INTRODUCTION

There are about 235,000 species of flowering plants, far more than in any other plant group. Angiosperms are generally divided into two groups, the *dicotyledons* (or "dicots" for short) and *monocotyledons* (or "monocots"), based upon the number of cotyledons (seedling leaves) as well as other characteristics. The next two labs are concerned with the life cycle of flowering plants and the morphology and development of flowers and fruits, structures unique to the angiosperms. In addition, angiosperms will provide most of our examples of the structure and development of the vascular plant body during the remainder of the course. In this laboratory you will examine the life cycle and reproductive features of flowering plants.

In PBIO 211, you learn about a series of increasingly complex variations on the sporic life cycle in the Chlorophyta-Plant clade. The life cycle of the green alga *Ulva*, with its isomorphic alternation of phases (generations), is the simplest of these. The angiosperm life cycle is the most complex. As you study the material provided today, be sure you understand the homologies of the various structures--that is, which are sporophytic and which gametophytic, and which ones are homologous to leaves, sporangia, spores, etc. in the plants you have seen in previous labs.

EXERCISE A: THE FLOWER

Flowers represent a determinate shoot that bears several series of modified vegetative and fertile leaves (i.e., sporophylls) on a swollen stem tip or receptacle. The members of a series of modified leaves usually form a whorl (that is, they are attached to the receptacle at the same level), but they are helically arranged in some flowers. The lowest (outermost) and usually most leaf-like series is called the **calyx** and is made up of **sepals**. Just above (inside of) the calyx is the **corolla** made up of **petals**, which typically are white or brightly colored. Together, the calyx and corolla make up the **perianth**. In some flowers, it is not possible to distinguish between sepals and petals, in which case the parts of the perianth are called **tepals**.

The next highest series is composed of **stamens** (which are **microsporophylls**), each made up of a **filament** and an **anther**. The **pollen sacs** (**microsporangia**) are located on the anther. The uppermost (innermost) series of parts are the **carpels** (**megasporophylls**), which contain the **ovules**. The carpels are frequently fused to form a single **pistil**, which occupies the center of the flower when viewed from above. When the carpels are separate from each other, or only one is present, the individual carpels are also called pistils. **Thus a pistil may be either one carpel or several fused carpels**. In either case, the pistil is usually composed of a basal **ovary** (containing the ovules), a terminal **stigma** (the part of the pistil that is receptive to pollen), and a more or less slender **style** connecting the stigma and ovary.

Flowers with both stamens and pistils present are said to be **perfect**. Flowers that have either stamens or pistils, but not both, are **imperfect**.

Part 1. Magnolia or Liriodendron

**Obtain a flower of Magnolia or Liriodendron, a plastic petri dish, dissecting needles, and a razor blade.**

- Examine the symmetry of the flower. It is radially symmetrical (referred to as **actinomorphic**). You will see other flowers that are bilaterally symmetrical (**zygomorphic**). If you are uncertain whether a flower (or anything else) is radially or bilaterally symmetrical, ask yourself how many ways you could cut it to get two halves that are mirror images of each other. If there is only one way you could do this, it is bilaterally symmetrical. If there are two or more ways, it is radially symmetrical.
symmetrical. Mammals are bilaterally symmetrical (at least externally), whereas starfish are radially symmetrical.

- Identify the **perianth**. Would you characterize the perianth of this flower as being differentiated into sepals and petals, or is it composed of undifferentiated tepals?

- Peel the perianth back and identify the numerous helically arranged **stamens** and **carpels**. Are these flowers perfect or imperfect?

- The stamens of *Magnolia* have a long anther and a very short filament. Find the **pollen sacs** on the anther. What are the homologies of the stamen and pollen sac to structures of other plants (e.g., a fern)? The pollen sacs initially contain **microspore mother cells**. These cells undergo meiosis to produce microspores and then **microgametophytes** (pollen grains).

- Section a carpel and look for ovules. Do you understand what the carpel is homologous to in other plants (i.e., is it a modified leaf, sporangium, spore, etc.?)

