Reproduction of Flowering Plants

31.9 The flower is the organ of sexual reproduction in angiosperms

It has been said that an oak tree is merely an acorn's way of making more acorns. Indeed, evolutionary fitness for any organism is measured only by its ability to produce healthy, fertile offspring. Thus, from an evolutionary viewpoint, all the structures and functions of a plant can be interpreted as mechanisms contributing to reproduction. In the remaining modules, we explore the reproductive biology of angiosperms, beginning here with a brief overview. (This would be a good time to review Modules 17.6–17.7, where this information was first presented.)

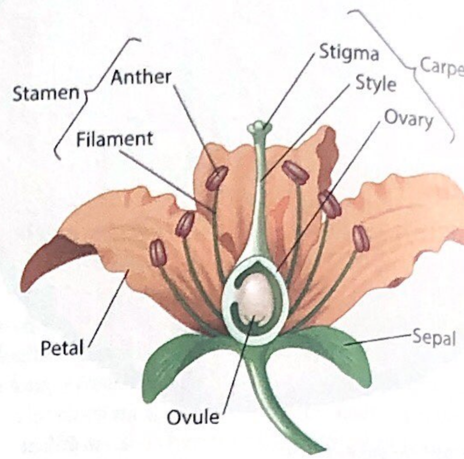
▲ **Figure 31.9A**
Some variations in flower shape

Flowers, the reproductive shoots of angiosperms, can vary greatly in shape (**Figure 31.9A**). Despite such variation, nearly all flowers contain four types of modified leaves called floral organs: sepals, petals, stamens, and carpels (**Figure 31.9B**). The **sepals**, which enclose and protect the flower bud, are usually green and more leaflike than the other floral organs (picture the green wraparound leaves at the base of a rosebud). The **petals** are often colorful and fragrant, advertising the flower to pollinators. The stamens and carpels are the reproductive organs, containing the sperm and eggs, respectively.

A **stamen** consists of a stalk (called the filament) tipped by an anther. Within the **anther** are sacs in which pollen is produced via meiosis. Pollen grains house the cells that develop into sperm.

A **carpel** has a long slender neck (called the style) with a sticky stigma at its tip. The **stigma** is a landing platform for pollen. The base of the carpel is the **ovary**, which contains one or more **ovules**, each containing a developing egg and supporting cells. The term **pistil** is sometimes used to refer to a single carpel or a group of fused carpels.

Figure 31.9C shows the life cycle of a generalized angiosperm. ❶ Fertilization occurs in an ovule within a flower. ❷ As the ovary develops into a fruit, ❸ the ovule develops into the **seed** containing the embryo and a store of food. The fruit protects the seed and aids in dispersing it. Completing the life cycle, ❹ the seed then **germinates** (begins to grow) in a suitable habitat; ❺ the embryo develops into a seedling; and the seedling grows into a mature plant.

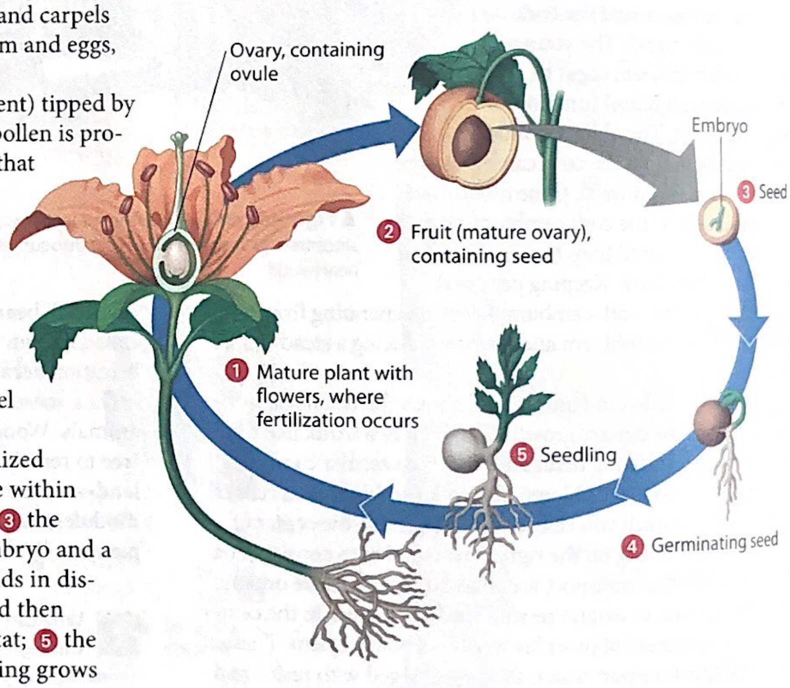


▲ **Figure 31.9B** The structure of a flower

In the next four modules, we examine key stages in the angiosperm life cycle in more detail. We will see that there are a number of variations in the basic themes presented here.

