Name: _____ Date: _____

Student Exploration: Natural Selection

https://www.explorelearning.com/

Vocabulary: biological evolution, camouflage, Industrial Revolution, lichen, morph, natural selection, peppered moth

Prior Knowledge Questions (Do these BEFORE using the Gizmo.)

The **peppered moth** (*Biston betularia*) is a common moth found in Europe, Asia, and North America. It is commonly found in two forms, or **morphs**: a dark morph and a light, speckled morph. Birds are a frequent predator of the peppered moth.

1. Which morph do you think would be easier to see on a dark tree trunk? _____
2. Which morph do you think would be easier to see on a light tree trunk? _____

Gizmo Warm-up

The *Natural Selection* Gizmo allows you to play the role of a bird feeding on peppered moths. The initial population of 40 moths is scattered over 20 tree trunks. Click on moths to capture them. Click the **Next tree** button (or the **spacebar** on your keyboard) to advance to the next tree.

How many moths can you find?

1. Check that LIGHT TREES is selected. Click **Play** ( ), and hunt moths for one year.
   A. How many dark moths did you capture? _____
   B. How many light moths did you capture? _____
   C. **Camouflage** is coloring or patterns that help an organism to blend in with the background. Which type of moth is better camouflaged on light bark? _____

2. If a forest contained mostly light-colored trees, which type of moth would you expect to be most common? _____

Activity A: **Light trees**	Get the Gizmo ready: • Click **Reset** ( ). • Check that the LIGHT TREES tab is selected.	

Introduction: Before the 19th century in England, the air was very clean. The bark on trees was usually light in color. Abundant **lichens** growing on tree trunks also lightened their appearance.

Question: How does the color of a peppered moth affect survival?

1. Predict: Over time, what will to happen to the populations of light and dark moths on light trees?

   _____

2. Experiment: Click **Play** and hunt peppered moths on light tree trunks for five years. In each year, try to capture as many moths as you can. Note: You can use the **spacebar** on your keyboard to quickly advance to the next tree.

   After 5 years, select the TABLE tab and record the percentages of each moth type. (Note: The table shows current populations of each moth, not the number of captured moths.)

Year	Dark moths	Light moths
0		
1		
2		
3		
4		
5		

3. Analyze: What do your results show? _____

   _____

4. Apply: Which type of moth do you think was more common before the 19th century, when most trees were light in color? _____

5. Extend your thinking: What strategies did you use to hunt for moths? _____

   _____

   _____

Activity B: **Dark trees**	Get the Gizmo ready: • Click **Reset**. • Select the DARK TREES tab.	

Introduction: The 19th century was the time of the **Industrial Revolution** in England. Most of the new industries used coal for energy, and the air was polluted with black soot. In forests near factories, the soot coated trees and killed lichens. As a result, tree trunks became darker.

Question: How did air pollution affect moth populations?

1. Predict: Over time, what will to happen to the populations of light and dark moths on dark trees?

   _____

2. Experiment: Click **Play** and hunt peppered moths on dark tree trunks for five years. In each year, try to capture as many moths as you can.

   When you are done, select the TABLE tab and record the percentages of each moth type.

Year	Dark moths	Light moths
0		
1		
2		
3		
4		
5		

3. Analyze: What do your results show? _____

   _____

4. Apply: Which type of moth do you think was more common during the 19th century? Why?

   _____

   _____

5. Draw conclusions: **Natural selection** is the process by which favorable traits tend to increase in frequency over time. How does this experiment illustrate natural selection?

   _____

   _____

_____

6. Think and discuss: Did the changes you observed in the moth populations result from individual moths changing colors? Or did they occur because the best-hidden moths survived and reproduced, passing on their colors to their offspring? Explain your answer.

_____

_____

_____

_____

_____

7. Extend your thinking: **Biological evolution** is the process by which populations of organisms change over time. How could natural selection lead to evolution? If possible, discuss your answer with your classmates and teacher.

_____

_____

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Student Exploration: Evolution: Mutation and Selection

https://www.explorelearning.com/

Vocabulary: adaptation, allele, allele sequence, chromosome, evolution, fitness, gene, genotype, mutation, natural selection, phenotype, trait

Prior Knowledge Questions (Do these BEFORE using the Gizmo.)

1. Imagine a white lizard and a brown lizard sitting on a brown rock. A hawk is circling overhead hunting for its next meal. Which lizard do you think the hawk would most likely try to catch? Explain your choice.

