Plant Propagation

UNIVERSITY OF WISCONSIN–MADISON • DIVISION OF EXTENSION
FOUNDATIONS IN HORTICULTURE

In a nutshell...

- Propagating plants is a fun way to create new plants.
- You have to think about plants in a different way if you plan on saving seeds.
- We're talking plant sex: You need to understand how plants reproduce to be able to effectively propagate them.
- Check the resources at **hort.extension.wisc.edu** for issues not covered in this chapter.

MASTER GARDENER
UNIVERSITY OF WISCONSIN–MADISON
DIVISION OF EXTENSION

Introduction

Many gardeners plant seed in the ground and watch it grow. Others browse the garden center for varieties of plants with little thought to where they came from. Some divide plants in their gardens to improve vigor or to share with a neighbor. In studying plant propagation you will learn how to affect a plant's growth by manipulating environmental growing conditions, resulting in more plants.

In gardening, plant propagation refers to the many ways of starting new plants. These various processes of multiplying or perpetuating a plant species may be by natural or artificial means. This chapter introduces concepts and techniques for growing new plants from seed and by asexual methods.

Learning objectives

1. Understand the biology involved in plant propagation.
2. Know the conditions for starting seeds.
3. Demonstrate techniques for asexual propagation.

Plant breeding

The terms "plant breeding" and "genetic engineering" are often confused. Both are methods of developing new plants with desirable characteristics. Genetic engineering is essentially a type of breeding.

Plant breeding has been practiced for thousands of years. It involves pollinating the flowers of a chosen plant with pollen from another chosen plant, both with desirable characteristics. The seeds produced are then planted and the resulting plants are evaluated for their quality. Promising plants are "selected" for their desirable characteristics or to be used for further breeding. With plant breeding, the same pollination could theoretically occur naturally; human involvement directs which two plants are combined.

Genetic engineering is a relatively new technology that involves manually inserting the DNA from one organism into the cells of another. In some cases, the gene inserted into a plant is not from another plant, but from a different organism altogether. For example, *Bacillus thuringiensis* is a bacterium whose DNA is often inserted into plants to provide pest control. Genetic engineering involves a recombination of genes that could not occur in nature without human involvement.

Patents, trademarks, and trade names

Plants developed through traditional breeding or genetic engineering have a unique, desirable characteristic that can be patented by the government. A patent gives the recipient the right to exclude others from asexually reproducing, selling, or using the plant for a set time, usually 20 years. Patent holders can sell licenses to producers who are authorized to propagate the plant, and it is illegal for those without a license to reproduce and sell the plant. Of the hundreds of thousands of plants available, only a small number of them are patented. For a plant to be patented, it must be distinctly different from existing cultivars. Patents are not awarded for plants found in the wild.

Trademarks are words, acronyms, phrases, logos, or symbols that identify the source or origin of a plant or type of plants. A trademark does not give exclusive rights to the plant as a patent does, but it prevents others from using the trademark. Trade names identify a company name, but do not specifically identify a plant or product.

All-America selections

All-America Selections (AAS) is a non-profit organization that tests and introduces significantly improved new flowers, bedding plants, and vegetables grown from seed. AAS tests are conducted at trial grounds throughout North America with official AAS judges supervising the trial and evaluating each entry. AAS Winners have been tested for home garden performance and are quite reliable because of these unbiased, independent tests. AAS Display Gardens in the U.S. and Canada are open to the public to provide gardeners with opportunities to view the most recent AAS Winners.

Propagation basics

Plants can be propagated in two main ways: sexually and asexually. **Sexual propagation** is the recombination of plant genetic material to form a genetically unique individual. This generally involves the floral parts of a plant, pollination that results in the formation of seeds, and starting plants from seed.

Asexual propagation produces new plants that are genetically identical to the parent plant by taking a vegetative part of the parent plant (stems, roots, leaves, or other non-reproductive plant parts) and causing it to regenerate into a new plant.

Sexual propagation: from seeds

Propagation by seed is a common method of producing new plants. Sexual propagation may be cheaper and quicker than other methods, and it is a way to obtain new cultivars and hybrid vigor.

Seed propagation results in a lot of genetic variability, so offspring may not have the exact characteristics of the parent plant. Seedling variation is quite high in some plants; many ornamental plants do not come "true" from seed. Other plants are more true to type. Many vegetables and annual flowers are easily grown from seed. Some perennials can also be grown from seed, but may not flower the first season.

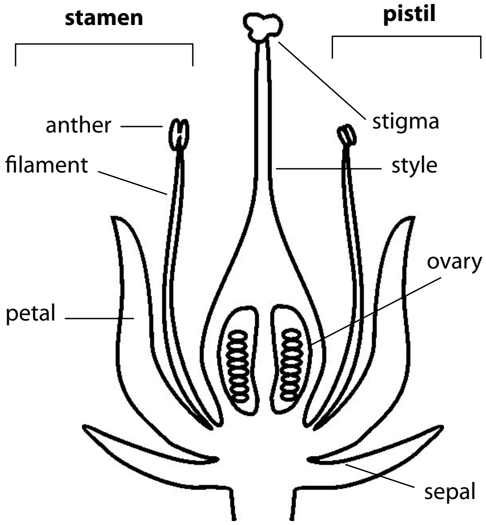
Pollination and fertilization

Pollination and fertilization are processes that result in the formation of new seeds.

- **Pollination** is transfer of pollen to the female flower parts by wind or pollinators, such as bees or other insects.
- **Fertilization** is the union of the male and female reproductive material.
- The **stamen** is the male portion of the flower that produces the pollen.
- The dust-like **pollen** is contained in the **anthers**, the sacs at the end of the **filament**.
- The typical female **pistil** consists of an enlarged **ovary** (containing the egg) at the base, a columnar **style** and the **stigma**, the organ that receives the pollen on the end.

When pollen grains land or are placed on the stigma, they germinate to form a pollen tube that grows down the style to the ovary, allowing the male reproductive material to move to the egg (figure 1). Once the male reproductive material fertilizes the egg, seeds can be produced. To understand these processes, it is important to know the parts and functions of a flower (see chapter 1, Botany).

FIGURE 1. The parts and functions of a flower

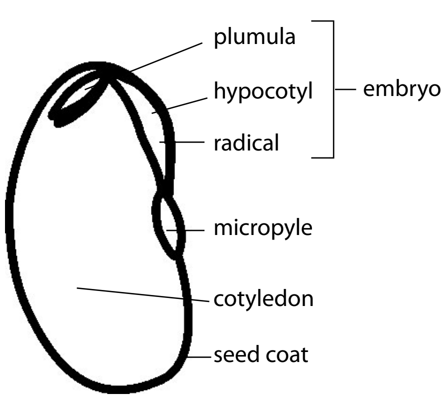


Anatomy of a seed

A seed is usually made up of three basic parts (figure 2):

- The **embryo**
- A food supply
- The outer protective covering

FIGURE 2. Anatomy of a seed



The **embryo** is a new plant resulting from the union of pollen and egg during fertilization. **Cotyledons**, or seed leaves, are attached to the embryo. **Monocotyledons** (monocots), such as grasses, have one cotyledon; **dicotyledons** (dicots), such as beans, have two cotyledons.

A mature seed contains enough stored food (or energy source) for seed germination and early seedling growth. The cotyledons of dicots usually contain this food reserve, while some seeds like monocots have a mass of food reserve called an **endosperm**.

Seed coverings are the **seed coat** and parts of the fruit or seed pod. These structures protect the embryo and food reserve inside the seed and sometimes prevent germination until conditions are suitable.

Selective pollination

Four seed types can be produced by selectively pollinating plants with specific parents: inbred lines, F1 hybrids, F2 hybrids, and seed mixtures.

Inbred lines

Inbred lines are created when plants from a single parent line are self-pollinated or interpollinated so they become nearly identical after several generations. These flowers or vegetables are often easier and faster to breed and produce. Common self-pollinated, non-hybrid, and purebred annuals and vegetables are suitable candidates for saving seed.

- Some vegetable seeds that can be easily saved include lettuce, beans, peas, herbs, and heirloom tomatoes.
- Annual flower seeds that can often be successfully saved include cleome, salvia, and nicotiana.

