Plant Diversity II: Seed Plants

* Before lab, read the following material on gymnosperms and angiosperms and complete Table 1 by listing (and comparing) the traits of each.

Laboratory Objectives

After completing this lab topic, you should be able to:
1. Identify examples of the divisions of seed plants.
2. Describe the life cycle of a gymnosperm (pine tree) and an angiosperm.
3. Describe features of flowers that ensure pollination by insects, birds, bats, and wind.
4. Describe factors influencing pollen germination.
5. Identify types of fruits, recognize examples, and describe dispersal mechanisms.
6. Relate the structures of seed plants to their functions in the land environment.
7. Compare the significant features of life cycles for various land plants and state their evolutionary importance.
8. Summarize major trends in the evolution of land plants and provide evidence from your laboratory investigations.

Gymnosperms

For over 500 million years, plants have been adapting to the rigors of the land environment. The nonvascular bryophytes with their small and simple bodies survived in moist habitats, habitats moist at least for part of their life cycle. During the cool Carboniferous period, vascular seedless plants dominated the landscape of the swamp forests that covered much of the earth. Although these plants were more complex and better adapted to the challenges of the land environment, they still were dependent on water for sperm to swim to the egg. During the Mesozoic era, 150 million years ago, Earth became warmer and drier and the swamp forests declined, presenting another challenge to terrestrial plants and animals. Earth at that time was a world dominated by reptilian vertebrates, including the flying, running, and climbing dinosaurs. The landscape was dominated by a great
variety of seed-bearing plants called gymnosperms (literally, "naked seeds"), which in the Carboniferous period had been restricted to dry sites. During the Mesozoic, a number of distinct gymnosperm groups diversified, and a few of the spore-bearing plants survived.

Vertebrate animals became fully terrestrial during the Mesozoic with the emergence of reptiles, which were free from a dependence on water for sexual reproduction and development. The development of the amniotic egg along with an internal method of fertilization made this major transition possible. The amniotic egg carries its own water supply and nutrients, permitting early embryonic development to occur on dry land, a great distance from external water. In an analogous manner, the gymnosperms became free from dependence on water through the development of a process of internal fertilization via the pollen grain and development of a seed, which contains a dormant embryo with a protective cover and special nutrient tissue.

Several features of the gymnosperms have been responsible for their success. They have reduced (smaller-sized) gametophytes; the male gametophyte is a multinucleated pollen grain, and the female gametophyte is small and retained within the sporangium in the ovule of the sporophyte generation. The pollen grain is desiccation resistant and adapted for wind pollination, removing the necessity for fertilization in a watery medium. The pollen tube conveys the sperm nucleus to an egg cell, and the embryonic sporophyte develops within the gametophyte tissues, which are protected by the previous sporophyte generation. The resulting seed is not only protected from environmental extremes, but also is packed with nutritive materials and can be dispersed away from the parent plant. In addition, gymnosperms have advanced vascular tissues: xylem for transporting water and nutrients and phloem for transporting photosynthetic products. The xylem cells are called tracheids and are more efficient for transport than those of the seedless vascular plants.

**Angiosperms**

A visit to Earth 60 million years ago, during the late Cretaceous period, would reveal a great diversity of mammals and birds and a landscape dominated by flowering plants, or angiosperms (division Anthophyta). Ultimately, these plants would diversify and become the most numerous, widespread, and important plants on Earth. Angiosperms now occupy well over 90% of the vegetated surface of Earth and contribute virtually 100% of our agricultural food plants.

The evolution of the flower resulted in enormous advances in the efficient transfer and reception of pollen. Whereas gymnosperms are all wind-pollinated, producing enormous amounts of pollen that reach the appropriate species by chance, the process of flower pollination is mediated by specific agents—Insects, birds, and bats—in addition to wind and rain. Pollination agents such as the insect are attracted to the flower with its rewards of nectar...
and pollen. Animal movements provide precise placement of pollen on the receptive portion of the female structures, increasing the probability of fertilization. The process also enhances the opportunity for cross-fertilization among distant plants and therefore the possibility of increased genetic variation.

Angiosperm reproduction follows the trend for reduction in the size of the gametophyte. The pollen grain is the male gametophyte, and the eight-nucleated embryo sac is all that remains of the female gametophyte. This generation continues to be protected and dependent on the adult sporophyte plant. The female gametophyte provides nutrients for the developing sporophyte embryo through a unique triploid endosperm tissue. Another unique feature of angiosperms is the fruit. The seeds of the angiosperm develop within the flower ovary, which matures into the fruit. This structure provides protection and enhances dispersal of the young sporophyte into new habitats.

In addition to advances in reproductive biology, the angiosperms evolved other advantageous traits. All gymnosperms are trees or shrubs, with a large investment in woody, persistent tissue; and their life cycles are long (5 or more years before they begin to reproduce and 2 to 3 years to produce a seed). Flowering plants, on the other hand, can be woody, but many are herbaceous, with soft tissues that survive from one to a few years. It is possible for angiosperms to go from seed to seed in less than one year. As you perform the exercises in this lab, think about the significance of this fact in terms of the evolution of this group. How might generation length affect the rate of evolution? Angiosperms also have superior conducting tissues. Xylem tissue is composed of tracheids (as in gymnosperms), but also contains large-diameter, open-ended vessels. The phloem cells, called sieve-tube members, provide more efficient transport of the products of photosynthesis.

