

METHODS OF FOOD MODIFICATION CURRICULUM GUIDE

Timeframe:

50 minutes

Target Audience:

Grades 6-12

Content Area:

Life Science, Agriculture

Description:

This activity introduces students to the multiple ways foods have been or can be modified, either naturally or with human intervention. This includes natural selection, selective breeding, induced mutations, genome duplications, and gene editing.

Students learn the process involved with each modification method and the subsequent advantages and considerations via interactive, small group activities. Students gain insight about the reasons humans genetically modify plants (e.g. drought resistance, taste, color, pest resistance, herbicide resistance) and begin to understand how scientific intervention can be used to quickly and efficiently meet various agricultural goals. This lesson provides a foundation of content and a context for the additional activities including within this curriculum, as well as subsequent GMO-related case studies that will be added in the future.

Objectives:

- Students will know:
 - the process associated with 5 different types of food modification: gene editing, natural selection, selective breeding, induced mutations (mutagenesis), and genome duplications (polyploidy).
 - the advantages and considerations associated with each of those food modification techniques.

Activity Introduction:

1. Introduce students to the activity by asking the class “In what way would you want to modify a plant you eat?” As a class, brainstorm examples of genetic traits that could be desirable in food crops.
 - Examples include:
 - Drought tolerance
 - Resistance to plant disease
 - Resistance to pests and/or herbicides
 - Nutrition content of edible plant parts (fruits, vegetables, or grains)
 - Flavor or texture

- Size or color of flowers or leaves (for ornamental plants)
2. Continue the classroom discussion to draw on student’s prior knowledge and review basic concepts of inheritance and genetics. Students should be able to distinguish the difference between phenotype and genotype, understand basic principles of genetic inheritance from parent to offspring, and recognize the difference between dominant and recessive genes.
 3. After reviewing the vocabulary and principles above, explain to the class that there are numerous methods plant scientists can use to improve plants.

Activity Procedure:

1. Pass out *Crop Modification Technique* cards.
 - a. Each set has 15 cards and accommodates 15 students – each student receives one card. You will need to use a whole set to facilitate the activity. If you have less than 15 students, provide some students with 2 cards from the same set (e.g. the term and the example). If you have more than 15 students, introduce additional cards (make sure to introduce the entire group: term, definition, and example).
2. Students find the cards matching their method by discussing what is on their card with each other. Students group up once they have found the three matching cards for the method, definition, and example.
 - a. This may take students awhile and they will have to talk many other students to find their matches. If they are unable to find their matches through process of elimination, provide them with subtle hints.
3. Groups share their outcomes and the process that led them to believe they were a group.
 - a. During this time, the teacher builds on what students are saying to review each of the modification techniques and add additional information as necessary. The "Comparing Methods of Genetic Modification in Plants" PowerPoint can be used to guide this part of the activity.
4. Pass out the matching "Advantages and Considerations" to each group (e.g. Natural Selection table goes to the Natural Selection group).
5. Have each group review their table and use it to fill out the "Create Your Own Food Using Evidence and Reasoning" graphic organizer, which requires students to think critically about their modification and apply it to a specific type of food modification.
 - a. **Box 1:** Options A (herbicide resistance) and B (sterility) refer to modifications that can realistically be developed using any of the modification techniques included in Box 2. Additionally, there is enough evidence in the accompanying "Comparing Methods of Genetic Modification" handouts for students to successfully identify the evidence that will support whichever technique students select to create the modification. There is also an "other" option for those teachers that want to allow their students to have free choice of any modification, whether or not it is realistic (e.g. make broccoli taste like sugar).
 - b. **Box 2:** Students select the technique they would like to use to develop that modification.

