CHAPTER 8

Flowers, Fruits, and Seeds

OVERVIEW

The structure, parts, and some modifications of flowers are described in this chapter. Dicots and monocots are briefly compared. The nature and development of fruits are discussed next, and fruit structure and parthenocarpy are described. A listing and discussion of types of dry and fleshy fruits follows, and then fruit and seed dispersal are explored. An examination of seed structure and germination and some observations on dormancy and longevity of seeds, stratification, and vivipary conclude the chapter.

Some Learning Goals

1. Know the parts of a typical flower and the function of each part.
2. Learn the features that distinguish monocots from dicots.
3. Understand the distinction between a fruit and a vegetable.
4. Know the regions of mature fruits.
5. Learn five types of fleshy and dry fruits and know how simple, aggregate, and multiple fruits are derived from the flowers.
6. Learn the adaptations of fruits and seeds to the agents by which they are dispersed.
7. Diagram and label a mature dicot seed (e.g., bean) and a monocot seed (e.g., corn) in section to show the parts and regions.
8. Understand the changes that occur when a seed germinates and note the environmental conditions essential to germination.
9. Know the types of factors that control dormancy. Learn how dormancy may be broken both naturally and artificially.

Note to the Reader:

Although the numbers of bacteria, algae, and fungi are much greater than those of flowering plants, much of this text is devoted to various aspects of flowering plants, partly because flowering plants are more abundant than other true plants and more important to humanity than all the other kinds of plants. In early editions of this book, most basic features of flowers, fruits, and seeds were discussed in a single chapter. This followed a progressive examination of members of the Plant Kingdom, beginning with the simplest forms, so that the reader could appreciate how flowering plants developed and became the most advanced and complex of all plants. Some shorter courses, however, do not cover certain reproductive and evolutionary aspects of the Plant Kingdom, and instructors differ in their assessment of the relative importance of such matters in a short course.

In recognition of this dilemma, the original single chapter is represented in this edition by Chapters 8 and 23. Chapter 8 emphasizes form and structure of flowers, fruits, and seeds, with brief reference to reproduction. Chapter 23 covers more details of the life cycle and evolution of flowering plants. Even if your course does not include Chapter 23 in the curriculum, it is recommended that you read it as an adjunct to Chapter 8.

number of years ago, an Australian farmer, while plowing a field, glanced back and was startled to see what looked like flowers being tossed to the surface of the furrows. He climbed off his tractor to take a closer look and found that what he saw were, indeed, flowers. Furthermore, the plants to which the flowers were attached were pale and had no chlorophyll. He reported his find to a university, where botanists determined that the farmer had stumbled upon the first known underground flowering plant. The plant proved to be an orchid that lived on organic matter in the soil and was pollinated by tiny flies that gained access to the below-ground flowers via mud cracks that developed in the dry season (Fig. 8.1).

The underground-flowering orchid is only one of about 250,000 known species of flowering plants. Other unknown numbers of undescribed species grow in remote areas, particularly in the tropics. The flowering plants are vital to humanity, providing countless useful products, with just 11 species—10 of them members of the Grass Family (Poaceae)—furnishing 80% of the world's food. This subject is discussed in more detail in Chapter 24.

The flowers themselves range in size from the minute flowers of the duckweed, *Wolffia columbiana*, whose entire speck of a plant body is only 0.5 to 0.7 millimeter (0.02 to 0.03 inch) wide, with flowers little more than 0.1 millimeter long, to the enormous *Rafflesia* flowers (Fig. 8.2A) of Indonesia that are up to 1 meter (3 feet 3 inches) in diameter and may weigh 9 kilograms (20 pounds) each.

A unique species known as the corpse flower (*Amor-phophallus titanum*) produces an interesting bloom (also called an *inflorescence*, discussed later in this chapter) that deserves mention for its large size and offensive odor. The bloom itself (Fig. 8.2B), which can be over 2 meters (6 feet, 6 inches) tall, protects the smaller flowers within and is derived from an underground corm that can remain hidden for many years. Carrion beetles are attracted to an odor of rotting flesh emitted by the bloom, and presumably act as pollinators when they travel from one flower to the next. The rarity and impressive display of corpse flower blooms (less than 100 in recorded history) inspire curious spectators to visit and enjoy botanical gardens around the world.

Flowers may be any color or combination of colors of the rainbow, as well as black or white; they may have virtually any texture, from filmy and transparent to thick and leathery, spongy to sticky, hairy, prickly, or even dewy wet to the touch. Flowers of many trees, shrubs, and garden weeds are quite inconspicuous and lack odor (Fig. 8.3), but other flowers are strikingly beautiful, particularly when examined with a dissecting microscope. Their fragrances, which can range from exhilarating to seductive or even putrid, are the basis of international perfume and pet-repellent industries.

Flowering plant habitats are as varied as their form. Besides the underground habitat mentioned in the chapter introduction, some flowering plants (*epiphytes*) go through their life cycles dangling from wires or other plants (Fig. 8.4). They also occur in both fresh and salt water, in the cracks and crevices of rocks, in deserts and jungles, in frigid arctic regions, and in areas where the temperatures regularly soar to 45°C (113°F) in the shade. In fact, they can be found almost anywhere they receive their basic needs of light, moisture, and a minimal supply of minerals. One species of chickweed survives at an altitude of 6,135 meters (over 20,000 feet) in the Himalaya Mountains, and fumitory plants in the same area flower even when the night temperatures plummet to –18°C (0°F).

Flowering plants can go from the germination of a seed to a mature plant producing new seeds in less than a month, or the process may take as long as 150 years. In **annuals,** the cycle is completed in a single season and ends with the death of the parent plant. **Biennials** take two growing seasons to complete the cycle; **perennials,** however, may take several to many growing seasons to go from a germinated seed to a plant producing new seeds, although many species that aren't annuals do produce seeds during their first growing season. Perennials may also produce flowers on new growth that dies back each winter, while other parts of the plant may persist indefinitely.

Flowering plants have been placed in two major classes, the *Magnoliopsida* and *Liliopsida*, previously known as the *Dicotyledonae* and the *Monocotyledonae.* Despite the revised class names, the two groups are still commonly referred to as **dicots** and **monocots.** Members of the two classes are usually distinguished from one another on the basis of features listed in Table 8.1.

DIFFERENCES BETWEEN DICOTS AND MONOCOTS

Slightly less than three-fourths of all flowering plant species are dicots. Dicots include many annual plants and virtually all flowering trees and shrubs. Monocots, which are primarily herbaceous, are believed to have evolved from primitive dicots. They include species that produce bulbs (e.g., lilies), grasses and related plants, orchids, irises, and palms. Palms, like other monocots, do not have a vascular cambium but become large through a *primary thickening* process of cells that occurs just below the apical meristem. Note the recent revisions of our understanding of dicots discussed in Chapter 16.

