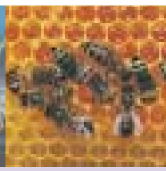
Unit 4 How Does Evolution Work?

Evolution TV Show
"Why Sex?"



At a Glance

Learning Goals

Recognize the importance of sexual reproduction for variability in organisms

Understand the process of natural selection and how it accounts for adaptations in organisms

Recognize that populations, not individuals, evolve

Quick Clicks

Teacher's Guide Web Resources

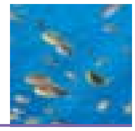
Access the Web resources referenced in this guide—from handouts to video segments to Web features—by going to **pbs.org/evolution** and clicking on Teachers and Students, and then going to the *Evolution Teacher's Guide,* where the material is presented by unit.

For more than 25 years, Robert Vrijenhoek has been returning to the remote hills of the Sonoran Desert in Mexico to study unique populations of minnows. Living side-by-side in the small hillside pools are two different species of minnows, one an asexual reproducer and the other a sexual reproducer. Vrijenhoek has been trying to understand which conditions might favor the sexual minnows and which favor the asexuals. He has noticed that the sexual species tends to predominate in the river where they are 60 percent to 80 percent of the total fish population. Early on Vrijenhoek discovered that 40 percent of all minnows were infected with a parasite that causes black spot disease. Upon closer investigation, he observed an interesting pattern—most of the parasitized fish were asexual reproducers. "Why should they be more parasitized than the sexual reproducers they were living right beside?" he wondered.

At first Vrijenhoek didn't have an answer. Finally it hit him; he was looking at a real world demonstration of the value of sexual reproduction related to an evolutionary hypothesis called the "Red Queen." This hypothesis, suggested by scientist Leigh Van Valen, asked "Does evolution stop when things get perfectly well adapted to their environment?" The answer is no. Evolution is a race like the one in Alice in Wonderland. Alice and the Red Queen are running as fast as they can and Alice says, "Isn't this curious, as fast as we run, nothing seems to change. We're staying in the same place." The Red Queen answers, "Yes, you have to run just as fast as you can to stay in the same place."

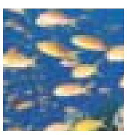
Evolution is like that too. We live in a complex world full of parasites, viruses, bacteria, predators, and competitive species—all of them evolving. At the moment any species stops evolving in response to these challenges and threats, it is doomed.

Background



How does the Red Queen hypothesis explain what happens to the minnows? It appears that the asexual minnows have stopped running the race. They are genetic clones of each other and an easy target, especially for a short-lived, quickly evolving parasite. Sexual reproduction creates variability in sexual minnows' offspring so that the parasite cannot easily adapt to them. That is the value of sexual reproduction.

The variability in the sexual minnows is primarily caused by **recombination** of chromosomes during sexual reproduction: the random assortment of maternal and paternal chromosomes during the production of sperm and eggs, the random joining of gametes at fertilization, and the crossing over of chromosomes during **meiosis**. Variability can also be caused by **mutations,** but in this example sexual reproduction is the most immediate cause. It is this variability in individuals that allows those best adapted to their environment to survive and reproduce to create future populations. Thus, the sexual minnow population, with its variability, was better adapted to resisting the parasite than the asexual population. This is a clear demonstration of the process of **natural selection** at work—the primary mechanism of evolution in populations.



An interesting change in Vrijenhoek's pools demonstrated another mechanism for evolution. A bad drought dried up the pools and killed most of the minnows. Eventually, the water returned and so did the minnows. They had hopped up stream like trout. But, when Vrijenhoek checked the top pool, he made a surprising discovery. Now the parasites were decimating the sexual minnows and the clones were doing quite well.

Vrijenhoek was stymied. He collected the fish and examined them carefully. He found that the sexual minnow population had lost its genetic variation; it had become inbred and lost its advantage. The sexual fish were clone-like in their variability and since they outnumbered the true clones, they were the biggest targets of the parasites.

To test his idea that reduced variability in the sexual minnow population had caused the turn of events, Vrijenhoek tried an experiment. He brought sexual minnows from a lower pool, where the fish still had genetic variability, up to one of the higher pools. A year later he came back to see what had happened. To his delight, the situation had reversed itself to the normal pattern. Now in fact, the asexual minnows again were more parasite-prone and the genetic variability of the sexual minnows had returned.

The recolonization of the upper pools demonstrated another mechanism for evolution—the **founder effect.** This happens when a small population with limited diversity founds a new population in a new location. Because of this, the limited population of sexual minnows became inbred. This mechanism, unlike natural selection, is random. It is by chance that this particular group of individuals recolonized the upper pools.

Vrijenhoek's work demonstrates key mechanisms for evolution: the genetic variability created by sexual reproduction and the effect of natural selection on individuals within a population. It also showed how a non-selective mechanism, the founder effect, can cause evolution within a small population.

