timed so as to require only moderate pruning. However, if the trees are along streets, the vigorous growth of lower branches may require more frequent and severe pruning though not necessarily by the utility. Residents and local authorities usually are not pleased if they are responsible for pruning the low

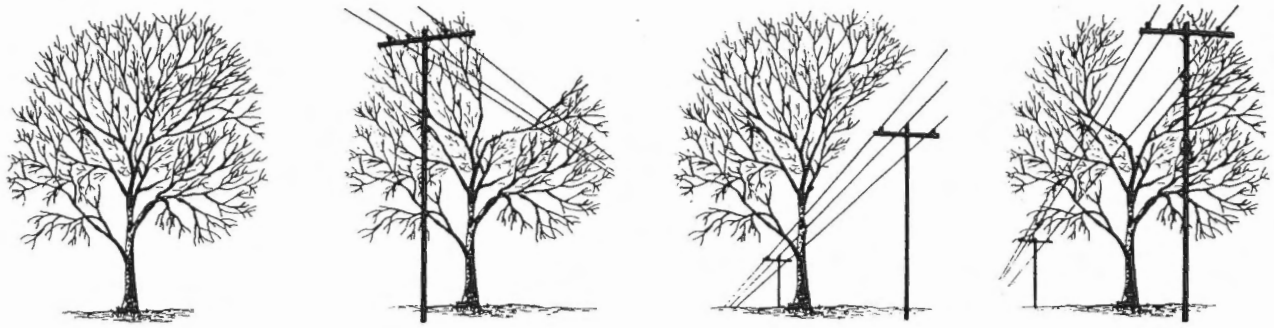


FIGURE 14-36 Directional pruning of mature trees under utility lines has been found to be cost effective and to increase reliability of electrical service (R. A. Johnstone, Delmarva Power & Light Co., Salisbury, MD). Thinning cuts direct growth away from the conductors. Mature tree before pruning (extreme left). A through-side trim or side trim with underbuild (branches under the conductor) (left center). Undertrim style of pruning (right center). Through or V trimming when tree is directly under the conductors (extreme right).

branches. In the conversion to directional pruning the first cycle is critical and more time consuming. The value is realized in the following pruning cycles: The basic structure is established, problem trees and branches are removed, regrowth is less vigorous, the intervals between pruning cycles increases, and many trees do not need to be pruned every cycle. In 1987, only 15 crews were used to maintain the same circuits that required 20 crews 3 years previously. Considering inflation, productivity was increased 15% with fewer crews (Johnstone, 1988).

In the conversion to directional pruning, certain large trees near utility wires should be replaced with smaller-growing species. The remaining ones should be shaped, removing smaller branches to laterals where possible. Trees near utility lines should be pruned beginning at a younger age to develop more acceptable forms from both the visual and utility points of view.

In rural settings and some natural stands of trees, some utility companies follow similar pruning guidelines as in urban areas because of long-term cost savings (Keith Jones, Central Illinois Public Service, 1990, pers. comm.). Along transmission lines in more remote rural, forested, and wildland areas chemical, biological, and helicopter-suspended-aerial-pruning techniques may be used. The use of plant-growth regulators, coupled with directional pruning, is further increasing the efficiency and effectiveness of utility line clearance (see Chapter 15). Conscientious vegetation management in wooded and forested areas is extremely important to reduce the possibility of disastrous fires caused by tree failures.

PRUNING NEAR ENERGIZED LINES Energized lines can be hazardous. **Any power line can be lethal,** depending on the contact that completes the circuit between an energized conductor and the ground. Because it is not possible to anticipate when a power line may energize other lines because of a storm or accident, the ANSI recommends that, "All overhead and underground electrical conductors and all communication wires and cables shall be considered to be energized with potentially fatal voltages and shall never be touched either directly or indirectly" (cited in Haupt, 1980). This includes fire alarm, cablevision, telephone, and house drops, as well as utility transmission and distribution lines.

ANSI (1994) established minimum distances between electrical conductors and working arborists (ANSI Z133). Arborists who have had special line-clearance training can work nearer than those who have not been so trained. Even then, line-clearance workers must stay at least 0.6 m (2 ft) from a primary conductor carrying up to 15 kV (15,000 V) and at least 4.5 m (15 ft) from a conductor carrying 552 to 765 kV. Arborists who do general tree work must stay at least 3 m (10 ft) from conductors carrying up to 50 kV. Because standards are revised periodically, be sure that current standards are followed.

Before beginning work, the treeworker and supervisor should inspect individual trees if an electrical conductor passes through the trees or is within reaching distance of the treeworker. The utility company should be notified before any work is performed within 3 m (10 ft) of an electrical conductor. Work should be started within 3 m (10 ft) of an electrical conductor only after a representative of the utility company has declared the condition safe. The utility may move the conductor, deenergize the line temporarily, or send a line-clearance tree-pruning crew to do the work near the conductor. During and following storms, telephone lines, wire fences, and metal guardrails within 1 km (0.6 mi) of dam-

aged lines may be lethally energized. Workers should be alert to the possible dangers.

Tree crews should be trained to work safely near energized conductors, whether they climb in trees or use an aerial lift. Lowering cut branches near conductors requires planning and special care. During any work in large trees, a trained person should be on the ground at all times to assist the person in the tree and to act in emergencies.

Urban tree utility pruning should follow the ANSI A300 standard (Part 1, 2001), considering the following:

- Where possible, before a tree nears utility conductors, locate pruning cuts depending on branching habit so as to direct growth away from utility lines (Fig. 14-36); seldom should limbs be headed, especially near preestablished clearing limits.
- In achieving clearance, make most thinning cuts back to medium-sized branches within the crown. Pruning of small branches in the outer crown should be kept to a minimum. In so doing, trees are pruned more quickly, and more terminal buds growing away from the lines will be retained.
- To the extent possible, on decurrent trees, make thinning cuts to the trunk or a branch or thin to a lateral that is at least one-third the diameter of the portion being removed.
- Remove the entire branch if more than 50% of live foliage needs to be removed from it.
- Severe height reduction pruning (including heading) may occasionally be the only alternative when trees are directly under lines; vigorous, tall-growing trees directly under power lines should be removed if possible. Some utilities offer tree removal and replacement with appropriate trees.
- Make pruning cuts close to but outside the branch bark ridge and the branch collar; avoid stripping or tearing bark when removing limbs.
- Severed limbs and dead branches should be removed from trees.
- Do not use climbing spurs or irons, gaffs, or hooks except in a life-threatening emergency when removing a tree, or where branches are more than a short distance away or apart.
- Utilities should sponsor educational programs for the general public about planting compatible tree species close to utility lines.

SHORT PRUNING

Short pruning is one of the techniques used to maintain an artificial form of a tree or shrub after its structural framework has been developed. The range of the more common forms include screen or hedge, pollard, espalier, topiary, and pleach. When established, the structure is maintained primarily by heading cuts of 1-year-old shoots to be retained (traditionally to three buds or eyes, or to a third of its length); other unwanted growth is removed. Short pruning is particularly adapted to shaping trees and shrubs: Each heading cut determines where branching will occur. With those plants that react well to short pruning, almost any type of artificial form is possible, though labor intensive (Raimbault, 1996).

SCREEN (CURTAIN) PRUNING

After tree structure has been developed, screen pruning is used to maintain the intended form (Fig. 14-37). Two types of operation are involved. Current shoots are trimmed (headed) to a third to half their length up to four times during a growing season. Branching occurs soon after each trimming. Each cut increases the distance between the center of the tree and its outer edge. Every 4 or 5 years, a dormant pruning to clean and reduce a tree's size allows simplification of the branching by reducing their number and a

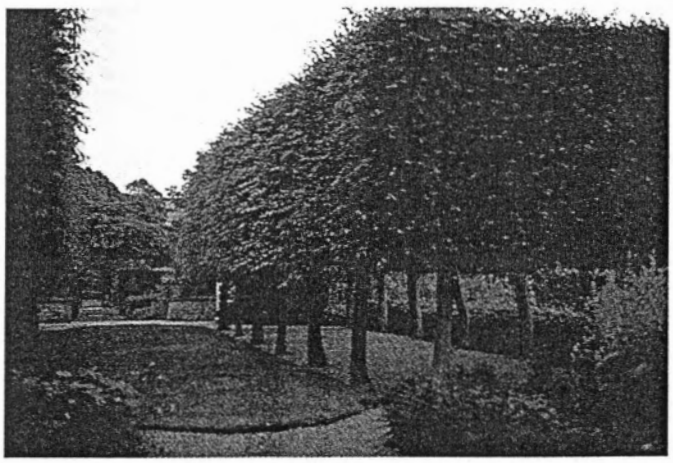


FIGURE 14-37 Screen (curtain) pruning of bosc pear (*Pyrus communis* 'Bosc') trees; they need to be sheared several times during a growing season to control size and maintain the vitality of each base from which they grow.

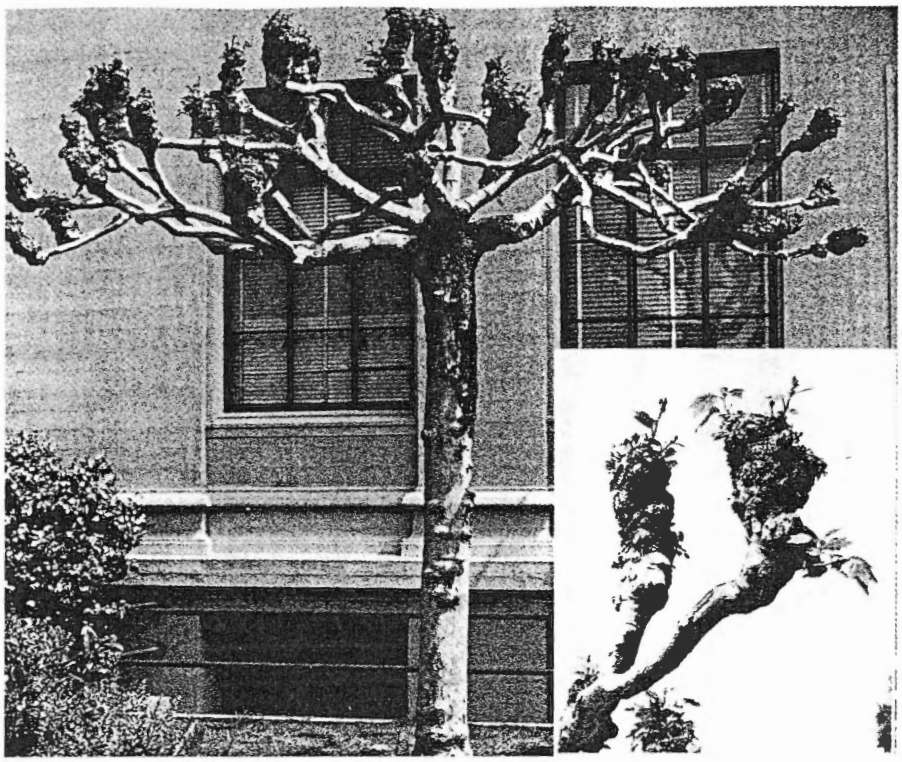


FIGURE 14-38 A pollarded London plane tree *(Platanus x acerfolia)*. Enlarged knobs develop at the branch ends to which the shoots are cut back each year (inset).

return to the original size and shape by reducing the length of the branches.

In Europe, tree screen pruning is used primarily on Siberian elm *(Ulmus pumila)*, horse chestnut *(Aesculus hippocastanum)*, plane tree *(Platanus)*, lime (linden) *(Tilia)*, and to a less extent European hornbeam *(Carpinus betulus)* and beech *(Fagus)* (Raimbault, 1996).

POLLARD

A *pollarded* tree has an established framework with a knob (a nub or head of callus and previously headed shoots) at each branch ending with numerous vigorous, upright, unbranched sprouts a year after being pruned (Fig. 14-38). A swollen branch end is called a knob instead of head so as not to confuse the term with the pruning cut with the same name. The word *pollarding* comes from the Norman French *poil*, to behead.

