Activity Set C:
Field Study of Flowers and Pollinators

Summary: In outdoor field settings, students investigate animal pollinators, most likely insects and hummingbirds. Student inquiry questions will be explored by collecting data on pollinator visits to flowers. Students count the number of pollinator visits to flowers during timed observation periods. They can also explore the percentage of pollinator visits by certain types of pollinators (e.g., butterflies, bees, beetles, etc.). Visitation rates (number of visits per minute) will be calculated, and pollinator visitation rates compared among plants. Students can also calculate the proportion of visits from each pollinator group. Students communicate with online scientist mentors about their investigations.

Learning Activities:

1. Activity 1: Pollinator Visitation Rates
    - Students investigate a research question based on observing pollinators visit plants
2. Activity 2: Insect Visitor Composition
    - Students investigate the types of pollinators visiting plants

Skills:

1. Develop a research question
2. Design and conduct an investigation based on a research question
3. Collect data through quiet observation in outdoor environment
4. Maintain field journal
5. Use field guides to identify organisms in the field
6. Analyze data and develop conclusions
7. Communicate ideas, questions, observations, conclusions

Concepts:

- Flowering plants often rely on animal pollinators.
- Plants that rely on animal pollinators tend to have characteristics that attract important pollinators.
- Pollinator syndromes refer to flower traits that tend to attract specific pollinators (such as white flowers attracting moths, yellow flowers attracting bees, red tubular flowers attracting hummingbirds).
- Environmental factors, such as habitat or weather, can affect pollinator visits.

Juicy Questions for Discussion and Investigation:

- *Why do some plants rely on animal pollinators?*
- *What happens if plants do not get visited by pollinators?*
- *What plant characteristics attract certain pollinators? How do you think these evolved?*
- *What kinds of animals pollinate flowers?*
- *Do different pollinator types visit different types of flowers?*

Prepare for Field Observations

For Both Activities

You Will Need:

- Access to outdoor site with flowering plants over a series of days – options include:
    - Natural field site (meadow, shrubs, small trees)
    - Garden or flower beds
    - OR – you can set potted flowering plants in an outdoor setting – it is recommended that you let them set for 60 minutes to a few hours prior to students observing so insects might locate them before students observe
- Field notebooks for students (graph paper type ideal)
- Calculators
- Graph paper and/or computer database (e.g., excel) for data analysis
- Optional: hand lenses, binoculars (using in reverse fashion, they serve as excellent magnifiers)
- Optional: field guides for students to identify plants and insects
- Optional: cameras

Safety Concerns:

- Be cautious with sun and heat (or cold) exposure – be sure to drink lots of water.
- Check with students for allergies to insect bites or bee stings.
- Check for ticks.
- Take cover immediately in a storm involving lightning or strong winds.

Preparation:

- Spend time yourself at field location beforehand to:
    - See what plants are flowering and what insects are active (Are flowers open all day – sometimes they close at night or fade in the heat of day. Are insects active during classtime?)
    - Delineate boundaries for students
    - Make note of any important features of field location
- Think about how you want student teams to work together
- Think about how to guide students in research design

Prepare Students for Field Observations:

- Be as quiet and still as possible to not discourage insects from visiting.
- Don't wear brightly colored clothing (try to wear gray, brown, dark green, black or something similar so insects aren't attracted to clothing disguised as flowers!)
- Beware of hair products – insects can be attracted to the scents, waxes and oils in hair products.
- Try not to wear strong scents like perfumes, colognes or even strong-smelling lotions, creams, etc.

For the Teacher: Instructional Procedure

1. Introduce / assign thought questions for homework / discuss concepts of pollination (as relevant to your purposes).
2. Explain the general idea of the research study and have students communicate with mentors about it.
3. Review boundaries and safety concerns (see page50)
4. Send teams outside to find their study site(s) and describe it in their field notebook.
    a. You may want to give students time to really explore and decide themselves where they want to set up observations and what flowers to observe, or you might want to assign these elements.
    b. Draw the area from a bird's eye-view. Include relevant features:
        i. Structures such as buildings, sidewalks, roads, etc.
        ii. Plants in the area, such as trees, shrubs, grasses, etc.
        iii. Flowers in the area.
    c. Write notes describing area (such as sun, shade, windy, etc.).
    d. If using a natural area, have students choose a particular species of flower to study, and identify it using field guides.
5. Once students know which flower they will study, have them draw the flower, trying to identify the reproductive parts of the flower. Note: this may not always be as easy as one might expect – flowers are very diverse, and the anatomy is not always straightforward. After they draw their flower, you might give an assignment for students to learn more about their flower, either through flower guides or the internet. Have students discuss this with their online mentors.
6. Identify a clear question, hypothesis and experimental design, and post these on the website (Refer to possible questions on p. 52).
7. Hold a class discussion to define terms and variables (e.g., when do you count an insect as a "pollinator"?) (see definition on p. 55). Consider input from online mentors.
8. Have students conduct experiments with timed observation periods (see p. 55).
9. Discuss their observations at the end of each class, and have them discuss with online mentors.
10. Have teams analyze their data and present to other class members (see pp. 56-57), and share with mentors.
11. Have teams combine their data into one class data set and analyze (see page 53). Be sure to leave time to have students share their data with mentors, and to have discussion with them about the meaning and significance of their findings.

