Dedication

To the Penn State Extension Master Gardeners in recognition of their outstanding volunteer efforts promoting sustainable horticultural practices and environmental stewardship in Pennsylvania communities.

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The following University faculty members, extension educators, and Master Gardeners contributed to this edition of the training manual by updating and reviewing content, offering valuable comments, and providing illustrations and photos. Material was adapted from the original Penn State Extension Master Gardener Manual, The Maryland Master Gardener Handbook, The Virginia Master Gardener Handbook, and various Penn State Extension publications.

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As a volunteer for the Penn State Extension Master Gardener program, you will be representing Penn State. For this reason, it is important for you to become familiar with the history and organization of Penn State Extension and understand the responsibilities of a Master Gardener.

THE LAND-GRAIN SYSTEM AND COOPERATIVE EXTENSION

Land-grant institutions constitute a uniquely American educational system. Before the latter half of the nineteenth century, when the land-grant system was created, America’s colleges and universities existed primarily to prepare wealthier citizens for the professions of medicine, law, and the ministry. As the need for higher education grew, educators and politicians proposed a different kind of university—one devoted to educating all people, particularly those seeking a vocation in the nation’s businesses, farms, and trades. The result was the land-grant institution.

A remarkable cooperation among federal and state governments, university educators, and laypeople marked the creation and growth of the land-grant system. It was established with the Morrill Act of 1862, by which Congress provided large grants of federal land for each state to sell. The states were to use these funds to create an endowment, on which interest would accrue to sustain the colleges. It soon became apparent that these monies were insufficient, and with the second Morrill Act of 1890, Congress provided for additional federal funding. The act also established funding for a second system of land-grant institutions in 16 southern states where existing land-grant colleges practiced segregation. Thus, historically black land-grant institutions joined the system.

At this time, colleges were severely hampered by the general lack of sound research in support of teaching. In 1887, Congress passed the Hatch Act to create and support experiment stations. Then in 1914, the Smith-Lever Act created Cooperative Extension as a partnership among federal, state, and county governments for its support and oversight. The Smith-Lever Act gave land-grant institutions the responsibility “to aid in diffusing among the people of the various states, useful and practical information on subjects relating to agriculture and home economics; and to encourage the application of the same.”

The land-grant idea evolved to include three central functions: resident teaching, research, and extension. Cooperative Extension is the premier organization for fulfilling the extension function of each state’s land-grant institution.

Cooperative Extension’s ultimate goal is personal development—to enable people to be self-directed, manage their resources, and handle change in primary dimensions of their lives. The means for personal development is education, which empowers
people by helping them acquire knowledge, attitudes, skills, and aspirations. Cooperative Extension's methods are informal, off campus, and oriented toward people's problems and needs.

**PENN STATE EXTENSION**

The Penn State College of Agricultural Sciences has nine traditional academic departments (Agricultural and Biological Engineering; Agricultural Economics, Sociology, and Education; Animal Science; Ecosystem Science and Management; Entomology; Food Science; Plant Pathology and Environmental Microbiology; Plant Science; and Veterinary and Biomedical Sciences). These units include faculty with extension education, resident education, and research responsibilities. Faculty members with extension responsibilities prepare content for extension programs.

The College of Agricultural Sciences also operates four research and extension centers. The Russell E. Larson Agricultural Research Center located in Rock Springs is in close proximity to University Park. The other three research facilities are located in areas with high concentrations of agricultural production: Biglerville, Erie, and Landisville. Each has a different focus and provides University faculty with the opportunity to conduct research under the same environmental conditions facing the agriculture industries in Pennsylvania. The Fruit Research and Extension Center (FREC) in Biglerville is located in the heart of apple and peach country, while the Lake Erie Regional Grape Research and Extension Center in Erie is nestled between the escarpment and shores of Lake Erie with deep soils and an ideal climate for growing grapes. The Southeast Agricultural Research and Extension Center (SEAREC) in Landisville is located near some of the highest concentrations of vegetable, small fruit, and agronomic crop production in the state of Pennsylvania.

Each of Pennsylvania's 67 counties has a physical presence through a Penn State Extension office. Counties are organized administratively into 21 districts and two urban extension centers. Each district and urban center has a director. The county extension staff may include extension educators, nutrition education advisers, a Master Gardener coordinator or horticulture assistant, and support staff. The extension educators may be working in the agriculture, family living, 4-H, urban forestry, community development, or water quality subject matter areas. County staff deliver information to the community.

The Penn State Extension Master Gardener program is led by the state coordinator under the direction of the assistant director for horticultural programs. The Master Gardener State Steering Committee works in an advisory capacity with the state coordinator to provide overall direction and planning for the program in Pennsylvania.

At the county level, a Master Gardener coordinator directs the program with support from the district director, extension educators, and office staff working directly with Master Gardener volunteers. Faculty with extension education appointments in areas such as horticulture, agronomy, entomology, and plant pathology contribute technical support in their areas of expertise.

**THE MASTER GARDENER PROGRAM**

The Master Gardener program was designed to use the services of trained volunteers who have horticultural knowledge and a willingness to share that knowledge with other county residents through Cooperative Extension. The program was initiated in 1972 in Seattle. David Gibby, King County extension agent, realized that keeping up
with the growing number of gardening questions coming into his office was a losing battle. Dr. Gibby and Dr. Arlen Davison, then the extension plant pathologist, put their minds to the problem and came up with plans for the initial season of a Master Gardener program.

The guiding philosophy, as stated by Dr. Davison, was to develop a core of knowledgeable volunteers to assist Cooperative Extension in meeting the demand for reliable gardening information. In 1973, 120 Master Gardeners were trained by extension specialists in King and Pierce Counties. The program’s success was remarkable. Today, there are Master Gardener programs in all 50 states; however, funding solutions, organizational styles, and program scope may vary from county to county and state to state.