Pollarding has been practiced for centuries throughout the world for many purposes: animal feed, fuel for heating and cooking, fencing, framing, staking, basket making, and so forth. Pollards for many of these uses were pruned when the branches were the size desired for the specific use (some only every 5 to 7 years). Suitable species for these purposes commonly were planted along city streets and country roads and around homes. Pollarding has continued with recommended annual or biennial pruning of adaptable deciduous species for landscape use. In the European countryside English oak *(Quercus robur)*, European ash *(Fraxinus excelsior)*, and Siberian elm *(Ulmus pumila)* are pollarded, whereas plane tree, horse chestnut, and lime are more common in urban areas (Raimbault, 1996). Gilman (2000) lists 10 genera having species that respond well to pollarding.

Pollards have particular advantages for some landscapes. Species that respond well to pollarding usually adapt to urban situations. Species that normally grow too large for some landscapes can be pollarded to fit the area. Pollards can allow for dense shade in summer and almost full sun in winter. Trees can be kept small in this manner and have a compact appearance, which complements formal landscapes. Annual pollarding eliminates fruiting of species that fruit on 1-year-old shoots. Anthracnose *(Apognomonic platani)* on American sycamore *(Platanus occidentalis)* is sometimes minimized by pollarding because less disease inoculum is carried over to the next spring; but heavy shade of the dense growth often causes early fall of interior leaves.

Properly pollarded trees remain healthy and vigorous, and are long lived. The knobs become a mass of dormant–latent buds encased in callus-like wood. Vigorous knobs compartmentalize very effectively (Fig. 14-39). Beech *(Fagus)* and English oak were pollarded annually in the New Forest in southern England for many years until the practice was forbidden by the king in 1697. Even though pollarding was stopped in 1697, the largest and oldest oaks in the forest are pollards;

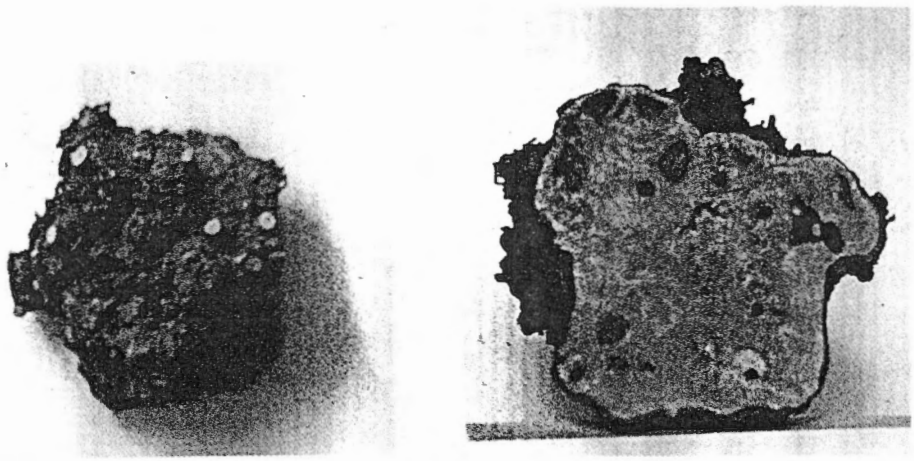


FIGURE 14-39 On a horizontal pollarded London plane tree branch, the sprouts grow from near the top of a knob (left). Heading cuts have been well compartmentalized as shown by the cut through the knob on the left (right).

ring counts on fallen trees give an age of about 340 years (Deputy Surveyor, 1988).

Even though once established, maintenance pruning is simple and straightforward, pollarding requires more time than long pruning. Maintaining an annually pruned mature pollarded plane tree *(Platanus* x *acerifolia)* requires from 2 to 3.5 times more labor than is needed to prune a mature natural-form plane tree of similar trunk diameter on a 4- or 5-year pruning cycle (Kenneth Schmitz, University of California, Berkeley, 1997, pers. comm.). Annually removed shoots usually are too slender to be chipped, so disposal is more of a problem.

Pollarding should be started soon after the lowest permanent branches are selected or at a subsequent dormant period during the first few years. Pollarding older trees is more difficult and usually results in a less attractive tree more subject to decay. First, a basic branch structure and shape need to be developed. A pollarded tree can be trained to an excurrent form, with laterals distributed around and up and down a central leader, or to more decurrent forms, with branches arising radially around and along the upper trunk (Fig. 14-38). Branches can be single or branch several times. Be sure that future clearance will be adequate beneath the branches. Each year remove all sprouts not associated with the developing knobs.

For a decurrent shape, the main laterals are vertically spaced within 1 m (3 ft) or so of the height selected for the top of the trunk. Head each lateral branch (ideally only 1 or 2 years old when the cut is made) to an upright bud where a pollard knob is wanted. At each of the next three or four dormant seasons, cut back all previous years' growths except the two or three most desirable upright sprouts on each knob, which should be cut to one or two buds. Vigorous shoots will grow from the buds left on the sprout stubs, as well as from the bases of some of those cut close. After a tree has been pruned this way for a few years, a knob of callus and cut stubs forms at the end of each branch.

Thereafter, each dormant season cut back the previous year's shoots to their respective knobs. None of the shoots need be left as short spurs. If the interval between prunings is more than 2 years, the carbohydrate storage in the polled knobs decreases, thereby weakening sprout growth and the vitality of the knobs.

Pollarding is not synonymous with topping, lopping, or stubbing, as stated by the BSI (1989b). Pollarding, as pointed out earlier, results in high carbohydrate storage in the pollard knobs (Bory and others, 1996). Shigo (1989) states that pollarded trees "stay healthy, beautiful and safe for many years."

ESPALIER An espalier is a tree, shrub, or vine trained to grow on a trellis or against a wall (Fig. 14-40). In the United States, espalier is used either as a noun or a verb to describe a method of training. Fruit trees have been espaliered along walls and stone fences that face the equator in European gardens for centuries. The heat capacity of walls and stone fences usually hastens bloom and fruit maturity of plants growing against them. These walls protect plants from frosts and winter cold. Espaliered plants, sometimes referred to as wall shrubs, also require less space, an important factor in small gardens.

In contrast to pollarding, which results in a bold landscape statement, espaliers play a more subtle role in a landscape. They become an expression of their creator. Developing and maintaining espaliers requires understanding and close observation of their growth habits and regular, frequent pruning during the growing season.

Species and the type of espalier should be selected for the landscape effect wanted. Species

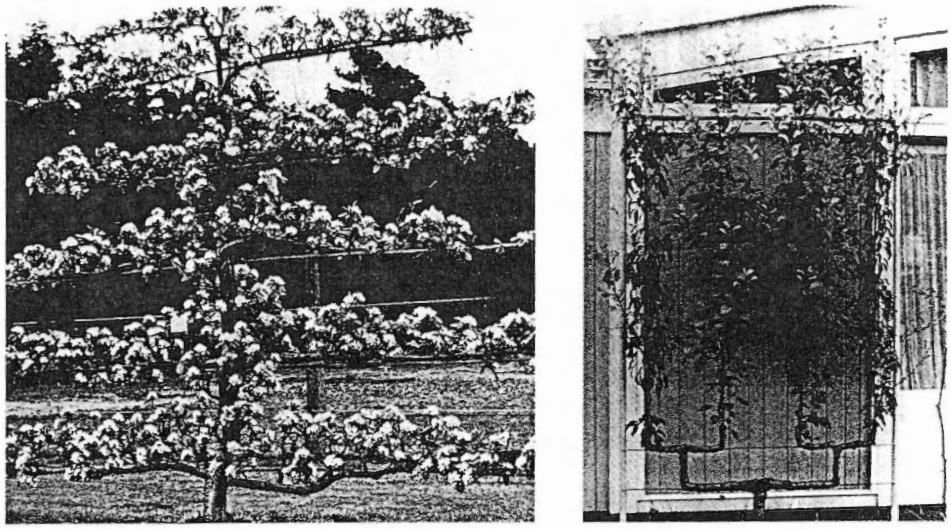


FIGURE 14-40 A pear tree *(Pyrus communis)* at Wisley Gardens, England, trained as a palmette espalier (left). *(Photo: H. T. Hartmann and others. Plant Science: Growth, Development, and Utilization of Cultivated Plants, 2nd ed. © 1988, p. 352. Reprinted by permission of Prentice Hall, Upper Saddle River, NJ.)* A candelabra or double-U espalier of pear at Cornell University, NY (right). (Photo courtesy Clarence Lewis, East Lansing, MI.)

that flower on spurs, such as apple *(Malus sylvestris)*, pear (*Pyrus* sp.) and *Pyracantha*, are well suited for formal espaliers, especially if branches are to be horizontal. Species that flower on vigorous 1-year-old shoots, such as peach *(Prunus persica)*, or on current growth, such as citrus, are better suited to more informal or upright patterns. Brenzel (1995, 1997) lists 25 and *Wyman's Gardening Encyclopedia* (Wyman, 1971) 40 genera and species to consider for espaliering. Wyman has an extensive discussion of espaliering.

Espaliers are usually trained on tightly stretched wires or wood supports. Horizontal and vertical supports are usually 400 to 500 mm (16 to 20 in.) apart. A trellis 100 to 150 mm (4 to 6 in.) from a wall allows the sun to create interesting shadows on the wall, particularly behind deciduous espaliers in winter. Fruit injury caused by high temperatures can be reduced by encouraging more foliage to shade the wall, or espaliers of fruit can be grown in the open. Species that must be sprayed for pests should not be espaliered on walls, painted or unpainted, because pesticides can discolor or stain the surface.

PALMETTE TRAINING Palmette and cordon are forms of espalier whose distinctions have become unclear, at least in the United States. A palmette plant has one vertical trunk with parallel pairs of laterals arising at about equal intervals along it (Fig. 14-40). A proper cordon is a plant grown to a single horizontal trunk or to two main branches trained in opposite directions (Bailey, 1916).

Palmette training is the most common espalier form (Fig. 14-40). The following discussion is based on detailed directions given by Halliwell, Turpin, and Wright (1979) to develop tree or shrub palmette espaliers. Begin with a moderately vigorous upright maiden, known as a *whip*, 1-year stem with no feathers (laterals). In early spring before growth begins, notch the bark (cut a sliver, 1 to 2 mm, 0.06 in. wide about one-fifth of the circumference of the stem) just above each bud where a branch is wanted. The notched buds will be forced to grow. Laterals should arise from the leader (stem) just below the horizontal supports to which they are to be tied. Where laterals are available, select one in each direction from the leader. It may be possible to position two laterals at each of two levels. Use a slender stake to support the leader vertically. Let all the laterals grow the first season without being tied.

The next spring pull and tie the best-placed laterals down toward their horizontal supports, but not so far as to lie on the support. Head surplus shoots to two or three buds. Notch selected buds on the leader as the year before; allow resulting shoots to grow freely.

Before growth starts the third spring (1) tie the lowest laterals to their horizontal supports, leaving their terminal shoots free to grow and be tied down the next year; (2) bend and tie the laterals selected the year before as those selected the first year; (3) cut back surplus laterals to two or three buds; and (4) tie the leader to the vertical stake. Repeat this each year until the top of the espalier support is reached. Keep the leader headed back to the two top laterals.

While laterals are kept horizontal, some vertical shoots can be allowed to develop along them to carry foliage and form flower and fruiting

spurs. Those forming only shoots may need to be headed to confine them. Frequent pinching of a vertical branch checks its growth, allowing the horizontal branch beyond the vertical to maintain vigor. The shoots pinched to hardened wood will not grow back as quickly as they would from a softer pinch.

