DRIVING QUESTION: WHERE WOULD WE BE WITHOUT "GMOS"?

LENGTH: 1 hour

OBJECTIVES: Students will be able to:

- describe how crops are genetically modified

Standards:

Next Generation Science Standards Addressed

Disciplinary Core Ideas

LS3.A Inheritance of Traits

LS3.B Variation of Traits

Practices

Asking Questions and Defining Problems

Constructing Explanations

Cross-Cutting Concepts

Cause and Effect: Cause and effect relationships may be used to predict phenomena in natural systems.

Common Core English Language Arts Standards Addressed

Speaking and Listening Standards 6-12, Comprehension and Collaboration (1)

Materials:

- Copies of Lesson 7 Student Handout: Genetically Modified Matching Cards (1 per group of 3–5 students)
- Copies of Lesson 7 Student Handout: Behind "GMOS" (1 per student)
- Copies of Lesson 7 Student Handout: Discussion Prompts (1 per student)
- Scissors (for lesson preparation only)
- Student computers (1 per student)

Suggested Video:

"Are There Any Proven Health Risks Associated with Biotech Food?" by FoodInsightTV

http://www.foodinsight.org/media/food-biotechnology-videos (2:04)

https://www.youtube.com/watch?v=BwMw9TLOLno (2:53)

"The Case for Engineering Our Food" by Pamela Ronald/TED Talks

http://www.ted.com/talks/pamela_ronald_the_case_for_engineering_our_food?language=en (17:49)

Lesson Context

This section provides guidance for teachers for how lessons build on each other.

By now we have defined what DNA is and its major components. Students have done their own DNA extraction and have seen what clumps of millions and millions of DNA molecules look like. They have learned that in this DNA molecule, there are groups of genes that have certain desirable inheritable traits. Through the process of selective breeding, humans have manipulated desired outcomes of offspring for thousands of years. Then, the students learned that with biotechnology our food supply can be improved while being socially, economically and environmentally sustainable to feed our world's growing population. During Lesson 6, students learned that there are processes to isolate desired genes. In Lesson 7, they will learn how these desired genes can be inserted into organisms to produce genetically modified crops by transgenics. RNA interference and mutagenesis will be added to the students' biotechnology vocabulary. By the end of Lesson 7, students will understand that the processes of genetic engineering are no more dangerous than older methods of genetic modification.

KEY CONCEPTS: Genetic modification includes traditional breeding, mutagenesis, RNA interference and transgenics. Products made using transgenics have become known as "GM" (genetically modified) or "GMO" (genetically modified organisms), even though genetic modification through traditional breeding has been occurring for thousands of years.[xvi]

SETUP: Preview videos listed above. Print student handout Genetically Modified Matching Cards. Cut matching cards apart and place in an envelope for each group. Prepare copies of other handouts.

Outline:

