FOR GRADES 7–10
VERSION 3.0

BRINGING BIOTECHNOLOGY TO LIFE

AN EDUCATIONAL RESOURCE

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WELCOME

"Bringing Biotechnology to Life" is a resource for science educators and others interested in learning more about biotechnology and its role in food production. This unit of instruction addresses national learning standards for 7th–10th grade, yet the interest level may be much broader. Eight sequential lessons guide the learner through the process of understanding DNA, selective breeding over time and agricultural biotechnology today, including foods produced through biotechnology (often referred to by consumers as genetically modified organisms or "GMOs"). Students are also presented with tools to evaluate the reliability of information they see and hear. The unit culminates with a relevant research paper and presentation to people beyond the students' classmates and teacher. This unit follows the principles of Project Based Learning by engaging students with a driving question, encouraging voice and choice, incorporating critique and revision and including a public audience for the final project.



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DRIVING QUESTION: WHAT IS DNA?

WELCOME LENGTH: 1 hour

OBJECTIVES: Students will be able to:

- identify the primary components in a DNA structure
- describe the role of DNA in trait inheritance

Standards:

Next Generation Science Standards Addressed

Disciplinary Core Ideas

LS1.B Growth and Development of Organisms

LS3.A Inheritance of Traits

LS3.B Variation of Traits

Practices

Asking Questions

Cross-Cutting Concepts

Structure and Function: Complex and microscopic structures and systems can be visualized, modeled and used to describe how their function depends on the relationships among its parts, therefore complex natural structures/systems can be analyzed to determine how they function.

Materials:

- Copies of Lesson 1 Student Handout: Delicious DNA (1 per group of 2–3 students)
- Paper towels (1 per group of 2–3 students)
- *Licorice vines (2 per group of 2–3 students)
- Toothpicks (20 per group of 2–3 students)
- *Gummy candy in four colors (20 per group of 2–3 students)
- Optional: Student science textbook for additional information on DNA (1 per group of 2–3 students)

** You may wish to substitute fruit and/or vegetables for the candy options in the DNA model. The materials list suggests using licorice vines for the sugar phosphate backbone; gummy candies such as gummy bears, jellybeans or colored marshmallows for the bases; and toothpicks to connect components.*

Suggested Video:

"The Double Helix" by BioInteractive

http://www.hhmi.org/biointeractive/double-helix (16:53)

Note: Due to the length of this video, you may wish to show only a portion of the history of DNA research.

Lesson Context

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

"Bringing Biotechnology to Life" provides students a journey through the understanding of biotechnology with an emphasis on food production. Lesson one presents the foundational knowledge to build upon in regard to DNA's role in the inheritance of traits and variations of these traits over time. It all starts with the DNA structure discovery, as explained in the suggested video link, and how models played a vital role in the double helix discovery. Students will build their own DNA model during this lesson and get to eat it too!

KEY CONCEPTS: Before we can jump into a discussion about biotechnology, we must know how genetic information is passed from generation to generation. In eukaryotic organisms chromosomes are found in the nucleus of the cell. Chromosomes are made up of DNA. Genes on the double helix DNA structure contain genetic information, which will provide a blueprint for the characteristics/traits of the offspring. During meiosis, this information is passed from parent to offspring.

SETUP: Set out lab supplies and prepare copies of the student handout.

Outline:

1. Draw three boxes on a whiteboard. Above the first box, draw a large pair of eyes. Above the second box, draw a movie slate board clapper. Above the third box, draw a question mark.
2. Ask students to think about what they already know about DNA. Help them "unpack" this knowledge by sorting concepts into three categories: what DNA looks like (eyes), what it does (clapper) and why we should care/significance of it (question mark). Solicit responses and capture information in each box.

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LISTEN FOR THE FOLLOWING!

- double helix, ladder, found in nucleus
- made up of genes that code for traits like eye color, hair color, height, etc.
- all living things have DNA; studying DNA helps us understand plants and animals; studying DNA helps us identify desirable traits like taste, nutritional value and productivity in crops
- Invite students to ask questions to clarify relationships about the role of DNA and genes in coding the instructions for characteristic traits passed from parents to offspring. Encourage students to think of What?, Why?, How? and Where? questions. Capture questions on the whiteboard or poster paper for review throughout the unit.

3. Preview the activity by sharing with students that they'll have a chance to build their own DNA structure and eat it too!
    - Just like our DNA, DNA in plants and animals contain what we refer to as the genetics of that organism. Each strand of DNA consists of four nitrogen bases: adenine (A), cytosine (C), thymine (T)and guanine (G). It does not matter if the DNA is from an animal, insect or a human, we all share the same four bases. In different organisms, the bases are just arranged to code for different proteins.[i]
    - Nitrogen bases follow a base pairing rule: adenine always pairs with thymine. Guanine always pairs with cytosine.
    - Gene is the root word of "genetics." Understanding genetics is the basis for understanding food production.
    - Genes make up an organism's "genotype." The genotype of an organism is expressed outwardly as the organism's "phenotype." The phenotype is typically what we see or notice.
4. Distribute student handout Delicious DNA. Pre-read the handout with the students. In this activity, students will create a DNA structure using a variety of food items and toothpicks. Students must be able to clearly describe the components of the DNA structure and create a logical legend using the candies provided.
    - Note: Students may elect to use food items for different components of the structure. Part of the learning process is giving students the opportunity to make logical connections and create their own roadmap of understanding.
5. Break students into collaborative working groups of two to three.
6. Clarify expectations: By the end of the class period, students should have assembled a 3D DNA model and completed the student handout.
7. Distribute lab supplies and one paper towel to each group. Monitor student progress and address questions.
8. After all students have completed the activity, prompt students to clean work areas.
9. Refer back to the boxes of information drawn on the whiteboard at the beginning of class. Ask students to re-evaluate this information, taking into consideration the knowledge they now have. Ask students what statements they would modify or add to the list. Share additional information as needed.
10. As a take-home challenge, ask students to think of a fruit or vegetable that can be found in different varieties (e.g., apples), and consider the role genetics plays in the traits we observe about that food item.

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 DNA? Deoxyribonucleic acid
2. Where is DNA found? In the cell nucleus of eukaryotic cells and in the cytoplasm of prokaryotic cells
3. What does DNA look like? A double helix
4. What components make up DNA? Cytosine, Guanine, Adenine, Thymine, Sugar-phosphate backbone
5. Why is DNA important in trait inheritance? DNA carries the genetic information from parent to offspring from generation to generation

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. Unpacking students' prior knowledge during the questioning activity will be key to determine level of understanding about the DNA structure.
    b. If students do not know the primary components of the DNA structure, the suggested video goes over not only the history of the DNA structure discovery, but also the components of DNA and the critical use of modeling for this discovery. (See video from 10:40.)

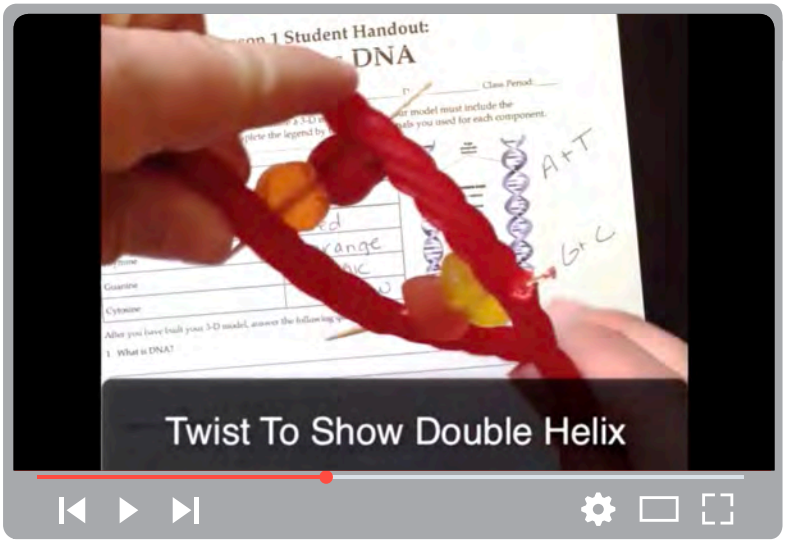
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2. For students who have already met performance expectations and have high interest:
    a. History of the discovery of the double-helix structure is rich with scientists influencing other scientists in the race for the complete understanding of the DNA structure. To enhance the understanding of this discovery and how science builds upon asking questions, students may investigate the following questions.
        - How is the discovery of the double-helix structure of DNA an example on how one scientific hypothesis can influence another?
        - How did the base ratios play a role in the final model of the DNA structure?
        - How many scientists were involved and what were their contributions in the influence of the discovery of the double-helix structure?
        - What scientist(s) received the acknowledgment for the discovery of the structure of DNA? Do you think any other scientists should have received acknowledgment? Why or Why not?
3. For students who are English Language Learners, have special needs or are reading below grade level:
    a. Display the color image of DNA with a projector in order for students to see which base pairs match up.
4. For engaging ways to connect learning to students' home and community:
    a. Question students to see who has a dog. Have the students share some dog breeds with which they are familiar. As breeds are shared, ask the student to explain what they look like. Share that these characteristics are called traits and these traits are inherited from the animal's parents through DNA. This example will come back on another day. Ask students, "What is DNA?" and proceed with the DNA question activity.

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.



CHECK THIS LAB OUT ON YOUTUBE!

https://youtu.be/f5bANXd10As

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

DELICIOUS DNA

DIRECTIONS: Using the supplies provided, create a 3D model of DNA. Your model must include the components in the table below. Complete the legend by listing the materials you used for each component.

LEGEND	
DNA Component	**Item We Used**
Sugar Phosphate Backbone	
Adenine	
Thymine	
Guanine	
Cytosine	

NITROGEN BASES:

- Adenine
- Thymine
- Cytosine
- Guanine



BASE PAIRING RULES:

Adenine pairs with Thymine

Cytosine pairs with Guanine

After you have built your 3D model, answer the following questions.

1. What is DNA?

2. Where is DNA found?

3. Why is DNA important?

GRADING RUBRIC – FOR TEACHER		
Model includes all required components. Score _____/_____	Model is assembled correctly and follows legend. Score _____/_____	Questions are thoroughly completed on lab sheet. Score _____/_____

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

Pre/Post Learning Assessment

1. What is DNA?

2. Where is DNA found?

3. What does DNA look like?

4. What components make up DNA?

5. Why is DNA important in trait inheritance?

Bringing Biotechnology to Life · Educator's Guide

LESSON HANDOUT 1

NAME: _____ DATE: _____ CLASS PERIOD: _____

Pre/Post Learning Assessment

1. What is DNA?

2. Where is DNA found?

3. What does DNA look like?

4. What components make up DNA?

5. Why is DNA important in trait inheritance?

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NAME: _____ DATE: _____ CLASS PERIOD: _____

RUBRIC

		ADVANCED	PROFICIENT	NOVICE
DISCIPLINARY CORE IDEAS	Growth and Development of Organisms	Student can explain that organisms inherit traits from their parents and organisms change over time by genetic variations from parent to offspring during meiosis or the creation of sex cells.	Student can explain that organisms inherit traits from their parents and change over time by genetic variations.	Student can explain that organisms inherit traits from their parents.
	Inheritance of Traits			
	Variation of Traits			
PRACTICES	Asking Questions	Student can identify six or more questions that had to be asked while the structure of DNA was being researched.	Student can identify three to five questions that had to be asked while the structure of DNA was being researched.	Student can identify one to two questions that had to be asked while the structure of DNA was being researched.
CROSS-CUTTING CONCEPTS	Structure and Function	DNA double-helix model is complete with accurately paired nitrogen base pairings with the DNA components identified in the legend. All three questions on Student Handout are correctly answered with question three's answer mentioning inheritance of traits from parents.	DNA double-helix model is complete with accurately paired nitrogen base pairings with the DNA components identified in the legend. Two of the three questions on Student Handout are correctly answered.	DNA double-helix is incomplete or nitrogen base pairs are inaccurately paired. All three questions on Student Handout are answered incorrectly.

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DRIVING QUESTION: HOW CAN WE EXAMINE DNA?