Review the characteristics of gymnosperms and angiosperms described in this introduction, and summarize in Table 1 the advantages of these groups relative to their success on land. You should be able to list several characteristics for each. At the end of the lab, you will be asked to modify and complete the table, based on your investigations.

You will want to return to this table after the laboratory to be sure that the table is complete and that you are familiar with all these important features.

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**EXERCISE 1**

**Gymnosperms**

The term *gymnosperms* refers to a diverse group of seed plants that do not produce flowers. Although they share many characteristics, including the production of pollen, they represent four distinct groups, or divisions. In this exercise, you will observe members of these divisions and investigate the life cycle of a pine, one of the most common gymnosperms.
<table>
<thead>
<tr>
<th></th>
<th>Adaptation to the Land Environment</th>
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<tbody>
<tr>
<td>Gymnosperms</td>
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<tr>
<td>Angiosperms</td>
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</tbody>
</table>

**Lab Study A. Divisions of Gymnosperms**

**Materials**
living or pressed examples of conifers, ginkgos, cycads, and Mormon tea

**Introduction**
Gymnosperms are composed of several divisions. The largest and best known is Coniferales, which includes pines and other cone-bearing trees and shrubs. Cycads, which have a palm-like appearance, are found primarily in tropical regions scattered around the world. Ginkgos, with their flat fan-shaped leaves, are native to Asia and are prized as urban trees. An extract of Ginkgo is used as an herbal medicine purported to improve memory. Gnetophyta is composed of three distinct and unusual groups of plants: gnetums, which are primarily vines of Asia, Africa, and South America; Welwitschia, a rare desert plant with two leathery leaves; and Mormon tea (Ephedra), desert shrubs of North and Central America. Compounds from Ephedra, ephedrines, used in diet aids and decongestants, have raised serious concerns due to side effects including cardiac arrest.
Procedure
1. Observe demonstration examples of all divisions of gymnosperms and be able to recognize their representatives. Note any significant ecological and economic role for these plants.
2. Record your observations in Table 2.

Table 2
Divisions of Gymnosperms

<table>
<thead>
<tr>
<th>Divisions</th>
<th>Examples</th>
<th>Characteristics/Comments</th>
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</thead>
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<tr>
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<td></td>
</tr>
<tr>
<td>Ginkgophyta</td>
<td><img src="Ginkgophyta.png" alt="Pic" /></td>
<td></td>
</tr>
<tr>
<td>Cycadophyta</td>
<td><img src="Cycadophyta.png" alt="Pic" /></td>
<td></td>
</tr>
<tr>
<td>Gnetophyta</td>
<td><img src="Gnetophyta.png" alt="Pic" /></td>
<td></td>
</tr>
</tbody>
</table>

Results
1. In the margin of your manual, sketch the overall structure of the plants. Label structures where appropriate.
2. Are there any reproductive structures present for these plants? If so, make notes in the margin of your lab manual.

Discussion
1. What are the key characteristics shared by all gymnosperms?
2. What is the ecological role of conifers in forest systems?

3. What economically important products are provided by conifers?

Lab Study B. Pine Life Cycle

Materials
living or preserved pine branch, coverslips
male and female cones prepared slides of male and female
(1, 2, and 3 years old) pine cones
fresh or dried pine pollen or colored pencils
prepared slide of pine pollen slides

Review the pine life cycle (Figure 1) before you begin. Follow along as you complete the exercise.

Introduction
All gymnosperms are wind-pollinated trees or shrubs, most bearing unisexual, male, and female reproductive structures on different parts of the same plant. Gymnosperms are heterosporous, producing two kinds of spores: male microspores, which develop into pollen, and female megaspores. The megasporo develops into the female gametophyte, which is not free-living as with ferns but retained within the megasporangium and nourished by the sporophyte parent plant. Numerous pollen grains (the male gametophytes) are produced in each microsporangium, and when they are mature they are released into the air and conveyed by wind currents to the female cone. Pollen tubes grow through the tissue of the megasporangium, and the sperm nucleus is released to fertilize the egg. After fertilization, development results in the formation of an embryo. A seed is a dormant embryo embedded in nutrient tissue of the female gametophyte and surrounded by the hardened sporangium wall, or seed coat.

Having trouble with life cycles? The key to success is to determine where meiosis occurs and to remember the ploidal level for the gametophyte and sporophyte.
Figure 1.
Pine life cycle. Observe the structures and processes as described in Exercise 1. Using colored pencils, indicate the structures that are haploid or diploid. Circle the terms mitosis, meiosis, and fertilization.

