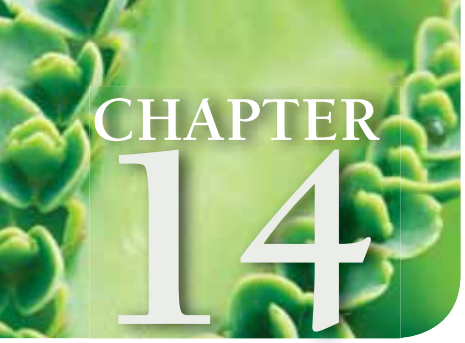

CHAPTER 14 Stem and Leaf Propagation

Chapter Outcomes

After studying this chapter, you will be able to:

- Understand the biological principles of stem and leaf propagation.
- Describe sources of plant material for stem cuttings and environmental conditions required for rooting.
- Describe the propagation methods for leaf cuttings and root cuttings.
- List materials used to mix rooting media.
- Explain the role of plant growth regulators in the propagation process.
- Identify careers related to stem and leaf propagation.

Words to Know

abscise
acclimatization
adventitious root formation
asexual propagation
auxin
callus tissue
cutting
cytokinins
deciduous
dedifferentiate
differentiate
distal
hardwood
herbaceous
leaf-bud cutting
leaf cutting
nursery liner
phytohormone
plantlet
polarity
preformed root
proximal
softwood
stem cutting
stock plant
suberin
vegetative propagation
wound-induced root

Before You Read

Before you read the chapter, read all of the table and photo captions. What do you know about the material covered in this chapter just from reading the captions?

Copyright Goodheart-Willcox Co., Inc.




While studying this chapter, look for the activity icon to:

- **Practice** vocabulary terms with e-flash cards and matching activities.
- **Expand** learning with the Corner Questions and interactive activities.
- **Reinforce** what you learn by completing the end-of-chapter questions.

www.g-wlearning.com/agriculture

G-WLEARNING.COM

magnetix/Shutterstock.com; whitemaple/Shutterstock.com; senee sriyota/Shutterstock.com; Kazakov Maksim/Shutterstock.com; Terry McClary/Shutterstock.com

Have you ever walked through a garden and pinched off a piece of a plant and later tucked it into a vase of water? Did you see roots begin to grow? This horticultural method of starting new plants from existing plant material is called ***vegetative*** or ***asexual propagation***. It is an important clonal regeneration technique that produces a plant genetically identical to its parent. Many plants have been developed through plant breeding processes where seed propagation is not feasible, for sterile specimens, or simply for the joy of starting more plants.

A *Aggie 11/Shutterstock.com*

B *saiko3p/Shutterstock.com*

Figure 14-1. A—Corn stalks will naturally send adventitious brace roots towards the soil to stabilize the plant and provide additional support. B—Banyan trees have preformed root initials that, when given the right conditions, emerge as adventitious aerial roots.

Biological Principles of Leaf and Stem Propagation

The most widely applied method for vegetative propagation using a piece of leaf or stem is called a ***cutting***. The cutting has the ability to adventitiously form roots, which allows subsequent normal growth and development of the new plant. The new plant is genetically identical to the plant from which the cutting was taken. ***Adventitious root formation*** is the process of roots forming from any plant part other than the root. Many adventitious roots form naturally, such as the brace roots on a corn stalk, or the aerial roots of a banyan tree, **Figure 14-1**.

The cellular tissue in the leaf or stem cutting actually ***dedifferentiates***, meaning the cell regresses from a specialized function to a simpler state. For example, callus tissue forms from plant tissue in response to wounding. The ***callus tissue*** is a bundle of undifferentiated cells that cover the wound and begins to initiate new cellular divisions that ***differentiate*** (develop a specialized function) to form into meristematic growing regions or roots. There are two kinds of adventitious roots: preformed roots (with cells that have existing root initials) and wound-induced roots.

Copyright Goodheart-Willcox Co., Inc.

Preformed Roots

Preformed roots develop naturally on stems while they are still attached to the parent plant. These roots are underneath the stem tissue and may not emerge until the stem piece is cut and placed in environmental conditions conducive to the emergence of roots. For example, the easily rooted willow tree will form adventitious roots once it is placed in a potting medium and given a proper environment. Other species that have preformed roots include coleus (*Plectranthus scutellarioides*), *Hydrangea*, poplar (*Populus*), jasmine (*Jasminum*), currant (*Ribes*), and the houseplant pothos, **Figure 14-2**.

amphaiwan/Shutterstock.com

Figure 14-2. Pothos are easy to propagate with preformed roots that emerge at the node.

Wound-Induced Roots

Wound-induced roots only develop after a cutting is made. Roots develop as a direct response to the wounding that occurs when the stem piece or leaf from the parent plant is severed. Plants that are wounded (whether intentionally for the process of propagation or accidently as in when the lawn mower runs into a tree) exhibit a wounding response. The wounding response has three key steps:

1. The outer layer of injured cells die. The cambial layer forms a barrier zone that is rich in a waxy substance called ***suberin*** that seals the wound. This prevents plant tissue from drying out and protects the plant from pathogens.
2. Cells behind the wound begin to divide and form a callus.
3. Cells near the vascular cambium and phloem begin to divide and initiate adventitious roots.

Adventitious Shoot and Bud Formation

Plants started from leaf cuttings need to develop both roots and shoots. Adventitious shoot, or bud, formation arises from the active cellular regions of the primary or secondary meristems. Preformed, primary meristems are undifferentiated cells that are constantly dividing. Wound-induced, secondary meristems are cells that have already differentiated into some kind of tissue but change into new, undifferentiated meristem cells that allow bud tissue to grow.

Piggyback plant (*Tolmiea*), **Figure 14-3**, is a unique specimen that grows ***plantlets*** (small or young plants) that originate from the primary meristem. As the plantlets develop, they detach from the mother plant.

joto/Shutterstock.com

Figure 14-3. Piggyback plant forms adventitious shoot tissue from preformed shoot initials.

