# The Case of the Bad Hives - Genetically Engineered Bees

**Secrets of the Sequence Video Series on the Life Sciences • Grades 9 – 12**

**Teaching materials developed by VCU Life Sciences.**

Virginia Commonwealth University

## Classroom Tested Lesson

## Video Description

"Secrets of the Sequence," Show 142, Episode 1
"The Case of the Bad Hives" – approximately 10 minutes viewing time

Dogs aside, you might consider the honeybee as man's best friend. Not only does it produce honey and wax, but it also pollinates fruits and vegetables. However, the honeybee is in grave danger from something called American Foulbrood Disease, as well as a dozen other pathogens and parasites. Should this insect succumb, the loss to American agriculture would be catastrophic. Scientists at the USDA are fighting to save the honeybee by mapping its' genome, and they are closing in on certain disease-resistant genes. A genetically engineered disease-resistant honeybee would certainly cause a buzz...

Ward Television
Producer: Dave Bolton
Associate Producer: Mara Mlyn
Featuring: Mark Feldlaufer, Research Leader, US Department of Agriculture; Jeff Pettis, Entomologist, US Department of Agriculture; Jay Evans, Research Entomologist, US Department of Agriculture
Lesson Author; Reviewers: Elizabeth Armstrong; Cathie Alder, Selvi Srirangnathan
Trial testing teachers: Renwai Hanewald, Sharon Padget

## National and State Standards of Learning

### National Science Education Standards Connection

#### Content Standard C: Life Science

As a result of their activities in grades 9 - 12, all students should develop an understanding of:

- Interdependence of organisms
- Behavior of organisms

#### Content Standard F: Science in Personal and Social Perspectives

As a result of their activities in grades 9 - 12, all students should develop an understanding of:

- Science and technology on local, national, and global challenges

### Selected State Science Standards of Learning Connections

Use http://www.eduhound.com (click on 'Standards by State') or a search engine to access additional state science standards.

Virginia

BIO.5 The student will investigate and understand life functions of organisms, including:
how structure and function vary between and within the kingdoms;

BIO.8 The student will investigate and understand how populations change through time, including:
how genetic variation, reproductive strategies and environmental pressures impact the survival of populations;

BIO.9 The student will investigate and understand dynamic equilibria within populations, communities, and ecosystems.
d) The effects of natural events and human influences on ecosystems.

Oregon

Life Science: Heredity

- Understand the transmission of traits in living things. 9 – 12 grade students will describe how the traits of an organism are passed from generation to generation. Specifically, identify traits, which are inherited, and those that are acquired through interaction with the environment.

- Understand the relationships among living things and between living things and their environments. 9 – 12 grade students will identify and describe the factors that influence or change the balance of populations in their environment. Specifically, understand and differentiate between relationships among organisms including predator-prey, parasitism, mutualism, and communalism.

# Overview

A significant portion of the world's fruit and vegetable crops rely on pollination by insects to reproduce. In agriculture, when pollinators are required, relying on the hit-or-miss pollination of nature is not an option; the professionals are brought in. *Apiarists* – professional beekeepers – bring their hives into the orange groves, apple orchards, and squash fields of the world, providing a win-win situation for both the apiarist and the farmer: The farmer gets his crops pollinated and the apiarist gets his honey. Without this cooperative arrangement, our supermarkets would not be able to stock fruits and vegetables all year round. Bees are under attack and the future of agriculture may be in the hands of a tiny organism – a bacterium that is attacking the hives.

There are many factors, both biological and climatic that can destroy bee colonies. One of these, American Foulbrood Disease, is caused by the bacterium *Bacillus larvae.* This disease attacks the larvae of honeybees, causing them to rot in their chambers. When the colony is attacked by bacteria and weakened, the hive becomes susceptible to predation. The problem is serious enough that all cases of foulbrood disease must be reported to state bee inspectors so that they can be treated, isolated, or destroyed. The condition can be treated with antibiotics, but honey produced by antibiotic-treated hives is not fit for human consumption due to the possibility of introducing human antibiotic allergies.

Therefore, researchers are turning to genetics to help produce healthier honeybees by working to isolate the genes that produce immunity to foulbrood and other diseases. There are two ways of manipulating the genetics of a population – selective breeding and genetic engineering. Of these two, genetic engineering is the more precise and efficient method. Instead of performing round after round of delicate breeding experiments, scientists hope to find a way to change bees' DNA on a molecular level. Researchers are extracting and comparing RNA before and after larvae have been infected by the bacteria in order to identify the gene or genes that confer immunity.