F1 hybrids

F1 hybrids are created by crossing two inbred parent plants—often that differ in several important traits—resulting in uniform, often very prolific plants. Control of the cross-pollination of these plants is critical for hybrid seed production. These crosses are made to develop qualities like good vigor, heavy yields, uniformity, disease resistance, and other desirable traits. Hybrids are often more vigorous than either parent, but cannot breed true. Seeds collected from F1 hybrids will not produce plants identical to those from which they were collected.

F2 hybrids

F2 hybrids are the result of self-pollination or indiscriminate pollination of F1 hybrids. These plants are more variable than the original hybrid but may maintain some of the characteristics of their parents. Plants grown from seed saved from F2 hybrids can be variable and unpredictable.

Seed mixtures

Seed mixtures contain seeds collected from plants—generally flowers—that vary only in a single trait, such as color. Field grown mixtures come from plants of different colors growing together, which can result in slightly variable and unpredictable color mixtures. Formula mixtures blend seed in predetermined proportions from plants of different colors that were grown separately to produce a constant and predictable balance of colors.

Obtaining seeds

Seed selection

Purchase good quality seed from reputable seed companies that produce seed with controlled genetics and store seed properly.

Seed saving

Seed left over in a package after planting can be saved for next year's garden, usually with little loss in germination, if stored properly (see "seed storage").

You may also choose to save seed from plants you grow in your garden from one year to the next. Saved seed may not produce plants that are the same as the parent plant. Cross-pollination in some crops may result in altered genetic characteristics, so new plants grown from these seeds might have any combination of new characteristics, such as fruit size, blossom color, shape, or flavor. Some vegetables that are self-pollinated and therefore are good seed-saving bets include beans, eggplant, peas, and tomato.

Seed storage

It is important to store seeds properly to maintain their **viability**. Seed is a living product that, once harvested, is constantly in decline. The storage life of seed depends on both environmental conditions and the plant species. Most flower and vegetable seeds will keep for one year without special protection, and many will remain viable for up to 5 years if stored properly (table 1). The best conditions for seed storage are just the opposite of those required for germination—cool, dark, and dry.

In general, the drier the seeds, the longer they will last. A relative humidity of 30% is ideal. The highly variable environment in the average home allows far too much (or too little) moisture exchange for long-term storage in paper envelopes, cloth bags, or cardboard boxes. Place seeds in an airtight container such as tight-sealing glass jars or resealable plastic bags. To help reduce moisture in the container, you can

TABLE 1. Storage life of flower and vegetable seeds

LONG-LIVED SEEDS (5 OR MORE YEARS)	MEDIUM-LIVED SEEDS (UP TO 5 YEARS)	SHORT-LIVED SEEDS (1 TO 2 YEARS)
beets, broccoli, Brussels sprouts, cabbage, cauliflower, cilantro, cucumber, lavender, lettuce, melons, mustard greens, oregano, peppers, radish, sunflower, tomato, turnip	basil, beans, calendula, carrot, celery, chard, dianthus, dill, eggplant, forget-me-not, lupine, marigold, nasturtium, parsley, peas, pumpkin, sage, snapdragon, squash, sweet pea, thyme, zinnia	alyssum, aster, blanketflower, coleus, corn, cosmos, delphinium, leek, onion, pansy, parsnip, phlox, spinach, strawflower

include a desiccant such as calcium chloride, silica gel, or powdered milk—any of which will absorb moisture from the seeds—but do not allow the desiccant to touch the seed.

Store seeds in a cool place with temperatures between 35 and 50˚F. Cool temperatures slow seed respiration, prolonging seed life. Constant cool temperature and humidity will break the dormancy of certain seeds and slows the gradual loss of viability in seeds that are not dormant. A cool corner of the basement—away from heat sources such as furnaces, water heaters, or warm-air ducting—such as a root cellar or vegetable storage area is adequate for storing most seeds. A refrigerator will also provide suitable conditions for seed storage.

Absolute darkness is the best for seed storage. Exposure to direct sunlight or bright, artificial light—one of the conditions that stimulates germination—can reduce seed viability and vigor.

Germination

Germination is the active growth of the embryo in the seed that results in breaking of the seed coat and emergence of a young plant. Germination is affected by water (moisture), oxygen, light (or dark), and warmth.

- Water is essential to inducing germination. Water penetrates the seed coat and causes the endosperm to swell, which in turn causes the seed coat to split open as growth begins. Keep the growing medium moist but not wet. If the medium is allowed to dry out, the sprouting embryo may die; excessive moisture, however, can lead to disease and rotting.
- The embryo needs oxygen to begin growing. This is one reason to use a light, well-aerated growing medium to start seeds.
- Light can stimulate or inhibit a seed's germination. This is why some seeds need to be sown on the surface of the growing medium and some below the surface. Check the seed packet or catalog for light requirements.
- Each type of plant has an optimal sprouting temperature. Although most seeds will germinate at lower temperatures, it may take 10 times as long. Slower than optimal germination also increases the chance for disease. Warmth usually improves germination, with most plants doing well at 60 to 75˚F. Most seeds have a fairly wide temperature range, but some are more limited. The temperature range is usually listed on the seed packet or in the catalog. For most vegetables, raise the temperature of the medium a little above that of the average house for the best results. Bottom heat is preferred and can be supplied by an electric heating mat specially made to place under flats of seedlings, with heating cables, or just by placing the pots in a warmer location in the house, such as on top of the refrigerator or near a radiator (but be sure the spot isn't too warm). Once the seedlings have sprouted, a lower temperature is usually best for seedling growth.

Planting seeds when the water, oxygen, light, and temperature conditions are optimal, whether outdoors for direct seeding or indoors for transplants, will increase germination rates and speed.

Seed dormancy

When seeds ripen, they are **quiescent**—in an inactive stage that enables them to survive for a long time. When given the proper environmental conditions seeds germinate readily. But some plant species may not be able to germinate even when planted in favorable environmental conditions. Viable seeds that do not germinate are in **dormancy**, a lack of growth due to an external or internal cause. Dormancy can be regulated by the environment or by some inhibitory factor of the seed itself, and may be caused by several different mechanisms. Dormant seeds must undergo certain changes before germination can occur. Depending on the type of dormancy, different techniques can be used to break dormancy.

An impermeable seed coat is one major mechanism of dormancy, in which the seed covering physically restricts water uptake or is too hard to allow embryo expansion. The embryo inside is generally quiescent, so if the seed coat can be opened, the seed will grow. In nature certain environmental agents soften seed coats:

- The acid in digestive tracts of animals that ingest the seeds.
- Microorganisms in warm, moist environments.
- Forest fires.
- Weathering by exposure to freezing and thawing.

The length of time needed to soften the seed coat depends on the plant species, and may be several years or more.

The most common technique to overcome seed coat dormancy is **scarification**, physically altering the seed coat to allow moisture penetration. Two methods of scarification commonly used by the home gardener are mechanical and hot water.

- Mechanical scarification can be done using a metal file, a pin, or a knife to make an opening in the seed coat or by rubbing the seeds between two pieces of sandpaper. Larger seeds may even be gently cracked with a hammer. Take care not to injure the embryo. Sweet pea seeds benefit from scarification before planting. Plant seeds soon after scarification, as they are more susceptible to microbial infection.
- For small to medium-sized seeds hot water treatment is more practical than mechanical scarification. Drop seeds into about six times their volume of 180 to 200˚F water and leave the seeds to cool and soak in the water for 12 to 24 hours. Cacti, morning glory, and many prairie perennial dicots can benefit by such treatments.

Chemical inhibitors in the outer coverings of many fruits and seeds may cause dormancy, particularly in seeds with fleshy fruits, hulls, or capsules. This kind of dormancy often disappears with dry storage. In nature, examples include many desert plants, where the water-soluble, germination-inhibiting chemicals are leached from the tissues by heavy rains or absorbed by the soil. Remove these inhibitors by soaking the seeds in water that is changed daily for several days, or by leaching the seeds in slowly running water for several days (the exact length of time depends on the species).

