Lab 9: The Reproduction of Angiosperms and the Role of the Pollinator

Understanding the role and structure of a flower
Flowers are the reproductive organs of angiosperms. They are not simple structures, and the diversity of flower shape, color, and fragrance suggests that angiosperms have evolved a variety of ways to reproduce. Indeed, botanists have identified a number of reproductive strategies among angiosperms that are based on differences in how flowers are structured. For many angiosperms, the differences in flower anatomy are related to how the plants are pollinated. However different they may look, most flowers do contain specific structures that assist in transfer of reproduction agents, structural support and attraction of pollinators. A diagram and list of these parts are shown in Appendix A. Familiarize yourself with the names and organization of these structures before coming to class.

Pollination
The crucial step in sexual reproduction of angiosperms is pollination, the transfer of pollen from anther to stigma. This is the part of the reproductive process that the plant does not control itself. Instead, some other agent must transfer the pollen to the stigma. In some cases, gravity or wind may allow pollen to move from anther to stigma. These mechanisms are strictly mechanical, and may result in pollination of the same flower that produced the pollen. To avoid this self-fertilization, many plants rely on other agents, or use wind differently, to help insure cross fertilization with other flowers. Most frequently, these other agents are animals (such as beetles, flies, bees, butterflies, moths, birds, bats, and mice) that visit the flower, “accidentally” pick up pollen, and carry it to another flower that they visit where it will fall on the stigma.

Pollination alone does not guarantee that fertilization will occur. Many factors interact to predict whether a pollination event will result in successful fertilization (union of sperm and egg). For example, if pollen of one species falls on the stigma of a flower from an unrelated species, it may be “wasted”, as the incompatible pollen will not develop a pollen tube and fertilization will not occur. The odds of successful fertilization are increased if pollen is deposited on the stigma of a flower from the same species. From the perspective of a plant, the most efficient pollinating animals are the ones most likely to visit another flower of the same species. If the plant cannot directly control where a visitor goes next, can it at least indirectly increase the chance the visitor will next go to another flower of the same species? Botanists have discovered that the answer, surprisingly often, is yes.

Plant “Sexual Selection”
Sexual selection is a version of natural selection in which the phenotypes of individuals impact their likelihood of reproduction through mate choice. In animal-pollinated plants, mate choice is affected through the decisions of animals about which plants they will visit. Plants can influence the behavior of their visitors (and thus, improve their odds of successful reproduction) by:

Making the Flowers More Detectable to the Visitor
Potential pollinators differ in how they detect flowers. Some have good eyesight. Larger flowers that have colors animals can detect would be more recognizable. Other pollinators rely on odor. For these visitors, plants are more recognizable if they have distinctive odors. Finally, pollinators differ in what time of day they are active. Flowers will be more detectable to visitors if they are open at the appropriate time of day.

Rewarding the Pollinator
Most animals will be more likely visit a flower if it provides them with energy or nutrients. Plants have developed the ability to provide both to visiting animals. Pollen itself can be a food source for pollinators if the plant produces more than it needs for reproduction. In addition, plants can provide nectar, a fluid
secretion made by specialized parts of a flower that provides visitors with a high energy, nutritious food source. If an animal receives a reward like nectar at one flower, it will likely seek out a similar flower after leaving to find more.

**Structuring the Flower for One Visitor**
Detectability and rewards for visitors are not enough to guarantee that a flower will be effective in attracting pollinators. The flower structure must be sufficient to support the body weight of a pollinator that may need to land on the flower during a visit. Additionally, the structures of the flower must be designed so that the visitor can come into contact with pollen and stigma as it seeks its reward. Since most plants benefit from avoiding self-fertilization, they have the added problem of structuring a flower that allows a visitor to come into contact with pollen while getting their reward yet avoiding contact with the stigma of the same flower. Ideally, the visitor will then come into contact with the stigma of the next flower, without contacting that flower’s pollen first. This constraint has influenced the organization of the parts of many flowers, allowing them to rely on specific visitors while avoiding self-fertilization. The flower must also permit the visitor to make a visit. Structurally, the flower and its pedicle must be strong enough to support a visitor that walks on the flower.

