Throughout the guide teaching tips are in red.

Activity Description and Estimated Class Time

In this simulation of natural selection, students enact a predator/prey relationship to see how variations in prey traits affect the makeup of a population under pressure from predators. The students act as predators to capture prey. The prey are colored toothpicks, with different colors representing genetic variation among them. Over multiple generations, the class continues preying on the toothpicks, tracking and analyzing shifts in the proportion of traits in the population.

Objectives

Students will develop an understanding of:

- How genetic variation affects an organism's ability to survive (both positively and negatively),
- Natural selection,
- Predator/prey relationships.

Correlations to North Carolina Science Standards

8.L.4.2 Explain the relationship between genetic variation and an organism's ability to adapt to its environment.

8.L.3.2 Summarize the relationships among producers, consumers, and decomposers including the positive and negative consequences of such interactions including:

- Coexistence and cooperation
- Competition (predator/prey)
- Parasitism
- Mutualism

Brief Science Background

See appendix on page 90.

Part 1 – The Hunt (2 days)

Materials

Materials for the whole class

- 8 boxes of flat toothpicks (750 per box)
- 1 set of food coloring
- 3 plastic trays
- Tape measure
- Surveyor flags
- String

- 2 clip boards
- 1 timer
- Calculator (supplied by teacher)
- 2 copies of BLM-1, "Student Recording Sheet" for each class period
- 1 copy of BLM-2, "Teacher Recording Sheet" for all classes

Materials for each student

- One 9-oz. cup
- Graph paper
- Colored pencils

Preparation

1. Three days before the activity, dye the toothpicks with food coloring. Empty two boxes, 1500 toothpicks, into one plastic tray. In a 9-oz cup, pour 3/4 bottle of red food coloring and fill the cup with water. Pour this into the plastic tray of toothpicks. Stir the toothpicks enough for all toothpicks to come in contact with the colored water. Repeat this with blue and green food coloring. Place the trays on a window sill until most of the dye evaporates (2-3 days). Spread the toothpicks out on cardboard to dry completely. Keep colors separate. Two boxes of toothpicks will be untreated and used as natural colored toothpicks.

Tip: bundle toothpicks by color in groups of 50, and a few groups of 10. This makes it easier to add toothpicks to the habitat after each hunting season.

2. The day of the lesson, lay out a 15 x 15 foot square outdoors with surveyor flags Connect the flags with string to make a border. This will be the toothpick habitat for all classes to use. Look for a location with grass and space for students to congregate around it.

3. Make two copies of BLM 1 for each class. Bring these outside on a clipboard. Students will record their hunting results on these sheets.

4. Bring outside near the habitat

- A copy of BLM-2 (the teacher will record the data on this sheet)
- A calculator
- A timer
- the toothpick bundles
- enough 9-oz plastic cups for each student

Day 1 – The Hunt

Procedure

1. For each class, explain that the class will go outside for a predator/prey exercise. Each student will be a predator. The prey are toothpicks. The toothpick prey can be red, blue, green or natural. Tell students only that they will hunt toothpicks, but do not discuss variation or natural selection at this time. Divide the class into two equal groups and explain that each group will hunt separately, one after the other. Explain that the other classes will also do this.

2. Show the class a diagram of the toothpick habitat and explain the following predator rules:

a. Before the hunt, line up around the habitat facing away (no looking for tooth picks before the start).

b. Each student hunts only once. Half the class will hunt first, all at the same time. The second half of the class will do a second hunt.

c. Students may only take "baby steps." Both feet must always be touching each other.

d. Collect toothpicks in a 9-oz. cup.

e. The hunt will last exactly 15 seconds. When the teacher calls time at 15 seconds, all hunting must stop.

3. Take the first class outside to the habitat, with everyone facing away from the habitat. From inside the habitat, randomly spread 50 of each color toothpick and tell the class what you are doing. You will do this only once, for the first half of the first class. For all other hunting groups, toothpicks will already be present. Identify half of the class to be the first hunting group. Give each student in the group a 9-oz cup and ask them to line up around the perimeter of the habitat facing away from it. Their challenge is to collect as many toothpicks in their cup as they can in 15 seconds. Ask the second half of the class to stand aside and watch quietly.

4. Conduct the 15-second hunt for the first group. Afterward, ask them to sort, count and record their catch on **BLM-1**. After all students record their results, the teacher totals the number of each color toothpick captured for the whole hunting group in column **C** to the right of column **G_0** on **BLM-2**. Subtract this total from the number in column **G** to fill in column **L** on **BLM-2**. The number in column **L** is the number of each color left over in the habitat. Later, you will add this number of toothpicks to the habitat before the next hunt. Adding this number to the habitat represents the fact that the surviving toothpicks of that color all reproduced one time. The next generation starting population is always double the number in column **L**. Fill in that number in the next **G** column to the right.

