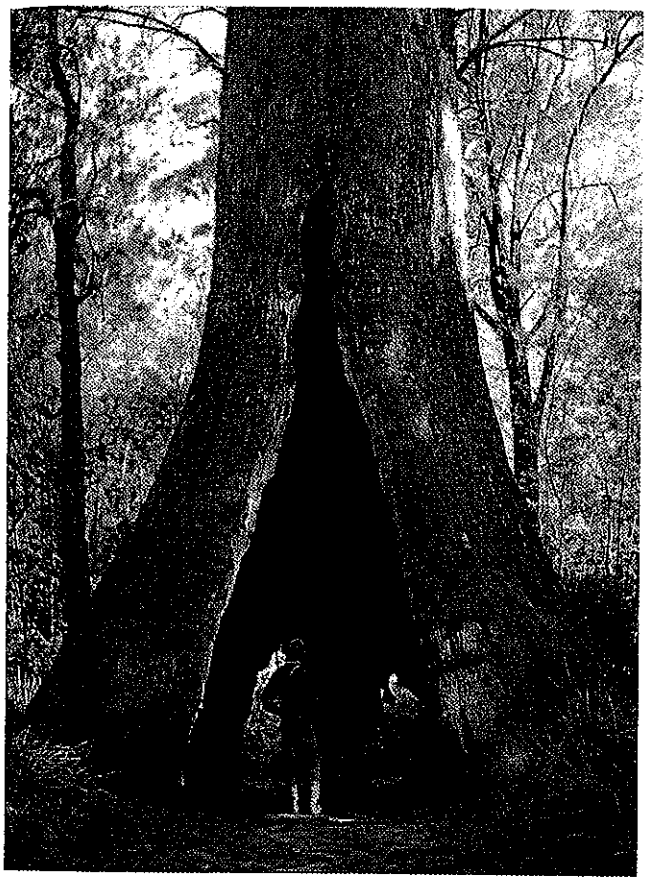
Attached is the first part of Chapter 21 on Introduction to the Angiosperms from the *Plant Biology* text (Raven, Evert, Eichhorn – 6th ed)

The description of the flower – its parts and variation – may be helpful and augment the handouts and lecture pdf.

You will have the opportunity in Mon/Tues lab (lab 4) to dissect several flowers and learn their parts, arrangement, symmetry, fusion, and position of ovules. Floral formulas, fruit types, and inflorescence types will be discussed in lab as well.

Chapter 21 Introduction to the Angiosperms



21–1
A giant eucalyptus, or red tingle (Eucalyptus jacksonii), *growing in the Valley of the Giants in southwestern Australia. Note the man standing in the burnt-out base of this enormous angiosperm.*

OVERVIEW

Of all the plants, angiosperms—the flowering plants—are the ones that most directly affect our lives. The grains, fleshy fruits, and vegetables we eat are angiosperms, and the cotton and linen in the clothes we wear are from angiosperms as well.

The most obvious characteristic of a flowering plant is, of course, the flower. The flower contains the sexual reproductive parts of the plant and thus is of crucial importance not only for the formation of offspring but for the evolution of the species as a whole. This chapter focuses first on the basic structure of the flower. Emphasis then shifts to the formation of both the male and female gametophytes and an examination of pollination and fertilization, two processes that have features unique to angiosperms. Last to be discussed in the reproductive process are the conversions of the ovule into a seed and the surrounding ovary into a fruit. The chapter concludes with a comparison of outcrossing and self-pollination, including the different strategies angiosperms have evolved that ensure reproductive success.

CHECKPOINTS

By the time you finish reading this chapter, you should be able to answer the following questions:

1. What is a flower, and what are its principal parts?
2. What are some of the variations that exist in flower structure?
3. By what processes do angiosperms form microgametophytes (male gametophytes)? How are these processes both similar to and different from those that give rise to megagametophytes (female gametophytes)?
4. What is the structure or composition of the mature male gametophyte in angiosperms? Of the mature female gametophyte?
5. What is meant by "double fertilization" in angiosperms, and what are the products of this phenomenon?
6. What are some of the conditions that promote outcrossing in angiosperms, and under what circumstances might self-pollination be more advantageous than outcrossing?

