TEXAS FARM BUREAU®

Soybeans & Genetic Modification

Audience: 9-12 grade

Activity Length: 1-2 class periods

TEKS:
English
- ➢ English I §110.36.c
  - 1.A, 1.C, 1.D, 3, 4.G, 5.D
- ➢ English II §110.37.c
  - 1.A, 1.C, 1.D, 3, 4.G, 5.D
- ➢ English III §110.38.c
  - 1.A, 1.C, 1.D, 3, 4.G, 5.D
- ➢ English IV §110.39.c
  - 1.A, 1.C, 1.D, 3, 4.G, 5.D

Science
- ➢ Biology §112.42.c
  - 1.A, 1.B, 7.C, 7.D, 13.D
- ➢ Environmental Systems §112.50.c
  - 11.C, 12.C

Agriculture, Food, and Natural Resources
- ➢ Principles of Agriculture, Food, and Natural Resources §130.2.c
  - 1.B, 6.A, 6.B, 11.C
- ➢ Advanced Plant Science §130.25.c
  - 1.B, 15.A, 15.E, 17.B, 17.C, 18.B, 18.C

Objectives:
- Differentiate between genetic engineering, genetic modification, selective breeding, induced mutation, and CRISPR and provide examples for each,
- Explain how genetic modification has benefitted soybeans,
- Explain the impact of the Texas soybean industry and U.S. soybean industry, and identify uses for soybeans, and
- Design a hypothetical gene and diagram the technique for removing, adding, or modifying the gene.

Introduction:
Students will explore the world of genetic modification to alter characteristic traits of different organisms. They will research the role of genetic modification in Texas soybean production and discover the impact of the soybean industry.

Materials Needed:

- PowerPoint presentation (prepared by teacher):
  - Photos of foods for Explore section (watermelon, corn, banana, eggplant, carrot, cabbage)
  - Information from Explain and Elaborate section
- Copies of Process Name, Process Description, and Example cards (provided)

Engage:

1. Present students with the following problem:

   - Weeds in soybean fields compete for water, nutrients, and sunlight that the soybeans need to grow. Because they are broadleaf plants (same as the weeds), farmers can't spray herbicides while the plants are growing. This results in a significant reduction in crop yield.
     - The goal is for them to come to the following conclusion by the end of the lesson: RoundUp Ready Soybeans were first commercially produced in the mid-1990s. This transgenic variety can be sprayed with RoundUp (glyphosate) with no damage to the plant because the soybean plant has been modified to resist glyphosate. The RoundUp will kill other plants (weeds) that compete with the soybeans ultimately helping improve yields.

2. After presenting students with the problem, begin asking the following questions to encourage deeper thinking of the problem at hand and how it has been/could be solved. Present the question to the students, give them one minute to write down their answer (one minute per question) and then solicit a few volunteers to share their answers to encourage discussion. By writing them down, students can refer back to their answers throughout the lesson to gauge how their answers and thoughts have changed as a result of the content learned. Throughout the lesson, questions will become increasingly harder to encourage deeper thinking and evaluation of the problem (based off Bloom's Taxonomy). Early on in questioning, students may or may not have the correct answers. However, the goal of these questions is to encourage them to think about the problem and potential solutions before the material and solution are taught.

   - KNOWLEDGE: List the problems within the overall problem. (Encourages students to break down the problem into chunks and ensure comprehension.)
     - i.e., weeds in soybeans, competition for sunlight, nutrients, etc., inability to spray herbicides, reduction in crop yield
   - COMPREHENSION: Applying what you already know, discuss potential solutions for this problem. If you so wish, you can discuss solutions for each of the problems within the overall problem. (Encourages students to pull from past knowledge and try to apply to the problem at hand.)

Explore:

3. Ask students who has heard of genetically modified organisms (GMOs) and what they know about them. Allow this discussion to go on for three to five minutes. You can use the following questions to provoke thought and discussion. If students are not giving any answers, you can provide answers to help them along.
   - Who knows what GMO stands for? (Genetically Modified Organism)
   - Raise your hand if you have heard of a GMO. (This will give you, the teacher, an idea of where your students are with basic knowledge on GMOs.)
   - What is a GMO?
   - What role do they play in modern food production?

