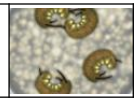
Name: _____ Date: _____

PART 1: Genetic Engineering

Some bacteria are able to produce a toxin that kills Lepidoptera sp. larvae.
Find out which gene is responsible for this toxin in the next step.

Activity A: **Caterpillar-resistant corn**	Get the Gizmo ready: • Click **Reset** ( ) and check that **Task 1** is selected in the dropdown menu.



Introduction: Lepidoptera sp. larvae (caterpillars) eat corn kernels, leaves, and stalks. In this activity, use genetic engineering techniques to create a corn plant that is resistant to caterpillars.

Question: How can we produce corn that is resistant to Lepidoptera sp. larvae?

1. Observe: Click **Play**. Select one of the strains of bacteria harmful to larvae (by clicking on the plate).

   Which strain did you select? _____

2. Investigate: Click **Continue**. The screen now shows the **genome**, or set of genes, of the selected bacteria. One of these genes produces the protein that kills the caterpillars. You will test each gene by adding it to the genome of a bacteria that does not kill caterpillars. This process is called **transformation**.

   Drag three genes into the Petri dishes at lower right. These genes are now inserted into the genomes of the sensitive bacteria in the plates. Press **Play**. If none of those genes help to kill the caterpillars, click **Reset** and try three other genes. When you find a gene that kills the caterpillars, click on the Petri dish to select the gene that confers resistance.

   Which gene did you select? _____

   In reality, finding a gene with a desired trait is much less common. Scientists search through many more bacterial strains and potential genes to find the traits they are looking for.

3. Observe: Click **Continue**. **Promoters** are regions of DNA that initiate the **transcription** of a gene. Some promoters only work in specific types of cells, such as leaf cells or root cells.

   To determine which cells of a corn plant a promoter works in, four promoters have been attached to the **Green Fluorescent Protein** (GFP) gene. Each promoter-GFP gene has been inserted into a corn plant. Select **Lights off** to see the parts of each plant glow green and fill in the table below.

Promoter	Glowing plant part(s)	Promoter	Glowing plant part(s)
1		3	
2		4	

   Which promoter is active in only the leaves? _____ In the whole plant? _____

   Select the promoter you would like to use by clicking on a plant, and then click **Continue**.

4. Choose: The resistance gene that was chosen in step 2 was attached to the promoter chosen in step 3, and the new DNA was inserted into five **calluses**. A callus is a group of cells that will incorporate the new gene into their genome and grow into a mature corn plant.

   In each genome, genes are shown as green bars. Each gene contains light green **exons**, or sections that code for proteins, and medium green **introns**, which do not code for proteins. The dark green bars represent promoters and the red bars represent gene termination sites.

   Use the left and right arrow buttons to observe where the new gene (blue bar) was inserted into each of the corn calluses genomes. Problems can occur if the new gene is inserted into the middle of an existing corn gene (green bar).

   In which calluses did the new gene insert inside an existing corn gene? _____

   Select one of the corn calluses that *do not* disrupt an existing corn gene and click **Continue**.

5. Experiment: On the left is a control plant that does not contain any new genes. On the right is the transformed plant you created. Click **Play**. When the plant has finished growing, click on each of the circles to observe the leaves, cobs, and roots of each plant.

   A. Did the transformed plant grow into a healthy mature plant? _____

      If not, you may have chosen a bad callus. (Click **Back** to try a different callus.)

   B. Click **Reset** and select **Add Lepidoptera sp. larvae** for each plant. Click **Play**. What do you observe? _____

   C. Compare the up-close views. How do the roots, leaves, and cobs compare? _____

      _____

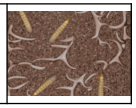
   D. Select **Show statistics**. How did the results for the transformed plant differ from the control plant?

      _____

   E. Click **Submit for review**. Was your plant resistant to Lepidoptera? _____

      If not, click **Back** or **Start again**. Be sure to choose genes that kill bacteria and a promoter that protects the corn cobs, leaves, and stalks.

Activity B: **Beetle grub-resistant corn**	Get the Gizmo ready: • Click **Start again** to reset the Gizmo. • Select **Task 2** in the dropdown menu.



Introduction: Coleoptera sp. larvae are immature beetles. They feed on corn plant roots. Your goal in this challenge is to create corn that is resistant to Coleoptera sp. larvae.