Time the heavy annual pruning depending on the plant's flowering habit (see Fig. 14-2a and b). A challenge of horizontal espaliers is to maintain the lower laterals in a full and healthy condition. As espaliers age, the lower laterals become shaded and not as vigorous as the upper ones. They have some of the same problems as dense shrubs and hedges with shading out of lower and inside foliage (see Fig. 14-53).

The upper-region horizontals should be pruned more severely even if it causes watersprouts; they can be cut back to let more light reach the lower laterals. The lower laterals should be pruned less and their fruit thinned more (Scott Mayer, Seattle, WA, 1997, pers. comm.).

CORDON TRAINING Cordon training is best for fruit trees and some grape *(Vitis)* cultivars that form or are pruned to spurs. Cordons are developed by bending an unbranched trunk (whip) about 2 m (6 ft) tall onto a single-wire trellis about 500 mm (20 in.) above the ground. The trunk should usually be twisted at the bend to slow growth and hasten flower-bud formation.

Some cordons are trained to one straight trunk, either vertical or inclined at about a 30° angle from the vertical. Many cordons have one vertical trunk terminating in two lateral branches that grow horizontally in opposite directions.

FAN TRAINING To form a fan, head the trunk 200 to 300 mm (8 to 12 in.) above the ground; select about 10 shoots and tie them to a trellis in a narrow fan (Bailey, 1916). Before the next growing season, cut back the top two branches about halfway to reduce their total growth and to encourage branching. Head back the other branches to mature wood. Tie remaining branches to the trellis in a broad fan (Fig. 14-41). Species that flower on vigorous 1-year-old wood or on current growth are more productive when fan-trained than when trained as palmette or cordon espaliers.

INFORMAL TRAINING Many plants are better adapted to informal or more upright espalier training (Fig. 14-42). Informal espaliers are trained similarly to fan espaliers, except that shoots of informal espaliers are tied in a desired pattern. Shoots of species that do not readily form spurs should grow at an angle of at least 30° above the horizontal or have their terminal growth so inclined. This will help maintain branch vigor and flower production.

All espaliers require persistent attention during the growing season so that growth can be directed where it is wanted and unwanted growth removed before it competes with the rest of the plant and mars the beauty of the espalier.

TOPIARY

Topiary is the practice of training and shearing plants into various formal shapes, geometric or mimetic. Topiary was practiced by the Romans and is widespread even today (Fig. 14-43). Small-leaved

FIGURE 14-41 This pear tree at Wisley Gardens, England, has been trained as a fan espalier. *(Photo: H. T. Hartmann, and others. Plant Science: Growth, Development, and Utilization of Cultivated Plants, 2nd ed. © 1988, p. 352. Reprinted by permission of Prentice Hall, Upper Saddle River, NJ.)*

evergreen plants that grow readily from latent buds are best adapted to topiary. Creating the more intricate designs requires skill and patience. Wire may be used to hold a developing branch in a desired position until new growth in diameter will keep it there. Trees may also be sculpted to simple geometric shapes. Plants must be clipped often during the growing season to keep them attractive.

Small-leaved evergreen vines are sometimes trained over wire-mesh frames to create topiary-like forms. This is a quicker way to develop garden sculptures, and few people will be aware that the plants are not true topiary forms.

The next two types of training are not short pruning, but this seems the most logical place to discuss them.

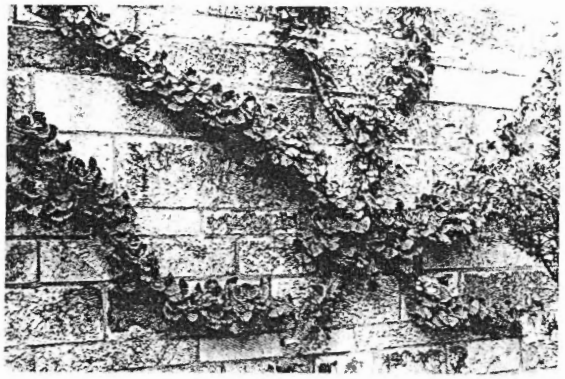


FIGURE 14-42 A young ginkgo *(Ginkgo biloba)* informally espaliered against a wall at the Morton Arboretum, Lisle, IL. *(Photo courtesy of Clarence Lewis, East Lansing, MI.)*

PLEACH

To *pleach* is to weave or intertwine. Suitable species of trees are grown in one or more rows to a height of 3 to 5 m (10 to 15 ft), where they are headed. The more horizontal vigorous shoots are tied to horizontal wires or other support. Eventually, as the shoots from adjacent trees intermingle, they are pleached (woven together) (Fig. 14-44). Upright branches and those from along the trunks are cut off. Species suitable for pleaching have supple branches that can be woven without breaking. Beech *(Fagus)*, hornbeam *(Carpinus)*, buttonwood *(Platanus racemosa)*, apple *(Malus sylvestris)*, peach *(Prunus persica)*, and pear *(Pyrus communis)* have been successfully pleached (Free, 1961).

A double row of closely planted trees can be arched and pleached on a strong wood or metal frame to form a covered walkway, or allée. Upright branches are arched over, tied to the frame, and eventually tied and pleached with branches from trees in the other row. When these branches graft together, the arch can stand without support. The upright shoots are cut back so that leaves on the inside of the allée will receive adequate light.

BONSAI

This ancient Chinese *(penjing)* and Japanese *(bonsai)* art produces miniature replicas of landscapes and mature trees (Fig. 14-45). The essential procedures are detailed pruning of the top, occasional use of wire to bend a trunk or branch, maintenance of a small but healthy root system in a shallow container, and sensitive placement in a complementary microlandscape, which includes

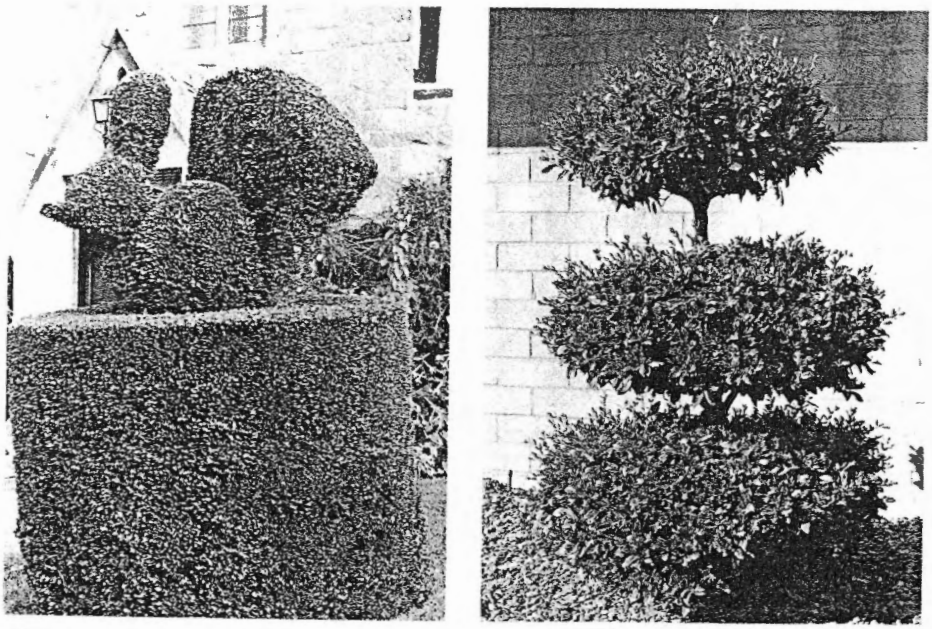


FIGURE 14-43 English holly *(Ilex aquifolium)* topiary (mimetic) in a home garden near Stratford-upon-Avon, England (left); waxleaf privet topiary *(Ligustrum japonicum)* (geometric) at Oki Nursery, Sacramento, CA (right).

FIGURE 14-44 This pleached allée of golden chain trees *(Laburnuma anagyroides)*, the Royal Botanic Garden, Kew, England, has been trained on a pipe and cable trellis (left). The branches are intertwined and could eventually support the allée without the trellis. Three London plane *(Platanus x acerifolia)* trees in a Whittier, CA, park have been pleached to form a pergola (right).

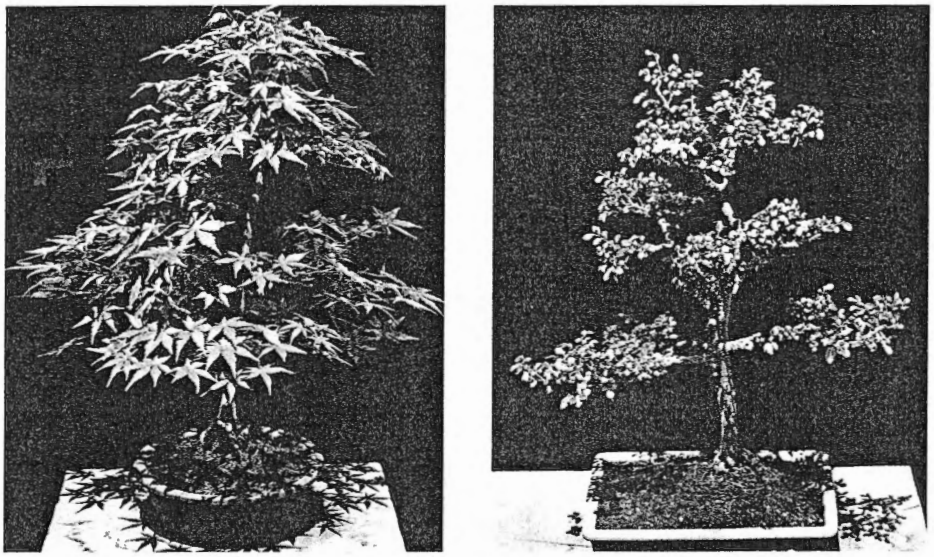


FIGURE 14-45 Japanese maple *(Acer palmatum)* (left) and ginkgo (right) grown as bonsai by N. William Stice, Davis, CA.

rocks, moss, and lichen. Species selected for bonsai should have small leaves, flowers, or fruit that will be in scale on a plant less than 600 mm (24 in.) tall. Frequent pruning of shoots not only keeps the plant small but also increases the taper of the trunk and branches and makes branch growth more tortuous, to simulate old trees. Roots should be pruned back and repotted with new soil every 2 to 4 years. Plants are kept in moderate vigor, but growth is pinched back to control size and form. Bonsai plants must be protected from extreme heat and cold and must be watered frequently because of their limited root systems. A number of good books are available on the art of bonsai (Wyman, 1971).

CONIFEROUS TREES

Most conifers have an excurrent growth habit, particularly while young, and their training and pruning needs are similar in many respects to those of excurrent broad-leaved trees. Because most conifers have strong central leaders, they need little or no training unless an atypical effect is desired. Conifers are pruned primarily to control the density of branching, the shape of young trees, and the size of older ones. **Double leaders should be thinned (reduced) to one; dead, diseased, crowded, and structurally unsound branches should be removed.** Also see that branches are smaller in diameter than the trunk. Smith (1962) reports that several investigators found that 25 to 30% of the live crowns of a variety of conifers can be removed without reduction to height growth or serious decline in diameter growth.