## Testing: A sample related multiple-choice item from State Standardized Exams

Which of these most closely relates to the concept of natural selection?

a. Population explosions
b. Genetic mutation
c. Food webs
d. Survival of the fittest *

Source: Oregon Sample Item: Diversity/Interdependence

## Video Preparation

Preview the video and make note of the locations at which you will later pause the video for discussion

## Before Viewing

Ask the students:

1. "How do fruit and flowers reproduce?"
   *Through cross-pollination or self-pollination*

2. "What are some of the most common pollinators?"
   *Generally, we think of bees and butterflies, although moths, birds, bats, even ants are responsible for pollination. The often-used phrase "the birds and the bees" comes from this fact. This video focuses on bees.*

3. 'If bees ceased to exist, what would happen to the plants?"
   *Due to the alternative pollinators, as stated in the answer above, other organisms might take over their job. What else might happen? Response: decreased plant reproduction, decreased harvests, food shortages, etc.*

4. "What are some reasons that bees might die in great numbers?"
   *Diseases, climatic changes, loss of habitat, loss of food supply*

Explain to students: This video will tell us about problems that bees are currently having. As you watch this video segment, think about how scientists are searching for a way to make these helpful insects healthy enough to withstand the bacteria that can kill them, and in so doing; increase the number of bees for pollination and honey production.

## During Viewing

1. START the video.

2. PAUSE the video after the scientist, Mark Feldlaufer, describes bees as 'white men's flies' (2:18 minutes into the video). Ask: "How do you think pollination occurred before honeybees were introduced to America?"
   *Other insects acted as pollinators, the wind.* (See Appendix A: "What can you do to improve Cranberry Pollination" by Dr. Marla Spivek, Department of Entomology, University of Minnesota )

3. RESUME the video.

4. PAUSE the video after the scientist, Jay Evans, says, "…in their ability to mount what's essentially an immune response to this pathogen." (6:31 minutes into the video)

   Explain: Just as we have the ability to make antibodies to bacteria that invade our bodies, many bees can produce antibodies to the foulbrood bacterium. Researchers are finding that bees differ in their ability to produce these antibodies.

Ask: "What benefit can you see in researchers identifying the gene that triggers immunity in bees?"
*The ultimate goal is for all bees to be resistant to foulbrood. Researchers could genetically engineer queen bees by inserting genes that code for foulbrood resistance into their genomes. This would ensure that entire hives would be immune to the bacterium - thus, preserving bees for the important role they play as pollinators.*

5. RESUME the video and play to the end.

## After Viewing

1. Review the steps researchers use to determine levels of immunity in bees to a particular bacteria in the hopes of eventually isolating that gene that codes for immunity. Geneticists are looking for the genes that are responsible for triggering immunity to bacteria.
    - Extract RNA from larvae that are immune
    - Inject bacteria into the larvae
    - Collect larvae after 12 and 24 hours (found to be the maximum response time)
    - Extract and measure amounts of RNA for specific genes involved in the immune response
    - Correlate those levels of RNA with those found in bees not exposed to bacteria
    - If there is a change, this signals larvae are producing antibodies

2. Have students select one of the following questions to research in small groups or as individuals:
    - In the video a scientist said, "Don't think of individual bees, but think of the entire population of the hive as one entity." What did he mean?
    - If pollinators become extinct, what would happen to the plants that depend on them for fertilization?
    - What are the effects in humans of antibiotics consumed second-hand vs. antibiotics consumed directly?
    - Which has the greater impact on immunity level? Genotype or the environment.
    - Is artificial pollination a potential replacement/augmentation for bees?
    - How might changing one part of the genome (selecting for a desirable trait) produce undesirable consequences? An interesting article for further exploration is http://www.biotrin.cz/enpages/effects_of.htm
    - How did killer bees' genes enter honeybee populations?

    (See http://www.si.edu/resource/faq/nmnh/guginfo/killbee.htm or use a search engine)

3. Choose among the following three student laboratory activities. The first two are available from the Internet and the third is outlined below as part of this lesson.

    DNA Science: Find the Gene
    http://www.carolina.com/biotech/find_the_gene/default.asp (note the underscores in 'find_the_gene'). This activity provides students with experience in being 'gene hunters' by sifting through 300 DNA bases to find a gene.

    Gene Mining
    http://www.carolina.com/biotech/genemine1.asp This activity simulates a portion of what molecular biologists face when they examine genome data for meaningful gene data.