Procedure
1. Pine sporophyte.
   a. Examine the pine branch and notice the arrangement of leaves in a bundle. A new twig at the end of the branch is in the process of producing new clusters of leaves. Is this plant haploid or diploid?
b. Examine the small **cones** produced at the end of the pine branch on this specimen or others in lab. Recall that cones contain clusters of sporangia. What important process occurs in the sporangia?

c. Locate an ovulate cone and a pollen cone. Elongated male **pollen cones** are present only in the spring, producing pollen within overlapping bracts, or scales. The small, more rounded female cones (which look like miniature pine cones) are produced on stem tips in the spring and are called **ovulate cones**. Female cones persist for several years. Observe the overlapping scales, which contain the sporangia.

d. In the margin of your lab manual, sketch observations for future reference.

   a. Examine a longitudinal section of the pollen cone on a prepared slide and identify its parts. Observe that pollen cones are composed of radiating scales, each of which carries two elongated sacs on its lower surface. The sacs are the **microsporangia**. **Microspore mother cells** within microsporangia divide by meiosis. Each produces four haploid **microspores**, which develop into **pollen grains**.
   b. Observe a slide of pine pollen. If pollen is available, you can make a wet mount. Note the wings on either side of the grain. The pollen grain is the greatly reduced male gametophyte. The outer covering of the pollen is desiccation resistant. Once mature, pollen will be wind dispersed, sifting down into the scales of the female cones.
   c. Sketch, in the margin of your lab manual, observations for future reference.

3. Female gametophyte—development in ovulate cones.
   a. Examine a longitudinal section of a young ovulate cone on a prepared slide. Note the **ovule** (containing the megasporangium) on the upper surface of the scales. Diploid **megaspore mother cells** contained inside will produce haploid **megaspores**, the first cells of the gametophyte generation. In the first year of ovulate cone development, pollen sifts into the soft bracts (pollination) and the pollen tube begins to grow, digesting the tissues of the ovule.
   b. Observe a second-year cone at your lab bench. During the second year, the ovule develops a multicellular female gametophyte with two archegonia in which an egg will form. Fertilization will not occur until the second year, when the pollen tube releases a sperm nucleus into the archegonium, where it unites with the egg to form the **zygote**. In each ovule only one of the archegonia and its zygote develops into a seed.
   c. Observe a mature cone at your lab bench. The development of the embryo sporophyte usually takes another year. The female gametophyte will provide nutritive materials stored in the seed for the early stages of growth. The outer tissues of the ovule will harden to form the **seed coat**.
   d. In the margin of your lab manual, sketch observations for future reference.
Results

1. Review the structures and processes observed.
2. Using colored pencils, indicate the structures of the pine life cycle in Figure 1 that are haploid or diploid, and circle the processes of mitosis, meiosis, and fertilization.

Discussion

1. What is the function of the wings on the pollen grain?

2. Why is wind-dispersed pollen an important phenomenon in the evolution of plants?

3. Are microspores and megaspores produced by mitosis or meiosis?

4. Can you think of at least two ways in which pine seeds are dispersed?

5. One of the major trends in plant evolution is the reduction in size of the gametophytes. Describe the male and female gametophyte in terms of size and location.

EXERCISE 2

Angiosperms

A unique characteristic of angiosperms (division Anthophyta) is the carpel, a vessel in which ovules are enclosed. After fertilization, the ovule develops into a seed (as in the gymnosperms), while the carpel matures into a fruit (unique to angiosperms). Other important aspects of angiosperm reproduction include additional reduction of the gametophyte, double fertilization, and an increase in the rapidity of the reproduction process.

The flowers of angiosperms are composed of male and female reproductive structures, which are frequently surrounded by attractive or protective leaflike structures collectively known as the perianth. The flower functions both to protect the developing gametes and to ensure pollination and fer-
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tilization. Although many angiosperm plants are self-fertile, cross-fertilization is important in maintaining genetic diversity. Plants, rooted and stationary, often require transfer agents to complete fertilization. A variety of insects, birds, and mammals transfer pollen from flower to flower. The pollen then germinates into a pollen tube and grows through the female carpel to deliver the sperm to the egg.

Plants must attract pollinators to the flower. What are some features of flowers that attract pollinators? Color and scent are important, as is the shape of the flower. Nectar and pollen provide nutritive rewards for the pollinators as well. The shape and form of some of the flowers are structured to accommodate pollinators of specific size and structure, providing landing platforms, guidelines, and even special mechanisms for the placement of pollen on body parts. While the flower is encouraging the visitation by one type of pollinator, it also may be excluding visitation by others. The more specific the relationship between flower and pollinator, the more probable that the pollen of that species will be successfully transferred. But many successful flowers have no specific adaptations for particular pollinators and are visited by a wide variety of pollinators.

Some plants do not have colorful, showy flowers and are rather inconspicuous, often dull in color, and lacking a perianth. These plants are usually wind-pollinated, producing enormous quantities of pollen and adapted to catch pollen in the wind.

The origin and diversification of angiosperms cannot be understood apart from the coevolutionary role of animals in the reproductive process. Colorful petals, strong scents, nectars, food bodies, and unusual perianth shapes all relate to pollinator visitation. Major trends in the evolution of angiosperms involve the development of mechanisms to exploit a wide variety of pollinators.