LENGTH: 1 hour

OBJECTIVES: Students will be able to:

- extract DNA from common fruits/vegetables

Standards:

Next Generation Science Standards Addressed

Disciplinary Core Ideas

LS1.B Growth and Development of Organisms

LS3.A Inheritance of Traits

LS3.B Variation of Traits

Practices

Planning and Carrying Out Investigations

Cross-Cutting Concepts

Structure and Function: Complex and microscopic structures and systems can be visualized, modeled and used to describe how their function depends on the relationships among its parts, therefore complex natural structures/systems can be analyzed to determine how they function.

Materials:

- Copies of Lesson 2 Student Handout: Discovering DNA (1 per student)
- Pint/quart sized sealable plastic bag (i.e., Ziploc) (1 per student)
- Previously frozen strawberries (1 per student)
- DNA extraction buffer (10 mL) pre-mixed for class: 50 mL dish soap, 15g NaCl (2 tsp plain salt), 900 mL water
- Paper towels, filter paper or cheese cloth (1 per student)
- Ice cold 90% ethanol or isopropyl alcohol
- Test tube or plastic champagne flute (1 per student)
- Funnel (optional)
- Plastic coffee stir straw (1 per student)

Optional: tomato, banana, avocado, cucumber or other produce to replicate lab

Suggested Video:

"Genetic Engineering" by MIT K12 Videos

https://www.youtube.com/watch?v=nfC689ElUVk (7:20)

Lesson Context

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

Now that the students have made their own models of DNA during Lesson 1, it is time they see actual DNA. Lesson 2 provides the opportunity to extract DNA from common fruits and vegetables. The video link will provide the laboratory connection of genetic engineering and how we isolate specific genes in DNA. It also explains the process to clone a desired gene using restriction enzymes, bacterial plasmids, antibiotics and bacteria. This concludes with explaining how gel electrophoresis is used to separate different genes to isolate the desired genes. Gel electrophoresis will be extensively explained during Lesson 6. This is the same technique used to mass-produce insulin for diabetics.

KEY CONCEPTS: The process for discovering biotechnology begins with a strong foundation of understanding DNA. DNA is found in all living things. Sections of DNA are referred to as genes. These genes code for specific amino acids. Amino acids form together to make long chains which are called proteins. These proteins are expressed to give an organism its unique characteristics. In this lab, students will have a hands-on experience extracting DNA.

SETUP:

- Chill the alcohol in a freezer or ice bath for at least one half hour to make it as cold as possible.
- Freeze produce and then allow thawing prior to class. Freezing helps break down the plant material.
- Optional: You may wish to melt the end of a coffee stir straw with a flame to form a hook/knob for ease in catching the DNA.
- Optional: You may wish to place fruit in individual bags prior to the lab to save time in class.

Outline:

1. Distribute student handout Discovering DNA and have students preview the lab procedure.[ii] Answer questions before beginning lab.
   - Place one thawed strawberry in the plastic bag and squeeze until all lumps are turned into a uniform puree.
   - Add 10 mL of buffer solution. Zip the bag closed.
   - By squeezing the bag, mix the strawberry with the buffer solution completely.

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- Fold the paper towel into a half circle, then a quarter circle, opening it to form a cone.
- Fill the test tube or champagne flute (approximately two inches) with ice-cold alcohol. Place the filter paper cone into the test tube/flute so that half of the cone is on the inside and half is on the outside of the test tube/flute.
- Fill the paper towel cone with the strawberry solution.
- As the strawberry mixture filters through the cone and comes in contact with the cold alcohol, the DNA will form ribbons and then coagulate at the top of the alcohol.
- Use the straw to scoop and retrieve the DNA.

2. Have the students compare their DNA sample with those of other classmates. Discuss their observations. Ask the students: *Did everyone's DNA look the same? Why did some people have more DNA? Why is isolating DNA an important process? What do you think scientists can learn from studying DNA?* Listen for students to recall that DNA contains genetic information. By studying DNA, scientists are able to identify the genes (genetic markers), which code for specific traits.
3. In the event that one or more students did not have any DNA, explore why not. Listen for students to evaluate if they followed the procedure correctly.
4. If desired, repeat the process with additional samples.
5. When observations have been made, have the students pour contents of the test tubes back into a plastic cup and dispose of the materials as directed.
6. Optional Extension Opportunities:
   - Have students weigh the strawberry prior to testing, and the DNA after separating. Create a class graph evaluating the relationship between weight and amount of DNA collected.
   - Increase the variables (e.g., hot vs. cold alcohol, 70% vs. 90% alcohol, type of soap used in buffer, different types of fruit/vegetables, frozen vs. unfrozen samples, etc.) and compare results.

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 are genes? A section of DNA that encodes certain traits.
2. What is genetic engineering? The direct manipulation of an organism's genome. For example, if a frog gene is inserted in bacteria, when the bacteria reproduce, the frog gene is multiplied also.
3. What is the role of bacterial plasmids in genetic engineering? They carry desired genes into bacteria to be duplicated by the bacterial growth.
4. What is the role of bacteria in genetic engineering? After the desired gene is inserted into the bacteria's DNA, the bacterial growth provides duplication of the desired gene.
5. What is used to separate the desired gene from the other genes after plating the bacteria? Gel electrophoresis.

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 is important for students to realize that DNA is a microscopic molecule. During their lab, students will see millions and millions of DNA molecules coagulate together like tangled string. As they become large enough bundles of DNA, they can be seen by the naked eye.
   b. This task is sensitive to the procedure. If any students do not get DNA results, have them observe from a student's sample that did extract DNA.
2. For students who have already met performance expectations and have high interest:
   a. Biotechnology is a growing science that utilizes what is known about plant science and genetics to improve the food we eat and how it is produced. Genetic engineering is a type of biotechnology. Have students choose to research how we are benefiting more and more each day in the fields of medicine and/or food science due to genetic engineering.
3. For students who are English Language Learners, have special needs or are reading below grade level:
   a. Before Lab: Identify and share each material being used in the lab. Model the procedures 1–7.
   b. During Lab: Partner ELL students with a non-ELL students and provide them an opportunity to perform their own DNA extraction watching the procedure from their partner.
4. For engaging ways to connect learning to students' home and community:
   a. Ask the students if they know of anyone with diabetes. Be sensitive to any students who may be diabetic themselves when you explain the seriousness of the illness.
   b. Your body breaks down the sugars and starches you eat into a simple sugar called glucose, which the body uses for energy. Insulin is a hormone that the body needs to get glucose from the bloodstream into the cells of the body. In type 1 diabetes, the body does not produce insulin. With the help of insulin therapy and other treatments, even young children can learn to manage their condition and live long, healthy lives.
   c. Where does the insulin come from that type 1 diabetics inject into themselves for this insulin therapy? Today's lesson will show you the process of genetic engineering that is utilized to produce this insulin.

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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.

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

DISCOVERING DNA

Lab Procedure:

1. Place one thawed strawberry in the plastic bag and squeeze until all lumps are turned into a uniform puree.
2. Add 10 mL of buffer solution. Zip the bag closed.
3. By squeezing the bag, mix the contents with the buffer solution completely.
4. Fold the paper towel into a half circle, then a quarter circle, opening it to form a cone.
5. Fill the test tube or champagne flute with (approximately two inches) ice-cold alcohol. Place the filter paper cone into the test tube/flute so that half of the cone is on the inside and half is on the outside of the test tube/flute.
6. Fill the paper towel cone with the strawberry solution.
7. As the strawberry mixture filters through the cone and comes in contact with the alcohol, the DNA will form ribbons and then appear supernatant (floating) at the top of the alcohol.
8. Use the straw to scoop and retrieve the DNA.
9. Compare your DNA with that of other classmates and complete questions below.
10. Repeat with other produce samples as directed by your teacher.
11. Clean up your lab area.

	Describe your DNA. What does it look like? How much is present?
Sample 1: Strawberry	
Sample 2:	
Sample 3:	

1. Compare your solution to your classmates' solutions. Does everyone's DNA look the same? Speculate why or why not.

2. Why is isolating DNA an important process?

3. What do you think scientists can learn from studying DNA?

GRADING RUBRIC – FOR TEACHER		
Student successfully completed lab according to written procedure. Score _____/_____	Lab responses indicate a working knowledge of the role of DNA in science. Score _____/_____	Sections are thoroughly completed on handout. Score _____/_____

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NAME: _____ DATE: _____ CLASS PERIOD: _____

Pre/Post Learning Assessment

1. What are genes?

2. What is genetic engineering?

3. What is the role of bacterial plasmids in genetic engineering?

4. What is the role of bacteria in genetic engineering?

5. What is used to separate the desired gene from the other genes after plating the bacteria?

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LESSON HANDOUT 2

NAME: _____ DATE: _____ CLASS PERIOD: _____

Pre/Post Learning Assessment

1. What are genes?

2. What is genetic engineering?

3. What is the role of bacterial plasmids in genetic engineering?

4. What is the role of bacteria in genetic engineering?

5. What is used to separate the desired gene from the other genes after plating the bacteria?

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NAME: _____ DATE: _____ CLASS PERIOD: _____

RUBRIC

		ADVANCED	PROFICIENT	NOVICE
DISCIPLINARY CORE IDEAS	Growth and Development of Organisms	Student can explain that desired genes can be inserted into bacteria to be replicated by a process called genetic engineering using restriction enzymes and bacterial plasmids.	Student can explain that desired genes can be inserted into bacteria to be replicated by a process called genetic engineering.	Student can explain that genes can be inserted into bacteria.
	Inheritance of Traits			
	Variation of Traits			
PRACTICES	Planning and Carrying Out Investigations	Student followed the DNA extraction procedures and isolated DNA with a scoop to retrieve from more than one sample.	Student followed the DNA extraction procedures and isolated DNA with a scoop to retrieve from one sample. Or the student was not able to extract DNA but analyzed the procedures and evaluated where an error in the procedures may have happened.	Student followed the DNA extraction procedures and was not able to extract DNA and did not analyze the procedures and evaluate where an error in the procedures may have happened.
CROSS-CUTTING CONCEPTS	Structure and Function	Student can explain the function of the restriction enzymes, bacterial plasmids, bacteria, antibiotics and gel electrophoresis during genetic engineering.	Student can explain the function of the restriction enzymes, bacterial plasmids, bacteria and antibiotics during genetic engineering.	Student can explain the function of restriction enzymes, bacterial plasmids and bacteria.

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DRIVING QUESTION: WHAT IS SELECTIVE BREEDING?

LENGTH: 1 hour

OBJECTIVES: Students will be able to:

- define selective breeding
- describe how selective breeding changes a population over time

Standards:

Next Generation Science Standards Addressed

Disciplinary Core Ideas

LS3.A Inheritance of Traits

LS3.B Variation of Traits

Practices

Developing and Using Models

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

Reading Standards for Literature 6-12:
Craft and Structure, 4

Writing Standards 6-12:
Production and Distribution, 4

Materials:

- Scissors (1 per group of 2 students)
- Copies of Lesson 3 Student Handout: Superhero! (1 per group of 2 students)
- Lesson 3 Resource: Wild Mustard Plant (1 copy per student, or display using projector)
- Internet access and projector or printed images from "How Your Food Would Look If Not Genetically Modified Over Millennia" http://www.geneticliteracyproject.org/2015/02/02/how-your-food-would-look-if-not-genetically-modified-over-millennia/

Suggested Video:

"Backcross Breeding" by University of Nebraska

http://passel.unl.edu/pages/animation.php?a=BXbreed.swf&b=990818773 (self-paced)

"Marker Assisted Selection" by University of Nebraska

http://passel.unl.edu/pages/animation.php?a=MASBreeding.swf&b=1130281891 (self-paced)

Lesson Context

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

At this point, students have seen DNA for themselves in Lesson 2. They learned how genes can be isolated and then replicated using bacteria. It is now time to learn that people have been selecting preferred traits for thousands of years. During Lesson 3, students will learn about the process involved in selectively breeding plants with desirable traits. In fact, the food that we enjoy in the grocery store would look much different if selective breeding had not happened. A few examples of what food would have looked like without selective breeding will be shared via one of the suggested website links.

