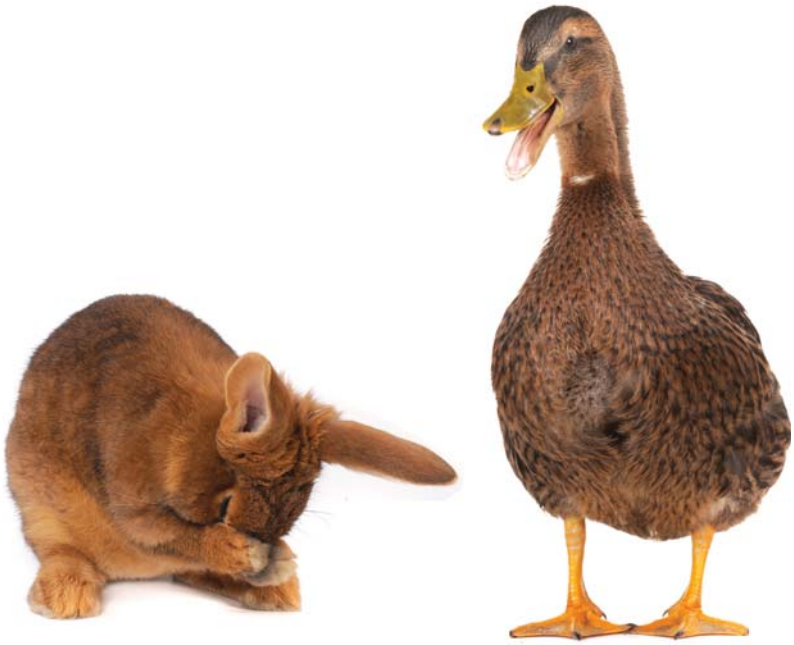

Quackers and Cottontails

Investigating Natural Selection

MATERIALS AND RESOURCES

EACH GROUP

plate, paper

bag with white and yellow Cheez-It®

computer with online access

TEACHER

bags, zipper-lock, quart

Cheez-It®, white

Cheez-It®, yellow

ABOUT THIS LESSON

This activity is designed to introduce the concept of natural selection. One of the main points of this activity is to help students see that a single organism cannot adapt to its environment, but that it will survive if it possesses a beneficial adaptation. The data collected in this activity can be used as a reference point for terms used during presentations on evolution and speciation.

OBJECTIVES

Students will:

- Simulate the impact of natural selection on a population of ducks ("quackers"), represented by two different colors of snack crackers
- Participate in a guided inquiry activity using a computer simulation that is used to test student-created questions about the survivability of a population of "bunnies" under several different mutations and population limiting factors

LEVEL

Biology

TEACHER PAGES

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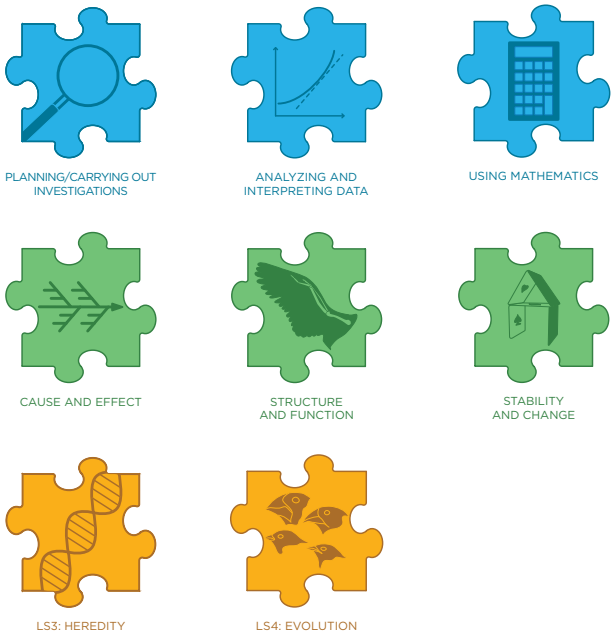
NEXT GENERATION SCIENCE STANDARDS



CONNECTIONS TO AP*

A.1 Natural selection is a major mechanism of evolution.

A.2 Natural selection act on phenotypic variations in populations.