   _____

   _____

2. Now imagine that the same two lizards were sitting on a dune of white sand. Which lizard do you think the hawk would then most likely try to catch? Why?

   _____

   _____

Gizmo Warm-up

How long could a parrot survive in Antarctica? It would probably not survive long. Parrots do not have **adaptations**—or helpful characteristics—to survive icy cold weather. Because of this, a parrot is not fit for Antarctica. **Fitness** describes how well an organism can survive and reproduce in an environment.

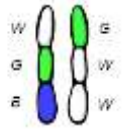
In the *Evolution: Mutation and Selection* Gizmo, you will see how a species' fitness can change over time as it becomes better adapted to its environment.

3. On the SIMULATION pane, what is the **Average fitness** of the population? _____

4. On the CONTROLS pane, experiment with the **Background color** sliders.

   A. Which background color results in the highest fitness? _____

   B. Which background color results in the lowest fitness? _____

Activity A: **Inherited variation**	Get the Gizmo ready: • Set **Red** to 100, **Green** to 255, and **Blue** to 50.	

Introduction: An organism's **traits**, or characteristics, are controlled by **genes**. Genes are located on rod-like structures called **chromosomes**. Different versions of genes that code for the same trait are called **alleles**. In this Gizmo, there are 3 genes on each chromosome. For each gene there are eight possible alleles: *W* (white), *R* (red), *G* (green), *B* (blue), *C* (cyan), *M* (magenta), *Y* (yellow), and *K* (black).

Question: Where does variation in a population come from?

6. Observe: Hold your cursor over one of the insects. The two rod-like structures under **Genotype** on the right side of the Gizmo represent chromosomes. The three letters next to each chromosome represent alleles.

   Which alleles does the insect have? _____

   The alleles carried on an organism's chromosomes make up the organism's **genotype**.

7. Observe: An organism's alleles combine to produce a trait. The physical expression of that trait is a **phenotype**. In the Gizmo, phenotype is expressed in red, green, and blue values.

   A. What is the phenotype of the insect? Red: _____ Green: _____ Blue: _____

   B. What color is the insect? _____

8. Run Gizmo: Move the **Sim. speed** slider all the way to the left. Click **Play** ( ). You will see the insects move to the left in pairs. The pairs mate and produce a set of four offspring. As soon as you see at least one offspring with an oval around it, click **Pause** ( ). Move your cursor over the circled offspring.

   A. What is its genotype and phenotype? _____

   B. How does its genotype and phenotype differ from the non-circled offspring?

      _____

9. Explain: The change in the circled offspring's genotype was caused by a **mutation**. A mutation is a change in a gene. Mutations happen when a mistake is made when a cell's chromosomes are copied. How might mutations introduce variation into a population?

   _____

   _____

(Activity A continued on next page)

Activity A (continued from previous page)

10. Collect data: Move the **Mutation rate** slider to 3.0, and click **Play**. Allow the Gizmo to run for another 10–15 generations. (You can see the generation number below the insects.)

    Click **Pause** when the parents are ready to have offspring. Find a set of two parents that has four *different* chromosomes. (If you can't find any, allow the Gizmo to run a few more generations and try again.) Write the allele sequences for these parents in the table below. Note the labels for each of these chromosomes: A1, A2, B1, and B2.

Organism:	**Parent A**	**Parent B**
Allele sequence of chromosome 1:	(A1)	(B1)
Allele sequence of chromosome 2:	(A2)	(B2)

    Click **Play**, and then click **Pause** immediately after the offspring are produced. Write the allele sequences of chromosomes 1 and 2 for each of the offspring of your selected parents.

Offspring	**Allele sequence of chromosome 1**	**Allele sequence of chromosome 2**
Offspring 1	( )	( )
Offspring 2	( )	( )
Offspring 3	( )	( )
Offspring 4	( )	( )

    Label the offspring chromosomes A1, A2, B1, or B2. Circle any mutated chromosomes.

11. Analyze: Study the completed table.

    A. Look at the inheritance patterns. What do you notice? _____

    _____

    B. Can a single offspring inherit both chromosomes from one parent? _____

    Explain: _____

    C. Did any mutations occur in this set of offspring? _____

    If so, which chromosome mutated? _____

12. Challenge yourself: You have already learned that mutation is one source of variation in a population. Based on what you have just seen, what is a second source of variation?

    _____

Activity B: **Survival of the fittest**	Get the Gizmo ready: • Click **Reset** ( ). • Set **Red** to 255, **Green** to 0, and **Blue** to 130. • Set the **Mutation rate** to 1.0.	