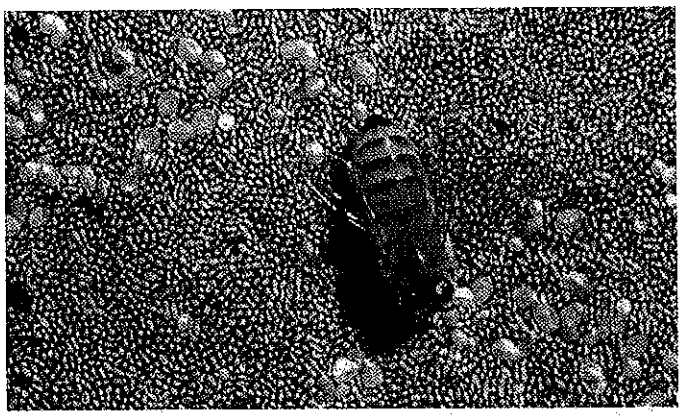
Angiosperms—the flowering plants—make up much of the visible world of modern plants. Trees, shrubs, lawns, gardens, fields of wheat and corn, wildflowers, fruits and vegetables on the grocery shelves, the bright splashes of color in a florist's window, the geranium on a fire escape, duckweed and water lilies, eel grass and turtle grass, saguaro cacti and prickly pears—wherever you are, flowering plants are there also.

Diversity in the Phylum *Anthophyta*

Angiosperms make up the phylum *Anthophyta*, which includes about 235,000 species and is thus, by far, the largest phylum of photosynthetic organisms. In their vegetative features, angiosperms are enormously diverse. In size, they range from species of *Eucalyptus* trees well over 100 meters tall with trunks nearly 20 meters in girth (Figure 21–1), to some duckweeds, which are simple, floating plants often scarcely 1 millimeter long (Figure 21–2). Some angiosperms are vines that climb high into the canopy of the tropical rainforest, while others are epiphytes that grow in that canopy. Many angiosperms, such as cacti, are adapted for growth in extremely arid regions. For over 100 million years, the flowering plants have dominated the land.

In terms of their evolutionary history, the angiosperms are a group of seed plants with special characteristics: flowers, fruits, and distinctive life-cycle features that differ from those of all other plants. In this chapter, we outline these characteristics and place them in perspective, and in the following chapter, we discuss the evolution of the angiosperms. In Section 5, we consider in some detail the structure and development of the angiosperm plant body (sporophyte).

Angiosperms share so many features that do not exist in other plants that it is clear they were derived from a single common ancestor (a monophyletic group). Current investigations, based on an improved understanding of the fossil record, as well as better methods of analysis and comparisons of nucleic acid sequences, have led to a clearer recognition of the major evolutionary lines of angiosperms. Two of the major classes into which the group is divided are the *Monocotyledones* (monocots), with about 65,000 species (Figure 21–3), and the *Eudicotyledones* (eudicots), with about 165,000 species (Figure 21–4). Monocots are distinctive, including such familiar plants as the grasses, lilies, irises, orchids, cattails, and palms. The more diverse eudicots include almost all of the familiar trees and shrubs (other than the conifers) and many of the herbs (nonwoody plants). Other groups of archaic flowering plants that are neither monocots nor eudicots will be discussed in Chapter 22. Formerly these plants were grouped with the eudicots as "dicots," but we now know that this is an artificial system of classification that simply overemphasizes the dis-



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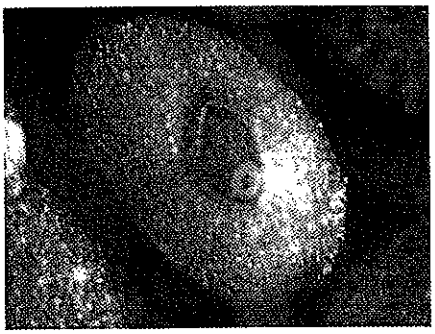