STRUCTURE OF FLOWERS

Regardless of form, all flowers share certain basic features. A typical flower develops several different parts, each with its own function (Fig. 8.5). Each flower, which begins as an embryonic *primordium* that develops into a *bud* (discussed in Chapter 6), occurs as a specialized branch at the tip of a stalk called a **peduncle,** which may in some instances have branchlets of smaller stalks called **pedicels.** A peduncle or pedicel swells at its tip into a small pad known as a **receptacle.** The other parts of the flower, some of which are in *whorls***,** are attached to the receptacle (a whorl consists of three or more plant parts—such as leaves—encircling another plant part—such as a twig—at the same point on an axis).

The outermost whorl typically consists of three to five small, usually green, somewhat leaflike **sepals.** The sepals of a flower, which are collectively referred to as the **calyx,** may, in some flowers, be fused together. In many species, the calyx protects the flower while it is in the bud.

The next whorl of flower parts consists of three to many **petals;** the petals collectively are known as the **corolla.** Showy corollas attract pollinators, such as bees, moths, or birds. Bees, which can see in ultraviolet light, detect in some corollas special markings invisible to humans. The petals are distinct separate units in peach flowers, but in some flowers (e.g., petunias), the petals are fused together into a single, flared, trumpetlike sheet of tissue (Fig. 8.6). The corolla may not be showy or conspicuous in many tree and weed species and is often missing altogether or highly modified in wind-pollinated plants such as grasses. The calyx and the corolla together are referred to as the **perianth.** *Bracts* are specialized leaves that may be as colorful as petals and can attract pollinators the way petals do; they are discussed in Chapter 7.

Several to many **stamens** are attached to the receptacle around the base of the often greenish **pistil** in the center of the flower. Each stamen consists of a semi-rigid but otherwise usually slender **filament** with a sac called an **anther** at the top. The development and dissemination of **pollen grains** in anthers is described in Chapter 23. In most flowers, the pollen is released through lengthwise slits that develop on the anthers, but in members of the Heath Family (Ericaceae) and those of a few other groups, the pollen is released through anther pores.

The *pistil***,** which often is shaped like a tiny vase that is closed at the top, consists of three regions that merge with one another. At the top is the **stigma,** which is usually connected by a slender, stalklike **style** to the swollen base called the **ovary.** The stigma may be little more than a point, a slight swelling, or may consist of up to several divergent arms or branches. The ovary later develops into a *fruit.*

There is evidence that ovaries first developed when the margins of leaves bearing ovules rolled inward. Such ovule-bearing leaves were called **carpels.** In some instances, two or more carpels eventually fused together, and many ovaries are now *compound*, consisting of two to several united carpels. The number of carpels present is often reflected by the number of lobes or divisions of the stigma. Each segment of a mature ovary, such as a tomato or orange, for example, represents a carpel. Carpels are discussed further in Chapter 23. Some texts refer to pistils as carpels, but since a pistil can consist of one to several carpels, such references are unfortunate and unnecessarily confusing.

The ovary is said to be **superior** if the calyx and corolla are attached to the receptacle at the base of the ovary, as in pea and primrose flowers. In other instances, the ovary becomes **inferior** when the receptacle grows up around it so that the calyx and corolla appear to be attached at the top, as in cactus and carrot flowers. A cavity containing one or more egg-shaped **ovules** lies within the ovary; ovules are attached to the wall of the cavity by means of short stalks. An ovule, the development of which takes place after *fertilization* has occurred, eventually becomes a **seed.** Details of fertilization and ovule development are given in Chapter 23.

Peach flowers are produced singly, each on its own peduncle, but many other flowers such as lilac, grape, and bridal wreath are produced in **inflorescences.** Inflorescences are groups of several to hundreds of flowers that may all open at the same time, or they may follow an orderly progression to maturation (Fig. 8.7). The single peduncle of an inflorescence has many little stalks called *pedicels* attached to it—one pedicel for each flower.

A discussion of primitive and specialized flowers, along with their evolutionary development and ecological adaptations, is given in Chapter 23.

FRUITS

Introduction

In 1893, the U.S. Supreme Court, in the case of *Nix* v. *Hedden*, ruled that a tomato was legally a vegetable rather than a fruit. This was in keeping with the public's general conception of fruits as being relatively sweet and dessertlike. Vegetables, on the other hand, were considered more savory and useful as salad or main-course foods. Regardless of the court's decision, a **fruit,** botanically speaking, is any ovary and its accessory parts that has developed and matured. It also usually contains seeds. By this definition, many so-called vegetables, including tomatoes, string beans, cucumbers, and squashes, are really fruits. On the other hand, vegetables can consist of leaves (e.g., lettuce, cabbage), leaf petioles (e.g., celery), specialized leaves (e.g., onion), stems (e.g., white potato), roots (e.g., sweet potato), stems and roots (e.g., beets), flowers and their peduncles (e.g., broccoli), flower buds (e.g., globe artichoke), or other parts of the plant.

All fruits develop from flower ovaries and accordingly are found exclusively in the flowering plants. *Fertilization* (see Chapter 23) usually indirectly determines whether or not the ovary or ovaries (and sometimes the receptacle or other tissues) of a flower will develop into a fruit. If at least a few of the ovules are not fertilized, the flower normally withers and drops without developing further. Pollen grains contain specific stimulants called *hormones* (discussed in detail in Chapter 11) that may initiate fruit development, and sometimes a little dead pollen is all that is needed to stimulate an ovary into becoming a fruit. It is the hormones produced by the developing seeds, however, that promote the greatest fruit growth. These hormones, in turn, stimulate the production of more fruit growth hormones by the ovary wall. In a few instances (e.g., the cultivated banana), fruits develop without fertilization. Such development is called *parthenocarpic.* Parthenocarpy is discussed in Chapter 23.

Fruit Regions

Most of a mature fruit has three regions, which sometimes merge and can be difficult to distinguish from one another (Fig. 8.8). The skin forms the **exocarp,** while the inner boundary around the seed(s) forms the **endocarp.** The endocarp may be hard and stony (as in a peach pit around the seed). It also may be papery (as in apples), or it may not be distinct from the **mesocarp,** which is the often fleshy tissue between the exocarp and the endocarp. The three regions collectively are called the **pericarp.** In dry fruits, the pericarp is usually quite thin.

