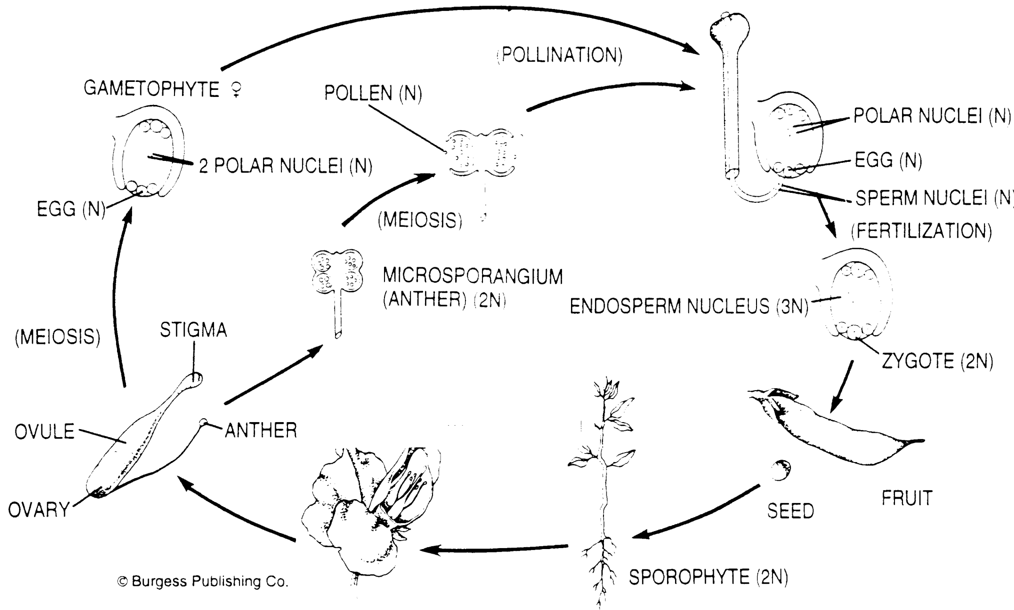
Reproduction in Angiosperms (Flowering Plants)



Things To Do Before Lab

1. Read this lab text BEFORE coming to lab.

2. As a team, collect a weed that possesses a flower somewhere on or near campus. Bring your flowering weed to lab (you'll use it to complete a graded assignment).

Things To Bring To Lab

Make sure you bring your textbook. The photos and figures will help in understanding the material in this lab.

Major Objectives Of This Lab

IT IS MOST IMPORTANT THAT YOU APPRECIATE THAT A *SUNFLOWER* PLANT AND A MAGNOLIA TREE BOTH REPRESENT SPOROPHYTES. TODAY, WE WILL LOOK CAREFULLY AT SPOROPHYTES, BUT WE WILL ALSO EXAMINE GAMETOPHYTES. **YOUR MAJOR GOAL** IS TO LINK THESE TWO GENERATIONS IN YOUR STUDY OF THE REPRODUCTIVE CYCLE OF FLOWERING PLANTS.

1. Focus on details of the life cycles of angiosperms.
2. Understand the similarities AND differences in the life cycles of angiosperms and the groups of plants you have studied to date.
3. Understand the structures that make up the flower and their function.
4. Understand from what parts of the flower fruit and seeds develop.
5. Relate what you see in this lab to where it exists in the life cycle.

Angiosperms

Perhaps the most notable difference between angiosperms and gymnosperms is that which is associated with their names. Ovules in gymnosperms are exposed naked to the world when the ovuliferous scales of conifers separate to let in pollen. Angiosperm ovules are completely isolated from the outside world by a barrier of sporophytic tissues. For sperm to reach an egg, pollen tubes must grow through parental sporophyte for a considerable distance (Fig. 3.1).

Two other unique features of angiosperms are the phenomenon of double fertilization and triploid endosperm formation. Of the two fertilizations, only one results in a zygote, the other sperm joins with two nuclei in the megagametophyte to form a triploid tissue (the endosperm) that will become the source of nutrients for the developing embryo.

