ANIMAL SCIENCE (MS)

Animal science challenges

This lesson has been adapted with permission from the Timeline Challenge web-activity developed by the HudsonAlpha Institute for Biotechnology which appears in The American Biology Teacher (2021) 83 (6): 404–406. The original resource and supplemental material can be found at `hudsonalpha.org/technology-tools/`.

Focus questions	What food production challenges have we solved in the livestock industry? What are other challenges in food production that still need to be solved? How might farmers use genetics to solve on-farm challenges?
Learning target	Students will communicate a solution to an animal sceience challenge to peers through argumentation.
Vocabulary	Genetics, heredity, inheritance, allele, DNA, genetic modification, selective breeding/artificial selection, hybridization, induced mutation/mutagenesis, recombinant DNA, genetic engineering, genome editing/CRISPR

MS LS-4: Biological Evolution: Unity and Diversity

Performance expectation MS-LS4-5	**Classroom connection:** Students explore the history of genetics and its relationship to agriculture specifically. **Classroom connection:** Students determine which genetic modification technique might be best suited to meet the needs of an animal science challenge.

Science and engineering practices

Constructing Explanations and Designing Solutions	**Classroom connection:** Students construct an explanation based on gathered evidence and communicate results to peers.
Obtaining, Evaluating, and Communicating Information	**Classroom connection:** After designing a solution to the challenge presented, students evaluate and communicate evidence for the solution design to their peers.

Disciplinary core ideas

LS4.B: Natural Selection **LS4.C: Adaptation**	**Classroom connection:** Students explore artificial selection and how these techniques have shaped different species populations, allowing for adaptations that are advantageous to humans.

Cross-cutting concepts

Patterns **Cause and Effect**	**Classroom connection:** Students determine patterns of inheritance and the cause/effect ramifications of genetic modification on subsequent populations of a species.
Interdependence of Science, Engineering, and Technology	**Classroom connection:** Students examine the interdependence of science, engineering, and technology by student analysis of technology advances within the realm of genetics.
Science addresses questions about the natural and material world	**Classroom connection:** Students determine that genetics and science disciplines are able to solve problems and answer questions about the natural world to help agriculture and farmers produce higher yields and better quality food.

This activity is designed to follow the *Selective breeding* activity which provides needed background information for students.

Background

In order to complete this lesson successfully, the teacher must have knowledge of the history of genetic modification in agriculture, genetically modified organisms, and various types of genetic modification techniques, including selective breeding/artificial selection, hybridization, induced mutation/mutagenesis, genetic engineering (use of rDNA), and genome editing (TALENs, ZFNs or CRISPR).

These are the defintions that will be used for this lesson. It may be helpful to print these out or make them visible to students throughout the teaching of this lesson.

- **Genetic modification:** Any change to an organism's DNA through any method from selective breeding to genome editing.
- **Selective breeding/artificial selection:** The process of choosing an organism with a particular genotype to cross with another of the same species in order to produce offspring with a specific trait(s)
- **Hybridization:** The practice of crossing two pure varieties of an organism to create a more hardy offspring; many different hybrids have been created in many different organisms
- **Induced mutation/mutagenesis:** The use of radiation or chemicals to create a change in the DNA of an organism
- **Genetic engineering:** A method of changing the DNA of an organism by inserting a piece of DNA from another organism using recombinant DNA technology—this is how a GMO might be created; also referred to as 'bioengineered'
- **Genome editing:** Targeted method to cut, paste, or replace portions of DNA in an organism; Transcription Activator-Like Effector Nucleases (TALENs) Zinc-Finger Nucleases (ZFNs) or Clustered Regularly Interspaced Short Palindromic Repeats (CRISPR)

You may use these resources to create your own deck to describe each area you want students to study or use the Selective Breeding deck listed below.

- George Harrison Shull, hybrid technology: **dnalc.cshl.edu/view/16312-Biography-12-George-Harrison-Shull-1874-1954-.html**
- Hybridization Method of Crop Improvement: **biologydiscussion.com/crops/improvement/hybridization-method-of-crop-improvement/17701**
- Plant breeding: Induced mutation technology for crop improvement **iaea.org/sites/default/files/34405682533.pdf**
- Genetic modification FAQs: **geneticliteracyproject.org/gmo-faqs**
- Plant breeding including CRISPR e-learning: **elearning.grownextgen.org/plant-breeding-crispr/**
- CRISPR click and learn: **biointeractive.org/classroom-resources/crispr-cas-9-mechanism-applications**

Humans have modified the genetics of plants and animals since 7000 BC when humans began to selectively breed for advantageous traits in corn. For additional history of genetic modification in agriculure, please visit "The Progress of Science Timeline" developed by HudsonAlpha Institute for Biotechnology.(**timeline.hudsonalpha.org**) This timeline is a comprehensive listing, so if choosing to have students use it to do research, specific timeframes may need to be assigned where technologies were developed that advanced agriculture (for example: 1927, Hermann Muller discovers x-rays cause DNA mutations; 1930, radiation-induced mutation).