Some fruits consist of only the ovary and its seeds. Others have adjacent flower parts, such as the receptacle or calyx fused to the ovary or different parts modified in various ways. Fruits may be either fleshy or dry at maturity, and they may split, exposing the seeds, or no split may occur. They may be derived from a single ovary or from more than one. Traditionally, all these features have been used to classify fruits, but unfortunately, not all fruits lend themselves to neat pigeonholing by such characteristics. Some of these problems are pointed out in the classification that follows.

Kinds of Fruits

Fleshy Fruits

Fruits whose mesocarp is at least partly fleshy at maturity are classified as fleshy fruits.

Simple fleshy fruits develop from a flower with a single pistil. The ovary may be superior or inferior, and it may be *simple* (derived from a single modified leaf called a **carpel**), or it may consist of two or more carpels and be *compound* (for a discussion of the derivation of carpels and compound ovaries, see Chapter 23). The ovary alone may develop into the fruit, or other parts of the flower may develop with it.

A **drupe** is a simple fleshy fruit with a single seed enclosed by a hard, stony endocarp, or pit (Fig. 8.9). It usually develops from flowers with a superior ovary containing a single ovule. The mesocarp is not always obviously fleshy, however. In coconuts, for example, the *husk* (consisting of the mesocarp and the exocarp), which is usually removed before the rest of the fruit is sold in markets, is very fibrous (the fibers, incidentally, are used in making mats and brushes). The seed ("meat") of the coconut is hollow and contains a watery *endosperm* (see Chapter 23) commonly but incorrectly referred to as "milk." It is surrounded by the thick, hard endocarp typical of drupes. Other examples of drupes include the stone fruits (e.g., apricots, cherries, peaches, plums, olives, and almonds). In almonds, the husk, which dries somewhat and splits at maturity, is removed before marketing, and it is the endocarp that we crack to obtain the seed.

Berries usually develop from a compound ovary and commonly contain more than one seed. The entire pericarp is fleshy, and it is difficult to distinguish between the mesocarp and the endocarp (Fig. 8.10). Three types of berries may be recognized.

A *true berry* is a fruit with a thin skin and a pericarp that is relatively soft at maturity. Although most contain more than one seed, notable exceptions are dates and avocados, which have only one seed. Typical examples of true berries include tomatoes, grapes, persimmons, peppers, and eggplants. Some fruits that popularly include the word *berry* in their common name (e.g., strawberry, raspberry, blackberry) botanically are not berries at all.

Some berries are derived from flowers with inferior ovaries so that other parts of the flower also contribute to the flesh. They can usually be distinguished by the remnants of flower parts or their scars that persist at the tip. Examples of such berries include gooseberries, blueberries, cranberries, pomegranates, and bananas. Because fruit development in the cultivated banana is parthenocarpic, there are no seeds. Several other species of banana produce an abundance of seeds.

Pepos are berries with relatively thick rinds. Fruits of members of the Pumpkin Family (Cucurbitaceae), including pumpkins, cucumbers, watermelons, squashes, and cantaloupes, are pepos.

The *hesperidium* is a berry with a leathery skin containing oils. Numerous outgrowths from the inner lining of the ovary wall become saclike and swollen with juice as the fruit develops. All members of the Citrus Family (Rutaceae) produce this type of fruit. Examples include oranges, lemons, limes, grapefruit, tangerines, and kumquats.

Pomes are simple fleshy fruits, the bulk of whose flesh comes from the enlarged floral tube or receptacle that grows up around the ovary. The endocarp around the seeds is papery or leathery. Examples include apples, pears, and quinces. In an apple, the ovary consists of the core and a little adjacent tissue. The remainder of the fruit has developed primarily from the floral tube, with a little tissue contributed by the receptacle (Fig. 8.11). Botany texts often refer to pomes, pepos, some berries, and other fruits derived from more than an ovary alone as *accessory fruits* or as fruits having *accessory tissue.*

Dry Fruits

Fruits whose mesocarp is definitely dry at maturity are classified as *dry fruits.*

Dry Fruits That Split at Maturity (Dehiscent Fruits) The fruits in this group are distinguished from one another by the way they split.

The **follicle** splits along one side or seam (*suture*) only, exposing the seeds within (Fig. 8.12). Examples include larkspur, columbine, milkweed, and peony.

The **legume** splits along two sides or seams (Fig. 8.13). Literally thousands of members of the Legume Family (Fabaceae) produce this type of fruit. Examples include peas, beans, garbanzo beans, lentils, carob, kudzu, and mesquite. Peanuts are also legumes, but they are atypical in that the fruits develop and mature underground. The seeds are usually released in nature by bacterial breakdown of the pericarp instead of through an active splitting action.

Siliques also split along two sides or seams, but the seeds are borne on a central partition, which is exposed when the two halves of the fruit separate (Fig. 8.14A). Such fruits, when they are less than three times as long as they are wide, are called *silicles* (Fig. 8.14B). Siliques and silicles are produced by members of the Mustard Family (Brassicaceae), which includes broccoli, cabbage, radish, shepherd's purse, and watercress.

Capsules are the most common of the dry fruits that split (Fig. 8.15). They consist of at least two carpels and split in a variety of ways. Some split along the partitions between the carpels, while others split through the cavities (*locules*) in the carpels. Still others form a cap toward one end that pops off and releases the seeds, or they form a row of pores through which the seeds are shaken out as the capsule rattles in the wind. Examples include irises, orchids, lilies, poppies, violets, and snapdragons.

Dry Fruits That Do Not Split at Maturity (Indehiscent Fruits) In this type of dry fruit, the single seed is, to varying degrees, united with the pericarp.

Only the base of the single seed of the **achene** is attached to its surrounding pericarp. Accordingly, the husk (pericarp) is relatively easily separated from the seed. Examples include sunflower "seeds" (the edible kernel plus the husk constitute the achene) (Fig. 8.16), buttercup, and buckwheat.

Nuts are one-seeded fruits similar to achenes, but they are generally larger, and the pericarp is much harder and thicker. They develop with a cup, or cluster, of bracts at their base. Examples include acorns (Fig. 8.16), hazelnuts (filberts), and hickory nuts. Botanically speaking, many nuts in the popular sense are not nuts. We have already seen that peanuts are atypical legumes and that coconuts and almonds are drupes. Walnuts and pecans are also drupes, whose "flesh" withers and dries after the seed matures. Brazil nuts are the seeds of a large capsule, and a cashew nut is the single seed of a unique drupe. It appears as a curved appendage at the end of a swollen pedicel, which is eaten raw in the tropics or made into preserves or wine. Pistachio nuts are also the seeds of drupes.