Copyright Goodheart-Willcox Co., Inc.

chonrawit boonprakob/Shutterstock.com

Figure 14-4. Mother of thousands develops foliar embryos from primary meristem tissue.

freya-photographer/Shutterstock.com

Figure 14-5. African violets will only begin shoot emergence after wounding.

If they are in a moist rooting medium, they can easily root and become independent plants. Mother of thousands plant (*Bryophyllum*) has preformed primary meristems that develop foliar embryos on the leaf margins and will easily root given the right environmental conditions, **Figure 14-4**.

Most leaf cuttings form adventitious buds through a wounding response that prompts the secondary meristem to dedifferentiate cells into new meristematic cells. The African violet is a classic example of this process, **Figure 14-5**. Leaves are cut from the stock plant and veins are wounded. New shoots emerge from tissue beneath the epidermis after adventitious roots have been established. Other species vary slightly in where the bud tissue arises. In the lily plant, buds originate in the parenchyma, and in the *Peperomia* plant, new shoots form from the callus tissue.

Plant Material Used for Stem and Leaf Cuttings

Along with stem and leaf cuttings, there are other methods of vegetative propagation. They will be explored in later chapters. The type of cutting used to propagate a plant depends on the species, how easily a species roots, and the most cost-effective option for propagation.

Most commercial propagators use stock plants as the source of material, **Figure 14-6**. ***Stock plants*** are plant material kept specifically for the purpose of propagation. Stock material is managed using techniques such as pruning and girdling (making incisions or bending the stem), which encourages growth that will have high rooting potential. Any stock material should be disease free, uniform, true to type, and fairly vigorous.

Did You Know?

Piggyback begonia (*Begonia hispida* var. *cucullifera*) develops little plantlets along the veins of leaves, much like the piggyback plant, *Tolmiea*. An army of fuzzy little plantlets can separate from the mother plant and fall to the earth. Given the right conditions, they can begin to grow on their own.

Scisetti Alfio/Shutterstock.com

Figure 14-6. The stem cutting of this boxwood is typical for many woody ornamentals.

Copyright Goodheart-Willcox Co., Inc.

STEM Connection

Spiny or Spineless?

Honey locust (*Gleditsia triacanthos*) carries sharp thorns, some up to 1″, and could cause serious pain to any person or animal that draws too close. Interestingly, this native tree has no known animal predators from which to defend itself. The honey locust grows easily and quickly, has reasonably strong branches, provides dainty, dappled shade from pinnate leaves and is tough enough to withstand nearly any setting. Horticulturists found a thornless form, *Gleditsia triacanthos* var. *inermis*, that embodies the classic appeal of the thorned tree, but without any risk of bodily harm. It is vegetatively propagated to maintain thornlessness.

Sari ONeal/Shutterstock.com

Other sources of materials include trimmings from nursery plants, tissue culture liners, and plants growing in the landscape or in the wild. Cut plant material used for propagation may be a stem cutting, a leaf cutting, or a root cutting.

A ***stem cutting*** is a portion of the shoot and may include the tip or just a section of stem. Stem cuttings are classified by the plant's type of stem tissue. Stem tissue may be ***hardwood*** (mature, dormant, and woody plant material), semihardwood, ***softwood*** (soft, succulent, new growth on woody plants), ***herbaceous*** (nonwoody, soft-stemmed plants), or ***deciduous*** (trees or shrubs that lose their leaves annually). A ***leaf cutting*** is a leaf or a portion of a leaf used to propagate a new plant. Leaf cuttings may be just a leaf with no stem, or a ***leaf-bud cutting*** which includes a leaf blade, petiole, and a short piece of the stem with a bud attached.

Hardwood Cuttings

Hardwood refers to mature, dormant, and woody material. Hardwood cuttings tend to have a long shelf life and require no specialized equipment. They are the least expensive and easiest to use material for stem propagation.

Hardwood cuttings are taken from wood that has stopped actively growing and is dormant, generally in the late fall, winter, or early spring, **Figure 14-7**. The wood most often comes from the last year's growth. Some species can be propagated from wood that is two years old or older, such as figs, olives, and some plums. The material should be pathogen free, vigorous, and growing in full sunlight.

Chuck Wagner/Shutterstock.com

Figure 14-7. This dormant maple is a source of good hardwood cuttings.

Copyright Goodheart-Willcox Co., Inc.

It should have normal internode lengths and preferably be taken from the upper part of the plant. The material is ready to be cut when the wood is firm and does not bend, when the leaves can be removed without tearing the bark, or when the leaves have ***abscised*** (fallen off). Typically, the central and basal portions of the cutting are used for propagation because they contain the most stored carbohydrates needed for root and shoot growth. Avoid using material with flower buds, if possible, as flowers pull stored energy to flowering rather than rooting. Tip portions are generally discarded because of their low levels of carbohydrates. They also often have unwelcome flower buds.

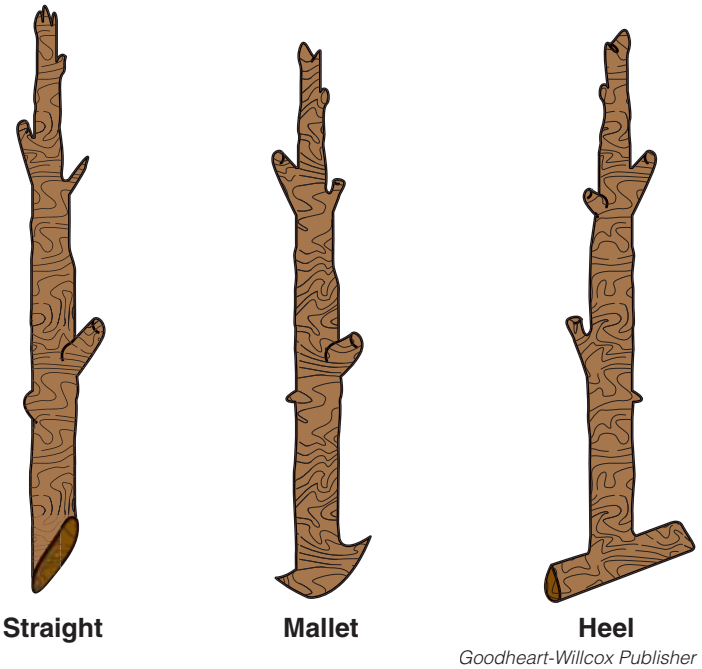

Figure 14-8. The diagram illustrates three ways to make hardwood cuts.

