PART 1

HORTICULTURAL BIOLOGY
Horticulture is a field of study in which career opportunities abound; in fact, recent indications from several sources suggest that there are many career openings available for graduates of baccalaureate programs in horticulture. Entrepreneurial opportunities include owning and managing horticulture businesses such as orchards and vegetable farms, nurseries, floral shops, and landscape businesses. A strong need exists for professional horticulturists to fill positions in public horticulture, such as golf course superintendents and managers of parks, public gardens and arboreta. Consider also the myriad opportunities in communicating horticultural information to the public—writing for the various newspapers, journals, and television and radio programs—and in the pursuit of careers in teaching, extension, and horticultural sales.

Challenging career opportunities in research are clamoring for attention. The first practical applications of biotechnology were developed and commercialized with horticultural plants by horticultural scientists, and rapid growth in this exciting arena of opportunity will occur as the 21st century unfolds. Robots and computers, genetic engineering, and basic science—all will come together as horticultural scientists lead the way toward a better future for this planet’s burgeoning population.
Just what is this field called Horticulture? It's the science and art of producing nutritious food for the body—fruit, nut, and vegetable crops—and beautiful food for the soul—flowers and ornamental plants, landscapes, and lawns. In short, horticulture impacts us all every day, day in and day out (Figure 1-1). Indeed, it would be nearly impossible to go through a single day without horticulture influencing our lives. Try to picture a day in the life of an average citizen without horticulture—what would it mean?

- No orange juice for breakfast, no strawberries on your cereal, no blueberry muffins.
- No flowers on the table, no Monet or van Gogh prints framed on the wall.
- No shrubbery or lawn to enhance the aesthetics and value of your home (did you know that landscaping enhances the value of a home by as much as 20%?).
- No fruits or vegetables to enrich your diet (diseases such as scurvy and nightblindness would be rampant because of a lack of vitamins C and A).
- No alternatives to cereals as sources of the basic needs for calories and protein, since potatoes, cassava, beans, and peas would be unavailable.
- No golf courses for your leisure time, no sports-turfs for football, soccer, croquet, and lawn tennis.
- No coffee breaks, no chocolate bars, no afternoon tea!

HORTICULTURE DEFINED

The word horticulture was first used in the 1600s. It is derived from two Latin words: hortus, which means garden, and cultura, which means cultivation. Therefore, in its strictest sense, horticulture means “cultivated garden,” or more commonly, “culture of garden plants.”

Horticulture is a branch of agriculture that is different from agronomy and forestry for the following reasons: (1) In general, horticulture requires more intensive management and higher labor inputs than the other branches. In horticulture the individual plant is important. For example, the street or landscape tree has a much greater value than...
a single tree in the middle of the forest, and that street or landscape tree receives much more intensive care, such as pruning and fertilization. Comparison of a horticultural crop such as strawberries and an agronomic crop such as wheat is also appropriate. Each strawberry has value, unlike the individual plant in a field of wheat. It is not uncommon to see a farmer back his or her truck onto the field of wheat so that a few hundred plants are crushed. That would be inconceivable on a field of strawberries because each strawberry plant is too valuable. (2) Horticulture offers a higher gross return per unit area per unit time. A good greenhouse grower can obtain total sales of over $20.00 per square foot ($215/square meter) of bench space per year. This profit level can be accomplished through intensity of production and careful scheduling of crops to take advantage of the entire 365-day year. If that grower has about an acre (0.4 hectare) of production, this translates to between $800,000 and $1,000,000 worth of sales a year. Certainly that is intensive production and a very high value crop!

The purpose for growing the crop often determines into what commodity area or field of study it is placed. For example, Kentucky bluegrass grown as a forage or pasture crop is considered an agronomic crop, whereas Kentucky bluegrass in a lawn is considered horticultural. A maple grown for its wood is considered under forestry, whereas a maple grown as a shade tree is considered a horticultural plant. Custom and tradition of a geographical area or a specific state will often determine the commodity area into which a particular crop is placed. However, in this textbook we will consider most commodities that require intensive management under the broad umbrella of horticulture.

Within horticulture there are several branches, divisions, or topic areas. These include:

**OLECULTURE** The growing and study of vegetables.

**POMOLOGY** The growing and study of fruits and nuts (from Pomona the Roman goddess of fruit trees).

**VITICULTURE** The growing and study of grapes or vines. Vitis is Latin for vine, hence viticulture is vine culture. Viticulture may be included under pomology.

