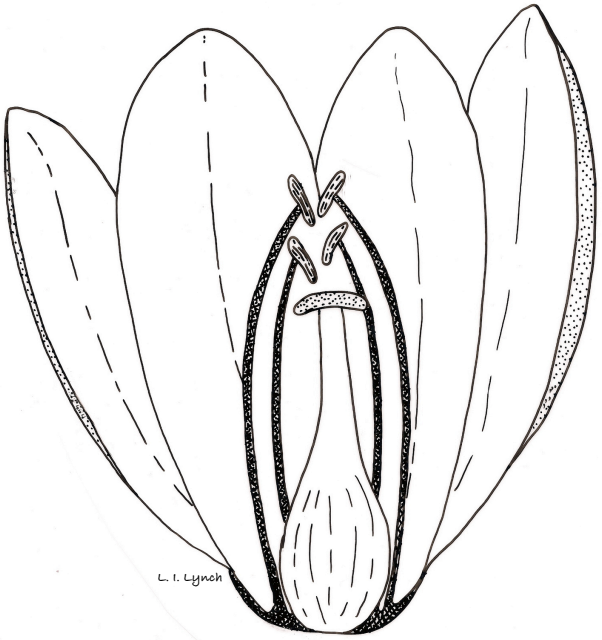
Pollination and the Honey Bee



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See www.beeslouise.org for more bee lessons!

Target Audience

Grades 4th through 8th

Number of Class Periods to Complete Lesson

1-2 class periods (60-120 minutes) to introduce topic, and complete dissection and activities. Additional activities are provided and may require additional time.

Overview

Honey bees are arguably our most valuable insect. Our food supply greatly relies on them. It is estimated that one third of the food we eat is the product of insect pollination and bees are our most significant agricultural pollinators. This highly social insect is an excellent model for studying how an organism interacts with its environment. Many fruits, vegetables, nuts, seeds and even fish and dairy products are attributable to pollination by bees. Understanding the biology of pollination and the honey bee offers insight into a coevolutionary relationship that impacts our every day life.

This one-period lesson will discuss pollination, the biology of honey bees as pollinators and the role bees play in Earth's ecology and our agriculture. It will demonstrate the impact that these insects have on our daily lives. Students will have the opportunity to study the anatomy of a flower specimen, design their own nectar guide and research food pollinated by bees. Additionally, students will be introduced to the honey bee life cycle, adult anatomy, honey bee castes, and the significance of honey bee declines.

Learning Objectives

Each student will study the anatomy of flowers, the biology of pollination and the coevolutionary relationship between bees and flowering plants. As a result of carrying out this activity, students will develop:

- An understanding of the classification, anatomy and life cycle of honey bees
- An understanding of hive structure and biology of the the honey bee
- An understanding of pollination and flower anatomy
- An understanding of how flowers attract bees and how bees are adapted for pollination
- An understanding of the role honey bees play in the pollination of our food crops
- An understanding of alternative bees used in agricultural pollination
- Knowledge, skills and abilities required to work with a group

National Science Education Standards *from www.nap.edu*

Unifying Concepts and Processes Standards (Levels K-4, 5-8)

- Form and function

Science as Inquiry Standards (Levels K-4, 5-8)

- Skills necessary to become independent inquirers about the natural world

Life Science Standards
- Characteristics of organisms (Levels K-4)
- Life cycles of organisms (Levels K-4)
- Organisms and environments (Levels K-4)
- Regulation and behavior (Levels 5-8)
- Structure and function in living systems (Levels 5-8)
- Diversity and adaptations of organisms (Levels 5-8)

Science in Personal and Social Perspectives Standards
- Changes in environments (Levels K-4)
- Populations, resources, and environments (Levels 5-8)

Materials Needed

1 Lab report per student (from beeslouise.org)
1 Flower per pair of students (Lilies, tulips, any flowers with visible stamens and pistil will do!)
1 Compound microscope per student pair
1 microscope slide and cover slip per student pair
Colored pencils (optional)

Background Information on Pollination, Flower Anatomy and the Honey Bee

Classification. Bees belong to phylum Arthropoda because they are invertebrates (backbone absent) with an exoskeleton, jointed legs and a segmented body. Bees belong to class Insecta because they have 6 jointed legs, a 3-segmented body (head, thorax and abdomen), 2 compound eyes and 2 antennae. Bees belong to the same order as wasps and ants, order Hymenoptera.

