BIOTECHNOLOGY

Genetic improvement method: genetic engineering

Focus questions	How are breeding techniques being used in agriculture to solve problems? How might we model genetic engineering through paragraph construction?
Learning target	Students synthesize paragraphs about genetically modified organisms.
Vocabulary	GMO, traits, genes

HS-LS3-3: Heredity: Inheritance and Variation of Traits

Performance expectation HS-LS3-2	**Classroom connection:** Students construct a written paragraph using a sentence ("gene") from another paragraph to make their paragraph more accurate.

Science and engineering practices

Obtaining, Evaluating, and Communicating Information **Engaging in Argument from Evidence**	**Classroom connection:** Students read and comprehend grade-appropriate complex texts and synthesize information from multiple sources.

Disciplinary core ideas

LS3.A: Inheritance of Traits	**Classroom connection:** Students discover that specific genes can be moved from one organism (paragraph) and included in the DNA of another (paragraph) to create a more favorable organism.

Cross-cutting concepts

Cause and Effect	**Classroom connection:** Students identify how combining specific traits (causes) creates improved outcomes (effects), mirroring genetic modification processes.

This lesson is one in a series that describes genetic improvement methods. The lessons can be used as a group to compare the methods once all are completed or each lesson can be used to provide a new lens to teach a familiar concept.

Background

A genetically modified organism (GMO) is a plant, animal, or other living thing that scientists have changed by altering its genes. Genetic engineers can take a helpful gene from one organism and add it to another organism to give it new traits. For example, they might add a gene to corn that helps it resist insects, or add a gene to rice that makes it more nutritious. This is different from traditional breeding, where farmers select the best plants or animals over many generations. With GMOs, scientists can make specific changes much faster by working directly with the genes in a laboratory. Common examples of GMOs include crops that can survive weed killers, soybeans that produce healthier oils, and papayas that resist certain plant diseases. Some GMOs are created to feed more people, while others reduce the need for pesticides or to survive in harsh growing conditions.

Prior knowledge

- Genes occur as alleles for traits which control the making of proteins to perform most cellular functions.
- Changes in organisms can result from genetic changes.

Suggested timing

1 class period

Materials

- Sample paragraphs
- Computers for word processing

Teacher preparation

1. Print materials: There are seven paragraph sets that may be used for student groups and a sample paragraph for practice.
2. Set up technology: Students may use digital copies of the paragraphs or hand-write their new paragraphs.
3. Review content: Read background information and familiarize yourself with the specific GMOs students are reading about.
4. Consider how to teach the analogy using the practice paragraphs (located on student document):
    - Paragraph A = Organism with desirable trait (data/evidence about garden benefits)
    - Paragraph B = Organism that would benefit from that trait (needs supporting evidence for its claims)
    - The sentence = Specific gene conferring the desirable trait
    - Transfer process = Genetic engineering/modification
    - Result = Paragraph B is “improved” with new function (more convincing argument)
5. Explain that students do not always have to choose one sentence from Paragraph A to add to Paragraph B. The goal is to critically read and determine the one sentence (trait) that will make the other paragraph stronger.
6. Prepare visuals: Show the sample paragraphs on screen to help students work through the example paragraph together.

Procedure

1. **Engage:** Ask students to write out their definition of a GMO (How would you describe a GMO to someone?).
2. Have students keep their definitions to compare to what they discover during the lesson.
3. **Explore:** Pass out practice paragraphs to students with the following directions.
    a. Analyze your source paragraph: organism with desirable trait (5 min).
        - Highlight the strongest, most interesting "traits" (facts or sentences) in each paragraph.
        - Identify what makes each paragraph unique.
        - Compare the two paragraphs, looking for similarities and differences.
    b. Plan your "modified" paragraph: organism that would benefit from a desirable trait (5 min) by creating a brief outline.
        - Which trait (sentences/ideas) will you keep from Paragraph A?
        - Which traits will add value or benefit to Paragraph B?
        - How will you combine them to show an "improved" paragraph with new function (more convincing argument)
        - What transitions might you need?
    c. Write your synthesis paragraph (10 min) by combining the sentence from one paragraph to make an improved cohesive paragraph that:
        - Flows naturally (proper transitions)
        - Includes the strongest information from both sources
        - Eliminates repetitive information
        - Creates something better than either original
4. **Explain:** Reflection (10 min)
    a. Define a GMO based on the information you learned about in your paragraphs.
    b. How is this process similar to creating a GMO?
    c. What are the benefits of combining traits?
    d. What challenges did you face?
    e. What types of misinformation are most common when people talk about GMOs?
    f. Why is verifying sources important before sharing science claims online?
    g. How does accurate communication about GMOs affect public perception of biotechnology?