Flowering plants form the largest division in the plant kingdom comprising about 250,000 species. Angiosperms are incredibly diverse in size and form ranging from species of *Eucalyptus* trees well over 100 meters tall to some duckweeds that are barely 1 millimeter in diameter. Other forms include epiphytic vines, succulent cacti, non-photosynthetic parasites and insectivorous plants. For over 100 million years, they have dominated the landscape of the earth with color and scent.

The angiosperms are divided into two major groups:

1. **Monocots.** These usually have floral parts in multiples of threes and leaf venation is usually parallel. As the name implies, only one cotyledon is present in the embryo. In a cross section of the stem anatomy, vascular bundles are usually scattered in a complex pattern with no secondary tissues. The first root of <u>monocot</u> embryos is short-lived, and the root system develops from adventitious roots arising from the stem.

2. **Dicots.** These usually have floral parts in multiples of fours or fives and leaf venation is usually netlike. Two cotyledons are present in the embryo. Vascular bundles in the stem cross section are arranged in a circular pattern and secondary tissues are often present. The first root in the <u>dicot</u> embryo will persist giving rise to a taproot system.

Flowers. The basic structural unit of sexual reproduction in angiosperms is the flower. Although flowers come in a spectacular array of sizes, shapes, and colors, they are, in essence, believed to have developed from shoots that have become modified for reproductive purposes. Flowers typically have fours kinds of foliar appendages usually arranged in a series of whorls: sepals, petals, stamens, and carpels, arranged in this order from the bottom to the top of the floral axis. Although the typical flower displays all of these types of appendages, sometimes the parts are modified, reduced in size, fused with other parts, or they fail to develop or abort. These developmental changes contribute to the complexity of flowers.

The two outermost sets, **sepals**, and **petals**, are sterile. That is, they do not produce spores. Sepals are typically green, and petals are often brightly colored. However, both sepals and petals can be green or showy. Collectively, the sepals are known as the calyx, and the petals as a unit, the corolla. Together the calyx and corolla comprise the perianth. The term “perianth” is especially useful in flowers which do not have a distinct whorls of petals and sepals i.e. only one set of appendage is present instead of the usual two.