Internal dormancy is a general term encompassing a number of physiological conditions that delay germination. Not all of these conditions are fully understood, but may be regulated by the embryo itself and involve plant hormone dynamics. These seeds—including those of many trees and shrubs and certain perennials—must be exposed to moisture and cold temperatures for a certain period of time.

The most common method for breaking internal dormancy is cold **stratification**, or moist chilling. This simulates the cold winter conditions that the seeds would encounter in nature.

- Mix the seeds with an equal volume of a moistened medium (such as vermiculite or peat moss) in a closed container and store them in a refrigerator (approximately 40˚F).
- Check the containers periodically to see that the medium is moist but not wet and to see if they have started to germinate. The length of time it takes to break dormancy is generally greater than 8 weeks, but varies by species.
- Don't remove the seeds too early, or a secondary dormancy that is more difficult to break than the original may be induced.
- Warm stratification is similar except temperatures are maintained at 68 to 86˚F, depending on the species.
- Sow the seeds promptly after stratification before they dry out.

Double dormancy is a combination of seed coat and internal dormancy. To overcome this, the seeds generally must be scarified first and then stratified for the appropriate length of time. Other species may have two or more distinct internal dormancy factors, requiring a sequence of different temperatures to initiate germination. This is often a warm period to stimulate primary root growth, then a cold period to break shoot dormancy, and finally a second warm period to allow shoot growth. In nature, seedlings of plants with these dormancy types will not appear until the first or second spring after the seeds have matured and dropped from the parent plant.

In a few other seeds, an immature embryo causes dormancy, meaning the embryo is not fully developed and requires additional growth after the seed is separated from the plant. Examples include:

- Herbaceous flowers such as ranunculus and poppy.
- Woody species such as holly.
- Tropical plants such as date palms.

Seeds with immature embryos often have other kinds of dormancy, such as hard seed coats. Alternating warm and cool temperatures will help accelerate embryo growth.

Starting seeds indoors

Many plants can be successfully planted directly in the ground as seeds, but other species do much better if started indoors. Environmental conditions early in the season in Wisconsin are not often conducive to seed germination. The growing season is often too short for certain plants to fully develop from seed if planted when conditions are appropriate for germination. Start transplants several weeks or months before they are to be placed outside.

Containers

You can use almost any type of container to start seeds indoors, as long as it is sterile, small, and provides good drainage. Many types of plastic or wooden flats have been designed especially for this purpose, but any plastic containers (with drain holes poked in the bottom), soil blocks, peat pots, or homemade newspaper pots will work as well. Sterilize any containers that have been previously used for growing plants—soak the containers for a couple of minutes in a 10% bleach solution and thoroughly rinse—to prevent plant diseases.

Growing medium

Use seed starting mix (see box) or other indoor planting medium (outdoor soil may have disease organisms). Soilless planting mixes are recommended for seed starting. They are lightweight, drain well, do not pack down, and are free of weed seeds and pathogens. You can purchase soilless mixes or create your own (see chapter 13, Houseplants). Moisten the growing medium well so it is evenly wet, not soggy, BEFORE filling your container and planting the seed.

Sowing seeds

For large seeds, fill each container to the top and add two to four seeds in holes poked in the medium. Putting more than one seed per pot will guarantee one strong plant per pot, especially if the germination rate is not good, which is possible with some heirloom varieties or seed saved from a previous year. Normally the planting depth should be four times the thickness of the seed, but consult the seed packet for the proper planting depth.

For smaller seeds, add less mix to the containers—up to about ¼ inch from the top—and broadcast the seeds thinly and uniformly over the surface of the mix by gently tapping the seed packet until seeds slowly come out. Consider mixing very small seed with sterile sand or another fine medium to increase the volume and make spreading easier. Then cover the seeds with fine, screened soil mix or a layer of vermiculite. Extremely fine seed such as begonia, petunia, or snapdragon should not be covered but just lightly pressed into the medium.

A seed starting mix

1 part perlite

1 part peat

1 part sterile potting soil

Mix all together and moisten slightly. Place mix in an aluminum baking pan or other heat-resistant container and bake at 250˚F until the soil temperature reaches 180˚F for 2 hours (the length of time to reach this temperature depends on the volume and moisture content). Remove the pan and allow it to cool before using the mix.

After sowing

Cover the seed flats or groups of containers to keep the seeding medium from drying out. You can use clear plastic bags, plastic wrap, or the clear plastic tops sold with many seed flats. Keep the plastic at least 1 to 1½ inches above the soil surface. Seeds will germinate best with soil temperatures that are much warmer than the average home. Constant bottom heat from heating tape, cables, or mats placed under the containers will speed germination.

Place the covered containers in a location with moderate light, but not in direct sunlight. A few seeds, such as delphinium, forget-me-not (*Myosotis*), phlox, verbena, and violets require darkness to germinate—cover those containers with a piece of cardboard or black paper. Check the containers daily and water as necessary. Keep the seeds constantly moist but not wet, to avoid disease problems. Water carefully to prevent displacing seeds or knocking over tiny seedlings; misting can be useful here.

As soon as the first seedlings appear, remove the plastic cover and artificial heat and place the pots in the best available light. Young seedlings need intense light more than older plants.

- A shelf or windowsill in a sunny, south-facing window may be sufficient for satisfactory results, but rotate the pots frequently to prevent lopsided plants.
- Some supplemental light from ordinary fluorescent lights (grow-lights aren't necessary) is often beneficial.

Eighteen hours of light is optimal, but don't leave lights on all the time—plants need some darkness to grow normally.

After one set of **true leaves** emerges, transplant multiples of seedlings to their own small containers. Individual 2- or 2½-inch pots are large enough to grow most seedlings to the transplant stage. If you choose to use trays that contain individual cells, make sure the cells are at least 1½ inches across.

Prepare the pots or cells by filling them with soil or a growing mix. Make a deep hole in the growing mix in the center of each pot or cell with your finger or a pencil. Remove the seedlings from their container in a clump and carefully separate the seedlings with as little damage to the roots as possible. Handle individual seedlings by a leaf, not the stem, so you won't damage the stem and kill the plant. Take care that the exposed roots of separated plants do not dry before planting. Place each seedling a little deeper in the hole than it was in the seed flat and firm the soil around the roots. Water the newly transplanted seedlings gently to settle the soil around the plant. Fertilize seedlings once or twice a week with a water-soluble fertilizer and less often if there is soil or fertilizer in the planting medium.

Transplants must be **hardened off** before planting in the garden. Hardening off gradually acclimates the plant to the wind, more intense light, and fluctuating temperatures they will be exposed to outdoors.

- Decrease watering and stop fertilizing about two weeks before you plan to plant the seedlings in the garden, and, if possible, lower the temperature slightly to slow growth and make the foliage less succulent.
- Place the plants outdoors in a sheltered location or cold frame during this 1- to 2-week period.
- Gradually increase the exposure to sun during this time so the plants won't be sunburned.
- Move plants back indoors temporarily if frost or other adverse conditions are predicted.
- Reduce watering and withhold fertilizer while plants are being hardened off.

Asexual propagation: vegetative

Reproduction without genetic recombination is an important, even dominant manner of reproduction for many types of plants. Asexual propagation allows us to get exact replicates (clones) of desirable species or cultivars, propagate difficult-to-germinate plants, create larger plants faster, or save desirable plants from disease.

Asexual propagation is the only way to multiply plants that do not produce seed. To increase the numbers of these plants, various methods involving many different plant parts may be used. To understand why asexual plant propagation is possible, you must know about how plants grow and how growth is regulated.

Totipotency and plant hormones

The reason we can produce new plants from parts of the parent plant is that plant cells are **totipotent** (toe-TI-po-tent)—capable of regenerating an entire organism from a single cell. Each cell possesses all the necessary genetic information to produce a complete new plant, but most of the time cells lack the trigger to change their development. If cells can be induced to switch their development, then new plants can be obtained.

In some cases this is as easy as providing an appropriate environment, such as roots developing from stem cuttings. A severed coleus stem or African violet leaf roots easily when placed in moist soil, for example. In many other cases, more technical methods—such as tissue culture or treatment with growth regulators—must be used to induce plant regeneration.

