ECOS Inquiry

1. CONTRIBUTOR'S NAME: ALISON PERKINS

2. NAME OF INQUIRY: A PLETHORA OF POLLINATORS

3. GOALS AND OBJECTIVES:

a. Inquiry Questions: What is pollination and who are pollinators? Do all pollinators look the same? Do all pollinators act the same?

b. Ecological Theme(s): Flowers have suites of characteristics (shape, color, and odor) to attract pollinators, and pollinators have suites of adaptations for exploiting the food provided by flowers. These characteristics have co-evolved because flowers benefit from the advantages of cross-pollination and pollinators benefit from the food rewards.

c. General Goal: To begin thinking about plant and pollinator adaptations and how these suites of characteristics interact.

d. Specific Objectives:

Academic: To learn about pollinators and compare visitation rates between two flower species.

Experimental: To conduct a descriptive experiment designed to determine the common pollinators for plants in the school yard. Students can be encouraged to expand the comparison, make predictions, and collect their own data.

Procedural/technical: To learn techniques for studying pollination.

Social: Working in small groups to collect biologically relevant data.

Communication: To be able to summarize data collected and apply results.

e. Grade Level: 3-12

f. Duration/Time Required: several days to collect data

4. ECOLOGICAL AND SCIENCE CONTEXT:

Background (for Teachers) from the North American Pollinator Protection Campaign and The Coevolution Institute (http://www.nappc.org/curriculum/index.php)

Pollination is central to successful reproduction in most plants. Simply stated, it is the transfer of pollen grains from the stamen of one flower to the stigma of the same or another flower. Some plants are self-pollinated or wind-pollinated, but most depend on insects, birds, bats, and other organisms — collectively referred to as pollinators — to transport the pollen for them.

Photo by Nan Vance.

The coevolution of pollinators and the pollination process is one of nature's unique solutions to the dilemma of sexual reproduction among stationary plant organisms. Plants have developed scents, colors, and shapes that make them attractive to pollinators who, in turn, have developed physical characteristics that allow them to gather and transport pollen as they seek food. See the Flower Courtship supplement below.

Pollinators are essential to the survival of over ninety percent of the 250,000 flowering plants species on the planet today.

Blueberries beginning to ripen.
Photo by Suzanne DeJohn/NGA.

The relationships between flowering plants and their pollinators have evolved since the early Cretaceous period, some 140 million years ago. These relationships are usually mutually beneficial to both parties. Pollinators assist in the reproduction of plants by transporting pollen. (Flowers that are not pollinated are not able to produce fruits and seeds.) In return, flowering plants produce nectar, a highly nutritious, sugar-based substance and a critical source of food for pollinators.

Flower Courtship: Alluring Advertisers
Author: Eve Pranis, National Gardening Association

Many announce their presence with bold and vibrant hues, while others remain modest and drab. Some are simple and open in form, but others feature tricky entries or convoluted mazes. They have long inspired humans with their beauty and fragrances, and we've bestowed them with symbolic meanings.

Myths and symbolism aside, the real job of flowers is to ensure that plants produce offspring. Animals can roam about and seek mates with whom to reproduce, but imagine the challenge for a plant, rooted firmly to the ground, to achieve this same end.

Over millions of years, flowers have evolved a remarkable range of strategies to guarantee that male pollen is transferred to female flower parts so fertilization and seed production can occur. Relying on wind to move pollen, as grasses and many trees do, is the oldest method of ensuring pollination. But a more efficient — and fantastic — means is by luring unsuspecting animal partners to inadvertently make the transfer as they search for food. In this indispensable partnership, flowers and pollinators are utterly dependent on one another for survival. So, in turn, are we.

Welcoming Pollinating Partners

To compete for the attention of pollinators, flowers have evolved ingenious methods to entice hungry bees, birds, moths, butterflies, and beetles to inadvertently act as pollen-carrying liaisons between blooms that would otherwise never touch. Their main offerings? Sugar-filled nectar and protein- and vitamin-rich pollen.

The amazing diversity of flowers results from their unique adaptations to lure a range of pollinators. Every aspect of a flower, from the designs on its petals to the timing of its blooming, is vital to the process. As your students observe flowers and pollinators in indoor and outdoor settings, invite them to consider and investigate how this unsurpassed advertising lays the groundwork for pollination. This section describes some of the more apparent features used to draw in customers.

