Lesson title:
GMOs and Genetic Variation

Overview:
GMO or "genetically-modified organism" is a broad term that refers to anything living that has been manipulated for a different set of genes. The term GMO may include such aspects as cross breeding which also is a modification technique. In this activity, students will explore the history of GMOs by creating a timeline. Furthermore, students will examine the role that different types of GMOs play in feeding a growing population as well as future innovations using Clustered Regularly Interspaced Short Palindromic Repeats (CRISPR-Cas9) genome editing technology. As an extension, students will perform an experiment to isolate DNA from smashed strawberries.

Objectives
Students will be able to:
- Describe what GMOs are and explore the history of GMOs
- Examine how different types of GMOs have benefited agriculture
- Describe the potential benefits of using CRISPR genome editing in agriculture
- Extract DNA from plant cells and examine its characteristics

Materials
- Computer connected to the Internet for watching the video
- Copies of handout, "Brainstorm Wheel: GMOs in Agriculture"
- Copies of handout, "GMOs Timeline"
- Extension: GMO Investigator Kit or similar DNA extraction kit
  Kits can be purchased through teacher science supply companies

Have you ever wondered . . .
How scientists take DNA out of an organism?
How biotechnology has helped the agriculture industry?

Make connections!

How does this connect to students?	How does this connect to careers?	How does this connect to our world?
GMO crops, such as aid in the reduction of sediment from soil erosion that has the potential to pollute our waterways. By utilizing biotechnology in agriculture, farmers are better able to control weeds without disturbing or plowing the soil. An interesting example of a GMO crop is the arctic apple in which the apple's own DNA was used to turn off the protein that makes it go brown.	**Agricultural scientists** spend part of their time outdoors on farms studying farm crops and animals in order to improve quality and yield **Genetic engineers** work as part of a team to rearrange fragments of DNA so organisms are better able to thrive in certain environments **Molecular biologists** study how genetic information is encoded in DNA molecules. They develop new crops, diagnose and treat disease, and investigate methods to remove environmental pollutants.	The Food and Agriculture Organization of the UN estimates that we need to grow 70% more food by the year 2050. Scientific research into CRISPR genome editing holds great potential for providing sustainable food options and possibly reducing the pressure to chop down forests to grow food.

Blueprint for Discovery

1. Write the following guiding questions on chart paper or a classroom board.

- How does diversity in agriculture help farmers and ranchers adapt during periods of drastic climate change?
- What role do GMOs play in feeding a growing population?

2. As a class watch the video, "A Day on a Cattle Ranch" [3 minutes 16 seconds]. Invite students to watch the video to look for evidence to answer the questions.
   http://www.fooddialogues.com/videos/how-to-farming-series/a-day-on-a-cattle-ranch

3. Lead a class discussion to elicit the following key points from students:

- During extended periods of drought, cattle ranchers have to adapt to maintain agricultural as well as financial sustainability. Growing an additional agricultural product (such as grapes) helps ranchers and, in turn, this gets passed down to the consumer.
- Genetically modified crops have the potential to benefit farmers and ranchers since these crops can be more to drought and damage by insects.

4. Explain to students that our ancestors were able to influence the DNA of organisms by using selective breeding. They did not have any knowledge of DNA at the time, but uncovered they could choose organisms with desired traits and mate them in order to have these traits expressed in offspring. Today, more sophisticated techniques are used to influence traits at the genetic level. Invite students to investigate the past, present, and future of GMOs.

