Biology 20 Laboratory  
Plant Diversity and Reproduction  

OBJECTIVE  

- To understand the unique characteristics of different plant groups  
- To learn and study the two major systems of plant anatomy (parts and functions)  
- To be able to visually identify the structures of a plant, a flower and a fruit  
- To study plant reproduction and pollination  
- To relate plant reproduction and the formation of fruit  

INTRODUCTION  

Botanists have traditionally divided the plant kingdom (Kingdom Plantae) into dozens of different “divisions”, but for our brief review of these multi-cellular organisms, we will separate the members of the plant kingdom into four informal types: bryophytes (mosses, liverworts, hornworts), seedless vascular plants (ferns, horsetails, club mosses), gymnosperms (conifers or “cone-bearing” trees, including pine, spruce, redwood, juniper and cypress trees), and angiosperms (flowering, “seed-bearing” plants). Angiosperms are the most prevalent group on earth today, including such flowering plants as the common decorative flowers of roses, orchids, carnations, etc., as well as angiosperms like oak trees, corn and cactus. The majority of our lab, therefore, will focus on angiosperms. Before we begin, let's review some characteristics of the four types of plants listed above:  

**Bryophytes** (mosses, liverworts, hornworts)  
- Lack a vascular system for transporting water and other substances against the force of gravity  
- Sexual reproduction via external fertilization by sperm swimming through water or dew to the eggs  
- No roots – have single celled extensions called rhizoids to absorb water and minerals and anchor them to their underlying material  
- Do not produce seeds as a part of reproduction  

**Seedless Vascular Plants** (ferns, horsetails, club mosses)  
- Possess a vascular system for transporting water and minerals throughout the plant  
- Sexual reproduction via external fertilization by sperm swimming through water or dew to the eggs  
- Possess roots that extend into the ground to anchor and absorb water and minerals for the plant  
- Do not produce seeds as a part of reproduction  

**Gymnosperms** (conifers or “cone-bearing” trees, including pine, spruce, redwood, juniper, cypress)  
- Possess a vascular system for transporting water and minerals throughout the plant  
- Sexual reproduction via pollination by means of seed-bearing cones and sperm carried in pollen grains through the air or on animals to the female gametes (cones)  
- Possess roots that extend into the ground to anchor and absorb water and minerals for the plant  
- Non-flowering, seed-bearing (cone-bearing) plants  
- Commonly called “naked seed” plants (seeds not enclosed by tissue or fruit)  

**Angiosperms** (roses, orchids, carnations, oak trees, corn, cactus)  
- Possess a vascular system for transporting water and minerals throughout the plant  
- Sexual reproduction via pollination by means of seed-bearing flowers and sperm carried in pollen grains through the air or on animals to the female gametes (pistil)  
- Possess roots that extend into the ground to anchor and absorb water and minerals for the plant  
- Flowering, seed-bearing plants  
- Seeds enclosed in the protective tissue covering called the fruit  

Because botany is such a vast subject, we will divide our lab into three main categories:  
**PLANT STRUCTURE, PLANT REPRODUCTION, AND FRUITS AND NUTS.**
A. PLANT STRUCTURE

Plants have two main systems: the **shoot system** and the **root system** (Figure 1). The shoot system is above ground and is responsible for photosynthesis, transpiration and respiration. This system includes the stems, leaves and adaptations for reproduction (flowers). The root system is below ground and functions to anchor the plant to the underlying material and to absorb nutrients and water. The root system also stores food for the plant and transports nutrients to the shoot system.

Major parts of the plant shoot system include the stems, leaves and flowers. Each of these has specific anatomical features that lend to their functions.

![Figure 1: The root and shoot system of a flowering plant.](image)

**Stems**

Stems have three main functions: mechanical structure, storage for food reserves, and the pathway for water, minerals and hormones to move throughout the plants. Stems can be **herbaceous (non-woody)** or **woody**. Woody plants have stems composed of cellulose and lignin (protein-like structure).

The structure of the stem includes three types of tissues: **ground tissue** (the “muscles and bones” of the plant), **dermal tissue** (the “skin, hair and nails” of the plant) and the **vascular tissue** (the “veins and arteries” of the plant).

Ground tissue includes **parenchyma** (functions in food storage and wound repair, alive at maturity), **collenchyma** (functions in structural support, alive at maturity) and **sclerenchyma** (specialized for water proofing vascular bundles of the vascular tissue and providing strong support for the plant, dead at maturity, contain **cellulose** running through cell walls). Long, slender bundles of sclerenchyma cells form fiber. Hemp is an example of such a fiber which is used to make rope.