Student handout

Procedure

1. Write out your definition of a GMO (How would you describe a GMO to someone?).
2. Keep your definition to compare to your answer at the end of the lesson.
3. Complete the practice paragraph with your instructor.

Practice: Roundup Ready soybeans

Paragraph A
Herbicide-tolerant crops, known as Roundup Ready varieties, contain a gene that allows them to survive exposure to glyphosate, a broad-spectrum herbicide. This genetic modification enables farmers to spray their entire field with a single herbicide that kills all plants except the modified crops. The simplified weed control reduces the number of herbicide applications needed, lowers overall chemical use, and decreases fuel consumption from fewer tractor passes across fields. Farmers appreciate the flexibility to control weeds throughout the growing season without worrying about damaging their crop, though some scientists caution about potential development of herbicide-resistant weeds.

Paragraph B
Weed control represents one of the biggest challenges in farming. Weeds compete with plants for nutrients, water, and sunlight, significantly reducing crop yields if left unchecked. Traditional farming methods require labor-intensive mechanical cultivation and the careful application of multiple herbicides. Farmers use selective herbicides that kill weeds without harming soybeans. The timing and complexity of weed management made farming particularly demanding.

4. Using the practice paragraph, write your new paragraph below.
   (Use paragraph B as a starting point.)

Weed control represents one of the biggest challenges in farming.
Weeds compete with plants for nutrients, water, and sunlight, significantly reducing crop yields if left unchecked. Traditional farming methods require labor-intensive mechanical cultivation and the careful application of multiple herbicides. Farmers use selective herbicides that kill weeds without harming soybeans. The timing and complexity of weed management made farming particularly demanding.

(paragraph B)

This genetic modification enables farmers to spray their entire field with a single herbicide that kills all plants except the modified crops.

(sentence from paragraph A)

Student handout

Topic 1: Cattle with slick coats

Paragraph A
Traditional cattle breeds struggle in hot, humid climates, leading to heat stress that reduces their productivity and health. Farmers in tropical regions often see their cattle suffer from decreased milk production, slower weight gain, and higher rates of disease. The thick, heavy coats that protect cattle in cooler climates become a liability in extreme heat. Ranchers have long sought solutions to help their herds cope with rising temperatures, especially as climate change intensifies heat waves across cattle-raising regions.

Paragraph B
Scientists discovered a natural genetic variant that produces a shorter, sleeker coat in some cattle breeds. This "slick" gene allows cattle to regulate their body temperature more efficiently by facilitating better heat dissipation through the skin. Cattle with slick coats show improved feed efficiency, better reproductive rates, and higher overall productivity in hot environments. By introducing this gene into traditional beef and dairy breeds, researchers have created heat-tolerant cattle that thrive in climates where conventional breeds struggle, offering hope to farmers facing the challenges of global warming.