? **Pollen develops within the ________ of ________.**
Ovules develop within the ________ of ________.

● anthers . . . stamens . . . ovaries . . . carpels



▲ **Figure 31.9C** Life cycle of a generalized angiosperm

31.10 The development of pollen and ovules culminates in fertilization

The life cycles of plants are characterized by an alternation of generations, in which haploid (n) and diploid ($2n$) generations take turns producing each other (Figure 31.10). The diploid plant body is called the **sporophyte**. A sporophyte produces special structures, the anthers and ovules, in which cells undergo meiosis to produce haploid cells called spores. Each spore then divides via mitosis and becomes a multicellular **gametophyte**, the plant's haploid generation. The gametophyte produces gametes by mitosis. At fertilization, gametes from the male and female gametophytes unite, producing a diploid zygote. The life cycle is completed when the zygote divides by mitosis and develops into a new sporophyte. In angiosperms, the sporophyte is the dominant generation: It is larger, more obvious, and longer-living than the gametophyte.

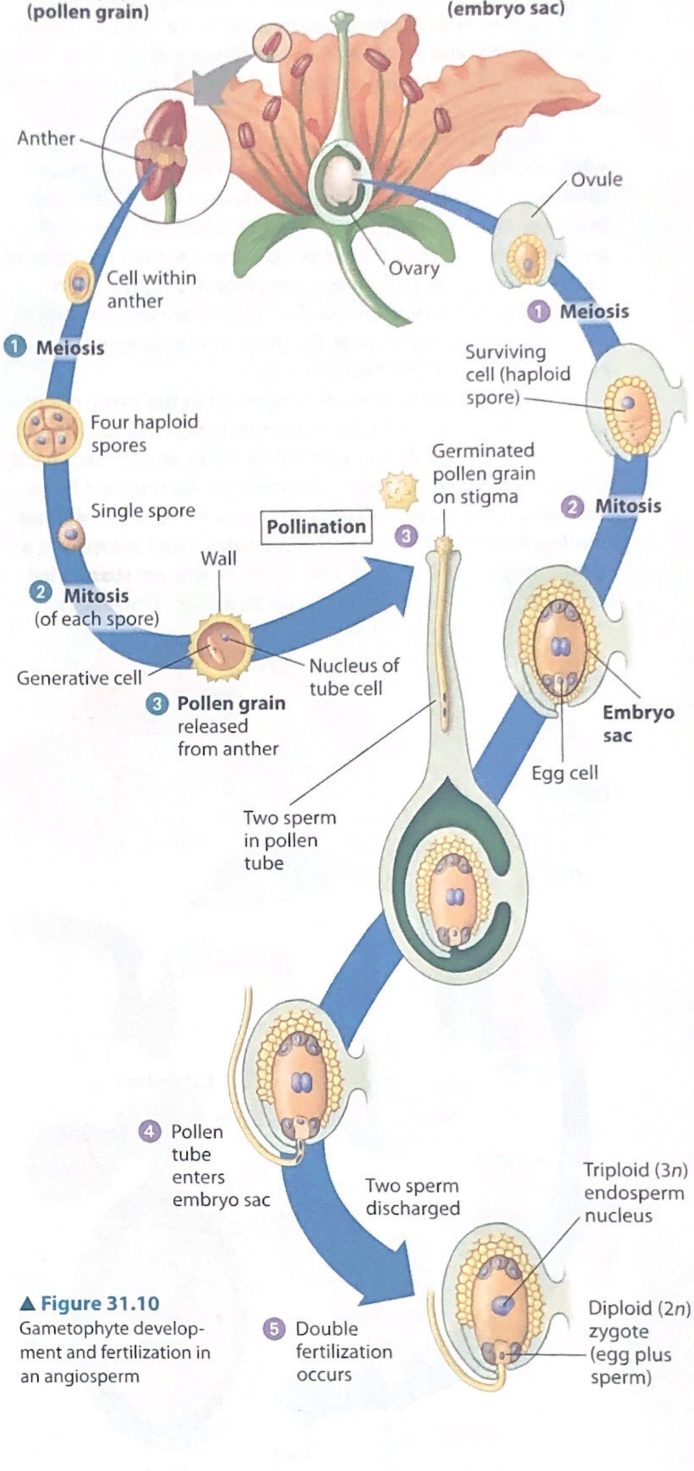
The cells that develop into pollen grains (the male gametophytes) are found within a flower's anthers. ① Each cell first undergoes meiosis, forming four haploid spores. ② Each spore then divides by mitosis, forming two haploid cells, called the tube cell and the generative cell. The generative cell passes into the tube cell, and a thick wall forms around them. ③ The resulting pollen grain is ready for release from the anther.

