ECOS
Ecologists Educators and Schools: Partners in GK-12 Education

ECOS Inquiry Template

1. CONTRIBUTOR'S NAME: ALISON PERKINS

2. NAME OF INQUIRY: PLANT AND POLLINATOR ADAPTATIONS

3. GOALS AND OBJECTIVES:

a. Inquiry Questions: Why do plants produce flowers? Why are flowers attractive? Do all flowers attract pollinators equally well? What attracts pollinators to certain flowers? What adaptations do pollinators have to find flowers?

b. Ecological Theme(s): Flowering plants and pollinators have co-evolved. Flowers have suites of characteristics (shape, color, and odor) to attract pollinators with some probability that they will visit other flowers of the same species, and pollinators have suites of adaptations for exploiting the food rewards provided by flowers.

c. General Goal: To begin to understand the floral adaptations that attract pollinators and the characteristics of pollinator vectors.

d. Specific Objectives:

Academic: The main function of flowers and the complex co-evolution of flowers and their pollinators

Experimental: research into the kinds of flowers available to pollinators

Procedural/technical: learning to use the ECOS Natural History Guide to research plant characteristics

Social: work as part of a team to collaborate on building the ideal flower

Communication: written justification for selecting plants as possible food sources for specific pollinators and oral presentation of their ideal flower

e. Grade Level: 7-8

f. Duration/Time Required: two class periods

→ Preparation involves making transparencies (or Powerpoint slides), and gathering materials for building the ideal flowers

→ Implementing exercise during class – Day 1: introduction (15-20 minutes), student research (20 minutes), wrap up (5-10 minutes); Day 2: flower building (15-20 minutes), student presentations (15-20 minutes), wrap up (10 minutes)

→ Assessment – in class on Day 2

4. ECOLOGICAL AND SCIENCE CONTEXT:

Background (for Teachers):

Sexual reproduction is vital to genetic diversity in plants, and the flower is the main apparatus for this important function. Many flowering plants rely on animals for cross-pollination. These animals include insects, birds, and mammals such as:

- insect pollinators: bees, butterflies, wasps, flies, beetles, and moths
- bird pollinators: hummingbirds, honey creepers (Hawaii), sunbirds (Africa/Asia), and honeyeaters (Australasia)
- mammals: bats

Animals seek out flowers for food, consuming nectar and pollen. In the course of their travels, these animals serve as vectors to disperse pollen, cross-pollinating plants and insuring reproduction. Plants benefit because insects, birds, and bats may fly long distances between widely separated plants. But plants have to be attractive to pollinators. In fact, to bring about pollination, these pollinators must be attracted to the same species repeatedly. Attraction and competition among plants for pollinators and competition among pollinators for food sources has lead to specialized relationships between plants and the animals that are their pollinators; the interactions between the two different groups resulting in the co-evolution of characteristics of both plant and pollinator. Indeed, plants have developed elaborate methods to attract animal pollinators, and specialized body parts and behaviors that aid plant pollination are common in animals. Natural selection favored those flowering plants that were most attractive to pollinators and those pollinators best able to get floral rewards. The result has been mobility in plant genes that rivals the mobility in animals.

Some clever coevolutionary quirks:

Nectar of Queen Anne's lace flowers is right at the base of its tiny flowers where pollinators with short proboscises such as honeybees, ants, wasps, flies, and beetles can reach it when they crawl on the flower. Bumblebees, butterflies, and moths have long proboscises, which enable them to reach nectar in places inaccessible to honeybees and ants. The long curving columbine flower complements the long tongue of bees, butterflies, and hummingbirds. By concealing the nectar deep within its trumpet-like blossoms, the columbine prevents animals who are not its pollination partners from accessing the nectar. Petals may serve as landing platforms for visiting insects, and some function in the pollen transfer. For example, when a bee lands on the lower petal of a snapdragon, its weight causes a stamen to swing down and dust the bee with pollen. Petals of many plant species even have lines or other marks that guide the pollinator to the nectar. These markings may not be visible to the human eye. Insect pollinators see color differently than we do; they are sensitive to ultraviolet (UV) light. To humans, a buttercup appears a uniform yellow, but to a bee's eyes the flower's center reflects UV light and forms a dark center, like a bullseye. Bees also are attracted to blue and violet flowers. Hummingbirds are usually attracted to red flowers. As it turns out, red flowers are typically loaded with especially rich nectar, instant energy for the fast-moving hummingbirds. Flowers pollinated by animals searching for food at night are often pale reflecting the little bit of natural light available. A flower's scent also attracts pollinators. Honeysuckles are known for their sweet smell on a midsummer night. Wouldn't you know it, nighttime is the best time to attract the honeysuckle's pollinators, not humans but nocturnal moths. Other flowers don't have the pleasant fragrance of honeysuckle. Many plants smell like rotten meat in order to attract their pollinators: flies.

How does the process of plant pollination by animals work? In general, flowers offer nectar rewards secreted in specialized glands tucked it away in its blossom. Once an animal is attracted to the flower, it crawls around the blossom to find the nectar. In the process, the pollinator rubs against the pollen, which may become attached to different parts of the pollinator's body. The pollinator leaves and visits other blossoms. Stigma are strategically placed on flowers of the same species, and the unsuspecting pollinator rubs up against the stigma transferring the pollen grains from its body. The pollen grain grows a tiny pollen tube down the style and into an egg-filled ovary. Eventually, the pollen and the egg form a seed.

5. MOTIVATION AND INCENTIVE FOR LEARNING:

Students get to learn about some of the flowers in their local communities and schoolyards. They get to race to find the most flowers for their nectar rewards and receive their own reward for finding the most. They also get to be creative and construct their own flowers.

6. VOCABULARY:

7. SAFETY INFORMATION: students will be working with sharp objects, scissors, and rubber bands.

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

FIGURE 1. General design of a flower (transparency)
FIGURE 2. Honeybee photo and diagram of mouthparts (transparency)
FIGURE 3. Butterfly mouthparts and photo (transparency)
TABLE: Adaptations of Pollinator Vectors and Flowering Plants (transparency)

colored paper
pipe cleaners
empty pop bottles, large and small
rubber bands
colored pens
scissors
tape
tacks
paperclips

9. METHODS/PROCEDURE FOR STUDENTS:

a. Pre-investigation work (Day 1):

Talk to the students about flowers. Why do plants have flowers? Get them to think about sexual reproduction and how important the resulting genetic variation is to natural selection. Since flowers can't move around like animals or students can, how do they reproduce sexually? See if they know all of these pollinators:

- insects (bees, flies, butterflies, moths, beetles)
- birds (hummingbirds in the US)
- bats
- wind.

Leaving wind aside, ask the students if they know how plants attract pollinators?

- providing free food in the form of nectar or even the pollen itself (flowers easily produce more than is necessary to pollinate other flowers)
- advertising this nectar by deep shape and recognizable floral patterns, colors, and smells
- providing shelter and places to lay eggs for insects

Use Figure 1 (the general design of the flower) to explain pollen transfer. Then using Figure 2 as a guide, draw in the common locations of nectaries. Have the students discuss where the nectaries sit in relation to the stigma.

For purposes of this inquiry, focus the students on two of the major pollinators: bees and butterflies. Using Figure 2 (the honeybee), explain that bees are extremely important pollen vectors, as well as being economically important for not just honey, but many of our fruit crops. Bees use nectar to make honey to feed the hive and they also eat the pollen of flowers. Make sure the students understand that bees have a relatively short labium.

Using Figure 3 (the butterfly), have students point out the differences in the mouthparts. Note how long the proboscis (galea) is. What does that enable the butterfly to do that bees can't?