**FLORICULTURE** The growing and study of flowers (from Flora the Roman goddess of flowers). Floral design and production of indoor foliage plants are usually included under floriculture.

**GREENHOUSE MANAGEMENT** The growing and study of plants in greenhouses. The principles of greenhouse management are also employed in other controlled-environment growing systems.

**TURFGRASS MANAGEMENT** The growing and study of turfgrasses. This includes home, municipal and commercial lawns; sports turf maintenance; highway rights-of-way; and seed and sod production.

**NURSERY MANAGEMENT** The growing and study of trees and shrubs that are produced primarily for landscape purposes.

**ARBORICULTURE** The growing and study of trees (from arbor means tree in Latin, so “arboriculture” means tree culture; it is termed silviculture in forestry). Arboriculture is essentially synonymous with urban forestry.

**LANDSCAPE HORTICULTURE** The application of design and horticultural principles to the placement and care of plants in the landscape. This term implies the close tie between horticulture and landscape architecture.

**INTERIORSCAPING** The application of design and horticultural principles to placement and care of plants in indoor environments.

**HORTICULTURAL THERAPY** The use of horticultural plants and methods as therapeutic tools with disabled and disadvantaged people.
There often is a distinction between pure, or basic, science and applied science. In the past, horticulture has sometimes been called “applied botany.” Horticulture applies principles of many other pure and applied sciences. In order to understand how to successfully grow a horticultural crop, for example, we apply the science of botany, including the study of plant structure—morphology and anatomy. We also use plant physiology, another division of botany, that explains how plants function. A horticulturist also needs a knowledge of chemistry, because chemical reactions are important for understanding why we use particular cultural practices, such as fertilizer application and specific pest control practices. Biochemistry helps the horticulturist to explain metabolic reactions within and among cells to understand how plants will respond to external stimuli. We use mathematics in calculating spray rates and for a host of other computations; we use physics to understand light and plant structure; we use plant pathology to understand and cure or prevent plant diseases; we use a knowledge of soil science because plants are commonly grown in the soil; and we use a knowledge of genetics because the genes in a plant interact with the environment to control the makeup of the organism.

Is horticulture a science or an art? This is an age-old question and horticulture is undoubtedly both; one may employ the science but there is an art involved in successfully cultivating plants or placing them in a landscape design. This is where practical experience will be helpful. This concept may be better understood with an analogy between the art of horticulture and piano playing. One can know technically how a piano functions and attend concerts for years, but that will probably not prepare one to perform like Beethoven. Grafting is an example of combining the art and science of horticulture. One can understand the mechanics of grafting as well as the biology (anatomy of cells at the graft union), but it is only through practice that the art is mastered and a high degree of success is achieved. Seldom do all horticulturists agree on everything relating to plants. Surprisingly, however, two scientists can both be correct when they differ in opinion about a cultural practice or its application. This certainly suggests that our applied science of horticulture is also an art form.

**HISTORY OF HORTICULTURE**

Prehistoric people were primarily hunters and gatherers; that is, they took what their environment provided for them but did not attempt to modify what nature provided. These early gatherers simply collected fruits, seeds, and nuts that they found to be edible and readily available in their immediate surroundings. Subsequently, primitive people began to study plants in an early attempt to control their environment and began to adapt the environment to their advantage. First studies of plants considered practical questions.

- Is it edible? Poisonous?
- Does eating it modify well-being?
- Does it taste good?
- Can it be used to keep me warm? As fuel? As clothing?
- Is it useful to combat pain? Disease?

People first began cultivating edible plants in the Neolithic Age, about 7000 to 10,000 years ago. By 3000 B.C., which is approximately 5000 years ago, land preparation, irrigation, and pruning were all practiced in Egypt. People east of Egypt, in Mesopotamia, Babylonia, and Assyria, made irrigation canals lined with burnt brick with sealed asphalt joints. This extensive system helped keep 10,000 square miles under cultivation, which in 1800 B.C. fed over 15,000,000 people. These societies cultivated many ornamental, medicinal, and orchard species, including roses, figs, dates, grapes, and olives.
As early people’s curiosity increased, they began to seek answers to questions about plants. How do they grow? How do they reproduce? How are they constructed? How are they nourished? How are they related to one another? How are various traits passed from one generation to the next?

