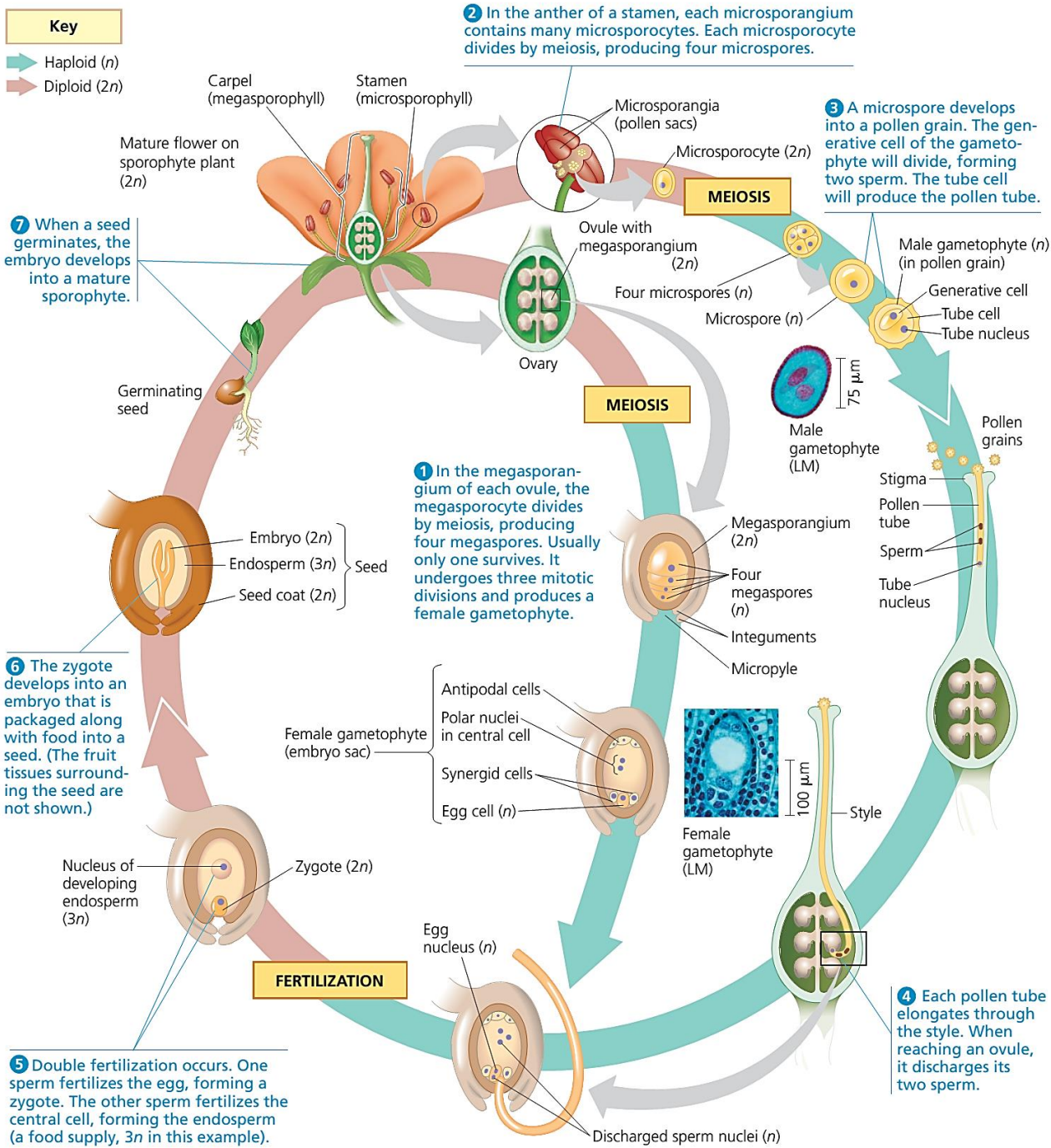
The Angiosperm Life Cycle:

Pollination is one step in the angiosperm life cycle. Figure 38.6 provides a complete overview of the life cycle, focusing on gametophyte development, sperm delivery by pollen tubes, double fertilization, and seed development. Over the course of seed plant evolution, gametophytes became reduced in size and wholly dependent on the sporophyte for nutrients (see Figure 30.2). The gametophytes of angiosperms are the most reduced of all plants, consisting of only a few cells: They are microscopic, and their development is obscured by protective tissues.