A variety of hormones affect plant processes such as flowering, aging, root growth, stem elongation, fruit coloration, leaf fall, and many other aspects of the plant life cycle. These small molecules work together in complex, interconnected ways to control growth and development. Plants produce these hormones naturally, while plant growth regulators are extracted hormones or synthetic mimics of the natural hormones that humans use to affect plant growth. Very small concentrations of these substances can produce major growth changes. The effects of applied plant growth regulators are short-lived, and they may need to be reapplied in order to achieve desired effects. There are five groups of plant hormones (see table 2), each with its own function in plant growth.

TABLE 2. The five plant hormones and their functions

Hormone	Source in plant	Major functions in plant propagation
Auxin	Seed embryo, young leaves, apical bud meristems	• Stimulates cell elongation • Involved in phototropism, geotropism, apical dominance, and vascular differentiation • Stimulates fruit development • Induces adventitious roots on cuttings
Cytokinin	Synthesized in roots and transported to other organs	• Stimulates cell division • Reverses apical dominance • Involved in shoot growth • Delays leaf sequence
Ethylene	Tissues of ripening fruits, nodes of stems, senescent leaves, and flowers	• Stimulates fruit ripening • Promotes leaf and flower senescence and abscission
Abscisic acid	Leaves, stems, green fruit	• Stimulates stomatal closure
Gibberellin	Meristems of apical buds and roots, young leaves, embryo	• Stimulates cell division and shoot elongation • Breaks dormancy and speeds germination • Stimulates bolting and flowering in biennials

Auxins are one of the most important groups of plant hormones for plant propagators. These hormones are produced in actively growing shoot tips (**meristems**) and induce and initiate **adventitious growth** of roots. They only move from the top of stem tissue to the bottom of stem tissue (polar transport).

In the stem, auxin is responsible for **apical dominance**, or suppressing the growth of lateral bud meristems. If the apical growing point of the plant is removed, the remaining buds will grow because of reduced auxin.

Auxin is important in the formation of adventitious growth of both roots and shoots, or growing in an atypical location during normal growth. It is the active ingredient in most rooting compounds in which cuttings are dipped during vegetative propagation.

Auxins also play a role in **phototropism**, or movement towards light. Sunlight degrades auxin, so the part of the shoot tip of the plant receiving direct sunlight will have the least amount of auxin. The higher concentration of auxins on the shaded side promotes more cell division and elongation, causing the plant to bend towards the sunlight through lopsided growth. One of the most common auxins is indole acetic acid (IAA). The most commonly used auxin for asexual propagation and adventitious rooting is indole-3-butyric acid.

Cytokinins stimulate cell division and are often included in sterile media used for growing plants from tissue culture.

Abscisic acid (ABA) is a general plant-growth inhibitor that induces dormancy and prevents seeds from germinating, causes abscission (shedding) of leaves, fruits, and flowers, and causes stomata to close.

Ethylene, found only in the gaseous form, induces ripening and promotes **senescence**. Increased ethylene in leaf tissue in the fall is part of the reason leaves fall off trees.

Gibberellins stimulate cell division and elongation, break seed dormancy, and enhance seed germination. Dwarf plants do not make enough active forms of these hormones. Gibberellic acid is the most commonly used form of gibberellins in asexual propagation of plants. Soaking the seeds of some difficult-to-germinate species will get them started.

Cuttings

Cuttings are used to propagate many types of plants—both woody and herbaceous. A **cutting** is a vegetative plant part that, when removed from the parent plan, will produce adventitious growth of lost parts to form a whole new plant. Rooting cuttings is an easy way of propagating many plants and saving some garden plants, such as geraniums and impatiens, over the winter.

Successful home propagation of plants relies on providing the appropriate propagation environment for each particular plant. To do so, you can manipulate various environmental factors, including moisture, temperature, light, and the propagation medium.

- Moisture (humidity) is essential to prevent desiccation in plants that are regenerating root systems; regulate this with your choice of planting medium, by misting, or by placing a lid over the container.
- Temperature affects cell respiration and growth; use bottom heat to stimulate root regrowth.
- Balance natural and artificial light sources with moisture and temperature.

Plant parts used in asexual propagation are often embedded in some form of substrate, or medium, for support and to hold moisture. A rooting medium should be sterile and low in fertility, should drain well enough to provide oxygen to newly forming roots, and should retain enough moisture to prevent water stress.

Materials most often used are coarse sand, perlite, vermiculite, peat moss, and sphagnum moss; each has advantages and disadvantages. Propagation mixes that combine these materials are commercially available. Water is generally not a good medium for rooting because sufficient oxygen can't reach developing roots and any roots that do develop are fragile and may not transplant well.

Leaves, stems, or root cuttings may be used as cutting sources, depending on the plant species (see table 3).

TABLE 3. Plants for cuttings

Herbaceous stem	coleus, chrysanthemum, dahlia, fuchsia, geranium, impatiens, phlox, Russian sage, salvia, sedum, vinca
Softwood stem	azalea, boxwood, English ivy, lilac
Semi-hardwood stem	*Cotoneaster*, euonymus, juniper, serviceberry
Hardwood stem	forsythia, hydrangea, rhododendron, rose, spirea, weigela, and many evergreens (holly, fir, pine, and spruce)
Root	anemone, gaillardia, phlox, yucca
Leaf	African violet, begonia, *Sansevieria*, *Streptocarpus*

The general process for taking a cutting is:

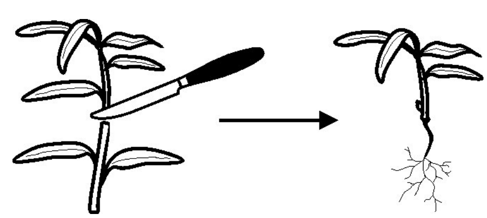
1. Take cuttings with a sharp blade and wash any dirt off of the plant part to minimize pathogens.
2. Remove any flowers, flower buds, or fruits so the cutting will direct its energy and stored carbohydrates for root and shoot formation rather than fruit and seed production. Reduce the area of large leaves to lower water loss from the plant part.
3. Dip the area you wish to root in a rooting hormone, preferably one containing a fungicide, to increase the success or speed of rooting. Insert the cuttings into moistened rooting medium and keep the medium evenly moist while the cuttings are rooting and forming new shoots.
4. Place a plastic bag over the entire rooting container and lightly fasten it to help maintain high humidity (or use a special rooting chamber with a plastic top).
5. Place the container in a warm area (65 to 75°F) where it will receive plenty of light but no direct sunlight. Open the bag or lid every day for a few minutes to allow fresh air to reach the cuttings and to prevent mold from forming. The length of time needed for roots to form depends on the kind of plant, the temperature, and other factors. Many kinds of houseplants will root in 10 to 21 days; some woody plants may require months.
6. Transplant the cuttings when their roots are about 1 inch in length. Carefully lift the plants out of the rooting medium to avoid damaging the new roots. Water them thoroughly after potting and leave them in indirect light for a week to ten days until new growth begins.

Specific stem, root, and leaf cutting techniques follow.

Stem cuttings

Numerous plant species are propagated by stem cuttings, especially woody ornamentals (figure 3). Some can be taken at any time of the year, but stem cuttings of many woody plants must be taken at specific times during their growth cycle. The four main types of stem cuttings are herbaceous, softwood, semi-hardwood, and hardwood.

FIGURE 3. Taking a stem cutting



Herbaceous cuttings are made from non-woody, herbaceous plants such as coleus, chrysanthemums, and dahlias. Cuttings should be about 3 to 5 inches long and should be taken just below a leaf. Remove the leaves on the lower one-third to one-half of the stem, leaving three to four leaves on the upper portion of the cutting for the best rooting. A high percentage of the cuttings should root quickly.

Softwood cuttings are prepared from soft, succulent new growth of woody plants, just as the growth begins to harden. Actively growing shoots are suitable for making softwood cuttings when they can be snapped easily when bent and the newest leaves are still small and not mature. This stage typically occurs in May, June, or July. The soft shoots are quite tender, and extra care must be taken to keep them hydrated.