Colors/Patterns

Since most pollinators fly, flower color sends a bold signal to potential partners passing by. Different pollinators may see the same colors differently, and some can't see certain colors at all, but they may be drawn by other characteristics, such as scent. The colors that humans see are not necessarily what bees or beetles see. Regardless of how it is perceived, color is a primary means by which flowers grab attention. Many flowers, such as foxgloves and irises, also feature stripes, spots, or other markings that guide pollinators toward food. (Some of these nectar guides are invisible to humans but quite apparent to hungry bees!) Some, such as Gaillardia (blanket flowers) have concentric rings, providing a target focused on the nutritious nectar "bull's eye." Lilies have ridged petals that similarly guide their guests. Have your students look at a delphinium blossom. Don't those tufts of hairs in the center look like a bee who has already found the flower appealing?

As your students observe who visits which flowers, see what they can uncover about the relationships between flower colors and patterns and the visitors who frequent them. If students notice that some flowers change color over time, invite them to conjecture why. (Color changes can be a way of preventing pollinators from wasting energy on an already-fertilized flower so the other flowers on the plant have a better chance of being visited.) Students in the South can discover that bluebonnets lure bees with a white or yellow spot, which turns red (a color bees can't distinguish) after pollination.

Scents

Aromatic blooms signal food to roving bees, butterflies, moths, wasps, and some flies. Certain orchids actually emit an odor evocative of female insects to arouse the males to visit! Other flowers, such as skunk cabbages, smell like rotting flesh to attract insects such as carrion-eating flies or certain beetles looking to lay eggs. Flowers that appeal to a wide range of pollinators often have light aromas, which accommodate a variety of taste buds. Others, such as those that bloom at night, have strong, distinct scents that attract moths and bats in the dark. Many flowers typically pollinated by hummingbirds, such as nasturtiums, don't need to be fragrant because their pollination partners have little sense of smell. Consider inviting students, blindfolded, to try to distinguish among different flower smells. Tough? Honeybees can tease out hundreds of aromas!

Shapes

Flowers' shapes are important for protecting pollen, attracting or precluding certain pollinators, or ensuring that pollen is picked up and transferred. For instance, butterflies tend to prefer flat, open surfaces with views (e.g., zinnias), while certain bees seem to like those with special petals that serve as landing platforms (e.g., delphiniums). Open, bowl-shaped flowers (e.g., poppies) can be easily seen by and offer warm access to short-tongued insects. The shallow blossoms of milkweeds, phlox, mints, and similar flowers also appeal to short-tongued insects such as honeybees and wasps. The nectar in tubular flowers, such as bee balm, is available to beaks and tongues with a long reach. Drooping, bell-shaped flowers protect their sexual parts from weather and offer food and shelter for honeybees and bumblebees, who can feed while hanging. Some flowers, such as snapdragons, have hinged petals or other mechanisms, to conceal their sexual parts and nectar. They are closed to all but selected pollinators (in this case, certain bees) who have the dexterity, strength, and tenacity to open the flower. What can your students discover or infer about flower shapes and their relationships to different pollinators?

Numbers

Many of what we call flowers are actually groups of tens or hundreds of tiny flowers in a cluster or along a stem. Imagine what the advantages of this arrangement might be for the flowers or pollinators. The large display of tiny flowers signals loudly to passing pollinators, saving them time and energy. Many such plants bloom and supply food for a long time, keeping pollinators coming back as the flowers open in sequence.

One of the largest families of plants, the Composites, has flowers so tightly packed that they look like one bloom. This family, which includes familiar sunflowers, daisies, and zinnias, has showy outside ray flowers that are exclusively for advertising and hundreds of plain inside disc flowers, ready to be fertilized. These ubiquitous flowers offer up loads of nectar over long periods to hundreds of long- and short-tongued insects. But if they fail to get pollinated, many can take care of business themselves!

Challenge your students to try to find flowers that grow in groups, imagine how the grouping might improve chances of pollination, and use hand lenses to explore these tiny miracles. Consider displays of flower clusters in a clover, dill, or Queen Anne's lace. Or observe plants with flowering spikes, such as loosestrifes or liatrises, over time as they bloom from the bottom up or top down, in sequence.