Kingdom	Animalia
Phylum	Arthropoda
Class	Insecta
Order	Hymenoptera (Bees, wasps, and ants)
Family	Apidae (Carpenter bees, bumblebees, sweat bees, etc.)
Genus	*Apis* (Honey bees, 7 recognized species)
Species	*mellifera* ("honey-bearing")

Bee Anatomy. The bee has three body regions, as do all insects.
1. **The head**: this segment aids in sensing the environment and feeding. It has two large compound eyes, three small simple eyes called ocelli, two segmented antennae and a mouth with several appendages such as mandibles and a glossa (tongue).
2. **The thorax**: this middle segment of the body aids in locomotion. It has six legs, four wings and it contains the muscles required for flight and leg movements.
3. **The abdomen**: this posterior segment of the body aids in reproduction and defense. It contains the reproductive organs and, in female bees only, a stinger at the very tip.

Bee life cycle. Bees exhibit complete metamorphosis. They begin their life cycle as a tiny white egg. This hatches into a white, worm-like larva. After feeding on pollen and nectar for several days, the larva develops into a pupa within a cocoon. Finally, a winged adult emerges. In a

honey bee hive, only the Queen lays eggs. The rest of the females are workers, carrying out the many tasks of an active hive.

The hive and its members. Honey bees are social insects in which the young are cared for communally. A colony can contain 80 thousand or more individuals. Hives are perennial and may remain intact for several years. Each winter, most of the bees die off. A small cluster of worker bees and the queen survive through the winter by huddling for warmth and eating the honey they produced the previous season. Once flowers, and thus food, return in the spring, the hive's population will grow rapidly. There are 3 castes, or groups, in a honey bee colony, each with a specific role and distinct appearance:

1. Queen: Female. Under normal circumstances, there is 1 queen per hive. She is larger than the other bees, having a very long abdomen. She can live several years. The queen directs all hive activities, communicating with pheromones. Her most important function is laying eggs: 1,500-2,000 per day during the warmer months of the year.
2. Drone: Male. Drones comprise a small portion of the overall population. They are larger than worker bees, have very large eyes and do not have a stinger (they cannot sting!). Drones mate with new queens and die after doing so.
3. Worker: Female. There can be up to 80,000 or more worker bees in a hive. They are the smallest but most commonly seen bees. Workers are responsible for carrying out all tasks of the hive such as cleaning, brood care, foraging for pollen and nectar and building wax comb. Workers do not mate or lay eggs. During the summer months, they live for only 4 to 6 weeks (literally working themselves to death).

Flower anatomy. A flowering plant is made up of three basic parts: the roots, stem and flowers. Flowers are the reproductive part of a plant. The most notable features are the petals, which can vary in color, shape and size. The petals surround the male and female parts of the flower. In this case, we will discuss plants that have both male and female reproductive parts in the same flower. The male reproductive part is called the stamen, composed of a stalk-like filament topped with the pollen-producing anther. Several stamens are often present, circling the central female part of the plant, the pistil (carpel). The pistil has a sticky, stigma at the top, followed by a long neck-like style that leads to the swollen ovary at the base of the flower. Once pollen reaches the stigma (pollination), it makes a channel, called a pollen tube, down the length of the style in order to reach the ovary. Once the pollen reaches the ovary, fertilization, seed production and finally maturation can occur.

Attracting pollinators. Flowering plants that rely on insect pollination generally have several ways of attracting their desired pollinator. The list below is limited to those rewards and signals used to attract bees.

Nectar. This sweet, sugary (carbohydrate-rich) fluid is found in the center of a flower. Nectar powers the flight of a bee and is the main ingredient of honey, a vital food supply produced by bees back at their hive. Nectar is produced by small glands within a flower down near the base of the ovary. Flowers produce a small amount of nectar per visit. This ensures that a bee visits more than one flower, thereby increasing the likelihood of pollen transfer between plant individuals.