Much of the early information about plants was related to agricultural and medicinal uses. Such information was often passed on by word of mouth, but various ancient records exist. Early manuscripts, hieroglyphics, and pictures painted on caves and tombs or carved in stone give clues to the early knowledge about plants. Most commonly, the plants depicted or described were horticultural plants, such as the lotus and other flowers seen in paintings from ancient Egyptian tombs.

Most information was of a practical nature, pertaining to various cultural practices, selection of the best clones, irrigation styles, and harvest methodologies. However, some discoveries of a scientific nature were emerging in this period, including an understanding of sexuality in date palm and recognition of the need for pollination for fruit development (noted in Mediterranean cultures). The Chinese had developed highly advanced cultural practices for tea, oranges, and ephedra, a source of a medication for relief of nasal congestion.

Concomitantly, early civilizations in the Americas were developing crops destined to hold great significance in the world of horticulture. The Pre-Incas of Peru are thought to be the first to cultivate maize (corn). Records indicate that they were growing corn more than 5000 years ago. Potatoes, sweet potatoes, squashes, several types of beans, tomatoes, peppers, avocados, cocoa (cacao, the source of chocolate), and many other important species were cultivated by the various aboriginal American peoples. Objectives again were primarily to produce food, clothing, shelter, beverages, fuel, and medicines.

The use of plant products as drugs or for medicinal purposes eventually gave rise to specialists who were drug sellers, the forerunners of both physicians and plant scientists. The early Greek drug sellers, as they strove to learn more about medicinal values of plants, also made discoveries related to plant structure and function and found apparent relationships among plants.

One could argue that Theophrastus was one of the first scientific horticulturists. A student of Plato and Aristotle, Theophrastus wrote books entitled History of Plants and The Causes of Plants. In his History of Plants, he described morphology of roots, flowers, leaves, and other structures and also gave details of anatomical features such as bark, pith, fibers, and vessels. The relationship of weather to soils and agricultural practices, the importance of seeds, the value of grafting, the tastes and fragrances of plants, and the death of plants were subjects he treated in The Causes of Plants. Early in the Christian era, Dioscorides, following the lead of Theophrastus, wrote a valuable treatise on the medicinal uses of plants. In this book Dioscorides also proposed some advanced ideas about the relationships of plants, primarily the composite, mint, and legume families.

Relatively little advancement of plant science (or any other science, for that matter) occurred in the Middle Ages. However, Arabian cultures established botanical gardens, primarily for the study of medicinal plants, in the period between A.D. 800 and 1300. Also during this period, much of the scientific advances of antiquity and Greek and Roman cultures were preserved in the monasteries and convents of medieval Europe. As the Middle Ages came to a close, the Renaissance Period signalled a re-birth of energetic attention to scientific discovery. Taxonomy, morphology, and anatomy began to expand as branches of botany, with many of the studies involving horticultural species. English anatomists Robert Hooke, Nathaniel Grew and the Italian scientist Marcello Malpighi made significant contributions during this period.
As civilization and agriculture continued to advance, more and more plants were recognized as being useful to people, and a system of plant classification became necessary. During his lifetime, from 1707 to 1778, the Swedish botanist, Linnaeus developed a binomial classification scheme for plants based on their sexual or flowering systems, which is the basis of all modern plant classification systems today. Linnaeus's system built upon the information presented in the works of the Greek drug purveyors and writers (especially Dioscorides) and other emerging plant scientists. For more information on this subject see Chapter 2.

As the Renaissance period evolved and developed, the budding flower of horticulture burst forth. Formal gardens of various sorts were established in all parts of Europe; those at Versailles and Belvedere in Vienna exemplify some of the best of this art. Meanwhile, systematic improvements were being made in fruit, nut, and vegetable production throughout most of Europe. Flowers, vegetables, fruits, and other plants from “the colonies”—the Americas, Africa, and Australia—became subjects of much attention and in some cases, (e.g., potato, tomato), became mainstays of the diet in many European countries.