▼ **Figure 38.6 The life cycle of an angiosperm.** For simplicity, a flower with a single carpel (simple pistil) is shown. Many species have multiple carpels, either separate or fused.



Development of Female Gametophytes (Embryo Sacs)

As a carpel develops, one or more ovules form deep within its ovary, its swollen base. A female gametophyte, also known as an embryo sac, develops inside each ovule. The process of embryo sac formation occurs in a tissue called the megasporangium **1** within each ovule. Two integuments(layers of protective sporophytic tissue that will develop into the seed coat) surround each megasporangium, except at a gap called the micropyle. Female gametophyte development begins when one cell in the megasporangium of each ovule, the megasporocyte, enlarges and undergoes meiosis, producing four haploid megaspores. Usually only one megaspore survives; the other three degenerate. The nucleus of the surviving megaspore divides by mitosis three times without cytokinesis, resulting in one large cell with eight haploid nuclei. The multinucleate mass is then divided by membranes to form the embryo sac. Near the micropyle of the embryo sac, two synergid cells flank the egg and help attract and guide the pollen tube to the embryo sac. At the opposite end of the embryo sac are three antipodal cells of unknown function. The other two nuclei, called polar nuclei, are not partitioned into separate cells but share the cytoplasm of the large central cell of the embryo sac. The mature embryo sac thus consists of eight nuclei contained within seven cells. The ovule, which will become a seed if fertilized, now consists of the embryo sac, enclosed by the megasporangium (which eventually withers) and two surrounding integuments.