In Pennsylvania, Philip N. Rhinehart is recognized as the program’s initiator. In 1980 Mr. Rhinehart, then vice president of the Clearfield County Extension Executive Committee, came across an article on the Master Gardener program describing how the program had begun and grown. Aware that the extension staff in Clearfield County was inundated with gardening questions, he immediately identified with the problem that had led Drs. Gibby and Davison to recruit and organize volunteers in Washington. Mr. Rhinehart requested information on the program from Washington and other states involved with the program. He then conveyed the information to Harold R. Bock, at that time county extension director, who in turn proposed the idea of a Master Gardener program in Pennsylvania to Penn State. The University supported the idea, and in 1981 a committee was formed to organize the program. In 1982 the first Penn State Extension Master Gardeners completed their training.

**MASTER GARDENER VOLUNTEERS**

Master Gardeners receive a minimum of 40 hours of instruction. Along with an orientation, volunteers are given core training in botany, plant propagation, soil health, plant pathology, entomology, integrated pest management, lawn care, vegetable gardening, woody and herbaceous plants, native plants, weeds and invasive species, pruning, and communication skills. The core section of the manual gives the Master Gardener trainee the basic horticultural knowledge necessary to assist extension staff effectively. The remaining elective classes cover specific gardening topics, including indoor plants, garden wildlife, tree fruit and small fruit culture, landscape design, and gardening equipment.

After training is completed, the volunteers are ready for action. Each new Master Gardener provides the county extension office with 50 hours of horticulture-related volunteer work in the first year. Volunteer activities must have an educational purpose and/or a teaching component. The following are examples of acceptable volunteer opportunities:

- Answer consumer/home gardeners’ telephone and email inquiries, assist extension office visitors with plant and insect samples for identification or diagnosis, and give general pesticide recommendations.
- Assist with extension educational programming, such as poison prevention programs, talks for local organizations, extension-sponsored workshops, exhibits, and displays.
- Write research-based gardening and horticultural information for fact sheets, newsletters, newspapers, magazines, websites, and blogs.
- Design or assist with establishing and maintaining educational demonstration
After trainees have satisfactorily completed the formal training and 50 hours of volunteer service, they are awarded a Penn State Extension Master Gardener certificate. To maintain the title “Certified Master Gardener,” volunteers are required to attend a minimum of 10 hours of continuing education training per year and serve a minimum of 20 hours of volunteer time per year. When an individual ceases active participation, his or her designation as a Master Gardener becomes void.

By every measure, the Master Gardener program has been highly successful and provides benefits for everyone involved. The public benefits by being able to talk with knowledgeable gardeners face to face. Master Gardeners enjoy the feeling of accomplishment that comes through their service and appreciate the professional training they receive. Cooperative Extension benefits because Master Gardeners extend the organization’s reach to a greater number of gardeners.

• Teach Master Gardener training sessions.
• Develop or assist with community-based environmental stewardship projects.
• Assist teachers, 4-H volunteers and youth, and/or children with gardening education projects.
• Conduct/teach horticulture-related clinics, pruning, or other demonstrations at extension offices, local libraries, farmers markets, government centers, fairs, expos, garden clubs, civic groups, community events, and flower shows.
• Serve as neighborhood “plant expert” in the community by answering home gardening questions, diagnosing plant problems, and/or instructing neighbors on proper care of lawn, landscape, garden, or houseplants.
Teaching and Communication

CHAPTER 1
INTRODUCTION

We are here to learn, but we’re also here to help others learn; this means learning not only about plants, pests, and gardens but also how to share what we know with others.

TEACHING

Teaching is a large part of what Master Gardeners do. The mission of the Master Gardener program is to provide research-based information to the community. There is more to this task than simply talking at the front of a room or showing a PowerPoint presentation. Teaching involves preparation, careful attention to questions and discussion, and a willingness to explore. Learning is also a big part of teaching. Teaching things to others is a great way to learn about them!

Teaching can be hard work, but it’s also very rewarding. Your challenge is to make learning fun, informative, and satisfying for both your students and yourself.

Understanding Your Students

You may do Master Gardener work with young people, but many times you will be teaching other adults. Children, teens, and adults all approach learning in different ways.

When teaching adults, keep the following in mind:

• Adults are participating by choice. Adults are generally more invested in learning and attach more value to the process.

• Adults have a broad base of experience from which to draw and share with others. Keep in mind that some previous experiences might lead adult students to make incorrect assumptions about the material they are learning; for example, an amateur gardener may be following outdated wisdom about using pruning paint on freshly cut wounds. Check with your students often to make sure everyone is on the same page.

• Adults have busy, complicated lives. While adults are generally invested in learning, they also have many other obligations. Family, job, community, and social responsibilities could require adult students to be flexible about the amount of time and energy they can invest.

• Many adults face barriers to learning. Some examples of this are having unrealistic goals or diminished vision and hearing. Work with your students to find ways around frustration and make the material accessible to everyone.

• Adults are sensitive to failure in learning situations.

• Adults want information to be relevant to their needs and immediately applicable. Most adults want to learn how to perform a task or accomplish a goal and will be focused on the steps they need to take.

• Adults respond better when the material is presented through a variety of different senses. Try to design your lessons with hands-on experiences that engage as many of the senses (sight, sound, scent, taste, and touch) as possible.

LEARNING OBJECTIVES

• Develop effective communication skills.
• Understand how to organize and simplify information.
• Explain how to prepare and present a program, and create an effective display.
• Understand the value of publicity and marketing.
Effective adult educators are confident in their abilities, accepting of themselves and others, flexible, capable of admitting their limitations, and appreciative of the contributions of others.

When teaching children, keep the following in mind:

- Younger students have less experience on which to ground new knowledge. Establishing context can be helpful to younger learners.
- Children are motivated to learn through exploration and curiosity. Give younger students the freedom to explore a topic in a way that makes sense to them.
- Children have different strengths and learning styles. Try to give students many ways to approach the material.
- Let children choose how they learn. This will help them process and retain new material.
- Give students choices. Some children learn by reading, some by watching, and some by doing. Letting children find their own way will make the lesson more relevant and give the students an opportunity to find their motivation to learn.