Hardwood cutting lengths range from 4″ to 30″ (10 cm to 76 cm), depending on the species of plant and purpose of the cutting. For fruit trees, long cuttings allow for the insertion of a bud graft. Include at least two nodes in the cut, with the bottom cut immediately beneath a node and the top cut 1/2″ to 1″ (1.3 cm to 2.5 cm) above a node. The diameter of a cutting varies depending on species and may range from 1/4″ to 1″ (0.6 cm to 2.5 cm). Three types of cuts may be used in hardwood cuttings, **Figure 14-8**:

- Straight cutting—a straight cut across the stem. The most commonly used cutting.
- Mallet cutting—a cutting that includes a short section of the stem of older wood. Mallet cuttings are used on harder to propagate material.
- Heel cutting—a cutting that includes a small section of older wood at the base of the cutting. This type of cutting is also used on plants that may be difficult to root.

Early morning is the best time to take cuttings because the plant is fully turgid. Cuttings should be kept cool and moist until they can be stuck in a planting medium. An ice chest or plastic bag with wet paper towels can be used to store cuttings and avoid desiccation (drying up).

Hardwood cuttings are most commonly used to propagate deciduous woody species, but they can also be used for some evergreens, **Figure 14-9**. Many trees and shrubs readily and easily propagate, such as willow (*Salix*), *Forsythia*, privet, spirea, crape myrtle (*Lagerstroemia*), and dogwood (*Cornus*). Some commercial fruit trees are also started by hardwood cuttings and include fig (*Ficus carica*), quince (*Cydonia oblonga*), mulberry (*Morus*), grape (*Vitis*), pear (*Pyrus*), pomegranate (*Punica granatum*), and some plums. Other species require special considerations, such as hormone treatments, to encourage rooting and need finely regulated environmental conditions.

Corner Question

What is one of the most popular shrubs planted in the landscape?

Copyright Goodheart-Willcox Co., Inc.

Propagation Methods for Woody Ornamentals

Abelia (*Abelia* spp.**) SH, HW
Arborvitae, American (*Thuja occidentalis*) SH, HW
Azalea (deciduous) (*Rhododendron* spp.) SW
Azalea (evergreen & semi-evergreen) (*Rhododendron* spp.) SH
Barberry, Japanese (*Berberis thunbergii*) SH, HW
Barberry, wintergreen (*Berberis julianae*) SH
Basswood; American (*Tilia americana*) SW
Birch (*Betula* spp.) SW
Blueberry (*Vaccinium* spp.) SW, HW
Boxwood, common (*Buxus sempervirens*) SH, HW
Boxwood, littleleaf (*Buxus microphylla*) SH, HW
Camellia (*Camellia* spp.) SW, SH, HW
Cedar (*Cedrus* spp.) SH, HW
Chamaecyparis; false cypress (*Chamaecyparis* spp.) SH, HW
Cherry, flowering (*Prunus* spp.) SW, SH
Clematis (*Clematis* spp.) SW, SH
Cotoneaster (*Cotoneaster* spp.) SW, SH
Crabapple (*Malus* spp.) SW, SH
Crape myrtle (*Lagerstroemia indica*) SH
Daphne (*Daphne* spp.) SH
Dawn redwood (*Metasequoia glyptostroboides*) SW, SH
Deutzia (*Deutzia* spp.) SW, HW
Dogwood (*Cornus* spp.) SW, SH
Elderberry (*Sambucus* spp.) SW
Elm (*Ulmus* spp.) SW
English ivy (*Hedera helix*) SH, HW
Euonymus (*Euonymus* spp.) SH, HW
Fir (*Abies* spp.) SW, HW
Forsythia (*Forsythia* spp.) SW, SH, HW
Fringe tree (*Chionanthus* spp.) SW
Gardenia; Ellis Cape jasmine (*Gardenia jasminoides*) SW, SH
Ginkgo, maidenhair tree (*Ginkgo biloba*) SW
Goldenrain tree (*Koelreuteria* spp.) SW
Heath (*Erica* spp.) SW, SH
Hemlock (*Tsuga* spp.) SW, SH, HW
Holly, American (*Ilex opaca*) SH
Holly, Chinese (*Ilex cornuta*) SH, HW
Holly, English (*Ilex aquifolium*) SH
Holly, Japanese (*Ilex crenata*) SH, HW
Holly, Yaupon (*Ilex vomitoria Aiton*) SH, HW
Honeylocust (Gleditsia triacanthos) HW
Hydrangea (*Hydrangea* spp.) SW, HW
Japanese cedar (*Cryptomeria japonica*) SH
Jasmine (*Jasminum* spp.) SH
Juniper, Chinese (*Juniperus Chinensis*) SH, HW
Juniper, creeping (*Juniperus horizontalis*) SH, HW
Juniper, shore (*Juniperus conferta*) SH, HW
Larch (*Larix* spp.) SW
Leyland cypress (×*Hesperotropsis leylandii*) SH, HW
Lilac (*Syringa* spp.) SW
Magnolia (*Magnolia*) SH
Maple (*Acer* spp.) SW, SH
Mock orange (*Philadelphus* spp.) SW, HW
Mulberry (*Morus* spp.) SW
Photinia (*Photinia* spp.) SH, HW
Pine, eastern white (*Pinus strobus*) HW
Pine, mugo (*Pinus mugo*) SH
Pittosporum (*Pittosporum* spp.) SH
Poplar; aspen; cottonwood (*Populus* spp.) SW, HW
Quince, flowering (*Chaenomeles* spp.) SH
Redbud (*Cercis* spp.) SW
Rhododendron (*Rhododendron* spp.) SH, HW
Rose (*Rosa* spp.) SW, SH, HW
Rose of Sharon (*Hibiscus syriacus*) SW, HW
Serviceberry (*Amelanchier* spp.) SW
Shoeblackplant (*Hibiscus rosa-sinensis*) SW, SH
Smoketree (*Cotinus coggygria*) SW
Spirea (*Spiraea* spp.) SW
Spruce (*Picea* spp.) SW, HW
St. Johnswort (*Hypericum* spp.) SW
Sweetgum (*Liquidambar styraciflua*) SW
Trumpet creeper (*Campsis* spp.) SW, SH, HW
Tulip tree (*Liriodendron tulipifera*) SH
Viburnum (*Viburnum* spp.) SW, HW
Virginia creeper (*Parthenocissus quinquefolia*) SW, HW
Weigela (*Weigela* spp.) SW, HW
Willow (*Salix* spp.) SW, SH, HW
Wisteria (*Wisteria* spp.) SW
Yew (*Taxus* spp.) SH, HW