Conifers have several characteristic, though not unique, growth patterns, which should be kept in mind during pruning (Table 14-2). The main leader of a conifer is seldom subdued by the several branches that arise at or near one level on the trunk. Therefore, branches arising in whorls or

TABLE 14-2

Pruning guidelines for conifers

		Method of Pruning for a given Response[a]			
Genus and Branching Pattern	*Distribution of Latent Buds or Dormant Growing Points*	*Type of Growth*	*Reduce Size, Direct Growth*	*Increase Density*	*Comments*
Usually whorled					
Pine *(Pinus)*	Almost none. See comments for exceptions.	From preformed initials in most species. Some have more than one flush of growth.	Tip or cut to lateral shoots only.	Pinch candle when it expands in the spring. This may be done on each flush of growth.	Canary Island pine and a few others have latent buds and may be pruned more severely if necessary.
Spruce *(Picea)* Fir *(Abies)* Douglas fir *(Pseudotsuga menziesii)*	Some	Growth from preformed initials.	Tip or cut to lateral shoots or visible dormant buds.	Pinch lateral shoots in spring when they expand. The terminal (leader) may or may not form multiple leaders if pinched.	These usually require little pruning. Remove bottom limbs for clearance over several years.
Random-branching					
True cedar *(Cedrus)* Larch *(Larix)*	Some latent buds on short, spurlike shoots.	Long shoots have new growth from preformed initials but continue growth with favorable conditions.	Cut to lateral on long shoots. Short shoots may start long shoot growth.	Pinch expanding shoots.	These usually require little pruning. Remove bottom limbs for clearance over several years.
Podocarpus *(Podocarpus)*	None or few	More or less continuous under favorable conditions.	Thin to laterals or visible foliage.	Pinch expanding shoots.	Removal of leader may produce a multi-stem crown.

Bald cypress *(Taxodium distichum)* Dawn redwood *(Metasequoia glyptostroboides)* Cryptomeria japonica Giant sequoia *(Sequoiadendron giganteum)*	May have some growing points capable of new growth.	More or less continuous under favorable conditions.	Thin to laterals or visible foliage tufts.	Pinch expanding shoots.	These species have both persistent and annual (deciduous) shoots. Prune to persistent shoots.
Arborvitae *(Thuja)* False cypress *(Chamaecyparis)* Incense cedar *(Calocedrus decurrens)* Cypress *(Cupressus)* Juniper *(Juniperus)*	No true buds. Numerous dormant growing points where foliage persists.	More or less continuous under favorable conditions.	Thin to laterals or within visible foliage.	Tip prune.	Do not prune into bare wood. Cypress are very slow to make new growth after pruning.
Yew *(Taxus)*	Numerous dormant growing points in foliage areas, some on older wood.	More or less continuous under favorable conditions.	Thin to laterals, tip prune.	Tip prune.	Those with needlelike foliage may not respond to pruning as well as those with awl-shaped or scalelike foliage.
Coast redwood *(Sequoia sempervirens)*	Numerous latent buds.	More or less continuous under favorable conditions.	Thin to laterals, tip prune.	Tip prune.	Remove multiple leaders.

[a]For maximum dwarfing effect, prune in any of the suggested ways in late summer.
From Leiser, Harris, and Matheny, 1981, unpublished.

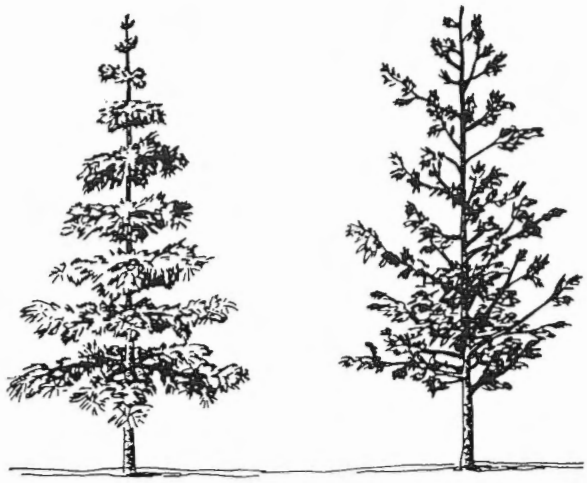


FIGURE 14-46 Some conifers, such as pines *(Pinus)* (left), have whorled branching; others, such as cedar (*Cedrus*) (right), have random branching along the trunk (see Table 14-2).

close together along the trunk can be left. Branches may be thinned, however, to reduce wind resistance, improve visibility, or enhance appearance.

Laterals on conifers radiate from the trunk either randomly or in whorls (Fig. 14-46). In species that branch in whorls, shoot elongation is usually determined by the number of preformed initials in the terminal buds; those that branch randomly continue growth as long as conditions are favorable. To a large measure, the distribution of latent buds or growing points limits the severity with which conifers can be pruned (Table 14-2). **Few conifers have latent buds below the foliage area in older wood; if branches are headed back to older wood with no foliage, the branch stub usually dies.** A pruned branch should have foliage on it in order to remain alive and grow. More severe pruning can be done by cutting back to active laterals while retaining a semblance of natural form. However, when conifers are able to form new shoots from older wood, pruning is much simpler and trees are better able to recover from injury by storm or fire.

WHORL-BRANCHING SPECIES

Whorl-branching species should be selectively pruned back to a bud or the branch from which the pruned portion originated. In vigorous trees, branch whorls are sometimes farther apart on the trunk than will be desired. A denser tree can be created by heading current growth back to a bud. This is easily done with pine trees, whose buds elongate into candles before starting their period of greatest elongation (Fig. 14-47). As candles approach full length, needles begin to elongate; this is the time to pinch them (USDA, 1969). Growth

FIGURE 14-47 The growth of pine shoots can be easily reduced by pinching (breaking) their candles back proportionately to the growth reduction desired.

will be inhibited according to the severity of the pinch. Break or pinch candles, if feasible; cutting the needles with shears causes them to develop brown tips. If you must shear, shorten candles after they have hardened.

A pine tree can be shaped by removing most of the candles on shoots that you wish to discourage and leaving most or all on those you wish to encourage. Reduce the size of whorl-branching conifers by thinning a branch tip back to a laterally growing shoot. Spruce *(Picea)*, fir *(Abies)*, and other whorl-branching trees whose buds elongate into shoots can be kept dense and small if you pinch the expanding shoots in the spring. Trees that have short internodes, as do fir, may need little or no pruning. In fact, Scarlett and Wagener (1973) warn that the topmost whorl of firs should not be pinched because regrowth may be poor.

Pinching the terminal reduces the distance between the topmost branch whorl and the next one to be formed; excessive distance between existing whorls cannot be decreased. Bare trunks between widely spaced whorls can be unattractive on vigorous pines. Heading to shorten a long distance between whorls usually results in a stub that will not resprout. Some arborists and Christmas tree growers induce branching between whorls by girdling or removing needles between the whorls. To girdle a trunk, remove a narrow 3 mm (0.12 in.) band of bark at the height at which branching is desired. One or several branches may grow below the girdle and help to fill the void. Alternately, one can remove the needles 25 to 50 mm (1 to 2 in.)

above the level at which branching is wanted; this may stimulate shoot growth from the band of needles just below the exposed area (Francis, Breece, and Baldwin, 1974). Branches developed in this way have a relatively late start and will not grow as large as older limbs. The younger the tree and the closer to the terminal girdling or needle removal is done, the more successful the process will be.

RANDOM-BRANCHING SPECIES

Random-branching species usually can be sheared or pinched to control size, branching, and form. When latent buds occur along older branches as well as on younger shoots, pruning cuts are usually made near a latent bud, which will then become active and develop a new growing point.

To control the spread of most random-branching conifers, prune back new growth of side branches to their halfway point in late spring. The branches can be taken back more severely and still appear natural if each lateral is pruned back to a shorter shoot growing on the top of it. The small shoot will hide the pruning cut and give a tip-end appearance to the shortened lateral. When conifer branches reach 250 to 300 mm (10 to 12 in.) in length, new growth can be cut back to 20 to 30 mm (1 in.). Small side shoots will develop, making the tree more dense. A tree can be maintained at about that size by cutting back new growth. Williamson (1972) suggests that even tall-growing deodar cedar *(Cedrus deodara)* can be kept as low as 2 m (6 ft) by cutting back the leader each year and taping a side branch near the cut into a vertical position to form the new top.

PRUNING SEVERITY

Response to pruning severity is largely determined by the presence or lack of latent buds on older wood. Pruning severity can also be based on the duration of growth during the season. If conditions are favorable, some species (including some pines) with preformed shoot initials in their buds may experience more than one growth flush during a season. Young, expanding shoots can be pruned during any or all of these flushes. If there are no visible latent buds, however, pruning into old wood will usually produce a stub from which no new growth will arise.

At the other extreme are species with buds or dormant growing points (with no bud scales) whose shoots continue to elongate even after their preformed initials are fully expanded. These species grow almost continuously or in successive flushes during the growing season. Their usually abundant latent buds produce new growth even when pruning is severe and extends into old wood. Branching is usually spiral or random, and growth may be either excurrent or decurrent, at least when the trees mature. Even though plants in this group can be pruned severely, thinning will produce the most attractive results.

As with all natural things, there are intermediate forms. Many conifers continue growth in a series of flushes under favorable growing conditions or the stimulation produced by pruning or the removal of adjacent trees. These conifers usually have latent buds randomly spaced along stems; they may retain active laterals or short shoots for many years on older wood. If pruning is needed on such conifers, it should be moderate. These species may either maintain or develop a decurrent growth habit with age.

As conifers begin to develop a decurrent structure, it would be wise to be concerned about potential branch size and attachment. Large limbs near the same size as the main stem on some conifers are more subject to failure in wind or snow storms.

COLUMNAR CONIFERS

A number of upright conifers, such as arborvitae *(Platycladus orientalis)*, cypress *(Cupressus)*, false cypress *(Chamaecyparis)*, and yew *(Taxus)*, whose branches arise from the ground to the top, are often used in formal settings. Many are clipped into "unnatural, spectacular ugliness" (Chandler and Cornell, 1952), but most can be pruned to have a natural, textured appearance. The branches of columnar conifers that start near the ground may become quite tall, growing up on the outside of the branches above; the inside foliage is shaded and may be lost. Outer branches that bend away from the column are unattractive. Most of these conifers can be trained or retrained to have short branches if upright branches are cut back to short, spreading laterals. These spreading laterals can be spaced to provide pleasant shadows and glimpses of the trunk. Much of the weak and dead foliage usually can be washed out with a garden hose spray of water.

Outside branches are often held close by wires wrapped around the tree at several elevations to keep them from bending out of the columnar form. Even though some of the outside shoots will be sheared, the plants accumulate many dead twigs and leaves between the inner stems. As such trees mature or lose vigor, the multitude of bare, slender branches becomes quite unattractive.

Yew and *Podocarpus* may be too slender or sparse if branches are cut back to spreading laterals. In these cases, the branches should be headed

at varying lengths above their laterals; the branches of yew might be left 300 mm (1 ft) or more long, and those of *Podocarpus* cut to stubs with 6 to 10 leaves and as many buds, several of which will grow and increase the number of branches (Chandler and Cornell,. 1952). Overgrown yews can be cut back to main branches to force new shoots (Brown, 1972).

NURSERY-GROWN TREES

Young nursery-grown conifers may have asymmetrical or decurrent growth in a normally excurrent species, as well as particularly compact branching. Unless these features are wanted, do not select such trees for planting. Such growth usually is the result of nursery pruning or vegetative propagation from lateral shoots (buds or cuttings) of species that have strong radial symmetry. A compact conifer, trained by severe pruning or shearing in the nursery, may look well proportioned when young, but unless similar pruning is continued when the tree grows in the landscape, the new branches will be more widely spaced, giving the appearance of a tree growing on top of a shrub.

To correct asymmetry in a small tree, choose the most upright and vigorous shoot to produce a new leader so that the growth habit will be changed from decurrent to excurrent. This shoot should have strong 2- or 3-year-old wood below it and a cluster of buds at the tip. If the chosen branch is not the longest, remove competing branches or reduce them in size to direct major growth into the new leader. If you must plant an asymmetrical conifer, partially tip (rotate) the root ball in the planting hole to keep the selected leader vertical. The selected leader can be staked into a vertical position. Continue follow-up pruning and staking until radial symmetry is obtained.

Excessive and closely spaced laterals can be corrected by selectively thinning to match the more normal later growth. Thin crowded laterals lightly until tree growth in the landscape indicates what the new spacing between whorls or branches will be. Even then, extend the thinning over 2 to 3 years. The tree will usually be most attractive if this thinning is done early in its life so that the selected branches develop without crowding. If remedial pruning is delayed, much of the interior foliage may die from shading.