Write your new paragraph below:

Traditional cattle breeds struggle in hot, humid climates, leading to heat stress that reduces their productivity and health. Farmers in tropical regions often see their cattle suffer from decreased milk production, slower weight gain, and higher rates of disease. The thick, heavy coats that protect cattle in cooler climates become a liability in extreme heat. (paragraph A)

This "slick" gene allows cattle to regulate their body temperature more efficiently by facilitating better heat dissipation through the skin. ***(sentence from paragraph B)***

Ranchers have long sought solutions to help their herds cope with rising temperatures, especially as climate change intensifies heat waves across cattle-raising regions. (paragraph A)

Student handout

Topic 2: Bt corn

Paragraph A
Corn farmers have battled destructive insects for generations, with pests like the European corn borer causing billions of dollars in crop damage annually. These insects tunnel into corn stalks and ears, weakening plants and reducing yields significantly. The resulting Bt corn produces its own protection against destructive pests, eliminating the need for multiple pesticide applications. Traditional pest control required repeated applications of chemical insecticides throughout the growing season. The spraying process was expensive, time-consuming, and raised environmental concerns about pesticide runoff into waterways and effects on beneficial insects like bees and butterflies.

Paragraph B
A common soil bacterium called *Bacillus thuringiensis* naturally produces proteins that are toxic to certain insect larvae but completely harmless to humans, animals, and beneficial insects. Scientists isolated the gene responsible for an insect-fighting protein and successfully inserted it into corn plants. Farmers growing Bt corn have reported significant yield increases, reduced production costs, and less environmental impact from decreased chemical use, while maintaining safe food for human consumption.

Write your new paragraph below:

Corn farmers have battled destructive insects for generations, with pests like the European corn borer causing billions of dollars in crop damage annually. These insects tunnel into corn stalks and ears, weakening plants and reducing yields significantly. (paragraph A)

Scientists isolated the gene responsible for an insect-fighting protein and successfully inserted it into corn plants. ***(sentence from paragraph B)***

Traditional pest control required repeated applications of chemical insecticides throughout the growing season. The spraying process was expensive, time-consuming, and raised environmental concerns about pesticide runoff into waterways and effects on beneficial insects like bees and butterflies. (paragraph A)

Student handout

Topic 3: Arctic apples

Paragraph A
When apples are cut or bruised, they quickly turn brown due to a natural enzymatic reaction. This browning doesn't affect taste or nutrition, but consumers often perceive brown apples as old, damaged, or unappetizing. The fresh-cut apple industry faces significant waste as sliced apples must be treated with chemical solutions like calcium ascorbate or lemon juice to prevent browning. Schools, restaurants, and food service companies discard tons of perfectly good apples simply because of cosmetic browning, contributing to food waste and economic losses.

Paragraph B
Scientists developed Arctic apples by "silencing" the genes responsible for producing polyphenol oxidase, the enzyme that causes browning. These genetically modified apples maintain their fresh, white appearance for weeks after being cut, without any chemical treatments. The modification doesn't affect the apple's flavor, texture, or nutritional content—it simply prevents the browning reaction. Arctic apples offer a solution to the fresh-cut apple industry, reducing food waste significantly, and making healthy snack options more appealing to consumers, particularly children who might otherwise reject brown apple slices.

Write your new paragraph below:

When apples are cut or bruised, they quickly turn brown due to a natural enzymatic reaction. This browning doesn't affect taste or nutrition, but consumers often perceive brown apples as old, damaged, or unappetizing. The fresh-cut apple industry faces significant waste as sliced apples must be treated with chemical solutions like calcium ascorbate or lemon juice to prevent browning. (paragraph A)

These genetically modified apples maintain their fresh, white appearance for weeks after being cut, without any chemical treatments. ***(sentence from paragraph B)***

Schools, restaurants, and food service companies discard tons of perfectly good apples simply because of cosmetic browning, contributing to food waste and economic losses. (paragraph A)

Student handout

Topic 4: AquAdvantage salmon

Paragraph A
Traditional salmon farming faces limitations in meeting the growing global demand for this nutritious fish. Farm-raised Atlantic salmon typically require 24 to 30 months to reach market size, consuming significant amounts of feed and occupying valuable tank or pen space throughout this extended growth period. The long production cycle increases costs for farmers and limits the supply of affordable salmon to consumers. Wild salmon populations continue to decline due to overfishing and habitat loss, making aquaculture increasingly important for sustainable seafood production.