SW = softwood, SH = semihardwood, HW = hardwood	**spp = multiple species

Goodheart-Willcox Publisher

Figure 14-9. This table lists a number of woody ornamentals and the recommended method of propagation material.

Copyright Goodheart-Willcox Co., Inc.

Liz Driscoll/Goodheart-Willcox

Figure 14-10. Hard-to-root species benefit from bottom heat which hastens rooting in cuttings.

There are four propagation processes that may be used to root hardwood cuttings:

- Direct fall planting. In regions with mild temperatures, cuttings can be taken in late fall and immediately planted in the nursery. Growers in California and Texas propagate hardwood cuttings in this manner.
- Warm temperature pretreatment. Hardwood cuttings are prepared in the fall while the buds are quiescent (or in a state of suspended growth). The cuttings are treated with ***auxin***, a plant growth hormone that induces adventitious root formation. They are stored for three to five weeks in warm, moist conditions before planting or storing at a cooler temperature. This pretreatment allows root initiation while the buds are dormant, so there is little competition for carbohydrates.
- Bottom heat. For species that are difficult to root, a treatment of bottom heat can hasten rooting. Cuttings are collected during dormancy. Auxin, in the form of indole-3-butyric acid (IBA), is applied. After sticking cuttings in a soil medium, they are placed on a heating mat, **Figure 14-10**.
- Direct spring planting. Species that easily root can be taken as cuttings during dormancy and stored in cool (32°F–40°F or 0°C–4.5°C), moist conditions. In the spring, the cuttings are placed in propagation trays or in a field nursery bed and given intermittent misting until rooted. Most propagators use an intermittent mist system that delivers fine droplets of mist to reduce water loss.

The propagation methods used for hardwood cuttings of narrow-leaved evergreens are similar to the methods used for deciduous hardwood cuttings. However, they root much more slowly, sometimes taking a year to fully root. Because evergreen species retain their leaves, there is a risk of desiccation. The cuttings must be rooted in high humidity conditions or receive frequent, light misting. Some evergreen species, such as false cypress (*Chamaecyparis*), arborvitae (*Thuja*), and prostrate juniper, root easily. Upright junipers, spruces, hemlocks, firs, and pines are much more challenging to root. Each species has specific propagation needs. In general, most species respond well to high humidity, bottom heat, bright light, and a treatment of auxin to hasten rooting.

Semihardwood Cuttings

Semihardwood cuttings come from the partially matured wood of broadleaf evergreens and deciduous plants during the summer and early fall months. For the broadleaf evergreen shrubs, cuttings are taken from new shoots after a burst of growth has occurred. The timing of this growth varies depending on the

Copyright Goodheart-Willcox Co., Inc.

species, usually occurring from late spring through early fall. Species such as *Camellia*, *Pittosporum*, *Rhododendron*, and holly propagate well as semihardwood cuttings, **Figure 14-11**.

Semihardwood cuttings range in length from 3″ to 6″ (7.5 cm to 15 cm). The lower leaves may be removed from the stem before inserting it into the propagation medium. These cuttings are more perishable than hardwood cuttings and will dry out quickly. Large leaves may need to be trimmed by as much as one-third to one-half to reduce the surface area. Minimizing the leaf surface reduces water loss through transpiration. To optimize rooting potential, semihardwood cuttings should be collected early in the morning when plants are turgid and then stored in cool, moist conditions. Cuttings are placed in a soilless medium and misted intermittently. Depending on the species, bottom heat, auxin, and wounding can be beneficial.

happykamill/Shutterstock.com

Figure 14-11. This camellia easily roots as a semihardwood cutting. It should be collected from new shoots after a flush of growth.

Softwood Cuttings

Collect softwood cuttings when soft, succulent, new growth on woody plants is beginning to harden (mature). The best softwood cuttings come from shoots that snap easily when bent and that have both mature leaves and small, young leaves. Most softwood cuttings are taken during growth flushes, which generally occur from April or May to August, depending on the region. Many woody ornamental species are started by softwood cuttings, including *Magnolia*, spirea, maple (*Acer*), lilac (*Syringa*), smoketree (*Cotinus*), *Hydrangea*, redbud (*Cercis*), and *Wisteria*.

Softwood cuttings typically root easily and more swiftly than other types of cuttings. Because the shoots are quite tender and stress easily, they must be prevented from drying out.

"Success is the result of perfection, hard work, learning from failure, loyalty, and persistence."
—Colin Powell

History Connection

J.C. Raulston

The late J.C. Raulston was a well-respected professor at North Carolina State University (NCSU) and strong advocate for the nursery industry. He was instrumental in introducing innovative plant material throughout the southeast and in establishing the NCSU arboretum (now the J.C. Raulston Arboretum). Mr. Raulston trialed hundreds of plants for growing, testing, and sharing with the industry and the public. His enthusiasm and promotion of new and interesting plant material shifted landscapes from a limited number of species to a broad range of species. He also pushed the plant palette to include a broad range of beautiful and functional woody trees and shrubs that flowered or had other interesting features in all months of the year. He invited nursery owners to the arboretum to take cuttings and he freely distributed rooted cuttings he propagated himself. Mr. Raulston worked tirelessly to enhance the diversity of trees and shrubs that could support the nursery trade.