Activity 1: Pollinator Visitation Rates

Plants are different from animals in many ways. One of the most significant differences is that plants cannot move around to find a mate like animals can. Plants rely on external means, such as wind or animals, to transfer male gametes to female gametes. Flowering plants have evolved and diversified to such a great degree largely due to their ability to attract animal pollinators. These animal pollinators vary from insects to birds to mammals to lizards. Of all these groups of animals, insects comprise the major group of pollinators.

Scientists actively investigate the relationships between pollinators and plants. In this investigation, you will formulate a research question based on exploring the number of pollinators that visit specific flowers. To formulate a research question, think about the types of questions scientists ask listed below. Also, ask your online scientist mentor about possible inquiry questions. They will have thoughts and insights for you.

Scientists study these basic questions related to specific species:

- Do certain species of plants receive more insect visits than others?
- Do flowers of a certain color receive more insect visits than others?
- Do flowers of a certain height receive more insect visits than others?
- Do flowers that appear in groups or clusters receive more visits than flowers that stand alone?
- Do bees visit one type of flower more often than others (color, shape)?
- Do flowers of a certain species receive more insect visits in different environmental or weather / climate conditions?
- Do flowers of a certain species receive more insect visits at particular times of the day than others?

Possible hypotheses:

- Sunflowers will have more insect visitors than dandelions.
- Honeysuckle will have more insect visitors than irises.
- Flowers of a given species will have more insect visitors in the sun than in the shade (or vice versa – it may likely be dependent on plant species).
- Flowers that are grouped or clustered together will receive more insect Insects than flowers more with more distance between them.
- Yellow flowers will attract insect visitors at a higher rate than flowers of other colors (or other color combinations).
- Clover will receive more insect visits in the afternoon than in the morning.
- Flowers of a given species will have more insect visitors in a lush meadow than near a rocky outcrop.
- Flowers with radial symmetry will receive more insect visitors than flowers with bilateral symmetry.
- Flowers receive more insect visits on warm sunny days than on damp cloudy days.

Data to collect: Number of insect visits per flower in a given timed period (e.g., 10 minutes)

Experimental Design

Relationship of team to class

Replication of experimental conditions yields greater and more complete data sets. You could gain the greatest amount of data by having each team's data contribute to data of the whole class. We consider this "pooling" data. There are two ways to accomplish this. Let's say you have 4 flower species to explore.

A

B

C

D

<u>Option 1:</u>
If each team is composed of four students, each student in the team could observe a different species of plant:

Team 1: A,B,C,D

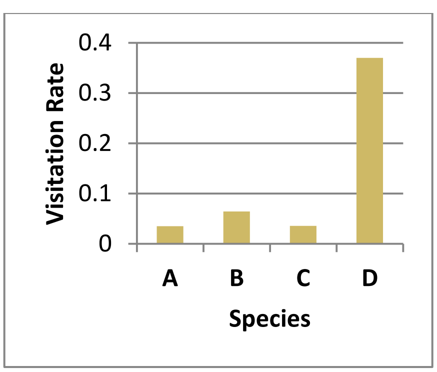
Team 2: A,B,C,D

Team 3: A,B,C,D

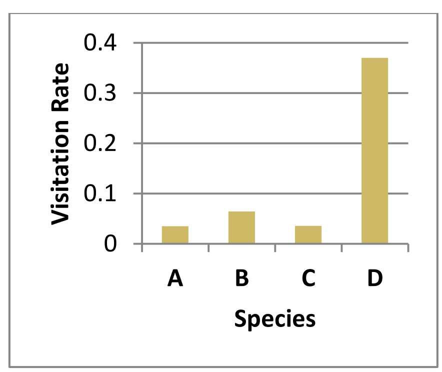
and so on…..