The pericarp of the **grain** (**caryopsis;** plural: **caryopses**) is tightly united with the seed and cannot be separated from it (Fig. 8.16). All members of the Grass Family (Poaceae), including corn, wheat, rice, oats, and barley, produce grains.

In **samaras,** the pericarp surrounding the seed extends out in the form of a wing or membrane, which aids in dispersal (Fig. 8.17). In maples, samaras are produced in pairs, but in ashes, elms, and the tree of heaven, they are produced singly.

The twin fruit called a **schizocarp** (Fig. 8.18) is unique to the Parsley Family (Apiaceae). Members of this family include parsley, carrots, anise, caraway, and dill. Upon drying, the twin fruits break into two one-seeded segments called *mericarps.*

Aggregate Fruits

An **aggregate fruit** is one that is derived from a single flower with several to many pistils. The individual pistils develop into tiny drupes or other fruitlets, but they mature as a clustered unit on a single receptacle (Fig. 8.19). Examples include raspberries, blackberries, and strawberries. In a strawberry, the cone-shaped receptacle becomes fleshy and red, while each pistil becomes a little *achene* on its surface. In other words, the strawberry, while being an aggregate fruit, is also partly composed of accessory tissue.

Multiple Fruits

Multiple fruits are derived from several to many individual flowers in a single inflorescence. Each flower has its own receptacle, but as the flowers mature separately into fruitlets, they develop together into a single larger fruit, as in aggregate fruits. Examples of multiple fruits include mulberries, Osage oranges (Fig. 8.20), pineapples, and figs. Pineapples, like bananas, usually develop parthenocarpically (see Chapter 23), and there are no seeds. The individual flowers are fused together on a fleshy axis, and the fruitlets coalesce into a single fruit.

Figs mature from a unique "outside in" inflorescence. The individual flowers of the inflorescence are enclosed by the common receptacle, which has an opening to the outside at the tip (Fig. 8.21). Such a multiple fruit arrangement is referred to as a *syconium.* Some fig varieties develop parthenocarpically, but others are pollinated by tiny wasps that crawl in and out through the opening. Some multiple fruits, such as those of the sweet gum, are dry at maturity.

FRUIT AND SEED DISPERSAL

Why are so many species of orchids rare, while dandelions, shepherd's purse, and other weeds occur all over the world? Why are some plants confined to single continents, mountain ranges, or small niches occupying less than a hectare (2.47 acres) of land? The answers to these questions involve many different factors, including climate, soil, the adaptability of the plant, and its means of seed dispersal. How fruits and seeds are transported from one place to another is the subject of the following sections. Other factors are discussed in Chapters 13 and 25.

Dispersal by Wind

Fruits and seeds have a variety of adaptations for wind dispersal (Fig. 8.22). The samara of a maple has a curved wing that causes the fruit to spin as it is released from the tree. In a brisk wind, samaras may be carried up to 10 kilometers (6 miles) away from their source, although usually most are relatively evenly distributed within a few meters of the tree. In hop hornbeams, the seed is enclosed in an inflated sac that gives it some buoyancy in the wind. In some members of the Buttercup and Sunflower Families (Ranunculaceae and Asteraceae), the fruits have plumes, and in the Willow Family (Salicaceae), the fruits are surrounded by cottony or woolly hairs that aid in wind dispersal. In button snakeroots and Jerusalem sage, the fruits are too large to be airborne, but they are spherical enough to be rolled along the ground by the wind.

Seeds themselves may be so tiny and light that they can be blown great distances by the wind. Orchids and heaths, for example, produce seeds with no endosperm that are as fine as dust and equally light in weight. In catalpa and jacaranda trees, the seeds themselves are winged rather than the fruits, which remain on the branches and split, releasing their contents. Dandelion fruitlets have plumes that radiate out at the ends like tiny parachutes; these catch even a slight breeze. In tumble mustard and other tumbleweeds, the whole aboveground portion of the plant may *abscise* (separate from the root) and be blown away by the wind, releasing seeds as it bumps along.

Dispersal by Animals

The adaptations of fruits and seeds for animal dispersal are legion. Birds, mammals, and ants all act as disseminating agents (Fig. 8.23). Shore birds may carry seeds great distances in mud that adheres to their feet. Other birds and mammals eat fruits whose seeds pass unharmed through their digestive tracts. Some bird-disseminated fruits contain laxatives that speed their passage through the birds' digestive tracts. In blackbirds, the seeds may remain in the tract as little as 15 minutes, but in mammals, the period is more commonly about 24 hours. In the giant tortoises of the Galápagos Islands, seeds do not pass through the tract for 2 weeks or more, and the seeds usually will not germinate unless they have been subjected to such treatment (see Chapter 11). Some seeds and fruits are gathered and stored by rodents, such as squirrels and mice, and then are abandoned. Blue jays, woodpeckers, and other birds carry away nuts and other fruits, which they may drop in flight and abandon.

Many fruits and seeds catch in or adhere to the fur or feathers of animals and birds. Bedstraw and bur clover fruits are covered with small hooks that catch in fur (or a hiker's socks). The large capsules of unicorn plants have two giant, curved extensions about 15 centimeters (6 inches) long. These catch on the fetlock of a deer or other animal that happens to step on the fruit, and the seeds are scattered as the animal moves along. Twinflowers and flax have fruits with sticky appendages that adhere to fur on contact, and those of the puncture vine penetrate the skin and stick by means of hard little prickles (Fig. 8.24).

Bleeding hearts, trilliums, and several dozen other plants have on their seeds appendages that contain oils attractive to ants (Fig. 8.25). The Scandinavian scientist Sernander once estimated that more than 36,000 such seeds were carried by members of a single ant colony to their nest, where the ants stripped off the appendages for food but did not harm the seeds themselves.

Dispersal by Water

Some fruits contain trapped air, adapting them to water dispersal. Many sedges, for example, have seeds surrounded by inflated sacs that enable the seeds to float (Fig. 8.26). Others have waxy material on the surface of the seeds, which temporarily prevents them from absorbing water while they are floating. Sometimes, a heavy downpour will create a torrent of water that dislodges masses of vegetation along a stream bank, carrying whole plants and their fruits to new locations. Large raindrops themselves may splash seeds out of their opened capsules.

Seeds and fruits of a few plants have thick, spongy pericarps that absorb water very slowly. Such fruits are adapted to dispersal by ocean currents, even though salt water eventually may penetrate enough to kill the delicate embryos. Enough fruits are beached before this occurs to ensure the survival of the species. Contrary to popular belief, coconuts that fall into water usually become waterlogged and sink in a few days. Rarely, if ever, are they carried hundreds of kilometers out to sea.