Copyright Goodheart-Willcox Co., Inc.

OlgaPonomarenko/Shutterstock.com

Figure 14-12. This hydrangea cutting has two or more nodes and was collected from a lateral shoot.

Take cuttings in early morning when plants are turgid. Store the cuttings in moist, cool environments to minimize stress and desiccation. Take cuttings from a lateral or side portion of the stock plant. They should be 3″–5″ (7.5 cm–12.5 cm) long and have two or more nodes, **Figure 14-12**. Because softwood cuttings always have leaves, remove the lower portion to make it easier to stick. Larger leaves can be trimmed to diminish water loss. Cuttings are perishable and should not be stored for more that one or two days. To ensure successful rooting, temperatures should be between 75°F and 80°F (23°C to 27°C), light should be adequate but not excessive, and intermittent misting should be applied.

Did You Know?

Large, fibrous begonia leaves can be cut into pieces, with each piece containing a large vein. The piece is inserted upright into the rooting medium. The new plant develops from the large vein at the base of the section of leaf.

Herbaceous Cuttings

Herbaceous cuttings are made from succulent, fleshy, nonwoody plants. Species that are propagated as herbaceous cuttings include coleus, geranium, sweet potato, poinsettia, carnation, and many houseplants. Most herbaceous cuttings are taken from the tip of the stem where there is a naturally high concentration of auxin. These cuttings typically root more easily than cuttings from other parts of the stem. Cutting should be from 3″ to 5″ (8 cm to 13 cm) long. The lower leaves should be removed before inserting the cutting into a soilless medium for rooting. The conditions used for softwood cuttings, including bottom heat, encourage rapid and uniform rooting.

Tharakorn Arunothai/Shutterstock.com

Figure 14-13. Peperomia propagates well as a leaf cutting.

Liz Driscoll/Goodheart-Willcox

Figure 14-14. Notice the new plants forming at the base of the begonia.

Leaf Cuttings

A leaf cutting is a leaf or a portion of a leaf used to propagate a new plant. Leaf cuttings use the leaf blade or leaf blade and petiole (stalk or area that attaches the leaf blade to the stem) to propagate new plants. Adventitious roots, buds, and shoots arise from the leaf, either at the base or on cuts made to the leaf. The original leaf dies and does not become part of the new plant. Not many plants can be started with leaf cuttings. Several plants that can be started this way include African violets, *Begonia*, *Peperomia*, snakeplants, pineapple lily, *Sinningia*, *Kalanchoe*, and some *Sedum* species, **Figure 14-13**.

Leaf cuttings of African violets and begonias often use the leaf blade or leaf blade and petiole. The cutting is placed in a potting medium, and new plants form at the base of the petiole, **Figure 14-14**. For some plants, such as rex begonia, the veins on the underside of the fleshy leaves of plants are cut. The leaf blade is laid flat in direct contact with the surface of the propagation medium. The leaf is secured with pins to keep it in constant contact with the medium surface. After spending time in a high humidity environment, new plants will emerge from where the cuts were made. The original leaf eventually shrivels and dies.

Copyright Goodheart-Willcox Co., Inc.

Some species, such as snakeplant (*Sansevieria*) and pineapple lily (*Eucomis*), are propagated using the entire leaf. The long leaf blades are cut in sections, **Figure 14-15**, and placed in propagation medium up to three-fourths of their length. The new plants arise from the base of the cutting.

All leaf cuttings require intermittent misting or high humidity conditions, such as in a propagation tent. Bottom heat may hasten root, bud, and shoot development. Ideal media temperatures are in the range of 65°F–77°F (18°C–25°C). An application of plant growth hormones can encourage bud formation and adventitious shoot formation.

Liz Driscoll/Goodheart-Willcox

Figure 14-15. Snake plant leaves are cut into sections and will form new plants at the base of the cutting.

Leaf-Bud Cuttings

Leaf-bud cuttings are similar to leaf cuttings, but they include a leaf blade, petiole, and a short piece of the stem with a bud attached. Because a bud already exists and can develop into the shoot, only the adventitious roots need to form. Many herbaceous greenhouse plants, some fruits (such as black raspberry, blackberry, boysenberry, and lemon), and some trees and shrubs (such as maple, camellia, and rhododendron) readily root as leaf-bud cuttings. Many plants can be started this way, and this method is useful if there is limited stock material, **Figure 14-16**. The cuttings are inserted into the soil medium with the bud under the surface. High humidity and bottom heat are applied to hasten growth.

bepsy/Shutterstock.com

Figure 14-16. This lemon tree grew from a leaf-bud cutting because there was limited stock plant material.

Root Cuttings

Root cuttings are not a commonly used propagation method, but for some species this method is the easiest way to develop new plants. Pieces of a root are cut from stock plants. The pieces are placed in a rooting medium, covered with the medium, and often covered with plastic or glass to prevent the plant material from drying out. Correct ***polarity*** (spatial orientation within plants) should be maintained, with the top of the plant placed upward and the bottom of the root placed downward, **Figure 14-17**. Often, commercial propagators will make a diagonal cut on the ***proximal*** end (end nearest the point of attachment or crown) and a straight cut on the ***distal*** end (end farthest from the point of attachment, or crown). Cuttings that are inserted into the soil vertically should ensure the proximal end faces up. Cuttings are placed about 1″–2″ (2.5 cm–5 cm) deep, depending on root size.

Liz Driscoll/Goodheart-Willcox

Figure 14-17. Note the angled cut for the proximal end and the straight cut for the distal end to ensure proper polarity when placing the cutting in the soil.

Copyright Goodheart-Willcox Co., Inc.

Figure 14-18 lists a number of ornamental and edible specimens that can be propagated by root cuttings.