Question: Are some organisms more likely to survive and reproduce than others?

1. Count: Move the **Sim. speed** slider all the way to the left. Click **Play**.

   A. After the parents mate, click **Pause**. How many offspring are there? _____

   B. Click **Play**. After the birds eat, click **Pause**. How many offspring are left? _____

   In nature, as in the Gizmo, more offspring are born than can survive long enough to reproduce. Because of this, the offspring must compete with one another for survival. In this Gizmo, the insect offspring compete to avoid being eaten by birds.

2. Observe: Move the **Sim. speed** slider one notch to the right. Click **Play**, and wait for about 20 generations to pass. You should see a variety of insect phenotypes. (If not, click **Play** and wait until you do.)

   A. What different colors of insects do you see? _____

   _____

   B. How do you think this variation might affect the competition between the offspring?

   _____

   _____

3. Analyze: Scroll over the insects and note their fitness (shown under the **Phenotype**). The fitness of an organism reflects how likely it is to survive and produce offspring. Each insect is given a percentage that reflects its chances of surviving to reproduce.

   Compare the fitness percentages to the insect colors. How does fitness relate to the color of the

   insects? _____

   _____

4. Predict: How do you think an insect's fitness will affect is chances of being eaten by birds?

   _____

   _____

5. Collect data: In nature, chance alone can affect whether an individual survives. However, general trends in survival rates can be seen by studying a larger group of individuals.
   Move the **Sim. speed** slider all the way to the left. Click **Play**, and then click **Pause** when all the offspring are visible. Write the generation number and the average fitness of all the offspring in the first two spaces of the table below.
   Next, click **Play**, and then click **Pause** immediately after the birds have fed and the 10 survivors are visible. Mouse over each survivor and record its fitness. Find the average fitness of the survivors by adding these values and dividing by 10.

   Repeat this experiment two more times, recording your results in the table.

Generation	Ave. fitness	Survivor fitness values	Ave. survivor fitness

6. Recognize trends: Study the table above. What trends do you see? _____

   _____

   _____

7. Analyze: In most situations, were the fittest insects or the least fit insects most likely to survive? Explain how the data from your experiment supports your answer.

   _____

   _____

8. Think and discuss: The principle of **natural selection** states that the best adapted organisms are most likely to survive and reproduce. Was this demonstrated in your experiment? Explain.

   _____

   _____

   _____

Activity C: **Evolution**	Get the Gizmo ready: • Click **Reset**. Set **Red** to 100, **Green** to 255, and **Blue** to 50.	

Introduction: You learned in activity B that fit individuals have a better chance of surviving and reproducing than individuals that are less fit. In this activity, you will observe how natural selection affects a population over time.
Question: How does a population change over time?

1. Experiment: Set the **Background color** to the values shown in the last column of the table below. Record the **Average fitness** of generation 1 in the second column of the table. Move your cursor over the insects and find the individual with the greatest fitness. (In the first generation, all the insects will have the same fitness). Record that individual's phenotype in the table's third column.

   Move the **Sim. speed** slider a quarter of the way to the right. Run the Gizmo, and complete the table for each listed generation. (The generation number does not have to be exact.)

Generation number	Average Fitness	Fitness of Fittest Individual	Phenotype of Fittest Individual (R, G, B)	Background color
1				red = 100 green = 255 blue = 50
25				
50				
75				
100				
150				
200				
300				

2. Describe: Examine the data collected for trends.

   A. How did the phenotype of the fittest individual change over time? _____

   _____

   B. How did the population's fitness change over time? _____

   _____

   The process by which populations change over time is known as **evolution**. This Gizmo only demonstrates how one trait—body color—can evolve.

3. Predict: Based on what you have just seen, how do you think the population will evolve if you made the **Background color** purple?

   _____

4. Test: Set **Red** to 120, **Green** to 0, and **Blue** to 160 to make a purple background. Click **Play**. After 300 more generations have passed, click **Pause**.

   Was your prediction correct? Explain. _____

   _____

5. Make connections: Why do you think it is necessary for there to be variation in a population in order for evolution by natural selection to occur?

   _____

   _____

6. Make connections: Why is it necessary for traits to be inherited for evolution to take place?

   _____

   _____

   _____

7. Apply: Look carefully at the picture below and you will see an insect called a katydid. Katydids evolved from grasshoppers through natural selection. Use what you have learned to explain how this could have happened.