5. Guide students to focus on the following landmark timeframes on their GMOs Timeline student worksheet:
   30,000 BCE, 7,800 BCE, 1973-1975, 1980-1982, 1992, 1995-1996, 2000, 2009, and Present Time – Future

   Use the following resources to assist students in completing the GMOs Timeline:
   http://sitn.hms.harvard.edu/flash/2015/from-corgis-to-corn-a-brief-look-at-the-long-history-of-gmo-technology/

   Direct link to video of a panel discussion with two of the scientists who helped make the GE revolution possible—Drs. Mary-Dell Chilton and Robert Fraley – the history is discussed:
   https://youtu.be/gqMdALbx3FM

   Link to the Smithsonian blog:
   http://americanhistory.si.edu/blog/pioneers-agriculture-reflect-genetically-engineered-revolution (the video is located ¾ into blog)

6. Now that students have completed their timeline, they will take a deeper dive into trangenics, one type of gene modification technique. Invite students to fold a piece of paper into quadrants. Ask students to label each quadrant with the following sections:
   - Designing the Gene
   - Transformation
   - Breeding
   - DNA testing

   Guide students to use the following resources from the "Plant and Soil Science eLibrary" to help students illustrate and explain the main steps of transgenics using their quandrant:
   http://passel.unl.edu/pages/ (useful animations)
   http://ge.unl.edu/journey-of-a-gene/ (steps of genetic engineering process; soybean SDS transgene)

7. Invite students to use their timeline and transgenics quadrant to engage the class in a discussion of the following questions:

- "What are examples of GMOs?"
- "What genetic traits have been altered in these crops?"
- "What are some of the benefits of GMOs to sustainable agriculture?"

Tell students to summarize their learning in the "Brainstorm Wheel – GMOs in Agriculture and Altered Traits" at the end of this lesson segment.

Some examples of GMO crops and their altered traits include:

- Soybeans (herbicide tolerance)
- Canola (altered fatty acid composition)
- Papaya (virus resistance)
- Arctic apple (no enzymatic browning by polyphenol oxidase)

More information on the adoption of genetically engineered crops in the US can be found at: http://www.ers.usda.gov/data-products/adoption-of-genetically-engineered-crops-in-the-us.aspx#.UfFqm9LCaM4

8. Students can summarize their learning by completing the sentence starter:

Three important ideas/things from the lesson today are ---, ---, and ---, but the most I important thing I learned today is ---.

Extension:

Ask students if they've ever heard of CRISPR (shorthand name for CRISPR-Cas9). Elicit feedback from students and then explain that CRISPR-Cas 9 is a powerful new gene-editing technology that has been shown to be extremely versatile in editing many different types of genomes.

Show the explanation of the CRISPR DNA editing system using the following URL:
Microbiology Society What is CRISPR-Cas

Invite students to compare and contrast CRISPR technology and GMO technology. Key points from the video include:

- CRISPR is a group of molecules that can edit DNA and theoretically be used to fix defected genes. It's like the search and replace or search and edit function on a computer. The process is very precise and unlike transgenics (GE/GMO), DNA is not added from another organism.
- This technology differs from GMO technology in which an existing gene is inserted from one species into another. CRISPR involves making precise changes within an organism's DNA.

Additional resources include:
http://www.yourgenome.org/facts/what-is-crispr-cas9 illustrations)

https://phys.org/news/2016-12-off-switch-crispr-cas9-gene.html (Cas9 off switch for CRISPR)
https://phys.org/news/2016-12-off-switch-crispr-cas9-gene.html
(Software methodology)

Engage the class in a discussion of potential benefits of this new technology to agriculture. Have students work in small groups of 3 or 4 and identify at least two potential benefits. Invite students to share out all of their ideas and list them on chart paper or a front board. Ask students to then vote on the most important benefit.

Potential benefits of the Cas 9 targeted genome editing system include:

- Boosting crop resistance to pests
- Suppressing populations of invasive species
- Reducing the prevalence of livestock diseases