Other Dispersal Mechanisms and Agents

Fruits of some legumes, touch-me-nots, and members of other families mechanically eject seeds, sometimes with considerable force. For example, the splitting action of drying witch hazel capsules may fling the seeds over 12 meters (40 feet) away. Fruits of dwarf mistletoes may be violently released in response to the heat of a warm-blooded animal coming close to the plants. In fact, small welts have been raised by dwarf mistletoe fruits on the skin of humans who ventured close to the plants. In manroots and a few other members of the Pumpkin Family (Cucurbitaceae), the seed release resembles a geyser eruption as a frothy substance containing the seeds squirts out of one end of the melonlike fruits.

In filarees and other members of the Geranium Family (Geraniaceae), each carpel of the fruit splits away and curls back from a central axis. Each fruitlet consists of a single, pointed seed with a long, slender tail that is sensitive to changes in humidity (Fig. 8.27). At night when the humidity increases, the tail is relatively straight, but in the sun, it coils up like a corkscrew, literally drilling the pointed seed into the ground as it does so and effectively planting it in the process.

Humans, both intentionally and unintentionally, are by far the most efficient transporters of fruits and seeds. Travelers and explorers have carried many noxious weeds and plant diseases, as well as valuable food and medicinal plants, from one continent to another. Most countries now have strict regulations barring the importation of plant materials, except by special permit, and carrying some plants across borders is not legal under any circumstances. In the United States, for example, certain fruits and seeds that might carry diseases harmful to local agriculture may be barred from entry. Arizona, California, and Hawaii have border inspections to try to prevent the importation of popcorn, citrus, and other fruits; in the past, such plants have been carriers of diseases or pests that are presently under control.

SEEDS

Structure

The concave side of an ordinary kidney bean (a dicot) has a small white scar called the *hilum.* The hilum marks the point at which the ovule was attached to the ovary wall. A tiny pore called the *micropyle* is located right next to the hilum. If this bean is placed in water for an hour or two, it may swell enough to split the seed coat. Once the seed coat is removed, the two halves, called **cotyledons,** can be distinguished (Fig. 8.28). The cotyledons, which have a tiny immature plantlet along one edge between them, are food-storage organs that also function as the first "seed leaves" of the seedling plant. The cotyledons, and the tiny, rudimentary bean plant to which they are attached, constitute the *embryo.* Some seeds (e.g., those of grasses and all other monocots) have only one cotyledon.

The tiny embryo plantlet has undeveloped leaves and a meristem at the upper end of the embryo axis. This embryo shoot is called a **plumule.** The cotyledons are attached just below the plumule. The very short part of the stem above the cotyledons is called the **epicotyl,** while the stem below the attachment point is the **hypocotyl.** In an embryo, it is often difficult to tell where the stem ends and the root begins, but the tip that will develop into a root is called a **radicle.** When a kidney bean germinates, the hypocotyl lengthens and bends, becoming hook-shaped. The top of the hook emerges from the ground, pulling the cotyledons above the ground. Once the cotyledons have emerged, the hook straightens out. In lima beans and peas, however, the hypocotyl remains short so that the cotyledons do not emerge above the surface (see Chapter 11).

In other seeds, the cotyledon(s) may not play a significant role in food storage. In corn, for example, the bulk of the food-storage tissue is *endosperm* (see Chapter 23). Corn "seeds" (Fig. 8.29) also display other features not seen in beans. The plumule and the radicle are enclosed in tubular, sheathing structures called the **coleoptile** and the **coleorhiza,** respectively. These protect the delicate tissues within as the seeds germinate. After the coleoptile and coleorhiza have become several millimeters long, their development ceases, and the plumule and radicle burst through the tips.

Germination

Germination, which is the beginning or resumption of growth of a seed, depends on the interplay of a number of factors, both internal and external. In order to germinate, a seed must first be *viable* (capable of germinating). Many seeds for various reasons (e.g., death of the embryo within) are not viable, and all lose their viability after varying periods of time. Many seeds also require a period of **dormancy** (see page 211) before they will germinate. Dormancy is brought about by either mechanical or physiological circumstances or both. In the Legume Family (Fabaceae) and others, the seeds may have seed coats so thick or tough that they prevent the absorption of water or oxygen. Some seeds even have a one-way valve that lets moisture out but prevents its uptake. Dormancy in such seeds may sometimes be broken artificially by *scarification,* which involves nicking or slightly cracking the seed coats or dipping the seeds in a concentrated acid for a few seconds to a few minutes. In nature, such seeds may remain dormant until cracks in the seed coat are brought about by the mechanical abrasion of rock particles in the soil, alternate thawing and freezing, or in some cases, bacterial action.

Dormancy may also be brought about by growth-inhibiting substances present in the seed coat, the interior of the seed, or tissues of the fruit surrounding it. Many desert plants have inhibitors in the seed coat. These have to be washed away by soaking rains before germination will occur. The inhibitors function in survival of the species by preventing germination unless there has been sufficient rainfall for a seedling to become established.

Apples, pears, citrus fruits, tomatoes, and other fleshy fruits contain inhibitors that prevent germination of the seeds within the fruits. Once the seeds are removed and washed, they germinate readily. The embryos of some seeds, such as those of the American holly, consist of only a few unspecialized cells when the fruit ripens. The seeds will not germinate after the fruit has dropped until the embryo has developed fully with the aid of food materials stored in its endosperm. Such a process of development is called *after-ripening.*

In many woody plants of temperate areas, germination stimulators need to be present to initiate growth. These normally do not develop unless the seeds encounter a wet period accompanied by cold temperatures. Usually this period needs to be a minimum of 4 to 6 weeks. The dormancy of such seeds can be broken artificially by placing them in a refrigerator, preferably in damp sand, for a few weeks.

Even when mechanical and physiological barriers to germination are not present, a seed will not normally germinate unless environmental factors are favorable. Water and oxygen are essential to the completion of germination, and light or its absence also plays a role. Many seeds imbibe 10 times or more their total weight in water before the radicle emerges. Some seeds, such as those of castor beans (Fig. 8.30) and certain spurges, have appendages that function in water absorption and thereby speed up the germination -process.

After water has been imbibed, enzymes begin to function in the cytoplasm, which has now been rehydrated. Some enzymes convert stored proteins to amino acids, -others convert fats and oils to soluble compounds, and still other enzymes aid in the conversion of starch to sugar. The soluble substances can then be conveyed to the embryo, and respiration, which in a dormant seed is almost imperceptible, can be greatly accelerated. In a few seeds such as rice and barnyard grass, anaerobic respiration initially furnishes the energy for embryo growth, but in most seeds, the energy is released through aerobic respiration. A new plant begins to develop as mitosis and cell elongation take place. Both forms of respiration are discussed in Chapter 10.