In most species, the ovary of a flower contains several ovules, but only one is shown at the top of the figure. An ovule contains a central cell (gold) surrounded by a protective covering of smaller cells (yellow). ① The central cell enlarges and undergoes meiosis, producing four haploid spores. Three of the spores usually degenerate, but the surviving one enlarges and ② divides by mitosis, producing a multicellular structure known as the **embryo sac**. Housed in several layers of protective cells (yellow) produced by the sporophyte plant, the embryo sac is the female gametophyte. The sac contains a large central cell with two haploid nuclei. One of its other cells is the haploid egg, ready to be fertilized.

③ The first step leading to fertilization is **pollination**, the transfer of pollen from anther to stigma. Most angiosperms depend on insects (mainly bees), birds, or other animals to transfer pollen. But the pollen of some plants—such as grasses and many trees—is windborne (causing pollen allergies in some people).

After pollination, the pollen grain germinates on the stigma. Its tube cell gives rise to the pollen tube, which grows downward into the ovary. Meanwhile, the generative cell divides by mitosis, forming two sperm. ④ When the pollen tube reaches the base of the ovule, it enters the ovary and discharges its two sperm near the embryo sac. ⑤ One sperm fertilizes the egg, forming the diploid zygote. The other contributes its haploid nucleus to the large diploid central cell of the embryo sac. This cell, now with a triploid ($3n$) nucleus, will give rise to a food-storing tissue called **endosperm**.

The union of two sperm cells with different nuclei of the embryo sac is called **double fertilization**, and the resulting production of endosperm is unique to angiosperms. Endosperm will develop only in ovules containing a fertilized egg, thereby preventing angiosperms from squandering nutrients.



▲ **Figure 31.10** Gametophyte development and fertilization in an angiosperm

? What are the two products of double fertilization?