In Lab Study A, you will investigate a variety of flowers, observing their shape, structure, and traits that might attract pollinators of various kinds. Following this, in Lab Study B, you will use a key to identify the probable pollinators for some of these flowers. You will follow the life cycle of the lily in Lab Study C and complete the lab by using another key to identify types of fruits and their dispersal mechanisms.

Lab Study A. Flower Morphology

Materials
living flowers provided by the instructor and/or students
stereoscopic microscope

Introduction
Working in teams of two students, you will investigate the structure of the flower (Figure 2). The instructor will provide a variety of flowers, and you may have brought some with you to lab. You will need to take apart each flower carefully to determine its structure, since it is unlikely that all your flowers will follow the simple diagram used to illustrate the structures. Your observations will be the basis for predicting probable pollinators in Lab Study B.
Procedure

1. Examine fresh flowers of four different species, preferably with different floral characteristics.

2. Identify the parts of each flower using Figure 2 and the list provided following the heading Floral Parts. You may be able to determine the floral traits for large, open flowers by simply observing. However, most flowers will require that you remove the floral structures from the outside toward the center of the flower. Some flowers or structures may require the use of the stereoscopic microscope. For example, the ovary is positively identified by the presence of tiny crystal-like ovules, and these are best seen with the stereoscopic scope.

3. In the margin of your lab manual, sketch any flower shapes or structures that you might need to refer to in the future.

4. Record the results of your observations in Table 3. You will determine pollinators in Lab Study B.

Floral Parts

Pedicel: stalk that supports the flower.

Receptacle: tip of the pedicel where the flower parts attach.

Sepal: outer whorl of bracts, which may be green, brown, or colored like the petals; may appear as small scales or be petal-like.

Calyx: all the sepals, collectively.

Petal: colored, white, or even greenish whorl of bracts located just inside the sepals.

Corolla: all the petals, collectively.

Stamen: pollen-bearing structure, composed of filament and anther.

Filament: thin stalk that supports the anther.

Anther: pollen-producing structure.
**Carpel:** female reproductive structure, composed of the stigma, style, and ovary, often pear-shaped and located in the center of the flower.

**Stigma:** receptive tip of the carpel, often sticky or hairy, where pollen is placed; important to pollen germination.

**Style:** tissue connecting stigma to ovary, often long and narrow, but may be short or absent; pollen must grow through this tissue to fertilize the egg.

**Ovary:** base of carpel; protects ovules inside, matures to form the fruit.

**Results**
Summarize your observations of flower structure in Table 3.

**Discussion**
What structures or characteristics did you observe in your (or other teams') investigations that you predict are important to pollination?

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**Lab Study B. Pollinators**

**Materials**
living flowers provided by the instructor and/or students
stereoscopic microscope

**Introduction**
Flowers with inconspicuous sepals and petals are usually pollinated by wind. Most showy flowers are pollinated by animals. Some pollinators tend to be attracted to particular floral traits, and, in turn, some groups of plants have coevolved with a particular pollination agent that ensures successful reproduction. Other flowers are generalists, pollinated by a variety of organisms, and still others may be visited by only one specific pollinator. Based on the floral traits that attract common pollinators (bees, flies, butterflies, and hummingbirds), you will predict the probable pollinator for some of your flowers using a dichotomous key. (Remember, *dichotomous* refers to the branching pattern and means “divided into two parts.”)

In biology, we use a key to systematically separate groups of organisms based on sets of characteristics. Most keys are based on couplets, or pairs of characteristics, from which you must choose one or the other, thus, the term *dichotomous*. For example, the first choice of characteristics in a couplet might be *plants with showy flowers and a scent*, and the other choice in the pair might be *plants with tiny, inconspicuous flowers with no scent*. You must choose one or the other statement. In the next step, you would choose from a second pair of statements listed directly below your first choice. With each choice, you would narrow the group more and more until, as in this case, the pollinator is identified. *Each couplet or pair of statements from which you must choose will be identified by the same letter or number.*
<table>
<thead>
<tr>
<th>Features</th>
<th>Plant Names 1</th>
<th>Plant Names 2</th>
<th>Plant Names 3</th>
<th>Plant Names 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of petals</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of sepals</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Parts absent (petals, stamens, etc.)</td>
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<tr>
<td>Color</td>
<td></td>
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<tr>
<td>Scent (+/-)</td>
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<tr>
<td>Nectar (+/-)</td>
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<tr>
<td>Shape (including corolla shape: tubular, star, etc.)</td>
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<tr>
<td>Special features (landing platform, guidelines, nectar spur, etc.)</td>
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<tr>
<td>Predicted pollinator (see Lab Study B)</td>
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</table>
Key to Pollination

1. Sepals and petals reduced or inconspicuous; feathery or relatively large stigma; flower with no odor wind
1. Sepals and/or petals large, easily identified; stigma not feathery; flower with or without odor
   A. Sepals and petals white or subdued (greenish or burgundy); distinct odor moth
   1. Odor strong, heavy, sweet bat
   1. Odor strong, fermenting or fruit-like; flower parts and pedicel strong fly
   1. Odor of sweat, feces, or decaying meat beetle
   A. Sepals and/or petals colored; odor may or may not be present
      1. Flower shape regular or irregular, but not tubular
         a. Flower shape irregular; sepals or petals blue, yellow, or orange; plant adapted to serve as a "landing platform"; may have dark lines on petals; sweet, fragrant odor bee
         a. Flower shape regular; odor often fruity, spicy, sweet, or carnationlike butterfly
      1. Flower shape tubular
         a. Strong, sweet odor hummingbird
         a. Little or no odor; flower usually red hummingbird

* A regular flower shape is one that has radial symmetry (like a daisy or carnation), with similar parts (such as petals) having similar size and shape. Irregular flowers have bilateral symmetry.

