Student Exploration: Evolution: Natural and Artificial Selection

Vocabulary: artificial selection, breed, chromosome, evolution, fitness, genotype, mutation, natural selection, phenotype

Gizmo Warm-up
This illustration from an old textbook shows some of the over 150 different dog breeds that can be seen around the world today. Dog breeds and other varieties of domesticated animals were developed through artificial selection. Over many generations, breeders selected which animals to mate in order to select for desired traits. The Evolution: Natural and Artificial Selection Gizmo allows you to try your hand at breeding insects with a variety of colors. To begin, select the Artificial selection option.

1. Drag the 10 insects into the breeding alcoves on the left side of the Gizmo.
   How many breeding pairs are there? ____________________
   How many offspring are produced? ____________________

2. Circled insects have mutations, or changes to their DNA. How many of the offspring insects in this generation have mutations? _________________

Activity A:
Genotype and phenotype

Get the Gizmo ready:
- Select Natural selection.

Question: How are genes inherited and modified over many generations?

1. Observe: The fitness of an organism is a measure of how well produces offspring in its environment.
   A. What is the initial Average fitness of these insects? _________________________
   B. Click Play ( ), and observe the simulation for several generations. What occurs in each generation? _________________________________________________________________
      ___________________________________________________________________
      ___________________________________________________________________
C. Increase the Sim. speed by one level. Click Pause ( ) after 30 generations. What is the Average fitness now? 

2. Analyze: Set the Sim. speed to its slowest level. Click Play, and then Pause when the offspring appear. Choose a pair of parents in which both parents have a different color.

A. Move your cursor over and click on a parent insect. The genes that control color make up the insect’s genotype, while its actual color is its phenotype. Fill in the genotypes and phenotypes of each parent below.

<table>
<thead>
<tr>
<th>Parent 1 genotype</th>
<th>Parent 1 phenotype</th>
<th>Parent 2 genotype</th>
<th>Parent 2 phenotype</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Red = _______</td>
<td></td>
<td>Red = _______</td>
</tr>
<tr>
<td></td>
<td>Green = _______</td>
<td></td>
<td>Green = _______</td>
</tr>
<tr>
<td></td>
<td>Blue = _______</td>
<td></td>
<td>Blue = _______</td>
</tr>
</tbody>
</table>

Now list the genotypes of each of the four offspring below.

<table>
<thead>
<tr>
<th>Offspring 1</th>
<th>Offspring 2</th>
<th>Offspring 3</th>
<th>Offspring 4</th>
</tr>
</thead>
</table>

Explain: Each rod-shaped structure is a chromosome. Real chromosomes contain hundreds or even thousands of genes. The simplified chromosomes shown in this Gizmo only contain genes that determine the insects’ colors.

How are the chromosomes of the offspring related to the chromosomes of the parents?

_____________________________________________________________________________________
_____________________________________________________________________________________

3. Investigate: Any insect that has a mutation will be circled. Click on an insect with a mutation to examine its genotype. (If there are none in this generation, click Play and then Pause when a mutation appears.)

A. Examine the genotype of the mutated insect as well as the genotypes of its parents to determine what the mutation is. What new gene appeared? __________________

B. Do you think this mutation is helpful, harmful, or neutral for the insect? Explain. __________________

C. Click Play, and then click Pause after the birds have finished eating. Did the mutated insect survive? Why or why not? __________________
4. **Observe**: Increase the **Sim. speed** by two levels. Click **Play**, and wait for a while. What occurs as time goes by ____________________________________________________________

5. **Explain**: In wild populations, **evolution** is often caused by **natural selection**. Based on what you have observed, how does natural selection occur?

__________________________________________________________________

__________________________________________________________________

__________________________________________________________________

__________________________________________________________________

**Activity B: Artificial selection**

<table>
<thead>
<tr>
<th>Get the Gizmo ready:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Select <strong>Artificial selection</strong>.</td>
</tr>
<tr>
<td>Set the <strong>Mutation rate</strong> to 2.0.</td>
</tr>
</tbody>
</table>

**Question: How can a species be changed through artificial selection?**

1. **Set a goal**: In this activity, your goal is to develop insects that are any color you would like.
   