KEY CONCEPTS: Selective breeding is not a new phenomenon. Humans have been trying to systematically improve their food supply for at least 10,000 years. As people began selecting and breeding plants and animals for desired traits, they improved these plants and animals for agricultural purposes.[iii]

We have been selecting plants and animals based on certain qualities for years! Moravian monk Gregor Mendel pioneered the study of inheritance and selective breeding. He discovered the interaction of dominant and recessive traits and patterns of inheritance with simple pea plants.

Today there are many food products we enjoy that humans have genetically modified over time through selective breeding. Nobel Laureate Norman Borlaug started the Green Revolution with successful selective breeding of wheat in Mexico, and as a result is said to have "saved more lives than any person who has ever lived."[iv]

SETUP: Write the following quote about Norman Borlaug on the whiteboard or display with a projector: "[He] saved more lives than any person who has ever lived."

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Outline:

1. Direct students' attention to the quote about Dr. Borlaug. Ask students to speculate what a person with this descriptor may have done. Share with students that this quote is about Dr. Norman Borlaug, a man who received the Nobel Peace Prize for his work breeding wheat plants which helped nourish billions of people around the world.
2. Ask students to recall key information from the previous lesson.

   In the last two lessons, we explored the structure of DNA. Today we'll take a closer look at an amazing process that has enabled scientists like Dr. Borlaug to save countless lives in a growing world. But first, we'll start with a superhero challenge!
3. Inform students that they will create a powerful colony of superheroes. Distribute the Superhero! student handout. Have students work in pairs to complete the handout.
4. After students have completed the student handout, talk through each scenario. For each scenario, ask students which offspring they selected and why. Listen for selections based on genetic traits that are beneficial in the given situation.
5. Ask students to identify the effect of their selection on the population of superheroes. Have students reflect on the action (selecting for specific traits) that caused this effect.
6. Reinforce that genes, which are encoded in the DNA located in our chromosomes/cell nuclei, control genetic traits. The process of selecting offspring based on their traits is called "selective breeding." This is a process that has been used for thousands of years to breed the right plants and animals for a specific situation.
7. Ask students to describe the ways we use plants and animals. Listen for answers such as food, fuel, shelter, medicines, transportation, etc.
8. Explain to students that humans have been using plants and animals for their benefit for thousands of years.
   - For example, humans harvested the best seed of wild grasses, saved it and planted it the next spring. Soon humans crossed one grass with another (or perhaps several) and created wheat on one continent and corn on another. Neither wheat nor corn, as we know them today, ever existed as a wild grain. This marked the beginning of manipulating genes to create new products that humans desired.
   - Domestication of animals soon followed through genetic modifications made by humans. For example, animal scientists and anthropologists believe that humans domesticated the dog from wolves 12,000 to 14,000 years ago.[v]
9. Connect superhero activity to selective breeding decisions in real-life. Just like the students selected superheroes for specific scenarios, people have selected plants and animals for specific scenarios over time.
   - *What might have been the most important trait selected in animals?* (Listen for: amount of meat produced, amount of milk produced, quality of wool, amount of fat, size, using feed efficiently, flavor of meat, tenderness of meat, rapid growth, ability to reproduce easily, good mothering behaviors (takes good care of offspring), ease of giving birth, for draft animals like oxen or workhorses: strength, sound feet and legs, good disposition, willingness to work, etc.)
   - *What might have been the most important trait selected in plants?* (Listen for: yield, flavor, texture, ability to dry, growing season/conditions needed, etc.)
10. Share the Lesson 3 Resource: Wild Mustard Plant illustrating the variety of crops we enjoy today which were developed through selectively breeding the wild mustard plant (Brassica oleracea). Ask students to evaluate the images and hypothesize the trait which breeders selected for to achieve each plant.
    - Kohlrabi – selected for stem
    - Kale – selected for enlargement of leaves
    - Broccoli – selected for suppression of flower development
    - Brussels sprouts – selected for lateral leaf buds
    - Cabbage – selected for terminal leaf bud
    - Cauliflower – selected for sterility of flowers[vi]
11. Display pictures of watermelon, corn, banana, eggplant, carrot and cabbage/kale from "How Your Food Would Look If Not Genetically Modified Over Millennia" at https://geneticliteracyproject.org/2014/06/19/how-your-food-would-look-if-not-genetically-modified-over-millennia/
12. Ask students to share observations and summarize selective breeding in their own words. Listen for students to clarify that animals or plants are selected because of a desired trait and bred to continually improve that trait over generations. Direct students' attention back to the quote about Dr. Borlaug. Inform students that Dr. Borlaug used this technology to breed specific varieties of wheat that could grow well in different areas, providing food for people who would otherwise be hungry.
13. As a take-home challenge, have students review the article and series of poems "Mendel's Peas" at http://www.thehumangenome.co.uk/THE_HUMAN_GENOME/Mendels_Peas.html. Have students draft their own poem about selective breeding of a food item and bring it to the next class period.

ENRICHMENT OPPORTUNITY: (Global) Have students research global agricultural challenges, such as breeding better corn in drought prone areas like Africa, and report back on how selective breeding could be applied to help people. (Local) If agriculture is prevalent in your area, bring in different seeds and plants from surrounding fields. Have students research why farmers choose the crop variety for your specific area, soil type and climate.

FOR MORE INFORMATION, CHECK OUT:

- "The Man Who Fed the World" by Leon Hesser. Book and educator guide available at www.agfoundation.org.
- Wieczorek, A., & Wright, M. (2012). History of agricultural biotechnology: How crop development has evolved.[vii]

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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 selective breeding? The process of changing a population over time by selecting for desired genetic traits in the following generations. Plant breeders and researchers use molecular markers, which are identified gene sequences, to identify these traits without altering the genes in the organism.
2. Why has selective breeding become part of human impact on plant and animal life? Humans have learned to take advantage of selecting organisms with desirable traits and breed them with other organisms with desirable traits.

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. Have students complete the self-paced module found at http://passel.unl.edu/pages/animation.php?a=MASBreeding.swf&b=1130281891 (self-paced).
    b. Students will learn about important traits that modern breeders (farmers) use to select the best crops. They will also learn about the Traditional Selection Process for disease resistance in plants along with today's biotechnology method of Marker Assisted Selection (MAS).
    c. Although these exercises are "self-paced," teacher guidance is highly recommended. Display the module with a projector and assist students with the content.
2. For students who have already met performance expectations and have high interest:
    a. Ten thousand years ago humans started cultivating wild plants. All the grains that feed billions of people today — wheat, rice and corn — come from annual plants. They sprout seeds, produce new seeds and die every year. Why didn't humans cultivate perennials instead of annuals? In your answer, be sure to include the advantages and disadvantages of each type of plant (annual, perennial).
3. For students who are English Language Learners, have special needs or are reading below grade level:
    a. Provide a translation of the word "superhero" in your students' native languages. Understanding this term is key to the student experience with their selection of traits for desired purposes.
4. For engaging ways to connect learning to students' home and community:
    a. Let's get back to the question about dogs from Lesson 1. We named a few different dog breeds a few days ago and also discussed the traits of each breed. It is believed that all dogs we know today started as wolves that have been bred for selected traits to meet the preferences of humans.
    b. What traits of the dachshund or "wiener-dog" were bred to become the ideal burrow hunting dog? Listen for short legs, long bodied, good scent. According to the American Kennel Club, the dachshund was bred to hunt small animals. They were developed to scent, chase and flush out badgers and other burrow-dwelling animals.

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.

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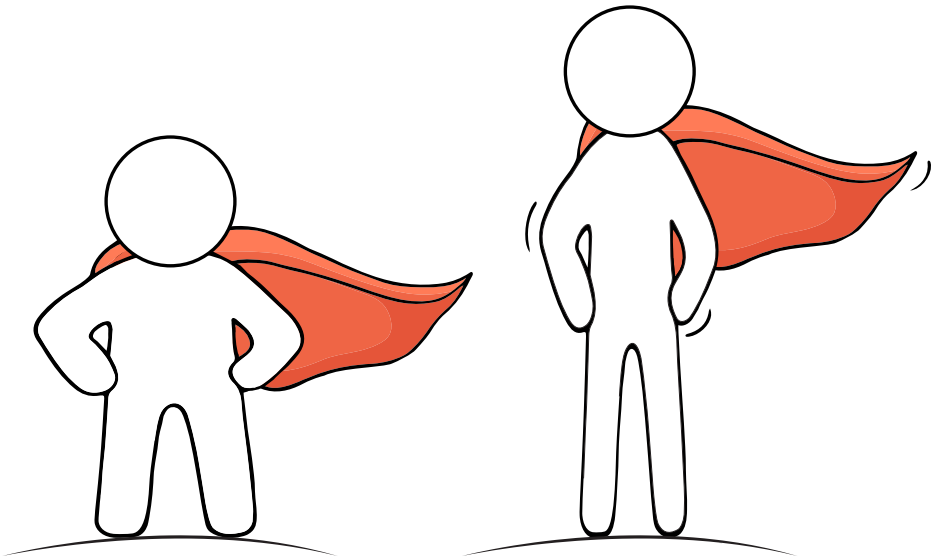
NAME: _____ **DATE:** _____ **CLASS PERIOD:** _____

SUPERHERO!

DIRECTIONS: You have a chance to save the world by creating an amazing superhero. Follow the steps to build your superhero family.

SETUP: Cut out the four genetic trait cards included with this activity. Place the two height cards in a pile, and the two strength cards in a separate pile. Fold all cards so that you cannot see the trait inside.

STEP 1: Meet your superheroes! We're crossing two superheroes to start your family.



Short and Strong

Tall and Weak

STEP 2: Build your superhero family! You have a chance to build 10 superheroes by crossing the parents we just met. For each child (1-10), draw one height card and one strength card. Record the outcome in the table below. Height: T (tall) S (short). Strength: S (strong), W (weak). After each drawing, put the cards back before you draw again.

	1	2	3	4	5	6	7	8	9	10
Height										
Strength										

(continued)

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

Superhero! (Continued)

STEP 3: Pick the right superhero for the job! Read each scenario below and decide which superhero child/children you would use for the job.

SUPERHERO SCENARIO A: Villains have overrun the city. They have flipped every car upside down and moved them under the shortest bridges. We need a superhero to turn the city right side up again.

Which of your superhero kids are right for the job?

Why?

SUPERHERO SCENARIO B: An evil villain has hidden all of the money for the entire town in tight places, high in the trees. We need a superhero to get all of the money back.

Which of your superhero kids are right for the job?

Why?

SUPERHERO SCENARIO C: The Super Rail is down! We need a superhero to lift the train cars back to the tallest train bridge.

Which of your superhero kids are right for the job?

Why?