Question: How can we produce corn that is resistant to Coleoptera sp. larvae?

1. Investigate: Using the Gizmo, select a bacterial strain that kills Coleoptera and determine the gene that will be used to develop resistance in the corn. Which choices did you make?

   Bacterial strain: _____ Gene: _____

   Click **Continue** to move on to the "Choose promoter" step.

2. Hypothesize: Turn the room lights off. Beetle larvae attack the roots of corn plants. Based on this, which promoters do you think would be effective against beetles? _____
Explain your reasoning. _____

_____

3. Apply: Knowing that the new corn strain will be eaten by humans, which promoter might be safer to use, and why? _____

_____

Select this promoter and click **Continue**.

4. Observe: Select a corn callus that you think will work and click **Continue**. On the next screen, add Coleoptera sp. larvae to each plant and click **Play**.

   A. Describe the control plant and the transformed plant. _____

   _____

   B. Select **Show statistics** and **Submit for review**. Is the experimental plant resistant to Coleoptera sp. larvae? _____

5. Explore: Click **Back** and select a corn callus in which the new gene (blue bar) is inserted in the middle of an existing gene (green bar).

   A. Click **Continue**. Grow the experimental plant with and without larvae. What do you observe? _____

   _____

   B. Click **Back** and choose another callus in which an existing gene is disrupted. What do you observe?

   _____

   Note that these are dramatic examples of mutations. Complex organisms often have many genes that can perform similar functions, so disrupting one gene may not cause a noticeable change to the phenotype of the plant.

6. Explore: Click the **Back** button twice until the **Choose promoter** step is shown. Use the Gizmo to test the effectiveness of each promoter.

   Which promoters were effective in creating beetle-resistant corn, and why? _____

   _____

7. Explore: Click **Start again**. This time, choose a bacterial strain in step 1 that only kills some of the larvae. Grow the experimental plant in the presence and absence of larvae.

   How does this plant compare to the plant you created in part 4 of this activity? _____

   _____

8. Think and discuss: What are some of the possible benefits of creating insect-resistant corn, and what are some of the possible drawbacks? If possible, discuss your answer with your classmates and teacher.

   _____

   _____

Activity C: **Herbicide-resistant corn**	Get the Gizmo ready: • Click **Start again** to reset the Gizmo. • Select **Task 3** in the dropdown menu.	

Introduction: Weeds are wild plants that compete with crops for resources. Farmers kill weeds using herbicides, but corn plants may also be damaged by herbicides. Herbicides affect the roots, stalks, leaves, and cobs of corn plants.

Question: How can we produce a corn plant resistant to herbicide?

1. Observe: Bacterial colonies are being grown in Petri dishes. The white disks on each dish have been soaked in an herbicide.

   Click **Play**. Describe what happens to the bacteria in the Petri dishes. _____

   _____

   Which strains of bacteria are *not* affected by the herbicide? _____

2. Observe: Choose a bacterial strain that is resistant to herbicide, find the gene that is responsible for the resistance, choose a promoter, and transform a corn plant. Observe the control and experimental plants in the presence and absence of herbicide.

   When you have created an herbicide-resistant plant, fill in your choices below. (Note: you may need to try a few promoters before finding the correct one.)

   A. Which bacterial strain did you choose? _____
   Which gene did you choose? _____
   Which promoter did you choose? _____
   Which callus did you choose? _____
   B. Describe the control and experimental plants. _____

   _____

   C. Select **Show statistics**. How do the results from the transformed plant differ from the control plant? Explain. _____

   _____

3. Experiment: Go back two steps and experiment with different promoters. Can any of the other promoters be used to create a resistant corn plant? _____
   Why or why not? _____

   _____

4. Analyze: What are some of the benefits of growing herbicide-resistant corn? _____

_____

5. Analyze: Are there any possible drawbacks to having an herbicide-resistant corn plant? _____

_____

6. Think and discuss: Herbicides and insecticides can be bad for the environment. Insecticides could harm beneficial insects like bees, and both herbicides and insecticides can contaminate nearby rivers and streams.