In Option 1, *the replicates will be among teams* (students from different teams will study the same flower species, but different individual flowers). Each team member will compare visitation rates of one species to the others (all four species will be represented within the team), and create a graph comparing visitation rates among all four species. Then they will contribute their data to the whole class, and see how their data compares to that of each other teams, and to that of the whole class. See below.

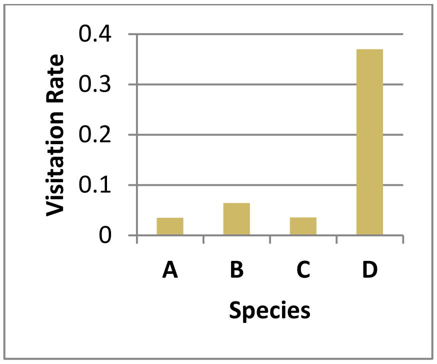
Graph from Team 1



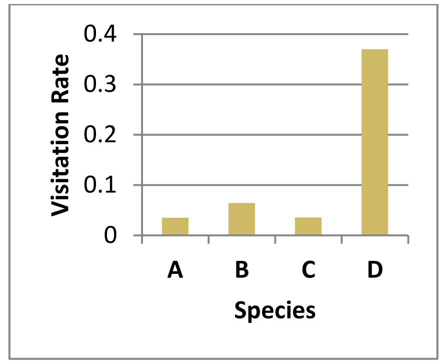
Graph from Team 2



Graph from Team 3



Graph from Team 4



Option 2:

Within one team, each member observes the same species (but different individual flowers). Different teams will observe different species. *The replicates will be within each team.*

Team 1: A,A,A,A

Team 2: B,B,B,B

Team 3: C,C,C,C

Team 4: D,D,D,D

In Option 2, team members will have the opportunity to compare different data sets of the same species, and perhaps speculate why there are differences (sun vs. shade, flower alone vs. flowers in a group, better quality nectar, more pollen). In Option 2, each team might be able to create a graph of visitation rate (on y-axis) for each observation period (on x-axis), and analyze differences in time of day. Each team can calculate an average visitation rate for one species. Then each team can contribute their data to the class data set, and one large comparison can be made among species.

Timed Observation Periods

Decide who will be time-keeper(s). In order to make comparisons, data need to be collected in the same way throughout the study (standardized). Visitation counts need to be timed, and all students in the class need to have the same length of visitation periods – say, 10 minutes long. You might be able to conduct a few observation periods in one class setting. Time-keepers will alert others as to when to start and when to stop counting.

When you get settled near your flowers, sit about 2-5 feet away. It's a good idea to sit still and quiet for a few minutes before starting your timed observation period. During this time, make note of the following in your field notebooks:

- Number of flowers you are observing at once (you should be able to see them all without moving)
- Weather conditions
- Observation period start and finish times

Once the observation period starts, students count in their notebook how often an animal "visits" the flowers they are observing. An easy way to do this is to simply tally by making hash marks so they can keep their eyes on their flowers, such as:

Definition of Pollinator

What counts as a pollinator? Every insect that visits a flower does not necessarily pollinate it. We can assume an insect or other animal that touches on the plant is a potential pollinator if it has touched the reproductive parts of the flower. An insect simply on the plant cannot be considered a visitor unless it contacts the anthers and/or stigma of the flower.

A *flower visitor*, then, is an animal that visits the flower and contacts the anthers and/or stigma (assumed to do so if it enters the flower). Each time an insect enters a *different flower* (whether it is on the same plant or not as a previously visited flower) is considered a new *visit*.