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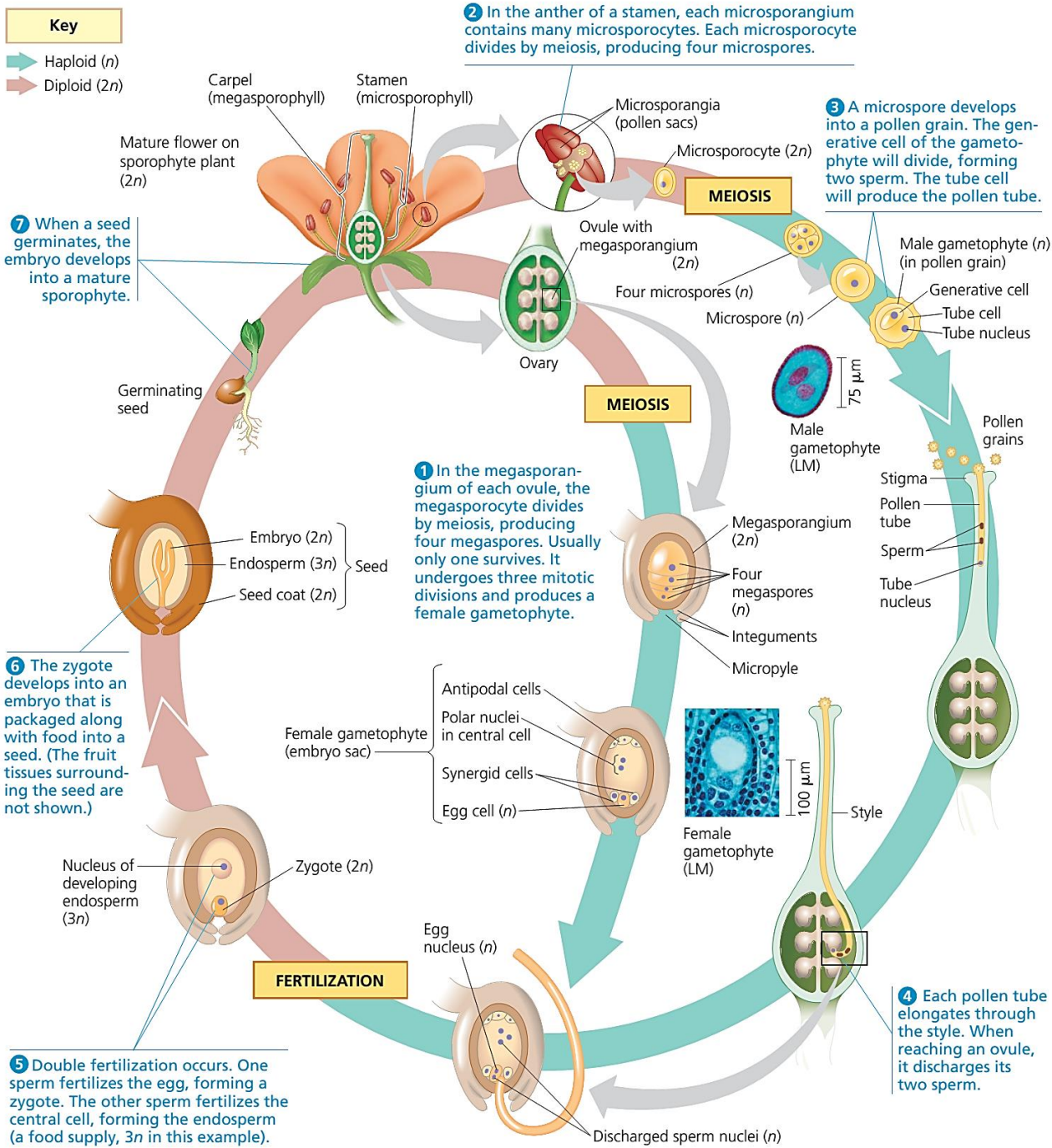
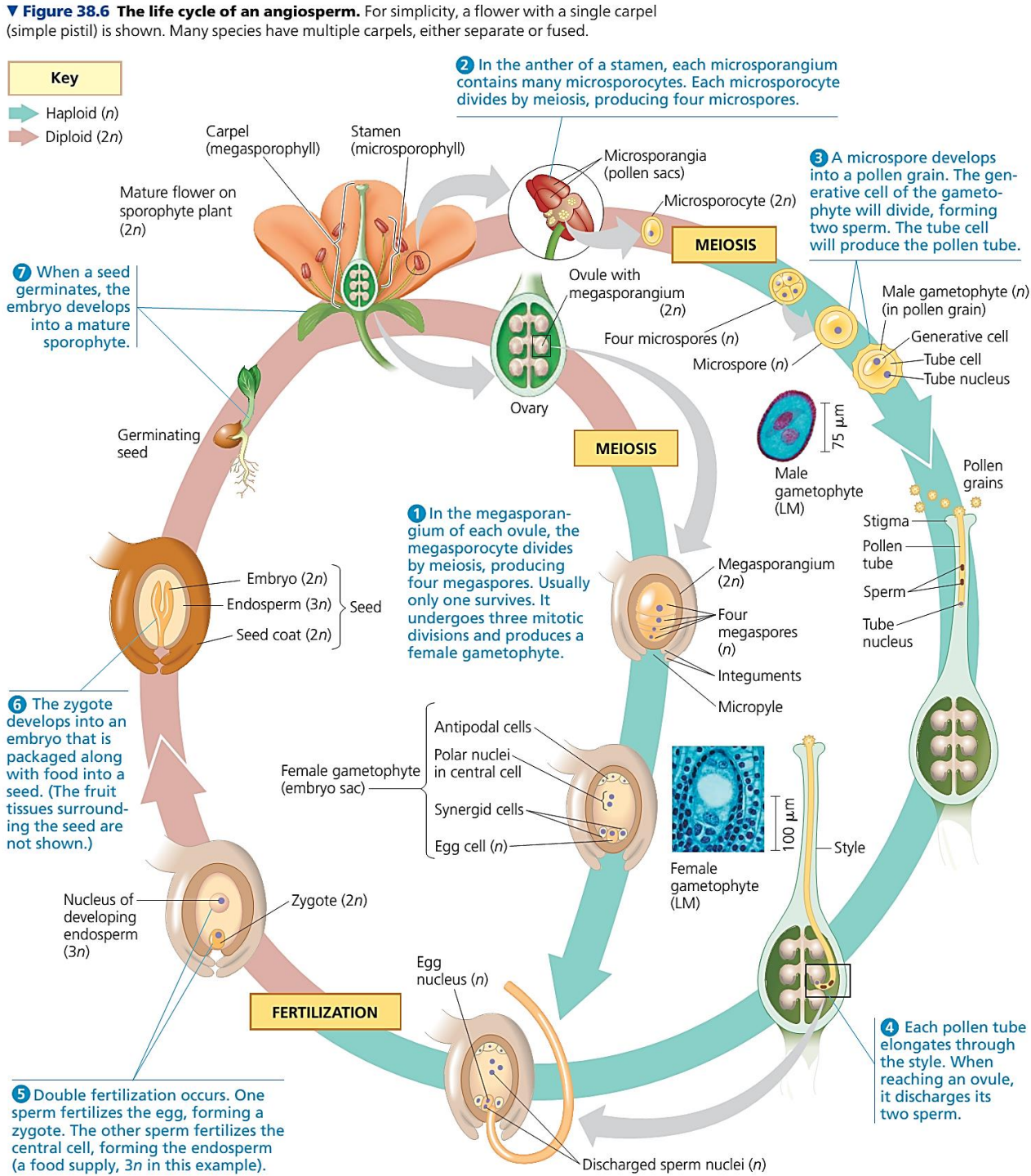