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COMMON CORE STATE STANDARDS

(LITERACY) RST.9-10.3

Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks, attending to special cases or exceptions defined in the text.

(MATH) A-CED.2

Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales.

ASSESSMENTS

The following assessments are located on our website:

- Evolution and Taxonomy Assessment

ACKNOWLEDGEMENTS

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TEACHING SUGGESTIONS

Students often struggle with the idea that individuals do not "adapt" to their environment. This lesson should allow them to see that the crackers do not change color and the bunnies cannot change their characteristics in response to an environmental or community-related stimulus.

Individuals are born with certain characteristics, and these characteristics are either favorable or not favorable in their environment. They should also see that it is not the individual organism that evolves but rather the population. Students also need to know about descent with modification, so be sure to explain that this means that changes in gene frequency have occurred over time and been passed down from our ancestors.

The students pretend to be predators of the "quacker" population. The quackers are represented in this activity by two different flavors of the same type of snack cracker. You can find relatively inexpensive store-brand white cheddar snack crackers to represent the light-feathered ducks. The dark feathered ducks can be represented by inexpensive store-brand yellow cheddar snack crackers. You could substitute two colors of candies if you have difficulty finding affordable crackers—the type of food is not significant. You just need two versions of the same type of item.

Prior to the activity, you will need to prepare 14 re-sealable bags containing 20 dark- and 20 light-colored snack crackers (or suitable substitutes).

This activity should be conducted in a classroom setting rather than a laboratory setting because the students will be simulating predation by eating the prey. Be sure to check for food allergies before conducting this activity. As an alternative, you may choose to use a non-food item for this simulation. For example, you could use two different colored poker chips as the prey.

Use the class data table to collect data on all five generations from each lab group. Students will then total the numbers for each generation and write the averages in Table 2.

If you need to raise the rigor for students who can be pushed further than the parameters of this lesson, you might try the following suggestions:

- Have the students investigate if some mutations are dependent on particular selection factors or environments.
- Have the students investigate if combinations of mutations have selective advantages.

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TEACHING SUGGESTIONS (CONTINUED)

If you have computers and online access readily available, encourage your students to do the Challenge at the end of the activity.

If you do not have online access in your classroom, the simulation can be downloaded to your computer or multiple computers to facilitate the lesson. If you only have one computer, you could project the image on a screen and facilitate Part II as a classroom discussion. This would also be a good idea for students who are struggling to get started with Part II. You could go through one or two of the prompts with them until they get the hang of the methodology, and then let them start asking their own questions.

The PhET simulation utilizes the Java Web Start application. You will need to have the following specifications to run the simulation:

- Windows users: Microsoft Windows XP/Vista/7 and Sun Java 1.5.0_15 or later
- Mac users: OS 10.5 or later and Sun Java 1.5.0_19 or later

If you have any technical issues, please refer to the troubleshooting page on the PhET website,

http://phet.colorado.edu/en/troubleshooting

or you can e-mail them directly at

phethelp@colorado.edu

Due to a compatibility issue, this simulation will not work on the iPad.

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PART II: COTTONTAILS

MANIPULATING THE SIMULATION

1. What variables are you able to manipulate in this simulation?

   You are able to add new mutations, selection factors, and the environment. The mutations available are brown fur, long tail, and long teeth. For each mutation, you are able to specify whether it is caused by a dominant or recessive allele. The selection factors are wolves (predator) and food availability. The two environments available are the equator and arctic.

2. Start the simulation by clicking the "PLAY" button. What happens if you never "add a friend"? Explain.

   The original bunny dies, and thus the population dies off. This is due to the fact that the original bunny did not have another bunny with which to reproduce, thus eliminating the possibility of a second generation.

3. Add a friend. Let the simulation continue to run until it stops, and then discuss what happens. Explain what "selection" factors were lacking for this to occur.

   You are prompted that, "Bunnies have taken over the world!" This is due to the fact that there was no limitation on the population growth such as predation (wolves) or lack of food availability (food).

4. What happens to the population sizes of the two phenotypes after several more generations? Explain why you think this occurred.