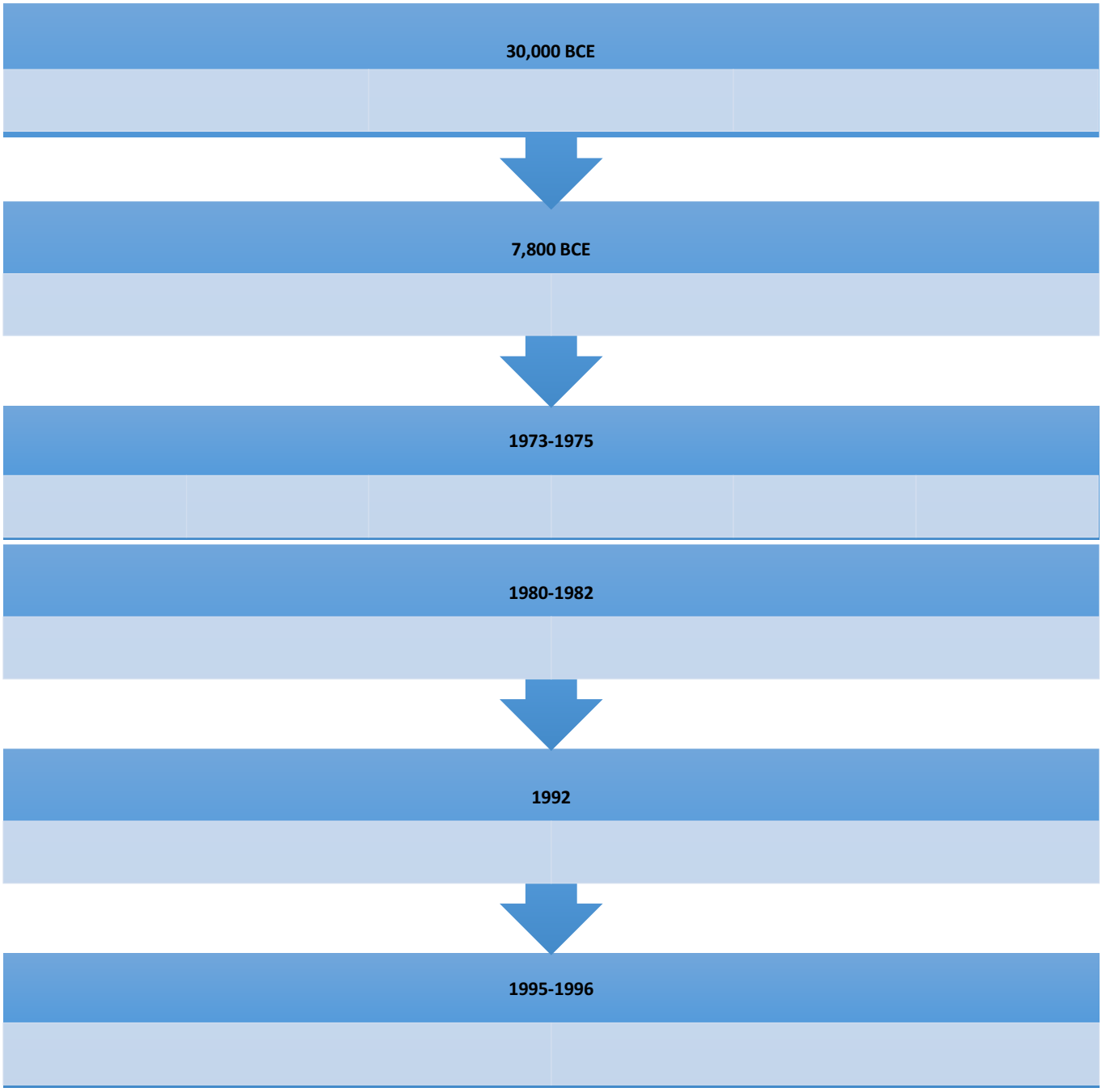
Teacher note: Given that CRISPR is such a new technology, it will need to be evaluated on a comprehensive range of social and environmental effects before it is considered for widespread use.

Take action!
Engage in a guided inquiry "GMO Investigation", in which you gather various food items from the grocery store, extract DNA from the samples, and amplify the DNA using polymerase chain reaction (PCR). Ultimately, you will identify the presence or absence of two different GMO-associated DNA sequences (the 35S promoter of the cauliflower mosaic virus and the terminator of the nopaline synthase gene of *Agrobacterium tumefaciens*) using multiple levels of controls. GMO Investigator Kits are available through science supply companies.