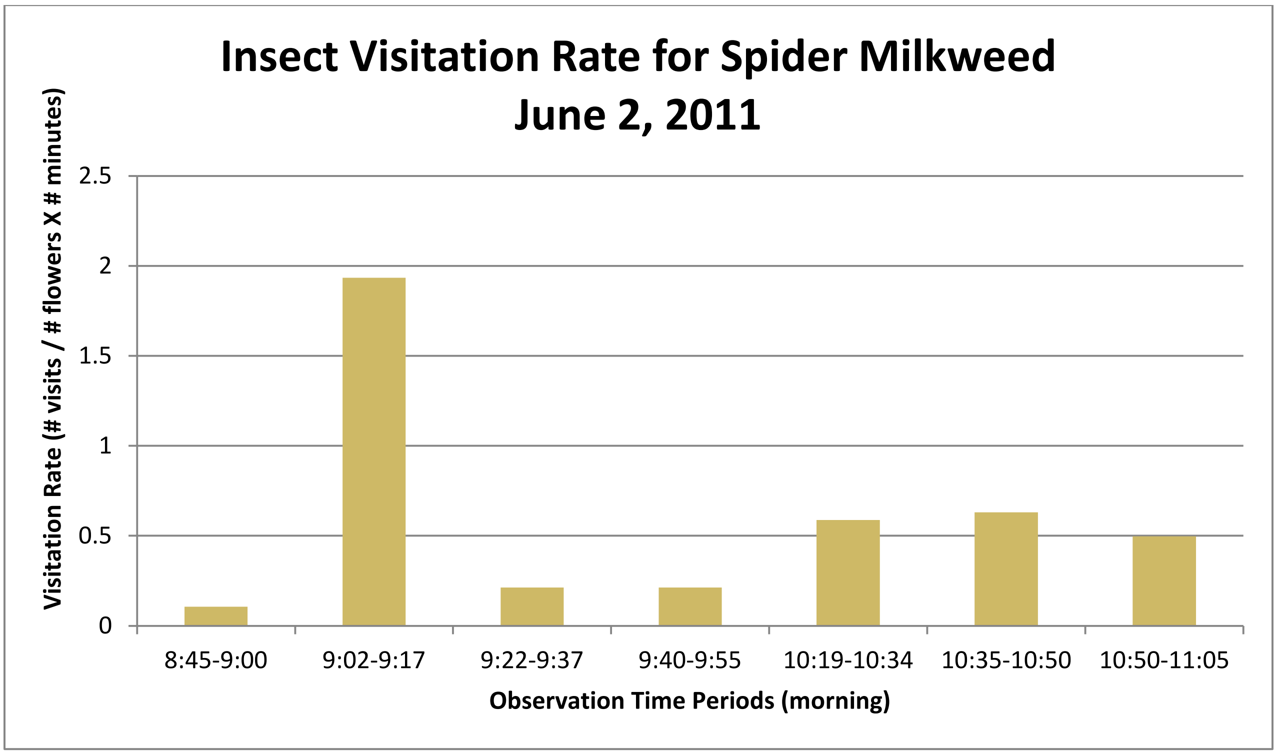
Analysis and Reflection

Data Analysis

Since different plant species will have different numbers of flowers, and different students may be observing different numbers of flowers, it is important to standardize the insect visitation rate so that comparisons can be made. Use the following formula:

$$\boldsymbol{Insect\ Visitation\ Rate\ (VR)} = \frac{number\ of\ insect\ visits}{(number\ of\ flowers\ X\ number\ of\ minutes)}$$

Once the VR is figured for each observation time, these values can be plotted on a graph. See the example below.



You can then calculate **average VR values** for each plant species, and make comparisons, either within your own teams, or by pooling data among the whole class. Comparisons can be made among the average values of different plant species, between the same species but different environments, etc. They can also be made among flowers of different colors. For instance, if the hypothesis was related to visitation rates among different colors of flowers, comparisons can be made for average VR values of white vs. yellow vs. purple colored flowers. What is important is that the analysis (comparisons) relate to the hypotheses, so that research questions can be addressed based on your evidence.

Formulating Conclusions and Discussion

Refer to your hypothesis, and address your original question(s) with the evidence and comparisons you have made.

Sometimes a conclusion is very clear, especially when clear trends can be seen. However, it is often the case that conclusions are not so clear. For instance, in the example of the Spider Milkweed above, it is interesting that the time period from 9:02 to 9:17 had such a high VR in relation to the others. Why might that be? Was that a time that certain insects were particularly active? Could it be a time when the flower nectar is particularly attractive? Was there one particular bee that kept returning to the flowers again and again? Can this phenomenon be corroborated by other students' data? Could the investigation be repeated over a number of days? Could it have been researcher error? This phenomenon is very interesting, and could be a point of significant discussion even if the conclusions are not particularly clear in this data set. It would also be interesting to figure out how to learn more about this phenomenon by additional experiments or data collection.

Sharing and Communicating

Preparing oral presentations, posters, and papers helps scientists pull data together and make it meaningful. Conversations with others help place a specific study in a broader context. Share and discuss your findings in class. Bring the online scientist-mentors into this conversation as well.

Much of the learning among scientists occurs through sharing research in meetings and publications. We encourage you to also place the same importance on communicating and learning from others. It is an opportunity to reflect and entertain new ideas.