Pollen. This protein-rich plant material provides the nutrients needed for bee larvae to develop into adults. Flowers produce a surplus of pollen. While some pollen is eaten by the

bees, enough is transferred to other flowers for reproductive purposes to outweigh this loss. Pollen can come in different colors- yellow, white, orange, pink, red, even violet and bright blue!

Aroma. Many flowers give off a sweet scent attractive to bees. In fact, flowers that smell sweet to us are often attractive to bees as well.

Petals and nectar guides. Physically, petals can serve as a landing platform for bees. They also serve other distinct purposes. Some colors are more attractive to bees than others. This is because bees see different colors than we do. Bees see most of the visible light spectrum (Orange, Yellow, Green, Blue, Indigo, Violet) as we do, but they do not perceive red. However, bees see beyond violet, into the ultraviolet (UV) range. Flower petals have markings called nectar guides that direct bees to the nectaries at the center of the flower. These markings are invisible to humans! Bees show a preference to white, yellow, blue and violet flowers.

Pollination and bees. Pollination is the transfer of pollen from the male stamen to the female pistil of the same plant species. This reproductive process results in the production of seeds, small plant embryos. Plants have various methods of transferring their pollen. Some, such as corn, achieve this transfer using the wind while other low growing plants, like mosses, use water. However, most of Earth's plants (about 75%) use animals to transfer their pollen. Many of these animals are insects, such as beetles, flies, moths and butterflies. But bees are considered the best adapted and most significant group of insect pollinators. Bees and flowering plants have a long evolutionary history. Their coevolution has resulted in a mutualistic relationship in which both organisms benefit from and depend on one another. Honey bees are excellent and efficient pollinators, especially in an agricultural setting. They are social, having thousands of foraging bees, they are domesticated, and their hives can be relocated easily. Honey bees can even communicate the location of very good food sources (flowers) to other hive mates using dances.

Honey bee pollination adaptations. The hairs covering a honey bee's body (and even eyes!) have an electrostatic charge that attracts pollen and lets it stick to the body. Honey bees tend to visit the same flower types, ensuring pollen is passed between plants of the same species. A honey bee can visit up to 3,000 flowers in a day! Pollen is a protein-rich food source, used to feed the hive's brood. Foraging honey bees pack pollen into small balls and store them in a pollen basket on the hind legs. There is 1 pollen basket on each leg, called a corbicula, made of long, stiff hairs that stick to the pollen. Bees also sip nectar, a sugary liquid produced by flowers as a reward for visiting. The liquid is siphoned with their straw-like glossa and stored in a special organ called the honey stomach, or crop. Here, the nectar mixes with digestive enzymes and thus begins the honey production process. Nectar is brought back to the hive and stored in a cell so honey processing can continue.

Alternative bee pollinators. There are more than twenty thousand types of bee species in the world. The honey bee is by far the most relied upon species for agricultural pollination, however there are several other types of bees that are also commercially used for pollination.

- B**umblebees** are native pollinators of plants such as tomatoes, blueberries, cranberries and peppers. They perform buzz pollination in which flight muscles are vibrated while visiting flowers. These vibrations release pollen and spread it all over the plant, resulting in larger fruits. Some bumblebee species are raised in captivity for use in greenhouse tomato production.

- **Squash Bees** specialize in pollinating plants like cucumbers, watermelons, pumpkins, squashes and gourds. These bees begin working before sunrise and males may rest inside the large flowers. One species, *Peponapis pruinosa*, is found across the United States wherever its favorite plants are found.
- **Mason Bees** are important pollinators of several orchard fruits such as apples, cherries and plums. The **Blue Orchard Mason Bee** readily nests in reed or wooden nests and is increasingly kept by orchard farmers for crop pollination. Other mason bee species are important pollinators of blackberries and blueberries.
- **The Alfalfa Leafcutter Bee** is originally from Europe, but is an important alternative to honeybees for alfalfa pollination. Alfalfa makes an affordable feed for farm livestock. Not many bees are willing to pollinate this flower which has a lock mechanism that hits an entering bee in the head. But Alfalfa leafcutter bees do not mind!