Learning is a step-by-step process, and it's important to make sure that younger students are comfortable with the current step before moving on to the next.

What People Retain

Increased involvement on the part of the learner leads to increased retention of the subject matter. The more involved learners are, the more they will retain. Students are better able to retain information when they are active participants.

In general, students can easily retain:

- 10 percent of what they read
- 20 percent of what they hear

- 30 percent of what they see and hear
- 70 percent of what they say or write
- 90 percent of what they do

When designing learning activities, try to incorporate a hands-on component to the lesson. As an example, if you are giving a presentation on pruning, a live demonstration is good, but even better is allowing students to prune a plant themselves. Not all subject material lends itself to this kind of instruction, but lessons that offer hands-on experience will be more effective in helping the students remember the material.

What People Ask

When students are trying to understand new material, they will ask a lot of questions. Students may ask specific questions to better understand a detail, while other questions may be about broader topics or asking about context. Listen carefully to questions when teaching—the kinds of questions your students are asking can help you understand what parts of the material they are comfortable with and where they might be having trouble.

Answering Questions

There are many useful strategies for answering questions well. First, make sure you understand the question! It is helpful to repeat the question back to the student to ensure that the entire room has heard the question, and it gives the student a chance to correct or amend the question if necessary. This also gives you some time to think about the question and prepare to answer it.

When answering questions, remember that the student knows different things than you do. The student may or may not have a good grasp of plant nomenclature or may not have experience with a particular propagation technique. Try to use vocabulary that is familiar to the student.
It is always better to give yourself time to offer a good answer than to give a poor answer quickly. If you cannot answer a question during the lesson, make a note of it and follow up with the answer later.

Teaching Methods

There are many ways to share information with students. One of the best ways to share large amounts of information is through writing. As a Master Gardener, you can help educate by developing handouts and pamphlets for the public or writing articles for in-house newsletters and the local paper.

One common method used to interact with students is speech. This can be a formal presentation, a group discussion, or even a conversation with a passerby while working in a demo garden. The ability to listen is also an important part of using speech to communicate.

Speech can also be used for broadcast by giving a presentation on television or the radio or recording a podcast. In these formats, it's often more difficult for the audience to ask questions, so always try to be clear and careful when presenting lessons via broadcast.

Presentations can be enhanced by visual aids. These can be as simple as handouts with illustrations or infographics, or as complicated as multimedia PowerPoint presentations. Storyboards and posters are good ways to present information in a group setting where there is no power or support for providing an onscreen presentation. Visual aids can take many forms—photographs, line art, charts, graphs, and maps are all ways to get information to your students.

The deepest learning experiences come from demonstration and interaction. Hands-on demonstrations give students valuable insight into a subject and the opportunity to ask better questions. Walks, tours, and field trips offer students the chance to learn about a topic in the context of its environment while using all of their senses.

Not all people learn the same way, so it's good to use several different methods to explain a single concept. Learning the material multiple times in various ways will also help students retain the material.

COMMUNICATION

Communicating effectively requires the following key skills:

- Providing information. As a Master Gardener, you want to provide good advice and knowledge to members of your community.
- Listening. To understand what to communicate, you first need to understand the information needs of your community.
- Preparation. Organizing and presenting your story takes planning and practice.

When providing information, be as clear and as easy to understand as possible. Use simple language, avoid slang and jargon, and only use technical language when you need to. When using technical language, pause to explain the terms. Use concrete details in your examples to ensure that you and the people you're working with agree on specifics. Be concise—say what you need to say. If those you are working with need more information, then provide more detail. It can also be helpful to summarize the topic both before and after the conversation.

Good communication is more than just giving information—it is a two-way street. Give your audience space to ask their questions, and let them finish before giving them answers. Pay attention to the questions; they can help you understand what your audience is looking for. Also try to understand the depth of the question. Is your audience looking for a simple answer, or do they need the complete story?
If you use a technical term, be prepared to explain it in terms familiar to your audience. If someone has a question, take time to repeat it. This gives your audience a chance to make sure they understand what they are asking. After answering the question, ask them if you have answered their question in a way that helps them.

Helping others with their gardening questions usually involves a lot of factual details. Remembering and managing these details can be difficult depending on the situation, but there are a few things you can do to make this easier. Before you begin, and during the conversation, take a moment to think about what you want to say next. You can also use these pauses to remember what you’ve already talked about. If there are topics that you still want to mention in the conversation, make a quick note to yourself to help you remember them—this will help you finish up a particular topic before moving on to the next one. Keeping track of topics can help to make your conversations simpler and easier to grasp.

If you find yourself unable to answer a question because you need to do research, that’s okay! It’s always best to give accurate information. If you need to break away from the conversation to do some research, ask the person you’re talking with for their contact information and how best to reach them with the answer to their question.

Communication Techniques

Writing

As a Master Gardener, you will have ample opportunity to use your writing skills. You can help produce publications about gardening, prepare scripts for slide sets, or write newsletters and columns for the local newspaper. You could even keep a simple journal of your Master Gardener group’s weekly activities. There are a lot of ways your writing can help get information to your fellow Master Gardeners and the public.

Getting organized early can make your writing easier, better, and more fun. When sitting down to write, build an outline of the topics you want to cover. This helps you understand the structure of what you want to write. An outline can help you figure out how you will arrange your subtopics, show you where you need to add more (or less) detail, and indicate places in your project where something is missing. An outline can help ensure you’ve covered everything you need to about a topic. If you need to reorganize your project, the work is a lot like pruning—it’s easier done when there are no leaves on the tree. A good outline at the start can make the project easier to manage later on.

A good outline should also help you develop a title for your project. A good title should be simple, short, and easy to understand. Your title should be accurate, too. Try to find a title that specifically captures your subject or topic. If your project is an overview, say so in the title. If your project is a focused piece on a particular plant, pruning technique, or any other specific topic, use the title to tell your reader. Having a good title is important since it is the first thing on your project that readers will see, and it will be a big part of whether they decide to read on.