- c. Box 3: Students use the “Advantages and Considerations” table to identify what type of evidence they could use to support their decision (e.g. technology is cost-effective, exact/immediate, accepted by society, produces larger plants).
 - d. Box 4: Students elaborate on their evidence and why it is applicable to their specific modification and technology choice.
 - e. Box 5: This question is meant to prompt student thinking about the complexity of using and marketing foods developed with this technology. Advantages could range from increased yield to pest resistance or enhanced nutritional value. Considerations could include cost effectiveness or societal response.
 - f. Box 6: Similar to Box 5, this question is meant to prompt deeper thinking about the approval and regulation of these types of products. Answers will vary, but options include determining any environmental effects, whether the plant is self-sustaining or if it has potential to “break loose” and contaminate non-modified varieties.
6. Have each group report out to the class by summarizing the information in the table and discussing their decision-making process to fill out the reasoning graphic organizer.
 7. As a class, discuss the benefits and potential drawbacks of each plant modification method. Summarize with students that scientific knowledge of genetics and inheritance has allowed improvements of crops to be healthier (more resistance to disease and pests), to utilize natural resources (such as water and soil nutrients) more efficiently, and to improve the overall quality and taste of our food. Additionally, each method has specific limitations and applications that may make it more favorable than other options, depending on the context and circumstances.

Guiding Questions:

- What is the responsibility of society in influencing how foods are modified?
- Why is there more controversy in food modification than in the production of medicine when they use many of the same techniques? (Example—Artificial insulin was first produced by Genetech in 1978 using GMOs)
- Would you consider food products from crops that have been artificially selected as GMOs?
- Why do you think people and organizations protest against GM crops? Are their claims based in science?

Optional Additional Extensions:

- GM plants and their subsequent GMO products are one of the most controversial topics in our society. Make a list of the reasons you have heard people raise against GM. Beside each reason, indicate whether it is a social, economic, health, or environmental concern. Rank the reasons in terms of how strongly you agree with them.

Materials:

- Crop Modification Technique Introduction Cards (1 card per student; 15 cards per set)
- Create Your Own Food Using Evidence and Reasoning

- Advantages and Considerations worksheet for each of the 5 food modification techniques
- Optional: Comparing Methods of Genetic Modification in Plants.ppt

Teacher Background:

There are many ways to modify the genes or genome of plants and other living things. These genetic modification techniques vary based on multiple factors, including plant type, available resources (time, expertise, funding), and what type of genetic modification is needed for acquiring/expressing specific traits. This lesson introduces various methods of plant modification and demonstrates the scientific process used to create a **genetically modified organism (GMO)**.

There are many terms and acronyms used to describe genetically modified organisms or biotechnologies applied in plant science. **Genetically engineered (GE)**, **genetically modified (GM)**, and **cis/transgenic** are three adjectives used to describe an organism that has a copy of a gene not previously found in the species. **Genetic engineering** is the deliberate modification of the characteristics of an organism by manipulating its genetic material, resulting in a **GMO**. The World Health Organization defines **genetically modified foods** as "foods that are derived from organisms whose genetic material (DNA) has been modified in a way that does not occur naturally, e.g. through the introduction of a gene from a different organism." **Transgenic organisms** contain genetic material from an unrelated organism, while **cisgenic organisms** contain genetic material from the same species or the host's breedable species.

Plant breeding and the **domestication** of plants dates back approximately 5,000 to 15,000 years ago when humans initially began the practice of farming. The introduction of **farming** allowed civilizations to stay in one place, rather than hunting and gathering their food on a constant move. Plants were domesticated in parallel in several regions around the globe (e.g. corn, squash and potatoes were domesticated in Mesoamerica approximately 10,000 years ago while China was domesticating rice and soybeans) (Purugganan and Meyer, 2013).

Plants are able **reproduce asexually**, meaning that their flowers are pollinated in a variety of ways that all depend on outside factors (e.g. wind, water, birds, bugs, etc.). Early farmers **selectively bred** food plants with desirable characteristics (e.g. larger corn cob size) to cultivate and provide their food supply. With each generation, plants with the best characteristics were chosen and crops improved (e.g. less branching, eliminated the hard casing around many grains) (Purugganan and Meyer, 2013; Catavelli et al., 2008).