What is most surprising is the diversity of mechanisms that plants have evolved to become detectable to, reward, and support visits by animal pollinators. Indeed, plants have done so well at attracting and rewarding potential pollinators that some groups of animals have evolved lifestyles of obligate use of a particular reward type, such as nectar. In more extreme cases, specific species of animals will pollinate only a specific species of plant in a very fine-tuned, mutual dependency. The details of how these interdependent pollination systems arose are still being studied by evolutionary biologists. But the things we find attractive in flowers, their shapes, colors, and smells, are all byproducts of the evolutionary interplay between flowers and their visitors to ensure effective pollination.

**Possible pollinators and their specific “mating” preferences**
Each pollinator has specific life history traits, as well as visual, smell and shape preferences. Flowers have evolved over generations to accentuate the particular traits their most effective pollinator prefers. Below are descriptions of preferences for a few pollinators we will consider today.

**Butterflies**, as adults, are active during the day when it is clear and sunny. They feed mainly on nectar from flowers for their food (some do not feed as adults). Butterflies must land on flowers to feed, as they are not capable of hovering. Butterflies have a long, tubular proboscis that is coiled under their head while they fly. The proboscis uncoils to feed, and the insect sucks up liquid through a hollow, central chamber of the proboscis. The proboscis has very few hairs or bristles along its length, though there are often barbs at the end to anchor it into plant tissue while feeding. The longest proboscis among butterflies is 25 cm; the “normal” range for butterflies in the northern United States is roughly 4–40 mm. The scales on the wings and head of butterflies, and the hairs and bristles on their legs, can collect pollen, but butterflies do not consume it. Butterflies differ in their olfactory and visual abilities. Butterflies have color vision and are capable of recognizing yellows, greens, and blues as separate colors. Some butterflies see red as a yellowish color while others do not perceive red. In behavioral tests, butterflies are attracted to yellows and blues but ignore greens. They can use the differences between colors on a flower to locate nectar sources. Butterflies can detect odors through their feet and antennae. They are attracted to heavy, sweet, fruity scents. Some butterflies locate food sources by scent; others rely on visual location, using scent to guide them when they are very close to a flower.

**Bees** are active on clear, sunny days. They feed on both pollen and nectar; unlike most other insects, their
larvae feed on nectar (transformed into honey in the hive). Like butterflies, adult bees land on flowers to feed. Bees have a protrusible tongue that is folded up beneath their head. The length of the tongue in honey bees is about 6 mm, but other species can have tongues two to three times as long. Like butterflies, they suck liquids into their tongue through a hollow, central chamber. Unlike butterflies, bees have many hairs and bristles on their tongues. Bees collect pollen on their legs, using comb-like bristles on the legs to scrape pollen from the hairs on other parts of their body. Bees can detect yellows, blues, greens, and ultraviolet as distinguishable colors; they do not detect red as a color. Because they detect ultraviolet as a color, bees’ perception of the color of flowers is different from ours. They can use the differences between colors, including ultraviolet, on a flower to locate a source of nectar. Experiments indicate that the excellent vision of bees is used to locate food sources from a distance, but they use odor cues when close to flowers. They are attracted to faint, sweet scents.

Several types of birds visit flowers to feed. Hummingbirds and honey creepers (Hawaii only) are the most common pollinators in the United States; other families of birds visit flowers in the tropics. Hummingbirds hover in front of flowers without landing and insert their long bill into a flower. They have long tongues that can reach out from the bill and lap up nectar. Hummingbird bills are often curved and shaped to fit the flowers they feed on. Because the bill is sharp, the ovary of the flower can be pierced by the bill. Some pollinating birds will steal nectar by piercing the base of a flower from the outside. The feathers at the base of the bill can collect pollen although the birds do not eat it. Birds do not have a well-developed sense of smell and locate food sources by sight. Red, orange, and unusual color combinations are particularly attractive to pollinating birds. Most bird pollinators live primarily on the nectar.

Bats are important pollinators in many parts of the world, including the desert southwest. Bats are active at night, have poor vision, but a well-developed sense of smell. Not surprisingly, bat-pollinated flowers are open at night, tend to be whitish or very pale in color, and have a very strong, musky-sweet fragrance. Bats may or may not land on the flower to feed, but bat flowers tend to be quite large in order to support the large volumes of pollen and nectar that bats consume.