GRADING RUBRIC – FOR TEACHER		
Genetic traits of 10 offspring are clearly identified. Score _____/_____	Working knowledge of selective breeding is demonstrated through logical responses to scenarios. Score _____/_____	Sections are thoroughly completed on handout. Score _____/_____

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

Superhero! (Continued)



GENETIC TRAIT

Height: **Short**

GENETIC TRAIT

Height: **Tall**

GENETIC TRAIT

Strength: **Strong**

GENETIC TRAIT

Strength: **Weak**

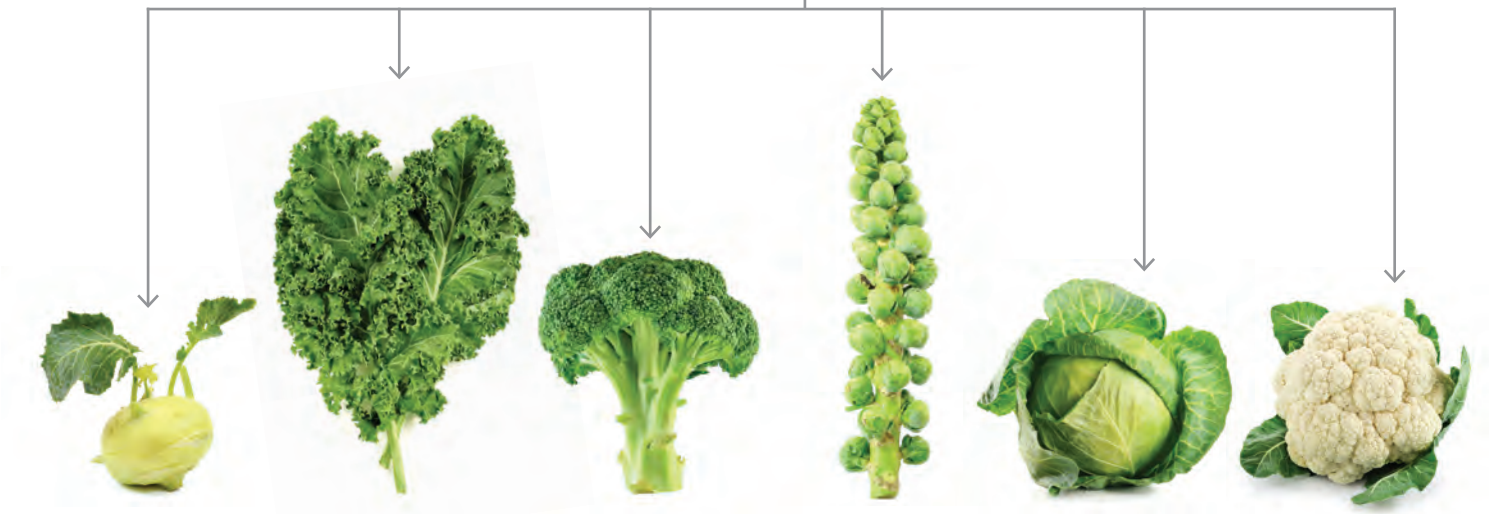
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NAME: _____ DATE: _____ CLASS PERIOD: _____

WILD MUSTARD PLANT



WILD MUSTRAD PLANT (BRASSICA OLERACEA)



Kohlrabi	Kale	Broccoli	Brussels sprouts	Cabbage	Cauliflower

STRAIN

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

Pre/Post Learning Assessment

1. What is selective breeding?

2. Why has selective breeding become part of human impact on plant and animal life?

3 LESSON HANDOUT
Bringing Biotechnology to Life · Educator's Guide

NAME: _____ DATE: _____ CLASS PERIOD: _____

Pre/Post Learning Assessment

1. What is selective breeding?

2. Why has selective breeding become part of human impact on plant and animal life?

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

RUBRIC

		ADVANCED	PROFICIENT	NOVICE
DISCIPLINARY CORE IDEAS	Inheritance of Traits	Student can explain plants and animals have desirable traits and humans have participated in selective breeding of plants and animals for thousands of years. Student can explain the advantages and disadvantages of selectively breeding annual plants versus perennials.	Student can explain plants and animals have desirable traits and humans have participated in selective breeding of plants and animals for thousands of years.	Student can explain that plants and animals have desirable traits that humans want to duplicate through selective breeding.
	Variation of Traits			
PRACTICES	Developing and Using Models	Student followed the superhero procedures and was able to select the correct superhero kids for each job scenario. Student correctly explained why the superhero traits match the job scenario.	Student followed the superhero procedures and was able to select the correct superhero kids for the job scenarios.	Student followed the superhero procedures but did not select all the correct superhero kids for the job scenarios.
CROSS-CUTTING CONCEPTS	Cause and Effect	Student can explain if humans select and breed organisms with desirable traits, then the result is a percentage of the offspring will have the desirable traits. Student can explain there are different processes of selection of desirable traits.	Student can explain if humans select and breed organisms with desirable traits, then the result is a percentage of the offspring will have the desirable traits.	Student can explain if humans select and breed organisms with desirable traits, then the result is the offspring will have the desirable traits.

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DRIVING QUESTION: WHAT IS BIOTECHNOLOGY?

LENGTH: 1 hour

OBJECTIVES: Students will be able to:

- define biotechnology
- identify how biotechnology can help the environment
- identify how biotechnology can improve our food supply

Standards:

Next Generation Science Standards Addressed

Disciplinary Core Ideas

LS3.A Inheritance of Traits

Practices

Asking Questions

Cross-Cutting Concepts

Patterns: Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them.

Common Core English Language Arts Standards Addressed

Writing Standards 6-12, Text Types and Purposes (2)
Write informative/explanatory texts to examine a topic and convey ideas, concepts and information through selection, organization and analysis of relevant content.

Materials:

- Copies of Lesson 4 Student Handout: The Technology of Life (1 per student)
- TV monitor or projector/screen and speakers
- Internet connection with YouTube access

Suggested Video:

"Your Food, Farm to Table" by FoodInsightTV

https://www.youtube.com/watch?v=K1XbEpNZ5yk (2:41)

"Food Biotechnology: Get the Facts" by FoodInsightTV

https://www.youtube.com/watch?v=b8EDEimG-DY (1:48)

Lesson Context

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

Students will continue to build their understanding of DNA and selective breeding during Lesson 4 as they dive into biotechnology. After a short review of DNA and selective breeding, there is a particular focus on biotechnology assistance with the food supply and the environment. This continues with a challenge for the students to organize their questions and understandings of selective breeding, plant biotechnology and organic production. They are finally encouraged to research any unanswered questions from reliable sources to bring back to class for a continued discussion. By the end of this lesson, students will have defined biotechnology and pursued their understanding of the overlapping relationships of selective breeding, biotechnology and organic production.

KEY CONCEPTS: The USDA's National Institute of Food and Agriculture defines plant biotechnology as "a set of techniques used to adapt plants for specific needs or opportunities."

SETUP: Write the key terms "DNA" and "Selective Breeding" on a whiteboard or display with projector. Preview videos and prepare copies of student handouts.

Outline:

1. Set context for lesson by reviewing key concepts from previous lessons. Refer to the terms on the board.
   - *What is DNA?* (Listen for: DNA is a large molecule that contains the genetic information for organisms.)
   - *What is selective breeding?* (Listen for: Selective breeding is the process of changing a population over time by selecting for desired genetic traits to produce the next generation. Plant breeders and researchers use molecular markers, which are identified gene sequences, to identify these traits without altering the genes in the organism.)[ix]
   - *What do you imagine could be some of the challenges of selective breeding?* (Listen for: Selective breeding takes a significant amount of time. Selective breeding also does not allow you to isolate one trait; many traits are passed on together to each generation, which may have a positive or negative impact in the given scenario.)
2. Play the video "Your Food, Farm to Table" (2:40) by FoodInsightTV at https://www.youtube.com/watch?v=K1XbEpNZ5yk.
3. Add the word "biotechnology" to the white board or projector screen. Give students a few minutes to brainstorm what they know about biotechnology independently or in groups.

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4. Ask students to break down the word and define each part.
   - "bio": life
   - "technology": using science to invent things or solve problems[x]
5. Share with the students that there are many definitions of biotechnology. Surprisingly, the term biotechnology was first coined in 1919. Karl Ereky, a Hungarian engineer, first used the term and defined it as "all lines of work involved in creating products from raw materials with the aid of living organisms." We are going to focus on plant biotechnology. The USDA's National Institute of Food and Agriculture defines plant biotechnology as "a set of techniques used to adapt plants for specific needs or opportunities."
   - Ask students: What do you hear about biotechnology? What concerns do you have?
   - Emphasize that students will have the opportunity to form their own opinion. The goal of this exercise is to take a look at what science says about biotechnology.
6. Distribute student handout The Technology of Life. Have students capture the definition of plant biotechnology.
7. Preview two guiding principles: Plant biotechnology can help the environment and the food supply. Ask students to look for examples of these two claims as they watch a short video.
8. Play the video "Food Biotechnology: Get the Facts" (1:47) by FoodInsightTV at https://www.youtube.com/watch?v=b8EDEimG-DY.
9. Have students capture notes and share responses. Ask students: *What is the need driving this technology?* (Listen for students to share about the demands on our environment to produce enough food to sustain a growing population.) Clarify that we will need all farming technologies/practices to feed, fuel and provide fiber to a growing population, and these methods can coexist.
10. Direct students' attention to the second half of the student handout What's in a Name? This section helps students distinguish between the terms "selective breeding," "plant biotechnology," and "organic production." Have students begin by writing down their assumptions in the table. Next, share the following information:
    - **Selective Breeding** is the process of changing a population over time by selecting for desired genetic traits. Plant breeders and researchers use molecular markers, which are identified DNA, to identify these traits without altering the genes in the organism.[xii] It is actually only very recent that the use of molecular markers has become widespread. For most of the history of selective breeding, the selection has been based on choosing preferred phenotypes, which are characteristics of the visible appearance of a plant or animal.
    - **Plant Biotechnology** is defined by USDA's National Institute of Food and Agriculture as a set of techniques used to adapt plants for specific needs or opportunities.
    - **Organic Production** refers to the growing process a farmer uses, not the actual seed. Organic production must follow specific guidelines as outlined by the USDA.[xiii] The use of genetically engineered seed is prohibited in organic production.[xiv]
11. Challenge students to review the organization of these three classifications and generate questions about their relationships.
12. Create a space on the whiteboard or a bulletin board for unanswered questions. Challenge students to seek answers from reliable sources and bring information back to class.

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 DNA? Deoxyribonucleic acid
2. Why is DNA important in trait inheritance? DNA carries the genetic information from parent to offspring from generation to generation.
3. What is selective breeding? The process of changing a population over time by selecting for desired genetic traits in the following generations. Plant breeders and researchers use molecular markers, which are specific gene sequences, to identify these traits without altering the genes in the organism.
4. What is plant biotechnology? The USDA's National Institute of Food and Agriculture defines plant biotechnology as "a set of techniques used to adapt plants for specific needs or opportunities."
5. How can plant biotechnology help the environment? Less pesticides, less land and less water use are needed with advancements made in biotechnology.
6. How can plant biotechnology help the food supply? Enhance nutrition, more healthful fats, eliminate trans fats, enhance food production
7. What is organic production? Organic production is a system that integrates "cultural, biological, and mechanical practices that foster cycling of resources, promote ecological balance, and conserve biodiversity." (Source: National Organic Program)

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. The videos are excellent resources for information. The "Your Food, Farm to Table" video is paced very quickly and the information delivery is by reading only. It is recommended that the teacher mute the sound and push pause as appropriate for students to read through each screen change. Teacher should read aloud to the students and elaborate on any words that may be new to them.
   b. The "Food Biotechnology: Get the Facts" video may need to be played more than once for the students to capture all the food and environmental benefits to biotechnology. Ask students to share observations. As students share, others in the class will write down any information any that they missed.

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2. For students who have already met performance expectations and have high interest:
   a. Organic production is a system that integrates "cultural, biological, and mechanical practices that foster cycling of resources, promote ecological balance, and conserve biodiversity." (Source: National Organic Program) Research what "conserve biodiversity" means and address its relationship with biotechnology.
3. For students who are English Language Learners, have special needs or are reading below grade level:
   a. The video modifications suggested for all students will assist ELL students. The videos are picture/graphic rich, which will help with some comprehension. Translation of the key terms for this lesson will benefit the student also. Biotechnology, environment, food supply and organic production are all key terms.
   b. Partnering the ELL student with a bilingual student may assist as information from the videos is a critical foundation for the products of Lesson 4.
4. For engaging ways to connect learning to students' home and community:
   a. Research where the closest farm is from where you live. If possible, identify conventional and certified organic farms.
   b. What methods of biotechnology are located in your area?
   c. Research how many people lived in your city in 1975 as compared to today. If a U.S. farm then could feed less than 100 people a year, how many farmers were needed in 1975 to feed all our citizens? Research how many people live in your city today. Today, each U.S. farm can feed 168 people each year. How many farmers are needed to feed your city? Do you think there has been an increase in farmland available or a decrease in recent years? Why?

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.

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

THE TECHNOLOGY OF LIFE

What is plant biotechnology?

How can plant biotechnology help the environment?	How can plant biotechnology help the food supply?

What's in a name?