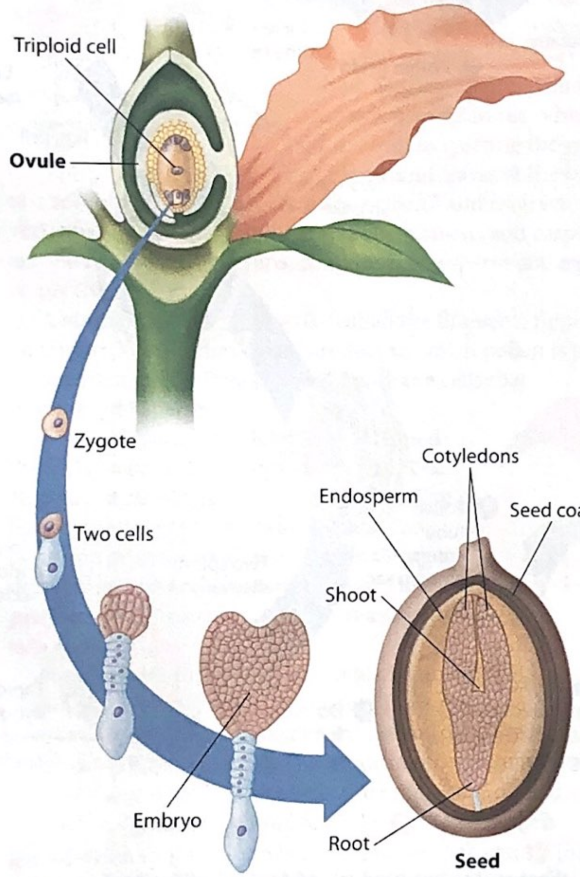
● A zygote and endosperm

31.11 The ovule develops into a seed

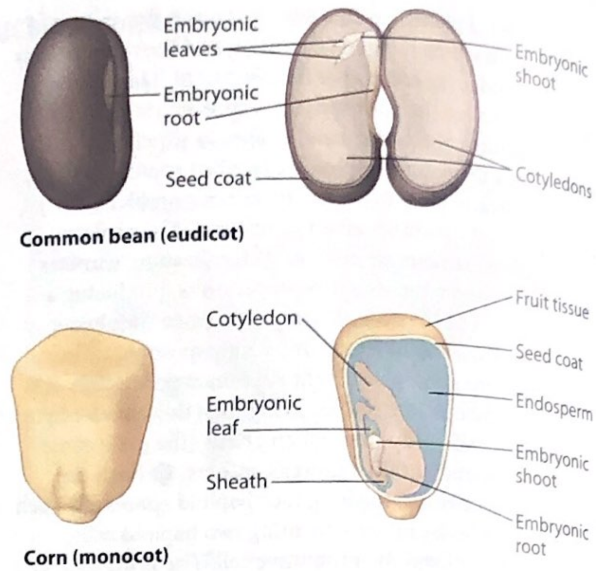
After fertilization, the ovule, containing the triploid central cell and the diploid zygote, begins developing into a seed. As the embryo develops from the zygote, the seed stockpiles proteins, oils, and starch to varying degrees, depending on the species. This is what makes seeds such a major source of nutrition for many animals.

As shown in **Figure 31.11A**, embryonic development begins when the zygote divides by mitosis into two cells. Repeated division of one of the cells then produces a ball of cells that becomes the embryo. Meanwhile, the other cell from the zygote divides to form a thread of cells that anchors the embryo to the parent plant and pushes the embryo into the endosperm. The bulges you see on the embryo are the developing cotyledons. You can tell that the plant in this drawing is a eudicot, because it has two cotyledons.

The result of embryonic development in the ovule is a mature seed (Figure 31.11A, bottom right). Near the end of its maturation, the seed loses most of its water and forms a hard, resistant **seed coat** (brown). The embryo, surrounded by its endosperm food supply (gold), becomes dormant; it will not develop further until the seed germinates. Seed dormancy, a condition in which growth and development are suspended temporarily, is a key evolutionary adaptation. Dormancy allows time for a plant to disperse its seeds and increases the chance that a new generation of plants will begin growing only when environmental conditions, such as temperature and moisture, favor survival.



▲ **Figure 31.11A** Development of a eudicot plant embryo



▲ **Figure 31.11B** Seed structure in eudicots and monocots

The dormant embryo contains a miniature root and shoot, each equipped with an apical meristem. After the seed germinates, the apical meristems will sustain primary growth as long as the plant lives. Also present in the embryo are the three tissues that will form the epidermis, cortex, and primary vascular tissues.

Figure 31.11B contrasts the internal structures of eudicot and monocot seeds. In the eudicot (illustrated here as a bean), the embryo is an elongated structure with two thick cotyledons (tan). The embryonic root develops just below the point at which the cotyledons are attached to the rest of the embryo. The embryonic shoot, tipped by a pair of miniature embryonic leaves, develops just above the point of attachment. The bean seed contains no endosperm because its cotyledons absorb the endosperm nutrients as the seed forms. The nutrients start passing from the cotyledons to the embryo when it germinates.

A kernel of corn, an example of a monocot, is actually a fruit containing one seed. Everything you see in the drawing is the seed, except the kernel's outermost covering. The covering is dried fruit tissue, the former wall of the ovary, and is tightly bonded to the seed coat. Unlike the bean, the corn seed contains a large endosperm and a single, thin cotyledon. The cotyledon absorbs the endosperm's nutrients during germination. Also unlike the bean, the embryonic root and shoot in corn each have a protective sheath.

? **What is the role of the endosperm in a seed?**

The endosperm provides nutrients to the developing embryo.

31.12 The ovary develops into a fruit

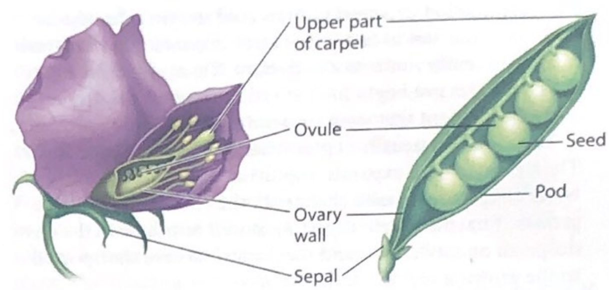
In the previous two modules, we followed the angiosperm life cycle from the flower on the sporophyte plant through the transformation of an ovule into a seed. While the seeds are developing from ovules, hormonal changes triggered by fertilization cause the flower's ovary to grow, thicken, and mature into a fruit. A **fruit** is a mature ovary that acts as a vessel, housing and protecting seeds and helping disperse them from the parent plant. Although a fruit typically consists of a mature ovary, it can include other flower parts as well. A pea pod is a fruit that holds the peas (the seeds of the pea plant; Figure 31.12A). Other easily recognizable fruits include a peach, orange, tomato, cherry, or corn kernel.