With your title and outline, you should have a good framework for developing your project. Use the title to keep you focused on the overall picture, and the outline can be helpful as a map of your project. Develop and explain each topic in your outline. Use references to support what you say, and include the list of references so that your reader can learn more. Introduce each topic to help your readers keep track of their progress, and finish each topic with a quick summary to help readers remember what you’ve written (and give them a moment...
INTRODUCTION

Botany is the science of plants. A study of botany is important for understanding horticulture, the art and science of cultivating vegetables, fruits, and ornamental plants. Home horticulture is the use of these arts and sciences by the home gardener. Taxonomy is the science dealing with the naming and classification of plants and animals.

To gain a working knowledge of horticulture, it is necessary to understand the structure and function of plants, as well as the environmental factors that affect their growth. All plants have certain structures and functions in common, as discussed throughout this chapter. Much of the information presented relates to higher plants, the seed-producing flowering plants and gymnosperms that are of greatest importance to horticulture, rather than more primitive spore-producing plants such as mosses, ferns, and their relatives. All vegetable and flowering ornamental plants are angiosperms, which produce seeds inside a fruit, while conifers and their relatives are gymnosperms, which produce seeds but lack protective fruits.

CLASSIFICATION OF THE PLANT WORLD

Plants are vital to our existence. In an effort to provide a means to catalog information about the vast number of living plants, scientists have classified them into various groups based on shared characteristics that are inherited from one generation to the next (Fig. 2-1).

Individual plants are grouped into species, or groups of individuals that share close...
genetic relationships, interbreed freely, and are very similar in their morphology (form and structure).

Closely related species are grouped into genera (plural of genus), which are groups of genetically related and thus morphologically similar species. Genera with similar traits are grouped into families. Families are grouped into orders, which are then grouped into classes. Classes are grouped into divisions. Many of our gardening and landscape activities use species in the angiosperm and gymnosperm divisions. The divisions are together classified in the plant kingdom, a group that includes all plants.

As you move through plant classification from species to kingdom, similarities among individuals become less distinct. The modern classification of plants is based on DNA characteristics that reflect underlying evolutionary relationships. Such a classification is called a natural classification, while one based on superficial similarities that do not reflect evolutionary relationship is said to be an artificial classification.

History of Plant Classification

Over the centuries there have been numerous attempts to name and classify plants in a natural fashion. Early attempts at naming relied on Latin words to describe various aspects of a plant. As more and more plants were identified and classified, the length of individual names increased as well. It was not uncommon to have plants named or described with eight or more words.

In the mid-1750s Carl von Linne, a Swedish botanist using the pen name Carolus Linnaeus, published a book titled *Species Plantarum* and changed the way plants are named. He gave all the plant species that were known at that time a name consisting of two words. The first word identifies the genus; the second is the specific epithet.

This format is known as the Latin system of binomial nomenclature, and it is still the basic structure of our modern system of nomenclature.

In the eighteenth century, Latin was the language of science and thus formed the basis for the language of nomenclature. Many Latin plant names were carefully constructed to provide information about the plant. Latinized descriptive phrases often reflect a particular plant quality. Examples are “alba” (white), “rubra” (red), and “serrata” (toothed). The medicinal value of some plants is seen in their names, such as lungwort (*Pulmonaria*).

Some plant names are tributes to mythological Greek and Roman characters. Plant names in this category include Narcissus, Dianthus, and Andromeda.

A number of plant names commemorate significant contributions from botanists, plant explorers, or other people. Most generic names ending in “-ia” honor people. Gardeners will be familiar with *Magnolia*, *Forsythia*, and *Zinnia*, named for Pierre Magnol, William Forsyth, and Johann Zinn, respectively.

Everyday Nomenclature

The complete name of any plant used in commercial trade includes the genus and the specific epithet. Many plants also have
Nymphaea alba (European white waterlily), for example, has 245 different common names across Europe. The Latinized species name is thus best used in discussions of plants since it is unique to this species.

Some plants may have a third Latinized name after the genus and specific epithet. Used to designate a variety, it is preceded by “var.” which signifies a group of plants subordinate to the species. The differences between varieties within a particular species are inheritable and passed on to succeeding generations. However, the morphological differences between two varieties of a particular species are smaller than the morphological differences between two different species. Varieties of a species are usually interfertile, while different species are usually not. Examples of varieties include Cercis canadensis var. alba, which has white flowers, and Gleditsia triacanthos var. inermis, a thornless variety of common honeylocust.

Another common horticultural term is cultivar, short for cultivated variety. A cultivar is a collection of cultivated plants that are clearly distinguished by certain characteristics and when reproduced (sexually or asexually) retain their distinguishing characteristics. Cultivars do not occur in nature and must be maintained under cultivation. Cultivar names are written in a modern language, not italicized, set within single quotation marks, and with the first letter of each word capitalized.

Examples of cultivars are Acer platanoides ‘Crimson King’ and Cornus florida var. rubra ‘Cherokee Chief’. ‘Crimson King’ maple has purple foliage instead of green like the species, and ‘Cherokee Chief’ dogwood has flowers of a deeper red than the variety rubra.

Occasionally, a plant name may have “×” between the genus and species. This represents an interspecific hybrid resulting from a cross between two species within the genus. An example is Viburnum × burkwoodii—Burkwood viburnum that resulted from a cross between V. carlesii and V. utile.
THE PARTS OF A PLANT

The parts of a plant fall into two groups: vegetative and sexual reproductive. Vegetative parts include roots, stems, leaves, and buds (Fig. 2-2). These plant parts may be used in asexual (vegetative) reproduction. Sexual reproductive parts include flowers, flower buds, fruits, and seeds.

Roots

A basic knowledge of root systems is essential for an understanding of plant growth, flowering, and fruiting. Root structure and growth habit have a pronounced effect on plant size and vigor, how a plant is propagated, how well the plant adapts to certain soil types, and how the plant responds to cultural practices and irrigation. Their principal functions are to absorb water and nutrients, anchor the plant in the soil, furnish physical support for the stem, and store food. In some plants, they may be used for propagation. The roots of certain vegetable crops are important as food.