1. Briefly walk students back through the objectives of the previous lessons to provide context for this lesson.
2. Write the letters "GMO" on the whiteboard. Ask students to consider the things they hear, read, or see about "GMOs". Respectfully listen and capture responses on the board around the term.
3. Acknowledge student interest and contributions. Let students know that they will have an opportunity in this lesson to gain a better understanding of the science behind genetically modified organisms ("GMOs").
4. First, define "GMO": *This term is used to describe the resulting product, after a scientist speeds up the process of selective breeding by moving a specific gene (or genes) from one organism to another. The gene becomes part of the genetic code of the new organism.*
5. Divide students into collaborative working groups of three to five students. Give each group an envelope containing the cut-apart Genetically Modified Matching Cards.
6. Set context for activity: *There are several methods for modifying crops: Traditional Breeding, Mutagenesis, RNA interference and Transgenics (what we refer to as genetic modification). In the envelope there are a series of cards, which convey important information about how crops are genetically modified.*
   - Challenge teams to race to correctly align each process card with its respective number of genes affected and safety testing requirement cards.
   - After teams are done, review the correct order using the attached student handout. Award one point for each card that is correctly matched. You may wish to share the infographic for this content at https://gmoanswers.com/current-gmo-crops.
   - Provide an opportunity for students to ask questions and share surprising discoveries.
7. Clarify with students that there are only certain genetically engineered crops on the market. You may wish to display the visual from "GMO" Answers found at https://gmoanswers.com/sites/default/files/genetic%20traits.png. The following genetically engineered crops are grown in the United States: corn, soybean, cotton, potato, papaya, squash, canola, alfalfa apple and sugarbeet.[xvii]
8. Distribute student handout Behind "GMOs". Have students read the three examples of "GMO" products on the top half of the sheet. You may wish to supplement this part of the lesson with additional images or samples of the crops listed. Ask students to consider:
   - *What prompted scientists to research new varieties of this crop?*
   - *Why was this discovery important?*
   - *How do you think things would be different today, if we did not have these "GMO" crops?* (Listen for students to identify concepts such as availability of the crop, cost, increased use of pesticides/herbicides, increased soil erosion, higher carbon emissions, increased mortality of non-target/beneficial insects, etc.)
9. Direct students' attention to the discussion prompts on the bottom half of the page.[xviii]
   - Have students independently read the scenarios and pick one on which to focus.
   - Have each student define the problem for his or her selected scenario.
   - Based on the information given, have each student write an initial response to the prompt.
   - Finally, have each student list additional questions they have about the scenario and proposed solution.
   - Share responses.
10. Revisit the initial "GMO" thoughts captured on the whiteboard. Revise and update according to student discussion.

Additional Content Support

Pre/Post Assessment

This section provides a suggested assessment tool that may be used before and after a lesson to assess student readiness. See the Pre/Post Assessment file for a ready-to-distribute copy for your students.

1. What is a GMO? This term is used to describe the resulting product, after a scientist speeds up the process of selective breeding, by moving a specific gene (or genes) from one organism to another. The gene becomes part of the genetic code of the new organism.
2. What are the differences between traditional breeding, mutagenesis, RNA Interference and transgenics?
3. Traditional breeding: crossing plants and selecting offspring, tens to hundreds of thousands of genes affected, no safety testing required.
4. Mutagenesis: exposing seeds to DNA-altering substances such as chemicals or radiation, no way to know numbers of genes affected, no safety testing required.
5. RNA Interference: not specific, switching off selected genes with RNA, one to two genes affected, safety testing may be required.
6. Transgenics or genetic engineering: more specific, inserting selected genes using recombinant DNA methods.
7. What are the understood risks of genetically modified crops?
8. "After 20 years of rigorous study and peer review by thousands of independent scientists, every major scientific organization in the world has concluded that the crops currently on the market are safe to eat. The process of genetic engineering is no more risky than older methods of genetic modification." —Pamela Ronald during TED Talk linked in lesson

Suggested Accommodations

This section provides optional tools to enrich learning and meet students where they are.

1. For students struggling to meet performance expectations:
   a. It will be important to show the infographic from the Genetic Literacy Project in step six and have a discussion to make sure students understand the four crop modification techniques before the "Behind GMOs" assignment.
   b. You may wish to print or post the bullet points in step nine for students to follow as they facilitate a group discussion to develop understanding for the assignment.
2. For students who have already met performance expectations and have high interest:
   a. Investigate Bacillus thuringiensis (Bt) in more detail and answer the following questions:
      - What are some products that contain Bacillus thuringiensis?
      - How does Bacillus thuringiensis (Bt) work?
      - What are some other microbes that are used as insecticides?
   b. Have students investigate applications of biotechnology in fields other than agriculture. See the examples below:

      Medical examples:

      - Pharmacogenomics is the study of testing the safety and impact of certain drugs based on the genetic information of the patient.[xxiii]
      - Gene therapy is used to integrate a beneficial gene into a patient in order to help cure a disease.[xxiv]
      - Insulin is made for diabetic patients using recombinant DNA technology. Scientists build the human insulin gene using bacterial plasmids.[xxv]

      Environmental:

      - Bioremediation is the process of using naturally occurring microorganisms—such as bacteria, fungi and yeast—to clean up polluted waterways, such as a body of water after an oil spill.[xxvi]
3. For students who are English Language Learners, have special needs or are reading below grade level:
   a. It is suggested to provide a translation of the terms and definitions in your students' native language. Terms include: traditional breeding, mutagenesis, RNA Interference and transgenics.
   b. Discussion prompts should also be translated so ELL students can have access to the assignment.
4. For engaging ways to connect learning to students' home and community:
   a. Ask the students if they have ever enjoyed sweet corn on the cob during a summer barbeque. If they have, they may have enjoyed the benefits of a genetically modified food. Sweet corn has insect resistance built in, reducing the need for the use of harmful insecticide.