Dermal tissue includes the **outer epidermis** (a protective layer) and, if the plant is a woody tree, the dermal tissue includes a **peridermis** (the bark).
The vascular tissue functions to transport water, minerals and food throughout the plant. Vascular tissue is organized in **vascular bundles** composed of **xylem** and **phloem** tissue. Xylem cells are dead at maturity and move water and dissolved minerals. These cells are large and close to the center of the vascular bundle and have two large vesicles (openings) down the center. The phloem cells are living cells and function to move food for the plant. They are located around the outer edge of the vascular bundles and are smaller, more compact cells than the xylem. As already mentioned, schlerenchyma cells surround the vascular bundles and function to help water proof the bundles. Outside of the vascular bundles, you will find parenchyma tissue.

**Leaves**

Leaves are the site of photosynthesis (leaves contain chloroplasts), transpiration (evaporation of water), and respiration (gas exchange). Leaves are thin, flat and broad, providing a large surface area to volume ratio for these processes.

Leaves are composed of dermal tissue, ground tissue and vascular tissue, similar to the arrangement seen in the stem.

There are two dermal tissue layers: a thin upper epidermis and a thin lower epidermis. The area in between is the ground tissue called **mesophyll**. The mesophyll consists of two layers, a **palisade** cell layer and a **spongy** cell layer. The palisade cells are elongated and tightly packed. The structure and arrangement of the palisade cells lends well to the absorption and direction of sunlight into the inner depths of the leaves. Most photosynthesis occurs in these mesophyll layers. The spongy layer is comprised of loosely packed cells under the palisade cells and is an area of gas storage (lots of air space – think of the process of photosynthesis and what is required and what is produced). Also in the dermal layer, **stomata** and **guard cells** are present. Stomata are pores on the lower portions of the leaves that allow for gas exchange and transpiration. On either side of the stomata are guard cells. Guard cells swell up to close the stomata and shrink down to allow the stomata to open to regulate transpiration, thus affecting gas exchange. You could look at these as the “breathing parts” of the plant.

In a cross section of the leaf, you will also see vascular tissue (vascular bundles). These vascular bundles are the veins you see in the leaf. Remember that vascular bundles allow for the transport of water and nutrients to and from areas of the plant. Think of the processes occurring in the leaves and how vascular tissue would be critical for these processes to occur.

**Flowers (Reproductive Parts)**

The flower of a plant is the reproductive part of the plant. A plant may have both male and female parts on the same flower (**perfect flower**) or separate male and female flowers (**imperfect flowers**). Most angiosperms have perfect flowers, but some, such as corn, have imperfect flowers (still located on the same plant, but the tassel is the male and the ear is the female). Some plants even have separate imperfect flowers located on separate male and female plants. An example of this is the hemp plant (**Cannabis**).

A flower consists of the **corolla** (typically a collection of colored petals) and the **calyx** (typically a collection of green sepals that surround and protect the bud of the flower). A perfect flower would have both female reproductive parts (collectively called the **pistil**) and male parts (collectively called the **stamen**). The pistil consists of the **stigma, style and ovary**. The stamen consists of the **anther and filament**. We will cover more on these structures under plant reproduction in the next section.
B. PLANT REPRODUCTION

Plants can reproduce **asexually (vegetative reproduction)** or sexually (**pollination**).

Asexual reproduction (**vegetative reproduction**) is familiar to us in the form of “cuttings” that can be taken from one plant to start another. The growth of a cutting represents a new plant that is an exact genetic replica of the original plant with no fertilization required. This could take place in **tubers** (underground stems) like with the potato when new shots arise from buds (“eyes”) on the tubers. **Bulbs** are also commonly known for vegetative reproduction. Onions and crocuses are examples of bulbs. In nature, however, reproduction often takes place via **sexual reproduction** with external fertilization between male and female gametes (sperm and eggs) via pollination.

As mentioned previously, the female reproductive parts of a flower are collectively referred to as the **pistil**. The pistil consists of the stigma, style and ovary. The stigma is at the top of the pistil and secretes a sticky substance that traps the pollen (male gametes). The stigma is supported by the style. At the base of the style is the **ovary**. The female gametes (the eggs) are produced in the ovary within chambers called **ovules**. Within the ovary, there are cells that will eventually form **endosperm**, a nutrient material for the developing embryo after fertilization.