    The Birds and the Bees
    This activity is a review of flower structure and plant reproduction that reinforces the role of pollinators.
    Consider asking a local florist to donate fading or damaged lilies needed for this lesson.

# Teacher Notes for the Student Activity: The Birds and the Bees

## Overview

In this activity students will investigate the reproductive structure of plants to better understand why healthy bees and other pollinators are so important in plant reproduction.

## Materials

For each group of 4 students:

- Worksheets: *"The Birds and the Bees"* (one per student)
- 1 lily (fading or damaged flowers are often available from local florists)
- Scalpel or razor, or a station where cutting will be done for students
- Paper towels

For the class:

- Bouquet of various flowers
- Ultraviolet lamp

Caution: Lily pollen can permanently stain clothing; smelling a lily (which has little or no odor) can leave you with orange streaks on your face for the rest of the day!

## Procedure

1. Place the bouquet in front of the class, and ask: "What is the purpose of a flower's scent?"
   *Most students will know the purpose is to attract pollinators.*
2. Ask: "Do all flowers have scents? "
   *Most will say no*.
3. Ask: "How do those flowers attract pollinators?"
   *Not all plants need pollinators; many flowers are self-pollinating, and so do not need a pollinator. Many flowers have other forms of attraction; including one that human's can't see*.
4. DARKEN THE ROOM. Allow the students to view the bouquet of flowers under the ultraviolet light. The flowers will exhibit different colors and many will show paths, tracks, and 'runways' that lead from the edge of the petals to the center of the flower.
5. Explain that insects see in a broader range of the electromagnetic scale than we do; their vision includes ultraviolet ranges, so they see things that we cannot.
6. Tell students that they will dissect a flower to learn about the structure and function of the parts of a flower and to relate each structure to its role in pollination.
7. Distribute the student activity handouts "The Birds and the Bees" and read the directions as a class.

# Student Handout: The Birds and the Bees

## Part I: As a class

1. Look at the flower you've been given. As a class, identify the following structures, then count, and describe them:

    a. The petals: _____

    b. The sepals: _____

    c. The stigma: _____

    d. The stamen: _____

Note: Although a lily appears to have 6 petals and no sepals, it actually only has three petals and three sepals. This is easiest to see if you attempt to close the flower.

2. What (if any) is the role of each of these structures in pollination?

    a. The petals: _____

    b. The sepals: _____

    c. The stigma: _____

    d. The stamen: _____

3. Touch the tip of the stigma. Is it sticky? _____ The more mature the flower, the stickier the stigma will become. Why do you think that happens?

    _____

    Is the stigma a male or female reproductive structure? _____

4. Touch one of the stamens. BE CAREFUL not to get pollen on your clothes. (It stains.)

    Is the stamen a male or female reproductive structure? _____

## Part II: In pairs

1. Pull the petals and sepals off your flower. Locate the stamen.

   Each stamen is made of two parts: the ***anther***, which is the part that produces pollen, and the ***filament***, which is the slender thread that holds up the anther. In the space to the right, draw and label the parts of a stamen.

2. Look at the stamens and compare their position to the stigma.
   - Are the anthers above or below the tip of the stigma? _____
   - How does this affect pollination? _____
   - Would you expect this flower to be self-pollinating? _____ Explain your answer.

     _____

     _____

3. Pull off all of the stamens. The remaining portion is the complete female reproductive structure, called the ***carpel***: The carpel is made of three parts:

   - The sticky, lobed ***stigma***,
   - The slender ***style***, or neck,
   - The round ***ovary*** that contains the ovules that will become seeds.
   - The ovary wall will become the fruit. In the space to the right, draw and label the carpel.

4. Look at the stigma from the top. You should see lobes, similar to a cloverleaf. How many lobes are there? _____ Pollen attaches to the lobes and a tube grows from the pollen grain down through the style to the ovary, where fertilization takes place.

5. Go to the cutting station or use your scalpel or razor to slice across the ovary. Look inside. How many chambers do you see? _____
   How is this related to the lobes on the stigma? _____
   Explain: _____

   Do you see seeds in the chambers? What does this tell you? _____
   _____

6. Look at the flowers in the bouquet at the front of the room. How many of them appear to need pollinators to reproduce? _____
   How can you tell? _____

7. Why is it important that there are government agencies whose sole purpose is to monitor the health of our honeybee populations? _____
   _____

# APPENDIX A

## WHAT CAN YOU DO TO IMPROVE CRANBERRY POLLINATION?

By Marla Spivak
University of Minnesota

When your cranberries are in bloom, do you observe bees gathering nectar and pollen from the blossoms? If you don't see an average of 3-4 honey bees or 1-2 bumblebees per 100 sq. ft. of cranberries, you may need to rent some bee colonies to enhance pollination.
Cranberries require insect (primarily bee) pollination to set fruit. Bees transfer pollen from the anthers of one flower to the stigmas of another flower. Multiple bee visits to many flowers ensure cross-pollination, which increase the size of the fruit, the number of seeds, and the consistency in the shape of the fruit.