Procedure
Using the key above, classify the flowers used in Lab Study A based on their floral traits and method of pollination.

Results
1. Record your results in Table 3.
2. If you made sketches of any of your flowers, you may want to indicate the pollinator associated with that flower.

Discussion
1. Review the Key to Pollination and describe the characteristics of flowers that are adapted for pollination by each of the following agents:
   a. wind
   b. hummingbird
   c. bat
2. Discuss with your lab partner other ways in which keys are used in biology. Record your answers in the space provided.

Lab Study C. Angiosperm Life Cycle

Materials

- pollen tube growth medium in dropper bottles
- dropper bottle of water
- petri dish with filter paper to fit inside
- prepared slides of lily anthers and ovary
- dissecting probe
- brush bristles
- compound microscope
- flowers for pollen

Introduction

In this lab study, you will study the life cycle of flowering plants, including the formation of pollen, pollination, fertilization of the egg, and formation of the seed and fruit. You will also investigate the germination of the pollen grain as it grows toward the egg cell.

* Refer to Figures 2 (flower structures) and 3 (angiosperm life cycle) as you complete the exercise.

Procedure

1. Pollen grain—the male gametophyte.

   a. Examine a prepared slide of a cross section through the stamens of Lilium. The slide shows six anthers and may include a centrally located ovary that contains ovules.

   b. Observe a single anther, which is composed of four anther sacs (microsporangia). Note the formation of microspores (with a single nucleus) from diploid microspore mother cells. You may also see mature pollen grains with two nuclei.

2. Development of the female gametophyte.

   a. Examine a prepared slide of the Lilium ovary and locate the developing ovules. Each ovule, composed of the megasporangium and other tissues, contains a megaspore mother cell (diploid), which produces megaspores (haploid), only one of which survives. The megaspore will divide three times by mitosis to produce the eight nuclei in the embryo sac, which is the greatly reduced female gametophyte. Note that angiosperms do not even produce an archegonium.
Figure 3.
Angiosperm life cycle. Observe the structures and processes as described in Exercise 2. Using colored pencils, indicate the structures that are haploid or diploid. Circle the terms mitosis, meiosis, and double fertilization.
b. Your slide will not contain all stages of development, and it is almost impossible to find a section that includes all eight nuclei. Locate the three nuclei near the opening to the ovule. One of these is called the egg cell. The two nuclei in the center are the polar nuclei.

3. Pollination and fertilization.

When pollen grains are mature, the anthers split and the pollen is released. When pollen reaches the stigma, it germinates to produce a pollen tube, which grows down the style and eventually comes into contact with the opening to the ovule. During this growth, one pollen nucleus divides into two sperm nuclei. One sperm nucleus fuses with the egg to form the zygote, and the second fuses with the two polar nuclei to form the triploid endosperm, which will develop into a rich nutritive material for the support and development of the embryo. The fusion of the two sperm nuclei with nuclei of the embryo sac is referred to as double fertilization. Formation of triploid endosperm and double fertilization are unique to angiosperms.

Once the pollen grain is deposited on the stigma of the flower, it must grow through the stylar tissue to reach the ovule. You will examine pollen tube growth by placing pollen in pollen growth medium to stimulate germination. Pollen from some plants germinates easily; for others a very specific chemical environment is required. Work with a partner, following the next steps.

a. Using a dissecting probe, transfer some pollen from the anthers of one of the plants available in the lab to a slide on which there are 2 to 3 drops of pollen tube growth medium and a few brush bristles or grains of sand (to avoid crushing the pollen).

b. Examine the pollen under the compound microscope. Observe the shape and surface features of the pollen.

c. Prepare a humidity chamber by placing moistened filter paper in a petri dish. Place the slide in the petri dish, and place it in a warm environment.

d. Examine the pollen after 30 minutes and again after 60 minutes to observe pollen tube growth. The pollen tubes should appear as long, thin tubes extending from the surface or pores in the pollen grain.

e. Record your results in Table 4 in the Results section. Indicate the plant name and the times when pollen tube germination was observed.

4. Seed and fruit development.

The zygote formed at fertilization undergoes rapid mitotic divisions, forming the embryo. The endosperm also divides; the mature ovule forms a seed. At the same time, the surrounding ovary and other floral tissues are forming the fruit. In Lab Study D, you will investigate the types of fruits and their function in dispersal.