If seeds are kept waterlogged after planting, available oxygen is greatly reduced and germination then may fail to be completed. Most seeds require temperatures within certain ranges to germinate. These usually need to be above freezing but below 45°C (113°F). Germination percentages tend to be low approaching either extreme, however. Most crop plants have an optimum (ideal) germination temperature of between 20°C and 30°C (68°F to 86°F).

The role of light in germination varies with the kinds of plants concerned. Seeds of some varieties of lettuce will not germinate in the dark (see the discussion of *phytochrome* in Chapter 11), while those of other seeds, such as the California poppy, germinate only in the dark. In lettuce seeds, the light apparently inactivates germination inhibitors, while in the California poppy, it stimulates inhibitor formation. (See the additional discussion of dormancy in Chapter 11.)

Longevity

From time to time, one reads or hears of seeds of wheat or other edible plants germinating after lying dormant in Egyptian pyramids or Native American tombs and caves for thousands of years, but none of these reports has been confirmed. In fact, there is evidence in a few instances that rats or rodents in recent times carried the seeds concerned to their nests. However, reports of seeds of the aquatic lotus plant germinating after about 1,200 years and another documenting the germination of Arctic tundra lupine seeds that were frozen for an estimated 10,000 years have been -confirmed.

Seeds remain viable (retain the capacity to germinate) for periods that vary greatly, depending on the species and the conditions of storage. Some seeds, such as those of -certain willows, cottonwoods, orchids, and tea, remain viable for only a few days or weeks, regardless of how they are stored, but the period of viability of most seeds is extended by months or even years when they are stored at low temperatures and kept dry.

By law, packets of vegetable and flower seeds sold in stores are dated, giving the buyer a rough idea of how long a significant number of the seeds might be expected to remain viable. Generally, seeds of Pumpkin Family (Cucurbitaceae) members (e.g., squash, cantaloupe, cucumber) retain a relatively high percentage of viability for several years, while those of members of the Lily Family (Liliaceae) (e.g., onion, leek, chives) retain a good percentage of viability for only 2 or 3 years. Properly stored wheat seeds have been reported to retain better than 30% viability for more than 30 years, and some weed seeds stored under conditions of low oxygen, high humidity, and cool temperatures have remained viable for even longer periods.

In 1879, William J. Beal, a botanist who pioneered in the development of hybrid corn, buried 20 pint-sized bottles of weed seeds on the campus of what is now Michigan State University in East Lansing, Michigan. Each bottle contained 1,000 seeds of 20 different species of weeds. Every 5 years, a bottle of seeds was dug up and the seeds were planted, until the schedule was changed in 1920 to every 10 years. When the first bottle was dug up in 1884, seeds of most of the weeds germinated; in 1960, seeds of evening primrose, curly dock, and moth mullein still germinated; and in 1980, 29 moth mullein seeds, 1 mullein seed, and 1 mallow seed germinated—101 years after they were placed in the bottles. It is of interest to note that a mallow seed previously had not germinated since 1899. Only six of the original bottles now remain; they are not scheduled to be unearthed until the year 2040. Recent evidence indicates that the timing of the digging up of the seed bottles did not take into account the fact that certain temperature patterns are critical to the germination of many weed seeds and that if Beal's experiment had been conducted in a different way, the germination results would have been quite different.

A few species of both dicots and monocots produce seeds that have no period of dormancy at all. In some instances, the embryo, which develops from the zygote, continues to grow without pause in a phenomenon known as *vivipary*. In the red mangrove, a tropical tree associated with coastal waters and estuaries, each fruit contains a single seed in which the embryo continues to grow while the fruit is still on the tree, reaching a length of 25 centimeters (10 inches) or more before the seedling becomes detached and essentially plants itself in the mud below (Fig. 8.31).

Summary

1. Flowers occur in a wide variety of sizes, colors, textures, and habitats. Annuals complete their life cycles in one growing season; biennials take two seasons; and perennials may take several to many years to complete their cycles.
2. Dicots and monocots are distinguished from one another by the differences in numbers of flower parts and cotyledons, venation, presence or absence of cambia, vascular bundle arrangement, and pollen grain apertures.
3. A typical flower consists of a peduncle and a receptacle to which are attached sepals (calyx), petals (corolla), stamens, and pistil. Flowers may have no petals, or the petals may be fused together. Many flowers may be in an inflorescence.
4. Stamens consist of a pollen-bearing anther and a stalk or filament.
5. A pistil consists of a stigma, style, and ovary. The ovary may be superior or inferior and contains one or more ovules.
6. A fruit, which is unique to flowering plants, is a mature ovary. Hormones promote the greatest fruit growth. Parthenocarpic fruits are seedless and develop without fertilization occurring, but not all seedless fruits are parthenocarpic.
7. A mature fruit has an outer exocarp, an inner endocarp around the seed(s), and a mesocarp between the exocarp and endocarp; the three regions may be fused together as a pericarp. At maturity, fruits may be fleshy or dry. A fruit may be derived from the ovary alone or from adjacent flower parts as well.
8. Fleshy fruits may develop from a flower with a single pistil (simple fruit); aggregate fruits develop from a single flower with more than one pistil; multiple fruits are derived from flowers in an inflorescence.
9. Simple fleshy fruits include drupes and berries; berries may be true berries, pepos, or hesperidiums. Pomes have flesh derived from both the receptacle and the ovary.
10. Accessory fruits consist of more than the ovary alone; some aggregate fruits (e.g., strawberries) are largely composed of accessory tissue. The individual fruitlets of a multiple fruit develop together into a single larger fruit.
11. Some dry fruits split as they mature; such fruits include follicles, legumes, siliques or silicles, and capsules.
12. Non-splitting dry fruits include achenes, nuts, grains (caryopses), samaras, and schizocarps.
13. Fruits and seeds may have wings, plumes, and other adaptations for wind dispersal. Some fruits and seeds have adaptations for animal, bird, or water dispersal. Some fruits eject seeds with force, and some have modifications that drill seeds into the ground.
14. Humans disperse many seeds, and most countries and a few states have strict regulations governing the importation of plant materials, primarily to control the spread of pests and diseases.
15. A bean seed has a hilum, a micropyle, a seed coat, two cotyledons, and an embryonic bean plant consisting of a plumule and a radicle.
16. In grains, the plumule and the radicle are protected by a coleoptile and a coleorhiza, respectively.
17. Germination of a seed depends on the cessation of dormancy. Dormancy may be sustained by mechanical circumstances; scarification may break dormancy in such seeds.
18. Dormancy may also be induced by growth or germination inhibitors, or after-ripening may need to occur. Cold temperatures may be necessary for the germination of some seeds; stratification may break the dormancy of such seeds.
19. A seed will not germinate unless environmental factors including water, oxygen, light, and certain temperature ranges are favorable.
20. Seeds remain viable for a few days to more than 100 years. The viability of most seeds is extended by storage at low temperatures under dry conditions, but some weed seeds have their viability extended by storage under humid, cool conditions that include little oxygen.
21. Some plants produce seeds that undergo no dormancy at all. The growth of the embryo while the seed and fruit are still on the plant is termed vivipary.