Wind can blow at any time of the day, during any type of weather. Nothing sticks to wind, and it cannot detect color or odor. It may blow in particular directions most of the time, but can change quickly and at random. Pollen carried on the wind is usually scattered over a broad area with very few pollen grains per cubic centimeter of moving air. Wind pollinated flowers are simple, lack color, odor or nectars, and have highly branched stigmas

What you will do:
In this lab, you will examine the structure and function of several different types of flowers in order to understand the process of pollination. You will also use information provided to explore how different types of flowers are structured to facilitate pollination by different pollinating agents.

Laboratory Objectives
In this lab, you will learn to:
1. Identify the reproductive parts of flowers and explain how they are involved in plant reproduction.
2. Predict likely pollinators based on the structural organization, color, and fragrance of different flowers
3. Evaluate the costs and benefits to both partners in relationships between animal pollinators and flowering plants.
4. Describe co-evolution and how it relates to plant pollinator relationships.
**Methods:**

**Part I: Pollination Video**

With your class, watch the short video that summarizes a variety of pollination strategies. Take notes on the structure of flower parts and the strategies of different pollinators. Use information from the video to answer the following questions.

1. List three specific rewards which a flower could provide its pollinator.

   ________________________________________  ________________________________________
   ________________________________________

2. Describe how the African water lily is pollinated. What type of insect pollinates the flower? How does the lily acquire the pollen from this pollinator?


   Trigger plant uses ________________________________________
   *Digitalis* uses ________________________________________

4. What adaptations do bird-pollinated plants have that improve the chances of birds acquiring and transferring pollen? Explain how the bird transfers the pollen to another plant.
5. Explain how the *Arum* lily tricks blowflies into spreading its pollen. Comment on what happens in the three days that the pollination is occurring. What does this plant have in common with a dead mouse?

6. Explain how a plant can be pollinated in water. What competes with the plant for the pollen?

7. Describe how the Arctic rose (*Dryas*) is able to reward its pollinator in this cold habitat. Comment on the two ways the rose helps its pollinator.

After the movie, discuss the following question with your groups:

Many of the examples highlighted in this movie illustrate highly specific relationships between plants and pollinators. **Discuss with your group and list potential advantages and potential disadvantages of highly specific relationships, such as the hammer orchid and its wasp pollinator.**
Part II: Predicting Potential Pollinators
1. In your groups, create a table that includes pollinator type (e.g., bird, butterfly, wind, bee, etc.) on one axis and floral characteristics (e.g., flower color, size, shape, smell, nectar, etc.) on the other axis. Feel free to use the information provided at the beginning of this lab when constructing your tables.
2. Each group of four students will be provided with several different flowers. Using your completed chart, predict which type of pollinator (Butterflies, bees, birds, or wind) would pollinate each of the example flowers. Construct a second table that reflects which pollinator would pollinate each flower and what characteristics of the flowers influenced your decision.

Part III: Examining the Flowers
Now that you have predicted which type of pollinator would pollinate each flower, examine your flowers and identify the various parts:
1. **Overall Appearance – DO NOT DISSECT YET!**
   a. In your guidebooks, diagram the flower you examine, labeling the parts identified in Appendix A. Be sure to identify all of the parts as best you can without dissecting the flower. Note the position of the flower on the plant (if possible) and whether more than one flower is present. What is the color, color pattern, and odor of the flower? How stiff and resistant are the pedicle, sepals, and petals? What size animal could walk on the flower and have its weight supported by the petals, sepals, or pedicle?
2. **Dissection**
   a. After you have diagrammed each flower, carefully dissect it. You should make one cut along the long axis of the flower, dividing it into mirror-image halves. Be sure the cut goes through the middle of the flower, bisecting the ovary and receptacle. Ask your TA for advice if you have difficulty. Use a dissecting microscope to see the fine details.
   b. Sketch the cut flower, and identify the parts of the flower. Pay particular attention to the location of the anthers and stigma. Where is the pollen located? Is it dry or sticky? Is there much pollen, or very little? Where is the stigma located? How would pollen travel to get from anther to stigma? Could the pollen get to the stigma of the same flower on its own?
   c. Prepare a wet mount of the ovary and anther from your flower to observe ovules and pollen. Place a drop of water on a slide. Using a scalpel, slice a thin cross section of the ovary or anther and place the thin slice in the water on the slide. Apply a coverslip. Using a compound microscope, view the wet mount under 2.5x or 4x, 10x and 40x. Sketch what you see and make notes on the structure of each.
3. Many flowers produce rewards for pollinators. Examine your flowers for such rewards, which may take the form of copious pollen, nectar, or oils. See if you can find areas of the flower that produce small amounts of liquid (ignore the sap that sometimes leaks out of the cut edge of a flower). Remove individual petals or other flower parts from one half of a dissected flower, looking for sources of nectar on the surface of petals, at the base where they attach to the receptacle, in tubular extensions of the petals or sepals, or any of the many “nooks and crannies” present in the flower. Indicate on your diagrams where nectar is produced. Indicate where any odors seem to be concentrated.
Post Lab