Pollination makes food. Pollination results in the production of seeds, nuts, fruits and vegetables. One third of the food consumed in this country is the result of bee pollination. Without bees, many crops would not be produced unless the flowers were pollinated by hand. Once pollen reaches the ovary of a flower and fertilization has occurred, the production of seeds begins inside the ovary. Food reserves for the growing plant embryo surround the seed inside it's protective seed coat. Seeds also need to be dispersed and animals offer an efficient route to do so. Fruits are often produced by plants to attract animals for seed dispersion. For example, the white fleshy part of an apple, which we enjoy raw and in many different recipes, is a 'reward' produced by apple trees to attract animals and help disperse the apple's seeds.

KWL Strategy: What I **K**now, what I **W**ant to learn and what I did **L**earn

The KWL strategy is a great way of getting students oriented to the lesson, forming individual goals within the group and recapping the lesson. It may be helpful to use a chalkboard or white board to make 3 columns for each component to gather and organize questions and ideas.

- The K component serves the purpose of brainstorming. Have the students work as a group (or individually followed by sharing) to drum up what they already know about honey bees and pollination. Questions listed below can be used to guide students through this process.
- The W component questions provide the students with lesson goals. They can also give each student the opportunity to come up with their own inquiries and concentrate on something they are curious about. Students can write these questions down and find the answers before, during or after the lesson.
- The L component questions help the students synthesize the lesson and the information covered. Questions may be completed in writing or discussed as a group.

K Component Questions:

- What comes to mind when you think of bees?
- What is a honey bee?
- Why are honey bees important?
- Where do honey bees live?
- What kinds of honey bees are there in a hive?
- What do honey bees eat?
- Why do flowers need bees?

- Why do bees need flowers?
- What attracts bees to flowers?
- Can all honey bees sting?
- What happens to a honey bee after it stings?
- What are the stages of metamorphosis in bees?
- Why are people worried about honey bee hives in the US?

W Component Questions:

- How do flowering plants reproduce and what structures are used in this process?
- How is the honey bee adapted for pollination?
- How are flowers adapted for attracting pollinators, like bees?
- Why are bees important to our food supply?
- Are there bees other than the honey bee that are important to our agriculture?
- What foods do we enjoy that require bee pollination? What plants do not?

L Component Questions:

- What are the basic parts of a flower?
- What is pollination?
- What is pollen? Where is it produced? How does it get to the female part of the flower?
- Why is pollination important to our agriculture?

T-Chart

The T-Chart is a simple pre-assessment method to determine what information students already know about bees, and whether it is factual or biased. This method asks two questions to the class and encourages group discussion. Answers can be pooled in two columns on a blackboard. An example for this lesson is *What do you know about a bees and pollination?* and *What questions do you have about bees and pollination?*

If any incorrect ideas are presented while answering *What do you know about a bees and pollination?*, write them down anyway and revisit them at a later time. Let students go back over the Column 1 list and determine if the 'facts' are correct.

Student Assessment and Worksheet Answer Keys

Assessments have been designed to meet the National Science Assessment Standards. It is left to the instructor's discretion which of these techniques to use and how to weigh them as part of a total assessment. The following assessments have been provided below, followed by answer keys, where appropriate:

Lab report: 3 page lab report with questions in student packet (pp. 1-3)
Essays: 9 research questions to choose from; provided in student packet (p. 4)
Nectar guide worksheet: provided in student packet (p. 5); directions below
Food pollination worksheet: provided in student packet(p. 6); answers & activities below
Food journal activity: provided in student packet (p. 7)
Quiz: short answer and diagram labeling in student packet (p. 8); answers below.
Comparative flower anatomy activity: directions below.
L component questions: use for writing or discussion purposes.