Root Anatomy

Roots typically originate from the lower portion of a plant or the base of a cutting (Fig. 2-3). They possess a root cap, but do not have nodes, and will never bear leaves or flowers directly. The inside of a root has three major parts:

- The meristem, located at the tip, manufactures new cells; it is an area of cell division.
- Behind the meristem is the zone of elongation. Here cells increase in size by absorbing food and water. As they grow, they push the root through the soil.
- In the maturation zone, cells undergo changes to become specific tissues, such as epidermis, cortex, or vascular tissue.

The epidermis is the outermost layer of cells covering the root and begins in the zone of maturation. Epidermis cells are responsible for the development of root hairs. Cortex cells are involved in moving water from the epidermis and storing food. Vascular tissue, located in the center of the root, conducts food and water.

Externally, a root has two major parts, root hairs and the root cap. Root hairs, found along the main root, absorb water.
A lateral, or secondary, root is a side or branch root that arises from another root. A fibrous root is one that remains small in diameter because of very little cambial activity. The cambium is a meristem, a site of cell division and active growth. One factor causing shrubs and dwarf trees to remain smaller than standard or large-sized trees is the inactivity of the cambium tissue in the roots.

A fibrous root system is one in which the primary root ceases to elongate and numerous lateral roots develop. These lateral roots branch repeatedly to form the plant’s feeding root system.

If plants that normally develop a taproot are undercut so that the taproot is severed early in the plant’s life, the root will lose its taproot characteristic and develop a fibrous root system. This procedure is done commercially in nurseries so that trees naturally having taproots will develop a compact, fibrous root system. The result is high transplanting success in the field.

The quantity and distribution of plant roots is very important because these two factors have a major influence on the roots’ ability to absorb moisture and nutrients. Root depth and spread are dependent on the plant’s inherent growth characteristics as well as the texture and structure of the soil. Roots will penetrate much deeper in a loose, well-drained soil than in a heavy, poorly drained one. A dense, compacted soil layer will restrict or terminate root growth. However, the roots of all plants will only grow where air and water are adequate to support life.

Types of Root

A primary root originates at the lower end of the embryo of a seedling plant. A taproot is formed when the primary root continues to elongate downward into the soil; it becomes the central and most important feature of the root system, with a somewhat limited amount of secondary branching (Fig. 2-4). Some trees, like pecan, oak, and tulip trees, have a long taproot with very few lateral or fibrous roots. This makes them difficult to transplant and necessitates that they be planted only in deep, well-drained soil.

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Adventitious Roots

In specialized situations, roots will develop from an unexpected position; these are called adventitious roots (Fig. 2-5). For example, in the soft, rain-soaked soils of the rainforest, adventitious roots will form on the trunks of the trees. These wedged-shaped buttress roots may extend 10 to 15 feet up the sides of the trunk and an equal or
greater distance away from the trunk. They provide additional support to the tree.

Prop roots, another form of adventitious roots, also provide added support for trees and plants. Tropical trees such as the screw-pine develop numerous prop or stilt roots on their trunks or branches. These grow downward and attach to the ground below. Corn also produces prop roots near the base of the plant to provide additional support for the weight of the fruit.

In some species, such as mangroves, pneumatophores facilitate the exchange of gases in plants growing in waterlogged environments. For other species, such as baldcypress, they appear to function more to stabilize trees growing in wet, less stable soils (Fig. 2-6).

In some bulbs, the roots in the upper region shorten and thicken to form contractile roots. These adventitious roots provide added protection for the bulb by pulling it downward to an appropriate soil depth.

Other adventitious roots develop on vining plants. Aerial (climbing) roots grow from the stem of the plant and can penetrate ridges in tree bark, wooden fences, and bricks to help anchor and support the vine.

**Roots as Food**
The enlarged root is the edible portion of several vegetable crops. For example, the sweet potato is a swollen tuberous root that serves to store food for the plant. Carrot, parsnip, salsify, and radish are also enlarged taproots.

**Stems**
Stems support buds and leaves while serving as conduits for water, minerals, and sugars.

**Stem Anatomy**
A stem’s three major internal parts are the xylem, phloem, and cambium. Xylem and phloem are the primary components of a plant’s vascular system, which transports water, minerals, and food while also supporting the plant. Xylem tubes are the water- and mineral-conducting channels that travel up the plant primarily from roots to shoots. Phloem tubes conduct food from the leaves to both the roots and the terminal buds. The cambium is a meristem, a site of cell division and active growth. Located between the xylem and phloem inside the bark of a stem, cambium produces the xylem and phloem tissues and is thus responsible for a stem’s increase in girth.

There are two classes of plants within the division of angiosperm: monocot and dicot (Fig. 2-7). The vascular system of a monocot (e.g., grasses, orchids, lilies) differs from that of other kinds of flowering plants. Each kind of plant contains xylem and phloem, but in different arrangements. In a monocot stem, the xylem and phloem are paired into bundles dispersed throughout the stem. The vascular system in other flowering plants is said to be continuous because it forms rings inside the stem. The ring of phloem is near the bark or external cover of the stem and is a component of the bark in mature stems. The xylem forms the inner ring and is the sapwood and heartwood in woody plants.
The pith, a region in the center of some stems and roots, consists of loosely packed, thin-walled parenchyma cells. Its chief function is food storage. In older stems the pith may disintegrate and be lost.

An area of the stem where leaves are located is called a node. Nodes are sites of great cellular activity and growth where buds develop into leaves or flowers. The area between nodes is called an internode. Along the internodes of woody plants are spongy areas referred to as lenticels. Lenticels are small openings that allow for the exchange of gases between internal stem tissue and the outside atmosphere (Fig. 2-8).
Stems may be long, with great distances between leaves and buds (e.g., on branches of trees and in runners on strawberries) or compressed, with short distances between buds or leaves (e.g., in fruit spurs and crowns of strawberry plants). Stems can be above the ground (like most stems we are familiar with) or below the ground (as in potatoes and tulip bulbs). All stems must have buds or leaves present to be classified as stem tissue.