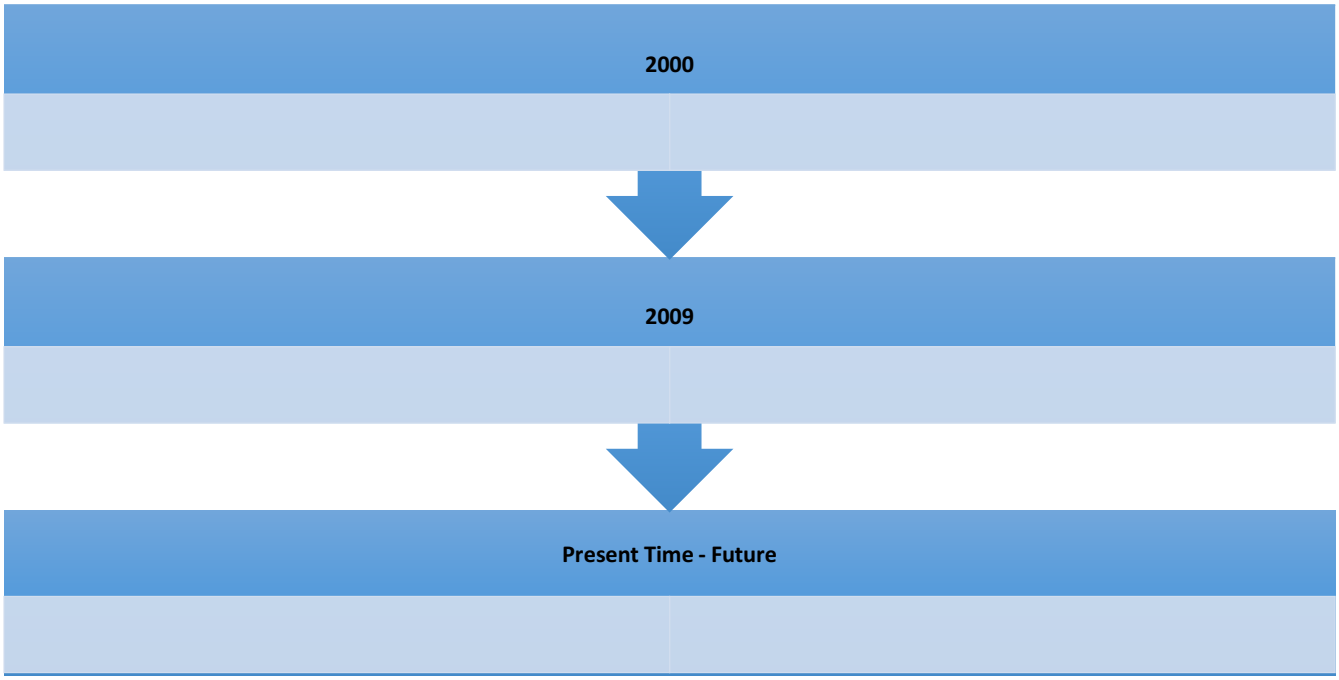
National Standards

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Obtaining, Evaluating, and Communicating Information Communicate technical information or ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically).	HS. Structure and Function HS-LS1-1: Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins which carry out the essential functions of life through systems of specialized cells. LS1.A: All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins, which carry out most of the work of cells. LS3.A: Each chromosome consists of a single very long DNA molecule, and each gene on the chromosome is a particular segment of that DNA. The instructions for forming species' characteristics are carried in DNA. All cells in an organism have the same genetic content, but the genes used (expressed) by the cell may be regulated in different ways. Not all DNA codes for a protein; some segments of DNA are involved in regulatory or structural functions, and some have no as-yet known function.	Structure and Function Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem.

GMOs Timeline



GMOs Timeline (continued)



BRAINSTORM WHEEL - GMOs in AGRICULTURE