

LESSON 1 – ERAS OF CROP IMPROVEMENT CURRICULUM GUIDE

Timeframe:

One 50-minute class period

Target Audience:

Any Middle School (6-8) or High School (9-12) class

Materials:

- Eras of Crop Improvement Worksheet
- Domestication Activity Flashcards
- Green Revolution Activity Flashcards
- Genetic Modification Flashcards
- Eras of Plant Improvement Presentation (optional)

Description:

Students learn about why farmers/plant scientists would want to improve traits, with students brainstorming the different types of traits that may be desirable for food producers and consumers (e.g. increased fruit size, enhanced taste, efficient production). Students engage in breakout activities related to 3 eras of agricultural improvements: domestication, the Green Revolution, and genetic modification. The goal here is for students to learn that all of these eras include similar goals – developing safe and nutritious food more efficiently for a growing population. This culminates in a class discussion about genetic modification as a result of our enhanced scientific knowledge about genetics and breeding.

Objectives:

- Students will understand:
 - Goals of conventional breeding and genetic modification in agriculture
 - Three different eras of plant improvements – domestication, Green Revolution, and genetic modification
- Students will be able to:
 - Identify different types of agricultural traits that are desirable for food production and/or consumption
 - Identify similarities and differences between non-domesticated and domesticated varieties of plants
 - Interpret graphs to make meaningful conclusions

Guiding Question:

- What are the goals of breeding and genetically modifying plants to exhibit desired traits?

Teacher Background:

DNA is a self-replicating material present within chromosomes of all living organisms. It is the basic building block of heredity and genetics. DNA is made up of nucleotides and specific sequences of nucleotides comprise a **gene** – the unit of heredity. Specific genes are associated with **traits**, such as eye

color, height, hair color, etc. Traits are sometimes influenced by one gene or can be tied to multiple specific genes that control how the trait is exhibited.

For thousands of years, humans have been domesticating plants to exhibit desired traits through breeding. Traits that simplify production and cultivation were especially desirable. Subsequently, domestication was often focused on improving physical characteristics of the plant (aka “**phenotype**”). Domesticating plants allowed for humans to establish permanent civilizations around their farming areas, instead of hunting and gathering food as available. This was an important societal transition that allowed individuals to focus more energy into agriculture to feed growing populations in their civilizations and develop more sophisticated farming tools. Additionally, the crops that were originally selected by these early farmers set the stage for the crops that make our modern food supply (e.g. corn/maize, wheat, and rice).

Here is a list of traits that were prioritized during **domestication** breeding efforts (approx. 5,000 – 10,000 years ago):

- grew **straighter** and **taller** (as opposed to bush-like structure) to increase productivity by increasing the number of plants on a specific land area and simplify harvesting because branches/stalks are clearly defined
- had **seeds without shells** (known as “non-shattering seeds”) to make it easier to collect and reuse seed from crops
- Had **increased fiber content** (such as cotton plants) to increase fiber availability for cloths and other goods
- **Bigger fruit** to increase calorie availability for human populations

Agricultural advancements have continued since this time. In the 1950s-60s, there was another large period of agricultural innovation known as the **Green Revolution**. During the early 1900s, agricultural operations were becoming larger and more complex. Industrialization also increased the amount of chemicals that were available within the marketplace, including those for farming. Subsequently, there was a significant increase in the use of toxic chemicals (fertilizers, pesticides, herbicides) to improve productivity on farms. This sparked concern about environmental and human health, prompting scientists and plant breeders to investigate ways to improve plant productivity without requiring extensive use of these types of chemicals. Primarily, these breeding efforts were focused on developing:

- **high yielding varieties** of crops that could produce a greater yield during a single growing season
- Varieties with **shorter, stiffer stalks** to support the weight of increased grain production (e.g. rice, wheat) without the plant breaking
- varieties that were **drought resistant** and **herbicide resistant** to simplify production processes.