4. Show students pictures of what different foods would look like had they not been genetically modified. (Use photos from the following two links: https://geneticliteracyproject.org/2014/06/19/how-your-food-would-look-if-not-genetically-modified-over-millennia/ & https://www.sciencealert.com/fruits-vegetables-looked-before-domestication)
   - It's important to note that not all of these foods are labeled as a GMO. Some have evolved due to domestication as well as cross breeding that has occurred naturally.
   - Explain to students that these foods have all been altered in a variety of methods, which we are going to explore throughout this lesson.

5. Ask more questions to continue moving up Bloom's scale. Give students one minute to write down their answers (one minute per question). Solicit a few volunteers to share their answers to encourage brief discussion.
   - COMPREHENSION: Infer how genetic modification can help solve this problem for soybeans. (Encourages students to use the brief knowledge of genetic modification they have just learned to the problem at hand.)
   - Consider your answers to your questions from earlier and revise as needed based off any new knowledge.

Explain:

6. Students will pair up and each group will be handed a set of cards. One stack will be titled "process name" and the other stack will be titled "process description." Give the groups three to five minutes to match the process name to the process description. Correct matching should be:

Process Name	Process Description
Genetic Modification	Alters the genetic composition of domesticated plants and animals to achieve a desired result through a variety of methods
Selective Breeding	Taking two sexually compatible crops and cross pollinate them to produce a hybrid variety with the desired traits of the parents
Induced Mutation	Use of mutagens such as radioactivity to induce random mutations creating the desired trait.
Genetic Engineering	Removes a gene from one organism and inserts it into another giving it the ability to express the trait encoded by that gene
CRISPR	A molecule that finds a string of DNA code, locks on, and makes a precision cut. Can be used to turn genes off or replace them with new versions.

- A discussion should follow this activity to better explain each process and what it entails. Below is some additional information you can include on each process:
  - Genetic Modification:
    - a blanket term to refer to any plant or animal with new traits that have been created through modern genetic manipulation
    - any organism that has been developed or changed by humans
  - Selective Breeding
    - AKA cross breeding
    - used since the 1700s
  - Induced Mutation
    - Mutagenesis (muta) are genetic changes that can switch, add, or delete nucleotides (those A, T, G, and C bases). These genetic changes can sometimes lead to new/enhanced traits, which is why plant breeders sometimes induce (genesis) these genetic changes using radiation or chemicals.
    - Hermann Muller, Charlotte Auerbach, and J. M. Robson founded this technique in the first half of the 20th Century.
  - Genetic Engineering
    - Genetic Engineering can also be known as transgenesis or transgenic.
    - There are many ways to introduce new genes such as using agrobacterium to carry it into the genome or using electricity.
    - Scientists use a process to copy traits from one organism and insert them into another organism's cell. By copying a

protein from a virus and inserting it into the seed of a fruit, the fruit becomes resistant to the virus.

- CRISPR
    - Stands for Clusters of Regularly Interspaced Short Palindromic Repeats
    - Newer technology
    - Allows scientists to easily alter DNA sequences and modify gene function
    - Potential applications include correcting genetic defects and treating and preventing the spread of diseases along with improving crops
    - Has the potential to create gluten free wheat
- Reference the following links for additional information:
    - https://agbiotech.ces.ncsu.edu/q1-what-is-the-difference-between-genetically-modified-organisms-and-genetically-engineered-organisms-we-seem-to-use-the-terms-interchangeably/
    - http://www.biotech-now.org/wp-content/uploads/2015/07/crop-modification-techniques.png
    - http://www.biotech-now.org/food-and-agriculture/2015/07/6-different-processes-used-to-genetically-modify-crops
    - https://cosmosmagazine.com/biology/what-crispr-and-what-does-it-mean-genetics