Development of Male Gametophytes in Pollen Grains

As the stamens are produced, each anther 2 develops four microsporangia, also called pollen sacs. Within the microsporangia are many diploid cells called microsporocytes. Each microsporocyte undergoes meiosis, forming four haploid microspores, 3 each of which eventually gives rise to a haploid male gametophyte. Each microspore then undergoes mitosis, producing a haploid male gametophyte consisting of only two cells: the generative cell and the tube cell. Together, these two cells and the spore wall constitute a pollen grain. The spore wall, which consists of material produced by both the microspore and the anther, usually exhibits an elaborate pattern unique to the species. During maturation of the male gametophyte, the generative cell passes into the tube cell: The tube cell now has a completely freestanding cell inside it.

Sperm Delivery by Pollen Tube

After the microsporangium breaks open and releases pollen, a pollen grain may be transferred to a receptive surface of a stigma—the act of pollination. There, it absorbs water and germinates by producing a pollen tube, a long cellular protuberance that delivers sperm to the female gametophyte. A pollen grain typically consists of the spore wall and two cells: a tube cell and a second cell, the generative cell, contained within the tube cell. As the pollen tube elongates through the style, the nucleus of the generative cell divides by mitosis and produces two sperm, which remain inside the tube cell. The tube nucleus leads ahead of the two sperm as the pollen tube grows toward the micropyle in response to chemical attractants produced by the synergid cells. The arrival of the pollen tube initiates the death of one of the two synergids, thereby providing a passageway into the embryo sac. The two sperm are then released from the pollen tube 4 in the vicinity of the female gametophyte.



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Double Fertilization

Fertilization, the fusion of gametes, occurs after the two sperm reach the female gametophyte. One sperm fertilizes the egg, forming the zygote. The other sperm combines with the two polar nuclei, forming a triploid (3n) nucleus in the center of the large central cell of the female gametophyte. This cell will give rise to the endosperm, a multicellular, food-storing tissue of the seed. 5 The union of the two sperm cells with different nuclei of the female gametophyte is called double fertilization. Double fertilization ensures that endosperm develops only in ovules where the egg has been fertilized, thereby preventing angiosperms from squandering nutrients on infertile ovules. Near the time of double fertilization, the tube nucleus, the other synergid cell, and the antipodal cells degenerate.

Seed Development

6 After double fertilization, each ovule develops into a seed. Meanwhile, the ovary develops into a fruit, which encloses the seeds and aids in their dispersal by wind or animals. As the sporophyte embryo develops from the zygote, the seed stockpiles proteins, oils, and starch to varying degrees, depending on the species. This is why seeds are such a major nutrient drain. Initially, carbohydrates and other nutrients are stored in the seed's endosperm, but later, depending on the species, the swelling cotyledons (seed leaves) of the embryo may take over this function. When a seed germinates, 7 the embryo develops into a new sporophyte. The mature sporophyte produces its own flowers and fruits: The life cycle is now complete.

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