Know More

Web Sites

www.talkorigins.org (In-depth background articles on evolution)

anthro.palomar.edu/synthetic/synth_7.htm (Discussion of natural selection and genotypes, using sickle cell anemia as an example)

bioserve.latrobe.edu.au/vcebiol/cat3/u4aos2p3.html (Discussion of natural selection and population genetics including founder effect)

www.literature.org/authors/darwin-charles/the-origin-of-species/chapter-04.html (Online version of Darwin's *On the Origin of Species* chapter on natural selection)

Books

Benz, Richard. *Ecology and Evolution: Islands of Change.* Arlington, VA: NSTA Press, 2000.

Dawkins, Richard. *The Blind Watchmaker.* New York: W.W. Norton and Company, Inc., 1996.

Freeman, Scott, and Jon Herron. *Evolutionary Analysis, Second Edition.* Upper Saddle River, NJ: Prentice Hall, 2001.

Quammen, David. *The Song of the Dodo.* New York: Touchstone, 1996.

Ridley, Matt. *The Red Queen: Sex and the Evolution of Human Nature.* New York: Penguin Books, 1993.

Strickberger, Monroe. *Evolution, Third edition.* Boston, MA: Jones and Bartlett Publishers, 2000.

Weiner, Jonathan. *The Beak of the Finch: A Story of Evolution in Our Time.* New York: Vintage Books, Random House, Inc., 1995.

Wilson, Edward O. *The Diversity of Life, College Edition.* New York: W.W. Norton and Company, Inc., 1992.

Zihlman, Adrienne. *The Human Evolution Coloring Book, Second Edition.* New York: HarperCollins Publishers Inc., 2000.

Videos

David Attenborough's "In Paradise" (Wallace's work on sexual selection in birds)

"What Darwin Never Saw" video of Grants' finch research in Galapagos (Kurtis Productions, 1-312-951-5700)

"The Blind Watchmaker" (Films for Humanities and the Sciences, Princeton, NJ)

pbs.org/evolution

SCILINKS **www.scilinks.org**

Topic	Keyword
evolution	EG19A
population genetics	EG19B

Activities

Darwin's Finches

Teacher's Guide Web Resources

Evolution Library
"Natural Selection in Real Time"

Handouts
"Grants' Finch Study Data"
"Answer Key to Darwin's Finches"

Evolution Web Feature
"An Origin of Species"

1. Have students look at "Natural Selection in Real Time" (see **Teacher's Guide Web Resources**).

2. Review with students the following **postulates** of natural selection:

Individuals within a population vary in their traits.

Some of these variable traits are heritable—passed on to offspring.

More offspring are produced than can survive because of limited resources such as food and nesting sites.

Individuals with advantageous traits will survive and reproduce.

3. Give students a copy of the "Grants' Finch Study Data" handout, covering the period from before to after the drought of 1976–77. Ask students to identify the specific data that supports each postulate and to write a story explaining how the Grants' data supports the occurrence of natural selection of the medium ground finches on Daphne Major.

4. Discuss students' explanations of natural selection of the finches on Daphne Major. Ask:

How do you know that finches' beak depth is heritable?

How did the finch population change from before the drought to after?

Why do you think the average beak depth of the birds increased?

Contrivances

(adapted with permission from an ENSI Lesson)

Teacher's Guide Web Resources

Video Resources
"Evolution of the Eye"

1. Give each student a block of wood (1"x2"x2" minimum size to 2"x4"x4," hardwood or softwood) and a screw or nail.

2. Ask them to put the screw or nail as far into the wood as they can without using a typical tool like a screwdriver or hammer. Tell them not to damage any people or property in the process.

3. After five minutes ask who has been successful. Have students share their different strategies. Ask:

- Was that the original intended use for the object they used?
- Did it work as well as a screwdriver or hammer would have worked?

4. Point out that these are all examples of **"contrivances,"** objects used or modified to do something clearly different from their usual use (and usually not as effective).

5. Have students brainstorm examples of traits in humans that are not perfectly adapted for a function (such as joints that wear down easily), including structures that are reduced and have little or no use **(vestigial)**, e.g., wisdom teeth, appendix. Ask:

- How does evolution by natural selection explain these (less than perfect) traits?
- Does natural selection result in perfect adaptations? Give evidence to support your answer.
- How could complex **adaptations** evolve from simple ones? Show students the "Evolution of the Eye" video and discuss.

Video 4 for Students

How Does Evolution Really Work?
This video describes how the process of natural selection operates in populations of rainforest hummingbirds.

Discussion questions:
What are the four components of natural selection?

What determines an individual hummingbird's beak length?

What factors in the environment might select for beak length and shape within hummingbird populations?

How can hummingbird DNA help Dr. Schneider determine the evolutionary history of hummingbirds?

Take It Further

Online Course for Teachers
Session 4: "What Are the Processes for Evolution?"