7. Following the discussion, the teacher will then hand out a third set of cards to each group titled examples. Each card will list one food item that is an example of one of the processes discussed in the previous activity. Students will match the example to the processes. Correct matching should be:

Process Name	**Example**
Selective Breeding	The Honeycrisp apple gets its famous texture and flavor by blending the traits of the parents, Macoun and Honeygold.
Induced Mutation	Radiation was used to produce a deeper color in the red grapefruit.
Genetic Engineering	The Rainbow Papaya is modified with a gene that gives it resistance to the Papaya Ringspot Virus.
CRISPR	Scientists created a non-browning apple, the Arctic Apple, by turning off the PPO enzyme.

- Process this activity with discussion questions to further explain each example and the benefits genetic modification has provided (to the food itself, to the environment, to growers, etc.).

8. Ask more questions to continue moving up Bloom's scale. Give students one minute to write down their answers (one minute per question). Solicit a few volunteers to share their answers to encourage brief discussion.

   - APPLICATION: Choose one of the methods we just discussed to solve this problem for soybeans.
   - Consider your answers to your questions from earlier and revise as needed based off any new knowledge.

Elaborate:

9. Begin discussing how what we just explored relates to the soybean issue and walk students through the following points.

   - Glyphosate: A synthetic compound that is nonselective (kills both broadleaf plants and grasses), systemic (travels through the plant) herbicide. Glyphosate is a group 9 EPSPS inhibitor.
   - RoundUp Ready: Crops that are resistant to RoundUp herbicide, an herbicide that has glyphosate in it.
   - Farmers need to be able to spray glyphosate to kill weeds, but not affect the soybeans.
   - Farmers only spray herbicides when absolutely necessary as this is an expensive input for the farm and takes away from the farmer's profit at the end.
   - Lead class discussion using the following question:
     - Knowing what you know now, how can we solve the problem for soybeans?

10. Homework assignment: Instruct students to research the U.S. soybean industry and Texas soybean industry. Research should include the benefits of the soybean industry to the U.S. and state of Texas, where and why soybeans thrive, and the many uses for soybeans. It is up to you, the teacher, on how the students should present these findings…research paper, bullet points, presentation to class, etc.

    - Key facts students should know after this include, but are not limited to:
      - Main weed and insect problems in soybeans:
        - Pigweed (Palmer amaranth)
        - Ryegrass
        - Soybean aphid

        - Kudzu bug
        - Stink bugs and red-banded stink bugs
    - Top 10 soybean producing states: 1. Iowa, 2. Illinois, 3. Minnesota, 4. Nebraska, 5. Indiana, 6. Ohio, 7. South Dakota, 8. North Dakota, 9. Missouri, 10. Arkansas.
    - The 135,000 acres of soybeans harvested in 2018 in Texas yielded 4,320,000 bushels valued at more than $33 million.
    - Advances in agricultural production have allowed Arkansas (a top soybean producing state) farmers to produce 38.6% more soybeans on 32.3 fewer acres today compared to 40 years ago.
    - The U.S. is the leading soybean producer and exporter in the world. Soybeans account for about 90% of U.S. oilseed production.
    - In 2014, animal agriculture consumed 27.9 million tons of soybean meal in the U.S. The poultry industry consumed the bulk of this as 15.2 million tons went to feed broilers (11.2), turkeys (2), and layers (2). In fact, processed soybeans are the world's largest source of animal protein feed.
    - Animal agriculture consumed the meal from more than 65 million bushels of soybeans in 2011.
    - In 2018, U.S. farmers planted over 90% soybean acres with genetically engineered seeds.
    - Soybean uses
        - Major ingredient in livestock feed because of high protein level
        - Soy milk
        - Soy flour
        - Tofu
        - Oil for cooking
        - Candles
        - Crayons
        - Soy-based foams for coolers, refrigerators, automotive interiors, and footwear
        - Auto upholstery
        - Carpet
        - Ink
        - Particleboard, laminated plywood, and finger-jointed lumber are made with soy-based wood adhesives

11. Ask more questions to continue moving up Bloom's scale. Give students one minute to write down their answers (one minute per question). Solicit a few volunteers to share their answers to encourage brief discussion.