Paragraph B
AquAdvantage salmon contain genes from Chinook salmon and ocean pout that enable year-round growth hormone production instead of only during warm seasons. This genetic modification allows the salmon to reach market size in approximately 16 to 18 months, nearly half the time of conventional farmed salmon. The faster-growing salmon require less feed per pound of fish produced and reduce the environmental footprint of aquaculture operations. These fish are raised in contained land-based facilities, preventing any interaction with wild populations, and studies confirm they are nutritionally equivalent to traditional salmon while offering a more sustainable protein source for a growing human population.

Write your new paragraph below:

Traditional salmon farming faces limitations in meeting the growing global demand for this nutritious fish. Farm-raised Atlantic salmon typically require 24 to 30 months to reach market size, consuming significant amounts of feed and occupying valuable tank or pen space throughout this extended growth period. The long production cycle increases costs for farmers and limits the supply of affordable salmon to consumers. (paragraph A)

AquAdvantage salmon contain genes from Chinook salmon and ocean pout that enable year- round growth hormone production instead of only during warm seasons. ***(sentence from paragraph B)***

Wild salmon populations continue to decline due to overfishing and habitat loss, making aquaculture increasingly important for sustainable seafood production. (paragraph A)

Student handout

Topic 5: Rainbow papaya

Paragraph A
In the 1990s, Hawaii's papaya industry faced complete devastation from the papaya ringspot virus, a disease that causes stunted growth, distorted leaves, and ring-shaped spots on the fruit. Infected trees produced inedible fruit and eventually died, and the virus spread rapidly through aphid insects that fed on the plants. Hawaiian papaya farmers watched helplessly as the disease swept through their orchards, destroying nearly half of the state's papaya production. By the mid-1990s, entire farming communities faced economic ruin, and it seemed Hawaii's papaya industry might disappear entirely.

Paragraph B
Scientists developed the Rainbow papaya by inserting a gene from the ringspot virus itself into the papaya plant, creating a form of genetic immunization. This modification allows the papaya tree to recognize and resist the virus before it can cause damage, similar to how vaccines work in humans. The Rainbow papaya saved Hawaii's papaya industry from collapse and allowed farmers to resume profitable production. Today, these virus-resistant papayas represent one of the most successful examples of genetic modification solving an agricultural crisis, and the fruit is safe, nutritious, and indistinguishable in taste from conventional papayas.

Write your new paragraph below:

In the 1990s, Hawaii's papaya industry faced complete devastation from the papaya ringspot virus, a disease that causes stunted growth, distorted leaves, and ring-shaped spots on the fruit. Infected trees produced inedible fruit and eventually died, and the virus spread rapidly through aphid insects that fed on the plants. Hawaiian papaya farmers watched helplessly as the disease swept through their orchards, destroying nearly half of the state's papaya production. By the mid-1990s, entire farming communities faced economic ruin, and it seemed Hawaii's papaya industry might disappear entirely.

(paragraph A)

Scientists developed the Rainbow papaya by inserting a gene from the ringspot virus itself into the papaya plant, creating a form of genetic immunization.

(sentence from paragraph B)

Student handout

Topic 6: Pink pineapple

Paragraph A
Traditional pineapples have yellow flesh due to the presence of carotenoid pigments, which are nutritious and give the fruit appearance. Consumers have become increasingly interested in novel and unique food experiences, with specialty produce commanding premium prices in markets. The pineapple industry sought ways to differentiate their products and create excitement around this tropical fruit. Plant breeders recognize that adding visual appeal could increase consumer interest and create new market opportunities for growers.

Paragraph B
Pink pineapples, marketed as Pinkglow, contain modified genes that allow them to produce lycopene, the same antioxidant that gives tomatoes and watermelons their red color. The pineapple industry sought ways to differentiate their products and create excitement around this tropical fruit. Scientists decreased the expression of enzymes that convert lycopene to other pigments, allowing the pink-red color to remain in the fruit's flesh. The genetic modification also reduces the enzyme that produces pineapple's characteristic acidity, resulting in a sweeter taste that many consumers prefer. These striking pink pineapples offer the same nutritional benefits as regular pineapples while providing additional lycopene, creating a product that is potentially more healthful.