Review Questions

1. Define calyx, corolla, receptacle, peduncle, pedicel, pistil, filament, ovary, and carpel.

2. Indicate the features by which dicots are distinguished from monocots.
3. What is the difference between a fruit and a vegetable?
4. What causes an ovary to develop into a fruit?
5. What are the various parts of a fruit?
6. How do fleshy fruits differ from dry fruits?
7. Distinguish among simple, aggregate, and multiple fruits.
8. Distinguish among achenes, grains, samaras, and nuts.
9. What adaptations do seeds and fruits have for dispersal by water and animals?
10. Define plumule, radicle, coleoptile, coleorhiza, hypo-cotyl, after-ripening, stratification, and vivipary.

Discussion Questions

1. Most wind-pollinated flowering plants have inconspicuous, nonfragrant flowers. How might nature be affected if all flowers were that way?
2. Do you believe the botanical distinction between fruits and vegetables is a good one? If not, how would you change it?
3. In discussing pomes, it was observed that the bulk of the flesh in an apple comes from the floral tube. What could you do to prove or disprove this?
4. Seed and fruit dispersal is achieved with the aid of wind, water, animals, mechanical means, and humans. If you were "designing" a new plant, can you think of any new way in which it might be dispersed?
5. When volcanic activity or coral polyps cause new islands to appear in the oceans, they eventually acquire some vegetation. Would you expect the types of dispersal mechanisms for the flowering plants on these islands to be the same as they were for ancient continents?

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Three sulfur butterflies (*Phoebis sennae*) visit this nectar-rich *Hibiscus* spp. flower in Cedar Key, Florida. *(Courtesy Cliff Pelchat)*

Figure 8.2A A *Rafflesia* flower. These flowers may be as much as 1 meter (3 feet 3 inches) in diameter. *(Courtesy Charles H. Lamoureux)*

Figure 8.1 Flowers of an Australian orchid produced by plants that complete their entire life cycle below ground. *(Drawing courtesy Karen Hamilton)*

Figure 8.2B The rare bloom of a corpse flower (*Amorphophallus titanum*), which is known for its large size and offensive odor. *(Courtesy Myriad Botanical Gardens, Oklahoma City)*

Figure 8.3 Male catkins of an alder, (*Alnus*). Each catkin consists of numerous tiny, inconspicuous, wind-pollinated flowers that have no petals.

Figure 8.4 Spanish moss (*Tillandsia*). Spanish moss is a non-parasitic flowering plant that goes through its life cycle suspended from other plants or objects such as tree limbs or wires. This plant should not be confused with *lichens,* which consist of an alga and a fungus (see Chapter 18), and which also may hang suspended from other objects.

TABLE 8.1

Some Differences Between Dicots and Monocots

DICOTS	MONOCOTS
1. Seed with two cotyledons (seed leaves)	1. Seed with one cotyledon (seed leaf)
2. Flower parts mostly in fours or fives or	2. Flower parts in threes or multiples
3. Leaf with a distinct network of primary veins	3. Leaf with more or less parallel
4. Vascular cambium, and frequently cork	4. Vascular cambium and cork cambium
5. Vascular bundles of stem in a ring	5. Vascular bundles of stem scattered
6. Pollen grains mostly with three *apertures* (thin areas in the aperture wall—see Figures 23.6 and 23.7)	6. Pollen grains mostly with one *aperture*

Figure 8.5 Parts of a generalized flower. The interior structure of the ovule and the sexual processes involved are discussed in Chapter 23.

Figure 8.6 A flower of jimson weed (*Datura*). The petals are united in a single, flared sheet of tissue.

Figure 8.7 Inflorescence types. Each ball represents a flower. In all inflorescences shown, except for the dichasium and catkin, the lowermost or outermost flowers open first. The flowers then open in succession upward or inward. In a dichasium, the central flower opens first, and the side flowers open simultaneously. In a catkin, all the flowers open simultaneously. *(From Moore, Clark, and Vodopich, Botany, 2nd edition. © 1998 The McGraw-Hill Companies. All rights reserved.)*

Figure 8.8 Regions of a mature peach fruit.

Figure 8.9 Representative drupes. *A.* Peaches. *B.* Almonds. *C.* Olives.

A.

B.

C.

Figure 8.10 Representative berries. *A.* Grapes. *B.* Tomatoes.

A.

B.

Figure 8.11 Apples (representative of pomes). The bulk of the flesh is derived from the floral tube that grows up around the ovary.

A.

B.

Figure 8.13 Legumes of a coral tree (*Erythrina*).

Figure 8.12 Follicles. *A.* Milkweed. *B. Magnolia.* The fruit of the magnolia is actually an aggregate fruit consisting of approximately 40 to 80 individual one-seeded follicles on a common axis. The follicles and axis fall from the magnolia tree as a unit.

B.

A.

Figure 8.14 *A.* A silique after it has split open. The seeds are borne on a central, membranous partition. *B.* Silicles of *Lunaria* (dollar plant).

Figure 8.15 Capsules. *A.* Butterfly iris (*Moraea*). *B. Bletilla* orchid. *C.* Autograph tree (*Clusia rosea*). *D.* Unicorn plant (*Proboscidia*).

A.

B.

C.

D.

Figure 8.16 Dry fruits that do not split at maturity. *A.* Achene of a sunflower sliced open. *B.* Grain (caryopsis) of corn, cut lengthwise. *C.* Nuts (acorns) of an oak. The acorn on the right was cut lengthwise above the cup.

Figure 8.17 Samaras of a big-leaf maple (*Acer macrophyllum*). Maple samaras are produced in pairs that separate at maturity.

Figure 8.18 Schizocarps of carrots. A schizocarp separates at maturity into two one-seeded fruitlets.

A.

B.