**Woody Stems**

A shoot is a young stem with leaves. A twig is a stem one year old or less and without leaves, still in the winter dormant stage. A branch is a stem over one year old that typically has lateral stems. A trunk is a main stem of a woody plant. Most trees have a single trunk.

A woody stem contains relatively large amounts of hardened xylem tissue in its central core (Fig. 2-9). It is characteristic of fruit trees as well as ornamental trees and shrubs. A cane is a stem that has a relatively large pith region (the central spongy tissue of certain stems) and usually lives only one or two years. Examples of plants with canes are rose, grape, blackberry, and raspberry.

**Modified Stems**

Although typical stems grow above the ground, stems can take many forms. Modified stems can be found both above the ground and below the ground. Examples of aboveground modified stems are crowns, spurs, stolons, and runners. The aboveground parts of a woody tree or shrub are similarly stem tissue. Belowground stems are bulbs, corms, rhizomes, and tubers.

A modified aboveground stem, known as a crown (e.g., dandelions, African violets), is a compressed stem having leaves and flowers on short internodes (Fig. 2-10). A spur is a compressed fruiting branch. It is short and stubby, with side stems that arise from the main stem. Spurs are common on fruit trees like pears, apples, and cherries, where they may bear fruit. If severe pruning is done close to fruit-bearing spurs, the spurs can revert to a longer nonfruiting stem.

A stolon is a fleshy or semi-woody horizontal stem that grows on the soil surface, forming a new plant at one or more nodes. Strawberry runners are stolons. Remember, all stems have nodes and buds or leaves. The leaves on strawberry runners are small but located at the nodes, making them easy to see. The nodes on the runner are the positions where roots begin to form. Spider plants have stolons that can produce an entirely new plant.

Belowground modified stems, such as the potato tuber, iris rhizome, and tulip bulb, are underground stems that store food for the
A corm is a solid, compressed stem with reduced, dry, scale-like leaves. Unlike bulbs, corms do not contain fleshy scales.

Rhizomes, like stolons, are specialized stems that grow horizontally. Unlike stolons, rhizomes grow at or just below the soil surface. In some plants, they act as a storage organ and a means of propagation. Some rhizomes are compressed and fleshy, as in an iris; they can also be slender, with elongated internodes, such as in quackgrass. Quackgrass is an insidious weed mostly because of the spreading capability of its long, thin rhizomes.

The tuber is an enlarged portion of an underground stem and, like any other stem, has nodes that produce buds. The eyes of a potato are actually the nodes on the stem. Each eye contains a cluster of buds. Some plants produce a modified stem known as a tuberous stem. Examples are tuberous begonia and cyclamen. The stem is shortened, flattened, enlarged, and below the ground. Buds and shoots arise from its top or crown, and fibrous roots are found on its bottom.

Some plants produce a modified stem known as a tuberous root. Examples are tuberous begonia and cyclamen. The stem is shortened, flattened, enlarged, and below the ground. Buds and shoots arise from its top or crown, and fibrous roots are found on its bottom.

Some plants, such as dahlia and sweet potato, produce underground swollen storage organs called tuberous roots (Fig. 2-12). While often confused with bulbs and tubers, these are roots, not stems, and have neither nodes nor internodes.
Stems as Food

The edible portion of cultivated plants such as asparagus and kohlrabi is an enlarged succulent stem. The edible parts of broccoli are stem tissue, flower buds, and a few small leaves. The edible part of the potato is a fleshy underground stem called a tuber. Although its name suggests otherwise, a cauliflower’s edible part is proliferated stem tissue. The flower of this biennial develops from buds in the compact branched stem tissue.

Leaves

The primary function of leaves is to absorb sunlight for the manufacture of plant sugars in a process called photosynthesis. The flattened surface presents a large area for efficient absorption of light energy.

Leaf Arrangement

The various ways leaves are arranged along a stem can be used to identify plants (Fig. 2-13). Opposite leaves are positioned across the stem from each other, two leaves at each node. Alternate or spiral leaves are arranged in alternate steps along the stem, with only one leaf at each node. Whorled leaves are arranged in circles along the stem, with three or more leaves per node. In a rosulate arrangement, the basal leaves form a rosette around the stem with extremely short nodes.

Leaf Anatomy

A leaf consists of a blade and a petiole. The blade is supported away from the stem by a stalk called a petiole. The base of the petiole is attached to the stem at the node. The smaller angle formed between the petiole and the stem is called the leaf axil. An active or dormant bud or cluster of buds is located in the axil. Petioles vary in length or, in the case of sessile leaves, may be lacking entirely when the leaf blade is attached directly to the stem.

The blade is the expanded, thin structure of a leaf on either side of the midrib. It is usually the largest and most conspicuous leaf part. The blade is composed of several layers. On the top and bottom is a layer of tough, thickened cells called the epidermis. The primary function of the epidermis is to protect the leaf tissue. The way epidermal cells are arranged determines the texture of the leaf surface. Some leaves have hairs that are an extension of certain epidermal cells. An African violet has so many hairs that the leaf feels like velvet.

A simple leaf has a blade that is a single, continuous unit (Fig. 2-14). A compound leaf is composed of several separate leaflets arranged in a single plane and attached to either the petiole or a central stalk called a rachis. Some leaves may be doubly compound, having two divisions of leaflets. A deeply lobed leaf may look like a compound leaf, but the lobes are connected by narrow bands of blade tissue, making it a simple leaf.

Part of the epidermis is the cuticle, which produces a waxy layer called the cutin (Fig. 2-15). This substance protects the leaf from dehydration and certain invading pathogens. The amount of cutin in the leaf is a direct response to sunlight, increasing with greater light intensity. For this reason, plants grown in the shade should be moved into full sunlight gradually over a period of a few weeks to allow the cuticle to develop in thickness and protect the leaves from the shock of rapid water loss or sunscald.
The middle layer of a leaf is the mesophyll. Situated between the upper and lower epidermis, it is the layer where photosynthesis occurs. The mesophyll is sometimes divided into a dense upper layer of cells called the palisade and a lower layer containing lots of air space, the spongy parenchyma layer. Cells in these two layers contain chloroplasts, the actual sites of the photosynthetic process.