▲ Figure 31.12A A pod, the fruit of a pea plant, holds the peas (seeds)

Figure 31.12B matches the parts of a pea flower with what they become in the pod. The wall of the ovary becomes the pod. The ovules, within the ovary, develop into the seeds. The small, thread-like structure at the end of the pod is what remains of the upper part of the flower's carpel. The sepals of the flower often stay attached to the base of the green pod. Peas are usually harvested at this stage of fruit development. If the pods are allowed to develop further, they become dry and brownish and will split open, releasing the seeds.

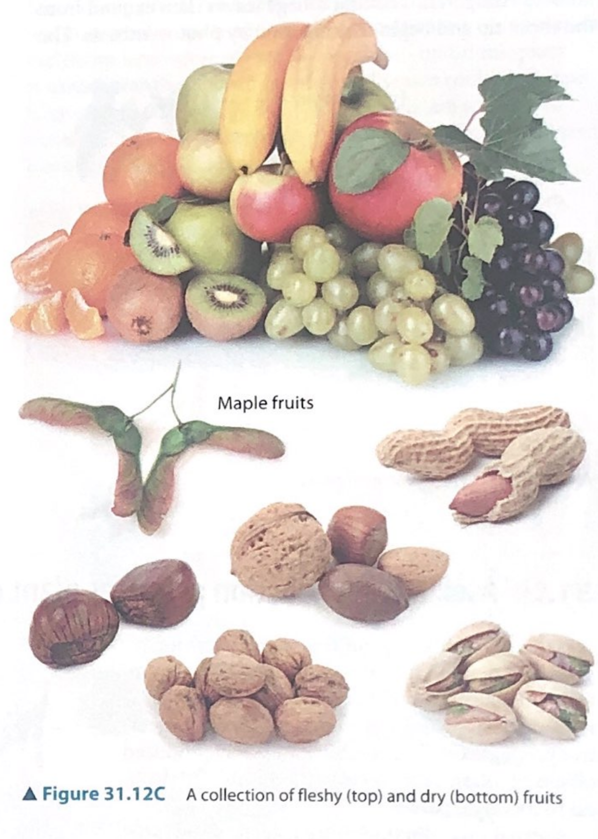
As shown in the examples in Figure 31.12C, mature fruits can be either fleshy or dry. Oranges, plums, and grapes are examples of fleshy fruits, in which the wall of the ovary becomes soft during ripening. Dry fruits include beans, nuts, and grains. The dry, wind-dispersed fruits of grasses, harvested while on the plant, are major staple foods for people. The cereal grains of wheat, rice, corn, and other grasses, though easily mistaken for seeds, are each actually a fruit with a dry outer covering (the former wall of the ovary) that adheres to the seed coat of the seed within.

Various adaptations of fruits help disperse seeds (Module 17.8). The seeds of some flowering plants, such as dandelions and maples, are contained within fruits that function like kites or propellers, adaptations that enhance dispersal by wind. Some fruits, such as coconuts, are adapted to dispersal by water. And many angiosperms rely on animals to carry seeds. Some of these plants have fruits modified as burrs that cling to animal fur (or the clothes of humans). Other angiosperms produce edible fruits, which are usually nutritious, sweet tasting, and vividly colored, advertising their ripeness. When an animal eats the fruit, it digests the fruit's fleshy part, but the tough seeds usually pass unharmed through the animal's digestive tract. Animals may deposit the seeds, along with a supply of fertilizer, kilometers from where the fruit was eaten.



▲ Figure 31.12B The correspondence between flower and fruit in the pea plant

Try This Explain why tomatoes and squash are more accurately called fruits rather than vegetables.



▲ Figure 31.12C A collection of fleshy (top) and dry (bottom) fruits

? Seed is to ____________ as ____________ is to ovary.

ovule ... fruit