Selective Breeding	Biotechnology	Organic Production

GRADING RUBRIC – FOR TEACHER		
Specific examples for helping the environment and food supply are listed. Score _____/_____	Table shows clear comparison of terms. Score _____/_____	Sections are thoroughly completed on handout. Score _____/_____

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NAME: _____ DATE: _____ CLASS PERIOD: _____

Pre/Post Learning Assessment

1. What is DNA?

2. Why is DNA important in trait inheritance?

3. What is selective breeding?

4. What is plant biotechnology?

5. How can plant biotechnology help the environment?

6. What is organic production?

4 LESSON HANDOUT
Bringing Biotechnology to Life · Educator's Guide

NAME: _____ DATE: _____ CLASS PERIOD: _____

Pre/Post Learning Assessment

1. What is DNA?

2. Why is DNA important in trait inheritance?

3. What is selective breeding?

4. What is plant biotechnology?

5. How can plant biotechnology help the environment?

6. What is organic production?

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NAME: _____ DATE: _____ CLASS PERIOD: _____

RUBRIC

		ADVANCED	PROFICIENT	NOVICE
DISCIPLINARY CORE IDEAS	Inheritance of Traits	Students can explain the impact plant biotechnology has had as beneficial traits of plants have impacted the food supply and the environment. Students can list the benefits for both food and environment.	Students can explain the impact plant biotechnology has had as beneficial traits of plants have impacted the food supply and the environment. Students can list the benefits for food or environment.	Students can explain the impact plant biotechnology has had as beneficial traits of plants have impacted the food supply and the environment but cannot list any specific benefits.
PRACTICES	Asking Questions	Student followed-up with the handout chart and created seven or more questions to research from a reliable source and the source citation was included.	Student followed-up with the handout chart and created at least six questions to research from a reliable source and the source citation was included.	Student followed-up with the handout chart and created at least three questions to research from a reliable source and the source citation was included.
CROSS-CUTTING CONCEPTS	Patterns	Student can explain the similarities and differences of selective breeding, plant biotechnology and organic production. Student can elaborate on organic production focused on conserving biodiversity and what that means in a world of ever-increasing use of plant biotechnology.	Students can explain the similarities and differences of selective breeding, plant biotechnology and organic production.	Students can explain the similarities or differences of selective breeding, plant biotechnology and organic production.

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DRIVING QUESTION: HOW IS BIOTECHNOLOGY USED?

LENGTH: 1 hour

OBJECTIVES: Students will be able to:

- identify specific ways biotechnology can improve food nutrition, safety and quality
- identify specific ways biotechnology supports social, economic and environmental sustainability
- identify specific ways biotechnology helps to meet the increasing needs of the world's growing population

Standards:

Next Generation Science Standards Addressed

Disciplinary Core Ideas

LS3.A Inheritance of Traits

Practices

Engaging in an Argument From Evidence

Cross-Cutting Concepts

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

National Standards for Art Education Addressed

NA-VA.9-12.1 Understanding and Applying Media, Techniques and Processes

Materials:

- TV monitor or projector/screen and speakers
- Internet connection with YouTube access
- Copies of "Food Biotechnology: A Communicator's Guide to Improve Understanding" (pages 6–11) available at www.foodinsight.org/biotech (1 per group of 2–3 students)
- Blank sheet of paper (1 per group of 2–3 students)
- Coloring utensils (1 set per group of 2–3 students)
- Sample infographic images. Great examples can be found by simply searching Google images for "infographics."

Suggested Video:

"What are the Benefits of Food Biotechnology" by FoodInsightTV

http://www.foodinsight.org/media/food-biotechnology-videos (2:33)

Lesson Context

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

Now that the students have defined plant biotechnology during Lesson 4, it is time to identify specific ways biotechnology can improve food nutrition, help the environment and meet the needs of the world's growing population. During Lesson 5, student teams become chief communicators as they prepare an infographic to convey an assigned key message about biotechnology. They will use pages 6–11 of "Food Biotechnology: A Communicator's Guide to Improve Understanding" as a key resource. This will need to be downloaded from www.foodinsight.org/foodbioguide.aspx and a copy provided to each student group.

KEY CONCEPTS: Biotechnology is being used to improve nutrition and enhance food safety and quality. Biotechnology supports the social, economic and environmental sustainability of agriculture. Biotechnology has a role to play in ensuring that safe and abundant food can be produced on existing farmland to meet the increasing needs of the world's growing population. In addition to food applications, biotechnology is used in other areas such as pharmaceuticals and environmental protection, such as the use of bacteria to clean up oil spills (bioremediation).

SETUP: Preview video and find examples of infographics. Set up coloring utensils and supplies. Prepare copies of handouts.

Outline:

1. Challenge students to recall five things they have learned in their exploration of biotechnology thus far. When they have five, they are to turn to a partner, share and give a high five.
2. Play the video "What Are the Benefits of Food Biotechnology" (2:33) by FoodInsightTV at http://www.foodinsight.org/media/food-biotechnology-videos.
3. Introduce the concept of infographics. Ask students if they are familiar with the term "infographic." Have them speculate what it might mean. (Listen for: An infographic is an image that conveys information using graphics. They are commonly seen in social media, magazines, commercials, etc.)
4. Share sample infographics found online. Ask students to generate a class checklist for qualities that make a great infographic. (Listen for observations such as purposeful graphics, minimal text and large numbers.)
5. Introduce infographic design project: In collaborative working groups, students will create an infographic using evidence to create an argument communicating the three key benefits of biotechnology. Break students into groups of two to three. Give each group a copy of "Food Biotechnology: A Communicator's Guide to Improve Understanding" pages 6–11.

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- Assign each group one of the three selected key messages:
  - (Message One) Plant biotechnology is being used to improve nutrition, enhance food safety and quality.
  - (Message Two) Biotechnology supports the social, economic and environmental sustainability of agriculture.
  - (Message Three) Biotechnology has a role to play in ensuring that safe and abundant food can be produced on existing farmland to meet the increasing needs of the world's growing population.

6. Instruct students to review the content provided for their section. Challenge student groups to highlight the three to five most interesting facts they discovered. In making their selection, prompt students to identify the need and summarize what research says about the need. Inform students that they will be asked to present their infographic.
7. Guide students as they work together to create an infographic communicating this information.
8. Have students present their infographics to the class.
9. Collect infographics and post them in a common area.
10. Remind students that fear of change is often driven by a lack of understanding. Effective communication of research-based information is crucial in the process of developing new strategies for solving problems.

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 file for your students.

1. What is plant biotechnology? The USDA's National Institute of Food and Agriculture defines plant biotechnology as "a set of techniques used to adapt plants for specific needs or opportunities."
2. What are some specific ways biotechnology can improve food nutrition, food safety and food quality? See pages 6–7 of "Food Biotechnology: A Communicator's Guide to Improve Understanding."
3. What are some specific ways biotechnology can support social, economic and environmental sustainability? See pages 8–10 of "Food Biotechnology: A Communicator's Guide to Improve Understanding."
4. What are some specific ways biotechnology helps to meet the increasing needs of the world's growing population? See pages 10–11 of "Food Biotechnology: A Communicator's Guide to Improve Understanding."

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. Students may have seen an infographic before on social media and not known what it is called. This could be an opportunity for them to create an infographic of something they know well to share details about it. Before the infographic design challenge, but after sharing infographic examples, have the students research something they enjoy and create an infographic to hang around the classroom.
2. For students who have already met performance expectations and have high interest:
   a. Using the resource "Food Biotechnology: A Communicator's Guide to Improving Understanding," have students research the answers to these tough questions.
      - Is there danger in genetically altering foods? What does research say?
      - Should GMO foods be labeled? What would be the effect of doing this?
      - What is the role of GM crops in alleviating world hunger?
      - What is the environmental impact of biotechnology?
      - Will biotech crops compromise seed integrity?
      - Are there any long-term studies on the health effects of genetically modified foods?
3. For students who are English Language Learners, have special needs or are reading below grade level:
   a. As the teacher chooses example infographics, selection should include easy-to-interpret images and numbers to provide access to the ELL students and their understanding of the assignment.
4. For engaging ways to connect learning to students' home and community:
   a. Have students explore "U.S. School Lunch Nutrition Facts & Calories," (http://nutritiondata.self.com/facts/recipe/1163312/2) where near the bottom of the page there is a sample school lunch of a hotdog with ketchup and mustard, with sides of French fries and raw broccoli and cauliflower and ranch dressing. Included is the nutrition label for this school lunch and infographics that graphically represent various aspects of the lunch such as a "fullness factor" or "nutrient balance" with a completeness score. Have the students pick an infographic and click on the link "How to interpret this" at the top of the page to assist with the nutritional information explanation. Have students report on their chosen information about the school lunch and what the graphic means.

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.

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

INFOGRAPHIC DESIGN

Your Task: Create an infographic communicating one of the three key benefits of biotechnology.

Our key message is:

_____ Biotechnology is being used to improve nutrition, enhance food safety and quality.

_____ Biotechnology supports the social, economic and environmental sustainability of agriculture.

_____ Biotechnology has a role to play in ensuring that safe and abundant food can be produced on existing farmland to meet the increasing needs of the world's growing population.

What makes a great infographic? Create a checklist below based on the ideas your class discusses.

- ☐ _____
- ☐ _____
- ☐ _____
- ☐ _____
- ☐ _____
- ☐ _____
- ☐ _____
- ☐ _____
- ☐ _____
- ☐ _____

What is the need (assumption) behind your key message?

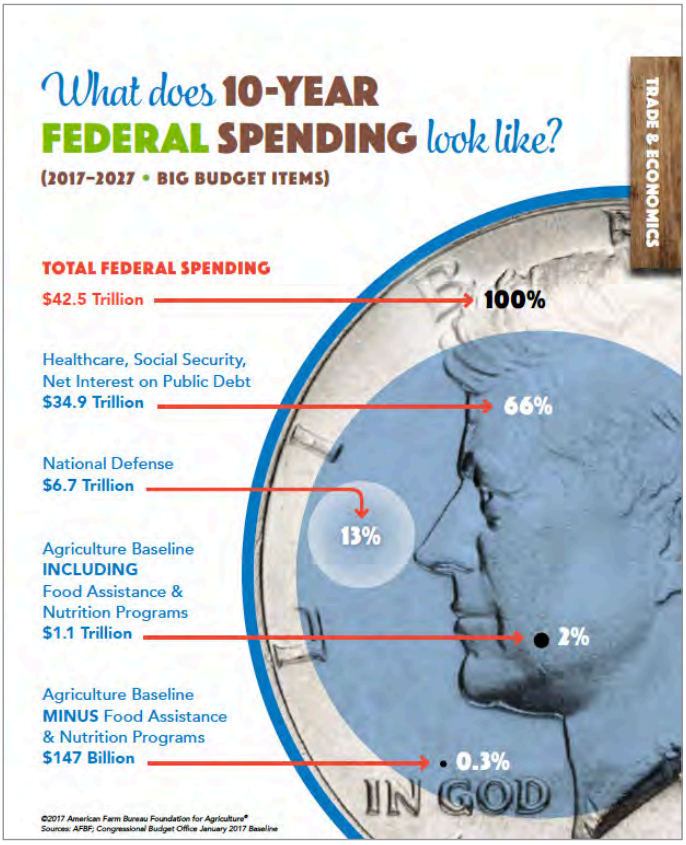
What does research say about your key message?

GRADING RUBRIC – FOR TEACHER		
Factual information is presented in the infographic. Score _____/_____	The infographic focuses on the selected key message. Score _____/_____	The infographic follows the student-driven checklist "What makes a great infographic?" established by the class. Score _____/_____

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INFOGRAPHIC SAMPLES



This sample infographic from Food and Farm Facts, by the American Farm Bureau, shows a single image with supporting text to convey a message.

This sample infographic from Food and Farm Facts, by the American Farm Bureau, shows multiple images with supporting text to convey a message.



