

## Chapter 4

### Biology of Flowering Plants: Reproduction

### Gametophytes, Fruits, Seeds, and Embryos

#### *Objectives*

**Angiosperms.** Understand alternation of generations. Understand the life cycle of angiosperms. Identify differences in the angiosperm life cycle and that of other plants. Understand micro- and megagametophyte development. Know which parts of the flower give rise to which parts of the fruit. (For example, the ovule gives rise to the seed.) Understand double fertilization and development of the seed and fruit.

**Seeds.** Understand the advantage of seeds for vascular plants in a terrestrial environment. Contrast the seeds of gymnosperms and angiosperms. Understand structures in seeds and their functions. Contrast the mature seeds of monocots and dicots.

**Fruits.** Understand the functions of fruits. Know the types of fruits. Understand modes of seed dispersal. Understand the relationship between the modes of seed dispersal and the structures of fruits.

#### *The Life Cycle of Flowering Plants*

The life cycle of plants is descriptively termed alternation of generations<sup>1</sup>. The alternating generations are the haploid, gamete-producing generation, the gametophyte, and the diploid, spore-producing generation, the sporophyte. Angiosperms have small gametophytes comprising only a few cells and large sporophytes. In this lab, we will observe and gain an understanding of aspects of the angiosperm life cycle including the microscopic gametophyte generations; seeds, formed from double fertilization and containing the embryo (new sporophyte generation) and endosperm; and fruits (the vessels that encase angiosperm seeds) and other forms of seed dispersal.

#### *Development of the Microgametophyte<sup>2</sup>*

The diploid sporophyte generation of angiosperms produces two types of spores through meiosis, one that develops through mitosis into a megagametophyte, which produces the egg, and one that develops through mitosis into the microgametophyte, which produces the sperm (two sperm cells for double fertilization). Both the mega- and microgametophytes are born on the floral organs of angiosperms. The microgametophyte forms within the anthers of the stamens. Each anther has pollen sacs containing hundreds of microspore mother cells<sup>3</sup>.

During microsporogenesis, each microspore mother cell undergoes meiosis to produce haploid microspores. These haploid microspores then develop into microgametophytes through mitosis, a process called microgametogenesis. First, the single haploid nucleus of the microspore undergoes

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<sup>1</sup> p. 236

<sup>2</sup> pp. 442-444

<sup>3</sup> Fig. 19-14

mitosis, then, one of these nuclei undergoes mitosis again resulting altogether in three haploid cells. Two of these cells, the sperm (gametes), are within the third cell, called the vegetative or tube cell. Both sperm undergo separate fusion events (syngamy) in double fertilization as will be described later. These three cells are the mature microgametophyte<sup>4</sup>, the pollen grain. The pollen grain is released from the sporophyte at or before maturity.

Each pollen grain has a protective wall, which causes allergic reactions in some humans. As indicated, the microgametophyte contains gametes that undergo syngamy within the megagametophyte, which, in angiosperms, is contained within the ovary of the carpel. During pollination, the microgametophyte lands on the stigma, an extension of the ovary; then, the tube cell containing the microgametes (sperm cells) grows down the style of the carpel until it reaches the megagametophyte. More about fertilization will be discussed later. We will observe the process of pollen-tube growth.

### **Specimen 1: pollen grains (try to observe growth of the pollen tube)**

1. Place a drop of pollen-growth medium (sucrose solution) on each of two slides.
2. Obtain an anther from at least two different types of flowers.
3. Dust a few pollen grains onto the medium and place a coverslip on top. Label your slides to know which type of pollen is on the slide.
4. Observe each at 10x.
5. After at least 10 minutes, observe and draw the pollen, which may be growing a pollen tube, again under 10x. Make comparisons with a partner.
6. Answer the following questions in your lab notebook.
  - a. Do all pollen grains develop pollen tubes uniformly?
  - b. Some pollen grains readily make pollen tubes in a nutrient solution. Do you think this poses a problem for pollination/fertilization specificity? Explain why or why not.
  - c. What are possible mechanisms that plants may have evolved for pollination/fertilization specificity?

### ***Development of the Megagametophyte***<sup>5</sup>

The diploid sporophyte generation of angiosperms produces two types of spores through meiosis, one that develops by mitosis into a megagametophyte, which produces the egg, and one that develops by mitosis into the microgametophyte, which produces sperm. Both the mega- and microgametophytes form within the floral organs of angiosperms. The megagametophyte is born within the ovules, which are within the ovary, the base of the carpel. There may be one or many ovules per ovary. (Some ovaries have up to several chambers, each one with many ovules, that arise from carpel fusion.)

Each ovule of the sporophyte contains hundreds of cells. During megasporogenesis, one of these diploid cells that is surrounded by many other cells differentiates into a megaspore mother cell (a.k.a. megasporocyte)<sup>6</sup>, which, through meiosis, produces four haploid spores. Three of these spores degenerate, leaving one haploid megaspore per ovule.