(b)

21–2
The duckweeds (family Lemnaceae*) are the smallest flowering plants. (a) A honeybee resting on a dense floating mat of three species of duckweed. The larger plants are* Lemna gibba*, about 2 to 3 millimeters long; the smaller ones are two species of* Wolffia*, up to 1 millimeter long. (b) A flowering plant of* Wolffia borealis *with a circular concave stigma (looking like a tiny doughnut) and a minute anther just above it, both protruding from a central cavity. The whole plant is less than 1 millimeter long. (c) Flowering plant of* Lemna gibba*; two stamens and a style protrude from a pocket on the upper surface of the plant.*

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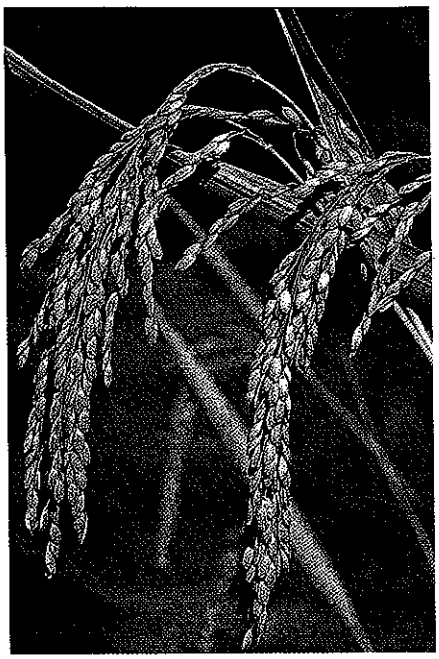
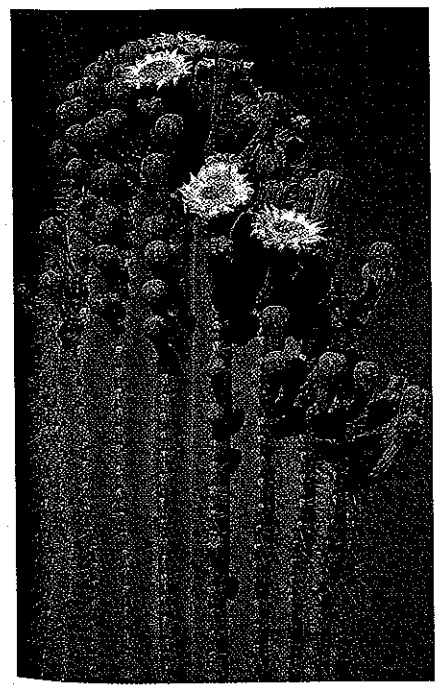


(c)

21–3
*Monocots. **(a)** A member of the palm family, the coconut palm* (Cocos nucifera), *growing in Tehuantepec, Oaxaca, Mexico. A coconut is a drupe, not a nut (see Chapter 22). **(b)** Flowers and fruits of the banana plant* (Musa × paradisiaca). *The banana flower has an inferior ovary, and the tip of the fruit bears a large scar left by the fallen flower parts. **(c)** Rice* (Oryza sativa) *is a member of the grass family.*

21–4
*Eudicots. **(a)** Saguaro cactus* (Carnegiea gigantea). *The cacti, of which there are about 2000 species, are almost exclusively a New World family. The thick, fleshy stems, which store water, contain chloroplasts and have taken over the photosynthetic function of the leaves. **(b)** Round-lobed hepatica* (Hepatica americana), *which flowers in deciduous woodlands in the early spring. The flowers have no petals but have six to ten sepals and numerous spirally arranged stamens and carpels. **(c)** California poppy* (Eschscholzia californica) *is the state flower of California and is protected by law.*