   A. What are some of the possible environmental benefits of GM crops? _____

   _____

   B. What are some of the possible environmental problems that can be caused by GM crops?

   _____

   _____

   C. What are some of the potential risks to humans and animals that eat GM crops?

   _____

   _____

PART 2: GMOs and the Environment

Gizmo Warm-up
In the *Genetic Engineering* Gizmo™ you just completed, **genetically modified** (GM) corn was created that was **resistant** to insect pests and tolerant of **herbicides**. In the *GMOs and the Environment* Gizmo, you will use these strains of corn to maximize corn yields while seeing how these techniques affect the environment.

On the Controls tab, make sure **One-year** is selected for the Mode and **None** is selected for the **Resistance type**. Make sure both sliders are set to zero. Click **Play** ( ).

1. Describe the corn field shown in the SIMULATION tab on the left. _____

   _____

2. Click **Reset** ( ). Drag the **Herbicide** and **Insecticide** sliders all the way to the right. Click **Play**. Describe the corn field treated with these **pesticides**. _____

   _____

Activity A: **One-year analysis**	Get the Gizmo ready: • Click **Reset** and drag the **Herbicide** and **Insecticide** sliders back to zero.	

Introduction: In a corn field, about 75,000 plants are grown per hectare (2.47 acres) of land. In this simulation, a small sample of test plants are grown on about 0.0005 hectares of land.

Question: How can we maximize corn yield using different strains of corn?

6. Observe: When the Resistance type is **None**, the corn isn't resistant to insects or herbicide.

   A. Click **Play**. Click on a few different corn plants to see a close-up. What do you observe? _____

   _____

   B. What is the corn yield at the top right of the SIMULATION tab? _____

   Yield is the amount of crops harvested, and can be sold, per area of land.

   C. Select the TABLE tab. Based on the recorded data, what factors do you think have reduced the corn yield from its maximum amount of close to 15 tons/ha? (Note: Spiders eat harmful insects but do not damage corn.)

   _____

7. Hypothesize: What Gizmo settings do you think would maximize crop yield? _____

   _____

8. Investigate: Click **Reset**. On the TABLE tab, click **Clear** to delete the current data. With the resistance type **None** still selected, adjust the **Insecticide** and **Herbicide** sliders until you get the best yield. (Note: Yields within 1.0 tons/ha are not significantly different.)

   A. What is the maximum yield? _____

   B. How much **insecticide** did you use? _____

   C. How much herbicide did you use? _____

   D. Why didn't it help to add more herbicide to the corn? _____

   _____

9. Experiment: For each of the remaining resistance types, try to maximize corn yield by adjusting the amount of herbicide and insecticide used. Then, fill out the table below.

Resistance type	Herbicide Amount	Insecticide Amount	Yield
Herbicide			
Caterpillars			
Caterpillars and herbicide			

10. Explore: When using caterpillar-resistant corn, does it help to add insecticide? _____

Explain. _____

11. Challenge: Try to maximize corn yield without using any chemicals at all. Which resistance type did you choose, and what was the yield?

    Resistance type: _____ Yield: _____

12. Observe: Clear any data in the table. Select the herbicide resistant corn. Set the **Herbicide** slider to 300 L/ha. Starting with no insecticide, run several simulations, adding an additional 20 L/ha insecticide after each simulation until the maximum is reached.

    Switch to the GRAPH tab. Change the dropdown menu on the right to **Insecticide**.

    A. Describe the shape of the graph. _____

    _____

    B. What does the shape of the graph indicate about the amount of insecticide needed to be effective?

    _____

13. Apply: What is the minimum amount of chemicals (herbicide and insecticide) required to get a yield above 13 tons per hectare? You can use any resistance type. Fill in the table below.

Resistance type	Herbicide Amount	Insecticide Amount	Yield

Activity B: **Long-term yield**	Get the Gizmo ready: • Select **Multi-year** for the Mode. • Set **Resistance type** to **None**. • Set **Insecticide** and **Herbicide** to 0 L/ha	

Question: What are the long-term effects of GMOs on the corn field?

9. Review: In Activity A, you determined how to maximize yield for each type of resistance. List the settings you used and the resulting yields in the table below.