Rubrics

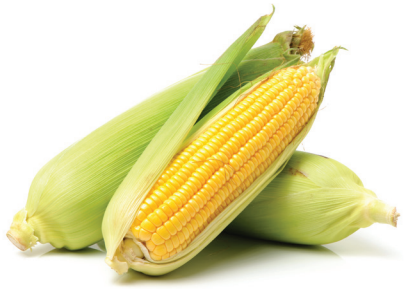
We have created two optional tools for evaluating learning at the end of each lesson.

- **LESSON RUBRIC:** This can be provided to students and used by the teacher for evaluation.
- **STUDENT REFLECTION:** This can be provided to students to empower them to self-assess learning before turning in the rubric and completed work. The general Student Reflection sheet can be found at the end of this educator guide.

NAME: _____ **DATE:** _____ **CLASS PERIOD:** _____

BEHIND "GMOS"

We often hear of genetically modified ("GMO") products, but what led to their development? Discover the background behind these "GMO" products.[xx]



Why did scientists develop genetically engineered corn?

Pests like the European corn borer can devastate a corn crop by eating through the stalk of the corn plant leaving it brittle and prone to breaking/falling over, known as "lodging." This reduces yields and lowers the quality of the corn that is produced. Scientists developed Bt corn that includes a gene from Bacillus thuringiensis, a very common bacterium that lives in the soil. This bacterium contains a protein that is only activated in the high pH insect gut. Once activated, it produces a toxin that naturally kills pests like the corn borer.[xxi]

Important Traits:

- Herbicide tolerance
- Insect resistance: Bt corn is able to resist pests including the corn borer, corn rootworm and corn earworm without using pesticides.
- Virus/fungi resistance

Why did scientists develop genetically engineered cotton?

Pests like the tobacco budworm and bollworm can ruin a cotton crop before the cotton has a chance to grow. The pest feeds on the squares, blooms and bolls of the cotton plant. Like Bt corn, Bt cotton includes a gene from Bacillus thurengeiensis, a bacterium that lives in the soil. This bacterium contains a protein that is only activated in the high pH insect gut. Once activated, it produces a toxin that naturally kills pests like the budworm and bollworm.[xxii]

Important Traits:

- Herbicide tolerance
- Insect resistance: Bt cotton is able to resist the tobacco budworm, the bollworm and the pink bollworm without using pesticides.

Why did scientists develop genetically engineered papaya?

In the mid-1990s the Hawaiian papaya crop was almost entirely wiped out by a virus. Researchers at Cornell University and the University of Hawaii used biotechnology to develop two new varieties of papaya that are resistant to the virus.

Important Traits:

- Virus/fungi resistance

NAME: _____ **DATE:** _____ **CLASS PERIOD:** _____

GENETICALLY MODIFIED MATCHING CARDS

TEACHER NOTE: Cut cards apart before activity and place in an envelope. Create one set for each group of three to five students.[xix]

PROCESS: TRADITIONAL BREEDING Crossing plants and selecting offspring	**PROCESS: MUTAGENESIS** Exposing seeds to chemicals or radiation	**PROCESS: RNA INTERFERENCE** Switching off selected genes with RNA	**PROCESS: GENETIC ENGINEERING** Inserting selected genes using recombinant DNA methods
10k–300k+ genes affected	No way to assess number of genes affected, but certain to involve multiple simultaneous unknown changes	1–2 genes affected	1–4 genes affected
No safety testing required	No safety testing required	Safety testing may be required	Safety testing required

NAME: _____ **DATE:** _____ **CLASS PERIOD:** _____

DISCUSSION PROMPTS

1. Imagine you are a sugar beet farmer. You love growing sugar beets that provide about half the sugar in the United States, but managing the weeds on your farm is very difficult. Each year the weeds threaten to choke out your crop, and you have to spray more herbicides to control them. You find out about a new genetically engineered sugar beet that is resistant to glyphosate, a common herbicide. This plant will allow you to spray glyphosate directly on your crop, which is less toxic than the other herbicides you have been using, without harming the sugar beet. What do you do?