YOUNG CONIFERS IN THE LANDSCAPE

Conifers are most attractive when the tips of low branches almost touch the ground; but if clearance is required under the canopy, remove lower limbs more gradually than you would with broadleaved trees, about 250 to 350 mm (10 to 14 in.) at a time on young trees. Some pruning back of laterals that are scheduled for removal will keep them relatively small so that later pruning wounds will also be smaller than they would be otherwise.

Conifers that normally have an excurrent growth habit often form multiple leaders; all but one of them should be removed. Some conifers, however, including a number of *Pinus*, some *Cupressus, Cedrus, Juniperus*, false cypress *(Chamaecyparis)*, and arborvitae *(Platycladus orientalis)* species, form decurrent crowns. In these conifers, allow multiple stems to develop into their characteristic form, unless the branches are too low or their attachments weak. These main stems should be differentially pruned, however, so that each is smaller in diameter than the trunk where they are attached to increase structural strength and present an interesting shape.

Conifers occasionally lose their leaders. When this occurs, a new leader may develop from one of the uppermost branches or from a latent bud near the top. In many conifers, when the top dies, is cut, or breaks out, branches in the topmost whorl will bend upward as reaction wood forms. One branch usually dominates to become the leader, and the others return to approximately their original orientation. Alternately, a latent bud may grow into a new leader. When a leader is lost, latent buds are more likely to grow if a 50 to 70 mm (2 to 3 in.) stub is left above the top whorl (Scarlett and Wagener, 1973). A leader from a latent bud should usually be selected over one developed from a lateral; the former will usually be more vigorous and more symmetrical. Shorten laterals in the topmost whorl to reduce competition with the developing leader. If no leader develops naturally, tie one of the topmost branches upright to induce it to become the new leader. If no leader is selected or encouraged, numerous leaderlike candles may develop randomly from upper branches, producing a particularly unattractive top (Fred Roth, Pomona, CA, 1989, pers. comm.).

PALM TREES

Palms are pruned primarily to remove old, potentially hazardous, and unsightly fronds and fruiting clusters. Several of the most commonly planted species must be pruned frequently and are consequently some of the most expensive trees to maintain. **The terminal growth is never removed because single-trunked palms have only one growing point.** Entire stems sometimes

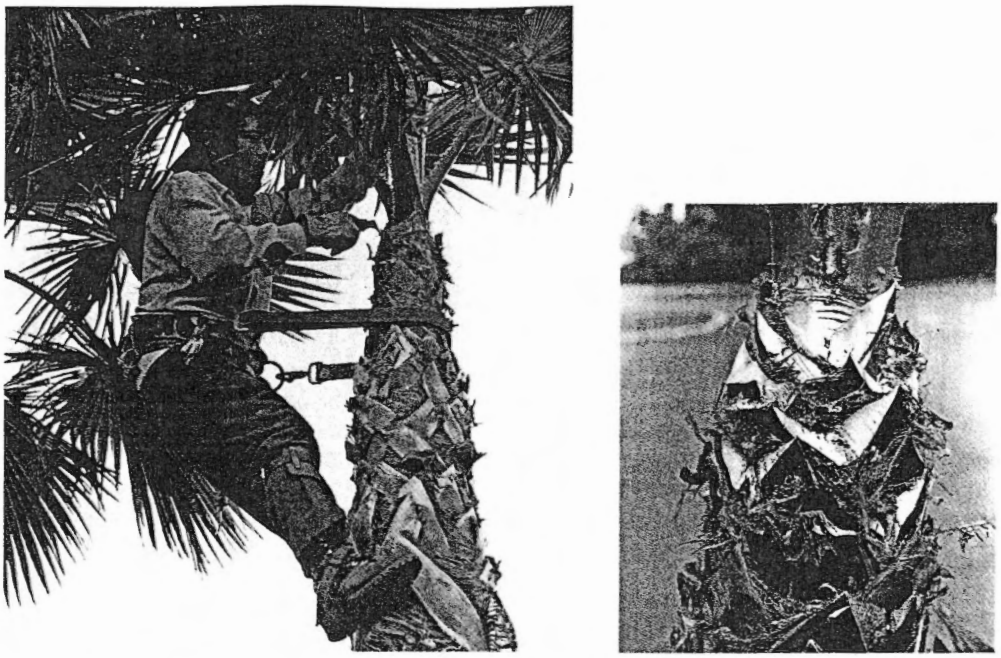


FIGURE 14-48 Mexican fan palms *(Washingtonia robusta)* are pruned frequently in intensively maintained landscapes to minimize litter from the flowering stalks. The green petioles are removed in two cuts of a sharp carpet knife (with a hooked point), leaving V-shaped tips (inset). The petiole bases will be removed a year or so later.

are removed in clustering species that produce more than one stem.

In public landscapes, certain palm species must be pruned frequently to keep them attractive and to remove dead fronds (Fig. 14-48). A palm normally maintains only a certain number of live fronds, depending on the species and growing conditions. As new leaves develop at the terminal, the lower, older fronds weaken and die. Some palms shed their old leaves; others retain dead fronds until they eventually rot away, are blown off by the wind, or are removed. Fronds can sometimes cover the trunk to the ground (Ledin, 1961). In some palms the leaf blade will break off, leaving the petiole base or boot remaining on the trunk for many years. Dead fronds or their bases harbor insects and rodents and can be a fire hazard. Falling fruit and fronds can be hazardous. Low-growing palms may have spines on their trunks or leaflets that can be dangerous. Such palms need to be maintained to minimize potential problems.

Except to minimize disease or fire damage, established palms need not be pruned for their own well-being. Broschat and Meerow (2000) state, "The removal of healthy leaves is a disservice to the palm." Such pruning "reduces the food-manufacturing efficiency of the palm" resulting in "suboptimal caliper development in the crown." There is some evidence that overtrimming makes the palm more susceptible to cold damage. Overpruning also can intensify deficiency symptoms of macronutrients, such as potassium or magnesium, by decreasing the movement of these nutrients from the old to the younger fronds. Broschat (1994) found that removal of older leaves with potassium deficiency symptoms accelerates the rate of decline and can result in the premature death of the palm.

Palms that produce hazardously large fruit, especially coconut, or frequently drop old fronds may have to be pruned every 3 to 6 months. Fruiting stalks, fronds, and loose petioles should be removed at each pruning. "In contrast to leaf removal, there is no harm in removing palm inflorescences at any stage of their development, or even removing flower stalks before they open" (Broschat and Meerow, 2000). Fruiting stalks should be pulled down and cut close to the base without damaging living trunk tissue. On regularly and frequently pruned coconut and other palms, usually only the bottom one or two rings of fronds are removed. A thin, fibrous sheath surrounds the frond base and makes cutting difficult unless the sheath is first pulled down and cut off. The exposed fronds are green and easily cut with a pruning knife or machete. The ends of the frond stubs can be shaped to one or two points by two cuts with a sharp knife (Fig. 14-48). The frond stubs left by the previous pruning are cut off close to the trunk.

An experienced pruner can usually climb and prune a mature coconut palm *(Cocus nucifera)* in 10 min. Unfortunately, most pruners use spurs (spiking), which create holes in the palm

FIGURE 14-49 Holes are punched in this Mexican fan palm trunk by using climbing spurs (left). The holes will remain for the life of this coconut palm (right). Except for being unsightly, decay is seldom a problem. *(Photo courtesy David Hensley, University of Hawaii.)*

trunks that do not close (Fig. 14-49). "*Spiking* is a prescription for future problems (in Florida). The holes left will never heal and instances of disease transmission have been documented as a result of this practice" (Broschat and Meerow, 2000). Even though it is quite humid in Hawaii, decay in spur wounds of coconut palms is almost nonexistent (Stephen Nimz, Honolulu, 1997, pers. comm.). Trunk dissections support the observation that coconut palms wall off spur wounds. Shorter spurs create smaller holes.

Some palms, including royal palms *(Roystonea)*, readily shed their old leaves. When the fronds begin to turn brown, they can easily be pulled from the trunk. This should be done fairly regularly on tall trees. The fronds of other palms are usually removed less frequently, depending on the species and the amount of effort required. Some of the date palms *(Phoenix dactylifera)* are pruned with a chain saw every 2 years. The cut frond bases can be quite acceptable if pruning is done carefully. Take care when cutting fronds so as not to cut into live growth, which could cause unsightly scars. Most fronds should be cut from below with a chain saw to minimize ripping fibers down the trunk. The chain housing may have to be enlarged to minimize clogging with palm fibers. However, do not use a chain saw on *Phoenix* sp. because of the possibility of transmitting the deadly fungus disease fusarium wilt *(F. oxysporum)*. Use a reciprocal saw, the blade of which can be sterilized after pruning each tree (Ohr, 1989). Somewhat similar recommendations are given for controlling fusarium wilt in Florida (Simone, 1998).

Most multiple-stemmed palms form new shoots just above the ground. Though there is little need to prune cluster palms, an entire stem is sometimes removed. Individual stems may need to be removed if they grow close to a building, the cluster occupies too much space, or a specimen plant is wanted. In some monocarpic clustering palms, each old stem should be cut off as close to the ground as possible after the final fruiting because that stem dies shortly afterward (Timothy Broschat, 1997, pers. comm.). However, in areas where *Ganoderma* butt rot is prevalent, the removal of mature stems of clustering palms can result in *Ganoderma* infecting the clump from the dead stumps (Broschat and Elliott, 1997, unpub. data). This fungus readily colonizes stumps of cut palms and produces billions of airborne spores that can infect nearby healthy palms. Therefore, all palm stumps and adjacent roots should be removed in areas where this fatal disease is prevalent.

Palms injured by cold usually suffer most damage in the lower leaves. Ledin (1961) recommends removing all injured fronds, except the inner two or three, at the terminal. Even when all the

fronds are injured, do not remove the tree for at least 6 months to determine whether it will survive. If the terminal bud is alive, it will send out new leaves. If the top leaf bases have hardened, the new growth may become stunted as it tries to push up. To prevent this, loosen the dried leaf bases as the new growth begins to show (Ledin, 1961).

SHRUBS

Shrubs are woody plants usually with several to many stems originating at or near the ground. Shrubs are not as tall as trees. They vary in height, spread, vigor, branching patterns, flowering and fruiting characteristics, and leaf retention. These characteristics should be considered when pruning shrubs and when selecting which species to plant in a particular landscape site. Unfortunately, mature height and spread of shrubs are often overlooked, subsequently requiring more severe and more frequent pruning later in order to control size. Severe pruning can result in the loss of the inherent qualities for which the species may have been selected as well as a loss of flowers. Dwarf or more compact cultivars may be wise choices if space is limited.

Most broad-leaved shrubs have abundant latent vegetative buds at their bases and along their branches. New shoots from their bases replace weak and dying branches and, in effect, keep shrubs young. A mature shrub that forms few or no new shoots from its base usually will do so if its top is pruned or its base opened to light.

Unlike most deciduous shrubs, not all broad-leaved and few coniferous evergreen shrubs resprout when pruned back to old wood. They grow primarily from buds on the previous year's growth.

GENERAL SHRUB PRUNING CONSIDERATIONS

Certain pruning procedures should be followed for almost all shrubs when a problem is seen and particularly when beginning to prune a shrub. The severity of pruning should be adjusted to what is to be accomplished and according to the shrub's response to previous prunings.

REMOVE DEAD, DAMAGED, INFECTED, AND INFESTED WOOD Regardless of the type of shrub certain basic pruning considerations apply. Disease infected and insect infested wood that could be a danger to it or other plants should be removed and disposed of properly. These branches along with dead, damaged, and broken ones should be the first task when a shrub is to be given a regular pruning. A shrub that has been damaged may benefit from prompt pruning and other necessary care to have the plant regain its former landscape effectiveness and to ensure an appropriate structure.