The male reproductive structure called the stamen consists of the anther and the filament. The anther is a sac in which meiosis occurs and **pollen grains** develop. The pollen grains house the cells that develop into haploid sperm. The anther is supported by the stalk-like structure called the filament.

**Pollination** is the transfer of pollen (and thus sperm) by wind, water or carried by an animal, from an anther to a stigma (from the male reproductive parts to the female reproductive parts). Once the pollen grain leaves the anther, it is bound for the stigma (whether on another flower or plant or the same flower or plant). The pollen grains “fit” the stigmas of the same species, similar to a lock and key analogy. When it lands on the stigma (remember, the stigma is sticky to hold on to the pollen once it lands), the pollen grain will germinate on the stigma (divide mitotically) and form a **pollen tube** that grows downward through the style toward the ovary. Each pollen grain contains two sperm. In gymnosperms, only one sperm enters the style. In angiosperms, these two sperm will travel through the pollen tube to the base of the style and to the ovary. One sperm will join with the female egg and forms the zygote and that is the time of fertilization. The other sperm moves down along with the first, but joins with the other cells in the ovary to form the nutrient **endosperm** that was mentioned earlier in the lab. The endosperm rapidly divides and surrounds the zygote and will protect it and provide nutrients for its growth. Thus, the reproductive process in angiosperms (flowering plants) is called **double fertilization** (two sperm entering the pistil and fertilizing two different bodies). A protective coating will enclose the zygote and the endosperm and this entire structure is now called collectively the **seed**. Remember that this takes place in the ovary, so the seed is now developing in the ovary of the plant.

The first leaves that appear on the plant embryo are called **cotyledons**. The endosperm will eventually be absorbed into the cotyledons. The number of cotyledons on a plant embryo can differ. If there is one cotyledon, the plant is termed a monocotyledon (**monocot**). If there are two cotyledons, the plant is termed a dicotcotyledon (**dicot**). This is a major distinction by which angiosperms are divided and classified. You will see remnants of the cotyledons when we look at fruits and nuts in the next section.
**The Biology of Pollination**
Pollination occurs with pollen being carried by wind or by animals from the anther to the stigma. Flowers and pollinators have different adaptations that allow them to be more successful at one form of pollination or another, or with one flower or another. Some pollinators are better adapted to certain flowers and can more efficiently obtain food from the plants they frequent, and are thus better suited to aid in pollination of that species. What we see is a **coevolutionary relationship** (the interdependent evolution of two or more species) that develops. We see with flowering plants and their animal pollinators, that coevolution can benefit both species and that this relationship is often **species specific**, to ensure that the pollen is delivered to the right stigma.

**Wind Pollinators**
Flowers that are adapted for pollination by wind or water, typically have smaller and more inconspicuous flowers. Large amounts of pollen are common with these flowers, because it will increase the chance that pollen grain will find the species-specific stigma to which it “fits”. Wind pollinated flowers also do not often have an odor or nectar, because they have no need to attract animal pollinators. Grasses are examples of wind pollinators.

**Animal Pollinators**
Flowers that are pollinated by animals (Table 1) have characteristics that function hand-in-hand with their pollinators. Flowering plants take full advantage of the mobility of animals to transport pollen from one plant to another. First and foremost, the flowers must attract their pollinators. Pollinators may be attracted to a particular flower by its fragrance, color, or pattern of visual elements. Insects or birds may be guided to the flower by certain color combinations. Flower size and shape, and food availability (nectar) are also targeting factors. After all, the pollinator is coming to the flower primarily to obtain food. So, plants pollinated by animals not only produce pollen, but are typically more ornate, fragrant and produce more nectar. Next you will see a few examples of how differences in these characteristics can attract different pollinators.
Table 1: A comparison of various pollinators.