<sup>4</sup> Fig. 19-16

<sup>5</sup> pp. 444-446

<sup>6</sup> Fig. 19-18a, b

During megagametogenesis, the haploid megaspore develops into the megagametophyte through three mitotic divisions, which are not immediately followed by karyokinesis, thus producing eight nuclei within the cell wall and membrane of the original megaspore. The eight nuclei become arranged into three groups, one group of three at each end of the megagametophyte, leaving two in the middle. Then, cell walls and membranes develop around each nucleus except the two in the middle. The resultant mature megagametophyte<sup>7</sup> consists of (a) three cells (the egg cell (megagamete) and two synergids) near the micropyle (opening in the integuments that allows the pollen tube access to the megagametophyte), (b) three antipodal cells at the end of the megagametophyte opposite the egg cell, and (c) the original larger cell that contains the two polar nuclei in the middle of the megagametophyte. Thus, the mature megagametophyte generation of angiosperms consists of only seven cells with eight nuclei and is contained within the ovule, surrounded by the integument (made of diploid cells of the sporophyte). The two polar nuclei and the egg cell participate in double fertilization, which is a distinguishing characteristic of angiosperms. Although the mature megagametophyte is a separate generation (a separate plant), in angiosperms, it is dependent on the sporophyte generation for nutrition and protection, essentially, a plant within a plant.

**Specimen 2: Prepared slide of cross section of *Lilium* ovary (to observe ovules containing the megagametophyte with egg cells)**

1. Before observing the slide, sketch a carpel indicating the stigma, style, ovary, and ovules. Draw a line that demonstrates a cross section of the middle of the ovary
2. Observe, draw, and label the specimen under 4x. This ovary has six chambers or locules (resulting from carpel fusion), each one contains one ovule. Answer the following in your notebook: based on this observation of the ovary, is *Lilium* a monocot or a dicot?
3. Observe one of the ovules under 10x. Do you see a megagametophyte? If not, move to another ovule until you locate one.
4. Draw an ovule containing a megagametophyte at 10x. Label the ovule and megagametophyte. Label, or indicate where you expect to find, the egg cell and the polar nuclei. Indicate the ploidy level of each of the labeled structures.

***Double Fertilization: Development of Seed and Fruit***

So far in this chapter, we have learned about the development of the micro- and megagametophytes. The gametes of these haploid generations undergo syngamy to form a zygote, the new diploid sporophyte generation<sup>8</sup>, which, in all plants, develops into an embryo.

After pollination, the microgametophyte is recognized by the stigma. The stigma provides the necessary environment for growth and penetration of the pollen tube down through the style to reach the ovule-containing ovary<sup>9</sup>. The megagametophyte is enclosed by the integument (of the maternal sporophyte generation). The pollen tube accesses the megagametophyte through the micropyle, an opening in the integument, and releases the two sperm cells into the megagametophyte.

One sperm cell fertilizes the egg cell resulting in a diploid zygote (new sporophyte generation). The other sperm cell fuses with the polar nuclei in the middle of the megagametophyte resulting

<sup>7</sup> Fig. 19-19

<sup>8</sup> p. 236 (Fig. 12-15c)

<sup>9</sup> Fig. 19-20

in a triploid endosperm. These two fertilization events are termed double fertilization<sup>10</sup>, which occurs only in angiosperms.

After double fertilization, the embryo and endosperm develop within the seed coat, which is derived from the “maternal” sporophyte. The ovary and, sometimes, associated tissue develop into the fruit. During seed development, the triploid endosperm grows mitotically and accumulates storage nutrients. In dicots<sup>11</sup>, the diploid embryo (including the cotyledons) then continues to grow through mitosis; the growth is supported by nutrients from the endosperm and continued release of nutrients from the seed coat. In contrast, the monocot embryo is small<sup>12</sup>, and the single cotyledon only absorbs endosperm nutrients when the endosperm degrades during germination. Thus, comparing monocot and dicot seeds, mature dicot seeds contain larger cotyledons and little endosperm; whereas, monocot seeds have a small cotyledon and much endosperm<sup>13</sup>. The integument, derived from the sporophyte tissue, becomes the seed coat. The ovary, which contained the ovule, develops into the fruit. There is a large diversity in fruit structure, as will be discussed in the next section. Fruits provide protection, nutrients, and, most importantly, a means of dispersal for the seeds that they contain.

See pages 448-449 for a complete review of the angiosperm life cycle demonstrated with soybean.

**Specimen 3: Prepared slide of longitudinal section of the *Capsella* ovary with seeds (to observe structures of a mature dicot embryo)**

1. Observe under 4x, draw, and label. The whole structure on the slide is the fruit and each small, oval structure within the fruit is a seed.
2. Observe under 10x, draw, and label one embryo-containing seed. Each embryo has a root apical meristem and a shoot apical meristem. Meristems are regions of perpetual growth. Each embryo also has one (monocots) or two (dicots) cotyledons. Label the seed, seed coat, embryo, cotyledons, root apical meristem, shoot apical meristem, and remains of endosperm.