   After several more generations, the ratio of white to brown bunnies changes. Before the introduction of the wolf, there are considerably more white bunnies than brown bunnies. After the introduction, the number of brown bunnies increases and the number of white bunnies decreases. This occurs due to the fact that the brown bunnies are camouflaged next to the similarly colored ground. The white bunnies are more easily seen by the wolves and thus are targeted first.

RESEARCH QUESTIONS

Answers may vary depending on the data that the students collect. For example, for Question 1 the students should include all of the following criteria:

1. *Question*: A population of short-toothed and long-toothed bunnies is living in the Arctic. Due to harsh conditions food becomes limited. What happens to the population sizes of both phenotypes over the next 10 generations?
2. *Hypothesis*: The long-toothed mutation is more advantageous than the short-toothed phenotype, causing bunnies with long teeth to out-compete the short-toothed bunnies.

ANSWER KEY

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PART II: COTTONTAILS (CONTINUED)

3. *Methodology*:
   a. I started the simulation and then pressed pause. I set up the simulation by choosing a "friend," the Arctic environment, and the long-toothed mutation.
   b. I pressed play and let the simulation run until the total number of bunnies equaled 100 or more and then paused the simulation. At this point, I recorded the total number of bunnies from each of the two phenotypes (long teeth and short teeth).
   c. I introduced a food shortage by selecting "Food" from the Selection Factor options. I then pressed play. At this point, some of the bunnies died from starvation.
   d. When the remaining bunnies reproduced, making another generation, I pressed pause and recorded the numbers of bunnies from the two phenotypes. I continued this process for eight more generations.
4. *Results*: See Table A and Figure A.
5. *Conclusion*: As seen in Figure A, the population started out predominantly having short teeth. However, starting with the third generation after the food shortage was introduced the individuals with the long-toothed mutation began to outnumber the ones with short teeth. The short-toothed individuals began to die out while the bunnies with long teeth began to thrive. This effect was due to their ability to acquire food better than the bunnies with short teeth. The long-toothed bunnies were able to get the proper nutrients they needed while the short-toothed bunnies were not, causing the steady decline in numbers.

CHALLENGE

When you figure out this challenge, describe the limiting factors and mutations involved in creating this situation, and then explain why the simulation keeps going indefinitely.

If you choose "long teeth" as the mutation (leaving it dominant) and create a food shortage, then the simulation will continue on forever. This is due to a certain amount of food that can "sustain" a certain number of individuals in the population. The long teeth allow those bunnies with the mutation to acquire the food more easily, allowing them to survive. This creates a situation where a "carrying capacity" is reached and can be measured using the simulation.

Table A. Population Growth of Two Bunny Phenotypes in Response to Food Shortage

Generation	Short Teeth	Long Teeth
1	117	50
2	55	42
3	42	47
4	12	67
5	8	105
6	16	130
7	5	135
8	10	165
9	2	160
10	2	170

ANSWER KEY

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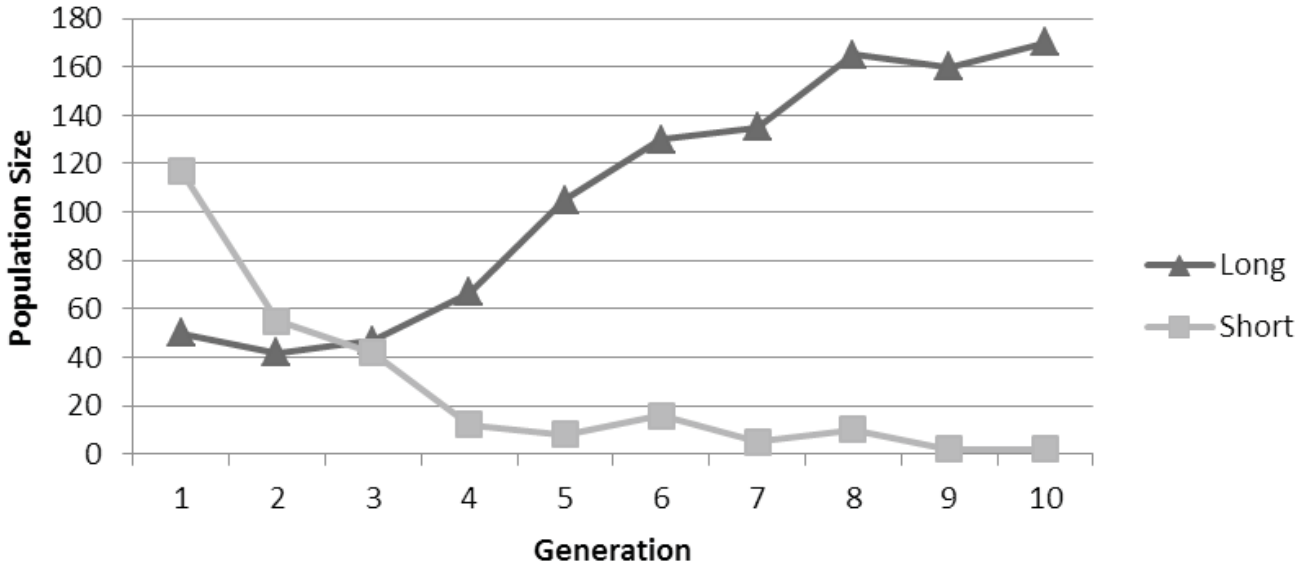