   What color do you want your insects to be? ____________________________________________

2. **Make a plan**: Follow the directions in the Gizmo to produce five generations of insects.
   
   A. How will mutations be useful in achieving your goal color? _________________________
      
      _____________________________________________________________________________
      
      _____________________________________________________________________________
   
   B. What strategy will you use to produce insects of your desired color? ______________
      
      _____________________________________________________________________________
      
      _____________________________________________________________________________

3. **Run Gizmo**: Use the Gizmo to produce insects that match your goal color. (This will take patience!)
   
   How many generations did it take for you to develop your insects? _________________

4. **Compare**: If possible, compare your insects to the insects developed by your classmates. What different colors of insects can be developed using artificial selection? ______________________________

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5. **Collect data**: Use the **Red**, **Green**, and **Blue** sliders to match the **Background color** as closely as possible to the phenotype of the insects. Select **Natural selection**.

Click **Play**, and then click **Pause** when the **Average fitness** first exceeds 90%. Record the number of generations in the table below, and then repeat for a total of five trials.

<table>
<thead>
<tr>
<th>Trial</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of generations to achieve 90% fitness</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

6. **Calculate**: Add up the number of generations and divide by five to find the mean number of generations required to reach at least 90% fitness. Fill in the last column of the table.

7. **Analyze**: Which process tends to occur more quickly, natural selection or artificial selection? Why do you think this is so?

____________________________________________________________________________________
____________________________________________________________________________________

8. **Summarize**: How are the processes of natural selection and artificial selection similar? How are they different?

____________________________________________________________________________________
____________________________________________________________________________________
____________________________________________________________________________________

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**Activity C**: **Mutation rates**

**Get the Gizmo ready**:
- Click **Reset** ( ). Be sure **Natural selection** is selected.
- Set **Red** to 100, **Green** to 255, and **Blue** to 50.

**Question**: How does the mutation rate affect a population’s ability to adapt to its environment?

1. **Gather data**: Change the **Mutation rate** to 0.1 and the **Sim. speed** slider to its lowest setting. Click **Play**, and then click **Pause** when the offspring appear. Record the number of mutations (circled offspring), and then repeat for two more trials. Do this for each mutation rate listed in the table, then calculate the mean number of mutations for each mutation rate.

<table>
<thead>
<tr>
<th>Mutation rate</th>
<th>Trial 1</th>
<th>Trial 2</th>
<th>Trial 3</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

How does the mutation rate relate to the number of mutations in each generation?

____________________________________________________________________________________

2. **Form hypothesis**: How do you expect the rate of mutations to affect the ability of the bug population to adapt to its environment?

____________________________________________________________________________________
3. **Gather data**: Click **Reset**. Set the **Mutation rate** to 0.1, and move the **Sim. speed** slider to a faster setting. Click **Play**, and then click **Pause** when the **Average fitness** is 90% or greater. Record the number of generations required to reach 90% fitness in the table below.

<table>
<thead>
<tr>
<th>Mutation rate</th>
<th>Number of generations to 90% average fitness</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Trial 1</td>
<td>Trial 2</td>
</tr>
<tr>
<td>0.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4. **Analyze**: How does the mutation rate affect the speed at which a population adapts to its environment?

_____________________________________________________________________________________
_____________________________________________________________________________________
_____________________________________________________________________________________

5. **Think and discuss**: You may have noticed that above a certain mutation rate the time required for a population to adapt to its background may increase. Why do you think this is so?

_____________________________________________________________________________________
_____________________________________________________________________________________
_____________________________________________________________________________________

6. **Apply**: Scientists doing artificial breeding experiments often use radiation or other methods to increase the mutation rate. Why is a high mutation rate useful?

_____________________________________________________________________________________
_____________________________________________________________________________________
_____________________________________________________________________________________

7. **Investigate**: Use the Gizmo to develop a population of insects that are well adapted to their environment. (**Average fitness** is above 90%). Change the **Mutation rate** to 0.1, and run the simulation. Then, observe the population with a **Mutation rate** of 10.0.

A. **What do you notice?**

Continued on next page...

B. **If a population is already well-adapted to its environment, will most mutations be helpful or harmful?**

Explain.__________________________________________________________

_______________________________________________________________________________
_______________________________________________________________________________
_______________________________________________________________________________