## Honey Bees and Bumblebees as Pollinators of Cranberry

Honeybees are the most effective pollinators of cranberries, but bumblebees are the most efficient. The difference is that honey bee colonies have 40,000 - 50,000 female workers while bumblebees have 200 - 300 female workers, so there are considerably more honey bees available for pollination per colony (from 25-50% of the workers in each kind of colony may actually be foraging on a nice day). In addition, honeybees have an effective communication system to recruit their nest mates to foraging sites. Bumblebees do not have a means to recruit other foraging nest mates. However, bumblebees are more efficient foragers than honey bees on cranberry flowers because they are capable of buzz-pollination. Bumblebees hang on to the flower and buzz it by vibrating their muscles that control flight. The pollen in the flower is actively shaken loose and released onto the bee, and the bee then grooms the pollen grains onto her hind legs. After visiting many flowers to collect pollen, she will have accumulated a large ball of pollen on each hind leg, and will have cross-pollinated the flowers along the way. Honeybees are not able to buzz-pollinate. They gather pollen passively by rubbing up against the anthers as they visit the flowers. They also collect large balls of pollen on each hind leg as they cross-pollinate, but they are not nearly as efficient in collecting the pollen from each flower as are bumblebees. Both honey bees and bumblebees must visit flowers to obtain significant quantities of pollen to sustain the nutritional needs of the colony. Pollen is the sole source of protein for bees, and their bodies are covered with fine hairs that help catch and hold the pollen. In addition, bees require carbohydrates, which they obtain from nectar. Nectar is a sugary solution that some flowering plants secrete to attract pollinators. Nectar is produced in nectarines located deep within the plant so the pollinator is forced to brush up against the pollen-bearing anthers to reach the carbohydrate reward. Some bees forage exclusively for nectar, others for pollen, and some bees forage for both. Even if bees are foraging for nectar, they transfer some pollen from flower to flower as they go. Honeybees gather huge quantities of nectar and convert it to honey within the colony. They require large amounts of honey (75-100 lbs in northern climates) to survive the winter months. Bumblebees collect nectar and store it as honey, but because the colony does not survive the winter, they do not need to store surplus quantities. They store the honey in small wax pots and usually only have enough to survive through short periods of dearth. A honeybee colony is perennial; it survives the winter as a colony and may produce a new queen and colony in early summer through the process of swarming. A bumblebee colony is annual; only newly mated queens that are produced in late summer survive the winter hibernating alone in the ground. In late spring, the surviving queens emerge and initiate a new nest.

There is only one species of honeybee in the United States, *Apis mellifera*, and it is not native. All honeybees originated from Europe and Asia, and were introduced into the US in the 1600's. There are at least 19 species of bumblebees in Minnesota and Wisconsin, all within the genus *Bombus.* Bumblebees are native to the US, as are cranberries, so they were the original pollinators of this plant.

Our dependence on honeybee pollination has increased because the number of native bees (bumblebees, orchard mason bees, sweat bees, etc.) has been reduced due to the use of pesticides and the destruction of nesting sites by modern agricultural technology. There are still a number of bumblebees in areas that are wooded (e.g., surrounding some cranberry properties), but in areas that have been cleared for development or for crop production, their presence may be scarce. In the past, introduced honeybees established wild populations in trees and were prevalent for pollination. However, in the last decade, the number of honeybee colonies has diminished due to the introduction of two, highly destructive parasitic mites specific to honey bees. Many

home gardeners and growers of large commercial crops have noticed the lack of bee pollinators and have taken an interest in renting or purchasing bee colonies to increase pollination.