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

Pre/Post Learning Assessment

1. What is plant biotechnology?

2. What are some specific ways biotechnology can improve food nutrition, food safety and food quality?

3. What are some specific ways biotechnology can support social, economic and environmental sustainability?

4. What are some specific ways biotechnology helps to meet the increasing needs of the world's growing population?

5 LESSON HANDOUT
Bringing Biotechnology to Life · Educator's Guide

NAME: _____ DATE: _____ CLASS PERIOD: _____

Pre/Post Learning Assessment

1. What is plant biotechnology?

2. What are some specific ways biotechnology can improve food nutrition, food safety and food quality?

3. What are some specific ways biotechnology can support social, economic and environmental sustainability?

4. What are some specific ways biotechnology helps to meet the increasing needs of the world's growing population?

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NAME: _____ DATE: _____ CLASS PERIOD: _____

RUBRIC

		ADVANCED	PROFICIENT	NOVICE
DISCIPLINARY CORE IDEAS	Inheritance of Traits	The student can explain the key issues that were focused on during the infographic design challenge and identify specific inherited traits of an organism that will assist with the key issues.	The student can explain the key issue that was focused on during the infographic design challenge and identify specific inherited traits of an organism that will assist with the key issue.	The student can identify specific inherited traits of an organism that connects to data on the infographic but does not explain how it will assist with the key issue.
PRACTICES	Engaging in an Argument From Evidence	The student can use information from the infographic design challenge to effectively convey the benefits of the use of biotechnology in ALL of the key areas: in food nutrition, safety and quality; how it supports social, economic and environmental sustainability; how it meets the needs of world's growing population.	The student can use information from the infographic design challenge to effectively convey the benefits of the use of biotechnology in one of the key areas: in food nutrition, safety and quality; how it supports social, economic and environmental sustainability; how it meets the needs of world's growing population.	The student uses information from the infographic design challenge to convey benefits of the use of biotechnology without identifying specific key areas that were assigned.
CROSS-CUTTING CONCEPTS	Cause and Effect	Student can explain specific ways biotechnology is utilized to benefit food nutrition, safety and quality. Also, how it supports social, economic and environmental sustainability to meet the needs of world's growing population. The student can also answer tough questions about the use of GMOs.	Student can explain specific ways biotechnology is utilized to benefit food nutrition, safety and quality. Also, how it supports social, economic and environmental sustainability to meet the needs of world's growing population.	Student can explain specific ways biotechnology is utilized to benefit food.

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DRIVING QUESTION: HOW DO RESEARCHERS COMPARE DNA?

LENGTH: 1 hour

OBJECTIVES: Students will be able to:

- demonstrate knowledge of the gel electrophoresis process

Standards:

Next Generation Science Standards Addressed

Disciplinary Core Ideas

LS3.A Inheritance of Traits

LS3.B Variation of Traits

Practices

Developing and Using Models

Cross-Cutting Concepts

Patterns: Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them.

Materials:

- Computers with internet access (1 per student or class computer with projector)
- Copies of Lesson 6 Student Handout: Electrophoresis Exploration (1 per student)
- Optional: gel electrophoresis lab kits for extension

Suggested Video:

"Gel Electrophoresis" by Kahn Academy Medicine

https://www.youtube.com/watch?v=mN5IvS96wNk (6:58)

Lesson Context

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

Back in Lesson 2, the students extracted DNA from fruits and vegetables. This is where they first learned that DNA is a large molecule of genetic information. They also learned that with the use of restriction enzymes, certain genes can be cut out of the DNA molecule and sorted by running them through a gel electrophoresis process. During Lesson 6 the students will learn more about gel electrophoresis as they view a video on a gel electrophoresis lab. This lesson culminates with an online virtual lab of electrophoresis where students "run a gel," summarize each step and create an icon for each major step in the process.

KEY CONCEPTS: Gel electrophoresis is a process that enables researchers to take a closer look at DNA. An electrical current passes from a negative electrode, through a gel (like a slab of Jello) to a positive electrode. Samples of DNA of different lengths are placed into the gel at one end, and their negative charge carries them with the current toward the positive electrode. The smaller molecules move faster, and the DNA molecules are thus sorted according to their size. A large number of molecules of a specific size will move at the same rate and appear as a band in the gel, which can be made visible with UV light. Researchers can compare different bands of DNA to detect changes in the DNA sequence.[xv]

SETUP:

- Ensure computer settings allow access to the gel electrophoresis simulation site and video.
- Prepare copies of the student handout.
- If you do not have access to an electrophoresis kit, it may be helpful to prepare a short slide deck showing electrophoresis equipment.

Outline:

1. Ask the students to recall what they know about the structure of DNA. Remind students that in eukaryotic organisms chromosomes are found in the nucleus of the cell. Chromosomes are made up of DNA. Genes on the DNA (genotype) code for specific traits (phenotype). Ask students to consider: How do scientists distinguish one set of DNA from another?
2. Explain that scientists discovered that DNA could be made to move through a gel using electrical charge.
3. Distribute student handout Electrophoresis Exploration. Preview the handout with students.
4. Play the video "Gel Electrophoresis" by Kahn Academy Medicine, found at https://www.youtube.com/watch?v=mN5IvS96wNk
5. Ask students to recall key words or short pieces of information from the brief video. Have students first capture these on their handout and then share.
6. Walk students through the process in greater detail. Challenge students to listen for key components of the process and capture notes on the student handout.
    - Just like a motorcycle can move more quickly through heavy traffic than a large truck, smaller molecules move more quickly than larger molecules through this gel.

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- The DNA molecules can be allowed to proceed for a given amount of time and then frozen in place by removing the electrical current before all molecules have time to get to the end. If the whole class were told to run to the end of the hall and when the fastest student got near the end all were told to freeze, the students would be spaced out.
    - To help students grasp this concept, you may want to facilitate this activity with students in a large, safe area. Prior to having students move, instruct a portion of the class to run, a portion to walk quickly, and a portion to walk slowly.
- This process is used to sort DNA into a line from small to large strands.
- Strands of the same length appear as though they clump together. These strands form distinct bands. The bands can then be compared with a known DNA composition of the same organism to determine which proteins are present. Each organism has a unique series of bands.
    - Think of these DNA bands as a secret code. If you have the "decoder" (known DNA composition of an organism), you can use that to identify unknown DNA.
- Whole DNA, like the DNA extracted in Lesson 2, does not show this banding pattern. Cutting the DNA with "restriction enzymes" generates the banding pattern. These enzymes recognize specific DNA sequences, usually 6–8 base pairs in length, and cut the DNA strand at that site. Fragments of the same length will then move through the gel at the same speed.

7. Have the students access the Genetic Science Learning Center website at the University of Utah at http://learn.genetics.utah.edu/content/labs/gel/. If student computers are not available, access the site using a projector and screen. Conduct the step-by-step virtual gel electrophoresis. You may wish to have students work independently or in pairs.
    - As students work, have them summarize each step in three to five words on the student handout.
    - If you do not have access to internet in class, you may wish to take screen shots of the process prior to class and share with your students.
8. After the virtual lab is complete, have students finish the handout by creating an icon for each step in the electrophoresis process covered in the simulation.
    - After students have created an initial draft, have students work in pairs to review one another's work and provide feedback.
    - Have students revise their process summary and submit.

ENRICHMENT OPPORTUNITY: You may wish to have students conduct a real gel electrophoresis experiment. You can learn how to build an electrophoresis chamber at http://learn.genetics.utah.edu/content/labs/gel/build_gel_box.pdf or search a major laboratory supplies distributor for an electrophoresis kit.

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 gel electrophoresis? A lab technique for separating cellular information such as DNA or protein based on their size.
2. Why is electricity used during gel electrophoresis? DNA has a negative charge and the attraction to the positive side (anode) of the gel electrophoresis box allows the DNA samples to migrate down the gel over time.
3. What is the purpose of the gel in gel electrophoresis? The gel acts like a filter that sorts the DNA strands based on their size. The shorter stands of DNA will move farther away from the starting point than the longer strands of DNA. DNA strands of the same length will move at the same speed and end up grouped together.
4. In what ways does the process of gel electrophoresis assist scientists? DNA strands or genes of the same length will move at the same speed and end up grouped together on the gel. Scientists can cut the desired genes out of the gel to utilize in future tests.

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. After the Khan Academy video but before the online virtual lab, students should view the video from Lesson 2 again to make the connection of the role gel electrophoresis plays in gene isolation and use. https://www.youtube.com/watch?v=nfC689ElUVk
2. For students who have already met performance expectations and have high interest:
    a. Electrophoresis is one of those inventions that has changed modern science in remarkable ways. Have students research Oliver Smithies' work as a scientist, which includes being the first to use starch as a medium for gel electrophoresis in 1955.
3. For students who are English Language Learners, have special needs or are reading below grade level:
    a. Partner students during the online virtual lab of electrophoresis.
    b. You may wish to guide ELL students through the gel electrophoresis online lab.
4. For engaging ways to connect learning to students' home and community:
    a. Forensics science on television has become one of the most popular themes influencing countless crime shows. Have the students list some crime shows they

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know of on television. Ask if they have ever heard of the term of "DNA fingerprinting." DNA fingerprinting uses gel electrophoresis to distinguish between samples of genetic material through the size sorting characteristic of the gel. The sorted genetic material form bands. For individual people, the bands of DNA created through this process will have a pattern that is specific to the individual. In forensics, suspects can be eliminated if their DNA pattern does not match the pattern of the DNA molecules found the crime scene.

b. Consider posting the gels of a gel electrophoresis after a run and show how these can be used to match or eliminate suspects.

Rubrics

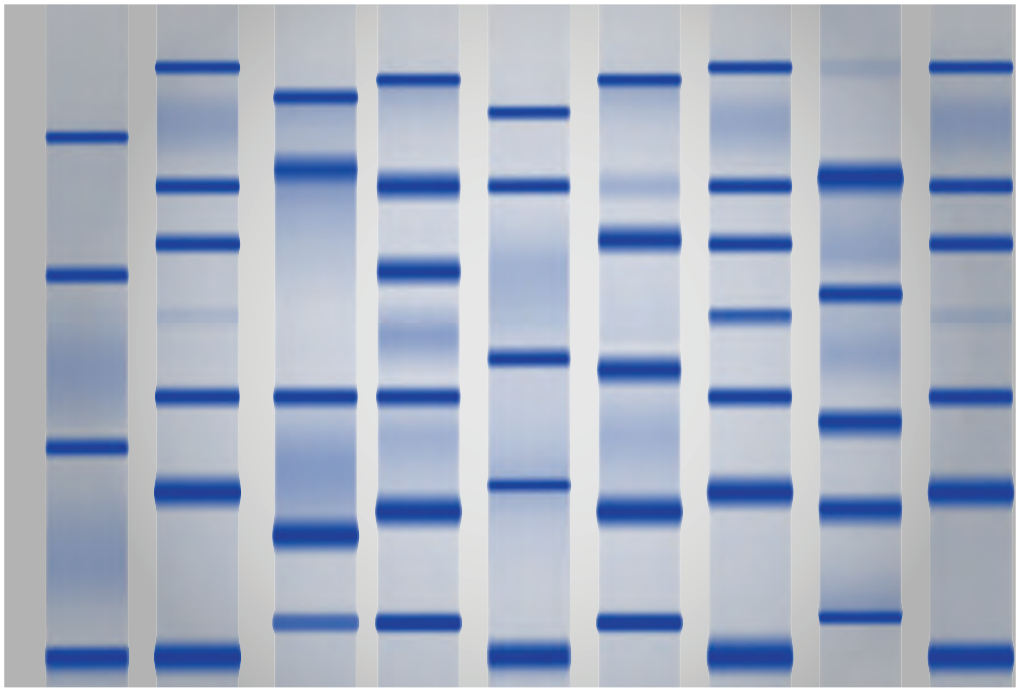
We have created two optional tools for evaluating learning at the end of each lesson.

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NAME: _____ DATE: _____ CLASS PERIOD: _____

ELECTROPHORESIS EXAMPLES



Gel Electrophoresis Separation Sample

Gel Electrophoresis Equipment



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

ELECTROPHORESIS EXPLORATION

What is gel electrophoresis?

Why is it used? What is the purpose?

Complete the virtual lab at http://learn.genetics.utah.edu/content/labs/gel/. Summarize each major step you took in the gel electrophoresis laboratory in three to five sentences below.

Create an icon for each major step in the electrophoresis process.