Hardening Off

"Men are mortal. So are ideas. An idea needs propagation as much as a plant needs watering. Otherwise, both will wither and die."
—B.R. Ambedkar

Rooted cuttings need to adjust away from the high humidity environment of a propagation chamber. This hardening off process, also call ***acclimatization***, gradually exposes plants to different environmental conditions. It enables the new plant to increase rates of photosynthesis and absorb water and nutrients through the root system. Cuttings that are left too long under the misting system can begin to deteriorate and growth will slow. This hampers production schedules and diminishes the quality of the new plant, with leaf drop and poor root growth. Most hardening off processes shorten the time of misting gradually until the cuttings are acclimated and mist is no longer needed.

Rooting Medium

The rooting medium used to propagate plants by stems or leaves should perform several functions. The rooting medium should:

- Hold the cutting in place during the rooting period.
- Provide moisture for the cutting.
- Allow gas exchange at the base of the cutting.
- Create a dark environment to encourage rooting.

Specimens Commonly Propagated Through Root Cuttings

Apple, crabapple (*Malus* spp.)	Kiwi (*Actinidia deliciosa*)
Barrenwort (*Epimedium* spp.)	Leadwort (*Plumbago* spp.)
Bayberry (*Morella pensylvanica*)	Summer ragwort (*Ligularia dentata*)
Bellflower (*Campanula* spp.)	Lilac (*Syringa vulgaris*)
Blackberry, raspberry (*Rubus* spp.)	Liriope (*Liriope* spp.)
Blanket flower (*Gaillardia* spp.)	Lungwort (*Pulmonaria* spp.)
Bleeding heart (*Dicentra* spp.)	Queen of the prairie (*Filipendula rubra*)
Bottlebrush buckeye (*Aesculus parviflora*)	Mint (*Mentha* spp.)
Bugbane (*Cimicifuga racemosa*)	Oriental poppy (*Papaver orientale*)
California poppy (*Eschscholzia californica*)	Plume poppy (*Macleaya cordata*)
Coneflower (*Echinacea purpurea*)	Poplar (*Populus* spp.)
Cranesbill (*Geranium* spp.)	Rose (*Rosa* spp.)
Daphne (*Daphne*)	Sage (*Salvia* spp.)
Evening primrose (*Oenothera* spp.)	Sassafras (*Sassafras albidum*)
Fall phlox (*Phlox paniculata*)	Sea holly (*Eryngium* spp.)
Gas plant (*Dictamnus*)	Siberian bugloss (*Brunnera macrophylla*)
Globethistle (*Echinops* spp.)	St. John's wort (*Hypericum calycinum*)
Glory-bower (*Clerodendrum trichotomum*)	Stokes' aster (*Stokesia laevis*)
Heartleaf saxifrage (*Saxifraga nelsoniana*)	Sweet gum (*Liquidambar styraciflua*)
Hop (*Humulus lupulus*)	Windflower (*Anemone hupehensis* var. *japonica*)

Goodheart-Willcox Publisher

Figure 14-18. These plants can be propagated as root cuttings.

Copyright Goodheart-Willcox Co., Inc.

As noted in Chapter 11, there are a number of different substrates that can be mixed to create a planting medium. For propagation mixes, growers use a mixture of organic materials, such as peat, sphagnum moss, and bark, and combine it with a mineral component, such as perlite, vermiculite, coarse sand, expanded shale, or rock wool, **Figure 14-19**. The mineral components provide aeration and drainage. Mineral soil (field soil) is rarely used, unless nursery liners are being grown in nursery beds. ***Nursery liners*** are young plants that will be grown in the nursery for an extended time until they are ready for sale.

Most commercial mixes are sterile to limit any introduction of pathogens. When mixing your own media, sterilize the soil with heat, using either an oven or steam.

Liz Driscoll/Goodheart-Willcox

Figure 14-19. Rock wool is commonly used as a medium to propagate herbaceous cuttings.

Plant Growth Regulators

Plants naturally produce chemicals called ***phytohormones*** that are present in small amounts and regulate plant growth and other functions. The five major plant hormones include auxin, cytokinins, gibberellin, abscisic acid, and ethylene. Many of these hormones play a role in propagation by inducing or sometimes inhibiting the formation of adventitious roots and shoots. ***Cytokinins*** are a class of plant growth hormone that encourages bud formation and adventitious shoot formation. Auxin and cytokinins are the hormones most commonly used in propagation. These plant hormones are naturally and synthetically manufactured as plant growth regulators (PGRs) to promote successful propagation through root, bud, and shoot formation.

Auxin

Auxin plays a number of roles within the plant. Related to propagation, auxin can promote the growth of adventitious roots, particularly in species that are hard to propagate. Indole-3-acetic acid (IAA) is an auxin that is naturally produced by plants. It can be extracted and applied to cuttings to stimulate rooting. Indole-3-butyric acid (IBA) and 1-naphthalene acid (NAA) are synthetic auxins that encourage rooting. They remain the most widely used auxins for stem cuttings. Auxins can also be used in combination with each other. Common combinations include IBA and NAA or IAA and IBA.

FFA Connection Agriscience Fair

The Agriscience Fair provides an opportunity for FFA students to develop an experiment that illustrates their creativity, curiosity, knowledge, and science inquiry skills. Consider doing an experiment that determines the best methodology for propagating your favorite plant. Do you need to use a plant hormone? Which one? At what rate will you apply the hormone? Be sure to follow the science process, replicate your experiment, and share your findings in a professional way.

Copyright Goodheart-Willcox Co., Inc.

Liz Driscoll/Goodheart-Willcox

Figure 14-20. Moistening the ends of the cuttings will increase the surface contact of the plant growth regulator to the base of the cut.

Apply auxin to fresh cuts. If you use cuttings taken earlier in the day or week, make new, fresh cuts. Auxins can be applied in powdered or liquid form. Cuttings are dipped into the substances and then stuck into the rooting medium. Generally, higher concentrations of auxin are used on plants that the grower expects to be hard to root. In most cases, recommended concentrations have been established. In powdered applications, the hormone is added to talcum powder. Cuttings are dipped individually or as a bundled group into the powder and then inserted into the rooting medium, **Figure 14-20**. If needed, cuttings can be moistened with water to encourage better contact with the powder.