Write your new paragraph below:

Traditional pineapples have yellow flesh due to the presence of carotenoid pigments, which are nutritious and give the fruit appearance. Consumers have become increasingly interested in novel and unique food experiences, with specialty produce commanding premium prices in markets. The pineapple industry sought ways to differentiate their products and create excitement around this tropical fruit. (paragraph A)

Scientists decreased the expression of enzymes that convert lycopene to other pigments, allowing the pink-red color to remain in the fruit's flesh. ***(sentence from paragraph B)***

Plant breeders recognize that adding visual appeal could increase consumer interest and create new market opportunities for growers. (paragraph A)

Student handout

Topic 7: Chicory

Paragraph A
Chicory plants naturally produce inulin, a dietary fiber that promotes digestive health, but conventional chicory varieties don't produce enough inulin to meet the growing industrial demand. Food manufacturers increasingly use inulin as a fat substitute, sugar replacement, and prebiotic fiber supplement in processed foods ranging from yogurt to protein bars. Extracting sufficient inulin from traditional chicory requires extensive agricultural land and processing facilities. As consumer demand for healthier food ingredients continues to rise, the food industry needs more efficient sources of this valuable plant fiber.

Paragraph B
Genetically modified chicory has been developed to produce significantly higher levels of inulin in its roots, making extraction more efficient and cost-effective. Scientists enhanced the plant's natural inulin-producing pathways by modifying genes that control fiber synthesis and storage. These high-inulin chicory varieties can produce two to three times more inulin per acre than conventional plants, reducing the land and resources needed for production. The modification provides a sustainable way to meet growing demand for natural fiber ingredients while supporting the food industry's shift toward healthier product formulations without synthetic additives.

Write your new paragraph below:

Chicory plants naturally produce inulin, a dietary fiber that promotes digestive health, but conventional chicory varieties don't produce enough inulin to meet the growing industrial demand. Food manufacturers increasingly use inulin as a fat substitute, sugar replacement, and prebiotic fiber supplement in processed foods ranging from yogurt to protein bars. (paragraph A)

Scientists enhanced the plant's natural inulin-producing pathways by modifying genes that control fiber synthesis and storage. ***(sentence from paragraph B)***

Extracting sufficient inulin from traditional chicory requires extensive agricultural land and processing facilities. As consumer demand for healthier food ingredients continues to rise, the food industry needs more efficient sources of this valuable plant fiber. (paragraph A)

Student handout

Reflection

1. Define a GMO based on the information you learned about in your paragraphs.

Answers may vary: GMOs are genetically engineered to contain a trait from another organism (donor) that does not exist in the recipient organism.

2. How is this process of combining paragraphs similar to creating a GMO?

Identifying a desirable sentence to insert into a recipient paragraph to make the information stronger or provide evidence is similar to a genetic engineer inserting a desirable trait into an organism to make it stronger or resistant.

3. What are the benefits of combining traits?

Organisms have traits they would not naturally be able to express to make them more adapted or better fit for an environment, such as resistance to an herbicide, thinner coats for warm climates, etc.

4. What challenges did you face?

Answers will vary, but could include: not being familiar with these traits; difficulty reading the sentences to determine which would make one of the paragraphs stronger; etc.

5. What types of misinformation are most common when people talk about GMOs?

These could include that GMOs are unsafe; that only "natural" products are non-GMO; that organic or non-GMO products are healthier; that the process is unnatural, so it must be unsafe; that genetic mutants are dangerous, etc.

6. Why is verifying sources important before sharing science claims?

Many claims online or on social media are untrue. The best sources for information about genetic engineering or GMOs are websites that end in .org, .edu, or the USDA.