GRADING RUBRIC – FOR TEACHER		
Gel electrophoresis is defined and explained clearly. Score _____/_____	Each major step in the electrophoresis process is listed and an icon is included to support. Score _____/_____	The student lab is thoroughly completed. Score _____/_____

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LESSON HANDOUT 6

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

Pre/Post Learning Assessment

1. What is gel electrophoresis?

2. Why is electricity used during gel electrophoresis?

3. What is the purpose of the gel in gel electrophoresis?

4. In what ways does the process of gel electrophoresis assist scientists?

Bringing Biotechnology to Life · Educator's Guide

LESSON HANDOUT 6

NAME: _____ DATE: _____ CLASS PERIOD: _____

Pre/Post Learning Assessment

1. What is gel electrophoresis?

2. Why is electricity used during gel electrophoresis?

3. What is the purpose of the gel in gel electrophoresis?

4. In what ways does the process of gel electrophoresis assist scientists?

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NAME: _____ DATE: _____ CLASS PERIOD: _____

RUBRIC

		ADVANCED	PROFICIENT	NOVICE
DISCIPLINARY CORE IDEAS	Inheritance of Traits	Student can explain that genes with desired traits can be sorted using gel electrophoresis and that the reason they sort is the variation in the size of the DNA samples. Students can further explain the sorted genes are cut out of the gel in isolation to be used in genetic engineering through transgenics.	Student can explain that genes with desired traits can be sorted using gel electrophoresis and the reason they sort is the variation in the length of the DNA segments.	Student can explain that desired genes can be sorted using gel electrophoresis.
	Variation of Traits			
PRACTICES	Developing and Using Models	Student followed the gel electrophoresis virtual lab, created icons for each major step of gel electrophoresis and included detailed descriptions of the step the icon represents.	Student followed the gel electrophoresis virtual lab and created icons for each major step of gel electrophoresis.	Student followed the gel electrophoresis virtual lab and created icons for the steps of gel electrophoresis but missed one or more major steps.
CROSS-CUTTING CONCEPTS	Patterns	Student can explain the reason DNA samples band in the gel at different distances from the starting point due to their lengths in numbers of base pairs as compared to a DNA size standard sample that was run as a comparison. They can also accurately estimate the length of the DNA sample in base pairs of the virtual electrophoresis lab.	Student can explain the reason DNA samples band in the gel at different distances from the starting point due to their lengths in numbers of base pairs as compared to a DNA size standard sample that was run as a comparison.	Student can explain the reason DNA samples band in the gel at different distances from the starting point due to their lengths in numbers of base pairs.

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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.

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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

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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.

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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

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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

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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]

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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?

Bringing Biotechnology to Life · Educator's Guide

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?

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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.

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DRIVING QUESTION: WHERE IS BIOTECHNOLOGY HEADED?

LENGTH: 1 hour

OBJECTIVES: Students will be able to:

- Compare and contrast gene editing and genetic engineering

Standards

Next Generation Science Standards Addressed

Disciplinary Core Ideas

LS3.A Inheritance of Traits

LS3.B Variation of Traits

Practices

Obtaining, Evaluating and Communicating Information

Cross-Cutting Concepts

Patterns: Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them.

Common Core ELA Standards

Writing Standards 6-12, Text Types and Purposes (2) Write informative/explanatory texts to examine a topic and convey ideas, concepts and information through selection, organization and analysis of relevant content.

Materials

- Biotechnology Venn Diagram handout

Suggested Video

"CRISPR-Cas for Healthy Seed Development" by Pioneer Seeds

https://www.youtube.com/watch?v=KUApt4RIU1M (3:25)

Lesson Context

Students understand the role that genes play in determining the unique characteristics of different organisms. In previous lessons, students have learned how genes can be isolated and then replicated using bacteria. In lesson 7, students learned that desired genes can be inserted into organisms to produce genetically modified crops by transgenics. They have defined selective breeding, biotechnology and GMOs. Now, in lesson 8, students will learn about one of the newest advancements in biotechnology — gene editing — and compare and contrast this technology to genetic engineering. While both gene editing and genetic engineering are techniques used in biotechnology, gene editing takes less time and allows for improved efficiency when compared to genetic engineering. Gene editing is much more precise because it allows scientists to make changes to a specific sequence of DNA within a gene. It's also relatively cost-effective compared to other methods[xxviii], meaning more scientists could gain access to it. In looking at the similarities, gene editing and genetic engineering are both tools that enable plants to produce higher yields, become better tolerant to drought or resistant to disease, or even provide more nutrition for humans who consume these plants.

KEY CONCEPTS: Gene editing allows scientists to make changes to a specific target sequence of DNA within a gene. It modifies the gene in a precise and predictable manner.[xxix] One of the newer gene editing technologies is CRISPR-Cas technology which stands for Clustered Regularly Interspaced Short Palindromic Repeats. With CRISPR-Cas, the most widely used gene editing technology, scientists can program genetic guides to target a location along the plant's DNA where the Cas9 enzyme cuts the DNA. The cells change the DNA sequence as the cut is repaired.[xxx]

SETUP: Preview video listed above. Print Biotechnology Venn Diagram handout.

Outline

1. Ask students to share the definition of plant biotechnology and genetic engineering from previous lessons. Emphasize that biotechnology is the umbrella that covers many different technologies. Genetic engineering falls under this umbrella of plant biotechnology.
2. Share that there are always new technologies evolving to help feed the world, and today students will be learning about one of the newer technologies, gene editing.
3. Recall the discussion students had in lesson 4 about the concerns they may have had before learning more about plant biotechnology and GMOs. Explain that scientists

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continually work to find technologies that will be widely accepted in today's society. This has led to a different kind of plant biotechnology called gene editing.

4. Define gene editing: *Gene editing allows scientists to make changes to a specific target sequence of DNA within a gene. It modifies the gene in a precise and predictable manner.*[xxxi] *One of the newer gene-editing technologies is CRISPR-Cas technology.*
5. Write CRISPR on the board vertically to allow for the acronym to be explained. Write what each letter stands for as you share with the students.

   Clustered
   Regularly
   Interspaced
   Short
   Palindromic
   Repeats

6. Explain CRISPR-Cas: *CRISPR stands for Clustered Regularly Interspaced Short Palindromic Repeats. With CRISPR-Cas, the most widely used gene editing technology, scientists can program genetic guides to target a location along DNA, where the Cas9 enzyme cuts the DNA. The cells change the DNA sequence as the cut is repaired.*[xxxii]
7. *Continue to share further information about gene editing with students: Gene editing tools provide a great deal of flexibility in the kinds of genetic changes that can be made. Changes that can be made include simple edits to, or deletions of, one or a few targeted letters in the genetic code. The tools can also be used to insert much longer genetic sequences from the same species or another one — similar to what can be done with older transgenic technologies. The key difference is that these edits and insertions can be made at very precise locations in the plant's genome.*
8. Divide students into groups of three to four. Hand out the Biotechnology Venn Diagram handout.
9. Set context for activity: *We know that genetic engineering and gene editing are both examples of plant biotechnology, but they do have their differences. Using what we've learned about genetic engineering and what we are going to be learning about gene editing, we will be comparing and contrasting these two technologies.*
10. Instruct groups to write down what they remember about genetic engineering in the "Genetic Engineering" circle of their handout. Give them five minutes to do this.
11. Ask for each group to share one characteristic of genetic engineering until all characteristics have been shared.
12. Have students watch "CRISPR-Cas for Healthy Seed Development" found at https://www.youtube.com/watch?v=KUApt4RlU1M. Instruct them to take notes in the "Gene Editing" circle. If there are similarities between genetic engineering and gene editing, have them write those characteristics where the circles overlap.
13. Explain that gene editing has an advantage over genetic engineering for several reasons. It's more precise than genetic engineering, and technology keeps getting more reliable.[xxxiii] It's also relatively cost-effective compared to other methods, meaning more scientists could gain access to it. All of these advantages mean more potential innovation.[xxxiv]
14. Give students 10 minutes to complete their Venn diagrams in their groups. Walk around the room and answer questions.
15. Have student groups find a partner group to share their Biotechnology Venn diagrams with and discuss what they've learned. Walk around the room and answer questions.
16. Based on what has been learned about the similarities and differences between genetic engineering and gene editing, have a class discussion on students' thoughts on the acceptance of gene editing.

Additional Content Support:

Pre-/Post-Assessment:

What is the definition of plant biotechnology?

- Plant biotechnology is a set of techniques used to adapt plants for specific needs or opportunities.[xxxv]

True or False: Genetic engineering is a type of plant biotechnology.

- True

How does gene editing differ from genetic engineering?

- Gene editing allows scientists to make changes to a specific target sequence of DNA within a gene. Because of this, it is much more precise than genetic engineering. Gene editing takes less time and allows for improved efficiency when compared to genetic engineering.[xxxvi]

Suggested Accommodations:

For students struggling to meet performance expectations:

- Remind students of the structure of a Venn diagram before asking students to complete the diagram with content.
- Discussing knowledge students acquired from previous lessons about genetic engineering will be important to help students compare and contrast genetic engineering and gene editing.
- The "CRISPR-Cas for Healthy Seed Development" video may need to be played more than once for the students to capture all the details around gene editing. Ask students to share observations. As students share, others in the class will write down any information any that they missed.

For students who have already met performance expectations and have high interest:

- Have students investigate applications of gene editing in fields other than agriculture. Consider the following examples:
  - Health/Medical
  - Environmental

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For students who are English language learners (ELL), have special needs or are reading below grade level:

- The video modifications suggested for all students will assist ELL students. The videos are picture/graphic rich which will help with some comprehension.
- Translation of the key terms for this lesson will benefit the student. Plant biotechnology, genetic engineering and gene editing are all key terms.
- Partnering the ELL student with a bilingual student may assist as information from the videos is critical.

For engaging ways to connect learning to students' homes and communities:

- Have students hypothesize what the benefits of more precise, reliable and cost-effective technologies used to adapt plants for specific needs or opportunities would mean for the agriculture industry. How would these benefits for agriculture benefit their community?

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NAME: _____ DATE: _____ CLASS PERIOD: _____