   _____

   _____

   _____

   _____

   _____

   _____

Name: _____ Date: _____

Student Exploration: Rainfall and Bird Beaks

https://www.explorelearning.com/

Vocabulary: adaptation, beak depth, directional selection, drought, evolution, natural selection, range, stabilizing selection

Prior Knowledge Questions (Do these BEFORE using the Gizmo.)
During the voyage of the HMS *Beagle* (1831–1836), the young Charles Darwin collected several species of finches from the Galápagos Islands. Two of Darwin's finches are shown below.

Geospiza magnirostris

3. Which species do you think is best adapted to a diet of small, delicate seeds? Explain why you think so.

   _____

   _____

Geospiza fortis

4. Which species do you think is best adapted to a diet of large, tough-to-crack seeds? Explain.

   _____

   _____

Gizmo Warm-up
Darwin's finches are one of many types of animals on the Galápagos Islands that have unique **adaptations**, or traits that help an organism survive in its environment. The *Rainfall and Bird Beaks* Gizmo™ allows you to explore how rainfall influences the range of beak shapes found in a single finch species.

1. The **beak depth** of a finch is the distance from the top of the beak to the bottom, as shown.

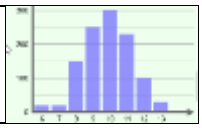
   A. What is the current average beak depth in the Gizmo? _____

   B. Select the HISTOGRAM tab. Do all the finches have the same beak depth? _____

2. Click **Play** ( ) and let the simulation play for five years with average rainfall (10 inches/yr). Select the GRAPH tab and view the **Finches vs time** and **Beak depth vs time** graphs.

   A. How does the finch population change? _____

   B. Does the beak depth change significantly? _____

Activity A: **Normal years**	Get the Gizmo ready: • Click **Reset** ( ).	

Introduction: The Galápagos Islands are very dry, with an average rainfall on some islands of only five inches per year. The amount of rainfall has a large impact on the abundance and types of seeds that are available to be eaten by finches. In the process of **natural selection**, only the finches that are best adapted to the available seed types survive and have offspring.

Question: How is the finch population affected by a period of average rainfall?

1. Observe: With the **Rain** sliders set to 10 inches, click **Play**, and then **Pause** ( ) after one year has passed. Select the TABLE tab and look at the **Month** and **Finches** columns.

    A. How did the finch population change over the course of one year? _____

    _____

    B. The finches have their young during the rainy season. Based on the table, which part of the year do you think is the rainy season? _____

2. Analyze: Click **Reset**, and choose the HISTOGRAM tab. The bars represent the numbers of finches that have different beak depths. The **range** of beak depths is equal to the difference between the largest and smallest beaks.

    A. What is the average beak depth of the current finch population? _____

    B. What is the range in beak depths in the population? _____

    C. Do most of the finches have beak depths near the lower extreme, the middle, or the higher extreme of the range? _____

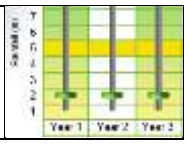
3. Experiment: Click **Play**, and observe the histogram as the simulation plays for five years.

    A. What is the average beak depth now? _____

    B. What is the current range of beak depths? _____

    C. Based on what you have seen, are finches with very small, medium, or very large beaks most likely to survive in times of normal rainfall? Justify your answer.

    _____

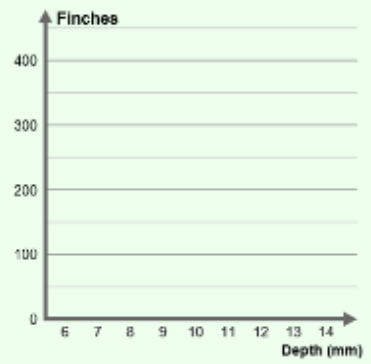
Activity B: **Drought**	Get the Gizmo ready: • Click **Reset**.	

Introduction: In years of extreme **drought**, Galápagos plants don't produce new seeds. The small, delicate seeds get eaten up quickly, leaving behind only the largest, toughest seeds.
Question: How does drought affect the finch population and average beak depth?

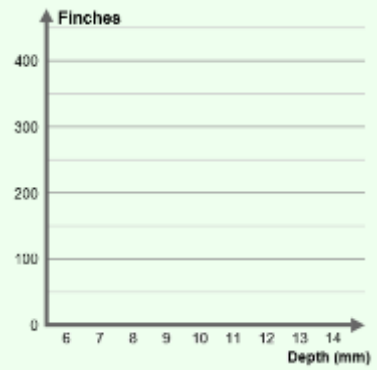
13. Form hypothesis: What type of beak do you think will be best for finding food in a drought?