Results

1. Review the structures and processes observed in the angiosperm life cycle, Figure 3. Indicate the haploid and diploid structures in the life cycle, using two different colored pencils.
Having trouble with life cycles? The key to success is to determine where meiosis occurs and to remember the ploidal level for the gametophyte and sporophyte.

2. Sketch observations of slides in the margin of your lab manual for later reference.
3. Record the results of pollen germination studies in Table 4. Compare your results with those of other teams who used different plants. This is particularly important if your pollen did not germinate.

Table 4
Results of Pollen Germination Studies

<table>
<thead>
<tr>
<th>Plant Name</th>
<th>30 min (+/-)</th>
<th>60 min (+/-)</th>
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</table>

Discussion

1. What part of the life cycle is represented by the mature pollen grain?

2. How does the female gametophyte in angiosperms differ from the female gametophyte in gymnosperms?

3. Do you think that all pollen germinates indiscriminately on all stigmas? How might pollen germination and growth be controlled?
Lab Study D. Fruits and Dispersal

Materials
variety of fruits provided by the instructor and/or students

Introduction
The seed develops from the ovule, and inside is the embryo and its nutritious tissues. The fruit develops from the ovary or from other tissues in the flower. It provides protection for the seeds, and both the seed and the fruit may be involved in dispersal of the sporophyte embryo.

Procedure
1. Examine the fruits and seeds on demonstration.
2. Use the Key to Fruits on the next page to help you complete Table 5. Remember to include the dispersal mechanisms for fruits and their seeds in the table.

Results
1. Record in Table 5 the fruit type for each of the fruits keyed. Share results with other teams so that you have information for all fruits in the lab.

Table 5
Fruit Types and Dispersal Mechanisms

<table>
<thead>
<tr>
<th>Plant Name</th>
<th>Fruit Type</th>
<th>Dispersal Method</th>
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</tbody>
</table>

2. For each fruit, indicate the probable method of dispersal—for example, wind, water, gravity, ingestion by birds, mammals, or insects, or adhesion to fur and socks.

3. For some fruits, the seeds rather than the fruit are adapted for dispersal. In the milkweed, for example, the winged seeds are contained in a dry ovary. Indicate in Table 5 if the seeds have structures to enhance dispersal. Recall that seeds are inside fruits. The dandelion "seed" is really a fruit with a fused ovary and seed coat.
Key to Fruits

1. Simple fruits (one ovary)
   A. Dry fruits (at maturity)
      1. Fruits with one seed
         a. Ovary wall and seed coat are fused achene*
         a. Ovary wall hard or woody but can be separated from the seed nut

1. Fruits with two to many seeds
   a. Ovary with several cavities (seen when cut in cross section) capsule
   a. Ovary with one cavity
      b. Mature ovary opens along both sides legume
      b. Mature ovary opens along one side follicle

   A. Fleshy fruits
      1. Ovary with one seed, which is surrounded by a very hard stone (outer covering of the seed is formed from the inner ovary wall) drupe
      1. Ovary with many seeds, does not have a "stone"
         a. All of mature ovary tissue is soft and fleshy; surrounding flower tissue does not develop into fruit berry†
         a. Fleshy fruit develops in part from surrounding tissue of the flower (base of sepals and petals); therefore, ovary wall seen as "core" around seeds pome

I. Compound fruits (more than one ovary)
   A. Fruit formed from ovaries of many flowers multiple fruit
   A. Fruit formed from several ovaries in one flower aggregate fruit

*In the grass family, an achene is called a grain.
†Berries of some families have special names: citrus family = hesperidium; squash family = pepo.

Discussion

1. How might dry fruits be dispersed? Fleshy fruits?

2. Describe the characteristics of an achene, drupe, and berry.
Questions for Review

1. Return to Table 1 and modify your entries and complete your comparison of gymnosperms and angiosperms.
2. Identify the function of each of the following structures found in seed plants. Consider their function in the land environment.
   - pollen grain:
   - microsporangium:
   - flower:
   - carpel:
   - seed:
   - fruit:
   - endosperm:

3. Plants have evolved a number of characteristics that attract animals and ensure pollination, but what are the benefits to animals in this relationship?

4. Why is internal fertilization essential for true terrestrial living?
Applying Your Knowledge

1. Explain how the rise in prominence of one major group (angiosperms, for example) does not necessarily result in the total replacement of a previously dominant group (gymnosperms, for example).

2. Complete Table 6. Compare mosses, ferns, conifers, and flowering plants relative to sexual life cycles and adaptations to the land environment.

3. How have gymnosperm ovules evolved to withstand desiccation and herbivorous animals?

<table>
<thead>
<tr>
<th>Features</th>
<th>Moss</th>
<th>Fern</th>
<th>Conifer</th>
<th>Flowering Plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gametophyte or sporophyte dominant</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vascular tissue (+/-)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seed (+/-)</td>
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<tr>
<td>Fruit (+/-)</td>
<td></td>
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<td></td>
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<tr>
<td>Water required for fertilization</td>
<td></td>
<td></td>
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<tr>
<td>Pollen grain (+/-)</td>
<td></td>
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<tr>
<td>Homosporous or heterosporous</td>
<td></td>
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<tr>
<td>Examples</td>
<td></td>
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</tbody>
</table>
4. Your neighbor's vegetable garden is being attacked by Japanese beetles, so she dusts her garden with an insecticide. Now, to her dismay, she realizes that the beans and squash are no longer producing. Explain to your neighbor the relationship among flowers, fruits (vegetables, in the gardening language), and insects.