**Horticulture in America**

When European colonists arrived in the Americas, they naturally brought seeds, cuttings, and plants of familiar horticultural and agricultural species with them. Orchards and other horticultural plantings were established, employing both imported and native species. Many early Americans, including George Washington and Thomas Jefferson, experimented with the cultivation of a wide range of species. Indeed, Jefferson, a noted wine enthusiast, made exhaustive attempts to establish vineyards in Virginia for the production of wine grapes.

Horticulture in the United States received new stimulus following the creation of land grant universities by the Morrill Act of 1862. These institutions encouraged growth of all agricultural knowledge, with horticulture emerging as an early beneficiary of educational opportunities.

In the latter part of the nineteenth century, Liberty Hyde Bailey began a career destined to earn him the accolade “Father of American Horticulture” (Figure 1-2). Born in 1858 in South Haven, Michigan, Bailey graduated in 1882 from the Michigan Agricultural College (now Michigan State University), and then studied under Asa Gray at Harvard University from 1883 to 1885. He became Professor of Horticulture and Landscape Gardening and Superintendent of the Horticulture Department at Michigan Agricultural College in 1885, where he remained until Cornell University, Ithaca, NY, lured him away in 1888 to become Professor of General and Experimental Horticulture. He remained at Cornell in various capacities until his retirement in 1913.

Bailey was a prodigious writer. He authored a great number of books containing much horticultural information, including *Hortus*, a taxonomic index of horticultural plants. He also wrote his famous *Cyclopedia of Horticulture*, which contains cultural as well as taxonomic information. He helped found the first horticulture department distinct from a botany program in the United States. Bailey’s philosophy was to live on the “25-year plan”: devoting the first 25 years of his life to his education, the second 25 years to gainful employment and public services, and the last 25 years of his life to retirement, doing as he pleased. Fortunately for horticulture, the last 25 years extended to more than 40, and were a period of intense activity—of writing, editing, plant exploration and description, and the establishment of the Bailey Hortorium, a tremendous contribution to the field of horticulture. *Hortorium* was a word coined by Bailey to be a repository for “things of the garden,” including his vast collection of plant specimens dating back to his days at Michigan Agricultural College. Who knows how extensive his contributions might have become had he not fallen and broken his leg in a New York bank in December, 1949, for in his pocket he had airline tickets to tropical Africa to collect more horticultural plants. Although his injury confined him to his home, he continued writing and editing, completing a book on bellflowers in the year preceding his death, in December, 1954.

Liberty Hyde Bailey, along with several other leading horticulturists of the day, was instrumental in founding the American Society for Horticultural Science (ASHS) in 1903. Many states had established State Horticultural Societies in the early 1800s, but these societies focused primarily on the utilitarian matters of culture, orchard establishment, fertilizer practices, and so on. The founding of ASHS finally gave the field of horticulture a national organization and a solid scientific base. Since that time, many important developments have revolutionized horticulture. The following paragraphs briefly describe some of the most important achievements for the horticultural industry.

**NEW CULTIVARS.** Breeders have developed new cultivars with improved quality, greater yield potential, improved growth characteristics, increased pest resistance, and greater tolerance to environmental extremes (see Figure 1-3). Genetic engineering and other modern technologies employed for cultivar development and improvement are covered in Chapter 4.

![Figure 1-3. 'Sugar Snap' pea, an example of an eminently successful new cultivar.](image_url)
PLANT-WATER RELATIONSHIPS. We have a better understanding of irrigation (Figure 1-4) and plant-water relationships, and of new application methods such as trickle or drip irrigation. Intermittent mist and fog systems have aided plant propagation. Improvements also have been made in hydroponic plant production, which still remains a minor, but important, horticultural industry.

TEMPERATURE. Our knowledge of plant responses to temperature has expanded phenomenally. Bottom heat is now used with many crops to increase their growth. We now more fully comprehend the phenomenon of vernalization, which is the direct effect of low temperature on flower initiation. Understanding the relationship between temperature and dormancy has enabled commercial producers to schedule their crops more effectively. New developments in temperature and energy management have helped horticulturists to use fuel reserves more wisely (Figure 1-5). Recent advances in the adjustment of night and day temperatures, for example, enable the grower to increase the production efficiency of greenhouse crops. We also now have a much better understanding of stresses caused by extremes of temperature.