Pollinator Preferences

Bees — Yellow, blue, purple flowers; there are hundreds of types of bees that come in a variety of sizes and have a range of flower preferences;

Butterflies — Red, orange, yellow, pink, blue; they need to land before feeding, so like flat-topped clusters (e.g., zinnias, calendulas, butterfly weeds) in a sunny location;

Moths — Light-colored flowers that open at dusk (e.g., evening primroses);

Beetles — White or dull-colored, fragrant flowers since they can't see colors (e.g., potatoes, roses);

Bats — Large, light-colored, night-blooming flowers with strong fruity odor (e.g., many cactus flowers); bats don't see well, but have a keen sense of smell;

Flies — Green, white, cream flowers; many like simple bowl-shaped flowers or clusters;

Carrion-eating flies — Maroon, brown flowers with foul odors (e.g., wild ginger);;

Hummingbirds — Red, orange, purple/red tubular flowers with lots of nectar, since they live exclusively on flowers (e.g., sages, fuschias, honeysuckles, nasturtiums, columbines, jewelweeds, bee balms); no landing areas needed since they hover while feeding;

Ants — Although ants like pollen and nectar, they aren't good pollinators, so many flowers have sticky hairs or other mechanisms to keep them out.

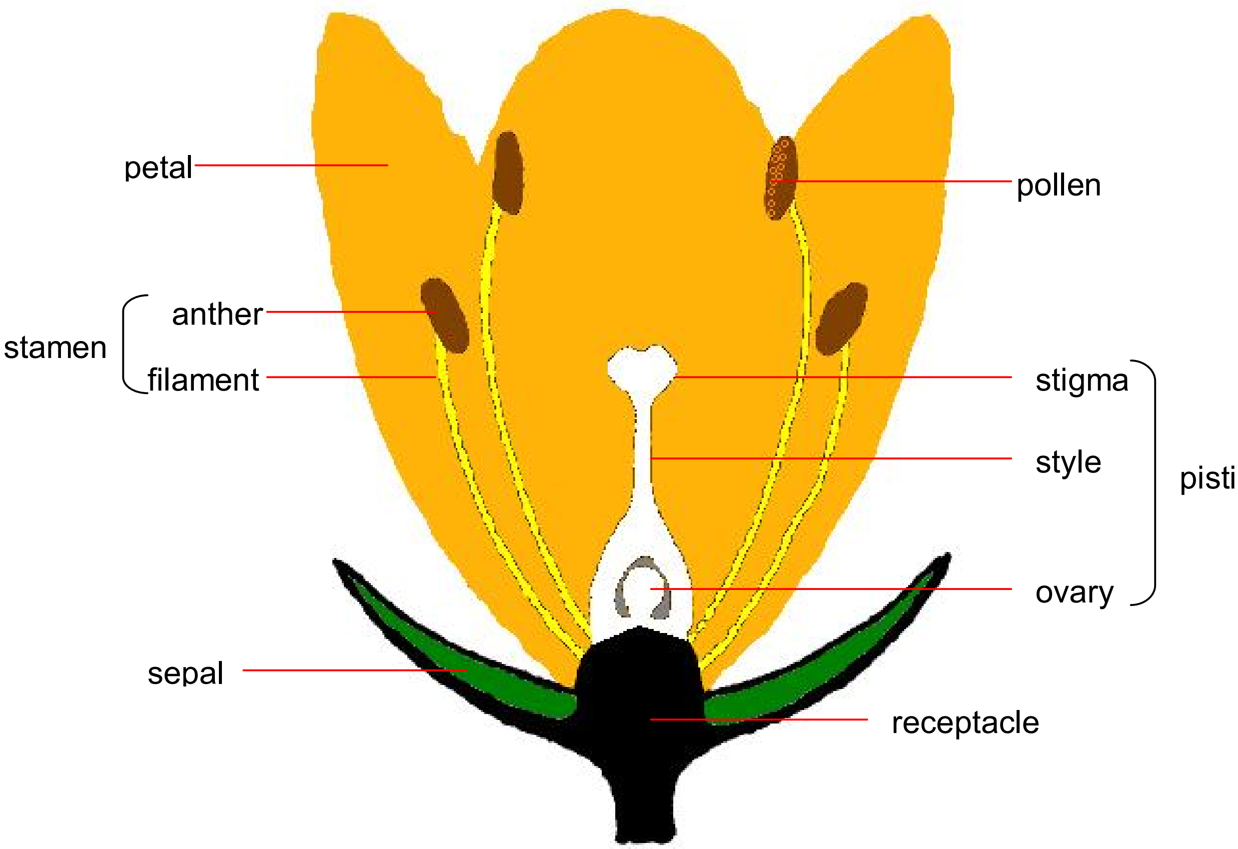
Evolutionary Excellence

Just how much energy should a flower expend to get pollinated? The oldest method, using wind to transfer pollen, requires little investment in producing flowers, but is not very efficient, since little pollen hits the right destination. Over millions of years, many flowers and pollinators have "co-evolved" to develop more complex relationships. Imagine how this might have happened. A pollinator that is capable of detecting certain colors or scents, or possessing structures that best fit certain flowers, passes these advantages on to its offspring. Over many generations, these traits become well established. Flowers, meanwhile, also evolve with characteristics suiting a variety of — or particular — pollinators. Some non-choosy flowers, such as daisies, play host to nearly any pollinator. Others, such as monkshoods, are adapted to be pollinated by just one pollinator (bumblebees). In tropical areas, it's common to find flowers and pollinators exclusively dependent on one another. Although these types of relationships require a lot of energy investment from the plant, they are very efficient.