<table>
<thead>
<tr>
<th>Pollinator</th>
<th>Foraging Behavior</th>
<th>Size</th>
<th>Sensory Characteristics</th>
<th>Adaptations or Not?</th>
<th>Example of a Typical Flower</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bees</td>
<td>Daytime</td>
<td>Small to medium</td>
<td>Attracted to sweet smells. Lack visual perception in red range. Attracted mostly to yellows and violets/blues. Can see UV.</td>
<td>Specialized hairs on posterior legs to hold pollen. Not good at hovering and do not possess feeding extensions.</td>
<td>Small to large. Possess fragrance and nectar with erect flowers for the bees to land on while feeding. Nectar source not obstructed. Yellow or violet/blue in color. Example: Dandelion</td>
</tr>
<tr>
<td>Moths</td>
<td>Nighttime</td>
<td>Small to medium</td>
<td>Good sense of smell.</td>
<td>Have elongated tubular mouthparts. Have ability to hover.</td>
<td>Medium size. Strong nocturnal fragrance. Typically no landing platform. Could be hanging down or arranged horizontally. Example: Easter Lily</td>
</tr>
<tr>
<td>Hummingbird</td>
<td>Daytime</td>
<td>Large</td>
<td>Poor sense of smell. Excellent color vision (especially red and orange)</td>
<td>Ability to hover. Elongated tubular beaks and long tongues.</td>
<td>Small, med or large. Not fragrant. Red or orange in color. Often tubular flowers or hanging upside down. Example: Hibiscus</td>
</tr>
<tr>
<td>Bats</td>
<td>Nighttime</td>
<td>Large</td>
<td>Well developed sense of smell. Attracted to scent of fermenting or rotting fruit. Color blind.</td>
<td>Long tongues to suck up nectar.</td>
<td>Fruity, nocturnal scent. Usually black or white (since bats are colorblind). Flowers large and sturdy. Ex: Saguaro Cactus</td>
</tr>
</tbody>
</table>

By examining the characteristics of a flower, (habitat, symmetry, shape, size, color, platforms, odor, amount of pollen, and presence or absence of pollen) you can reasonably choose a means of pollination and a probable pollinator.
Applying what we have learned so far, we know that flowers consist of male and female reproductive parts and that sexual reproduction takes place via pollination and the sperm fertilizes the egg in the ovary of the flower (Figure 2). What results is the formation of a seed inside the ovary. The ovary wall expands and develops into fruit. Strictly speaking, fruit is the mature ovary of any flowering plant. So, the sequence of occurrence is this: flower, pollination, double fertilization, seed formation, ovary development, petals and sepals fall off, ovary enlarges and bursts from calyx, ripened ovary = fruit. The fruit is the fleshy, spongy matter that protects the seed(s). The fruit functions not only to protect the seed, but also aids in dissemination of the seeds so they can germinate.

The fruit is the pericarp (ovary wall) and inside is the seed(s). The pericarp is divided into three layers. The outermost layer is called the exocarp (the orange outer layer of the skin of an orange), the middle layer is the mesocarp (the white, spongy layer under the skin of an orange), and the inner endocarp (the fleshy, juicy part of an orange). You cannot always distinguish the 3 layers of the pericarp in each fruit.

There are different types of fruits depending on the organization of the flowers from which they arise.

**Simple Fruits** - develop from one ovary (1 carpel). They can be dry or fleshy.

**Simple Dry Fruits**

Legumes - members of the pea family. This simple fruit has a dry pericarp (outer covering of the ovary) which splits (dehisces) along the edges when mature.

The pea pod is an example of a legume. The pod is the ovary containing the seeds (peas). On the stem end of the pod, you should see the sepals which had been below the pea flower. At the other end of the pea, look for the style. What you eat are the seeds of the ovary.
The peanut is another example of a legume with a stony shell. When you observe the peanut, you will note the persistence of the style at the far end of the shell. If you break one of the “nuts” in half, you will see a tiny structure stuck to one of the two halves. This is remnants of the embryo. What you eat are the seeds of the peanut.

**Note:** *When the peanut flower is pollinated, the stem bends over toward the ground and grows beneath the soil. The peanut then develops below the ground. It is not a root, but just grows subterranean.*

Achenes – dry pericarp, indehiscent. Include sunflower seeds and buckwheat. Achenes have a single seed attached to the pericarp (ovary wall) in only one place. The part you eat is actually the seeds of the achene.

Grains – members of the grass family such as corn, wheat and rice. Grains are dry, one-seeded (one cotyledon), indehiscent fruit. The pericarp and seed are firmly attached and cannot be easily separated. An example of a grain would be cornnuts.

Nuts – one seeded, indehiscent, dry fruit with a hard pericarp (shell). Examples are chestnuts, walnuts, and acorns.

**Simple Fleshy Fruits**

Drupes – develop from a single carpel and have one seed. The pericarp has 3 layers – the inner layer is hard and covers the seed, the middle layer forms the fleshy fruit and the outer layer forms the skin. Some examples include cherries, almonds, peaches, avocados, apricots, olives and coconuts.

Berries – come from a compound ovary having many seed embedded in the flesh. Berries include citrus fruits like lemons, limes, oranges, and grapefruit), tomatoes, grapes, melons, squash, pumpkins and cucumbers. Upon examination, you should be able to see the exocarp, mesocarp, endocarp, and seeds. In the citrus fruits, identify the carpel walls (the dividers between sections).