**Part 2. Diversity of flower structure**

There is a great deal of diversity among flowers, but all are variations of the general structure introduced above. In each case the flower is a shoot tip upon which there are several types of vegetative and fertile leaf-like organs. The variety of flowers that are available for you to examine and dissect in this lab show much of this diversity. For each flower that is available ask yourself the same set of questions. These are:

1. How many of the normal floral parts of a **complete flower** are present, and which (if any) are missing?

2. What is the number of each type of part?

3. What parts are fused together?

4. Is the flower **apocarpous** or **syncarpous**?

5. If the flower has a **compound pistil**, how many carpels are fused together? How can you tell?

6. Is the flower **zygomorphic**? If not, what term refers to the symmetry?

7. Is the ovary **inferior**, or **superior**?

- Draw, label, and identify each flower you examine. Be sure your labels include the answers to the questions above.
EXERCISE B: ANGIOSPERM LIFE CYCLE

The angiosperm life cycle is basically similar to that of other seed plants (i.e., sporic, heterosporous, seed-producing), but the gametophytes are even more reduced. The mature megagametophyte usually consists of only seven cells and the microgametophyte of only three. Neither archegonia nor antheridia are present. Angiosperms also differ from most other seed plants in having double fertilization involving two sperm nuclei. In the double fertilization of angiosperms, one sperm nucleus unites with the egg to yield the zygote, while the other unites with the two nuclei in the central cell of the megagametophyte to yield the first cell of a nutritive tissue called endosperm, which feeds the embryo during seed development.

Part 1. Lily (Lilium) ovary, ovule, and embryo sac (see p. 447 in text)

- Examine a prepared slide of several sections of a Lilium ovule (megasporocyte stage).

Ovules are visible in each of the three locules (chambers) of the ovary. Each ovule consists of a nucellus (megasporangium), which contains a megaspore mother cell (=megasporocyte), and is surrounded by two integuments. The ovule is attached to the wall of the ovary by a stalk called the funiculus.

- Identify the locules, ovules, integuments, nucellus, megaspore mother cell, and funiculus. How many ovules can you see in each locule?

What is the ploidy level of each of these structures? What process will occur in the megaspore mother cell subsequent to the stage shown in this slide?

- Examine a prepared slide of a Lilium ovule containing a four-nucleate megagametophyte. The megagametophyte of an angiosperm is called an embryo sac (not to be confused with an embryo!).

- Demo: Examine the demonstration slide of a Lilium ovule with a mature embryo sac. Inside the nucellus is the mature embryo sac consisting of seven cells and eight nuclei (see photograph and drawing on p. 507). There are three small cells at each end of the embryo sac and a large, binucleate cell in the center. You may not be able to see all of the cells and nuclei if the slide is not a perfect median section. The egg cell is the middle cell of the three small ones at the end of the embryo sac nearest to the micropyle. The large central cell contains two nuclei called polar nuclei, which play an important role in fertilization (see below).

Identify the integuments, nucellus, ovule, funiculus, and embryo sac. Are the egg and polar nuclei visible?

Part 2. Young anther and pollen grains of Lilium

- Examine a prepared slide of a Lilium anther showing tetrads of microspores following meiosis (compare to Fig. 19-14 on p. 442). This is a cross section through an immature anther.

There are four pollen sacs (megasporangia) per anther. In the center of each pollen sac are tetrads of microspores. A tetrad is simply a group of four. Why are the microspores in groups of four? The tetrads are surrounded by the tapetum, a nutritive tissue derived from the innermost layer of the pollen sac. Identify the pollen sacs, microspores, and tapetal remnants.

- What is the ploidy level of each of these structures?

- Were the microspores produced by mitosis or meiosis?
• Examine a prepared slide of *Lilium* mature anthers (see pp. 442, at bottom). The walls between the pollen sacs have broken down, and now there are two large pollen-containing chambers. The microspores have given rise to pollen grains (immature male gametophytes).

Each pollen grain consists of two cells: a large **tube cell** whose nucleus contains a conspicuous nucleolus, and a smaller, lens-shaped **generative cell**, which is often hard to discern. The generative cell will eventually divide mitotically to produce the two sperm cells. Identify the pollen grains. Find the tube cell and generative cell.

• You will be able to watch the germination and growth of a **pollen tube**. Take a piece of onion epidermis from the concave part of a layer of the onion and place it on a moistened microscope slide. Make sure that the side of the epidermis that faced the outside of the onion is face up on your slide. Place some pollen grains on top of the onion skin and observe germination of the pollen tubes. Over the course of about 20-30 minutes you will see the pollen tubes germinate and grow.

In nature, when the pollen lands on the stigma, the pollen tube begins to grow down the style. The two sperm cells produced from the generative cell travel down the tube to reach the embryo sac (see Fig. 19 & 20 on p. 446). One sperm unites with the egg to yield the zygote. The other unites with the two polar nuclei of the central cell to yield the **primary endosperm nucleus**. This process is called double fertilization. The primary endosperm nucleus subsequently develops into the **endosperm**, which nourishes the developing embryo inside the seed.

• Examine a prepared slide of pollen tubes. Identify the tube cell and sperm cells.

• Demo (if available): Examine the prepared slide of a *Lilium* ovule showing double fertilization, and compare it to Fig. 19-21 in your text (page 447).