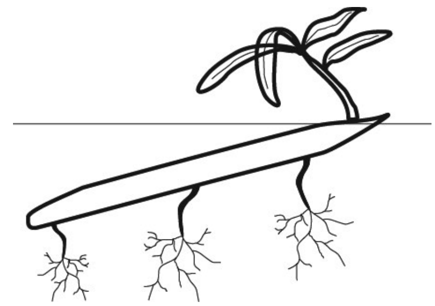
Semi-hardwood cuttings are taken from partially mature wood of the current season's growth, just after a flush of growth, generally from mid-July to early fall. The wood is reasonably firm—it bends but snaps only when bent to an angle of 70 to 80 degrees—and the leaves have reached their mature size. Many broadleaf evergreen shrubs and some conifers are propagated by this method.

Hardwood cuttings are taken from dormant, mature stems in the late fall, winter, or early spring when there are no signs of active growth. The wood is firm and does not bend easily. Hardwood cuttings are used most often for deciduous shrubs such as forsythia and spirea, but can be used for many evergreens. The cuttings should be stored in cool, moist conditions to produce a **callus**. Plant the cutting so that two nodes are below the soil line and one node is above the soil line.

Root cuttings

Any plant that will sprout from root sections can be propagated by root cuttings (figure 4). Cuttings are usually taken from two- to three-year-old plants during their dormant season. Root cuttings of some species produce new shoots, which then form their own root systems, while other plants develop root systems before producing new shoots.

FIGURE 4. A root cutting



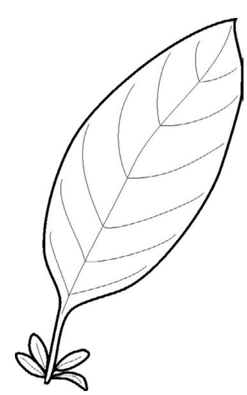
Select roots that are ⅛ to ½ inch in diameter and cut them into segments 1 to 4 inches long. Sand is the most common medium for rooting indoors; you can also place the cuttings directly into soil for propagation outdoors. Insert the cuttings of plants with small roots horizontally about ½ inch below the medium surface. Place larger roots vertically with the top approximately level with the surface of the rooting medium. Maintain high humidity in the rooting container until shoots appear.

Leaf cuttings

Leaves, taken as cuttings from most plants will produce a few roots but no plant—or just decay. But a few herbaceous or succulent indoor plants will regenerate shoots and roots from a single leaf. African violet, *Sansevieria*, begonias, and *Streptocarpus* are commonly propagated by leaf cuttings.

Whole leaf cuttings of plants with the **petiole** intact form one or more new plants at the base of the petiole (figure 5). For plants with **sessile** leaves (no petiole), the cutting forms a new plant from the auxiliary bud. The leaf may be removed when the new plant has its own roots.

FIGURE 5. A leaf cutting



Leaf sections are often used for *Sansevieria* and fibrous rooted begonias.

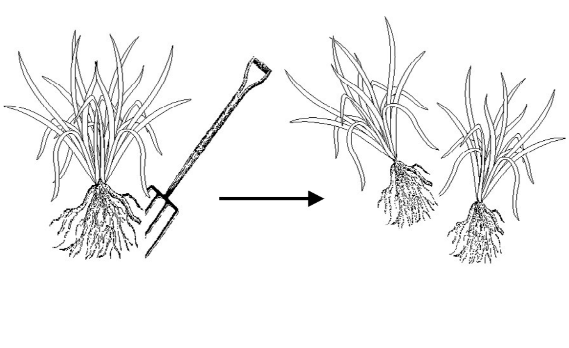
- Cut *Sansevieria* leaves into 2-inch sections, making the lower cut slanted and the upper cut straight (so you can tell which is the top), and insert these cuttings vertically with the basal end of the cutting inserted into the rooting medium. Roots will form fairly soon, and eventually a new plant will appear at the base of the cutting. Note that these and other succulent cuttings will rot if kept too moist.
- Cut begonia leaves into wedges with at least one vein and lay leaf pieces flat on the rooting medium. A new plant will arise at the vein.

Division and separation

One of the easiest and quickest means of plant propagation is separating a plant into sections (division) or by removing natural offsets from the parent plant (separation). Gardeners commonly refer to both means of plant propagation as division.

Division is only effective with certain plants that multiply vegetatively, such as hostas and daylilies (figure 6). Division cannot be used for plants with a single stem, and it differs from taking cuttings in that the new plants already have both roots and shoots. A few plants produce **offsets**, a characteristic type of lateral shoot or branch that develops from the base of the main stems, but many others have modifications of their vegetative structures (stems and roots) that allow for natural increase and are often used for propagation.

FIGURE 6. Plant division



Modified stems

Many plants reproduce themselves vegetatively by developing specialized structures modified from stems in a variety of ways. Typical stems are aboveground trunks and branches, but in many cases modified stems form above or below the ground and develop to form different types of vegetative reproductive structures or storage organs.

- Aboveground modified stems include crowns, stolons, and runners.
- Belowground modified stems include bulbs, corms, rhizomes, and tubers.

Aboveground

Crowns are compressed stem tissue at the surface of the ground from which new shoots are produced. In herbaceous perennials, the crown consists of many branches originating from the base of the preceding year's branch. Adventitious roots develop along the base of the new shoots. As a result of the annual production of new shoots and dying back of old shoots, the crown may become quite large within just a few years.

Most of the clump-forming herbaceous perennials such as irises, daylilies, and hostas develop a large crown with multiple shoots. Some of these must be divided every 2 to 3 years to prevent the plants from becoming overcrowded. It's best to divide these herbaceous perennials in early spring just before growth begins or in late summer or fall at the end of the growing season. As a general rule, divide spring and early summer bloomers in the fall, and divide summer and fall bloomers in spring. To divide:

- Dig up the whole clump and separate it into sections. If the stems are not joined, gently pull the plants apart with your hands.
- If the crowns are attached by horizontal stems or the roots are inextricably entwined, cut the stems and roots with a sharp knife or shovel.
- Separate the clump into individual plantlets, each with some roots and a tuft of leaves. Try to follow the natural path of least resistance, shaking off surplus soil to make it easier to pull the clump apart.

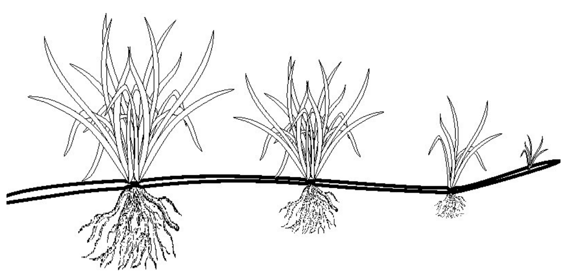
- Carefully replant each division and keep them well watered until the plants are re-established, usually in about 4 to 6 weeks.

Divide multi-branched woody shrubs in the same manner when they are dormant—you may need a hatchet to divide the crowns. Cut back the tops and trim the roots at the time of division and plant each section as a new shrub.

Stolons and runners are horizontally growing modified stems with long thin internodes (and no storage in the stem) that are produced above the ground.

- A **stolon** produces adventitious roots, generally when in contact with the soil, and then produces new shoots at that point. Spider plants and many grasses produce stolons.
- A **runner** is just another name for a stolon. Strawberries and ajuga are examples of plants whose stolons are commonly called runners.

FIGURE 6. Horizontal modified stem

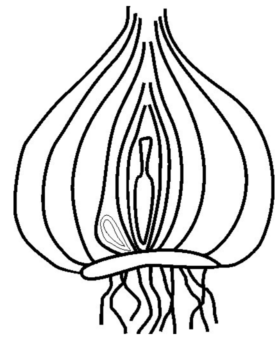


To propagate new plants from plants that produce stolons or runners, sever the new plants from their parent stems. New plants at the tips of runners may be rooted while still attached to the parent (they can be set into the soil and pegged down to speed up the rooting process), or detached and placed in a rooting medium.

Belowground

Bulbs are a dormant shoot system with a short, fleshy vertical stem enclosed by thick, fleshy modified leaves, usually termed **scales** or bulb scales (figure 7). Some plants with true bulbs include amaryllis, lilies, daffodils, onions, scilla, and tulips.