Figure A. Population growth of two bunny phenotypes in response to food shortage

ANSWER KEY

DATA AND OBSERVATIONS

Table 1. Light and Dark Quackers per Generation

Generation	Light Quackers	Dark Quackers
1	3	7
2	2	8
3	3	7
4	0	10
5	1	9

ANALYSIS

Table 2. Light and Dark Quackers per Generation, Class Averages

Generation	Light Quackers	Dark Quackers
1	4.3	5.7
2	3	7
3	2.3	7.7
4	1.6	8.4
5	1.4	8.6

GRAPH

See Figure B.

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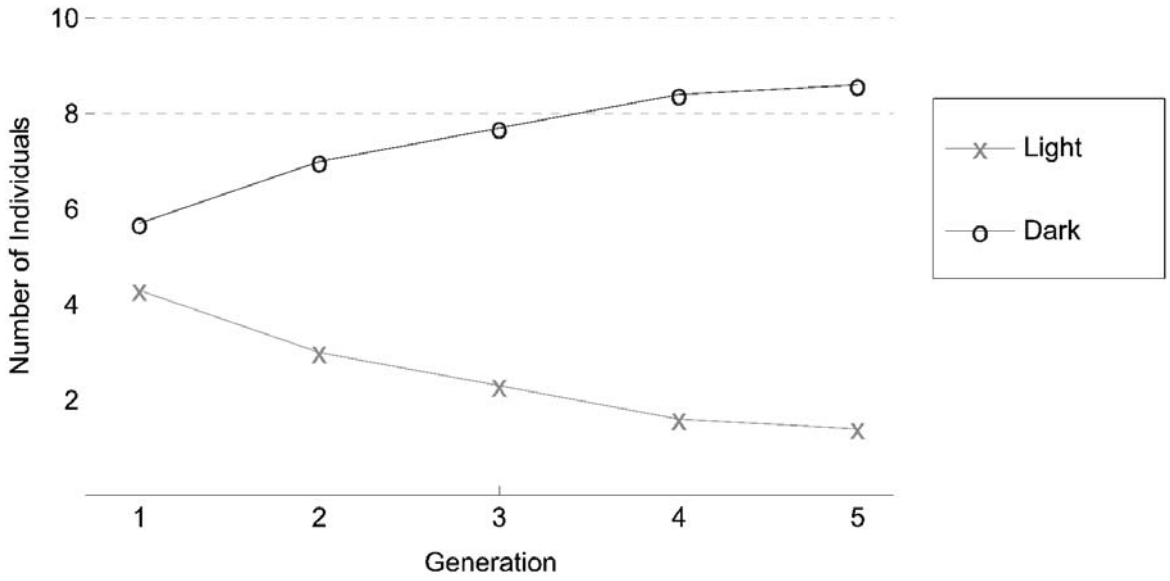