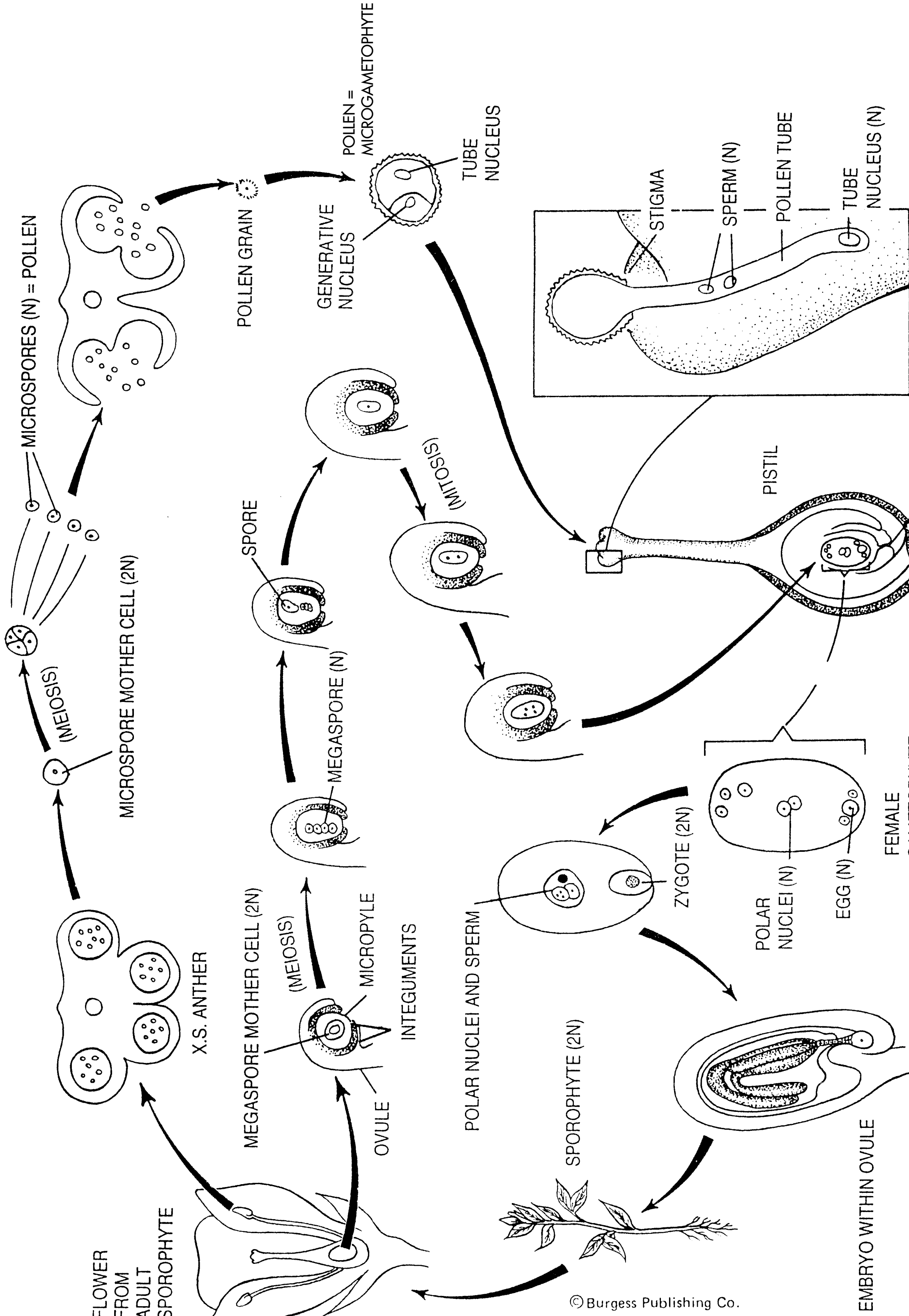


Fig. 3.1
Life cycle diagram of an angiosperm.

Next along the floral axis, inside of the perianth, are the **stamens**. Stamens are considered to be microsporophylls. A stamen typically consists of a four-chambered anther, in which pollen is produced, and a supporting stalk called the filament. Each anther chamber is equivalent to a microsporangium.

Megasporophylls—called **carpels** in angiosperms—are the most apical of the four floral appendages on the reproductive or floral axis. Carpels are thought to be derived from open leaf-like structures that had a series of ovules near each margin, but which through evolutionary processes, folded in half and became fused into hollow structures with the ovules inside. There may be one or more carpels per flower, and they may either be separate or fused into one structure. Collectively, the entire female portion of the flower is called the gynoecium. Carpels are divided into three portions: ovary, style, stigma. Pollen is deposited on the stigmatic surface. It may germinate, and pollen tubes (microgametophytes) may then grow through the style to the ovules located in the ovary. Locules are the chambers in which the ovules are found. The number of locules indicates the number of carpels that have been fused to form an ovary. The region where the ovules attach to the ovary walls is called the placenta.

Not all flowers have all four types of appendages. Those that have all four parts are complete flowers, whereas those without one or more types of appendages are incomplete. If they have both functional stamens and carpels, the flowers are said to be perfect (so a flower can be incomplete, and perfect… is there a moral hidden in here somewhere?) If, however they are missing either functional stamens or carpels, they are imperfect.

When perfect flowers are found or when both types of imperfect flowers (bearing either functional stamens only or functional carpels only) are found on the same individual plant, it is said to be monoecious. Plants that produce imperfect flowers of one sex only in each individual plant are said to be dioecious. Thus monoecious plants have perfect and/or imperfect flowers whereas dioecious plants only have imperfect flowers.