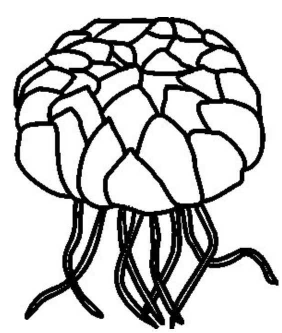
FIGURE 7. Cross-section of a bulb



There is a distinct **basal plate** on each bulb, which is a compressed stem and the primary growing point for the bulb during initial phases of regrowth. The fleshy scales protect the growing point in the bulb.

- **Tunicate** bulbs have layered flat, fleshy leaves and are further protected by an outer membrane, called a tunic. The tunic is relatively thin and dries after the bulb is harvested, creating a membranous-type covering. Onions and tulips are examples of tunicate bulbs and are better protected from drying and mechanical damage than nontunicate bulbs such as lilies.
- Scaly (or **nontunicate**) bulbs, such as lilies, have clusters of enlarged, fleshy leaf scales but no tunic (papery covering) to protect the scales (figure 8). Remove individual fleshy scales from a mature bulb and root them to create new plants. A scaly bulb can also be cut into several vertical sections—each containing a part of the basal plate—and planted to produce new plants after you've allowed the cut edges to dry and **cure**.

FIGURE 8. Scaly bulb



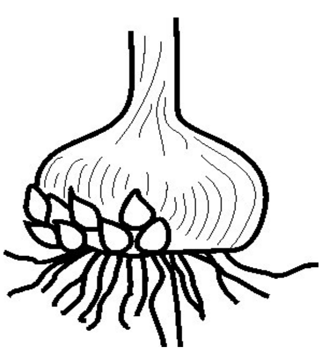
Bulbs produce side branches in the axils of the bulb's leaves called **bulblets**. Both the bulblets and the primary bulb increase in size with age to produce a clump of bulbs after a few years. To divide bulbs, dig up the clump after the plants have gone dormant. Separate the new bulbs from the parent bulb and replant them.

A **corm** is a compact, belowground, fleshy stem modified into a mass of storage tissue. Unlike a true bulb, the solid stem has distinct nodes and internodes and papery leaves. Examples of plants with corms include crocus, elephant ears (*Colocasia*), and gladiolus.

A corm does not have visible storage rings when cut in half, but corms are frequently (and mistakenly) called bulbs. Corms produce both fibrous roots for water and nutrient absorption, and enlarged roots for support and to pull the corm deeper into the soil for more uniform temperatures.

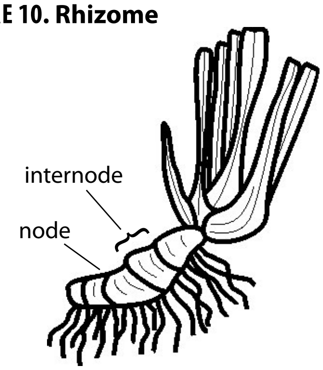
Corms propagate by forming **cormels**, miniature corms developed from buds that originate in the axils of the corm's leaves, around the base of the new corm (figure 9). Propagate these plants by separating the cormels from the primary corm. Dig up the plants after the foliage dies back, shake off the soil, and let them dry in indirect light for 2 to 3 weeks. Remove the cormels and gently separate the new corm and store them in a cool place until planting time. Cormels usually require an additional 1 to 2 years' growth before flowers are produced.

FIGURE 9. A corm with cormels



Rhizomes are non-fleshy underground horizontal stems that are distinguished from a root by the presence of nodes and internodes (figure 10). Unlike true roots, rhizomes have nodes, buds, and tiny leaves and do not die when cut from the parent plant. Upright, aboveground shoots and flowering stems are produced either terminally from the rhizome tip or from lateral branches. Most plants with rhizomes are monocots and include iris, horsetails, many ferns, lily of the valley, and many grasses.

FIGURE 10. Rhizome



Propagate these plants by clump division before or after a growth period. Cut rooted sections off, making sure that each piece has at least one lateral bud (or eye), and replant them. If rhizome-producing grasses, such as quackgrass, are cut or broken into pieces, such as by tilling, new plants will develop at almost all intact **nodes**.

Tubers are localized, fleshy swellings of a portion of the stem with nodes and axillary buds (eyes). Tubers are nutrient storage organs that allow for survival during dormant periods. Long photoperiods encourage shoot growth of tuberous plants, while reduced day length, lower night temperatures, and lower mineral nutrition encourage tuber development. Two of the best-known tubers are the Irish potato and caladium; some begonias, oxalis, and anemones are other plants with tubers.

Propagation of tubers involves either planting the entire tuber or cutting the tuber into pieces, each containing one to three buds. Dig up the tubers after the foliage dies back. If you cut the tubers into pieces, allow them to dry before planting.

Suckers are shoots that arise from an adventitious bud on a root or from the vicinity of the crown. The tendency to sucker is an innate characteristic of some plants such as lilacs, poplars, and sumac.

Suckering and the ability to grow plants from root cuttings are closely related. Suckers can be dug out and cut from the parent plant; pulling the sucker may injure its base and reduce its chances for survival. Treat the sucker the same as you would a rooted cutting since new roots often are not yet formed. Most suckers should be dug when the plant is dormant.

Modified roots

Certain herbaceous perennials such as dahlia, gloxinia, sweet potato, and tuberous begonia have roots modified for nutrient storage. These **tuberous roots** have the internal and external features of a typical root but are generally greatly enlarged or swollen (figure 11). They differ from true tubers in that they lack nodes and axillary buds. Buds are normally present only on the proximal (shoot) end, unlike true tubers, which can have "eyes" on all parts of the tuber.

FIGURE 11. Tuberous roots

Most tuberous roots are incapable of producing adventitious shoots and must be divided so each piece contains a shoot bud; sweet potato is an exception and can produce adventitious shoots. To propagate tuberous-rooted plants, divide the crown into sections with an eye-bearing portion of the stem left with each section of the root. Division should be done at planting time, not before placing in storage in the fall.

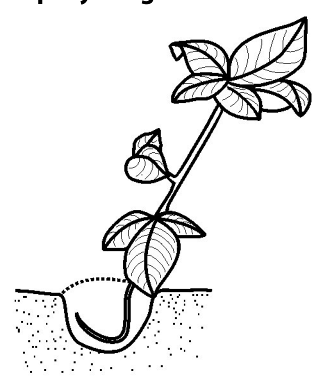
Layering

Layering is the process of causing adventitious root development on a stem still attached to the parent plant. Once severed from the parent plant, the rooted stem becomes a new plant. This method generally has a high success rate because the developing new plant has a continuous water and nutrient source that cuttings do not. A few plants layer themselves naturally, but this type of vegetative reproduction may also be induced artificially in many kinds of plants. Several procedures utilize different stem treatments to encourage the formation of roots.

Tip layering

Tip layering mimics a natural method of vegetative reproduction in purple and black raspberries and trailing blackberries. Bury the tip of a cane in a shallow hole 3 to 4 inches deep (figure 12). The tip will grow downward first and then should bend sharply and grow upward. Roots form at the bend, and the recurved tip becomes a new plant. Remove the tip layer by cutting below the zone of rooting and plant it in the early spring or late fall.

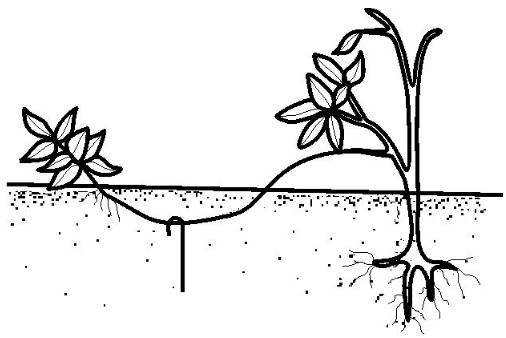
FIGURE 12. Tip layering



Simple layering

This method involves bending a low growing, flexible stem to the ground and covering a portion of it to induce rooting (figure 13). Simple layering can be done on many plants with low-growing branches. Some plants that can easily be propagated by simple layering include azalea, boxwood, climbing roses, forsythia, honeysuckle, rhododendron, and most vine-type plants such as philodendron, grape ivy, pothos, and Swedish ivy.