Other specific events relate to genetic engineering, which has resulted in the development of GMOs. "A GMO (genetically modified organism) is a plant, animal, or microorganism that has had its genetic material (DNA) changed using technology that generally involves the specific modification of DNA, including the transfer of specific DNA from one organism to another." (**fda.gov/food/consumers/agricultural-biotechnology**) In this case, events from the timeline may include: 1953, Watson and Crick discover the shape of DNA; 1955, Arthur Kornberg discovers DNA polymerase; 1957, Central Dogma described by Francis Crick; 1959, 1968, 1972, etc.

Altering an organism at the genetic level requires careful considerations about the future of the species. This lesson specifically focuses on five common techniques that scientists use for genetic modification: selective breeding/artificial selection, hybridization, induced mutation/mutagenesis, genetic engineering (use of rDNA), and genome editing (TALENs, ZFNs or CRISPR).

Prior knowledge

In order to successfully complete this activity, students should have completed an introductory lesson on inheritance and basic Mendelian genetics. A thorough overview of Punnett squares is not necessary, but students do need to understand that an organism's inheritance pertains to alleles being passed from parent to offspring during sexual reproduction. It would be helpful for students to have a basic understanding that mutations are a spontaneous change in an organism's DNA that may or may not pass from parent to offspring due to Mendelian genetics and basic genetic law assumptions. Otherwise, this activity can be used as a bridge between genetics and evolution or as a stand-alone unit to describe how human technology has an impact on an organism's genotype and phenotype.

Suggested timing

This activity is designed to use 135–140 minutes of class time. If class periods are 45 minutes, you can break it down: Day 1: introductory materials and research on specific agriculture challenges, Day 2: concluding research and CER formation, and Day 3: completion of CER and gallery walk.

Materials

- Animal science challenge cards
- Electronic device for student research and presentation
- Animal science page

Teacher preparation

Day 1

1. Review HudsonAlpha's "The Progress of Science Timeline": **timeline.hudsonalpha.org**.
2. Copy student sheets or link them digitally.
3. Review selective breeding deck (if you have not completed the lesson) or create a deck from resources listed in the background. (**nourishthefuture.org/curriculum/biotechnology/hs#selective-breeding**)

Day 2

1. Print off or assign animal science challenges to each group.
2. Be prepared to assign timeframes to help focus research and/or resources for additional understanding of the event/technology.

Procedure

Day 1

1. Pose the question: What challenges or problems have we faced growing food throughout human history? Give some examples such as: not enough rain, too much rain, harvesting crops by hand took a long time; using horses to pull plows was hard work. Give students two minutes to brainstorm on their own, then group brainstorm for three minutes with their table. Give each group a chance to share what they believe is the biggest challenge on their list.
2. Ask: What are the current challenges in agriculture or food production? (i.e., food may have lower nutrient content; soil may not be able to grow enough food) Have them again brainstorm on their own for two minutes, then group brainstorm for another three minutes. Collect their challenges on a document, parking lot, or jamboard to revisit.
3. Briefly discuss different ways that scientists have genetically modified organisms: Show the *Selective breeding* deck (**nourishthefuture.org/curriculum/biotechnology/hs#selective-breeding**) slides that follow the activity (selective breeding/artificial selection, hybrids, induced mutation/mutagenesis, genetic engineering (use of rDNA, TALENs, ZFNs, and CRISPR.) (Many of these words can be substituted for one another…it is important to be consistent in your usage of the terms for each method.) Ask students to create a KWL chart or a jamboard to begin their investigations of each of the above methods. Students will take note of what they know, what they want to know (questions), and what they learn after researching.
4. The teacher will assign various technologies for altering the genetics of plants/animals to student groups. Students will use research materials to gather information on each type of genetic technology (selective breeding/artificial selection, hybrids, induced mutation/mutagenesis, genetic engineering [use of rDNA], and genome editing (TALENs, ZFNs, CRISPR) and the HudsonAlpha timeline (timeline.hudsonalpha.org) to explore how these tools have been used by scientists throughout both ancient and modern civilizations.
   Time frames for techniques:
   - Selective breeding: 7000 BC–AD 1865
   - Hybridization: 1789–1940
   - Induced mutation: 1925–1980
   - Genetic engineering: 1965–1990
   - Genome editing: 2010–2020

5. Working in pairs, students will explore the online timeline, taking notes on notable contributions of genetic modification to the field of agriculture within their assigned time frames.
6. Through formative assessment monitoring, the teacher will determine if whole group instruction is required for the class or if small group remediation is sufficient for student understanding of the various genetic modification techniques.
7. Use the KWL or jamboard created by each student or student groups as an Exit Ticket for formative assessment purposes.