Judy Parrish developed a dichotomous key for pollination syndromes that can be a useful tool for older students.

Key 2 - Dichotomous key to pollination syndromes		
1	Flowers small, inconspicuous and usually green or dull in color, petals reduced or absent....	Wind
1'	Flowers conspicuous, usually with white or colored petals....	2
2	Flowers regular in shape, radially symmetrical....	3
3	Flowers purple-brown or greenish in color, often with strong odor of rotting fruit or meat, little floral depth....	4
4	Flowers purple-brown, sometimes with a “light window”....	Flies
4'	Odor day or night, dull color....	Beetles
3'	Flowers with little odor, or sweet odor....	5
5	Flowers with deep corolla tube....	6
6	Flowers red, open in day, little or no odor, no nectar guide, nectar plentiful....	Hummingbirds
6'	Flowers not pure red, usually sweet odor....	7
7	Flowers yellow, blue, or purple, corolla tube not narrow, but sometimes needing forced opening, often with nectar guides....	Long tongued bees
7'	Flowers red, purple or white, corolla tube or spur narrow, usually lack nectar guide....	8
8	Flowers purple or pink, diurnal, upright, with landing area....	Butterflies
8'	Flowers white or pale, pendant, open or producing odor at night....	Moths (in some areas, bats)
5'	Flowers more dish-shaped, reward accessible, yellow, or with abundant pollen....	Bees, Flies, small moths
2'	Flowers irregular in shape, bilaterally symmetrical....	9
9	Flowers red, little or no odor....	Hummingbirds
9'	Flowers with odor, usually with nectar guides....	Bees

The structures of a typical flower:



5. MOTIVATION AND INCENTIVE FOR LEARNING:

Students get to go outside, learn about the Orchard Mason Bees and other pollinators in their schoolyards.

6. VOCABULARY:

Pollination –
Pollinator –
Stamen –
Pistil –

7. SAFETY INFORMATION:

Because students will be examining pollinators, bees and wasps may be present. Most observations can be made from a distance without bothering these important species.

8. MATERIALS LIST (including any handouts or transparency masters):

- stopwatches or watches with second hand
- marking tape or flags

- “eyeball ID”
- hand lenses
- thermometer
- data sheets

9. METHODS/PROCEDURE FOR STUDENTS:

a. Pre-investigation work:

This activity will help students understand how pollination works. Pollinators are not trying to pollinate a flower; pollination occurs as insects accidentally brush up against a flowers pistil and transfer some of the pollen that has collected on their bodies.

Each student will need to make a “flower” and an “insect.” To make a flower, they will need a paper cup, a pipe cleaner, and some sticky two-sided tape. Poke a hole in the bottom of the cup that is just big enough to insert the pipe cleaner. After the student has pushed the pipe cleaner into the cup. Bend the bottom of the pipe cleaner 90 degrees and tape it to the bottom of the cup with the masking tape. Wrap the top ½ inch of the pipe cleaner (the end inside the cup) with a good length of sticky tape (so that the tape is fairly thick). This will represent the pistil of the flower. Different students can make their “pistils” longer or shorter to see what happens when the sticky end is closer or farther away from the pollen in the flower. Carefully sprinkle a teaspoon of jello powder in the bottom of the cup, trying not to get any on the tape on the pipe cleaner.

Next, provide each student with two more pipe cleaners. Students will need to bend one of the pipe cleaners into the shape of an insect, such as an Orchard Mason Bee. They can use the second pipe cleaner to twist around the center of the “insect” – this pipe cleaner will be what the student holds to “fly” their insect to different flowers.

Students will then be Orchard Mason Bees (or any insect pollinator) trying to get the pollen to take back to their nests. Have the students “fly” their insects in and out of other students’ flowers trying to get some of the pollen. After several minutes, have students examine their own flower’s “pistil” (the sticky tape on the end of the pipe cleaner. What does the pistil look like? Is there a difference between long pistils and short pistils? What do the insects look like?

b. Investigation work:

1. Each person in the group should find a branch (buckeye) or a plot (spring beauties) with receptive flowers (pollen is being shed, and/or stigmatic surface is visible and sticky). Mark the branch or plot with marking tape (buckeye) or flags (spring beauties).