Now explain that flowers compete for pollinators, and pollinators compete for the food rewards. As a result, both have co-evolved suites of adaptations for certain flower characteristics and certain pollinator characteristics. Using the Adaptations of Pollinator Vectors and Flowering Plants (also available at the end of the lesson with additional pollination vectors), point out the adaptation of these two pollinators and of the flowers typically pollinated by these two groups.

Vector	Characteristics of Vector	Characteristics of Flower
bees	• Good sense of vision, smell • Often have body hairs • Can perceive depth, "count" petals • Do not see true red – see UV	• Often blue or yellow, with landing platform • Often have markings that act as nectar guides, sometimes in UV spectrum • Reduced numbers of floral parts • Often irregular in shape • May have deep tube or spur for nectar
butterflies	• Active in day • Have long, thin proboscis for nectar acquisition • Can see red • Alight on blossoms (as opposed to moths which usually do not)	• Open in day, emit some odor in day • Landing platform • Long corolla tube, narrow • May be blue, purple, red, yellow • May have nectar guide

b. Investigation work:

Now the students must take on the characteristics of the pollinators and find food. Working in small groups, assign each group to be a bee or butterfly pollinator. Using the ECOS Natural History Guide, students have to find as many different species of flowers as possible for their pollinator (bee or butterfly). They must sketch the flower, record the flower name, colors, phenology (flowering time), and habitat (see data collection sheet). They must justify why they think their pollinator would be able to pollinate this plant. Offer a reward to be given on Day 2 to groups that can "survive the summer." (Let students grapple with what this means, but base their pollinator's survival on the number of plants they find and their flowering phenologies.)

Leave 5-10 minutes at the end of class to wrap up the activity and explain the challenge. Find out how many plants each group was able to describe and how confident they are that their pollinator might actually be a vector for that plant's pollen. Collect the data collection sheets.

Tell the students that next meeting time each group will be challenged with building a flower. These flowers will be based on what they learned about their pollinators and the flowers they researched, but the scale will be much larger – the nectaries will be pop bottles. They should think about it as a group; they will need to bring or request any specific materials other than the general materials (colored paper, pipe cleaners, pens, etc.) already provided.

c. Building on it (Day 2):

Give the groups 15-20 minutes to build their ideal flower for the giant-sized version of their pollinator, complete with stamens and pistils. While they build their flowers, count the number of appropriately sized/shaped plants that would be available to the pollinator based on the data collection sheets. Groups will need to present their flower and the justification for the characteristics they chose to include.

After their presentations, the instructor can play the role of "cheater" and illustrate how animals rob flowers of nectar without doing their job, or how other animal vectors (one's the students may not have thought about like hummingbirds or moths) may "outcompete" the group's pollinator and get the nectar rewards first. Reward the groups surviving and those that may have designed a flower that was "cheat-proof."

10. ASSESSMENT:
Assessment could address:

→ Did students understand the relationships between floral characteristics and pollinator characteristics? Were they able to find flowers that were appropriate for their selected pollinator?

→ Were they able to construct a flower and justify the characteristics they highlighted for their pollinator?

→ Did students enjoy activity?

11. EXTENSION IDEAS:

Students could explore their own schoolyards for different flower types, using sketches and the ECOS Natural History guide to identify them. Based on floral characteristics, they could predict the type of vector (see the "Adaptations of Pollinator Vectors and Flowering Plants" table at the end of the inquiry) and design a procedure to explore the pollinators the species attracts.

12. SCALABILITY

13. REFERENCES AND SOURCES FOR ADDITIONAL INFORMATION:

Johnson, Roxane J. Mutualism and Co-evolution: A study of Flowering Plants and their Pollinators with a focus on form and function. University of Arizona, Department of Biochemistry and Molecular Biophysics.

- developed the idea of using pop-bottle flowers. A great series of lessons developed for the General Biology Program for Secondary Teachers

Smithsonian in your Classroom. 1997. Plant and animals: Partners in pollination. November/December.

- a series of activities related to plants and pollinators for grades 4-9.