Resistance type	Herbicide Amount	Insecticide Amount	Yield
None			
Herbicide			
Caterpillars			
Caterpillars and herbicide			

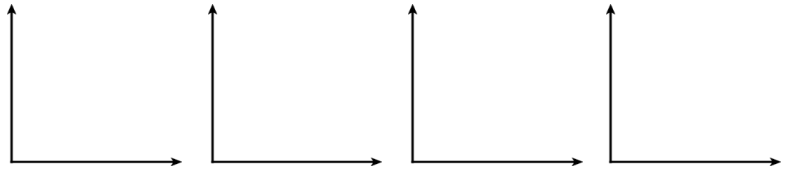
    A. How do you think the yields might change over a long period of time? _____
    B. Which method do you think will cause the least amount of harm to the environment?

    Explain. _____

10. Observe: Run a simulation for each resistance type using the settings in the table above. (For the caterpillars and caterpillars and herbicide resistant corn, use 0 L/ha insecticide.)

    Select the GRAPH tab. Below, roughly sketch the **Corn yield** graph for each resistance type. Fill in the final yield after 30 years below.

    None Herbicide Caterpillars Both

    Yield: _____ _____ _____ _____

11. Observe: Click **Reset**. Select the **Caterpillars and herbicide** corn. Set **Herbicide** to 300 L/ha and **Insecticide** to 0 L/ha. Run the simulation for 30 years.

    A. Describe the corn field. _____

    B. Switch to the GRAPH tab. You can change the data the graph displays using the dropdown menu. Roughly sketch the following graphs below.

    Corn yield Weeds Caterpillars

    C. Describe what happens to the population of caterpillars over time. _____

    _____

    D. How did this affect corn yield? _____

    E. Why do you think this is occurring? _____

    _____

    Caterpillars have evolved tolerance to the insect-resistant corn. This means they are no longer killed by the proteins the corn produces.

12. Explore: Click **Reset** and select the **Refuge field** box. A **refuge field** is a separate field that contains non-GMO corn. Click **Play**. What is the shape of the caterpillar graph now? _____

    A refuge field allows caterpillars that are not tolerant of the GMO corn to survive. This slows the spread of tolerance in the caterpillar population.

13. Think and discuss: Why is it necessary to continually produce new types of GMOs? _____

Activity C: **Effects on the environment**	Get the Gizmo ready: • Click **Reset** to reset the Gizmo. • Set **Resistance type** to **None**. • Set **Insecticide** and **Herbicide** to 0 L/ha	

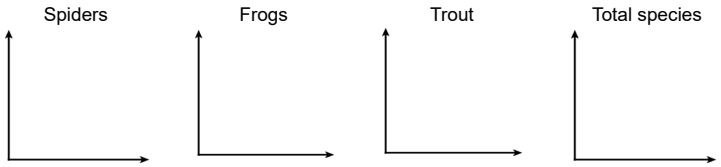
Introduction: Chemical pesticides from farms can pollute nearby water supplies, negatively affecting the environment. Water pollution from pesticides can harm sensitive animals and plants living in nearby streams, reducing populations and decreasing the number of species.

Question: What effects do pesticides and GM corn have on the environment?

1. Hypothesis: How do you think GMO's affect the environment over the long term? _____

2. Observe: Click on the stream.
   A. What species do you observe? _____
   B. How many total species are there? _____
   C. Run a simulation using 0 L/ha herbicide and 0 L/ha insecticide. Do you observe any changes in the stream over time? _____

3. Compare: Run a simulation with maximum herbicide and insecticide. Observe the stream.
   A. How does the stream change? _____
   B. Switch to the GRAPH tab. Roughly sketch the following graphs below.



   C. How do chemical pesticides affect the environment? _____

4. Challenge: Using the Gizmo, try to maximize the 30th year corn yield while retaining 35 or more species in the stream. Then, try to maximize the yield with 50 or more species. Fill in the table below to show how you did it.

Resistance type	Refuge?	Herbicide	Insecticide	Total species	Yield
				35+	
				50+	

Why did you make the choices you did in the table above? _____

_____

5. Challenge: Choose the non-resistant corn.
   A. What is the best yield you can get while still retaining 50 or more species? _____
   B. How does this compare to the GM corn? _____

_____

6. Think and discuss: Use everything you've learned to answer the following questions.
   A. What are the benefits of GM corn to the farmer? _____

_____

   B. What are the environmental benefits of using GM corn? _____

_____

   C. How can GM corn be harmful to the environment? _____

_____