Day 2

1. Upon entering the classroom, students will divide into groups to discuss their research from the previous day with others, so one student who investigated each technology is represented in each group (i.e. one person from each: selective breeding/artificial selection, hybrids, induced mutation/mutagenesis, genetic engineering (use of rDNA), and genome editing (TALENs, ZFNs, CRISPR) will meet together to share information).
2. After sharing information, students (remaining in the same groups) will receive a "challenge card" with a problem that a farmer would like to solve using biotechnology. Students may find resources to get them started here: **nourishthefuture.org/go/dairy-challenges** However, encourage student creativity in addressing the problems!
3. Using research information from day 1, students will determine the best genetic technology method to produce the desired results in order to help the farmer.
4. Students will continue online research to produce a CER (Claim–Evidence–Reasoning) in order to answer their challenge question.

Day 3

1. Students may need additional time for evidence and CER production. If so, provide time; however, limit this time to bell work.
2. Students will create a poster (using a white board, poster board, *or* online program) to display their information in a persuasive format.
3. Upon completion, students will communicate their evidence to peers through class presentation or an online format (such as FlipGrid).

Differentiation

- **Local community:** Invite a livestock farmer to talk about genetic modification techniques that might help his livestock production be more successful and create a better outcome for the desired product (i.e. meat or milk). If this is not locally available due to limitations, the teacher could provide a skype activity for students to speak with an agriculture specialist or local farmer in a virtual environment.
- **Students with special needs (language/reading/auditory/visual):** Within a classroom, heterogeneous groupings are the most advantageous accommodation for this assignment. All students possess prior knowledge about food products and should be able to be a successful member of a group. For visual impairments, all materials can be placed online for enlargement purposes. For special education students, models could be given for each genetic modification technique so that students can visually understand the modification technique.
- **Extra support:** Additional support should be offered for students without prior knowledge of genetic modification techniques. Students generally have a variety of misconceptions about this topic since many associate genetic modification with science fiction and pop culture. The teacher must be clear and concise with teaching materials in order to clear up misconceptions associated with pop culture-type ideas that students might have in regards to genetic modifications. **teach.genetics.utah.edu** is a great resource for both middle and high school teachers looking to provide a more solid background for students to avoid misconceptions.

- **Extensions:**
  - Engage students in individual research to discover specific genetic modifications that are occurring or in development in agriculture.
  - Ask students to list modifications that they think would be beneficial (i.e. making vegetables taste better).

Assessments

Rubric for assessment

Skill	Developing	Satisfactory	Exemplary
Construct an explanation to describe how genetic technologies are used in agriculture	Student can construct an explanation describing one way that genetic technologies are used in agriculture.	Student can construct an explanation describing a few ways that genetic technologies are used in agriculture.	Student can construct an explanation describing multiple ways that genetic technologies are used in agriculture.
Gather and synthesize information about the technologies that have changed the way humans influence the inheritance of desired traits in organisms	Student can gather and synthesize information about one technology that has changed the way humans influence the inheritance of desired traits in organisms.	Student can gather and synthesize information about a few technologies that have changed the way humans influence the inheritance of desired traits in organisms.	Student can gather and synthesize information about multiple technologies that have changed the way humans influence the inheritance of desired traits in organisms.
Communicate information about the technologies that have changed the way humans influence the inheritance of desired traits in organisms	Student can communicate information about one technology that has changed the way humans influence the inheritance of desired traits in organisms.	Student can communicate information about a few technologies that have changed the way humans influence the inheritance of desired traits in organisms.	Student can communicate information about multiple technologies that have changed the way humans influence the inheritance of desired traits in organisms.

Rubric for self-assessment

Skill	Yes	No	Unsure
I can communicate how genetic technologies impact agriculture and food production.			
I can describe selective breeding.			
I can describe gene editing/CRISPR.			
I can describe hybridization.			
I can describe induced mutation.			
I can describe genetic engineering			
I can name one agency that regulates GMOs.			