Pomes – form from an inferior ovary (the ovary is located beneath the flower). The fruit is the enlarged ovary wall called a receptacle. Examine an apple. Look for the stamens and the styles at the end opposite the stem (peduncle). Think of how the apple hung on the tree; first with the flower erect and then drooping over as the fruit develops and becomes heavy.

**Compound Fruits** - form from several ovaries. Compound fruits can be aggregate fruits or multiple fruits.

Aggregate Fruits - formed from several ovaries of one individual flower...Examples of aggregate fruit are strawberries (aggregate of achenes) and raspberries and blackberries (aggregates of berries). When you observe these aggregate fruits, you will see little “fuzzies” on the fruit. These are remnants of the styles of the pistils.

Multiple Fruits - formed from individual ovaries of several flowers fused together. Examples of multiple fruits include figs and pineapples.
MATERIALS
Various flower types, colored pencils, dissecting tools, various fruits and nuts (student provided)

PROCEDURE

A. Plant Structure
1. Observe the diagrams and/or prepared microscope slides of cross sections of different parts of a plant (the leaf and the stem) and include correct labels for all parts.
2. Observe, draw and label a typical example of a perfect flower.
3. Choose two different flowers from the class assortment and draw them, correctly labeling all plant and flower parts.

B. Plant Reproduction
1. With the two different flowers that you chose above, analyze the flower types and determine probable pollinators for those flowers.

C. Fruits and Nuts
1. Analyze various types of fruits and nuts and draw an example from each category, correctly labeling all the parts of the fruit.
A. Plant Structure

1. Label the appropriate areas of the following cross section of a dicot and monocot stem with the following terms:

   ![Cross Section of Stem Diagram]

   - Dermal tissue
   - Vascular tissue
   - Ground tissue
   - Epidermis
   - Vascular bundle
   - Xylem
   - Phloem
   - Pith

   Type of stem: ________________  
   Type of stem: ________________

2. Label the appropriate areas of the following cross section of a leaf with the following terms:

   ![Cross Section of Leaf Diagram]

   - Dermal tissue
   - Ground tissue
   - Vascular tissue
   - Mesophyll
   - Palisade cells
   - Spongy cells
   - Upper epidermis
   - Lower epidermis
   - Cuticle
   - Vascular bundle
   - Xylem
   - Phloem
   - Guard cells

3. **Draw and Label** a picture of a perfect flower.  
   Include the stem, sepals, petals and **ALL** reproductive parts.
4. Choose 2 different types of flowers from the class assortment. Draw and **LABEL ALL** parts of the flower (petals, sepals, male and female parts). Include the type of flower (perfect or imperfect).

**Flower #1**

common name _____________________ scientific name ______________________________

**Flower #2**

common name _____________________ scientific name ______________________________
5. What are several functions of the **stem** of a plant? How does the anatomy of the stem contribute to a successfully functioning **stem**?

6. What are several functions of the **leaf** of a plant? How does the anatomy of the **leaf** contribute to a successfully functioning **leaf**?

7. What are the two types of vascular tissues found in plants **and** what are their functions?

8. Where does photosynthesis occur in the leaf of a plant? **Explain** what is present in that area **and** how the structure of the different cells assists in photosynthesis.
B. Plant Reproduction

9. Analyze the two flowers you chose previously and determine the means of pollination and probable pollinators for those flowers.

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</tr>
<tr>
<td>Depth to nectar (deep tube)</td>
<td></td>
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<tr>
<td>Color</td>
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<td>Platform present? (y/n)</td>
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10. Explain why the observations you made with each of your flowers led you to choose that pollinator?

11. Describe the processes and events that lead to double fertilization.

12. Name all the parts of the male and female reproductive systems in plants.

13. What is produced from vegetative reproduction and how is that different from what is produced from sexual reproduction in plants?
C. Fruits and Nuts

14. Draw an example of each of following types of fruits. You must LABEL all parts of the fruit for full credit! Use the information in your lab, as well as your instructor’s lecture to label ALL the correct structures.

Achene

Pome

Nut

Berry

Grain

Aggregate fruit

Legume

Multiple fruit

Drupe
15. Describe the formation and functions of a fruit.

16. Distinguish between simple fruits, aggregate fruits, and multiple fruits. (i.e. - the origin of their development).

17. List two (2) “true” vegetables and the part of the plant which they represent.