FIGURE 13. Simple layering



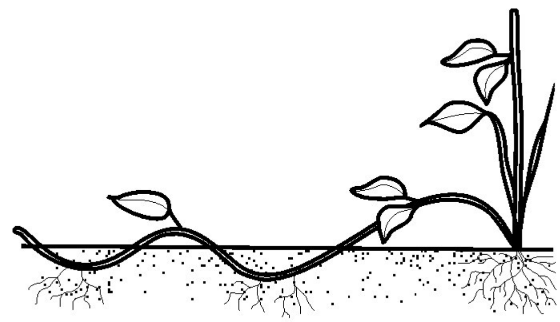
Simple layering is best done in the early spring using a dormant branch or in the late summer using a mature branch.

- Bend the stem to the ground and cover part of it with soil, leaving the last 6 to 12 inches exposed.
- Just bending the tip sharply into a vertical position and staking it in place will often induce rooting; however, wounding the lower side of the branch or loosening the bark by twisting the stem may be necessary in some cases.
- Periodically check for the formation of roots. Depending on the plant, it may take one or more seasons before the layer is ready to be removed for transplanting.

Compound layering

This method is essentially the same as simple layering, but the branch is alternately covered and exposed along its length to produce several layers from a single stem (figure 14). Compound (or serpentine) layering works well for plants producing vine-like growth such as clematis, grapes, heart-leaf philodendron, pothos, and wisteria. Bend the stem to the rooting medium as for simple layering, but alternately cover and expose sections of the stem. Each section should have at least one bud exposed and one bud covered with soil.

FIGURE 14. Compound layering

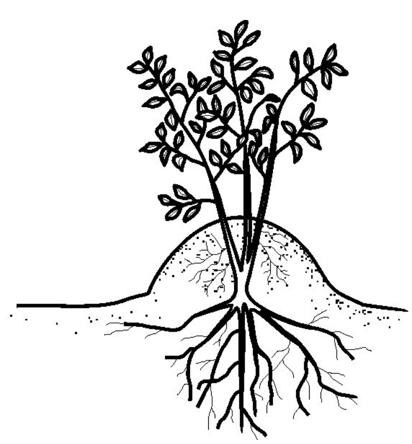


Mound layering

The mound (or stool) layering method is useful with heavy-stemmed, closely branched shrubs such as cotoneaster, magnolia and spirea, and tree fruit rootstocks (figure 15).

- Before new growth starts, cut the parent plant back to 1 inch above the soil surface. Dormant buds will produce new shoots in the spring.
- When the new shoots are 3 to 5 inches high, mound soil around the lower half of the shoot.
- Make a second mound of soil when the shoots are 8 to 10 inches tall and a final mound when they are about 18 inches high. Cover the base of the shoots with 6 to 8 inches of soil.
- Roots will develop at the bases of the young shoots, generally by the end of the growing season.
- Remove the layers in the dormant season.

FIGURE 15. Mound layering

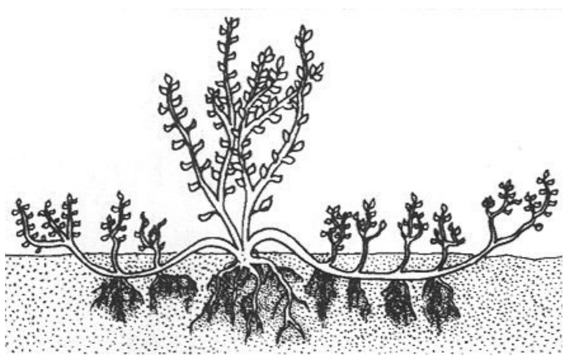


After these layers have been cut away, the parent plant can be left exposed and used again for mound layering the next season.

Trench layering

This method is used primarily for woody species that are difficult to propagate by mound layering, such as currents, gooseberries, mock orange, and cranberry viburnum. A plant or branch of a plant is grown in a horizontal position in the base of a trench (figure 16). The trench is gradually filled with soil as new shoots develop, so the shoot bases are elongated. Roots will eventually develop from the base of these new shoots. An established plant can be trench-layered by burying a low, flexible shoot to the ground—as with simple layering, but covering the entire length.

FIGURE 16. Trench layering



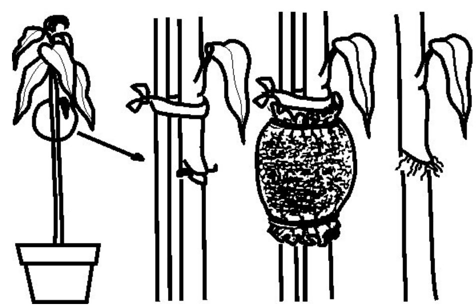
Air layering

This method is used to propagate a number of tropical indoor plants with rigid stems such as aralia, croton, dieffenbachia, ficus, and rubber plant, or to rejuvenate them when they become leggy or have lost most of their lower leaves. Woody ornamentals such as azalea, camellia, magnolia, and holly can also be propagated by air layering.

Air layering is seldom used on plants that root easily by other more simple methods. For optimum rooting, make air layers in the spring on shoots produced during the previous season or in mid- to late summer on shoots from the current season's growth. For woody plants, stems of pencil size diameter or larger are best (figure 17).

- Choose an area about 1 foot from the growing tip, just below a node, and remove any leaves or twigs on the stem 3 to 4 inches above and below this point.
- Wound the stem by either slitting the stem just below the node and prying open the slit with a toothpick or removing a ½- to 1-inch strip of bark from around the stem.
- Surround the wound with a handful of wet sphagnum moss—soak it in water first and squeeze it to remove excess moisture.
- Wrap plastic or foil completely around the moss and tie or tape it securely in place to retain moisture.
- Auxin is sometimes applied to woody plants being air layered at the site of wounding to stimulate root development.
- After the moss is filled with roots, sever the stem below the roots and pot the layer.

FIGURE 17. Air layering



Grafting and budding

Grafting and budding are methods of asexual plant propagation that join two pieces of living plant tissue so they will grow and develop as one plant. Budding is similar to grafting, but the shoot portion is reduced to a single bud. These techniques are used to propagate cultivars that will not root well as cuttings, whose own root systems are inadequate, or will not come true from seeds, and in some cases to produce dwarf plants by using special understocks.

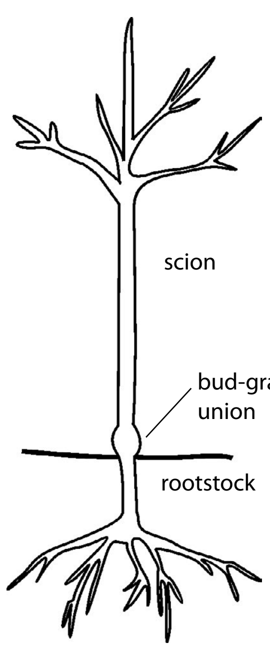
Although grafting usually refers to joining two plants, it may be a combination of several. Multiple grafts can produce a fruit tree with several varieties or an ornamental plant with several different colors of flowers. Although many types of plants technically can be grafted, this is typically only done with woody plants.

Not all plants can be grafted together. Generally, only plants that are closely related botanically will form a good graft union and they must be compatible. The compatibility of plants has been determined through many years of trial; this type of information is available in many publications. Most cultivars of a particular fruit or flowering species can be grafted, and plants of the same species can usually be grafted even though they are a different cultivar. Due to differences in vigor, some are better suited than others. Plants within the same genus can sometimes be grafted; plants of different genera are less likely to be grafted successfully.

Grafting has its own specific terminology for the plant parts used (figure 18).

- The **scion** is the upper portion that becomes the top of the plant. It consists of a piece of shoot with dormant buds that will produce the stem and branches. Scion wood should be made of ¼- to ⅜-inch diameter twigs from the previous season's growth, with two to three buds each.
- The **understock**, or **rootstock**, is the lower portion and provides the new plant's root system and sometimes the lower part of the stem. It may be a seedling, a rooted cutting, a layered plant, or a well-established plant.