Flower Anatomy Lab Directions

1. Provide each student with a Pollination and the Honey Bee Lab Report.
2.Provide each pair of students with one flower. Students can keep their flower in a petri dish or other small holding container to keep it safe from falling, damage and getting lost.
3. As students move through the lab report, they may want to check off what structures they have found on the **Flower Anatomy Checklist** section (page 3) of their lab reports.
4. Students should study and discuss the general appearance of their flowers and complete **Section 1** of their lab report. They may want to discuss and observe differences between the flowers of different student groups.
5. Students should carefully remove some of the petals of their flowers using forceps or their fingers. They can study the male parts of the flower and then sketch and label them in **Section 2** in their lab report.
6. Students should then observe the central female parts of their flower, and then sketch and label them in **Section 3** of their lab report.
7. Students should have fun looking at and studying the pollen on their flower. They should be assisted in making wet mounts of their pollen grains. After observing the slide under a microscope, they should complete **Section 4** of their lab report.

Nectar Guide Worksheet Directions and Activities

1. After discussing how flowers attract bees using nectar guides, direct students to their Nectar Guide Worksheets (page 5).
2. Students should use their imagination in designing their own nectar guides. The intent is to direct insects to the center of the flower. This activity can be made as challenging as desired. You may or may not want them to use words.
3. On the internet, search for images using the term "flower nectar guides". After students have completed their designs, look at different nectar guides that exist in flowers.

Food Pollination Worksheet Directions, Answers and Activities

Have students complete this activity sheet individually or in groups. Younger students can be directed to color the foods in. The answers are provided below.

The following foods on this worksheet are the direct result of bee pollination: almonds, apples, cranberries (juice), oranges (juice), coffee, watermelon, grapes (jelly), cherries, carrots, cucumbers (pickles), pumpkin, carrots, strawberries.

Alfalfa is an affordable feed for many of our livestock. While these animals can be fed other grains and foods, alfalfa helps keep meat and dairy prices down. The following foods on this worksheet are the result of alfalfa fed livestock: cheese, milk, ice cream, hamburger (cheese, too!).

Corn relies on wind for pollination. Wheat, used to make bread, relies on wind for pollination. Mushrooms reproduce using spores, not pollen.

Activity 1: Have students brainstorm (or research) and discuss what foods are made from those on the worksheet. For example, apples are used to make apple juice, apple pie, apple butter, etc.

Activity 2: Have students research additional foods that are pollinated by bees. They can pool their findings onto a large poster, on a chalkboard, etc.

Food Journal Activity Directions

Students may complete this activity on their own or with the assistance of their parents. This activity will help students make connections between pollination, honey bees and their very own refrigerator. Younger students may need assistance with the calculations. Everyone will have a unique answer. This activity is an excellent opportunity to spur a discussion of how honey bees impact our food supply and daily lives.

Quiz Answer Key

1. What are two ways that flowers attract insects, like bees?

Colorful petals with UV nectar guides; sweet scents, nectar, pollen.

2. Name five different foods that are pollinated by bees.

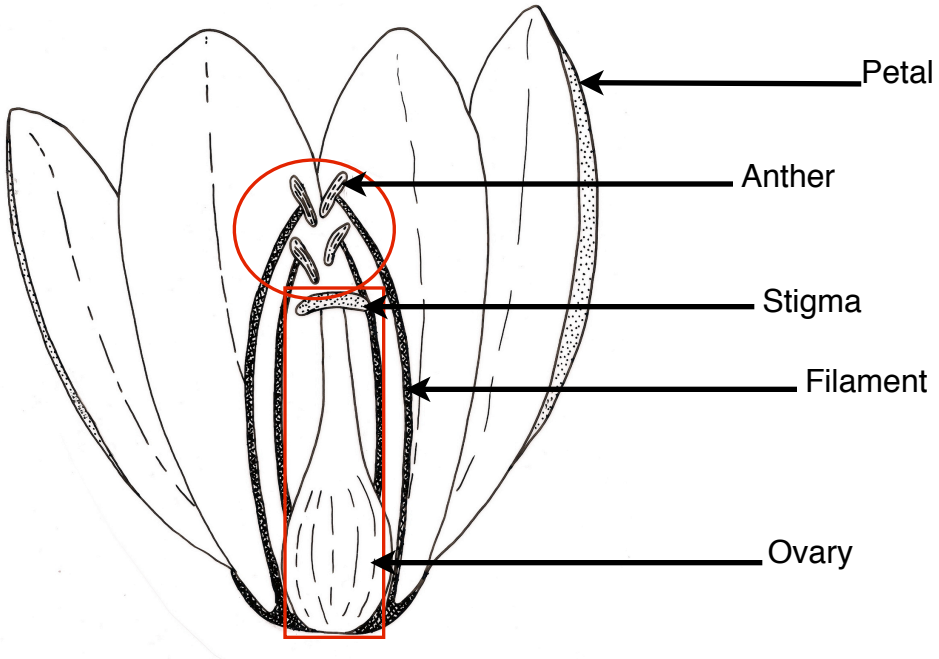
Any of the foods listed above in the Food Pollination Worksheet.