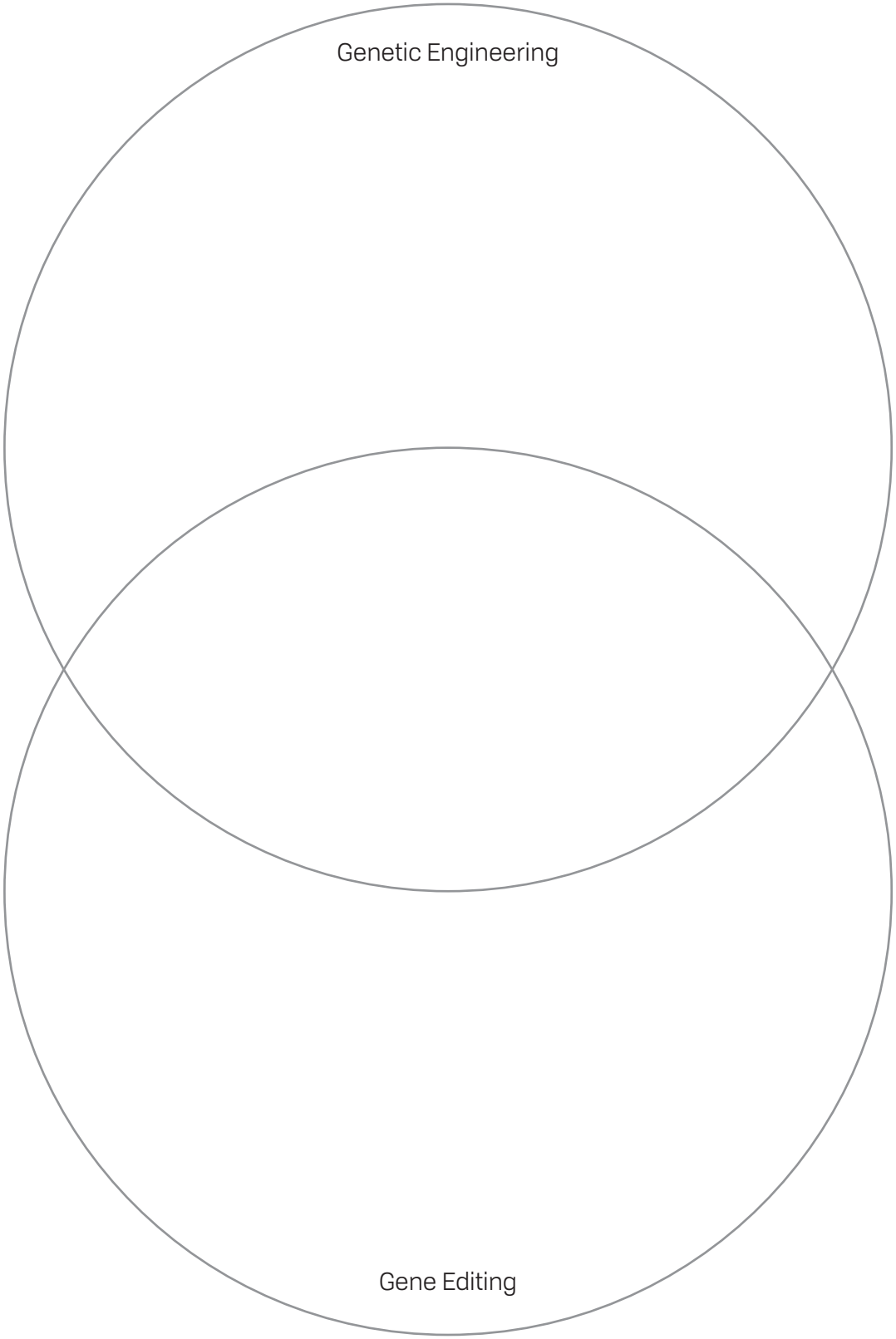
RUBRIC

		ADVANCED	PROFICIENT	NOVICE
DISCIPLINARY CORE IDEAS	Inheritance of Traits	Student can explain the impact that gene editing continues to have on the precision, reliability and cost of technologies used to adapt plants for specific needs or opportunities.	Student can explain some of the impacts that gene editing continues to have on the precision, reliability and cost of technologies used to adapt plants for specific needs or opportunities.	Student can explain the impact that gene editing continues to have on the precision, reliability or cost of technologies used to adapt plants for specific needs or opportunities.
	Variation of Traits			
PRACTICES	Obtaining, Evaluating and Communicating Information	Student can gather information about gene editing and genetic engineering and evaluate information to compare and contrast gene editing and genetic engineering. Based on that information, student can communicate their thoughts on the acceptance of gene editing.	Student can gather information about gene editing and genetic engineering and evaluate information to compare and contrast gene editing and genetic engineering.	Student can gather information about gene editing and genetic engineering.
CROSS-CUTTING CONCEPTS	Patterns	Student can explain the similarities and differences of gene editing and genetic engineering. Student can elaborate on what they believe public perception of gene editing could be in the context of current public perception of GMOs.	Student can explain the similarities and differences of gene editing and genetic engineering.	Student can explain the similarities or differences of gene editing and genetic engineering.

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

BIOTECHNOLOGY VENN DIAGRAM



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RESEARCH AND PUBLIC PRESENTATION

LENGTH: 1 hour plus additional research and presentation time

OBJECTIVES: Students will be able to:

- distinguish between fact and opinion
- use a credibility checklist tool to evaluate online media
- analyze information gathered or provided and categorize it as fact or opinion
- form an opinion on biotechnology, genetic engineering and labeling foods from genetically engineered ingredients using the information gathered
- write an essay expressing their opinions using correct form, grammar and spelling

Standards:

Next Generation Science Standards Addressed

Disciplinary Core Ideas

LS3.A Inheritance of Traits

LS3.B Variation of Traits

LS4.B Natural Selection

Practices

Engaging in Argument From Evidence

Obtaining, Evaluating and Communicating Information

Cross-Cutting Concepts

Cause and Effect: Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability.

Common Core English Language Arts Standards Addressed

Writing Standards 6-12, Text Types and Purposes (1) Write arguments to support claims with clear reasons and relevant evidence.

Writing Standards 6-12, Text Types and Purposes (2) Write informative/explanatory texts to examine a topic and convey ideas, concepts and information through the selection, organization and analysis of relevant content.

Writing Standards 6-12, Research to Build and Present Knowledge (7) Conduct short research projects to answer a question, drawing on several sources and refocusing the inquiry when appropriate.

Materials:

- Copies of Final Project Student Handout: Credibility Checklist (1 per student)
- Copies of Final Project: Student Rubric (1 per student)

KEY CONCEPTS: In our democratic society, all people are urged to be responsible citizens. This responsibility involves a willingness to become informed and involved and the willingness to take action. This lesson, designed to illustrate and encourage responsible citizenship, shows students how to become educated about an issue, examine evidence on all sides of the issue from credible sources and establish a personal position on the issue supported with factual information.

Students will apply knowledge gained from lessons within this unit and utilize the credibility checklist to evaluate information on a relevant issue. Students will have an opportunity to present their report to individuals from outside their classroom (e.g., other teachers, administrators, community members, agriculture industry representatives, etc.) and engage in meaningful dialogue.

SETUP: Secure access to student computers and prepare Final Project: Student Rubric. Identify members to engage in a listening panel for student presentations.

Outline:

1. Set context for the culminating project by reminding students that they have a tremendous opportunity to engage in their community and our country by voicing their opinion. Understanding the strategies for effective communication of opinion and fact is important for students, as consumers and communicators.
2. Ask students to think about where they get their information on a daily basis. As students share, create a list on the board.
3. Have all students stand along one wall in the classroom. Inform students that one corner of the room represents highly reliable sources — sources you would trust more. Point to the opposite side of the room and tell students that this corner represents unreliable sources — sources you would trust less. Ask students to move in the classroom toward one side or the other, based on how reliable they feel each type of information source is.
    - Note: Begin with easy comparisons and gradually work toward more challenging comparisons. It is ok for students to have different opinions about credibility at this stage. The purpose of this activity is to engage critical thinking in preparation for the next step.
    - Sample lead-in examples: teacher (reliable), used car salesman (unreliable), someone next to you on the bus (unknown reliability), your doctor (reliable).

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4. Ask students why it is often hard to assess reliability. Help students discover on their own that reliability of information on a topic is often dependent on the topic itself. For example, you might go to a professional baseball player for reliable information on how to hit a baseball, but just because they are successful in sports does not necessarily make them a reliable source of information on science. Social media and marketing often confuse this situation even more.
5. Inform students that you have a tool that will help them assess the reliability of information in many areas, especially science. Distribute student handout Credibility Checklist. Have students preview the checklist and clarify questions.
6. In class or as a take-home exercise, have students complete the credibility checklist for a website related to biotechnology. You may wish to have students search on their own to show a broad variety of sources, or you may wish to direct students' attention to a reliable database of information found at http://www.geneticliteracyproject.org/external-resources-links/.
7. Assess students' knowledge of the difference between facts and opinions. Define and discuss the differences. (Facts are neutral statements that can be proven. Opinions are points of view, judgments or conclusions.) Explain that opinions are sometimes stated as facts, but that does not make them facts. For example:
   - **Fact:** Many groups use fresh water.
   - **Opinion:** I believe farmers should be able to use as much water as they need.
   - **Opinion Stated as Fact:** It is important for urban areas to have priority in decisions about water use.
8. To reinforce students' understanding of the difference between topics and issues, have students identify the topic in the above example (water use). Then have them state the issue (allocation of water).
9. Explore the tone that writers or speakers use when discussing issues. The tone is the attitude or emotion conveyed toward the subject. With advanced students, discuss the use of the techniques of sidestepping and emotional appeal. For example, a writer debating allocation of water sidesteps the issue when he or she discusses levels of water pollution.
10. Have students work independently or in pairs to find an article online about labeling genetically modified organisms. Ask students to scan the article for facts, opinions and opinions stated as facts. Ask students to share aloud. Capture examples and discuss the importance of being able to read with this "filter" in mind.
11. Have students identify the effect of this article. What does it prompt the reader to do, think or feel? Next, have students identify the cause of that effect. What strategies did the writer use to elicit that response?
12. Help students understand that there are often many sides or positions about an issue. Ask students the following questions with regard to public acceptance of genetically modified organisms.
    - *Are there more than two sides to your issue? How many positions are there?*
    - *What are some of the different positions about your issue?*
    - *What areas of agreement exist between the different positions about your issue?*
    - *What are the exact differences which make it so difficult for individuals or groups to agree?*
13. Distribute Final Project: Student Rubric to students. Students will draft a short research paper sharing facts about both sides of the issue and their opinion about labeling of genetically modified organisms. Discuss rubric and address questions.
14. Allow student work time and clarify expectations for work done outside of class.
15. After research papers are complete, facilitate a presentation event where students share their papers to people beyond the students' classmates and engage in meaningful dialogue.

Research Tips:

You can quickly find peer-reviewed research using Google Scholar http://scholar.google.com/. Want to stay updated on a specific issue? Click on the "Alerts" tab to create an alert for a search topic.

You can also evaluate the credibility of a journal or publishing house by consulting one of the following:

http://www.researchgate.net/post/Where_can_I_find_journals_list_sorted_by_impact_factor_in_Thomson_Reuters_website

https://predatoryjournals.com/journals/

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CREDIBILITY CHECKLIST

Every day we are presented with information. We must determine if the information is valid or biased. As you take in new information, use this checklist to help determine credibility.

- ☐ Source/Website Link:
- ☐ Title of Article/Website:
- ☐ What can you learn from the web address (.com = company, .edu = academic institution, .gov = U.S. government agency, .mil = U.S. military site, .org = nonprofit)?
- ☐ Is there a bibliography included to reference the source(s) of the information?
- ☐ If so, are the sources credible?
- ☐ Are you able to identify an organization or person responsible for the information?
- ☐ What is the track record of the organization sharing the information?
- ☐ By what authority are they making claims? Is it research based?

(continued)

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

Credibility Checklist (Continued)

☐ Is the information shared factual or opinion?

☐ How long has the organization been in existence?

☐ What is the organization's purpose?

☐ Who funds the organization?

☐ When was the site last updated?

☐ Does the site have working links to external web pages?

☐ Is there contact information to follow up with the organization?

GRADING RUBRIC – FOR TEACHER
Credibility checklist is thoroughly completed for the selected site. Score _____/_____

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

Score _____/_____

	ADVANCED	PROFICIENT	NOVICE
Description of "GMOs" and biotechnology	Distinction is made between different processes of genetic modification. Biotechnology is clearly explained including the history and evolution of the science.	Genetic modification is explained at a high level without comparison of processes.	Genetic modification and biotechnology are not explained.
Facts are included and referenced from reliable sources.	Ten or more facts are included with citations listed from reliable sources.	Five to nine facts are included with citations listed from reliable sources.	Facts are omitted and/or a majority of sites are not reliable.
Opinion is expressed on the topic of "GMO" labeling.	The student expresses his/her opinion without passing opinion as fact. The opinion is supported by fact.	The student suggests an opinion but may not clearly make a case for this opinion.	The student does not clearly express his/her opinion.
Grammar, punctuation and fluidity	The student writes with fluid tone, correct grammar and punctuation.	Minor grammar or punctuation errors exist in the paper.	There are significant grammar and/or punctuation errors in the paper.
Presentation	The student confidently presents his/her paper, including fact and opinion.	The student presents portions of his/her paper.	The student does not present his/her paper to the selected audience.

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STUDENT SELF-REFLECTION TOOL

You have an opportunity to brag about your learning! Take a look at the rubric for this lesson. For each section below, tell me what proficiency level you believe you have demonstrated and why.

DISCIPLINARY CORE IDEAS	Proficiency Level I have reached: ☐ Novice ☐ Proficient ☐ Advanced Why?
PRACTICES	Proficiency Level I have reached: ☐ Novice ☐ Proficient ☐ Advanced Why?
CROSS-CUTTING CONCEPTS	Proficiency Level I have reached: ☐ Novice ☐ Proficient ☐ Advanced Why?

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