Figure B. Light and dark quackers per generation

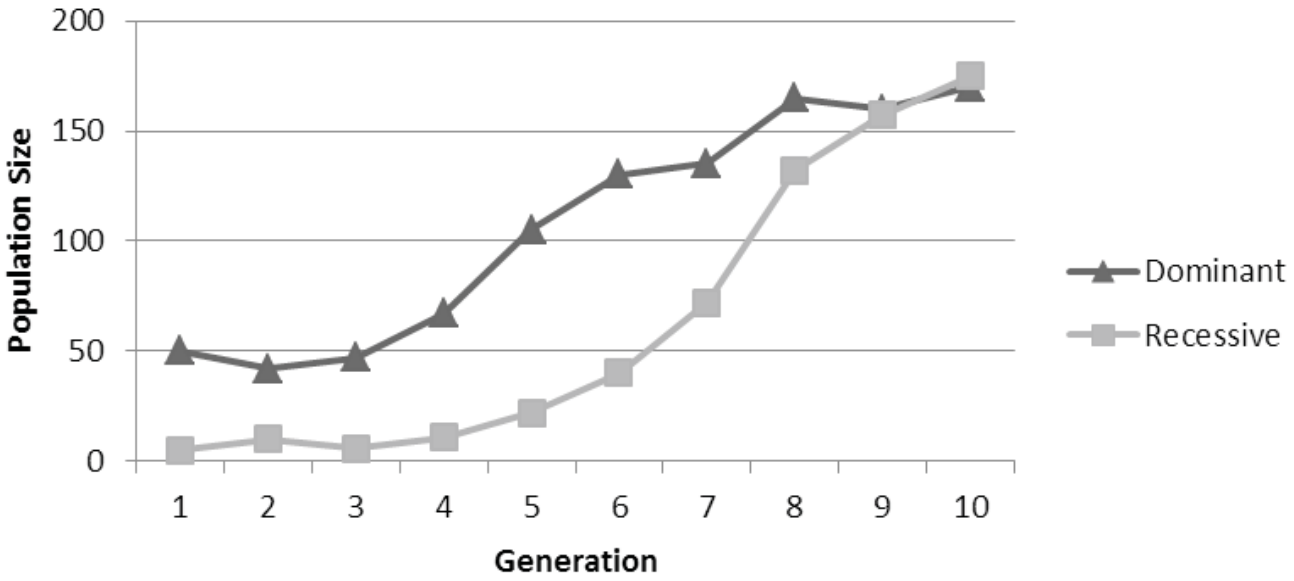

Figure C. Population growth differences between the long-toothed mutation being dominant or recessive

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CONCLUSION QUESTIONS

1. Write a statement describing how the number of light and dark quackers changed over the period of five generations.

   The number of light quackers decreases whereas the number of dark quackers increases from Generation 1 to Generation 5.

2. What do you predict would happen to the number of light quackers if you continued predation for a total of ten generations? Explain your prediction.

   The number of light quackers would continue to decline.

   The light quackers are being preyed upon in greater numbers, which reduces their presence in the gene pool. With fewer light quackers mating and producing light offspring, the light quaker numbers will decline.

3. Which type of quacker would Darwin consider "most fit" in this predation situation, the light quacker or the dark quacker? Why?

   The dark quackers would be considered most fit because they have survived predation and will live to be the parents of the next generation.

4. What adaptation do the dark quackers possess that allows them to survive? Explain why it is incorrect to say that an organism "adapts to its environment."

   The adaptation for dark-colored feathers allows them to survive.

5. Predict how the relative frequency of feather color would change if the predators began to prefer the dark quackers. Explain why these changes would occur.

   A single organism cannot willingly become adapted to their environment. The organism either possesses the favorable adaptation and survives or does not possess it and dies.

6. Using data collected during your "bunny" experiments, explain how variation in a population can increase the survivability of a population.

   Variation within a population increases the biodiversity of the population. Biodiversity ensures that when a new selection factor (introduction of a predator) or an environmental change occurs, there are members of a population that are able to survive.

7. Describe two other mutations that might affect the bunny populations and how they might affect allele frequencies over time.