Concentrated solutions of hormone can also be dissolved into a liquid, usually some kind of alcohol, such as isopropyl alcohol or ethanol. The basal ends of the cuttings are lowered 0.2″-4″ (0.5 cm–1 cm) into the solution for about three to five seconds and then inserted into the propagation medium. This process is called the *quick dip method*. Cuttings can be dipped in bundles or individually. The highest absorption of hormone occurs at the surface of the cut. Many commercial propagators prefer the quick dip method for uniformity of rooting and ease of application.

Cytokinins

Cytokinins play essential roles in cellular division. In propagation, the relationship between auxin and cytokinins determines whether root formation is promoted or shoots are developed. A high auxin-to-cytokinins ratio encourages root development. A high cytokinins-to-auxin ratio encourages adventitious shoot formation. A high concentration of both fosters callus formation. Cytokinins are an important factor in initiating buds and shoots from leaf cuttings.

Careers in Stem and Leaf Propagation

Stem and leaf propagation are important components of the horticulture industry. The work done in these areas guarantees a supply of new plants is always available for growers and consumers. Two careers in these areas are horticulture illustrator and nursery inspector.

Horticulture Illustrator

Horticulture illustration is the preparation of accurate renderings of botanical subjects and horticultural processes. These illustrations are used for textbooks, cooperative extension publications, journals, museum exhibits, websites, and many other applications. Illustrations may be hand or digitally drawn and communicate a visual explanation of complex information.

Copyright Goodheart-Willcox Co., Inc.

For example, an illustration of the leaf-cutting process helps gardeners understand the proper technique. Many illustrators have a background in fine arts and may have taken additional coursework specific to botanical or scientific illustration.

Nursery Inspector

A nursery inspector promotes the production and sale of nursery stock. Nursery inspectors conduct inspections of all plant material that will be sold or distributed to make sure they are free of diseases and pests. Most states require annual inspections of nurseries to ensure there are no damaging plant pests prior to the plants being shipped within and out of state. Inspectors are usually part of a state's agriculture department. They issue phytosanitary certificates by visiting nurseries, garden centers, chain stores, and landscape companies to monitor for any pests. Nursery inspectors should have a bachelor's degree in agriculture, horticulture, entomology, or a related field.

Career Connection

Mark Weathington

Arboretum Director

Mark Weathington

A very large, busy highway expansion is about to get started in the backyard of the J.C. Raulston Arboretum (JCRA). Mark Weathington, the arboretum's director, sees the increasing urbanization around the garden as an opportunity for innovation and to bring horticulture to the thousands of commuters that travel by each day. "We are trying to figure out a way to green the sound barrier walls through plants. We hope to provide a functional and beautiful space that minimizes noise and adds an attractive aesthetic."

Mark began his horticulture career while working in Virginia Tech's public garden. He learned nursery production and propagation while working in the public garden and then worked at both the Atlanta Botanical Garden and Norfolk Botanical Garden. Today, Mark finds himself firmly rooted at the JCRA as the arboretum's director and continues to serve the needs of nurserymen in the southeastern United States by evaluating new landscape ornamentals. This work is a continuation of the JCRA mission to propagate and share new plants to increase the diversity of woody ornamentals available in the nursery trade.

The JCRA has grown into an inviting public garden where visitors can increase their appreciation and understanding of horticulture. Mark finds that when he arrives at work each morning, everyone is happy to be there, sharing the same goal and mission. He says, "There are artists that cannot live without art, I am passionate about plants in the same way. I love being around plants, talking about them and sharing them." Mark takes deep personal satisfaction knowing the arboretum provides an interesting and innovative landscape that showcases plants that support the growth of the nursery trade across the United States and brings a spark to gardeners everywhere.

Copyright Goodheart-Willcox Co., Inc.

CHAPTER 14

Review and Assessment

Chapter Summary

- Plants have a unique ability to form new plants from a piece of stem, leaf, or root through a process called vegetative or asexual propagation. In this process, adventitious root, shoot, and bud formation occurs.
- There are two types of adventitious roots: preformed and wound-induced. Preformed roots develop naturally given the right environmental conditions. Wound-induced roots form in response to wounding or cutting of the plant.
- Stem cuttings can come from different types of tissue including hardwood, semihardwood, softwood, and herbaceous tissues.
- Hardwood cuttings are taken from dormant wood, usually from deciduous woody ornamentals and some narrow-leafed evergreens. Straight, mallet, and heel cuts are different techniques for making wood cuts.
- Semihardwood cuttings come from partially matured wood of broad-leaved evergreens and deciduous plants growing in the summer to fall months. Early morning collection of cuttings minimizes water loss and optimizes rooting potential.
- Softwood cuttings are taken from soft, succulent new growth of woody plants, usually from April through August. Softwood cuttings typically root easily.
- Herbaceous cuttings come from the succulent, fleshy growth of nonwoody plants. Bottom heat and intermittent misting encourage rooting of herbaceous cuttings.
- Leaf cuttings are derived from the leaf blade or leaf blade with the petiole attached. New plants form at the base of the leaf or cuts in the vein, with both adventitious root and shoot formation occurring. The original leaf dies; it does not become part of the new plant.
- Leaf-bud cuttings include the leaf blade, petiole, and small section of stem that includes a bud. This method of propagation is useful when there is limited stock material.
- Root cuttings use pieces of root cut from stock plants to propagate new material. The pieces are covered with rooting medium and often covered with plastic or glass to prevent them from drying out. Not all species can be propagated this way.
- Rooted cuttings need to acclimate to environments other than the high humidity environment of a propagation chamber. This hardening off process enables the new plant to increase rates of photosynthesis and absorb water and nutrients through the root system.
- Rooting medium should hold the cutting in place, provide adequate moisture, allow gas exchange at the base of the cutting, and create a dark environment favorable for rooting.
- Plants naturally produce chemicals called phytohormones. They are present in small amounts and regulate plant growth and other functions. The five major plant hormones include auxin, cytokinins, gibberellin, abscisic acid, and ethylene.

Copyright Goodheart-Willcox Co., Inc.

Words to Know

Match the key terms from the chapter to the correct definition.