Activity 2: Pollinator Visitor Composition

If you want to know what types of pollinators visit, and in what proportion, then we need to compare the percentages of visits of each pollinator type. For instance, we can determine if flies are the most frequent visitor, or hummingbirds, etc. In this way, we can test the hypotheses of pollinator syndromes, which states that certain types of pollinators are attracted by certain types of flowers (hummingbirds will be attracted to red tubular flowers, bees to yellow flowers, etc.). There may be other research questions relevant to this type of study too. To answer such questions, we will need to collect data on the types of pollinators in addition to the data collected in Activity 1. See the questions below for the types of questions scientists study in plants and animal pollinators, and the necessary data to collect to address these questions. Be sure to get the advice of your online scientist mentors!

Formulating a Research Question

Scientists study these basic questions related to specific plant species:

- What kinds of pollinators visit particular flowering plant species?
- Are pollinator syndromes always true (such as yellow flowers attracting more bees, etc.)?
- Do different shapes or sizes of flowers attract different types of pollinators?
- Do flowers at a certain height attract similar types of pollinators than flowers at another height?

Possible hypotheses:

- Red tubular flowers will attract more hummingbirds than insects.
- Flowers that are tubular with narrow openings will attract more butterflies and moths than bees and flies.
- Flowers that smell putrid will attract more flies than any other pollinator.
- White flowers that open at night attract more moths (or even bats) than any other pollinator.
- Flowers in the sun attract more bees than flowers in the shade.
- Carpenter bees will visit flowers over a meter tall, but fail to visit flowers that are closer to the ground.
- Invasive plant species will rely on honeybees more than on other pollinators.
- Check out the Pollinator Partnership resources for your area for further inspiration: http://www.pollinator.org/guides.htm

Experimental Design: Same as above in Project 1, except note differences in data to collect below.

Data to Collect

- Identification of pollinators
  - Identification can be as specific or general as you wish. See Discussion below.
- Number of pollinator visits by each type of pollinator per flower in a given timed period
  - This can be one long period, or several shorter ones.
  - The important thing is to keep the time period consistent among students so proper comparisons can be made.

Discussion on Pollinator Identifications

Researchers often use general categories for identifications they may be unsure of. For instance, one scheme might be: flying insects, crawling insects, hummingbirds.

Another scheme might be more refined: flies, mosquitoes, ants, bees, butterflies, lightning bugs, hummingbirds.

Another scheme might be even more refined: little black flies, hover flies, gnats, mosquitoes, big red ants, little black ants, humongous fuzzy bee, medium-sized bee, little sweat bee, purple butterfly, brown butterfly, lightning bug, soldier beetle, hummingbirds.

And finally, someone might want to actually identify different types of pollinators using a reference guide for your area.

See if your online mentor has suggestions that might suit your study.

Analysis and Reflection

Data Analysis

The values we are interested in this project are the proportions of total visits for each category of pollinator visitor. The data you will need to figure this are:

- The grand total number of all visits
- The number of visits for each category

You will use these two values to calculate percentages of total visits by each category of visitor.

For instance, consider the data set below, which was gathered by a scientist at Kansas State University in 2003. She observed *Lespedeza cuneata*, or Bush clover, for five days.

Number of Beetles	21
Number of Flies	85
Number of Bees	76
Number of Butterflies	14

Grand total number of all visits: 196

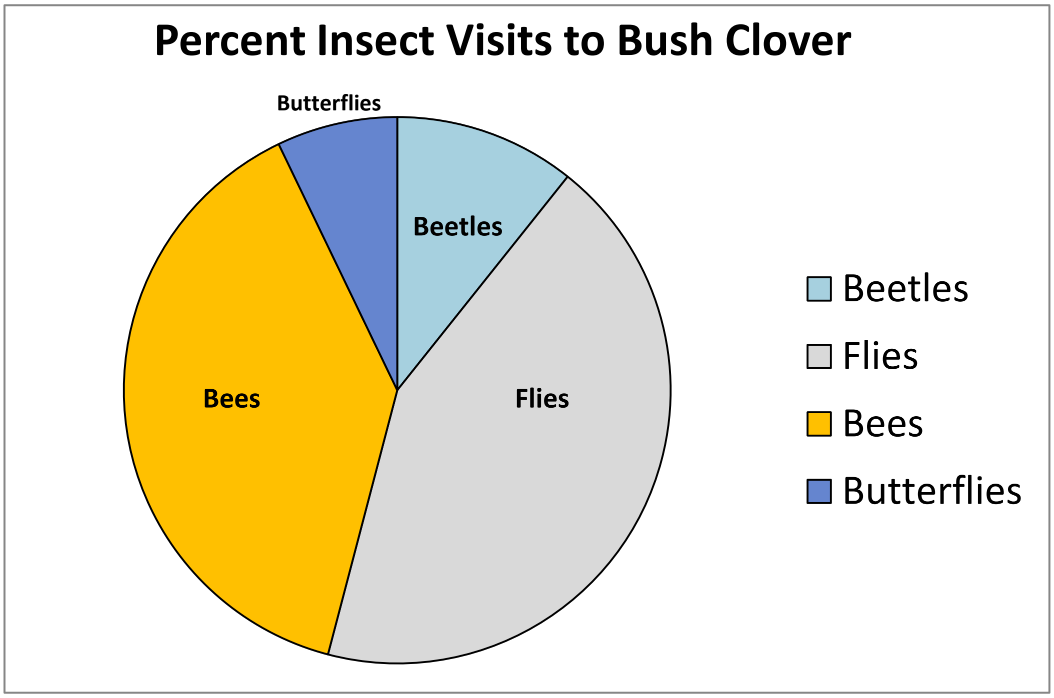
In order to find the percentages of visits comprised by each category of visitor, use the following formula:

$$\boldsymbol{Percent\ of\ visits\ by\ pollinator\ type = \frac{number\ of\ visits\ per\ category}{Grand\ total\ of\ all\ visits}\ X\ 100}$$

The percentages of visits by each category are then calculated to be:

Beetles	10.71%
Flies	43.37%
Bees	38.78%
Butterflies	7.14%

These percentages can be represented in a pie chart as shown:



It is easy to see from this chart that flies and bees were the prominent visitors to Bush Clover in this study.

Formulating Conclusions and Discussion

Refer to your hypothesis, and address your original questions with the evidence and comparisons you have made.

Sometimes a conclusion is very clear, especially when clear trends can be seen. However, it is often the case that conclusions are not so clear. For instance, in the example of the Bush Clover above, the scientist noted nearly no visits from flies when she studied pollinators to this plant in the subsequent two years. So if you show a trend in one instance, it may not hold in all instances. Can the phenomenon be corroborated or replicated by other students' data? Could the investigation be repeated over a number of days?

Sharing and Communicating

Preparing oral presentations, posters, and papers helps scientists pull data together and make it meaningful. Conversations with others can help place specific studies in a broader context. Share and discuss your findings in class. Bring the online scientist-mentors into this conversation as well.

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Background Information

Do all flowers have the same anatomy?

Most flowers contain some version of sepals, petals, pistil (ovary, style, stigma), and stamens (filament, anther, pollen). However, they appear differently in different flowering plant species, and it is an interesting exercise to try to find the structures in different types of flowers. Here are some common differences:

- **Perfect flower** (or hermaphrodite flower) refers to a flower that has both male and female reproductive structures.
- **Imperfect flower** (or unisexual flower) refers to a flower that has only male *or* female reproductive structures, but not both.
- **Conspicuous flowers** (or showy flowers) have colorful petals or other structures that likely attract pollinators.
- **Inconspicuous flowers** can easily be overlooked, and are often a nondescript color. These flowers are often wind pollinated. Examples include ragweed, trees such as oak or poplars with catkins, and grasses.
- **Petals** may be present, absent or reduced. At times the petals are not the colorful structures, but rather the sepals are colorful and showy (such as Poinsettia).
- **Stamens** can be short or long, can be fused together with others, or appear singly, and can be in plain view or hidden. The milkweeds and orchids have special structures that produce pollen collected in a waxy substance called pollinia. In such cases, the stigmas are not visible to the naked eye.
- **Stigmas** can be lobed, such as having 3 or 4 long lobes. See Evening Primrose as an example. They can also be feathery such as many grass stigmas. They can also be quite long, such as the stigmas that form the silk in corn plants. Stigmas in the same flower can have different forms, for instance, some can be longer with larger anthers, and some shorter with smaller anthers.
- **Clusters of flowers** can appear as one flower head. Clover and lilacs are excellent examples – look closely for the multiple flowers on each head. Each little flower contains its own reproductive structures.
- **Composite flowers** are special clustered flowers such as sunflowers, daisies, coneflowers, and asters (in the Asteraceae family, commonly referred to as Composites). If you look with a hand lens, you'll notice many tiny flowers all bunched into one head. Further, only the outside flowers produce the long petals (these are the ray flowers), and the inside flowers produce only tiny petals that are hardly noticeable (called the disc flowers). Each tiny flower has its own reproductive structures. Further, the stamens in each tiny flower tend to be fused, encircling the style and stigma.

What is pollination?

Pollination is the process of moving pollen from the anthers (top of the stamens) to the stigma (top of female structure). Pollination is necessary for the production of seeds in plants.