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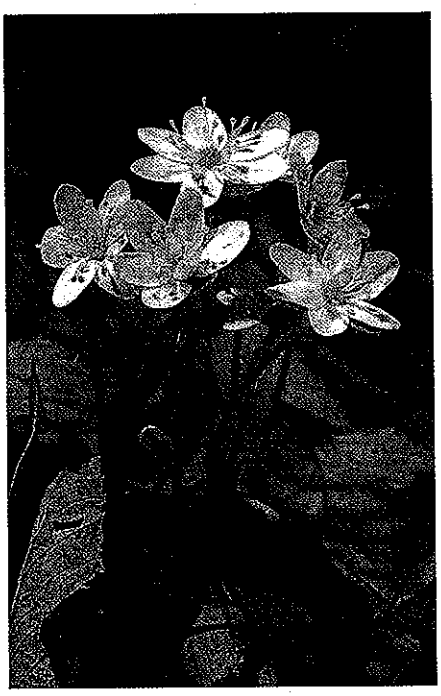

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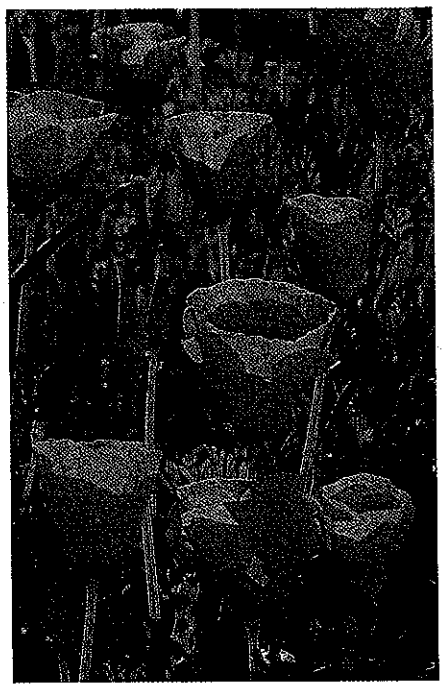

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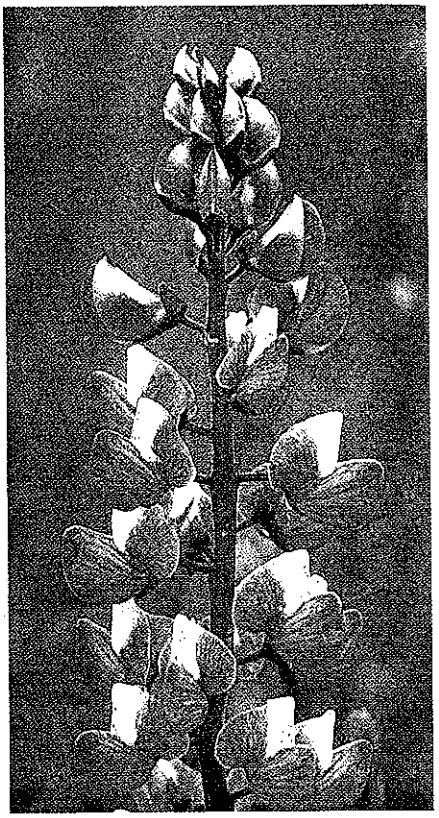