## Pollination Requirement – Honey Bees

Cranberries require 2-3 honeybee colonies per acre for adequate pollination. Colonies can be rented from a reputable commercial beekeeper that will truck the bees in and out of the property. It is strongly recommended that the grower and beekeeper draw up a pollination contract before the bees are brought into the property. The contract will ensure that the beekeeper will bring in strong, healthy colonies at the desired time and to the desired location, and that the grower will pay the beekeeper a specified amount and will either not spray toxic pesticides while bees are on the property. A sample pollination contract is supplied below. With recent funding from the WI Cranberry Board, Dr. Gordon Waller, graduate student Elaine Evans, and I are investigating if there is an optimal time during cranberry bloom to bring in and take out honeybee colonies from a cranberry property. However, the following are some common sense rules of thumb. Honeybees prefer to forage on clover, alfalfa, and some other wildflowers because they produce more nectar than cranberries. If the cranberry property is in a wooded area where clover and other flowers are not abundant, the honeybee colonies will forage predominantly on cranberries and can be introduced before 10% bloom. If the property is located where bees have access to large amounts of other flowers, it may be best to wait to introduce the bees until there is at least 10% bloom. That way, the honeybees will not learn the location of and recruit other bees to flowers off the property before the cranberries bloom. Honeybees may gather a small crop of cranberry honey in some locations and in some years, which the beekeeper can harvest. Cranberry honey is very delicious and unique. However, by bringing honeybee colonies in for cranberry pollination, the beekeeper sacrifices the larger crop and potential income he/she could obtain by moving bees into clover and alfalfa fields. It is important to come up with a pollination fee that is equitable for the beekeeper and the grower. Without bee pollination, the cranberry grower may have very low yield, so the grower must consider the value of the bees relative to the value of the entire cranberry crop.

## Pollination Requirement – Bumblebees

Some estimates indicate that 4 bumblebee colonies per acre are needed to pollinate cranberries. The number of colonies needed will vary depending on the number of feral bumblebees present and whether or not honeybee's colonies are also being used for pollination.

Honeybees and bumblebees seem to be compatible for use together. Bumblebee colonies can be placed in the bogs at or before the first flowering. Since bumblebees do not communicate with each other about foraging, most of them will not leave the cranberries in search of better rewards. Bumblebee colonies can be rented for a minimum of $75 each. The reason bumblebee colonies are so expensive is that there are only a few companies with the knowledge of how to rear them on a large scale. The species of bumblebee that is reared commercially in the Midwest is *Bombus impatiens.* Other bumblebee species are more difficult (if not impossible) to rear. We are investigating methods of rearing this species of bumblebee and hope to publish a small how-to manual in the near future. Setting out nest boxes around a cranberry property in the hope of attracting bumblebee queens in the spring is not a reliable way to obtain bee pollinators. The success rate of this method is very low. The best way to encourage native pollinators is to conserve native prairies and woodlands.

For further information on pollination requirements or on how to keep bees, contact:

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# Additional Resources

*Because Web sites frequently change, some of these resources may no longer be available. Use a search engine and related key words to locate new Web sites.*

The Gene School http://library.thinkquest.org/19037/heredity.html

Chromosome structure and the stages of gamete formation by meiosis (see Campbell, N. A., Reece, J. B., and Mitchell, L. G. Biology 5/e, and Campbell, N. A., Reece, J. B., Biology 6/e, chapters 13-15).

How genetic mutations produce changes in phenotype, and beneficial and detrimental results of mutations in a population (Campbell, N. A., Reece, J. B., and Mitchell, L. G. Biology 5/e, and Campbell, N. A., Reece, J. B., Biology 6/e chapter 17).

http://biologylab.awlonline.com/index.html or http://cdl-flylab.sonoma.edu/ An interactive fly lab that, in conjunction with the two suggested activities illustrates phenotypes vs. breeding.
Biology Labs On-Line offers a series of interactive, inquiry-based biology simulations and exercises designed for college and AP high school biology students.

http://www.accessexcellence.org/AB/IE/Animal_Genome_Mapping.html
'Animal Genome Projects' found within the 'Issues and Bioethics' website, National Health Museum, About Biotech.

http://www.carolina.com/biotech/dnai.asp
DNA Interactive Allows students to explore the history, mechanism and makeup of DNA.

http://www.pbs.org/wnet/nature/alienempire/multimedia/hive.html
Nature: Alien Empire. Interactive background information on the lives of honeybees.

Genomic Revolution
http://www.ornl.gov/sci/techresources/Human_Genome/education/education.shtmL
This Web site of the government-funded Human Genome Project has links about genomics, the history of the project, and more.

Secrets of the Sequence Videos and Lessons
This video and 49 others with their accompanying lessons are available *at no charge* from www.vcu.edu/lifesci/sosq