Parrish, Judy. 2004. Pollination Ecology: Field studies of insect visitation and pollen transfer rates by. Teaching Issues and Experiments in Ecology - Volume 2, August.

- lessons about pollinator communities

14. LIST OF EXPERTS AND CONSULTANTS

PAUL ALABACK, University of Montana – a valuable source for information about plants and a phenomenal photographer

BYRON WEBER, Florence-Carlton School – unbelievably knowledgeable about insects and habitats

15. EVALUATION/REFLECTION BY FELLOWS AND TEACHERS OF HOW IT WENT

This activity has not been tested.

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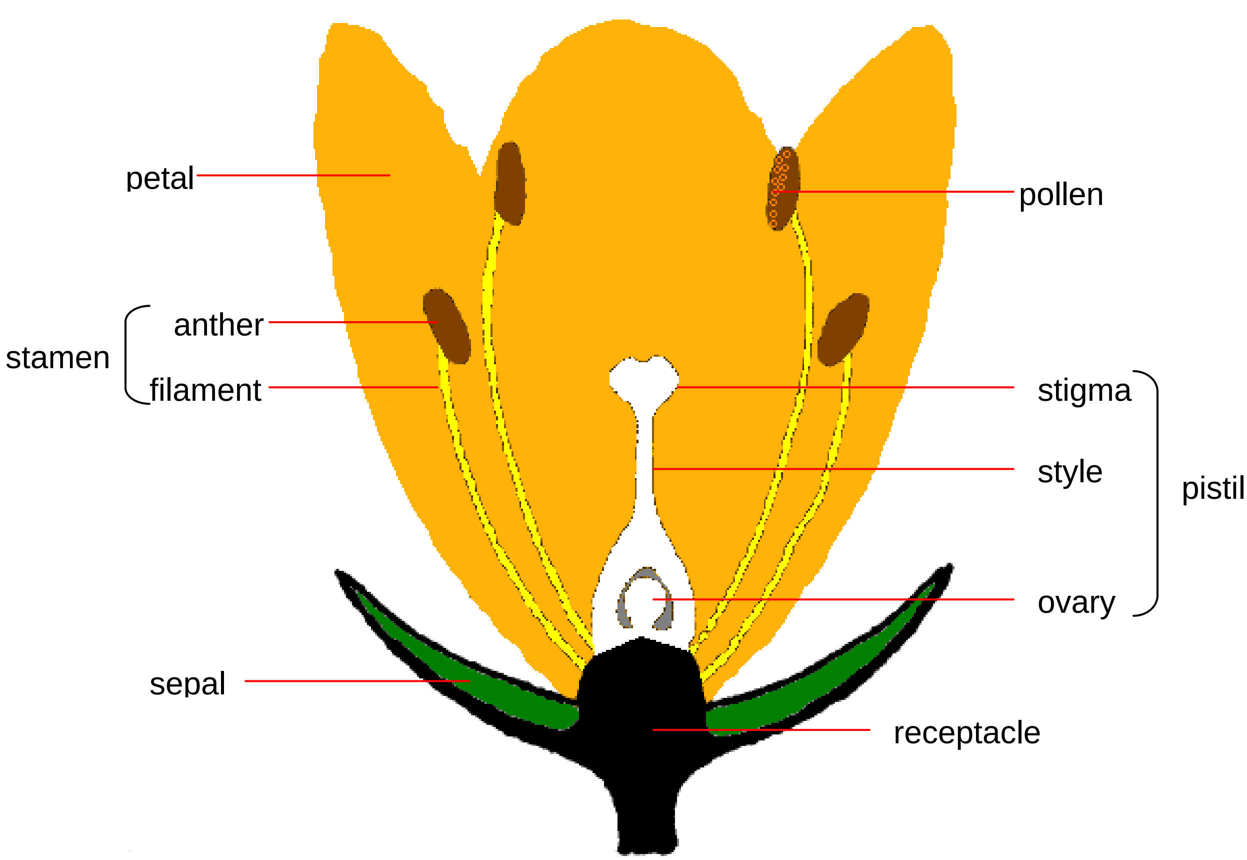
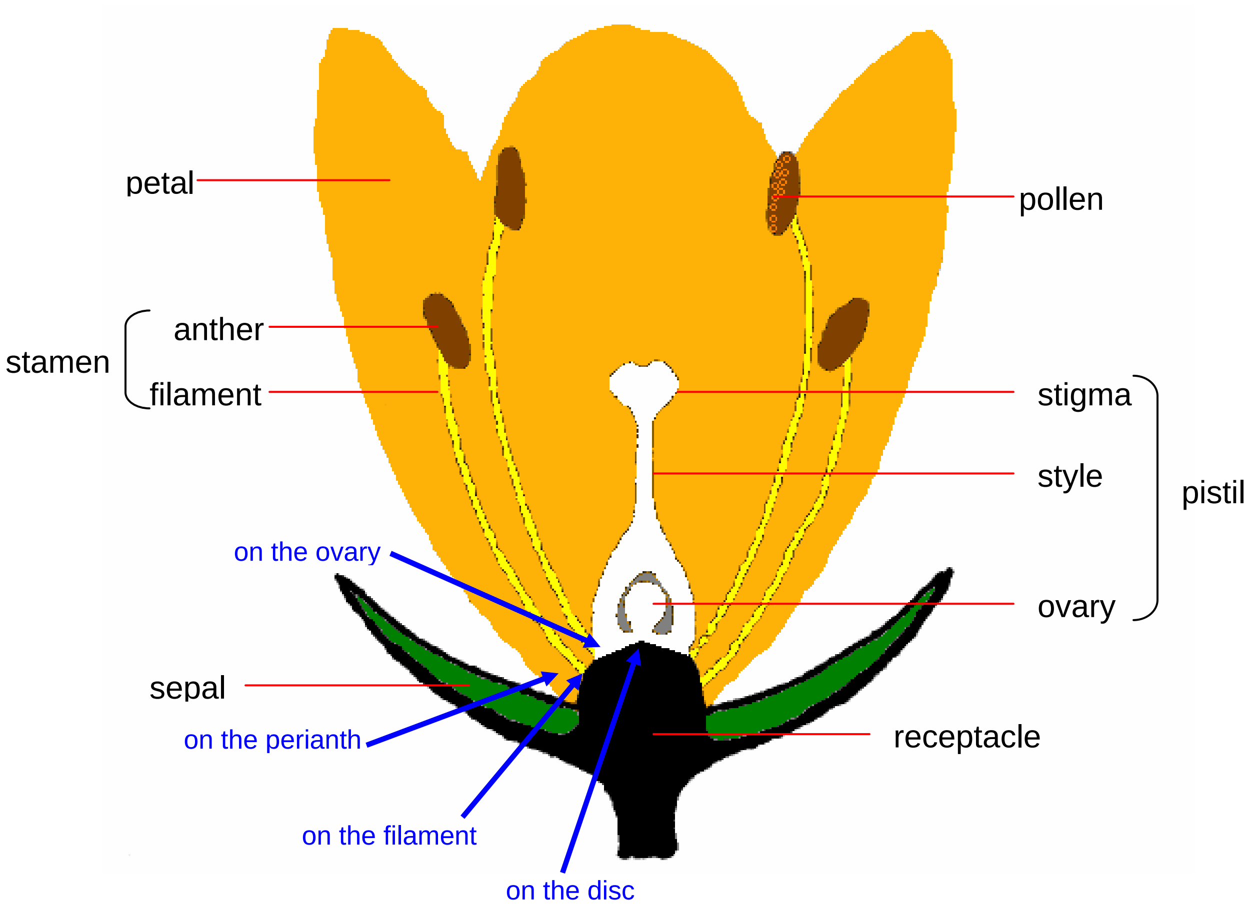


FIGURE 1. The general design of a flower. Pollen is picked up from the anthers of one flower and transferred to the stigma of the pistil of another flower as the vector searches for the food rewards. Adapted from Plant and animals: Partners in pollination. Smithsonian in your Classroom. November/December 1997.