Example: Below is a chart after a first hunt. The group captured 21 natural, 11 green, 28 blue, and 30 red toothpicks **(C)**. Looking at the natural colored toothpicks, we see 29 left over **(L)**. Each of those 29 reproduced once. After adding 29 natural tooth-picks to the habitat, the next generation will have 58 total natural toothpicks **(G_1)**.

	G_0	C	L	G_1
Natural	50	21	29	58
Green	50	11	39	78
Blue	50	28	22	44
Red	50	30	20	40
Total	200			220

5. Randomly add the number of each color toothpick from column L into the habitat for the second half of your class to hunt. After this, the habitat is ready for the next group to hunt. (Using the example above, you would add 29 natural colored toothpicks to the habitat. You would also add the numbers shown in column L for the other three colors.)
6. Gather the second hunting group around the habitat, facing away from it and holding their 9-oz cups. Go through the procedure and record as before with the new toothpick population. After recording and totaling, add the necessary toothpicks to the habitat, collect cups and leftover toothpicks, and return to the classroom leaving the habitat ready for the next class. Each student will have hunted once, and this will complete two generations. The next class will start with column **G2**.

   Tip: Toward the end of the activity, it is unlikely but possible that a population could exceed 1500. If this happens, continue using all 1500 toothpicks. This does not affect the overall goal of the activity.

7. Repeat this with all of your classes, using the habitat as left by the previous class. When the last class has hunted and you no longer plan to use the hunting area, ask students to collect toothpicks and remove the string and line. Students might continue finding toothpicks for weeks, which emphasizes the effect of camouflage as an adaptation.

Day 2 – Analysis

Preparation

The completed BLM-2 (teacher record sheet) will need to be projected for students to see.

Procedure

1. Begin class with a discussion about the hunt. Questions to address:
   a. What was it like while you were hunting?
   b. Which toothpicks were easiest to capture?
   c. Why, do you think, (color) was easiest/hardest to capture?
   d. Based on your observations, which color toothpicks do you think were most/least abundant at the end?
2. Project the filled-in BLM-2. Lead a brief discussion looking at the data. If you prefer an Excel file of BLM-2 to record toothpick populations on your own computer, go to **http://ciblearning.org/lesson-materials** and click on "Grade 8 Life Science Materials,"password **learn16$**
3. Hand each student a sheet of graph paper and access to colored pencils. Pairs of students can share colored pencils.
4. Have students create a line graph for each color of toothpicks over time on one graph. Match pencil color to toothpick color.
5. In addition to each toothpick, have students graph the total population of toothpicks, all colors combined.
6. When the graphs are complete lead a discussion about adaptation and natural selection and how these factors can affect populations in nature.

7. Questions to consider:

a. What do you notice about the population numbers for the various different colors?

b. Which toothpick population had the largest increase/decrease? Why so?

c. What caused the increase/decrease in population?

d. Were some colors easier to find than others? Explain.

e. How might the results differ if this activity were done on sand? Or mulch?

Tips for discussion: Be sure students understand that the toothpicks are all of the same species, and the different colors are the result of genetic variation within the species. Specific population numbers are determined by many factors. This activity focused on how well the different forms of a species blend into their environment. Most of the time, the colors that blend in best have large population increases while the other colors remain low. The low populations seldom go extinct but continue to survive at low numbers, while the environmental conditions remain the same. If the environmental conditions change and favor their color, one would expect an increase in population. This is an example of natural selection. Nature is “selecting” or the result of natural conditions favors one variation over another. See examples in the detailed science background section of this lesson.

In this example we analyzed how blending in with your environment can affect populations. Have students speculate other environment pressures that could affect survivability.

Date: ____________ **Class period:** ____________ **Generation:** ____________

Student	Natural	Green	Blue	Red
TOTALS				

Date:____________________

	G_0	C	L	G_1	C	L	G_2	C	L	G_3	C	L	G_4	C	L	G_5	C	L	G_6	C	L	G_7	C	L	G_8
Natural																									
Green																									
Blue																									
Red																									
Total																									

KEY
G_0 = number in original generation, G_1 = number first generation, etc.
C = number captured
L = number left over (This is the amount of toothpicks that will be added to the habitat before the next hunt.)

$G_0 - C = L$
$L * 2 = G_1$

Appendix

Detailed Background Information

Industrial Melanism

In the 1950s, H.B.D. Kettlewell ran a series of experiments that are now regarded as classics in the study of evolution and natural selection. This particular account is taken from *Ecology*, by Robert E. Ricklefs, Chiron Press, 1973, but descriptions of this work can be found in most biology textbooks.