CONTROL SUCKERS A sucker is unwanted growth from below the soil surface or the graft union. The sooner suckers are removed, the easier and more effective the task of pruning. Small succulent suckers can be rubbed or snapped off easily using fingers with a good possibility of their not regrowing. Woody sucker removal may require the use of pruning shears and/or a saw. Unless they are wanted, all suckers should be broken off or cut close, particularly those that originate at or below the soil surface. This minimizes the extent of their regrowth.

CONTROL REVERSION Occasionally a portion (a leaf or leaves on a shoot or branch) of a plant with variegated (color) leaves reverts to normal green coloration. A variegated plant has leaves with tissues of differing genetic make-up called chimeras. Usually a reversion is not wanted and the reverted branch should be pruned out. If not removed, the plant may not have the desired appearance, and the reverted branch, usually with higher-chlorophyll-content leaves, could outgrow those with variegated leaves.

DEVELOPING SHRUB STRUCTURE Vigorous shoots growing from the base of a young shrub should be selected to develop a well-balanced branch structure. This is particularly important for species that, when mature, have most of their growth at the periphery of the shrub but few vigorous shoots from their bases.

PRUNING DECIDUOUS SHRUBS

Deciduous shrub species vary in mature size, branching patterns, foliage size and shape, flower size, shape and color, and their need for pruning. Deciduous shrubs should be pruned primarily by thinning cuts so that the plants appear unpruned even though they are pruned to control size and/or shape (Fig. 14-50).

SHRUBS FLOWERING ON ONE-YEAR-OLD SHOOTS Flowers develop from lateral buds and some on short laterals that form on one-year-old wood. Flowers bloom on shoots in the spring and some on laterals in early summer. *Deutzia,* mock orange *(Philadelphus),* and *Weigela* species are examples of such shrubs.

The height and diameter of a shrub can be controlled and its natural form maintained by making appropriate thinning and heading cuts.

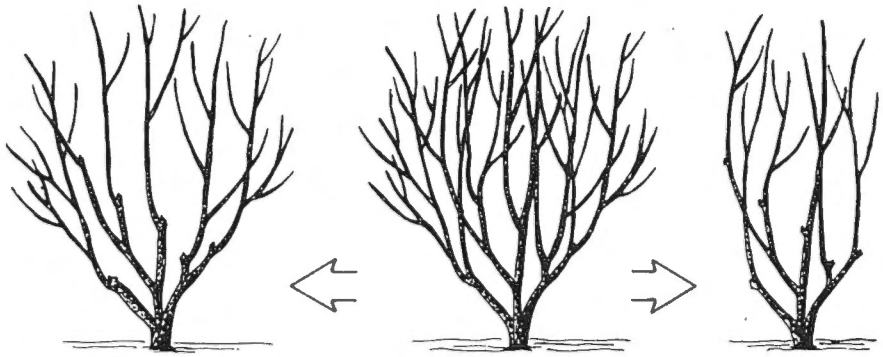


FIGURE 14-50 A shrub (center) can be pruned so that it becomes more spreading (left) or more upright (right) in habit. Short stubs indicate where the cuts have been made.

Spring-flowering shrubs should be pruned soon after blooming to foster vigorous growth for flowering the next year. Remove some old stems to the ground. Thin out weak one-year-old growth. Remaining stems that have flowered should be pruned back to one or two side laterals near their bases that have not bloomed. Thin new shoots leaving the most vigorous. New growth on existing stems and from the shrub base will be stimulated.

SHRUBS FLOWERING PRIMARILY ON SPURS As species in this group mature, the shoots form flowering spurs as do the shoots that continue to develop from the shrub base. This type of flowering includes such species as maple *(Acer)* and witch hazel *(Hamamelis)* genera. As the spurs increase in size and number the shrub gradually increases in size forming a fairly symmetrical periphery.

Early training is important in order to obtain a desired structure to display the flowers. As these shrubs mature the main pruning is to maintain the desired form and size by removing shoots and spurs growing beyond the general symmetry of the plant and those that are weak. Remove the shoots or spurs by pruning them back to where they are attached to larger branches within the shrub.

SHRUBS FLOWERING ON CURRENT-SEASON GROWTH *Fuchsia hybrida* and *Buddleja davidii* flower on current-season growth. The previous year's shoots can be cut back to ground level or to within a few buds of the base of each branch of an established shrub. Some of the older less vigorous branches may need to be removed so the shrub maintains the desired vigor and flowering.

SHRUBS PRUNED PRIMARILY FOR FOLIAGE DISPLAY Varieties such as 'Purpurea' hazel nut *(Corylus maxima)*, 'Plumosa Aurea' red elderberry *(Sambucus racemosa)*, and 'Folis Purpureis' smoke tree *(Cotinus coggygria)* are often grown for their foliage display (Combs and others, 1994). Develop the basic shrub structure and height for its chosen landscape location. Prune the shoots back to that height each spring. Select vigorous basal shoots to replace weak branches.

PRUNING EVERGREEN SHRUBS

Evergreen shrubs include broad-leaved and coniferous plants. Most species have a single flush of growth in the spring. Be sure that broad-leaved species are hardy in your area.

PRUNING BROAD-LEAVED EVERGREEN SHRUBS Most broad-leafed evergreens form a reasonably compact symmetrical shape. Even so, they should be given sufficient space to accommodate their mature size in order to have an attractive plant with a minimum of pruning. If space may be a problem it may be wise to select dwarf plants. Main shoots of young plants may be spindly and should be cut back several centimeters (a few inches). Early pruning involves primarily shortening shoots that are growing beyond the general symmetry of the plant. Growth to be removed should be cut back inside the shrub to the branch to which it is attached. Such thinning gives a soft, natural form to the shrub.

Do not shear broad-leafed shrubs; growth of shrubs so pruned stimulates many shoots to grow, requiring more frequent pruning, and the plants keep increasing in size each year. Most mid-to-large-leaf-sheared shrubs have little character and the mutilated leaves can be quite unattractive.

Severe pruning is recommended only for overgrown shrubs in certain situations, but it will usually not endanger the plants. In fact, most vigorous shrubs can be cut close to the ground (50 to 150 mm or 2 to 6 in.) (Brown, 1972). New shoots soon reestablish a shrub with renewed vigor and foliage clear to the ground (Fig. 14-51). Plants pruned severely would have less vigorous regrowth if some of their roots were cut, though roots seldom are pruned. Vigorous regrowth will develop a larger-diameter shrub if it is headed a

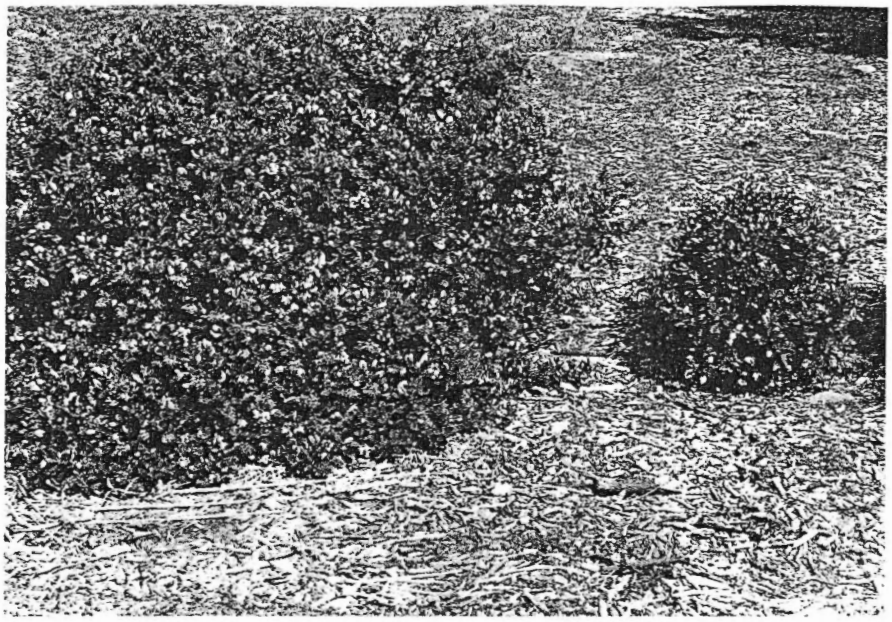


FIGURE 14-51 Many overgrown shrubs can be pruned close to the ground when there seems to be no other way to reduce their size without exposing bare branches. The *Escallonia* on the left was pruned within 150 mm (6 in.) of the ground 2 years before the photograph and the one on the right, 1 year. Compact symmetrical spheres result; frequent thinning will be necessary to develop any character in the plants.

few times during the growing season. Some of the new basal shoots should be thinned to favor the more desirable ones and to give the shrub a more natural look. Without thinning, the shrub might consist of many spindly upright shoots growing close together.

PRUNING CONIFEROUS SHRUBS Narrow-leaved evergreen shrubs are frequently used as foundation plantings and along walkways. As they mature, annual pruning is necessary to control size and maintain a desired form. Coniferous shrubs can be kept compact and natural looking by thinning back to lateral branches. An experiment in Ohio compared the growth of two identical 'Wardii' yew *(Taxus baccata* x *media)* shrubs: One was not pruned and the other was given an annual thinning (Roth and Buscher, 1994). Following are the results after 32 years:

	Unpruned Shrub	Thinned Annually
Diameter	8.9 m (27 ft)	1.6 m (5 ft)
Height	2.3 m (7 ft)	0.8 m (2.5 ft)

It was estimated that the unpruned yew would have outgrown its landscape space in 10 to 15 years.

Thin back long stems in early spring so new growth can quickly fill any voids. Vigorous second-flush shoots may need to be modestly shortened. However, severe pruning cuts in summer may not allow time for the cuts to be hidden by new growth.

SHRUBS INTO SMALL TREES

A shrub that has grown too large to be easily reduced in size can often be trained to become an attractive small tree (Fig. 14-52). Low-growing branches that do not carry into the top of the plant, and usually some of the main branches as well, should be removed. The remaining branches will then become more prominent visually. Seldom will a new branch structure need to be created; simply thin the existing one. Severe pruning and exposure of the lower trunk to more light may stimulate watersprouts. Make close cuts and, if necessary, treat the wounds with NAA to minimize watersprouts (see Chapter 15). If several shrubs in the same planting are to be trained into small trees, some should probably be removed to provide adequate room for the remaining ones.

