

Title: Honey Bees and the Geometry of Hives

Author: Olivia V. Sanderfoot

Topics: honey bees, geometry, biomimicry, art

Related Disciplines: biology, environmental science, geometry, art

Objectives:

- A. Learn how honey bees build hives from beeswax and produce honey from nectar and pollen.
- B. Think about shapes and patterns in nature and how natural selection generates incredibly efficient structures and strategies.
- C. Understand the importance of biomimicry to society, especially its role in inspiring technological innovation.
- D. Connect scientific knowledge to an artistic creation.
- E. Participate in a team building exercise.

Lesson:

A. Introduction (20 minutes)

This is a scripted lesson plan. Each bullet point aligns with a slide in the attached PowerPoint presentation. Feel free to adapt the script to best support the needs of your students.

- Honey, the caramel-colored syrup we pour on top of our pancakes or use to sweeten our tea, is produced by a small insect: the honey bee.
- While there are several species of honey bees in the world, the most common type of honey bee in North America and the one most commonly cared for by beekeepers is *Apis mellifera*.
- Honey bees are yellow with black stripes. *Apis mellifera* measures just 0.4 to 0.6 inches in length. These guys are tiny!
- Honey bees are herbivores. Herbivores are animals that feed on plant material. Unlike honey bees, we are omnivores. An omnivorous diet is one that includes plant material, such as fruits and vegetables, as well as meat.
- Honey bees feed on the nectar and pollen collected from nearby flowers.
- While foraging (or searching for food), honey bees collect much more nectar and pollen than they need to eat.
- The extra nectar and pollen is stored in a specialized second stomach where it is broken down to simple sugars. These sugars are used to make honey. Honey is stored by bees to serve as a source of food during the winter months.

- Honey is produced and stored in bee hives, which are made from beeswax. Honey bees produce beeswax from glands on their stomach and use it to build hives, which also serve as their home.
- Bee hives have a distinct shape. They are made from hexagon-shaped cells packed together.
- Bee hives have interested scholars, philosophers, and mathematicians for centuries. For hundreds of years, it was assumed that honey bees must be exceptionally good at geometry because their hives were so expertly crafted.
- Honey bees must expend an extraordinary amount of energy to produce beeswax, the stuff bee hives are made from. In fact, bees must consume 6 to 8 ounces of honey just to produce 1 ounce of beeswax. It is therefore to the bees' benefit to use as little beeswax as possible when building their hives. This leads to an interesting question: Which shape could the bees use to build their hives that would get them the most storage space while using the least amount of wax?
- Only three shapes can be packed together without gaps: equilateral triangles, squares, and hexagons. Of these shapes, hexagons have the smallest perimeter (or outside edge). This means hexagons are the best option for honey bees.
- Of course, honey bees can't actually do math. Instead, over time, those honey bee colonies that built the best hives were the most successful, and the best hives are built from hexagons! This is why hives always take on that classic "honeycomb" shape.
- So, how do honey bees make these hexagon shapes? Well, it turns out they don't. Instead, honey bees mold cylinders that are roughly the size of their bodies and tension pulls the cells into hexagonal shapes.
- This is exactly what happens when bubbles stick together. When two bubbles bump into each other, two walls become one. The laws of physics force the bubbles to morph into the most efficient shape. As more and more bubbles join together, their edges become less curved.
- Just moments after a cylinder is formed by the honey bees, the beeswax, warmed by the body heat from the bees, is pulled into a hexagonal shape. This explains how bees are able to produce such an efficient, sturdy structure without knowing how to do math: Nature is doing the work for them!
- Scientists are still trying to figure out if honey bees heat the beeswax to force the cylinders into hexagonal shapes. We still have lots to learn about honey bee behavior. How do honey bees know where to build the honeycomb? Is building hives something they know how to do instinctively or is it something they observe and then learn how to do? These are the types of questions scientists hope to answer.
- Many engineers are hopeful that better understanding of how honey bees build their hives will help us figure out how to build an artificial honeycomb that is just as strong as that of the honey bees. This could help us make better materials.