MAKE SURE YOU UNDERSTAND WHERE AND HOW THE HAPLOID MEGASPORES AND MEGAGAMETOPHYTES DEVELOP IN THE FLOWER.

Microsporangia and pollen grains. Next, we will look at the development of microspores. As is the case for all spores, microspores develop in sporangia (microsporangia). In flowering plants, the anther represents the site of the microsporangia. Anthers are often divided into chambers. Within each chamber, meiosis occurs, and the haploid pollen grains are produced. Remember that meiosis consists of two rounds of division: the first halves the chromosome number, and the second is essentially a mitosis. Hence, from one diploid microspore mother cell, four haploid microspores result. An angiosperm pollen grain, like that of gymnosperms, is the microgametophyte.

On a lily anther slide, available in this lab, you should be able to see pollen grains at various stages of development (i.e., 1, 2 or 4 cells).

Each microsporangium is lined with a layer of cells, the tapetum, which supplies nutrients to the developing pollen grains. Shortly before the pollen are released, the tapetum breaks down and covers them with varying materials, including proteins. These materials, which are sequestered in chambers in the pollen wall are important for a number of reasons, not the least of which is that they produce the allergic reactions in humans referred to as "hay fever." In some species, these proteins allow the stigma to distinguish pollen produced on the same plant from pollen produced on different individuals within the same species. In this way, some flowering plants can preferentially mate with different individuals of their own species, and avoid inbreeding.

Ovules. The megasporangium (nucellus) is contained within a protective covering of sporophytic tissues (the integument). However, unlike gymnosperms that have a single integument, angiosperms typically have two integuments covering the nucellus. Angiosperm ovules, like those of gymnosperms, consist of the integuments and their contents. However, angiosperm ovules unlike gymnosperm ovules, are completely isolated from the outside world by sporophytic tissue. Another difference between angiosperm and gymnosperm ovules is that those of angiosperms are attached to the placenta by a stalk called a funiculus. The small scar (the hilum) you see on seeds is where the funiculus attached the ovule to the placenta. There is only one megasporocyte (megaspore mother cell) in each megasporangium. Following meiosis, three of the haploid meiospores die, and only one will divide mitotically to form the megagametophyte. Megagametophytes, called embryo sacs in angiosperms, often consist of eight nuclei distributed among seven cells. The egg cell, and two synergids each have one nucleus apiece, and are nearest the micropyle. At the opposite (chalazal) end, are three uninucleate antipodals. The bulk of the megagametophyte (embryo sac) is occupied by the central cell containing the two polar nuclei.

Pollination. Pollination biology, that is the interaction between a pollinator and the flower, is a fascinating topic, which we touched upon briefly in lecture. In lecture we spoke of coevolution of the pollinator and the flower.

> Look at the extraordinary examples in the lab of plants that have coevolved with specific pollinators. Depending on the materials available, co-evolution can involve insects, birds, and in some cases, even mammals and marsupials.

Pollen tubes, double fertilization, and triploid endosperm formation. In nature, pollen tubes germinate on stigmatic surfaces of the gynoecium, and pollen tubes grow through the styles and emerge within the locule to enter the ovules through the micropyle. Shortly before it reaches the ovule, the generative cell divides to form two sperm cells. At maturity, the microgametophyte in angiosperms consists of three cells (not many cells, but enough to qualify angiosperms as having an alternation of heteromorphic generations). When the pollen tube reaches a mature megagametophyte, two sperm are released into one of the synergids. One sperm fertilizes the egg, to form the zygote, the new sporophyte. The other joins with the two polar nuclei to form a triploid tissue (endosperm), which will grow very rapidly and ultimately supply the developing embryo with its nutritional requirements.