   A rabbit's long ears allow it to radiate heat, allowing it to self-regulate heat in a hot environment. They also allow them to hear better, allowing the rabbit to hear predators. If a bunny was born with short ears it would be at a disadvantage, causing it and others like it to possibly die off.

   A rabbit typically has long, powerful legs that allow it to run quickly and avoid predators. Rabbits born with short legs would be at a disadvantage, and would run the risk of dying off as well.

8. Using your data from Part II, predict what changes would be seen if the long-toothed allele was recessive instead of dominant. Draw a graph to represent your prediction.

   Whether or not the "long-toothed" mutation is dominant or recessive, it is more advantageous than the short-toothed phenotype during food shortage. However, the population will increase faster if the allele is dominant than if it was recessive (Figure C).

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Quackers and Cottontails

Investigating Natural Selection

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MATERIALS

plate, paper

bag with white and yellow Cheez-It®

computer with online access

In 1778 the First Fleet, a group of English citizens, arrived to establish a new settlement in Australia. They brought with them a number of rabbits, which were to be bred for food. In 1859 Thomas Austin, missing the rabbit hunting he was accustomed to in England, had 24 European rabbits shipped to him so that he could establish a rabbit population in Australia that could be used for hunting.

Shortly after this, many farmers began releasing their rabbits as well. Australia has very mild winters, which allowed the rabbit population to breed continuously throughout the year. Extensive farming by the new settlers provided abundant low-lying vegetation for the increasing rabbit population to feed. By 1886, their exploding population had spread throughout Victoria and New South Wales. It is thought that even though over two million rabbits were shot every year, there was not a noticeable difference in the size of the rabbit population.

The rabbits had become a pest species in their new habitat. They caused a drastic increase in the loss of native plant species due to their voracious eating. Many tree species were depleted due to the rabbits "ring-barking" them, which is the act of removing a ring of bark (including all of the phloem that carries the sugars needed for energy) around the tree. The loss of vegetation caused a consequential increase in erosion, which in turn wreaked havoc on many aquatic ecosystems.

The government finally had to resort to dealing with the rising population by promoting increased hunting and trapping, destroying the rabbits' warrens (the series of interconnected tunnels that the rabbits inhabited), and by using viruses (*Myxoma* virus) that decreased the population by one sixth of its size. However, genetic resistance (through natural selection) allowed the numbers to rise three-fold by the early 1990s.

The government tried to use another virus (calicivirus), which causes rabbit hemorrhagic disease (RHD). This virus itself grew out of the government's control and started infecting many pets around the country. Australia still struggles with rabbits as a pest species today.

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PURPOSE

In this activity, you will simulate the events of natural selection. In the first part of this lesson, the population experiencing natural selection is a flock of ducks with light feathers and dark feathers. The predator more easily spots the light-feathered ducks than the dark-feathered ducks. Light- and dark-colored crackers represent the duck, or "quacker," population.

In the second part, you will ask your own questions regarding a "bunny" population, and use a computer simulation to experimentally test your hypotheses.

PROCEDURE

PART I: QUACKERS

In this activity, you will begin with a population that has equal numbers of light and dark "organisms" that will be fed on by you, the predator. As the predator, you prefer to eat the light organisms rather than the dark ones.

1. Formulate a hypothesis regarding what will happen to the ratio of light-colored to dark-colored organisms if the predator more easily preys upon the light-colored organisms. Record your hypothesis in the space provided on your student answer page.
2. Light-colored and dark-colored snack crackers represent the duck, or "quacker," organisms in this activity. Obtain a pond (or bag) of quackers from your teacher. This bag contains equal numbers of light and dark snack crackers.
3. Establish your Generation 1 flock of quackers by having one partner reach into the bag, without looking, and randomly select 10 quackers (crackers).

   Place the 10 quackers on a clean paper plate or napkin. Count how many light and how many dark quackers are present. Record your numbers for Generation 1 in Table 1 on your student answer page.

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PROCEDURE (CONTINUED)

4. Simulate predation by choosing three light-colored quackers from the flock of 10 and eliminate them. If you only have one or two light quackers, eat them first and then consume enough dark quackers to meet your quota of three.

   For example, if you have only one light quacker, eat it and two dark ones. If you have two light quackers, eat both of them and one dark one. Remember that as the predator, you prefer the light quackers.