LIGHT. We now have a better understanding of how light influences the all-important process, photosynthesis, and how light can trigger or delay flowering. Many crops can therefore be programmed to flower in a timely fashion or they can be managed to avoid flowering when no flowers are desired (Figure 1-6). Supplemental lighting can be utilized to increase yields of some species during periods of low light. Because of our knowledge of light, we now have successful indoor gardening and interiorscaping to beautify and enhance large public areas such as shopping malls.

PLANT NUTRITION. Many new and different types of fertilizers have been developed in recent years. Formulations are now available for varying needs, including different rates of availability to plants. However, it wasn’t until about 1920 that trace element fertilization began to be better understood. Great strides also have been made.
made in our comprehension of the fixation of atmospheric nitrogen within plant roots by microorganisms (symbiosis).

THE RHIZOSPHERE (ROOT ZONE). Properties of soils, the value of organic matter, and interaction among soil components, soil microflora, and microfauna have led to advances in commercial and home horticulture. Increased container plant production has been facilitated by the development of improved pots, flats, multipacks, and starter blocks. Root aeration has been improved by the development and use of peat-lite media, bark mixes, and other soil-less mixes (Figure 1-7). Our knowledge of the importance of organic matter in field soils has improved along with erosion control practices such as reduced tillage. Mulches have been developed to control soil moisture, temperature, erosion, and weeds.

INTEGRATED PEST MANAGEMENT (IPM). The management and control of insects, diseases, and weeds involves a program utilizing genetic pest resistance within plants, a knowledge of pests’ life cycles and epidemiology, crop scouting reports, growing plants under appropriate environmental conditions, and the proper use of pesticides. This integrated approach can emphasize the control or elimination of plant pests and minimize negative impact on the environment. The necessity for pest control has led to the growth of a large agrichemical industry that conducts research and markets a wide variety of products that aid in effective pest control. The strategy of integrated pest management has led to substantially increased yields and has given the public a much higher quality of agricultural products (Figure 1-8).

PLANT GROWTH REGULATORS. Horticulturists and plant physiologists have gained a better understanding of the nature of growth regulation in plants. This knowledge has led to the development of chemicals that enable growers to control plant growth responses more efficiently and thus to improve crops or adapt them for new uses. Plant growth substances have revolutionized the propagation of horticultural plants by increasing rooting of cuttings and facilitating effective application of tissue culture techniques. Growth regulators are also used to control plant height, plant branching, flowering, fruit set, fruit size, and fruit and leaf drop, along with many other responses (Figure 1-9).

**FIGURE 1-7.** Soilless mixes such as peat-vermiculite combinations have become popular for growing transplants and pot plants.

**FIGURE 1-8.** Encouraging natural predators can be an important part of an integrated pest management (IPM) program, as shown by this parasitized cutworm larva.
HORTICULTURAL ENGINEERING AND MECHANIZATION. Engineering advances in the field of horticulture have been tremendous. Controlled-environment growing facilities including greenhouses, have been greatly improved in recent years. Labor saving machinery is now available for soil preparation, cultivation, spraying, fertilizer application, mechanized seeding, transplanting, and harvesting. Aerial applications of pesticides and even remote sensing of stresses and other factors by satellites (global information systems, GIS) have become practices of importance in many areas of horticulture (Figure 1-10).

POSTHARVEST FACTORS. Expanded knowledge of the postharvest physiology of crops has led to longer shelf life of our horticultural products, such as fruits, vegetables, plants and cut flowers. Controlled-atmosphere cold storage, for example, enables good-quality apples to be available many months after harvest. Longevity of cut flowers has been enhanced so that a bouquet may provide beauty for two weeks or more, instead of only for a few days. Transportation has been revolutionized. Refrigerated trucks, airplanes, and railroad cars speed improved fresh fruits, vegetables, flowers, and plants to the consumer for year-round enjoyment (Figure 1-11).

FIGURE 1-9. Growth retardant chemicals are often used to produce more aesthetically pleasing plants, such as these poinsettias. The plant at right was treated with paclobutrazol, a chemical growth retardant. 
*Photo courtesy Kenneth Sanderson, Auburn University, Auburn Alabama.*

FIGURE 1-10. Computers have become a valuable tool for horticultural enterprises. The personal computer (above) may be employed in a variety of tasks; other equipment (right) may be used to monitor and control environmental factors in a greenhouse.

FIGURE 1-11. Modern refrigerated transport speeds fresh produce to market at the peak of quality.