On the undersides of leaves are epidermal cells that can open and close. Known as guard cells, they protect the leaf interior and regulate the passage of water, oxygen, and carbon dioxide through the leaf (Fig. 2-16). The openings in the leaf surface surrounded by the guard cells are called stomata. The opening and closing of a stoma is determined by weather. Conditions that cause large water losses from plants (high temperature, low humidity) stimulate guard cells to close. In mild weather, the guard cells open. They also close in the absence of light.

Leaf Venation

The vascular bundles extend through the petiole and spread out in the blade. The term “venation” refers to the patterns in which the veins are distributed in the blade (Fig. 2-17). Two principal types of venation are parallel venation and net venation.

Parallel-veined leaves have numerous veins that run parallel to one another and are connected laterally by minute, straight veinlets. Parallel venation is, for example, found in plants of the grass family where the veins run from the base to the apex of the leaf. Another type of parallel venation is found in plants such as banana and calla where the parallel veins run laterally from the midrib. Parallel-veined leaves occur on plants that are part of the monocotyledon group of flowering plants.
Net-veined, also called reticulate-veined, leaves have veins that branch from the main rib(s) and then subdivide into finer veinlets, which then unite in a complicated network. This system of enmeshed veins gives the leaf more resistance to tearing than most parallel-veined leaves. Net venation may be either pinnate or palmate. In pinnate venation, the veins extend laterally from the midrib to the edge, as in apple, cherry, peach, beech, and elm. Palmate venation occurs in grape and maple leaves where the principal veins extend outward, like the ribs of a fan, from the petiole near the base of the leaf blade. Net-veined leaves occur on dicots.

Dichotomous venation is rare and characterized by forked venation. Each vein divides into smaller veins, creating a “Y” pattern. Gingko (Gingko biloba) exhibits dichotomous venation.

Leaf Shapes

The following terms describe common shapes of leaves and/or leaflets (Fig. 2-18):

- **Linear**: narrow, several times longer than wide, and of approximately the same width throughout
- **Lanceolate**: longer than wide and tapering toward the apex and base
- **Ovate**: egg-shaped with the broadest part of the blade below the middle and tapering toward the apex
- **Obovate**: egg-shaped with broadest part of the blade near the apex
- **Cordate or heart-shaped**: broadly ovate and tapering to acute apex, with the base turning in and forming a notch where the petiole is attached
- **Peltate**: shield-shaped, having the petiole attached beneath the base of the leaf
- **Hastate**: arrowhead-shaped, basal lobes extend at nearly right angles to the midrib
- **Elliptical**: about two or three times long as wide and tapering to acute or rounded apex and base

Fig. 2-17. Leaf venation.

Fig. 2-18. Leaf shapes.
Leaf Margins

The type of margin is especially useful for identifying certain varieties of fruit plants. The following are the most common forms of leaf margins (Fig. 2-20):

- **Entire**: a smooth edge with no teeth or notches
- **Crenate**: having rounded teeth
- **Serrate**: having small, sharp teeth pointing toward the apex
- **Serrulate**: finely serrated
- **Doubly serrate**: having fine serrations within larger serrations
- **Undulate**: having a pronounced sinuous or wavy margin
- **Lobed**: incisions extending less than halfway to the midrib
- **Incised**: margin cut into sharp, deep, irregular teeth or incisions

Specialized Leaves

Distinct types of leaves may be found on certain plants. Leaves referred to as foliage are the most common and conspicuous, and serve as the centers of photosynthetic activity. Scale leaves, or cataphylls, are found on rhizomes; they are also small, leathery, protective leaves that enclose and protect the bud. Seed leaves, or cotyledons, are leaf-like structures found on the embryonic plant and commonly serve as storage organs. Spines and tendrils, as found on barberry and pea, are specialized, modified leaves that protect the plant or assist in supporting the stems. Storage leaves, such as those found in bulbous plants and succulents, serve to store food. Other specialized leaves include bracts, which are often brightly colored. The showy structures on dogwood and poinsettias are bracts, not petals (Fig. 2-21).
Leaves as Food

Leaf blades are the principal edible portion of some horticultural crops, including chives, collard greens, dandelion, endive, kale, leaf lettuce, mustard, parsley, spinach, and Swiss chard. The edible part of leek, onion, and Florence fennel is a cluster of fleshy leaf bases. The leaf petiole is the edible part of celery and rhubarb. In plants like Brussels sprouts, cabbage, and head lettuce, the leaves—in the form of a large naked bud—are the edible product.

Buds

A bud is an undeveloped shoot from which embryonic leaves or flower parts emerge. The buds of trees and shrubs growing in temperate zones typically develop an outer layer of small, leathery bud scales to protect the apical meristem. When growth resumes after dormancy, the bud scales fall off, leaving a ring of bud scale scars around the twig (Fig. 2-22).

Buds of many woody and perennial plants require exposure to a certain number of days below a critical temperature (rest) before they will resume growth in the spring. This period varies for different plants. The flower buds of Forsythia require a relatively short rest period and will grow at the first sign of warm weather. Many peach cultivars require from 700 to 1,000 hours of temperatures below 45°F (7°C) before they will resume growth. During rest, dormant buds can withstand very low temperatures, but after the rest period is satisfied, buds become more susceptible to weather and can be damaged easily by cold temperatures or frost.

Leaf buds are often less plump and more pointed than flower buds.

A flower bud is composed of a short stem with embryonic flower parts. In some cases, the flower buds of plants that produce economically important fruit crops are called
basal portions of the bracts of the flower bud are eaten along with the solid stem portion of the bud. Broccoli is the most important horticultural plant in which edible flower buds are consumed. In this case, portions of the stem and small leaves associated with the flower buds are eaten.