A. abscise	H. differentiate	O. polarity
B. acclimatization	I. distal	P. preformed roots
C. adventitious root formation	J. hardwood	Q. proximal
D. auxin	K. herbaceous	R. softwood
E. callus tissue	L. leaf-bud cutting	S. stock plant
F. cytokinins	M. phytohormone	T. suberin
G. dedifferentiate	N. plantlet	U. vegetative propagation

1. The process of roots forming from any plant part other than the root.
2. A method of starting new plants from existing plant material.
3. A bundle of undifferentiated cells that cover the wound and begin to initiate new cellular divisions that differentiate to form meristematic growing regions.
4. Develop a specialized function, such as in shoot cells.
5. Spatial orientation within plants.
6. A single node and adjacent internode tissue with the leaf attached.
7. Mature, dormant, woody plant material.
8. Soft, succulent, new growth of woody plants.
9. Regress (for cells or tissue) from a specialized function to a simpler state.
10. To fall off or separate from.
11. A nonwoody, soft-stemmed plant.
12. A waxy substance that seals a wound on plants.
13. A plant hormone that induces adventitious root formation.
14. Having existing root initials.
15. A class of plant growth hormone that encourages bud formation and adventitious shoot formation.
16. A chemical naturally produced in a plant that regulates growth and other functions.
17. Located closest to the point of attachment.
18. Located farthest from the point of attachment.
19. A small or young plant.
20. Plant material kept specifically for the purpose of propagation.
21. Gradually exposing plants to different environmental conditions.

Know and Understand

Answer the following questions using the information provided in this chapter.

1. What is vegetative or asexual propagation of plants and why is it important?
2. What is the genetic makeup of a vegetatively propagated plant?
3. What are two kinds of adventitious roots?

Copyright Goodheart-Willcox Co., Inc.

4. What are the three steps in a wounding response?
5. Draw or give an oral explanation of how a plant started from leaf cuttings can develop adventitious shoots.
6. Explain how to select material for a hardwood cutting.
7. Describe three types of cuts that may be used for hardwood cuttings.
8. List and briefly describe the four propagation processes that may be used to root hardwood cuttings.
9. Why would you reduce the leaf area on semihardwood cuttings?
10. Describe the process of collecting and starting semihardwood cuttings.
11. Describe the process for propagating softwood cuttings.
12. What are some plants that are typically propagated as herbaceous cuttings?
13. Describe the technique used to propagate a begonia from a leaf cutting.
14. What environmental conditions are favorable for propagation using leaf cuttings?
15. How do leaf-bud cuttings differ from leaf cuttings?
16. Describe the process of propagation using root cuttings.
17. What is meant by polarity regarding root cuttings?
18. Why do rooted cuttings need to acclimate or harden off away from the propagation chamber?
19. What are the primary functions of a rooting medium?
20. Name five major plant hormones and what role they play in propagation.
21. What are some benefits of using plant growth regulators?
22. Give one example of a natural plant hormone and two examples of synthetic growth regulators.

Thinking Critically

1. You have collected several hardwood cuttings from a woody ornamental shrub species on a recent walk through an arboretum. You propagate the cuttings, but they do not form roots. What do you think is happening? What can you do to get the cuttings to root?
2. Imagine that you are a small greenhouse owner who primarily sells herbaceous material. The economy is slowing, and you are trying to keep your business afloat. What ideas do you have to keep your business thriving?

STEM and Academic Activities

1. Science. Design and implement an experiment to determine the rooting efficiency that occurs due to bottom heat. Document the method you use and your results.
2. Science. Most plant species have different propagation requirements. Research a plant that you find interesting and write a report that summarizes your findings.
3. Math. You are small start-up retail nursery and need to determine the size of a greenhouse you want to build for propagation of bedding plants. You want to grow 2000 flats of bedding plants. If a bedding plant flat occupies 1 1/2 square feet per flat, how many square feet do you need? Additionally, 70% of the greenhouse space is production space, with the remainder in aisles. What size should the greenhouse be?

Copyright Goodheart-Willcox Co., Inc.

4. Social Studies. Research the work of J. C. Raulston, a famous horticulturist in the Southeast region of the United States. Find descriptions and images of his work. Select one plant that he propagated and introduced to the nursery trade. Does the plant introduction have any particular meaning to the nursery industry? What was his intent? How does this compare with plant introductions today?
5. Language Arts. Pretend that you are a commercial plant propagator. You keep a daily journal to help you remember information that you might need later. Today, you tried propagating five new species. Write a journal entry about these species and include all the information you might need in the future.

Communicating about Agriculture

1. Reading and Speaking. Research the propagation protocol for your favorite plant. Prepare a short demonstration for your classmates on this propagation technique, sharing information while actively showing your peers how to propagate your plant.
2. Listening and Speaking. Working with a partner, compare and contrast different propagation techniques. Consider the perspective of the manufacturer/grower, merchandiser, and consumer. In what situations would one technique be preferable to the other? Record the key points of your discussion. Hold a class discussion. Compare your responses to those of your classmates.

SAE Opportunities

Jodi Riedel/Goodheart-Willcox Publisher

1. Exploratory. Visit a commercial or home propagator and observe each step of the plant propagation process. What conditions does the grower create to encourage rooting and shoot development?
2. Exploratory. Create a propagation calendar for five of your favorite ornamental trees. When should you take cuttings? How should you prepare the cuttings? Include timing, depth, length, and other important details for each plant. Why do you think growers keep records of their propagations?
3. Experimental. Conduct an experiment using your favorite tree or shrub. Take cuttings at multiple points during the year and try to root them. What do you expect to observe? How will you collect data? Share your findings with your class.
4. Exploratory. Job shadow someone who commercially propagates plants. What are this person's daily tasks? What is the scope of his or her responsibilities? Why do you think the work is important for growers in your state?
5. Exploratory. Visit a local botanical garden or arboretum that propagates plants from stock in the garden. Volunteer to assist in propagation tasks and learn the techniques used for each plant.

Copyright Goodheart-Willcox Co., Inc.