2. Carefully examine the flowers. Use the key to pollination syndromes (sets of traits of flowers thought to attract and/or accommodate pollen vectors, and sets of traits of animals that allow them to exploit flowers with those traits) to predict visitors by floral morphology.

3. Count the number of individual OPEN flowers on the branch to be observed, or in the marked plot. Count only the flowers you will observe - and record visits on only the flowers selected or in the plot.

4. Observe the marked branch or plot for three observation periods of exactly 10 minutes, counting the number of visits by each category of visitor (categories include honeybees, bumblebees, small bees, flies, butterflies, beetles, and birds).

5. Note the ambient air temperature in ^{o}C.

6. Return to the same branch or plot and make three ten-minute observations at additional assigned time (later in the day, or earlier on another day - assigned times will cover two hour blocks - 0800 to 1000, 1000 to 1200, 1200 to 1400, 1400 to 1600, and 1600 to 1800 hr),

7. Note the temperature in ^oC

8. Calculate the average number of visits per category of visitor per flower per observation period.

9. Is the most frequent visitor the one you expected from the pollination syndrome key? If not, why might there be a difference in what the flower appears to attract and what actually visits most frequently?

10. What were each of the visitors doing at the flower? Does that activity promote pollen transfer?

c. Extension:
Estimate the number of visits that can be expected per flower at each observation time.

10. ASSESSMENT:

11. EXTENSION IDEAS:

12. SCALABILITY:

13. REFERENCES AND SOURCES FOR ADDITIONAL INFORMATION:

This inquiry is modified from Pollination Ecology: Field Studies of Insect Visitation and Pollen Transfer Rates, by Judy Parrish. The complete inquiry can be found on the Teaching Issues and Experiments in Ecology website at http://tiee.ecoed.net/.

14. LIST OF EXPERTS AND CONSULTANTS
John Holbrook, an expert in Orchard Mason Bees

15. EVALUATION/REFLECTION BY FELLOWS AND TEACHERS OF HOW IT WENT
This activity has not been tested.

Major Insect Visitors to Flowers		
1	Wings not visible, or hard wing covers concealing wings....	2
2	No wings, narrow area between thorax and abdomen....	Ants
2'	Hard wing covers conceal flight wings, form line down middle of back, chewing mouthparts....	Beetles
1'	Wings visible....	3
3	One set of filamentous wings, eyes large and obvious (careful - some Syrphid flies mimic bees)....	Flies
3'	Two sets of wings....	4
4	Both sets of wings often colorful, covered with scales....	5
5	Antennae with knob-like ends, wings usually folded when at rest....	Butterflies
5'	Antennae with feathered ends, no knob, wings often open at rest....	Moths
4'	Wings membranous, usually clear....	Bees and Wasps, 6
6	Thorax and abdomen joined by narrow “waist,” abdomen often pointed....	Wasps
6'	“Waist” not as marked, body usually hairy....	Bees, 7
7	Pollen carried on “belly”	Megachilid leafcutting bee Orchard Mason Bee!
7'	Pollen carried mainly on leg....	8
8	Usually small (~5-10mm), black or metallic green, short tongued....	Halictids, “sweat bees” Andrenids
8'	Long tongue, usually over 12 mm....	9
9	Spur on hind leg, abdomen often appears striped....	Anthophorid digger bees
9'	No spur, body robust, usually over 20mm, yellow and black, eyes not hairy....	Bumblebees *Bombus*
9"	No spur, golden brown color, 12-15mm, hairy eyeballs(!)....	Honeybees *Apis mellifera*

Based on Judy Parrish

Report Form: Visitation Rates - Group 1, In-class Observation

Time of Day________ Temperature ________

Number of flowers observed_________ Number of minutes observed____________

Category	Observation 1	Observation 2	Observation 3	Mean
Honeybees				
Bumblebees				
Small bees				
Flies				
Butterflies				
Beetles				
Other				
Total				

Report Form: Visitation Rates - Group 1, Additional Assigned Observation

Time of Day________ Temperature ________

Number of flowers observed_________ Number of minutes observed____________

Category	Observation 1	Observation 2	Observation 3	Mean
Honeybees				
Bumblebees				
Small bees				
Flies				
Butterflies				
Beetles				
Other				
Total				