5. In angiosperms, an abundance of pollen is transferred by insects to the stigma. Later, pollen grains germinate to produce pollen tubes that race through the style in their bid to fertilize a limited number of egg cells within the ovules. Explain how this process of gamete competition could be of selective advantage.

6. Describe the major trends in the evolution of land plants.
Plant Anatomy

3. Explain the observation that more stomata are found on the lower surface of the leaf than on the upper.

4. Explain the differences observed, if any, between the stomata from leaves kept in DI water and those kept in saline. Utilize your knowledge of osmosis to explain the changes in the guard cells. (In this activity, you stimulated stomatal closure by changes in turgor pressure due to saline rather than K⁺ transport.)

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**EXERCISE 4**

**Cell Structure of Tissues Produced by Secondary Growth**

**Materials**

preparation slides of basswood (*Tilia*) stem
compound microscope

**Introduction**

Secondary growth arises from meristematic tissue called cambium. Vascular cambium and cork cambium are two types of cambium. The vascular cambium is a single layer of meristematic cells located between the secondary phloem and secondary xylem. Dividing cambium cells produce a new cell at one time toward the xylem, at another time toward the phloem. Thus, each cambial cell produces files of cells, one toward the inside of the stem, another toward the outside, resulting in an increase in stem girth (diameter). The secondary phloem cells become differentiated into sclerenchyma fiber cells, sieve-tube members, and companion cells. Secondary xylem cells become differentiated into tracheids and vessel elements. Certain cambial cells produce parenchyma ray cells that can extend radially through the xylem and phloem of the stem.

The cork cambium is a type of meristematic tissue that divides, producing cork tissue to the outside of the stem and other cells to the inside. The cork cambium and the secondary tissues derived from it are called periderm. The periderm layer replaces the epidermis and cortex in stems and roots with secondary growth. These layers are continually broken and sloughed off as the woody plant grows and expands in diameter.
Procedure

1. Examine a cross section of a woody stem.
   a. Observe the cork cambium and periderm in the outer layers of the stem. The outer cork cells of the periderm have thick walls impregnated with a waxy material called suberin. These cells are dead at maturity. The thin layer of cells that may be visible next to the cork cells is the cork cambium. The periderm includes the layers of cork and associated cork cambium. The term bark is used to describe the periderm and phloem on the outside of woody plants.
   b. Observe the cellular nature of the listed tissues or structures, beginning at the periderm and moving inward to the central pith region. Sclerenchyma fibers have thick, dark-stained cell walls and are located in bands in the phloem. Secondary phloem cells with thick cell walls alternate with the rows of fibers. The vascular cambium appears as a thin line of small, actively dividing cells lying between the outer phloem tissue and the extensive secondary xylem. Secondary xylem consists of distinctive open cells that extend in layers to the central pith region. Lines of parenchyma cells one or two cells thick form lateral rays that radiate from the pith through the xylem and expand to a wedge shape in the phloem, forming a phloem ray.

2. Note the annual rings of xylem, which make up the wood of the stem surrounding the pith. Each annual ring of xylem has several rows of early wood, thin-walled, large-diameter cells that grew in the spring and, outside of these, a few rows of late wood, thick-walled, smaller-diameter cells that grew in the summer.

3. By counting the annual rings of xylem, determine the age of your stem. Note that the phloem region is not involved with determining the age of the tree.

Results

1. Review Figure 9 on the next page.
2. Sketch in the margin of your lab manual any details not represented in the figure that you might need for future reference.
3. Indicate on your diagram the region where primary tissues can still be found.

Discussion

1. What has happened to the several years of phloem tissue production?

2. Based on your observations of the woody stem, does xylem or phloem provide structural support for trees?
Figure 9.
Secondary growth. (a) Whole woody plant. (b) Photomicrograph of a cross section of a woody stem. (c) Compare the corresponding diagram with your observations of a prepared slide. If necessary, modify the diagram to correspond to your specimen.
3. What function might the ray parenchyma cells serve?

4. How might the structure of early wood and late wood be related to seasonal conditions and the function of the cells? Think about environmental conditions during the growing season.

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**Exercise 5**

**Grocery Store Botany:**

**Modifications of Plant Organs**

**Materials**

variety of produce: squash, lettuce, celery, carrot, white potato, sweet potato, asparagus, onion, broccoli, and any other produce you wish to examine

**Introduction**

Every day you come into contact with the plant world, particularly in the selection, preparation, and enjoyment of food. Most agricultural food plants have undergone extreme selection for specific features. For example, broccoli, cauliflower, cabbage, and brussels sprouts are all members of the same species that have undergone selection for different features. In this exercise, you will apply your botanical knowledge to the laboratory of the grocery store.