- Imitating the design of honeycomb is an example of biomimicry. Biomimicry is the use of structures, patterns, and strategies from nature to help us come up with new ideas in science, technology, and art.
- To help us understand how honey bees build their hives and think about biomimicry, we are going to create art inspired by honey bee hives in class today.

B. Class Project (60 minutes)

Here are step-by-step instructions on how to build artistic honey bee hives from construction paper. These instructions do not need to be read aloud to the class. They can be summarized verbally or printed for groups of older students to read and follow in small groups.

- Divide the class into groups of 4 to 6 students. Each group should be provided with the materials needed to create their own artistic honey bee hive. Materials needed include:
 - Multi-colored construction paper
 - Rulers (one per student)
 - Pencil (one per student)
 - Scissors (one pair per student)
 - Scotch tape
 - Paper clips
- To start, students should use the ruler to draw horizontal lines across each piece of construction paper. The paper should be oriented in “portrait mode” so that the lines are drawn parallel to the shorter side of the paper. The lines should be once inch apart.
- Next, students should carefully cut out one-inch strips of multi-colored construction paper, following the lines they drew in the step above. These should then be cut in half.
- Once all the paper is cut into strips, students will build the “cells” of the hive by attaching the ends of each strip with tape to form short cylinders.
- After the cells are built, students will work together to build the hive. To do so, students should create a circle of six cells and place once cell at the center (for a total of seven cells). Students should use paper clips to connect the cells together. All adjoining cells should be secured with a paper clip, so that the center cell is secured to six others with six different paper clips. This stable section of the hive will be referred to as a “unit.” Students should make as many units as possible, until every paper cell has been used.
- As a class, students will work to join the units together into one, large beehive. Students can connect their unit to the beehive in any way they wish, as long as every cell is connected to six others (excluding those along the edge).
- To complete the hive, student should fold the paper strips where they are secured with paper clips to illustrate how surface tension forces the cylindrical beeswax cavities formed by honey bees to collapse into hexagonal shapes.

- The finished piece of art could be hung in the classroom or hallway to serve as decoration as well as a useful talking point for future classes on science and art.

C. Discussion (10 minutes)

To conclude the class, ask for the students' input on the following questions:

1. Did it surprise you to learn that honey bees build their hives in the most useful shape? Why or why not?
2. Can you think of other animals that build structures? Do you think these structures are also designed for a specific purpose? Might there be a reason why the structures are built in a particular shape?
3. What other plants or animals might benefit from the work of honey bees?

Homework:

1. List two other plants or animals that might benefit from the work of honey bees (such as foraging, the production of honey, or the construction of bee hives). Why might these plants and animals benefit from living near honey bees?
2. What threats do honey bees face in the wild? List at least three.
3. What could you do to help honey bees? List at least two ideas.
4. Engineers would like to build artificial honeycomb inspired by the hives built by honey bees. Can you think of any other examples of biomimicry?
5. Would you like to be a bee keeper? Why or why not?

Further Reading:

<http://www.livescience.com/37611-what-is-honey-honeybees.html>

<http://animals.nationalgeographic.com/animals/bugs/honeybee/>

<http://kids.nationalgeographic.com/animals/honeybee/#honeybee-pink-flower.jpg>

<http://www.npr.org/sections/krulwich/2013/05/13/183704091/what-is-it-about-bees-and-hexagons>

<https://askdruniverse.wsu.edu/2015/11/02/why-do-bees-make-hexagons/>

<https://www.youtube.com/watch?v=GKvT1IRWhE0&feature=youtu.be>

<http://www.nature.com/news/how-honeycombs-can-build-themselves-1.13398>

<http://www.livescience.com/38242-why-honeybee-honeycombs-are-perfect.html>

<https://www.nature.com/articles/srep28341>