Part 1: Video and Discussion
1. Create a T-chart to represent your group discussion on the potential advantages and disadvantages of highly specific relationships between pollinator and flower.

Part 2: Predicting Potential Pollinators
1. Create a table (Table 1) to represent that includes pollinator type as the rows, and floral characteristics as the columns. Be sure to include appropriate labels and titles.
2. Create a table (Table 2) that reflects your prediction of which pollinator type will pollinate the 4 flowers in your group. Include in this table the characteristics that influenced your decision.

Part III: Examining the Flowers
1. Diagram your flower’s external appearance and label all applicable parts identified in Appendix A.
   a. Note: Include answers to questions asked in the methods section.
2. Sketch your flower’s internal anatomy and label all applicable parts identified in Appendix A.
   a. Note: Include answers to questions asked in the methods section.
3. Sketch the wet mount of both (a) the ovary and (b) the anther from your flower. Include notes on the structure of each.
4. Does your flower have a reward for pollinators? If so, what is that reward? Where is it located?
5. In a summary statement, reflect on what you learned this lab about pollination biology.

Part IV: Reading a Scientific Article – DUE at the beginning of your next lab
Read and summarize the article, “The ‘Invisible Hand’ of Floral Chemistry.” The summary should be less than one page and should focus on the main ideas of the article. Make sure the summary is in your own words and try to relate it to what you learned in lab this week. Do NOT plagiarize! This is part of your post-lab.
Appendix A. The structure of a flower

![Diagram of flower structure](image)

**Figure 1. Illustration of seed and flower structure of an angiosperm.**

Flower parts are arranged in “whorls” or concentric rings of structures. In some flowers, all 4 whorls are present. In others, one or more whorls may be absent. A complete flower includes the following whorls in order from outermost to innermost:

a. **sepals:** modified leaf, located below the petal of the flower, with the main purposes of supplying structural support and protection.

b. **petals:** modified, brightly colored leaf, with the main purposes of supplying protection and attracting pollinator agents.

c. **stamens:** the male reproductive parts of a flower.
   - **filament:** the stalk of the stamen, which terminates in the anther.
   - **anther:** the pollen-bearing structure of the stamen. Pollen contains sperm. Upon transfer to a compatible flower, the pollen grows a tube that penetrates the female tissue to deliver sperm to egg.

d. **pistils:** the female reproductive parts of a flower.
   - **stigma:** the terminal part of the pistil receives the pollen
   - **style:** the elongated stem of the pistil that connects the stigma to the ovary. The pollen tube must grow through the style in order to deliver the sperm to the location of the eggs in the ovary.
   - **ovary:** the swollen base of the pistil which contains “ovules”. Ovules contain eggs and will develop into seeds if fertilized.

A “peduncle” or stalk supports a flower or inflorescence and connects it to the rest of the plant. An “inflorescence” refers to many flowers connected to a common peduncle, Smaller stems, or “pedicels” connect to each individual flower in an inflorescence. Peduncles and pedicels are generally enlarged into broader base, or “receptacle” to which the actual floral whorls are attached.
Appendix B. References