- **Self-pollination** (the strictest form) occurs when pollen from one flower is transferred to the stigma in the *same* flower.
- **Cross-pollination** (the strictest form) occurs when pollen from one flower is transferred to the stigma of a flower on *another* plant.
- Intermediate versions exist, such as when pollen from one flower is transferred to the stigma of *another* flower on the *same* plant.

How does pollination occur?

- **Mechanical** – anthers and stigma are in contact inside a flower because they grow that way, or pollen falls on stigma due to gravity
- **Wind** – anthers release pollen into the wind and carry it to stigmas (plants that are wind pollinated tend to produce copious amounts of pollen)
- **Animal** – animals such as insects, birds, bats, and rodents carry pollen from anthers to stigmas
- **Water** – a small number of plants that live in water rely on currents to carry pollen from anther to stigma

Is pollination the same thing as fertilization?

No. Once pollination occurs (pollen landing on a flower's stigma), the pollen germinates (very much like a seed) and grows, increasing in length, down the inside of the stigma through the style to the ovary and right up to an ovule. This is called the pollen tube. At the ovule opening, sperm are released from the pollen tube and enter the ovule. *Only when sperm unite with the nuclei of the eggs do we consider that fertilization has occurred.*

Can different species of plants pollinate and fertilize each other?

- Pollen from different species can end up on stigmas of other species, but the pollen usually doesn't grow into pollen tubes, so cross-species fertilization usually doesn't occur.
- Fertilization tends to occur only within the same species.
- Different species of plants do *occasionally* fertilize each other, resulting in a hybrid species.
- Most often, hybrids are unable to produce viable offspring.
- Once in a great while, hybrid plants produce viable offspring, and spread (essentially creating a new species). This has been documented in a few invasive species.

Can all plants fertilize themselves if they self-pollinate?

No. Many plants are unable to fertilize themselves, even if they self-pollinate. How self-fertilization is blocked is an active area of research today, but in many plants it occurs through enzymes on the stigma or in the style preventing self-pollen to grow into a pollen tube.

Is it harmful to a plant that can't self-fertilize to have self-pollination occur?

While this is not fatal to a plant, it can use a lot of the plant's energy to produce enzymes to prevent self-fertilization. A lot of self-pollen that can't grow can also clog the inside of the style, preventing viable pollen tubes from growing toward the ovule. Sometimes self-pollen on a stigma can prevent fertilization from cross-pollen.

Are there other ways plants prevent self-pollination?

Yes. Many plant species have adapted strategies that encourage cross-pollination and discourage self-pollination. Discovering these strategies is an active area of research.

- The anthers and stigmas are separated in the flower, either by being different heights, or growing in different directions laterally (left, right).
- Flowers that contain only the male or female functions are separated on the plant: "Male" flowers that have only stamens are separate from "female" flowers that only have pistils.
- Entire plants only have "male" or "female" flowers, so the functions are separated on different plants: "Male" plants have only male flowers, and "female" plants have only female flowers.
- Pollen production in a flower occurs either before or after the time the stigma is receptive to pollen.

What are the advantages to cross-pollination and self-pollination?

This is an area of continuing scientific research. But in general:

- Cross-pollination allows exchange of genes, which is usually advantageous over time, allowing a plant population to adapt to changing conditions.
- Self-pollination assures the possibility of reproduction even if other plants are not near.
- Plant species that rely on both self-pollination and cross-pollination have a mixture of both of these advantages.

How do plants that rely on animal pollinators attract the animals?

- The most common way is to offer food for the pollinator. While the animal feeds, it also collects pollen which can then be transferred to another flower (or just moved to the stigma of the same flower).
    - Nectar is produced in nectaries – usually at the base of a flower.
    - Pollen is eaten by many animals.
- Another strategy is mimicry – "tricking" the animal to visit the flower.
    - Some flowers (e.g., orchids) look like mates, tricking an insect into trying to mate with it.
- Whether or not a flower offers a reward to an animal, it often attracts them through scent and color. The types of scent and color are referred to as "pollinator syndromes."
    - Red tubular flowers often attract hummingbirds.
    - White flowers often attract moths.
    - Putrid smelling flowers often attract flies.
    - Yellow or orange flowers often attract bees.
    - Flowers with large, sturdy petals that serve as "landing pads" often attract bees.
- Plants that have many flowers in one place, such as in clusters, often attract animals.

Do flowers rely on just one species of insect to pollinate them?