Seeds. Seeds are our most important sources of food. The development (and decline) of civilizations has often been coupled with the availability of cereal grains, seeds of high food value that are stable over time in dry storage. Every seed is an experiment. A seed is a new combination of genetic characters brought about by two independent meiotic events and the succeeding combination of gametes. Following double fertilization, two new genetic entities, the zygote and the endosperm, commence development (Fig. 3.2). The zygote divides, and through repeated mitoses, the embryo forms. The endosperm also enlarges, providing nutritive materials for the developing embryo, and often for the developing seedling later on.

Besides a shoot and a root pole, the embryo will also possess one or two cotyledons depending or whether it is a monocot or dicot. Cotyledons are sometimes called seed leaves since they are usually leave like and are formed while the embryo is still in the seed. Some seeds store their food in the endosperm as mentioned previously. However, in many seeds, the endosperm is used up during the development of the embryo and the food store is transferred to the cotyledons. This is evident when you find that the cotyledons fill up most of the seed like in the bean seed. It is important to note that cotyledons are part of the embryo and not just a seed structure.

Seed dormancy and germination. The dormant seed is really a set of miniature organs stored in a (usually) small dispersible package. It has enough food reserves to last until photosynthesis can reasonably be expected to supply food for growth. Food reserves may be stored in either the embryo (as in the cotyledons of peas and beans) or in the endosperm (as in cereal grains). The seed is a stage

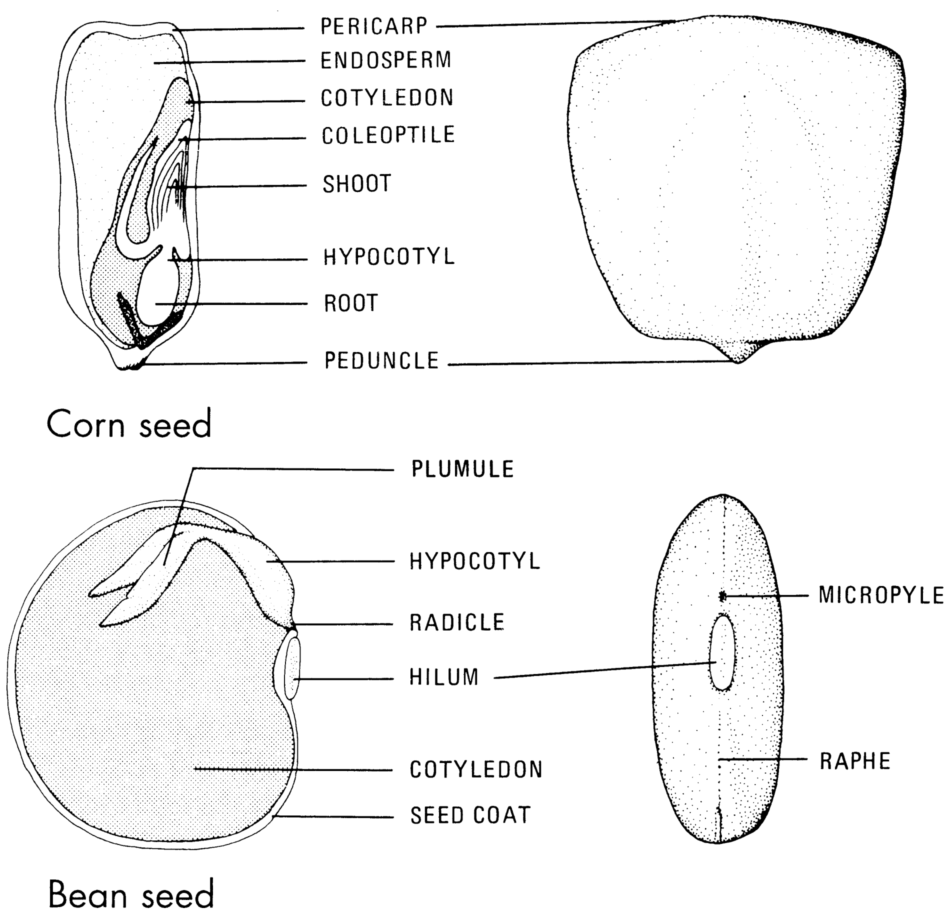


Fig. 3.2
Structure of longitudinally dissected corn and bean seeds.