Purugganan and Meyer (2013) outline a variety of traits that can be enhanced via the processes of **domestication** and **diversification**, including: seed size, seed coat thickness, seed dormancy, fruit/root flavor, nutritional quality, physiology/growth form, fruit size, color, toxicity, yield, harvest season, and abiotic/biotic stress responses. It can take many stages of intentional breeding for plants to exhibit these results.

Domesticated crops have less genetic diversity than their wild counterparts given **genetic bottlenecks** that are inherent to the domestication process. This is because selective breeding involves selecting for a specific trait and only allowing plants expressing that trait to reproduce, thus reducing the genetic material being passed down through generations. It is critical to maintain wild populations and seed banks of diversity in light of this (Purugganan and Meyer, 2013).

Knowledge of science and genetics advanced through the work of scientists such as Gregor Mendel, but only began to affect agriculture thousands of years after crops were first domesticated (start of 20th century). Modern plant breeding uses the same principles with the addition of advanced technology and ever-advancing knowledge of genetics. The average person's diet consists of food produced by plants that have been developed and improved through a variety of plant modification methods. Modified crops were domesticated from wild plants on nearly every continent, then moved during colonization and trade, and most of the major food crops are now cultivated globally.

Selective breeding has been practiced since the beginning of farming and utilizes the laws of inheritance to guide the specific selection of desirable traits in plants. After a desirable plant is selected, the pollen from one plant is placed on the female portion of the flower of another desirable plant which leads to the production of seeds that are hybrids of the two parent plants. This process is repeated with each generation of plants, slowly moving a plant toward more desirable traits. Plants with chosen characteristics are perpetuated and those without are removed. The offspring of two genetically different parents often show enhanced growth, an effect known as **hybrid vigor** or **heterosis**.

Induced Mutations: As a result of outside influences such as solar radiation, and natural errors during DNA replication, genetic mutations occur naturally and more or less randomly in the genomes of plants and animals. These mutations include the spontaneous deletion, addition, or insertion of base units in the organism's DNA, sometimes affecting its traits (Chopra, 2005).

Mutagenesis (referred to in the graphic organizers as "**induced mutations**") is a plant breeding method that purposely elevates the mutation rate as a way to create genetic diversity (Chopra, 2005). Plant breeders expose plants to various mutagens (e.g. UV light, chemicals, gamma rays) to increase the likelihood of mutations to occur. Most of the mutations will be detrimental or have no effect, but breeders scan many thousands of mutants to find the few that have an improved trait and then use them in selective breeding (Chopra, 2005).

Genome Duplications refers to the occurrence of more than two sets of chromosomes within the nucleus of the cell. Also known as polyploidy, this process dramatically increases the amount of genetic material available, which can increase the diversity of traits that are expressed or buffer the plant from any genetic mutations that may occur naturally during the DNA replication process. Genome Duplications can occur naturally or be induced by chemicals. This can increase fruit size or be used to create sterile varieties of a plant, such as the banana and seedless watermelon. Many crop species and flowering plants already have multiple sets of chromosomes and are prone to this type of breeding (Sattler, Carvalho, & Clarindo, 2016).

Gene Editing is the process of introducing one or more genes into an organism from another entirely separate organism by finding and isolating a chosen gene and adding it to the genome. **Genome editing** uses an enzyme to change the DNA of a cell at a specific place, either by adding, deleting, or editing the genetic sequence at that location.

CRISPR-Cas9 is a specific gene editing tool that helps plant breeders and scientists integrate desirable traits with more efficiency and precision than before. It is a promising and developing technology for all plants and animals. CRISPR is also being studied for its medical benefits, such as to correct human diseases.

Given the significant cost and resources that are involved in creating a genetically modified organism using gene editing techniques, it has primarily only been used to create modified versions of a small number of high-commodity crops. These crops are used in many processed foods on the market today, increasing human exposure to these plants. Below is a list of genetically modified foods that are approved in the United States and a brief synopsis of the specific modification. This information is sourced from the [Petitions for Determination of Nonregulated Status](#) database through the Animal and Plant Health Inspection Service of the United States Department of Agriculture.