- Most plants are considered *generalist pollinated* to some degree. That means that a number of different animal species pollinate the plant. For instance, several types of bees, wasps, ants, flies, butterflies and even hummingbirds may be attracted to the same flower.
- Some plants have very tight relationships with specific pollinators. These are considered *specialist plant-pollinator relationships,* and can involve tight mutualisms, in which each species relies on the other for mutual benefit.
    - Examples include fig trees that depend on a very few species of specialized wasps for pollination. In turn, the female wasp lays her eggs in the fruit (see the Figweb, http://www.figweb.org/Figs_and_fig_wasps/index.htm)
    - Some orchids attract special pollinators: See Orchid Bees and Orchid Pollination video with links from Hila Road at http://hilaroad.com/orchids
    - See another orchid example: Wild Orchid Wasp Mimic – David Attenborough http://youtu.be/-h8I3cqpgnA
    - Yucca flowers and yucca moths also have a tight mutualist relationship, as described on this U.S. Forest Service web page: http://www.fs.fed.us/wildflowers/pollinators/pollinator-of-the-month/yucca_moths.shtml

Are there some environments that have more pollinators than others?

Since most flowering plants rely on a number of different animal species to pollinate them, it is advantageous to have an environment that supports a number of different pollinators. Conversely, plant biodiversity is important to support pollinator (and other animal) biodiversity.

- More pollinators exist in an area with a variety of types of flowering plants. Thus, plant biodiversity helps support pollinator populations.
- Pollinators may need to feed for a number of weeks and months. Thus, an environment that has a variety of plants that flower at different times of the growing season helps support pollinator populations over the length of the season.
- Native pollinators often rely on native plant species. Populations of native pollinators can be supported by planting native flowering plants in home gardens. Visit the Pollinator Partnership for guides to selecting plants for pollinators in your region: http://www.pollinator.org/guides.htm

Additional Resources and References

Other Teaching Resources:

Plant Reproduction: Methods of Pollination (Brittanica) (4-minute video):
http://www.youtube.com/watch?v=RuYrFwDuYn0&feature=channel_page
Wonderful and engaging essay – could be background reading for students, certainly teachers. "Breezy Love, or the Sacking of Bees" by Olivia Judson: http://opinionator.blogs.nytimes.com/2010/03/09/breezy-love-or-the-sacking-of-the-bees/
TED talk by Louie Schwartzberg, "The Hidden Beauty of Pollination" with excerpts of his soon-to-be-released film:
http://www.ted.com/talks/louie_schwartzberg_the_hidden_beauty_of_pollination.html
PBS video on hummingbirds – note also links to classroom lessons:
http://www.pbs.org/wnet/nature/episodes/hummingbirds-magic-in-the-air/video-full-episode/5475/
Figweb, http://www.figweb.org/Figs_and_fig_wasps/index.htm)
Orchid Bees and Orchid Pollination video with links from Hila Road at http://hilaroad.com/orchids
BBC video: Wild orchid wasp mimic. http://youtu.be/-h8I3cqpgnA
Yucca flowers and yucca moths: http://www.fs.fed.us/wildflowers/pollinators/pollinator-of-the-month/yucca_moths.shtml

Background and Extensions:

Pollinator Partnership (among many resources here, they help you identify appropriate plants for your local region to create a pollinator garden): http://www.pollinator.org
Ecology Society of America's Pollination Fact Sheet, with linked resources
http://www.esa.org/ecoservices/poll/body.poll.fact.html
U.S. Forest Service: http://www.fs.fed.us/wildflowers/pollinators/index.shtml
U.S. Fish and Wildlife Service, Pollinators: http://www.fws.gov/pollinators
Monarch Watch, a citizen science project tracking the migration of monarch butterflies:
http://www.monarchwatch.org/
PBS information on Colony Collapse Disorder (the phenomenon of honeybee colonies experiencing mass declines):
http://www.pbs.org/wnet/nature/tag/colony-collapse-disorder/
The BugGuide.Net – an online resource to help identify insects: http://bugguide.net/node/view/15740

On Pollination Syndromes:

From the Pollinator Partnership: http://pollinator.org/Resources/Pollinator_Syndromes.pdf
Bioimages: http://www.cas.vanderbilt.edu/bioimages/pages/pollination.htm
From the U.S. Forest Service: http://www.fs.fed.us/wildflowers/pollinators/syndromes.shtml
An abstract of a research study demonstrating limitations of pollinator syndromes:
http://aob.oxfordjournals.org/content/103/9/1471.abstract
An abstract of a research study investigating genes related to adaptation of a flower type to bird versus insect pollination: http://www.rbge.org.uk/science/tropical-diversity/evolutionary-development/pollination-in-streptocarpus

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