7. How does accurate communication about GMOs affect public perception of biotechnology?

Answers will vary: accurate communication has not been able to allay the fears that some have about genetic engineering or GMOs. Although most commodity crops are grown with some genetic engineering, many fruits and vegetables are *not* genetically modified. Many medicines, including insulin for people who are diabetic, are made from genetically-engineered bacteria.

8. What is your definition of a GMO now? How does it compare to your definition at the beginning of the activity?

Answers will vary.

Differentiation

Other ways to connect with students with various needs:

- **Local community:**
  - Visit local farms or agricultural research stations that use improved crop varieties.
  - Invite a plant breeder, agricultural scientist or extension agent to discuss crop development using various techniques: selective breeding, hybridization, mutagenesis and genetic engineering.
  - Students may be assigned to photograph and document products in local stores that are GMOs.
  - Plant and compare heirloom vs. mutagenesis-derived or genetically modified varieties (if growing season permits).
- **Students with special needs:**
  - Language learners: Modify the text to lower grade levels and provide coaching on unfamiliar vocabulary.
  - Reading support: Pre-teach vocabulary with visual supports; provide audio recordings of background text; use graphic organizers for research notes; simplify research task to finding one example instead of multiple examples.
  - Auditory learners: Use verbal explanations with visual demonstrations; encourage students to read DNA sequences aloud; provide video resources showing transcription/translation.
  - Visual learners: Provide photos of GMO crops to show observable differences or buy organic and non-organic examples of GMO produce to compare.
- **Extra support:**
  - Meet with small group to pre-teach vocabulary and concepts.
  - Show What are GMOs? (**youtu.be/jYjvJyEMHZ4**) and How are GMOs made? (**youtu.be/2G-yUuiqIZ0**)
  - Provide written instructions with checkboxes for each part of the activity.
  - Strategically pair with peer mentors for reading help or oral completion.
  - Read for additional information: GMOs 101 (**fda.gov/media/135279/download**)
- **Extensions:**
  - Watch Animation E4, 1.2 Production of GM plants from Oxford University Press **youtu.be/7UZxS1o4geQ**
  - Research other genetically modified organisms approved in the United States at the GM Approval database. **isaaa.org/gmapprovaldatabase**

Assessments

Rubric for assessment

Skill	Developing	Satisfactory	Exemplary
Trait identification	Identifies 2 or more sentences that may be transferred but with limited explanation of their value, or no understanding of the strength of the sentence adding to the paragraph.	Identifies and chooses 1 best sentence to make the paragraph stronger, and can justify why that sentence is best.	Identifies and chooses more than one sentence to transfer, and explains how this might be engineered in a living organism. Demonstrates sophisticated understanding of information quality.
Analysis	Makes basic comparison but misses important similarities or differences.	Compares paragraphs and identifies what makes each unique with some specific examples.	Thoroughly compares paragraphs, identifies unique contributions of each source, and recognizes both similarities and key differences with specific examples.
Synthesis	Creates basic paragraph but lacks clear strategy or transition planning. Relies heavily on one source or fails to integrate information effectively.	Creates paragraph showing trait selection and general combination approach with some transitions identified.	Creates detailed paragraph showing strategic selection of traits, clear combination strategy, and identifies multiple specific transitions needed. Seamlessly combines strongest elements from both sources
Comparing the paragraph construction to the process of a GMO	Mentions trait selection but lacks examples or doesn't clearly connect writing to genetics.	Explains that both processes involve selecting desirable traits with some explanation and at least one example.	Clearly explains that both processes involve intentionally selecting specific desirable traits (strong sentences = beneficial genes). Describes how both scientists and writers evaluate traits for their value. Provides specific examples from their own synthesis work.

Rubric for self-assessment

Skill	Yes	No	Unsure
I can identify at least 4 strong facts or sentences from each paragraph.			
I can choose one sentence from the “donor” paragraph that will make the “recipient” paragraph stronger.			
I can give specific examples of similarities and differences between the sources.			
I can create a detailed outline showing which traits I'll use from each paragraph.			
I can identify the specific transitions needed to make my paragraph flow smoothly.			
I can explain how combining paragraphs compares to making a GMO.			