- Alfalfa - herbicide resistance (glyphosphate) and reduced lignin
- Apple - non-browning after being sliced
- Beet - herbicide resistance (glyphosphate and phosphinothricin)
- Canola - herbicide resistance (glyphosphate and phosphinothricin); applications for an altered oil profile and additional resistance is currently under review.
- Chicory - male sterility
- Corn - insect resistance (rootworm, moth and butterfly species, European corn borer); herbicide resistance (glufosinate, glyphosate, dicamba, imidazolinone, phosphinothricin); increased ear size; male sterility; drought tolerance; fertility restoration; nutrition enhancements (lysine amino acid)
- Cotton – herbicide resistance (glyphosphate, isoxaflutole, dicamba, glufosinate, phosphinothricin, bromoxynil); insect resistance (moth and butterfly species)
- Creeping bentgrass – herbicide resistance (glyphosphate)
- Eucalyptus – freeze tolerant
- Flax – tolerant to soil residues of sulfonylurea herbicide
- Papaya – disease resistance (papaya ringspot virus)
- Plum – disease resistance (plum pox virus)
- Potato – disease resistance (late blight, potato leafroll virus, potato virus Y); insect resistance (Colorado potato beetle, beetle species); non-bruising
- Rice – herbicide resistance (phosphinothricin)
- Rose – altered flower color
- Soybean – insect resistance (moth and butterfly species); herbicide resistance (HPPD, glufosinate, glyphosate, dicamba, isoxaflutole, imidazolinone, acetolactate synthase, phosphinothricin); increased yield; improved fatty acid profile; higher oleic acid;

- Squash – disease resistance (cucumber mosaic virus, watermelon mosaic virus, zucchini yellow mosaic virus)
- Sugarbeet – herbicide resistance (glyphosphate)
- Tobacco – reduced nicotine content
- Tomato – insect resistance (moth and butterfly species); fruit ripening altered; Fruit Polygalacturonase Level Decreased

Below is a list of classroom-appropriate video resources related to each of these techniques:

- Natural Selection
 - *The Theory of Evolution (by Natural Selection)*. Cornerstones Education. 24 February 2015. https://www.youtube.com/watch?v=BcpB_986wyk&list=RDQM2f9f-58wXaU&index=18
- Selective Breeding
 - *Selective Breeding*. FuseSchool – Global Education. 10 January 2017. <https://www.youtube.com/watch?v=fHS-OY9XDZc>
- Induced Mutations (mutagenesis)
 - *The Science of Agriculture: Methods of Modification Episode 2 – Mutagenesis*. Monsanto STEM Education Outreach. September 2017. <https://vimeo.com/231136851>
- Genome Duplications (polyploidy)
 - *Tragopogon: Understanding the evolution of polyploidy*. FloridaMuseum. 12 June 2014. <https://www.youtube.com/watch?v=0aoJaLUPSsQ>
- Gene Editing
 - *How are GMOs Created?* GMOAnswers. 2 August 2013. <https://www.youtube.com/watch?v=2G-yUuiqIZO>

Plant breeders often use one or more modification methods before ultimately achieving their goal. Each method of plant modification comes with both advantages and disadvantages or limitations and not every method will be effective in every situation. Regardless of the method or methods used, all plants are screened for overall safety before a seed variety is available on a commercial level.

Resources:

- This activity is adapted from the “Methods of Crop Modification” activity [National Agriculture in the Classroom](#).
- Food Evolution movie (2017) - able to stream for free on Hulu
 - Clip: [What are GMOs?](#)
- [Mutation Breeding for Crop Improvement](#). Geography and You. MC Kharkwal. May 17th, 2018.

Next Generation Science Standards:

- Disciplinary Core Ideas:

- HS-ETS1-3 Evaluate a solution to a complex real-world problem based on the prioritized criteria and tradeoffs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.
- HS-LS-1 Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring.
- Practices: Constructing Explanations and Designing Solutions
- Crosscutting Concepts: Structure and Function, Cause and Effect