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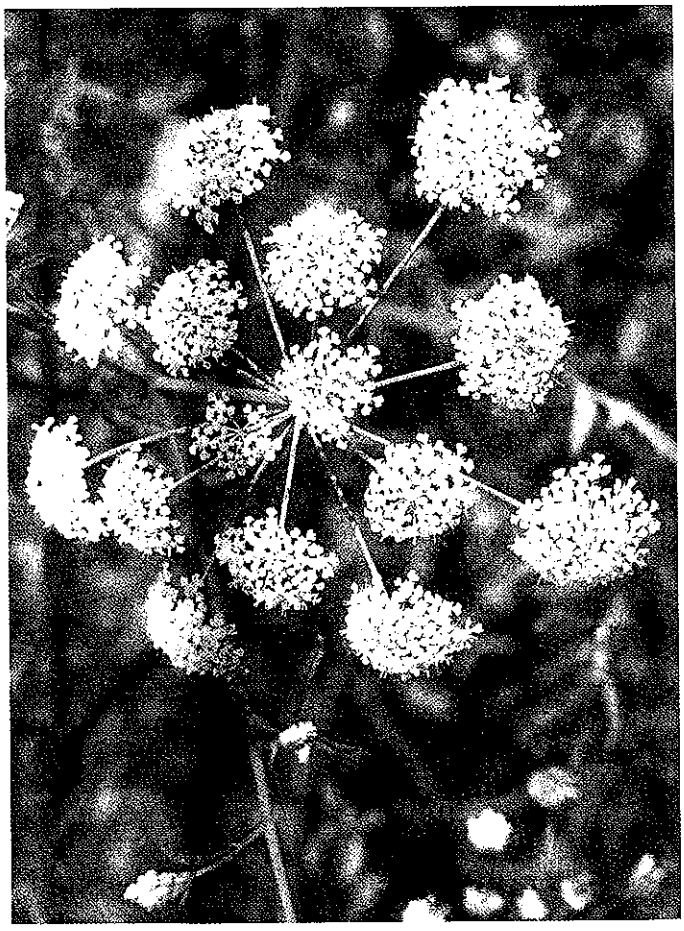


(e)

21–8
Inflorescences of (a) shooting star (Dodecatheon meadia), *(b) butter-and-eggs* (Linaria vulgaris), *(c) lupine* (Lupinus diffusus), *(d) bluebells* (Mertensia virginica), *and (e) water hemlock* (Cicuta maculata). *Using Figure 21–7 as a guide, can you identify the types of inflorescences shown here?*

The Flower Consists of Sterile and Fertile, or Reproductive, Parts Borne on the Receptacle

Many flowers include two sets of sterile appendages, the **sepals** and **petals,** which are attached to the receptacle below the fertile parts of the flower, the **stamens** and **carpels.** The sepals arise below the petals, and the stamens arise below the carpels. Collectively, the sepals form the **calyx,** and the petals form the **corolla.** The sepals and petals are essentially leaflike in structure. Commonly the sepals are green and relatively thick, and the petals are brightly colored and thinner, although in many flowers the members of both whorls (a whorl is a circle of flower parts of one kind) are similar in color and texture. Together, the calyx (the sepals) and corolla (the petals) form the **perianth.**

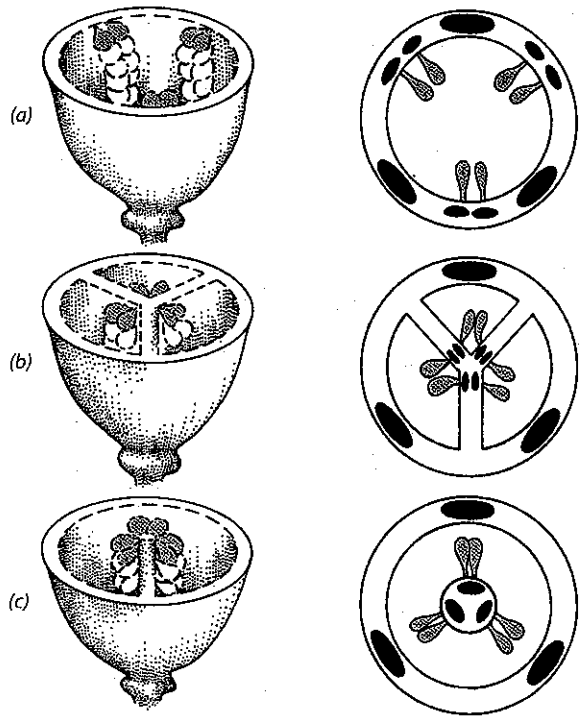
The stamens—collectively the **androecium** ("house of man")—are microsporophylls. In all but a few living angiosperms, the stamen consists of a slender stalk, or **filament,** upon which is borne a two-lobed **anther** containing four microsporangia, or **pollen sacs,** in two pairs—a characteristic defining feature of angiosperms.