Figure 8.19 *A.* A blackberry flower. Note the numerous green pistils. *B.* Blackberries, representative of aggregate fruits. *(B. ©Pixtal/age fotostock)*

Figure 8.20 An osage orange (*Maclura*), representative of multiple fruits. The mature ovaries of many flowers become united in a single unit.

Figure 8.21 Section through a developing fig.

Figure 8.22 Types of seeds and fruits dispersed by wind.

Figure 8.23 Types of seeds and fruits dispersed by animals and birds.

Figure 8.24 Fruits of a puncture vine (*Tribulus terrestris*) clinging to a bicycle tire.

Figure 8.25 Seeds of the Pacific bleeding heart (*Dicentra formosa*). The white appendages are *elaiosomes,* which are removed from the seeds by ants and used for food.

Figure 8.26 Sedge adaptation to water dispersal. *A.* A sedge plant. *B.* A sedge fruit. The seed is enclosed within an inflated covering that enables it to float on water.

Flowers, fruits, and seeds are focal points for ecological interactions between plants and biological aspects of the environment. Many types of flowers serve to attract animals that transfer pollen between flowers. Adaptations of fruits and seeds for dispersal by animals, mainly birds, mammals, and ants, are legion and include attractive colors, scents, and oils, laxatives to speed the passage of seeds through the animal gut, and adhesive structures that attach to fur or feathers. Seed germination is usually subject to very specific environmental controls.

Figure 8.27 Filaree (*Erodium*) fruitlet. *A.* Under humid conditions. *B.* Under dry conditions. Alternate coiling and uncoiling causes the fruitlet to be “screwed” into the ground.

Figure 8.28 A common garden bean. *A.* Seed structure. *B.* Germination and development of the seedling.

Figure 8.29 Corn. *A.* Grain structure. *B.* Germination and development of the seedling.

Figure 8.30 Castor bean (*Ricinus*) seeds. Note the small water-absorbing appendage (caruncle) at the end of each seed.

Box Figure 8.1 A lotus pod with 20 fruits.

The Seed That Slept for 1,200 Years

Rip Van Winkle would appreciate this. An Oriental Sacred Lotus (*Nelumbo nucifera*) seed collected from the sediment of a dry lake bottom near a small village in northeastern China has germinated after being dormant for over 1,200 years. It is one of the oldest living seeds ever found. The Beijing Institute of Botany donated Sacred Lotus seeds to a team of UCLA scientists who dated the seeds with a nondestructive method called accelerator mass spectroscopy. Small amounts of tissue (less than 10 milligrams) were sampled for radiocarbon dating prior to germination studies. Before the use of this newer dating method, whole seeds had to be destroyed in the process of dating, thereby eliminating the possibility of testing the seeds for viability. After lying dormant in a bed of black clay at depths of 0.5 to 2.8 meters (1.5 to 9 feet), the germinated 1,200-year-old seed (1,288 ± 271 years) was the oldest, but not the only survivor from the subterranean tomb. Three other ancient lotus seeds found at various depths germinated, and the UCLA team determined that one was more than 600 years old and another was more than 300.

While reports have claimed seed germination of more ancient seeds recovered from dry archaeological sites in Egypt (such as King Tut's tomb in the pyramids of Giza and from the tombs of other Pharaohs), experts now agree that these reports are unreliable. Apart from these lotus seeds, the oldest documented viable seeds are lupine seeds that were frozen in Arctic tundra and from Professor Beal's seed germination study (see text section entitled "Longevity" for discussion).

These Sacred Lotus seeds have managed to ward off the ravages of time. Existing in an impenetrable seed coat and mired in an oxygen-deficient mud, the seeds have intact genetic and enzymatic systems that reactivated when split open and soaked in water. (Enzymes are proteins that speed up chemical reactions in the cell.) A key enzyme that repairs proteins was present during germination; this enzyme has been found in similar quantities in modern-day Sacred Lotus seeds. The repair enzyme functions in converting damaged amino acids back to their naturally occurring functional form. This is especially important in "repairing" the proteins of the cell membrane. Without intact membranes, cells are not able to function, and such damage will lead to the death of the cell and eventually the organism.

The architecture of the fruit no doubt plays a key role in the longevity of these seeds. The fruits of the Sacred Lotus are round to oblong, 10 to 13 centimeters (4 to 5 inches) long, 8 to 10 centimeters (3 to 4 inches) in diameter, and each contains a single seed. The fruit wall, or pericarp, which is impervious to water and is also airtight, is initially green and turns purplish brown and becomes dry and notably hard. Chinese botanists who first investigated similar ancient lotus seeds collected from the same deposits were unable to get them to germinate, even after 20 months of soaking in water. It wasn't until they scarified (filed open to permit water absorption) the seeds, as prescribed in a 1,400-year-old Chinese manuscript, *Ch'i Min Yao Su* (Important Technology for People in Harmony), that they were ultimately successful in germinating the seeds. The hard, airtight fruit walls are the most significant of the structural features that contribute to the exceptional longevity of the seeds.

The Sacred Lotus was introduced to China following the introduction of Buddhism from India in the 1st century B.C. It is regarded as a symbol of purity and strength, emerging from the mire of lake waters and opening its crimson flowers to the heavens. The earliest dated depiction of Buddha (in A.D. 240) shows him surrounded with a halo and seated cross-legged on a lotus throne. From old Chinese manuscripts, we learn that lotus has been cultivated as a crop plant (most parts are edible) for the past 4,000 years and traditional Chinese herbal medicine considered the Sacred Lotus a mainstay of their pharmaceutical collections. The large number of lotus seeds collected from the site suggests that the plant was under cultivation in this now dried-up lotus lake. It is likely that the 1,200-year-old seed was derived from a plant cultivated by Buddhists at this site in northeastern China.

Unlike Rip Van Winkle, who, following a drink of liquor, slept for only 20 years, these Sacred Lotus seeds are remarkable in their capacity to revive after more than 1,000 years. Lessons learned from these plants can shape our thinking about our own aging and the possibilities that may exist in the future for extending life at the margins.

D.C. Scheirer

Figure 8.31 Young seedlings of red mangrove (*Rhizophora mangle*) whose seeds have no dormant period and germinate while the fruit is still on the tree. The seedlings grow to lengths of up to 25 centimeters (10 inches) before falling and becoming planted in the mud below. Ocean currents and tides also distribute mangrove seeds throughout tropical tidal zones. The dispersal has been so effective that there are 60,000 square kilometers (23,000 square miles) of mangroves in Southeast Asia alone. Mangrove wood is harvested for fuel, and in the past 40 years, the groves in some localities have been reduced in area by more than 50%. Incidentally, the fruit is sweet and edible.