FIGURE 18. Grafting terminology



For successful grafting to occur, five conditions must be met:

- The scion and understock must be compatible.
- Each must be at the proper physiological stage.
- The **cambium** of the scion and stock must meet.
- The graft union must be kept moist until the wound has healed.
- The plant must be given proper care for a period of time after grafting.

The best time for grafting is in late winter or early spring before new growth begins, preferably after the chance of severe cold has passed but well before hot weather arrives. Scion wood may be collected during the winter and stored in a cold, moist place at temperatures close to 34˚F, such as in a plastic bag in the refrigerator with moist paper towels. After the graft has taken and growth of the scion has started, cut off any side shoots or competing twigs that would shade or compete with the development of the new graft, as well as any regrowth on the rootstock portion.

Grafting methods can be divided into two basic types, which are largely determined by the size of the understock. One type joins a scion and understock of nearly equal size. Whip (bench) grafts and splice grafts are two common types. The other type attaches a small scion to a much larger understock. In this case, several scions may be attached to the understock. Some common types include the cleft graft, bark (veneer) graft, and side (stub) graft. Specific procedures for these and other types of grafting can be found in many publications.

Plant micropropagation

Plant tissue culture refers to the ability to establish and maintain in aseptic culture plant organs like embryos, shoots, roots, and flowers and plant tissues like cells, callus, and protoplasts to regenerate new plants. The various procedures used collectively are referred to as tissue culture, organ culture, *in vitro* culture, micropropagation, or biotechnology. Tissue culture is based upon the principle of cell totipotency; without cells being totipotent this means of propagating plants would not be possible.

Micropropagation is a powerful means by which plants can be rapidly increased to hundreds of thousands of plants in a matter of months. The technique is time-consuming, expensive, and not suited economically for all plants. Additionally, genetic instability can occur on some plants, resulting in permanent genetic change or a transient genetic change that will correct itself over time. Many of the newer plants you use in your gardens may have been developed, improved, or multiplied directly or indirectly using the techniques of micropropagation. Some examples of common plants propagated by tissue culture include deciduous and evergreen azaleas, daylilies, hosta, peace lily, dieffenbachia, and many more.

Micropropagation of plants is used widely in the agriculture and horticulture industries for rapid increase of elite plant genotypes or cloning a plant, disease elimination, plant screening for diseases and insects, plant breeding, genetic engineering of plants, and production of certain plant products. Its economic importance was realized first in the early 1970s and the impact of this technique has continued to increase over the years. While it can be technically sophisticated, you can do micropropagation in your own home with the proper materials and techniques.

The process of micropropagation is done in conditions where the plant tissue or organ is cultured under sterile conditions in a sealed container on a liquid or gel medium containing plant nutrients, vitamins, a sugar source, and plant hormones. Various types of media are used depending on the type of plant or plant part being cultured. The environment for tissue culture is important and based on the needs of the type of plant being cultured.

The manipulation of two plant hormones, auxin and cytokinin, is crucial to success in micropropagation. These hormones, discussed earlier in this chapter, work together in forming shoots or roots depending on the balance between the two hormones, which will vary depending on the type of plant. When the level of cytokinin exceeds the level of auxin in plant tissue, shoots proliferate. In the reverse situation, when auxin level exceeds the cytokinin level, rooting occurs. Through manipulation of these hormones, shoots or roots form and subsequently an intact plant becomes established.

Micropropagation success involves four developmental stages.

1. Stage I is establishment and stabilization of the explant (plant part being cultured). The function of this stage is to disinfest the explant, establish the explant on the culture medium, and stabilize the explant for multiple shoot proliferation.
2. Stage II is shoot multiplication. In this stage the explant proliferates into a cluster of shoots (microshoots) arising from the explant. This proliferated structure is divided into separate microshoots, which are then subcultured to new culture medium. The process is repeated many times until the desired number of plants is achieved. During this stage, the level of cytokinin is maintained at a higher level than auxin so microshoots form.
3. Stage III is root formation. Microshoots do not usually have roots. The hormones are altered in this stage so the level of auxin exceeds the level of cytokinin and roots form.
4. Stage IV is acclimatization. In this stage, rooted microshoots are gradually acclimated to normal growing conditions. Rooted microcuttings are removed from the culture vessel, culture medium is washed from roots, and plantlets are transplanted into pasteurized medium and grown under reduced light and high humidity. Over a period of several weeks to months microcuttings are adapted gradually to normal environmental conditions and grown to larger, sellable plants.

Conclusion

Plants have various natural reproductive strategies. Gardeners can use knowledge of plant biology to manipulate the environment to create more plants, preserve desired traits, or make plants grow more vigorously. Seed starting results in plants that may be genetically distinct from its parents and asexual, or vegetative, techniques create new plants that are genetically identical to the parent plant. There are many techniques for propagating plants, and success varies from gardener to gardener, as well as plant species to plant species. Propagation is an intriguing combination of science and horticultural technique that is accessible to all.

Resources

Wisconsin Horticulture publications are available at hort.extension.wisc.edu.

FAQs

Can I save seeds from my flowers? How long can I keep them?
Yes. Realize that seeds from hybrid plants are not likely to have the same characteristics as the parent—but heirloom varieties will. Most seeds will keep for several years if stored under cool, dry conditions, with some exceptions. Viability declines with age.

Why aren't my seeds growing?
A lot of factors affect seed germination. The seed coat could be too hard, the seed could be too dry or old, the soil could be too cold, or a critter or fungus could have damaged it. Double-check the seed packet instructions to ensure the soon-to-be seedlings have the right start.

What can I take a cutting from?
It depends on the plant. Some plants are easily propagated from the stems, others from roots, and others from a single leaf. Some plant cuttings are very difficult to root. Take cuttings at just the right developmental stage and keep under specific environmental conditions.

When do I divide my hostas?
The best time is early spring before the leaves emerge—but they can tolerate division almost any time except when the ground is frozen.

Plant propagation, practice exam questions

1. Which of the following is true about plant breeding?
a. Humans have been doing it for thousands of years
b. The goal is to develop plants with desirable characteristics
c. Genetic engineering is a type of plant breeding
d. All of the above

2. Which is NOT a type of asexual propagation?
a. Layering
b. Micropropagation
c. Leaf cuttings
d. Growing from seeds

3. Plant cells are totipotent. This means
a. They lyse when put in water
b. Plants can regenerate an entire plant from a single cell
c. Plant cells divide uncontrollably in the presence of ethylene
d. They contain auxin

4. Pollination is
a. The transfer of pollen to the female flower parts
b. The union of the male and female reproductive material
c. Only done by insects
d. a and c

5. Which of the following is TRUE about the hormone auxin?
a. Is responsible for apical dominance
b. Is the active ingredient in rooting compounds
c. Promotes adventitious root formation
d. Is produced in the meristems of shoot tips
e. All of the above

6. The final step in seed starting when transplants are acclimated to wind, intense light, and fluctuating temperatures is called
a. Propagation
b. Exposure acclimation
c. Weather acclimation
d. Hardening off

7. What plant part cannot be propagated asexually by cuttings?
a. Stem
b. Leaf
c. Root
d. None of the above

8. Corms, bulbs, tubers, rhizomes, stolons and runners are all modified ________ tissue
a. Stem
b. Leaf
c. Root
d. None of the above

9. Which of the following is FALSE about grafting?
a. Only closely related, compatible plants can be successfully grafted
b. The scion is the term for the portion of the plant below the bud-graft union
c. It is typically done with woody plants
d. The best time to graft is in late winter or early spring

10. The method used to break internal dormancy by exposing seeds to moisture and cold temperatures for a period of time is called
a. Scarification
b. Stratification
c. Sporification
d. Californication

11. This seed type is known for its vigor, high yield, disease resistance and uniformity
a. F1 hybrid
b. F2 hybrid
c. Inbred lines
d. Seed mixes

12. The following is TRUE about micropropagation
a. Plants are propagated in sterile conditions
b. It can only be used for very small plants
c. Plant hormones auxin and cytokinin play an important role in micropropagation
d. All of the above
e. a and c

Answer key
1. (d) 2. (d) 3. (b) 4. (a) 5. (e) 6. (d) 7. (d) 8. (a) 9. (b) 10. (b) 11. (a) 12. (e)