HEDGES

A hedge is a row of closely spaced shrubs or trees, usually of a single species, grown either informally with little or no pruning, or formally trained and sheared. Hedges can be thought of as small short-pruned tree screens (see Fig. 14-37). Hedges serve as visual and physical screens and dividers. They are more common in public and large private landscapes than in small residential plantings. Informal hedges are allowed to grow naturally and usually require considerable space; Wyman (1971) suggests that hedges, particularly conifers, be allowed to grow nearly as wide as they

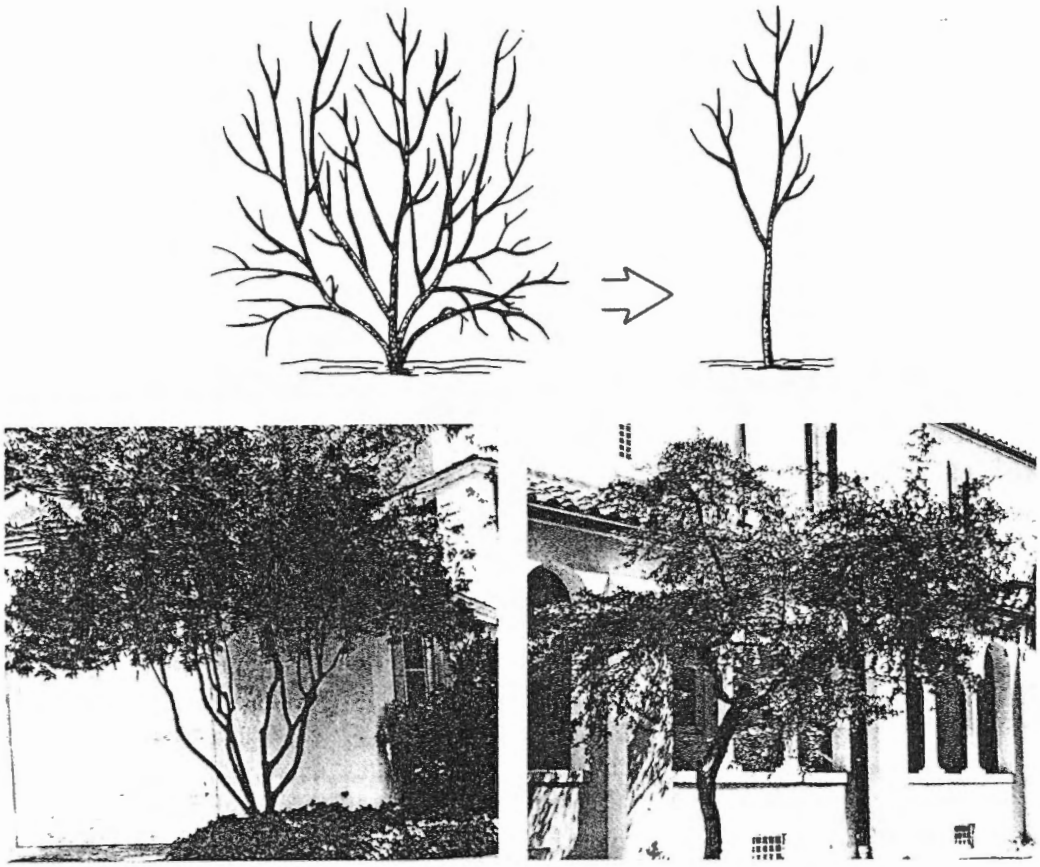


FIGURE 14-52 Occasionally, an overgrown shrub can be pruned into an attractive small tree (top). A more attractive plant will usually result if fewer branches are left than on the *Callistemon* (lower left), though they can be more than the single-trunked *Pyracantha* (lower right).

are high. Formal hedges are sheared fairly regularly to retain their form, size, and attractiveness.

Plants, particularly for formal hedges, should have small leaves, short internodes, and dense branches and should be able to sprout from old wood. Evergreens are preferred for effective year-round screening. In colder climates, conifers may be the only evergreens hardy enough to survive. Plants with larger leaves are often used for informal hedges, but the cut foliage of large-leafed plants is often unattractive when it has been sheared for more formal effects. Grounds (1973), Wyman (1971), and Dunmire (1988) recommend specific species for particular uses and geographical areas.

Informal hedge plants are spaced 500 to 900 mm (20 to 36 in.) apart, and all growth is headed back at least halfway to encourage low, dense branching. After this, only occasional pruning is needed to maintain moderately uniform growth and symmetry and to keep the hedge in bounds. Pruning individual branches with hand shears instead of shearing many branches at once will maintain an informal appearance. To create, maintain, and control the size of an informal hedge, individual branches should be removed with thinning cuts.

For a formal hedge, small-growing evergreens may be planted as close as 450 mm (18 in.) apart, whereas large-growing deciduous plants should be planted at least 900 mm (36 in.) apart. Depending on the size of the shrubs or trees at planting, small evergreens should be cut back to within 75 or 100 mm (3 or 4 in.) of the ground and large deciduous plants to within 150 or 300 mm (6 or 12 in.) of the ground. No further pruning takes place in the first growing season so that plants can become well established.

Before growth begins in the second year, the shoots of broad-leaved plants should be headed to within 100 or 150 mm (4 or 6 in.) of the pruning height at planting. Conifers should be tip pruned. Until the desired height is reached, head back new shoots one-half to two-thirds of their length each time that they grow 150 to 300 mm (6 to 12 in.). Severe heading of new growth encourages plants to spread and develop a dense, low-branched structure. When the developing hedge has filled in fairly well at the base, it should be allowed to grow more in height than width. Hedges, particularly

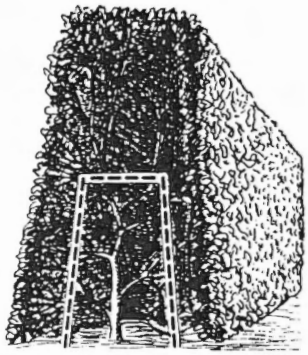


FIGURE 14-53 To maintain low foliage, shear a hedge so that it is wider at the base than at the top, particularly if oriented in an east–west direction. When a hedge has become too tall and wide, prune it back to about the size indicated by the dark broken line; after two or three shearings, the hedge will be well clothed in leaves.

conifer hedges, should be wider at the base than at the top to ensure that the lower foliage will receive enough light (Fig. 14-53). In areas subject to early frosts or cold winters, pruning should not take place after midsummer.

After a hedge has nearly reached the desired height, time when to shear according to the amount and cycle of growth. The effects of shearing will last longest if it is done after growth has ended for the season. Growth may be so vigorous, however, that the hedge becomes unattractive and must be sheared during the growing season. With experience, a compromise can be reached between minimizing the number of shearings and maintaining an attractive hedge. Most small formal hedges begin to look unkempt when new growth is 50 to 100 mm (2 to 4 in.) long.

Shear new growth on a mature hedge to within 10 mm (0.4 in.) of the previous shearing, leaving only one to three new leaves (and buds). This will clothe the hedge in new foliage and slow its increase in height and spread. After each shearing, the hedge will grow a little larger than it was after the previous shearing. Eventually, most hedges become too large for their sites or begin to lose their lower foliage. Light pruning removes most foliage without greatly reducing the size of the hedge. In contrast to many conifers, most broad-leaved hedges can be pruned back severely. It is best to cut broad-leaved hedges back to about half the desired mature height and width (Fig. 14-53). The pruned plants will have little or no foliage, but should soon develop new shoots. After one or two shearings, the hedge will return to its original beauty. Such heavy pruning should be done just before growth begins in spring so that the hedge is bare for the shortest time. Conifers must be pruned with greater care; be sure new shoots will grow from older wood (Table 14-2).

ROSES *(ROSA)*

Roses are usually pruned more severely than other shrubs, not only to keep them in bounds but to balance vegetative growth and flowering. This is done by varying the number and length of canes selected by pruning. In deciding how severely to prune, evaluate the plant's vigor and the size of the previous season's roses. If you want more vigorous growth and larger blossoms, leave fewer and/or shorter canes than previously. However, if growth has been vigorous with large blooms, you can leave more wood to take advantage of the plant's flower-producing capacity. Details for pruning roses can be found in many books specializing in roses and pruning, particularly those by Brown (1972) and Dunmire (1988).

VINES

Vines, also called climbers or wall shrubs, have vigorous, slender, flexible stems that require support in order to acquire much height. Vines are versatile and can grow quickly as a ground cover, a screen on a trellis, a cascade of foliage and flowers against a wall, a leafy cover on an arbor, or a climber on a pole or tree. Because they are vigorous growers, most vines must be pruned annually to keep them attractive, healthy, and in bounds. To be effective in the landscape, most climbing vines require as much attention as roses *(Rosa)* do. Vines can greatly enhance even a small landscape, but the species must be selected with regard to function and space.

Not all vines can climb. Although most have some means of holding onto a support, some need help. Vines climb upright in four basic ways (Fig. 14-54): as aerial roots, holdfasts, or sucker discs (ivy [*Hedera*] and Virginia creeper [*Parthenocissus quinquefolia*]); as tendrils (*Clematis* and grape (*Vitis*]); as twining stems (star jasmine [*Trachelospermum jasminoides*] and *Wisteria*); or using artificial means of support (*Bougainvillea* and rose). Thorns and hooklike projections on stems and leaves help other plants attach themselves to supports. Vines with aerial roots or holdfasts can climb almost any surface, whereas other vines need a trellis, fence, or wire for support.

Managing vine growth consists primarily of directing the stems on a support (training), pruning out old growth, and containing plants to their allotted space. Particularly when plants are

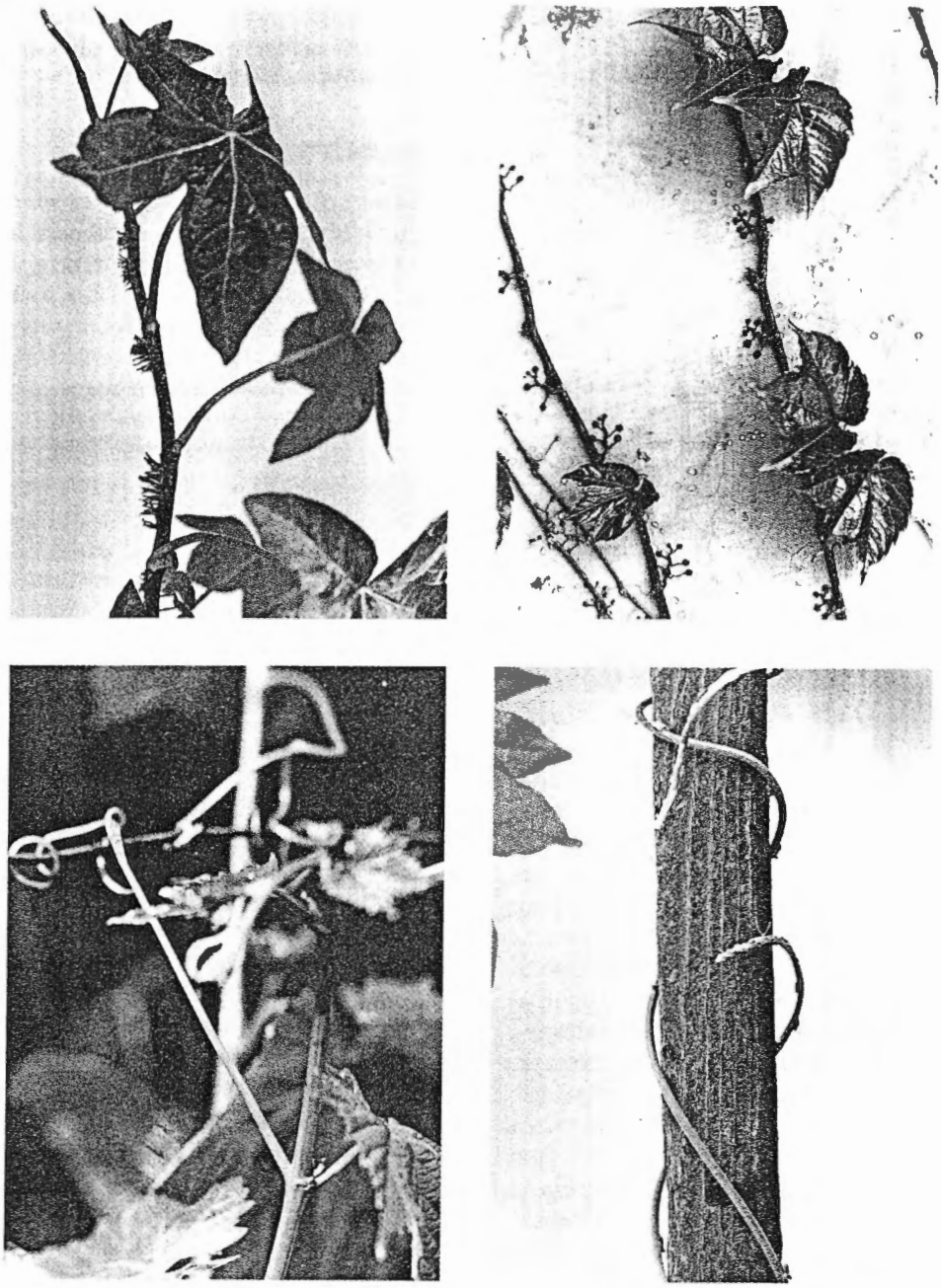
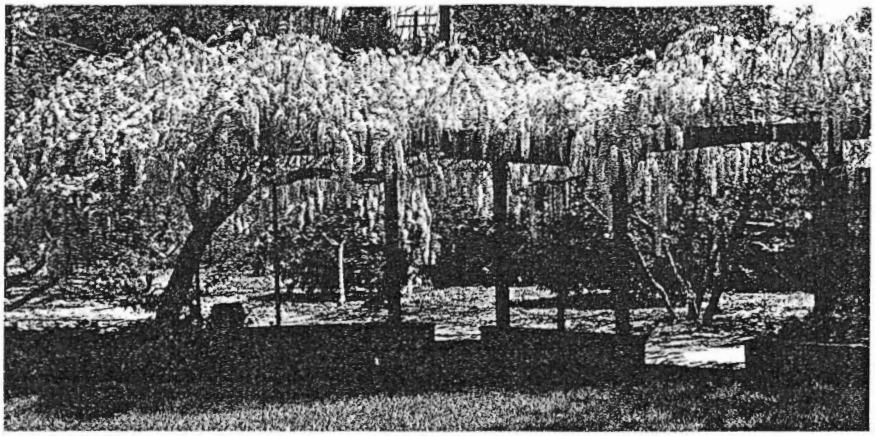