Common locations of nectaries on the flower. Draw these in on the transparency of Figure 1.

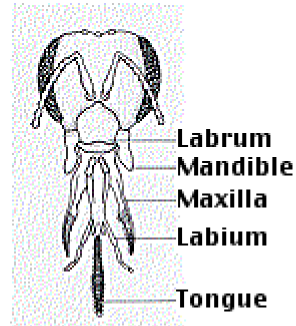
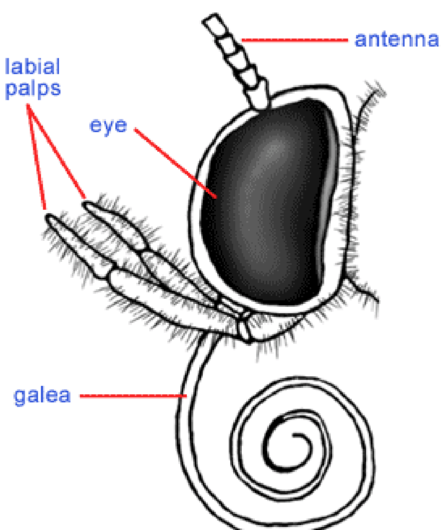


photo courtesy Mark A. Story, Department of Entomology, University of Nebraska-Lincoln

FIGURE 2. A honeybee with a diagram of the mouthparts. The maxillae and labium are modified to form a tube through which the food is drawn up into the mouth.



From:
http://bugs.bio.usyd.edu.au/Entomology/ExternalMorphology/imagePages/mouth_butterfly.html

FIGURE 3. The mouthparts of a butterfly and a picture of a monarch. The butterfly has modified mouth parts that act like a straw. Two galea fit together to form a tube (the proboscis) used to suck up nectar.

Adaptations of Pollinator Vectors and Flowering Plants

Vector	Characteristics of Vector	Characteristics of Flower
bees	• Good sense of vision, smell • Often have body hairs • Can perceive depth, "count" petals • Do not see true red – see UV	• Often blue or yellow, with landing platform • Often have markings that act as nectar guides, sometimes in UV spectrum • Reduced numbers of floral parts • Often irregular in shape • May have deep tube or spur for nectar
butterflies	• Active in day • Have long, thin proboscis for nectar acquisition • Can see red • Alight on blossoms	• Open in day, emit some odor in day • Landing platform • Long corolla tube, narrow • May be blue, purple, red, yellow • May have nectar guide
beetles, flies	• Good sense of smell • Some lay eggs in rotting flesh	• Dull colors, dark red, strong, spicy odor, or odor of rotting flesh, flat shape • May have light window (flies)
hummingbirds	• Vision much like human – see red • Long bill and tongue, large body • Little sense of smell • Intelligent – remember and return to flowers with abundant reward • Active in day • Approach flower and hover	• Red, large flowers with deep nectar tube and abundant nectar • Little or no fragrance • Open in day • No landing platform • No nectar guide
moths (and bats in some areas)	• Most active at night • Strong sense of smell • Have long proboscis for nectar acquisition	• Open at dusk or night, emit sweet odor at night • Often dull or white • Long corolla, no landing platform
wind	• Abiotic	• Inconspicuous, green or dull in color, petals reduced or absent, abundant and in canopy

From: Parrish, Judy. 2004. Pollination ecology: Field studies of insect visitation and pollen transfer rates. Teaching Issues and Experiments in Ecology: Volume 2, August

Team members: ____________________

Period: ____________________

sketch of flower	**name:**	
	color:	
	phenology:	
	habitat:	
	justification:	
sketch of flower	**name:**	
	color:	
	phenology:	
	habitat:	
	justification:	
sketch of flower	**name:**	
	color:	
	phenology:	
	habitat:	
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