5. To simulate reproduction in the population, close your eyes, reach into the bag, and choose three quackers to add to your plate. This should bring the total number of quackers back to 10.

   Record the number of light and dark quackers in this Generation 2 flock in Table 1.

6. Your partner should now take a turn at being the predator. The predator should eat three light quackers from the flock. If there are not three light quackers in the flock, follow the procedure described in Step 4.

7. Simulate reproduction in the population by repeating Step 5. Count the numbers of each type of quacker in the replenished flock and record the data in the Generation 3 space in Table 1.

8. Repeat Step 6 and Step 7 two more times for a total of five generations of data.

9. As instructed by your teacher, combine your individual data with the class data for each of the five generations. Calculate the class average for each color of quacker for each generation and record these values in Table 2.

10. In the space provided on your student answer page, graph the class averages of light and dark quackers for each generation. Be sure to include axes labels, units, and a title on your graph.

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PROCEDURE (CONTINUED)

PART II: COTTONTAILS

For this activity, you will be using a computer simulation as a tool to perform evolution experiments on a population of bunnies.

LAUNCHING THE SIMULATION

1. Navigate to http://phet.colorado.edu/en/simulation/natural-selection.
2. Click on the "RUN NOW" button to start the Natural Selection PhET simulation.
3. Once you have the simulation window active, click the "PAUSE" button at the bottom to stop the simulation.
4. Remember that you can always start over by pressing the "RESET ALL" button.

Download Java™ if prompted.

MANIPULATING THE SIMULATION

1. What variables are you able to manipulate in this simulation?
2. Start the simulation by clicking the "PLAY" button. What happens if you never "add a friend"? Explain.
3. Add a friend. Let the simulation continue to run until it stops, and then discuss what happens. Explain what "selection" factors were lacking for this to occur.
4. Reset the simulation. Now add a friend and introduce the "brown fur" mutation, and set the brown mutation as recessive. After the total number of brown and white bunnies is over 100, introduce a predator (wolves) to the bunny population.

   What happens to the population sizes of the two phenotypes after several more generations? Explain why you think this occurred.

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PROCEDURE (CONTINUED)

RESEARCH QUESTIONS

Following the steps of the scientific method, use the Natural Selection simulation to perform the following investigations to answer the questions or problems. After you have completed each investigation and have gathered the data, communicate your results in a brief paragraph using the following format:

1. State the problem or question.
2. State your hypothesis.
3. Briefly describe how you manipulated the simulation to run your investigation. Include in your description the following factors: mutations, limiting factors, control groups, experimental groups, independent variables, dependent variables, and environments involved.

   Make sure that you write sufficiently precise descriptions of your methodology so that other students could follow your same procedure and get the same results.
4. Construct a data table of your results. Using graph paper or computer graphing software, graph the data in the table. Label your axes and give your graph a proper title.
5. Using data from the graph, describe what changes occurred to the bunny population in the simulation. Explain why this change occurred.

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PROCEDURE (CONTINUED)

Question #1

Assume that the long-toothed mutation is dominant.

A population of short-toothed and long-toothed bunnies lives in the Arctic. Due to harsh conditions, food becomes limited. What happens to the population sizes of both phenotypes over the next 10 generations?

Create your own questions and then use the simulation to investigate each one. Write your questions in the space provided and then write your conclusion paragraphs as outlined in the previous steps on your own paper.

Question #2

Question #3

CHALLENGE

This could be a competition between individuals or teams.

Manipulate the simulation so that it never stops, that is, the bunnies do not "take over the world" and the population never dies out.

When you figure out this challenge, describe the limiting factors and mutations involved in creating this situation, and then explain why the simulation keeps going indefinitely.