The advent of biotechnology and the ability to **genetically modify** plants has greatly expanded the types of traits that can be established. These methods allow scientists to investigate a plant’s genetics and edit its’ DNA so the plant exhibits a specific trait. Now, scientists are able to establish traits that were not previously available by using DNA/gene sequences from other species. Instead of breeding a trait into a variety over the course of multiple generations, scientists can insert the DNA into the variety to establish the trait. This expedites the process. Although many of the desired traits are focused on improving production and harvesting, scientists have also used genetic modification to develop varieties with benefits for consumers. Some of the primary traits that have come from these advancements include:

- **Herbicide tolerance** varieties (e.g. “Round Up Ready Soybean”) that are resistant to specific types of herbicide, simplifying farmer’s weed management efforts.
- **Insect and pest resistance** (e.g. Rainbow Papaya – resistant to Ringspot Virus, Bt corn – resistant to a variety of pests) to reduce crop loss from pests and pathogens, which greatly affects productivity and farm profitability.
- **Non-browning** varieties (e.g. Arctic Apple, Innate Potato) that do not brown when cut, reducing food waste and increasing consumer satisfaction.
- **Increased nutritional content** (e.g. Golden Rice with significantly greater concentrations of beta carotene to facilitate Vitamin A production) to address malnutrition and nutritional deficiencies that greatly affect the developing world.
- **Increased sugar content** (e.g. sweet corn) to improve consumer satisfaction.

Currently, the majority of genetic modification has been focused on improving commodity crops (e.g. corn, soybean, canola, cotton) to impact large-scale production of these crops. **Moving forward**, scientific advancements in genetics may allow scientists to increase resilience for crops, especially in the context of a **changing climate**. These types of applications could help us ensure that our crops are able to withstand the various climatic changes that are anticipated – helping ensure our food supply remains. The National Academies of Sciences expect that we will see genetically modified varieties of crops that express these types of traits in the future:

- Drought tolerance
- Water-use efficiency
- Nitrogen-use efficiency
- Nutrient uptake and use efficiency
- Carbon fixation
- Cold/heat tolerance
- Salt tolerance

It is likely that these techniques will be used to improve other products, which might be more niche products that are grown at a smaller scale. For example:

- Reduced gluten content in wheat varieties
- Improved oil content/reduced fatty acid content in soybean oil
- Improved nutritional content

Ultimately, whether you are breeding or genetically modifying plants, the goal is to increase farm productivity and efficiency while growing safe and nutritious food for an increasing population.

Activity Introduction:

- Class brainstorms different traits that are important for agriculture. Provide students with a few minutes to think on their own before sharing out with the group.
 - What do/don’t you want as a consumer? What does your perfect apple look like?
 - What would/wouldn’t you want as a farmer?
- Briefly introduce students to the 3 different eras of crop improvement: domestication, Green Revolution, and genetic modification using the “Eras of Plant Improvement” powerpoint. Students will learn more about the focuses of these eras through breakout activities

Activity Procedure:

- Pass out the “Eras of Plant Improvement” worksheet to students.
- Students rotate through 3 breakout activities. Students use the “Eras of Plant Improvement” worksheet to identify similarities and differences between the non-domesticated and domesticated/Green Revolution varieties of the species and interpret different graphs related to these eras.
 - Domestication Activity Flashcards
 - Green Revolution Activity Flashcards
 - Genetic Modification Flashcards
- Students share out what they noticed at each of the stations.
 - Teacher guides discussion toward the idea that domestication focused on **phenotypic** (physical) characteristics, while the Green Revolution allowed plant breeders to focus on **genotypes**.
 - Domestication was focused on making the plants easier to grow in a uniform way to make it easier to harvest (specific traits outlined above in the Teacher Background), whereas the Green Revolution was focused on creating high yielding varieties of important staple crops (especially wheat and rice).
 - Another important concept for students to understand is that the Green Revolution was a response to increased chemical use (pesticides, fertilizers) in agriculture. Scientists and farmers were interested in increasing crop yields without increasing the need for these chemicals.
 - Genetic modification is even more important in the context of improving complex agricultural systems and food availability, especially in the context of a changing climate.

Discuss:

- What are some things you noticed about the different crops?
- Why would farmers and consumers want different types of traits in their food products?
- What were the major themes of each era? What were the most notable changes?
- Should we continue to genetically modify crops? Why or why not?

Resources and References:

- International Food Policy Research Institute. 2002. Green Revolution: Curse or Blessing? Link: <https://oregonstate.edu/instruct/css/330/three/Green.pdf>
- Current GMO Crops. GMO Answers. Link: <https://gmoanswers.com/current-gmo-crops>
- Genetically Engineered Crop: Experiences and Prospects. Chapter 8: Future Genetically Engineered Crops. Link: <https://www.nap.edu/read/23395/chapter/11>