**Procedure**

1. Working with another student, examine the numerous examples of root, stem, and leaf modifications on demonstration. (There may be some reproductive structures as well.)

2. For each grocery item, determine the type of plant organ, its modification, and its primary function. How will you decide what is a root, stem, or leaf? Review the characteristics of these plant organs and examine your produce carefully.

**Results**

Complete Table 1 on the next page.
Table 1
Grocery Store Botany

<table>
<thead>
<tr>
<th>Name of Item</th>
<th>Plant Organ (Root, Stem, Leaf, Flower, Fruit)</th>
<th>Function/Features (Storage, Support, Reproduction, Photosynthesis)</th>
</tr>
</thead>
<tbody>
<tr>
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</table>

Discussion
1. What feature of the white potato provided key evidence in deciding the correct plant organ?

2. Based on your knowledge of the root, why do you think roots have been selected so often as food sources?
Questions for Review

1. Use Table 2 to describe the structure and function of the cell types seen in lab today. Indicate the location of these in the various plant organs examined.

2. Some tissues are composed of only one type of cell; others are more complex. List the cell types observed in xylem and in phloem.
   Xylem:

   Phloem:

3. What characteristic of sieve-tube structure provides a clue to the role of companion cells?

4. Compare primary and secondary growth. What cells divide to form primary tissue? To form secondary tissue? Can a plant have both primary growth and secondary growth? Explain, providing evidence to support your answer.

Applying Your Knowledge

1. Cells of the epidermis frequently retain a capability for cell division. Why is this important? (Hint: What is their function?)

2. Why is the endodermis essential in the root but not in the stem?
## Table 2
Structure and Function of Plant Cells

<table>
<thead>
<tr>
<th>Cell Type</th>
<th>Structure</th>
<th>Function</th>
<th>Plant Organ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Epidermis</td>
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<tr>
<td>Guard cells</td>
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<td></td>
</tr>
<tr>
<td>Parenchyma</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Collenchyma</td>
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<td></td>
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<tr>
<td>Sclerenchyma</td>
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<td></td>
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<tr>
<td>Tracheids</td>
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<td></td>
</tr>
<tr>
<td>Vessels</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sieve tubes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Endodermis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Primary meristems</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vascular cambium</td>
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<td></td>
<td></td>
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<tr>
<td>Pericycle</td>
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<td></td>
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<tr>
<td>Periderm</td>
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<td></td>
<td></td>
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<tr>
<td>Ray parenchyma</td>
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</tbody>
</table>
3. When lateral roots grow outward from the pericycle, what effect does this have on the cortex and the epidermis? (Hint: Review the structure of the root and the location of these tissues.)

4. In the summer of 1998, after extremely hot, dry weather, the Georgia corn harvest was expected to be reduced by at least 25%. Using your knowledge of the dual functions of guard cells relative to water retention and gas exchange, explain the reduction in photosynthetic productivity.

5. The belt buckle of a standing 20-year-old man may be a foot higher than it was when he was 10, but a nail driven into a 10-year-old tree will be at the same height 10 years later. Explain.

6. Explain, from a cellular point of view, how it is possible to determine the age of a tree.

7. The oldest living organisms on Earth are plants. Some bristlecone pines are about 4,600 years old, and a desert creosote bush is known to be 10,000 years old. What special feature of plants provides for this incredible longevity? How do plants differ from animals in their pattern of growth and development?

8. Plant cells have cell walls and animal cells do not. How does this difference relate to differences in plant and animal function?
Table 3
Adaptations of Plant Cells and Structures to the Land Environment

<table>
<thead>
<tr>
<th>Environmental Factor</th>
<th>Adaptations to Land Environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desiccation</td>
<td></td>
</tr>
<tr>
<td>Transport of materials between plant and environment</td>
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<td>Gas exchange</td>
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<tr>
<td>Anchorage in substrate</td>
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<tr>
<td>Transport of materials within plant body</td>
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<tr>
<td>Structural support in response to gravity</td>
<td></td>
</tr>
<tr>
<td>Sexual reproduction without water</td>
<td></td>
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<tr>
<td>Dispersal of offspring from immobile parent</td>
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</tr>
</tbody>
</table>

9. Many of the structural features studied in this laboratory evolved in response to the environmental challenges of the terrestrial habitat. Complete Table 3 on this page, naming the cells, tissues, and organs that have allowed vascular plants to adapt to each environmental factor.

Investigative Extensions

1. The nut-and-bolt microtome can be used to separate a section of almost any part of a plant. You might grow your own plants from seeds and then embed small sections of each plant organ in paraffin and prepare slides for observation. Visualize the orientation of your material and sections before embedding.
2. Using the technique described in 1 or prepared slides, you can investigate plants that follow a different organization of tissues, including a group of angiosperms known as monocots. Stem sections and leaf sections should be different from those studied in lab.

References

Figure 3 and the idea for the nut-and-bolt microtome are from Dickey, J. Laboratory Investigations for General Biology: Redwood City, CA: Benjamin/Cummings, 1994. Used by permission.


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