The carpels—collectively the **gynoecium** ("house of woman")—are megasporophylls that are folded lengthwise, enclosing one or more ovules. A given flower may contain one or more carpels, which may be separate or fused together, in part or entirely. Sometimes the individual carpel or the group of fused carpels is called a **pistil.** The word "pistil" comes from the same root as "pestle," the instrument with a similar shape that pharmacists use for grinding substances into a powder in a mortar.

In most flowers, the individual carpels or groups of fused carpels are differentiated into a lower part, the **ovary,** which encloses the ovules; a middle part, the **style,** through which the pollen tubes grow; and an upper part, the **stigma,** which receives the pollen. In some flowers, a distinct style is absent. If the carpels are fused, there may be a common style, or each carpel may retain a separate one. The common ovary of such fused carpels is generally (but not always) partitioned into two or more **locules**—chambers of the ovary that contain the ovules. The number of locules is usually related to the number of carpels in the gynoecium.

The Ovules Are Attached to the Ovary Wall at the Placenta

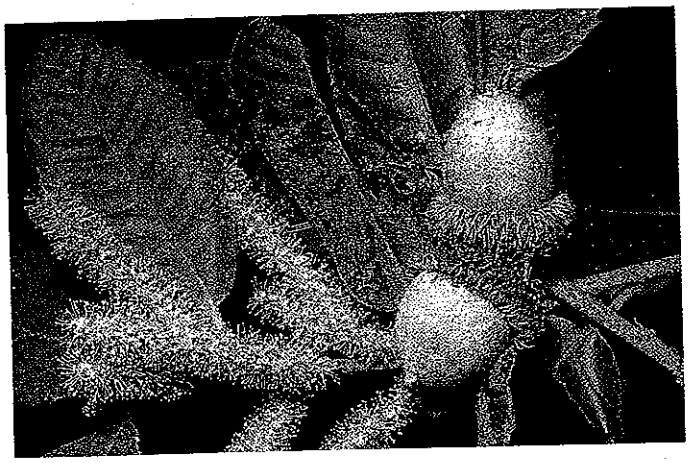
The portion of the ovary where the ovules originate and to which they remain attached until maturity is called the **placenta.** The arrangement of the placentae—known as the **placentation**—and consequently of the ovules varies among different groups of flowering plants (Figure 21–9). In some, the placentation is *parietal;* that is, the ovules are borne on the ovary wall or on extensions of it. In other flowers, the ovules are borne on a central column of tissue in a partitioned ovary with as many locules as there are carpels. This is *axile* placentation. In still others, the placentation is *free central,* the ovules being borne on a central column of tissue not connected by partitions with the ovary wall. And finally, in some flowers a single ovule occurs at the base or apex of a unilocular ovary. This is known as *basal* or *apical* placentation. These differences are important in the classification of the flowering plants.



21–9
Types of placentation, with the ovules indicated in color. (a) Parietal. (b) Axile. (c) Free central. Basal and apical placentation, a single ovule at the base or apex of a unilocular ovary, are not shown here. The vascular bundles are shown as solid structures in the ovary walls.