    - ANALYSIS: Identify how genetic modification has benefitted the U.S. soybean industry.

- SYNTHESIS: Compose a short argument for the use of genetic modification in soybean production.
- Consider your answers to your questions from earlier and revise as needed based off any new knowledge.
    - Particularly the application question from the Explain section. Help lead students to understanding that genetic engineering was used to put a gene in soybeans that made them resistant to glyphosate. The following is an excerpt from GMOanswers.com:
        - "Spurred by the incredible breakthroughs in recombinant DNA technology in the 1970's, Monsanto scientists recognized the many benefits to farmers if Roundup® could be applied directly to growing crops to control weeds within their fields. A small team of scientists (Rob Horsch, Steve Rogers and myself) led by Dr. Ernie Jaworski, began working on this challenge. By the early 1980s, this team had developed the first systems to introduce specific genes into plants and our attention shifted to developing virus resistant, insect resistant, and Roundup tolerant crops.
        - It was known that glyphosate likely inhibited the biochemical pathway in plants that produced aromatic amino acids (animals and people don't have this pathway which explains Roundup's high level of mammalian safety) and also that glyphosate was broken down very rapidly in the soil by microorganisms. By the mid-1980s, our researchers had identified both plant and microbial genes that conferred increased herbicide tolerance in laboratory tests, and in 1987 USDA approved the first field tests of genetically modified tomato plants that were tolerant to Roundup. A few years later, the bacterial gene that would become the Roundup Ready trait was discovered, isolated and introduced into crops." (https://gmoanswers.com/ask/how-did-roundup-ready-and-roundup-develop)

Evaluate:
This lesson will conclude with students designing a hypothetical gene for soybeans and diagramming the technique to add, remove or modify the gene. Have students pair up to complete this activity.

- Examples could include changing the color, creating a resistance to a bug or weed, etc.

Lead a final discussion on the solution to the problem.

- Discuss the final conclusion, which some of them may have discovered during their research in the Elaborate section. Before revealing the solution, ask students if they know what the solution to the problem is.

  - RoundUp Ready Soybeans were first commercially produced in the mid-1990s. This transgenic variety can be sprayed with RoundUp (glyphosate) with no damage to the plant because the soybean plant has been modified to resist glyphosate. The RoundUp will kill other plants (weeds) that compete with the soybeans ultimately helping improve yields.
- Following expiration of Monsanto's patent on the first variety of glyphosate-resistant Roundup Ready soybeans, development began on glyphosate-resistant generic soybeans. The first variety, developed at the University of Arkansas Division of Agriculture, came on the market in 2015. With a slightly lower yield than newer Monsanto varieties, it costs about half as much, and seeds can be saved for subsequent years. According to its creator, it is adapted to conditions in Arkansas. Several other varieties are being bred by crossing the original variety of Roundup Ready soybeans with other soybean varieties.
  - Seeds from crops produced with Monsanto seeds cannot be saved.

Sources:

- GMOanswers.com
- University of Nebraska-Lincoln
- Ricochet Science
- Cosmos Magazine
- Genetic Literacy Project
- North Carolina State Extension
- Biotech Now
- Arkansas Farm Bureau
- Arkansas Soybean Promotion Board
- USDA-ERS
- University of Arkansas Extension Service
- North Carolina Soybean Producers Association
- Texas Soybean Association
- Beef 2 Live
- AgAmerica Lending

Process Name

Genetic Modiÿcation

Process Name

Selective Breeding

Process Name

Induced Mutation

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Genetic Engineering

Process Name

CRISPR

Process Description

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A molecule that ÿnds a string of DNA code, locks on, and makes a precision cut. Can be used to turn genes o° or replace them with new versions.

Process Example

The Honeycrisp apple gets its famous texture and ¸a vor by blending the traits of the parents, Macoun and Honeygold.

Process Example

Radiation was used to produce a deeper color in the red grapefruit.

Process Example

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