2. You are an aid worker in Asia. Rice is a staple crop for most Asian families. It is inexpensive and readily available. You work in a poor area where people do not get enough vitamin A and are at higher risk for many diseases, including blindness. You hear of a rice crop that has been genetically engineered to contain high levels of beta carotene which humans can convert to Vitamin A. What do you do?

3. You are helping farmers in Africa learn new methods for growing cassava. Cassava is a starchy root, like a potato, that is an important part of the diets of many people around the world, especially in Africa. But the people in your community have just lost their entire crop of cassava, again, because of a virus. People are starving. They don't have access to other crops or herbicides. You hear of a new genetically engineered cassava plant that is resistant to the virus, and it contains improved levels of vitamins, proteins and minerals. What do you do?

4. You just started as the United States Department of Agriculture (USDA) Director for Sustainable Development. Part of your job includes assessing ways to cut down food waste in the United States. Through your research, you have learned about non-browning Arctic Apples that do not discolor after being exposed to air. You are to write a report with your recommendation of whether or not the United States should allow growers to produce this genetically engineered apple. What do you do?[xxvii]

NAME: _____ DATE: _____ CLASS PERIOD: _____

Pre/Post Learning Assessment

1. What is a GMO?

2. What are the differences between traditional breeding, mutagenesis, RNA Interference and transgenics?

3. What are the understood risks of genetically modified crops?

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LESSON HANDOUT 7

NAME: _____ DATE: _____ CLASS PERIOD: _____

Pre/Post Learning Assessment

1. What is a GMO?

2. What are the differences between traditional breeding, mutagenesis, RNA Interference and transgenics?

3. What are the understood risks of genetically modified crops?

NAME: _____ DATE: _____ CLASS PERIOD: _____

RUBRIC

		ADVANCED	PROFICIENT	NOVICE
DISCIPLINARY CORE IDEAS	Inheritance of Traits	Student can explain that desired genes can be expressed by modification of crops through multiple methods including traditional breeding, mutagenesis, RNA interference and transgenics also called genetic engineering. These methods differ in speed of desired outcome, hence, numbers of genes affected.	Student can explain that desired genes can be expressed by modification of crops through multiple methods including traditional breeding, mutagenesis, RNA interference and transgenics also called genetic engineering.	Student can explain that desired genes can be expressed in crops through multiple methods.
	Variation of Traits			
PRACTICES	Asking Questions and Defining Problems	Student chose a discussion prompt and defined the problem; wrote a response to the scenario; developed additional questions to ask about the scenario and their proposed solution; and researched their answers to modify their solution if needed.	Student chose a discussion prompt and defined the problem; wrote a response to the scenario; and developed additional questions to ask about the scenario and their proposed solution.	Student chose a discussion prompt and defined the problem; and wrote a response to the scenario or only developed questions to ask about the scenario.
	Constructing Explanations			
CROSS-CUTTING CONCEPTS	Cause and Effect	Student can explain in detail the differences in methods to modify crops and how these each lead to desired outcomes of the food supply, citing example crops and their important traits. Student expresses that every major scientific organization in the world has concluded that the modified crops currently on the market are safe to eat.	Student can explain in detail the differences in methods to modify crops and how they each lead to desired outcomes of the food supply. Student expresses that every major scientific organization in the world has concluded that the modified crops currently on the market are safe to eat.	Student can explain some of the differences in methods to modify crops and how they each lead to desired outcomes of the food supply. Student expresses that every major scientific organization in the world has concluded that the modified crops currently on the market are safe to eat.