There Are Many Variations in Flower Structure

The majority of flowers include both stamens and carpels, and such flowers are said to be **perfect** (bisexual). If either stamens or carpels are missing, the flower is **imperfect** (unisexual) and, depending on the part that is present, the flower is said to be either **staminate** or **carpellate** (or pistillate) (Figure 21–10). If both staminate and carpellate flowers occur on the same plant, as in maize (see Figure 22–32a, b) and the oaks, the species is said to be **monoecious** (from the Greek words *monos,* "single," and *oikos,* "house"). If staminate and carpellate flowers are found on separate plants, the species is said to be **dioecious** ("two houses"), as in the willows and hemp *(Cannabis sativa).*



21–10
Staminate and carpellate flowers of a tanbark oak (Lithocarpus densiflora), *of the family* Fagaceae. *Most members of this family, including the true oaks* (Quercus), *are monoecious, meaning that the staminate and carpellate flowers are separate but are borne on the same tree.*

Any one of the floral whorls—sepals, petals, stamens, or carpels—may be lacking in the flowers of certain groups. Flowers with all four floral whorls are called **complete** flowers. If any whorl is lacking, the flower is said to be **incomplete.** Thus an imperfect flower is also incomplete, but not all incomplete flowers are imperfect.

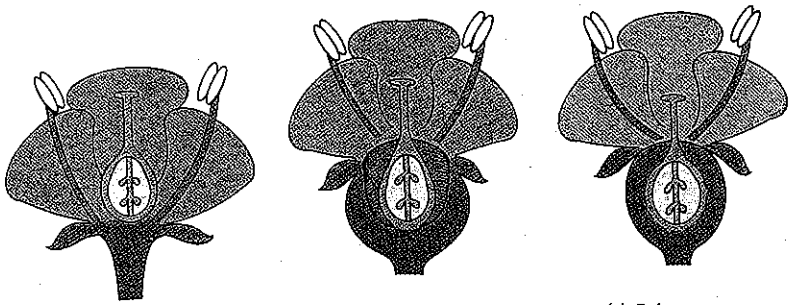
The particular arrangement of the floral parts may be spiral on a more or less elongated receptacle, or similar parts—such as petals—may be attached in a whorl. The parts may be united with other members of the same whorl *(connation)* or with members of other whorls *(adnation).* An example of adnation is the union of stamens with the corolla (stamens adnate to the corolla), which is fairly common. When the floral parts of the same whorl are not joined, the prefixes *apo-* (meaning "separate") or *poly-* may be used to describe the condition. When the parts are connate, either *syn-* or *sym-* ("together") is used. For example, in an aposepalous or polysepalous calyx, the sepals are not joined; in a synsepalous one, they are.

In addition to this variation in arrangement of flower parts (spiral or whorled), the level of insertion of the sepals, petals, and stamens on the floral axis varies in relation to the ovary or ovaries (Figure 21–11). If the sepals, petals, and stamens are attached to the receptacle below the ovary, as they are in lily, the ovary is said to be **superior** (Figure 21–6). In other flowers the sepals, petals, and stamens apparently are attached near the top of the ovary, which is **inferior.** Intermediate conditions, in which part of the ovary is inferior, also occur in a number of kinds of plants.

In terms of their points of insertion, the perianth and stamens are said to be **hypogynous**—situated on the receptacle beneath the ovary and free from it and from the calyx (Figure 21–6); **epigynous**—arising from the top of the ovary (Figure 21–12); or **perigynous**—with the stamens and petals adnate to the calyx and thus forming a short tube *(hypanthium)* arising from the base of the ovary (Figure 21–13).

Finally, mention should be made of symmetry in flower structure. In some flowers, the members of the different whorls of the flower are made up of members of similar shape that radiate from the center of the flower and are equidistant from each other; they are radially symmetrical. Such flowers—tulips are an example—are said to be **regular,** or actinomorphic (from the Greek root *aktin-*, "ray"). In other flowers, one or more members of at least one whorl are different from other members of the same whorl, and such flowers are generally bilaterally symmetrical. Bilaterally symmetrical flowers—for example, snapdragons—are said to be **irregular,** or zygomorphic (Gk. *zygon*, "yoke" or "pair"). Some regular flowers have irregular color patterns, which give their visitors an image similar to that of a structurally irregular flower.