Evolution Web Features
"Sex and the Single Guppy"
"The Mating Game"
"Microbe Clock"
"The Advantage of Sex"

Evolution Library (URL)
"Red Queen" video segment

Extensions
For an activity that illustrates contrivances in nature: see **www.indiana.edu/~ensiweb/lessons/contriv.html** (orchids and the panda's thumb).

We're Not Perfect

There are examples of natural "contrivances" in living organisms, including humans. Adaptations can often be traced to a structure that served a different function in an ancestral species. For example, an adaptation like the wing of a bat can be traced to an ancestral structure by studies of its embryological development and its homologous anatomy with other vertebrate forelimbs.

Some traits may resemble the original structure in an extinct ancestor, but be less efficient and not perfectly "adapted" for their new job—they are called "adaptive compromises." The location of the larynx in humans is an example of this; its position lower down in the trachea increases our ability to make sounds and communicate, but makes us more vulnerable to choking than other animals since food can become more easily caught in our air path.

(For more on this topic, see Olshansky, S. Jay, Bruce A. Carnes, and Robert N. Butler. "If Humans Were Built to Last," *Scientific American* 284/(March 2001): 50-55.)

In-depth Investigation

Birds, Beaks, and Natural Selection—A Simulation

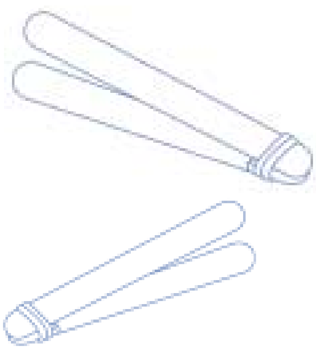
(adapted with permission from "Genetics and the Evolution of Bird Beaks" by Bonnie Chen)

In this simulation, students will gather data to see how beak mutations can influence natural selection.

Objective:
Students will learn about the role of mutations in natural selection and evolution.

Materials:

- *Teaching Evolution Case Studies: Bonnie Chen*—an extended version of this lab (see **Teacher's Guide Web Resources**)
- Bird beak materials: wooden tongue depressors (2 per student); 1.5" screws and rubber bands (1 per student)
- Long wooden tongue depressors (2 depressors glued end to end), enough for long beak mutations
- Scissors (1 per team)
- Aquarium or clear plastic container with water level to at least 15 cm (1 per team)
- Simulated food items (4 of each kind/ student) For example: floating (balloons with sugar or sand plus air), middle layer (balloon with sugar or sand, screw, and little air), and sinking food (sugar and screws)
- "Birds, Beaks, and Natural Selection" handout, "Bird Beak Data Sheet" (1 per person) and "Mutation" handout (1 per group) (see **Teacher's Guide Web Resources**)

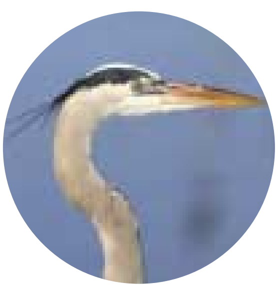


Procedures

Preparation: Watch Teaching Evolution Case Studies: Bonnie Chen *to see how the extended lab worked. Gather and prepare materials and handouts. Glue long wooden tongue depressors ahead of time. Make a bird beak model for students. Make copies of mutation handout; cut into sections and fold.*

1. Group students into three-to-four person teams that represent wading birds within a large population with wild-type beaks made of tongue depressors.

2. Show students the wild-type beak model and ask them to construct similar beaks following the directions on the "Birds, Beaks, and Natural Selection" handout.

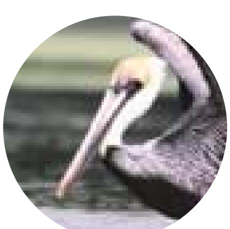


3. Explain that students will simulate the wading birds feeding. Instruct them to follow the feeding directions on the "Birds, Beaks, and Natural Selection" handout.

4. Have students compare the average number of food pieces and types of food captured by the team members.

5. After the first set of trials, explain that some birds will undergo mutations in the genes that code for beak length. Have each student pick a folded section of the mutation handout that will explain the kind of mutation and how it will affect the beak size of their offspring.

6. Tell students who received a beak mutation that requires a change to create the new beak for their offspring.



7. Have students now feed as if they were the offspring, Generation 1. Because this time *all members of a group will feed at once* to demonstrate competition for resources, two teams will work together during the feeding of the offspring. While one group feeds, the other group will time and monitor the feeding. Then teams will switch roles. There will be three feeding trials and students will record their feeding data on the "Bird Beak Data Sheet" after each trial.

8. Have students determine the survival rate of their offspring by following directions on the "Bird Beak Data Sheet."

9. Have students compare their data and answer the questions on the "Birds, Beaks, and Natural Selection" handout. Ask teams to share their answers in a class discussion. Ask students if the data turned out as they expected. Have students consider and discuss what variables might have affected their data.

See Assessment Rubric on p. 35.