In Great Britain, there has been a long tradition among enthusiasts of making collections of butterflies and moths. In the early 1800s, these collectors would be especially pleased when they found a melanistic form of the common Peppered Moth (*Biston betularia*). The usual Peppered Moth was mostly white with little black spots (the ‘pepper’). The melanistic form was just the opposite; it was mostly dark, with little white spots. And these melanistic individuals were quite rare. However, as the decades of the 1800s passed, the collectors noticed that the melanistic moths were becoming increasingly common, especially in and around cities known for their industrial development. This was, after all, the industrial revolution in Great Britain, and cities like Manchester, Birmingham, and Liverpool were thriving. By the mid-1900s, the melanistic moths made up close to 100% of the population in some of these areas and the normal (white) forms were the rare ones. On the other hand, the white forms were still the most common ones in other areas.

Through crossbreeding experiments, geneticists had determined that this melanism was an inherited trait. Therefore, Kettlewell considered the spread of the trait to be an example of evolution and an opportunity to look for evidence of natural selection. He hypothesized that something in the environment near the industrial centers was changing to give the dark moths an advantage over the light ones in both survival and reproduction. How could he test this hypothesis?

Kettlewell collected more than 3,000 caterpillars, fed them in his laboratory, and allowed them to pupate and undergo metamorphosis into adults. While he was raising the caterpillars, he selected two forest tracts—one near an industrial center, the other in a natural area. When his adult moths were ready, he marked each one with a small dab of a special paint on the underside of its wing where it couldn’t be seen by predators when the moth was resting on a tree trunk. He then released his moths, waited awhile, then set traps to recapture as many as he could.

Kettlewell didn’t really care about the total number of moths in his forests; he just wanted to know if there was a difference in the survival of the light and dark forms. At right are the results from one of his experiments, when he released moths near Birmingham, an industrial center:

	White moths	Dark moths
Number released	201	601
Number recaptured	34	205
Percent recaptured	16.0 %	34.1 %

Table 1 (polluted woods)

It looks like the dark forms survived much better than the light forms. But doesn’t it make a difference that he released so many more dark moths? If he released more, it would make sense that he would recapture more. But it’s the percentage that really counts here. He recaptured 34.1 % of the dark moths; that’s more than twice the percentage of white moths recaptured.

Skeptics could argue that white moths were smarter and once released, they were less likely to be caught in Kettlewell's traps. Or perhaps, white moths were stronger, flew further from the release point, and thus were less likely to be recaptured. In order to account for these possibilities, Kettlewell ran a control experiment by releasing moths in a natural area, presumably unpolluted woods. Below are the results:

Notice that this time, the white moths survived much better. This eliminates the possibilities of trap avoidance or differential dispersal.

	White moths	Dark moths
Number released	496	473
Number recaptured	62	30
Percent recaptured	12.5 %	6.3 %

Table 2 (unpolluted woods)

These experiments confirmed for Kettlewell that the two forms of moths survived differently in the two habitats. But why? Who or what was the agent of natural selection? That is, who or what did the actual selecting? Kettlewell thought that in the industrial areas, soot from the coal-burning factories was settling on the tree trunks and turning them dark. As a result, the dark moths were better camouflaged in those areas and were less likely to be seen by predators, probably birds. Against normal bark, the white moths had the better camouflage. To test this hypothesis, he placed equal numbers of white and dark moths on tree trunks in natural and polluted woods. He set up a blind and simply sat and watched to see what would happen. Since Peppered Moths only fly at night, once placed on the tree trunks, they stayed right where they were. Below is what Kettlewell observed:

	White moths eaten by birds	Dark moths eaten by birds
In natural woods	26	164
In polluted woods	43	15

Table 3 (predator experiment)

Clearly, many more dark moths were eaten in the natural setting, and many more white ones were eaten in the polluted woods.

Two other pieces of this story help to add the finishing touches. In the polluted woods, it turns out that it wasn't really the soot that turned the trees black, but rather it was the other pollutants from the factories that killed the lichens that normally grew on the tree trunks. White moths with black specks look remarkably like lichens. In recent years, as Britain has introduced more stringent pollution controls, the lichens are coming back to the trees, and the white moths are becoming much more common again.

Secondly, one particular bird species, the Treecreeper, ate both types of moths in equal numbers in both types of woods. This particular bird species creeps around the trunks of trees and finds its prey by seeing their silhouettes sticking out from the bark. For them, white or dark color doesn't make any difference. The exception that proves the rule!