_____

14. Predict: Select the HISTOGRAM tab. On the left side below, sketch the current histogram and list the average beak depth and range of beak depths. On the right side, sketch what you think the histogram will look like after five years of drought. Explain your prediction.



Initial beak depths



Beak depths after 5 years (predicted)

Initial number of finches: _____

Initial average depth: _____

Initial range of beak depths: _____

Explanation: _____

_____

_____

15. Experiment: Use the sliders to set the **Rain** to 2 inches for each of the five years in the simulation. Click **Play**, and wait for five years. Observe the beak of the finch.
    A. How does the beak depth change over time? _____
    B. What is the final average beak depth? _____
    C. What is the final range of beak depths? _____

16. Describe: Compare the final histogram to the initial histogram. How have the finches been affected by drought? Describe at least two changes that you notice.

_____

_____

17. Analyze: Was the increase in the average beak depth caused by an increase in large-beaked finches or a decline in small-beaked finches? Explain your answer.

_____

_____

_____

18. Draw conclusions: What do you think caused the changes in the finch population and average beak size during the drought?

    _____

    _____

    _____

19. Interpret: **Directional selection** occurs when individuals at one end of a range are more likely to survive than intermediate individuals or individuals at the opposite end of the range. **Stabilizing selection** occurs when intermediate individuals are the most likely to survive.

    Is directional selection, stabilizing selection, or both operating in this example? Explain.

    _____

    _____

    _____

20. Think and discuss: **Evolution** is the process by which populations of organisms can change over time. How is directional selection related to evolution?

    _____

    _____

    _____

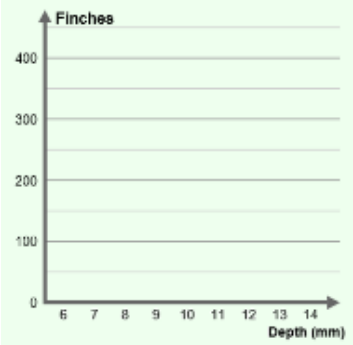
Activity C: **Rainy days**	Get the Gizmo ready: • Click **Reset**.	

Introduction: In years of abundant rainfall, there can be 20 inches or more of rain. In these years, plants produce an enormous number and variety of seeds.

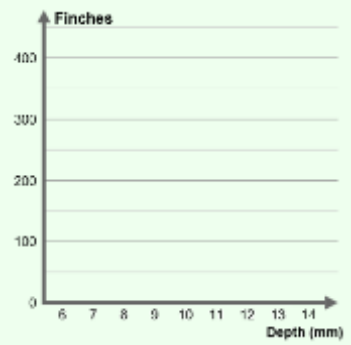
Question: How does plentiful rainfall affect the finch population and average beak depth?

1. Form hypothesis: What beak shape do you think will be best for finding food in a period of abundant rainfall? _____

2. Predict: Select the HISTOGRAM tab. On the left side, sketch the current histogram and list the average beak depth and range of beak depths. On the right side, sketch what you think the histogram will look like after five years of abundant rain. Explain your prediction.



Initial beak depths



Beak depths after 5 years (predicted)

Initial number of finches: _____

Initial average depth: _____

Initial range of beak depths: _____

Explanation: _____

_____

_____

3. Experiment: Click **Reset**. Use the sliders to set the **Rain** to 20 inches for each of the five years in the simulation. Click **Play**, and wait for five years. Observe the beak of the finch.

   A. How does the beak depth change over time? _____

   B. What is the final average beak depth? _____

   C. What is the final range of beak depths? _____

4. Describe: Compare the final histogram to the initial histogram. How have the finches been affected by abundant rain? Describe at least two changes that you notice.

_____

_____

5. Analyze: Was the decrease in the average beak depth caused by an increase in small-beaked finches or a decline in large-beaked finches? Explain your answer.

_____

_____

_____

6. Draw conclusions: What do you think caused the changes in finch population and average beak size during the period of abundant rain?

_____

_____

_____

7. Extend your thinking: Most scientists think that a small group of finches colonized the Galápagos Islands thousands of years ago. They would have been the only seed-eating birds on the islands. Suppose one island was very dry and another had plentiful rainfall.

    A. How would the finch populations on these islands change over time? _____

    _____

    _____

    _____

    B. What might happen to the finch populations after millions of years? _____

    _____

    _____

    _____