**Flowers**

The flower, often the most colorful plant part, is a structure distinctive to angiosperms (flowering plants). Fragrance and color are devices to attract pollinators, insects, and other animals that play an important role in reproduction.

Knowledge of flowers and their parts is essential for anyone interested in plant identification (Fig. 2-23). A flower contains the male pollen and/or the female ovule plus accessory parts such as petals, sepals, and nectar glands.

_**Sepals**_ are the outermost series of floral parts. They are the usually green, leaf-like structures at the base of a flower, collectively forming the calyx. Petals are the attractive, colorful parts of the flower. The number of petals on a flower is often used in identifying plant families and genera. The petals as a unit are called the corolla. Flowers of most plants typically have sepals and/or petals in numbers of four, five, or multiples thereof. Monocots typically have these floral parts in threes or multiples of three.

_The pistil is the female reproductive part. It is often shaped like a bowling pin and located in the center of the flower. It consists of the stigma, style, and ovary. The stigma is located at the top and connected by the style to the ovary. The ovary contains the ovules. After the ovule is fertilized, it develops into a seed._

_The stamen is the male reproductive organ. It consists of a pair of pollen sacs, the anther, and a long supporting stalk, called the filament. The filament holds the anther in position so the pollen it contains can be dispersed by wind or carried to the stigma by insects or birds._

**Location on Stem**

Buds are named for their position on the stem surface. Terminal buds are located at the apex or tip of a stem. Lateral buds are located on the sides of the stem at the nodes. Lateral buds typically arise in the axis of a leaf and are called axillary buds. In a few instances, more than one bud is formed. Adventitious buds are those that arise at sites other than from a terminal or axillary position on the stem. They may develop from the internode of the stem, at the edge of a leaf blade, from callus tissue at the cut end of a stem or root, or laterally from the roots of plants.

**Buds as Food**

Enlarged buds or parts of buds form the edible portions of some horticultural crops. Cabbage and head lettuce are examples of unusually large terminal buds. Succulent axillary buds of Brussels sprouts become the edible part of this plant. In the case of globe artichoke, the fleshy fruit buds. This terminology should not be used. Although flowers have the potential to develop into fruits, they may be prevented by adverse weather, lack of pollination, or other unfavorable circumstances. The structure is a flower bud and should be so designated since it may never set fruit.
Ovary Position

The ovary can be in different positions, as explained below (Fig. 2-24).

Superior Ovary

A superior ovary lies above the attachment of other floral parts (stamens, petals, and sepals). A superior ovary is found in types of fleshy fruits such as berries and drupes. With a superior ovary, you can see the remains of the calyx attached to the stem.

Half-inferior Ovary

A half-inferior ovary is embedded or surrounded by the receptacle. More specifically, a half-inferior ovary has nearly equal portions of ovary above and below the insertion point.

Inferior Ovary

An inferior ovary lies below the attachment of other floral parts. Some examples of flowers with inferior ovaries are orchids and fuchsia.

Types of Flower

If a flower has stamens, pistils, petals, and sepals, it is called a complete flower. If one of these parts is missing, the flower is called incomplete. If a flower contains functional stamens and pistils, it is called a perfect flower. Stamens and pistils, considered the essential parts of a flower, are involved in the seed-producing process. If either part is lacking, the flower is “imperfect” (Fig. 2-25). Pistillate (female) flowers are those possessing a functional pistil(s) but lacking stamens. Staminate (male) flowers contain stamens but no pistils.

Some plants bear only male flowers (staminate plants) or only female flowers (pistillate plants). Species in which the sexes are separated into staminate and pistillate plants are called dioecious. Most holly trees, for example, are either male or female. To get berries, it is necessary to have a male tree near a female tree to provide pollen. Monocious plants have separate male and female flowers on the same plant (Fig. 2-26). Corn plants and oak trees are examples. Some plants bear only male flowers at the beginning of the growing season but later develop both sexes, as in cucumber and squash.

Inflorescences

When plants bear only one flower per stem, such flowers are called solitary. Other
plants produce an inflorescence, a cluster of flowers. Most inflorescences may be classified into two groups: racemose (or indeterminate) and cymose (or determinate) (Fig. 2-27).

In the racemose group, the florets (individual flowers in an inflorescence) bloom from the bottom of the stem and progress toward the top. Racemose inflorescences include the following:

- **Spike**: many stemless florets attached to an elongated flower stem (peduncle), e.g., mullein, cattails, lady's tresses orchid, and blazing star (Fig. 2-28)
- **Raceme**: similar to a spike except that the florets are borne on small stems attached to the peduncle, e.g., snapdragon, foxglove, salvia, and baptisia (Fig. 2-29)
- **Panicle**: the main stem is highly branched and may support spikes, racemes, corymbs, or umbels, e.g., astilbe and goatsbeard
- **Corymb**: made up of florets whose stalks, pedicels, are arranged at random along the peduncle in such a way that the florets create a flat, round top, e.g., yarrow, ageratum, and candytuft (Fig. 2-30)
- **Umbel**: similar to a corymb except that the pedicels all arise from one point on the peduncle, e.g., dill, Queen Anne's lace, allium, and agapanthus (Figs. 2-31 and 2-32)
- **Head/composite**: composed of numerous stemless florets, e.g., daisies, asters, and coneflowers (Figs. 2-33 and 2-34)

In the cymose group, the florets bloom from the center of the inflorescence and progress outward. Cymose inflorescences include:

- **Simple cyme**: flat-topped inflorescence in which the central flowers open before the lateral florets, e.g., streptocarpus and sinningia (Fig. 2-35)
- **Scorpioid cyme**: florets alternate with one another along the peduncle, e.g., tomato and potato
Fig. 2-28. Spike (blazing star).
Fig. 2-29. Raceme (sage).
Fig. 2-30. Corymb (ageratum).
Fig. 2-31. Simple umbel (allium).
Fig. 2-32. Compound umbel (false Queen Anne’s lace).
Fig. 2-33. Composite flower (gerbera daisy).
Fig. 2-34. Composite ray flower.
Fig. 2-35. Simple cyme (cape primrose).
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