### ***Seed Dispersal***

Once the embryo is fully developed, the seed dries out and becomes dormant. The power of seeds as reproductive structures lies partly in their stored food reserves, partly in their ability to remain dormant while awaiting the proper growing conditions, and partly in their adaptations for dispersal. The fruit plays a critical role in seed dispersal. The reproductive strategy of each species is reflected in the structure of its seeds and fruits. Seed dispersal is particularly important because it facilitates invasion of new environments. Obviously, the seed was a remarkable evolutionary adaptation to terrestrial environments.

A fruit<sup>14</sup>, which develops primarily from the ovary following fertilization and seed development, may be either fleshy or dry. Fleshy fruits such as apples, oranges, and berries are adapted for dispersal by animals. The animals eat the fruit, but the seeds pass through the animal's digestive tract unharmed and, when they emerge, have not only been transported to a new habitat but have

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<sup>10</sup> Fig. 19-21

<sup>11</sup> Fig. 22-3

<sup>12</sup> Fig. 22-8, 22-13

<sup>13</sup> Fig. 22-7

<sup>14</sup> pp. 466-470

received an application of fertilizer as well! Some dry fruits, such as nuts, are also adapted for dispersal by animals. In nuts, the ovary wall dries out and forms a hard covering around the seed. Nuts are collected by small mammals, which take them to their burrows or bury them, as squirrels do. In the spring, the nuts that have not been eaten sprout. Other dry fruits are adapted for dispersal by wind, such as the winged fruits of maples and dandelions.

Still others have burrs, cling to animal fur and are thus transported to new habitats. Another interesting adaptation is found in fruits that dry out and discharge their seeds explosively. But perhaps the most unusual dispersal mechanism is that of the coconut, which has colonized all of the South Seas atolls by floating from island to island.

Fruits are generally classified as simple, multiple, or aggregate, depending on the arrangement of the carpels from which the fruit develops.

Simple fruits develop from one carpel or from fused carpels. Simple fruits may be fleshy, dry, or papery. Dry simple fruits may be dehiscent, the ovary wall opens and frees the seeds, or indehiscent, the seeds remain in the fruit after the fruit has been shed from the parent plant. Examples of dehiscent fruits include legumes<sup>15</sup> (e.g. peas) and poppies<sup>16</sup>. The most common indehiscent fruit is the **achene**, which is single-seeded. Examples of achenes include the fruits of ashes<sup>17</sup>, elms, grasses<sup>18</sup>, and strawberries. The fleshy part of the strawberry is a swollen receptacle and the “seeds” are the achene fruits.

Some common simple, fleshy fruits are described below.

**Berry.** Tomatoes, dates, and grapes are examples of berries. Each carpel typically contains many seeds. The inner layer of a berry is fleshy.

**Drupe.** The inner layer of the fruit, derived from the ovary wall, is hard and stony and usually sticks tightly to the seed. Peaches, cherries, olives, plums, and coconuts (which are not nuts) are examples of drupes. The outer layer of the drupe is often fleshy; in the coconut, though, it is fibrous. The coconut is a monocot and the seed retains its endosperm. In coconut, the endosperm is in two forms: the liquid endosperm (the milk) and the solid endosperm (the meat). The small embryo is hidden under one of the “eyes” of the coconut.

**Pome.** Apples and pears are more complicated fruits called pomes. The outer fleshy layer is derived from fused sepals and petals surrounding the ovary, while the core develops from the ovary. Strictly speaking, much of what we eat is not the fruit, because it is not derived from the ovary!

**Multiple fruits.** Multiple fruits develop from an inflorescence rather than from a single flower. Pineapples and mulberries are examples. Pineapples are unusual in that their fruit develops even in the absence of pollination and fertilization. Consequently, these fruits lack seeds. Blackberries and strawberries are not multiple fruits because they are derived from single flowers that contain many pistils.

### Specimens 4 and 5: Fruits

<sup>15</sup> Fig. 20-22

<sup>16</sup> Fig. 20-21

<sup>17</sup> Fig. 20-23

<sup>18</sup> Fig. 20-24

1. Observe, draw, and label (ovary, seeds, and endosperm (when visible)) at least two types of fruits that have been cut in cross section or longitudinal section.

### **Take-home assignment**

Obtain at least three seeds of at least one monocot and one dicot to germinate and begin to grow at home. They may be germinated in a cup of soil or in a plastic, sealable bag containing a damp paper towel (be sure it is not too wet or this will be an exercise in decay and fungi). In your lab notebook, record observations every other day. Bring your seedlings to class on the day (two weeks from now) we are scheduled to observe seedlings in class. You are encouraged, but not required, to conduct an independent experiment to understand factors that affect germination.

### ***Review questions***

1. How does the genesis of the gametophyte differ from the genesis of the sporophyte?
2. What are two distinguishing characteristics of angiosperms that pertain to seed and fruit development?
3. What are two types of seed dispersal mechanisms and what fruit structures or features facilitate these mechanisms?