FIGURE 14-54 Vines attach themselves for support in several ways: English ivy *(Hedera helix)* by aerial roots (top left); Boston ivy *(Parthenocissus tricuspidata)* by holdfasts (top right); grape *(Vitis vinifera)* by tendrils (bottom left); and Wisteria by twining stems (bottom right).

young, arrange stems on their support to form a pleasing pattern. If the stems do not branch readily, pinch their tips where branching is wanted. Pinched stems cover a trellis more densely, especially stems that radiate from the base. Many vines overgrow their space quickly and become unattractive tangles unless they are pruned regularly. New shoots that will not be useful replacements should be pruned back or out to keep a vine from becoming too dense and heavy. Older branching systems that fail to produce vigorous flowering shoots should be cut back to main branches or all the way to the base. Vigorous stems that grow beyond their allotted space or begin to climb where not wanted should be cut back or trained back on the vine's support.

The growth and flowering habits of vines provide clues for training and pruning the plants to carry out their landscape function. Vigorous vines that cling to a wall or support, such as ivy, can be clipped close to the wall at least once a year. Prune them before growth begins and again as needed during the growing season. This keeps the foliage close to the wall and, in ivy, prevents



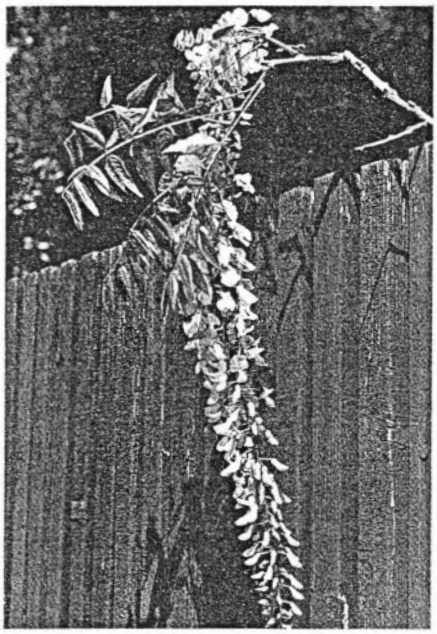


FIGURE 14-55 A 30-year-old wisteria in bloom (top). A wisteria shoot system that was headed to two to four buds during the growing season (lower right); the spur system could be cut back to the second spur before spring growth. Short flowering shoots grow from the basal spur buds (lower left).

mature branches from forming. Some vines, such as wisteria, form a heavy structure on which vigorous shoots grow; buds near the bases of shoots flower during spring following shoot growth. The first shoots of a young vine should be trained to become the permanent framework. Later shoots from the framework branches should be pinched or cut back to two or three leaves during the growing season. Succeeding growth flushes, in turn, must be headed (Fig. 14-55). Before spring growth, cut back each headed shoot system to the lowest one or two buds. Short shoots will grow from these basal spur buds and form terminal racemes (short shoots) of flowers.

On vines that flower along vigorous 1-year-old canes, such as honeysuckle *(Lonicera)* and rambler rose, the canes should be pruned out or back to new low-growing shoots after they have flowered in the spring. The pruned stems must be removed carefully so that the new shoots are not damaged, particularly if the shoots twine around each other. Other vines, such as weeping *Forsythia,* develop main branches from which pendulous shoots grow readily for several years. Flowers are borne on these 1-year-old shoots. The main branches should be trained to provide height from which the long shoots can hang. Although annual pruning is recommended, it need not be as severe as most vines require; remove about one-third of the older wood each year after flowering. Likewise, thin about one-third of the drooping shoots on remaining branches. Vines that flower on vigorous current-season growth, as some *Clematis* do, should be pruned severely each year, often close to the ground, before growth begins in the spring. This annual pruning keeps the plant vigorous and in bounds.

A number of vines, such as ivy and star jasmine, are also grown as ground covers. These spread quickly and some, such as ivy, root where shoots contact moist soil. These vines must be trimmed two or three times a season to keep them within their borders. Within a few years, the mass of canes builds up so high that it must be cut back. If ivy canes are not too large, a rotary power mower or hedge shears can be used to remove almost all the canes back to where they have rooted. Do this just before spring growth begins so that new growth quickly covers the bare canes.

Vines must be planted with care near buildings. Aerial roots and holdfasts of vine species can damage masonry walls. Small shoots can grow in cracks in walls, roofs, fences, and other structures and can cause considerable damage as they increase in diameter. They can clog downspouts and rain gutters. If not regularly pruned, some vines become so heavy that they collapse their support. Vines can engulf shrubs and small trees and sometimes kill them by blocking sunlight. Vines can be valuable features in a landscape but they may require considerable attention.

REVIEW

- Woody plants are pruned to train young plants; maintain health and appearance; control size; influence flowering, fruiting, and vigor; compensate for root loss; and create special plant forms.
- Pruning young nonflowering plants invigorates remaining growth but reduces total growth of the plant.
- Pruning flowering plants invigorates remaining growth and may increase total growth of the plants though reducing flowers and fruit.
- Time of pruning depends on species, plant condition, and the results desired.
- Essentially there are three types of pruning cuts:

  Thinning (removing) cuts a lateral branch at its point of attachment.

  Thinning to a lateral (reducing) cuts shortens a branch or leader by cutting it to a lateral large enough to assume the terminal role.

  Heading or heading back removes a currently growing or 1-year-old shoot back to a bud, or cuts an older branch or leader back to a stub or to a lateral not large enough to assume the terminal role.

- Response to thinning and thinning to a lateral (removing and reducing) cuts is similar and, unless severe, generally spread throughout the plant leaving it more open and natural looking.
- Response to heading cuts is vigorous, upright growth from just below the pruning cut, which, depending on the severity of pruning, is dense and weakly attached.
- A proper pruning cut should be made close to but beyond the branch bark ridge in the branch crotch and the collar at the base of the branch attachment.
- A dead branch stub should be cut back to but not into the live collar.
- Asphalt to reduce borer attacks or a fungicide to control canker fungi may be of value on large pruning cuts but, otherwise, trying to protect pruning cuts is of doubtful value.
- Structural strength of trees depends on branches being smaller than the ones to which they are attached, having wide angles of attachment and adequate vertical and radial spacing between scaffold branches, and well-tapered trunks and branches.
- In long-pruned (free or natural form) trees, the root collar and the trunk are the main storage zones for starch-type products. In contrast, the richest starch areas in short-pruned (sheared or pollarded) trees are in the branch-end calluses pruned to every year and in the main roots.
- Heading currently growing shoots 50% in early summer stimulates photosynthesis of basal leaves and does not weaken the tree but results in a marked increase in carbohydrates in the crowns and trunks of trees so pruned.
- Training young decurrent trees will provide the greatest benefit of any cultural practice in influencing the future structure, appearance, and maintenance costs of landscape trees.
- Young trees may not make as much total growth when trained, but the growth can be where it is wanted.
- Temporary branches along the trunk of a young tree strengthen, increase taper, and protect the trunk.
- The height of the first permanent scaffold depends on the function of a tree in the landscape.
- For safety and efficiency follow prepruning procedures for mature trees.
- Crown cleaning, thinning, raising, reduction, and/or restoration pruning may be needed to ensure safe, aesthetic mature tree performance.
- Hedges, pollarding, espalier, topiary, pleaching, and bonsai (penjing) use training techniques to create and maintain artificial forms of trees and shrubs.

- Confiers are pruned primarily to shape young trees, control the density of branching, and the size of older trees.
- The most common palm species are pruned frequently to remove old unsightly fronds and fruiting clusters and usually are costly to properly maintain.
- Shrubs range in height, spread, vigor, and flowering characteristics, each of which influence landscape use and pruning techniques.
- Vines require direction of growth, pruning out old growth, and confining them to their allotted space.

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Chapter 15

Control of Plant Growth

OBJECTIVES

- The limits on stimulating tree growth are examined.
- The class of compounds known as tree growth regulators (TGRs) and their application in utility arboriculture are introduced.
- The potential for chemical control of unwanted fruit and sprout growth is reviewed.
- Use of herbicide treatment for unwanted vegetation is discussed.

A number of chemicals and other treatments are used to either reduce the growth of shoots and roots or to prevent fruit set. An arborist who desires to "control" tree growth should understand the effects of growth-regulating chemicals and other physical restrictions, the limitations of their use, and the conditions under which they can be used safely and beneficially. Control of root growth in sewers and physical control of root growth through the use of barriers is discussed in Chapter 10.

STIMULATION OF GROWTH

When water or a nutrient is limiting, addition of the limiting item usually increases plant growth. Irrigation may be necessary for normal, vigorous growth of young plants and to maintain plants when soil moisture is limiting (see Chapter 13). Fertilization has been perfected to a science for many food, fiber, and greenhouse crops and is particularly important for stimulating the growth of young landscape plants (see Chapter 12).

There are, however, chemicals other than nutrients that stimulate the growth of shoots or the dry weight of leaves and stems. Gibberellin can stimulate stem elongation in many plants that are genetically dwarf or rosette. Gibberellin is used commercially on a few crop plants (to encourage melon [*Cucurbita pepo*] fruit set and grape [*Vitis vinifera*] enlargement, for example), but a use has not been found for it in the landscape. Similarly, we are not aware of any practical application for other plant growth substances that might stimulate cell division and growth. **In summary, there is no chemical substitute for good growing conditions in optimizing tree growth.**

CHEMICAL CONTROL OF PLANT HEIGHT

Chemicals can control shoot growth of many herbaceous and woody plants and are commonly known as growth inhibitors and growth regulators (PGRs). Arborists refer to this class of compounds as *tree growth regulators* (TGRs). These chemicals have been a part of greenhouse production for decades. Crops such as poinsettia *(Euphorbia pulcherrima)* and azalea (*Rhododendron* sp.) are commonly treated with growth-retarding chemicals to control height.

Use in the landscape market is more limited. Growth of turf grass can be inhibited by a number of compounds that are finding application in both roadside right-of-way and fine turf settings. Landscape maintenance firms use inhibitors to manage ground covers such as English ivy *(Hedera helix)*.

GROWTH CONTROL MECHANISMS

Control of the elongation of shoots can occur through manipulation of cell division and/or cell elongation. The focus has been on reducing shoot growth. In the shoot, there are two tissues active in cell division: the apical and subapical meristems. Chemicals have been developed that are active in both areas (Sachs and Hackett, 1972).

Terminal-bud inhibitors act to inhibit apical meristematic activity or reduce apical dominance, thereby allowing lateral buds to grow, which in