3. What two food items do bees get from plants?

Pollen (protein) and nectar (carbohydrates).

Directions: Label the flower illustration below with the following terms: Petal, Pistil, Stigma, Ovary, Anther

Next, put a CIRCLE around the male parts of the flower. Put a RECTANGLE around the female parts.



Comparative Flower Anatomy Activity

Flowers are very diverse in their form and appearance. Have students collect several different types of flowers and compare them. They can compare the following characteristics:

Petal color	Number of petals	Size of flower
Location of stamen	Number of stamens	Pollen color
Location of stigma	Number of stigmas	Scent of flower

What other differences can the students find?

Vocabulary

Abdomen: the last (hind) body segment of an insect.
Antenna (antennae, plural): a sensory appendage of the head used for taste, smell and hearing.
Anther: the pollen-producing part of the stamen that is supported by a long stalk-like filament.
Caste: a structurally distinct group within a species, having a specific task(s). There are 3 castes in the honey bee species: queen, worker, drone.
Coevolution: the joint evolution of two or more species in which their behavior and/or anatomy changes to benefit one another.
Complete metamorphosis: a four stage life cycle seen in most insects, including bees, in which the larvae have a radically different appearance from adults. Larvae enter a non-feeding pupal stage during which metamorphosis occurs and adult characteristics (such as wings) are developed.
Corbicula (corbiculae, plural): a pollen basket made of long coarse hairs located on the hind legs of a bee; stores pollen during flight.
Defensive behavior: a behavior used to avoid predation or harm.
Drone: a male bee.
Egg: the first, white, oval-shaped stage in the bee life cycle.
Exoskeleton: the hard, outer covering of insects; an external skeleton.
Filament: the long stalk-like part of the stamen that supports the anthers.
Fruit: the mature, seed-bearing ovary of a flower
Glossa: the tongue of a bee; used to siphon liquids.
Larva (larvae, plural): the second, worm-like stage of the bee life cycle.
Metamorphosis: the structural changes that occur through a bee's developmental stages.
Mutualism: a coevolutionary relationship in which interactions between the organisms are mutually beneficial.
Nectar: a sugary, liquid produced by flowers.
Nectary: gland within a flower down near the base of the ovary, which produces nectar to attract pollinators.
Ocellus (ocelli, plural): simple eye that is light-sensitive; bees have three such eyes.
Ovary (flower): the swollen base of the pistil where fertilization and seed maturation occur.
Petal: the often colorful parts of the flower that surround the reproductive organs of a flower
Pheromone: a chemical produced by bees to communicate with one another.
Pistil: the female reproductive part of a flower composed of a sticky stigma, a stalk-like style and a swollen ovary. The pistil is also referred to as the *carpel*.
Pollen: small, sperm-containing grains that are produced by the anthers.
Pollen basket: the pollen collecting structure of bees made of stiff hairs.
Pollination: the transfer of pollen from the anther to the stigma of plants.

Pupa: the third, non-feeding stage of the bee life cycle.
Queen: the only egg-laying female bee in a hive that directs all hive activities.
Seed: a plant embryo "package" containing the embryo, food reserves and protective seed coat
Stamen: the male reproductive part of a flower composed of a pollen-producing anther atop a long stalk.
Stigma: a sticky region at the top of the pistil where pollen sticks to and can enter the style.
Style: the long neck of the female pistil that bears the stigma and connects it to the ovary.
Thorax: the middle body section of an insect where wings and legs are attached.
Worker: a female bee in a honey bee colony that carries out many duties including foraging & cleaning.

References & Further Reading

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