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HYPOTHESIS

DATA AND OBSERVATIONS

Table 1. Light and Dark Quackers per Generation		
Generation	**Light Quackers**	**Dark Quackers**
1		
2		
3		
4		
5		

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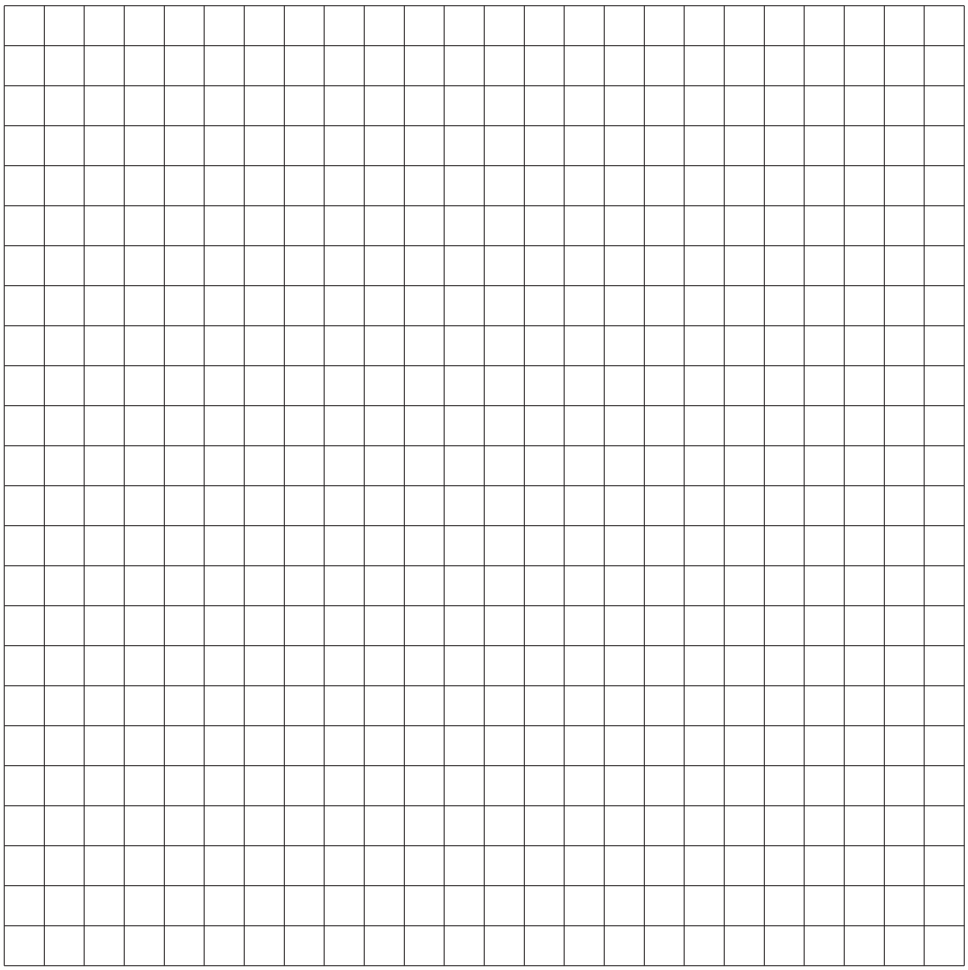
ANALYSIS

PART I: QUACKERS

Table 2. Light and Dark Quackers per Generation, Class Averages		
Generation	**Light Quackers**	**Dark Quackers**
1		
2		
3		
4		
5		

GRAPH



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CONCLUSION QUESTIONS

1. Write a statement describing how the number of light and dark quackers changed over the period of five generations.

2. What do you predict would happen to the number of light quackers if you continued predation for a total of ten generations? Explain your prediction.

3. Which type of quacker would Darwin consider "most fit" in this predation situation, the light quacker or the dark quacker? Why?

4. What adaptation do the dark quackers possess that allows them to survive? Explain why it is incorrect to say that an organism "adapts to its environment."

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CONCLUSION QUESTIONS (CONTINUED)

5. Predict how the relative frequency of feather color would change if the predators began to prefer the dark quackers. Explain why these changes would occur.

6. Using data collected during your "bunny" experiments, explain how variation in a population can increase the survivability of a population.

7. Describe two other mutations that might affect the bunny populations and how they might affect allele frequencies over time.

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CONCLUSION QUESTIONS (CONTINUED)

8. Using your data from Part II, predict what changes would be seen if the long-toothed allele was recessive instead of dominant. Draw a graph to represent your prediction.

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