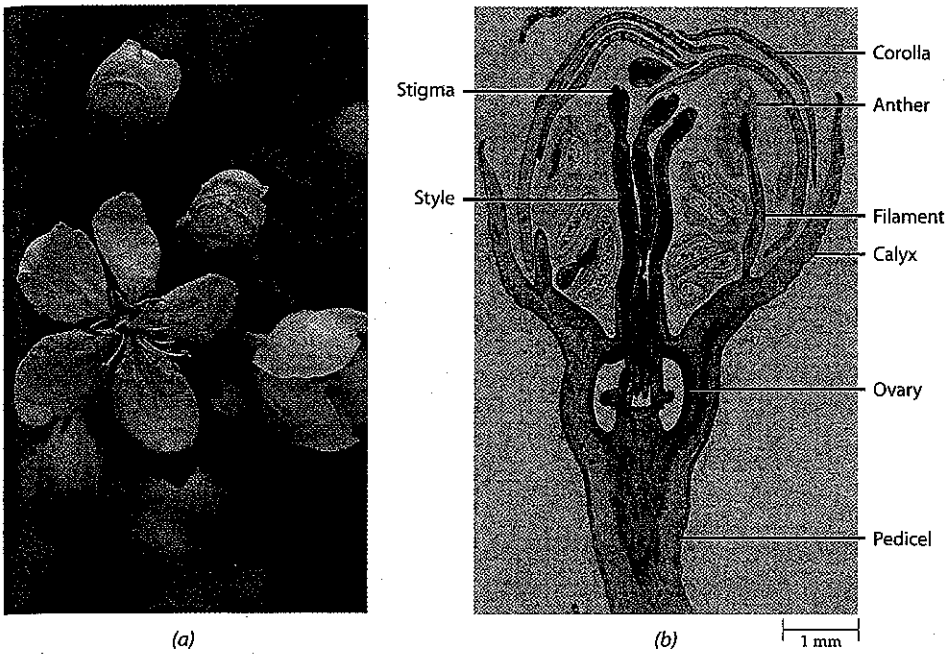
21–11
Types of flowers in common families of eudicots, showing differences in the position of the ovary. ***(a)*** *In* Ranunculaceae, *the buttercup family, for example, the sepals, petals, and stamens are attached below the ovary and there is no fusion; such flowers are said to be hypogynous.* ***(b)*** *In contrast, many* Rosaceae, *such as cherries, have superior ovaries, with the sepals, petals, and stamens fused together to form a cup-shaped extension of the receptacle called the hypanthium. Such flowers are said to be perigynous.* ***(c)*** *The flowers of other plants, for example* Apiaceae, *the parsley family, have inferior ovaries; that is, the sepals, petals, and stamens appear to be attached above the ovaries. Such flowers are said to be epigynous.*



(a) Hypogynous flower

(b) Perigynous flower

(c) Epigynous flower



21–12
Apple (Malus sylvestris) *flowers, (a) and (b), exhibit epigyny—their sepals, petals, and stamens apparently arise from the top of the ovary. In (b) the flower is nearly open, but the stamens are not yet erect.*

The Angiosperm Life Cycle

Angiosperm gametophytes are much reduced in size—more so than those of any other heterosporous plants, including the other seed plants (gymnosperms). The mature microgametophyte consists of only three cells. The mature megagametophyte (embryo sac), which is retained for its entire existence within the tissues of the sporophyte, or specifically of the ovule, consists of only seven cells in most kinds of angiosperms. Both antheridia and archegonia are lacking. Pollination is indirect; that is, pollen is deposited on the stigma, after which the pollen tube grows through or on the surface of tissues of the carpel to convey two nonmotile sperm to the female gametophyte. After fertilization, the ovule develops into a seed, which is enclosed in the ovary. At the same time, the ovary (and sometimes additional structures associated with it) develops into a fruit.


(a)

21–13
Cherry (Prunus) *flowers, (a) and (b), exhibit perigyny—their sepals (calyx), petals (corolla), and stamens are attached to a hypanthium. In (b) the filaments of the stamens are bent and crowded in the hypanthium because the flower has not yet opened.*