in the life cycle with very low water content. At this stage, metabolism is at a minimum, so food reserves are not used up. The dry state also enhances resistance to microbial attack. Seeds usually have special patterns of responses to environmental factors that will enhance the probability of germination in a favorable spot during the appropriate season. During germination, the stored proteins, lipids, and carbohydrates are enzymatically digested into small molecules which can be readily translocated to growing regions.

> Starch cannot be readily translocated, so it is converted to sugar for transport. Why doesn't a seed store its food reserves as sugar? Why go through all the work of making starch, just to convert it back into sugar?

Fruits. Fertilization stimulates growth of the ovule, which becomes the seed, and it often causes enlargement of the ovary to form the fruit. As the fruit develops, it serves to protect the developing seeds and the embryos they contain. The fruit is often important in seed dispersal as well. Mechanisms of seed dispersal can be highly varied and sometimes quite surprising:

1. Wings or light tufts of hair that aid in dispersal by wind.

2. Explosive devices that shoot seeds to considerable distances from the parent plant.

3. Barbs that attach fruits to the coats of animals.

4. Food that is attractive to animals, encouraging them to ingest the seeds and transport them (often over considerable distances).

Botanically, a fruit is a mature ovary with other associated parts often contributing to its make-up. When the fruit is formed from a single carpel in one flower, it is a simple fruit. An aggregate fruit consists of groups of simple fruits that formed from separate carpels in one flower. Multiple fruits are formed from the ovaries of two or more nearby flowers. In all three types, tissues from structures other than the ovary may be incorporated into the fruit.

Your Team's Assignments

Start pollen germination

At the beginning of the lab period, set up, as a team, one pollen germination experiment. Gently tap some pollen grains from the flowers that are provided (usually *Agapanthus*, *Camellia* or *Impatiens* flowers) onto a microscope slide with 1-2 drops of 10% sucrose solution. Add a coverslip. Check your sample every 15 minutes during lab. Add more sucrose solution if it begins to dry out. Be sure to turn off the light source when you are not looking or it will bake the pollen grains!

Plant Biology Comes Alive!

This interactive portion of the lab consists of three activities (Mystery Identification; Fruits, Seeds, Etc.; and Your Flowering Weed). Your GSI will base your grade for this part of the lab on the participation of all team members and demonstrated biological understanding. Each team member will receive the same grade.

Mystery Identification. Examine the Mystery Organism located on the front bench. As a team, decide whether this organism is a gymnosperm or an angiosperm. Assuming you could analyze this material in any way, how could you obtain support for your identification? Write your identification and a one-sentence justification on the chalkboard. When discussing the Mystery Organism at the end of the lab period, your GSI may ask you to explain your response to the class.

Fruits, Seeds, Etc. During the last hour of the lab period, your GSI will assign one of the nine specimens listed below to your team. Is your specimen a fruit, a seed, or something else? If the latter, what is it? Does your specimen come from a gymnosperm, dicot, or monocot? You may dissect your specimen and use a dissecting microscope. Answer these questions and justify your conclusions in a five-minute team presentation in front of the class. Include a chalkboard drawing of your specimen (or a section of it) with relevant labels.

1. Pear
2. Shelled hazelnut (filbert)
3. Juniper berry
4. Banana
5. Silver apricot
6. Cucumber
7. Unshelled pistachio
8. Orange
9. Apple

Your Flowering Weed. When instructed by your GSI, show your weed to the class. As a team, tell whether the weed is a dicot or monocot. Also, indicate whether the flower is complete or incomplete, and whether it is perfect or imperfect. Justify each conclusion.