PHENOMENA
TEACHER IDEA TOOL KIT

BEEF

Funded by the Beef Checkoff

Introduction: This toolkit is designed to offer ideas of anchor phenomena that could be used to create a coherent sequence of science lessons when working to incorporate Next Generation Science Standards into the classroom. Ideas in this toolkit could also serve as phenomena for transfer tasks.

We've aligned each phenomena to the *STEM teaching tools* Practice #28, http://stemteachingtools.org/tools, found on the next page.

STEM TEACHING TOOL #28

Qualities of a good anchor phenomenon for a coherent sequence of science lessons

Instructional sequences are more coherent when students investigate compelling natural phenomena (in science) or work on meaningful design problems (in engineering) by engaging in the science and engineering practices. We refer to these phenomena and design problems here as 'anchors.' What makes for a good phenomenon to anchor an investigation?

- ☐ A good anchor builds upon everyday or family experiences: who students are, what they do, where they came from. It is important that it is compelling to students from non-dominant communities (e.g., English language learners, students from cultural groups underrepresented in STEM, etc.).
- ☐ A good anchor will require students to develop understanding of and apply multiple performance expectations while also engaging in related acts of mathematics, reading, writing, and communication.
- ☐ A good anchor is too complex for students to explain or design a solution for after a single lesson.
    - ☐ The explanation is just beyond the reach of what students can figure out without instruction.
    - ☐ Searching online will not yield a quick answer for students to copy.
- ☐ A good anchor is observable to students. "Observable" can be with the aid of scientific procedures (e.g., in the lab) or technological devices to see things at very large and very small scales (telescopes, microscopes), video presentations, demonstrations, or surface patterns in data.
- ☐ A good anchor can be a case (pine beetle infestation, building a solution to a problem), something that is puzzling (why isn't rainwater salty?), or a wonderment (how did the solar system form?).
- ☐ A good anchor has relevant data, images, and text to engage students in the range of ideas students need to understand. It should allow them to use a broad sequence of science and engineering practices to learn science through first-hand or second-hand investigations.
- ☐ A good anchor has an audience or stakeholder community that cares about the findings or products.

BY WILLIAM R. PENUEL AND PHILIP BELL | MARCH 2016

STEMteachingtools.org/brief/28

Phenomenon: Proper grazing by cattle can increase the overall carrying capacity of a rangeland ecosystem for native wildlife species.

Make It Visible:

Summary:
Managed grazing can improve rangeland; grasses develop larger root systems, soil quality increases, undesirable woody species are minimized, native species have less competition. Cattle can even learn to eat particular undesirable rangeland species.

Related Standards:

- HS-LS2-1 Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales.
- HS-LS2-2 Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.
- HS-LS2-7 Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.
- HS-LS4-6 Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.
- HS-ESS3-3 Create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity.
- HS-ESS3-4 Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.

- MS-LS1-4 Use argument based on empirical evidence and scientific reasoning to support an explanation for how characteristic animal behaviors and specialized plant structures affect the probability of successful reproduction of animals and plants respectively.
- MS-LS2-5 Evaluate competing design solutions for maintaining biodiversity and ecosystem services.

- MS-ETS1-1 Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
- MS-ETS1-2 Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.
- MS-LS2-1 Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.
- MS-LS2-3 Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem.
- MS-LS2-4 Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.

Selected Resources:

- https://www.fws.gov/invasives/staffTrainingModule/methods/grazing/impacts.html
- http://ww.vernalpools.org/documents/Marty%20Cons%20Bio.pdf
- http://cesonoma.ucanr.edu/files/225913.pdf
- http://www.ebparks.org/about/stewardship/grazing/benefits.htm
- https://binged.it/2PXNJLE
- https://denver.cbslocal.com/2017/03/26/study-livestock-grazing-can-benefit-struggling-bird-species/
- https://www.beefresearch.org/CMDocs/BeefResearch/Sustainability_Home/Ecosystem_Services_ES.pdf
- https://www.beefresearch.org/CMDocs/BeefResearch/Sustainability_FactSheet_TopicBriefs/ToughQA/FS16EcosystemServices.pdf

Questions to Drive Instruction:

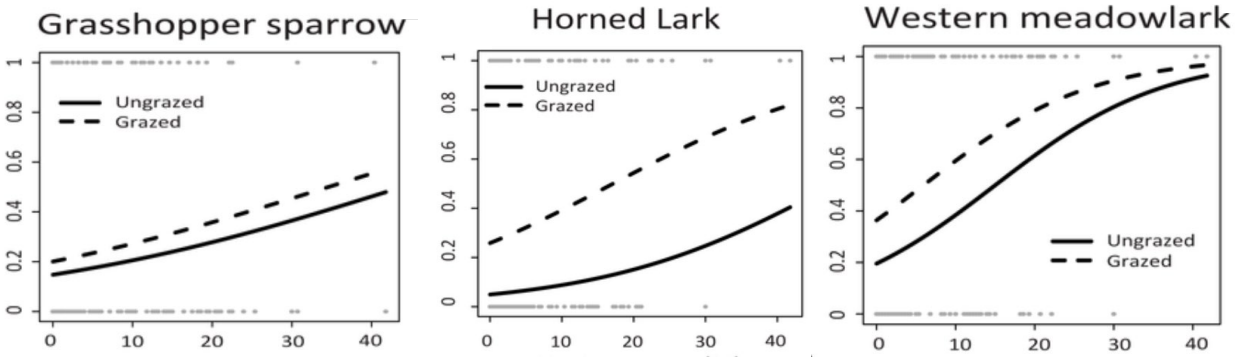
- How does grazing impact the plant community?
- Why is the composition of the plant community an important factor for wildlife?
- How are modern grazing techniques different from traditional grazing which was often detrimental to wildlife?

Phenomenon: Cattle are helping to save birds in the Great Plains.

Make It Visible:

Western Meadowlark

Horned Lark



https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0176367

Summary:
Since 1970, Great Plains grassland songbirds have declined nearly 70% due to climate change, outdated grazing practices, urbanization, and intensive agriculture. Increasing breeding habitat in collaboration with cattle ranchers is helping to save songbirds which fill a critical role in the ecosystem, dispersing seeds, controlling insects, and mitigating weeds.

Related Standards:

- HS-LS2-1 Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales.
- HS-LS2-2 Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.
- HS-LS2-7 Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.
- HS-LS4-6 Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.
- HS-ESS3-3 Create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity.

- HS-ESS3-4 Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.
- MS-LS1-4 Use argument based on empirical evidence and scientific reasoning to support an explanation for how characteristic animal behaviors and specialized plant structures affect the probability of successful reproduction of animals and plants respectively.
- MS-LS2-5 Evaluate competing design solutions for maintaining biodiversity and ecosystem services.
- MS-ETS1-1 Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
- MS-ETS1-2 Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.
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- MS-LS2-3 Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem.
- MS-LS2-4 Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.

Selected Resources:

- https://www.nationalgeographic.com/animals/2018/12/ranchers-environmentalists-cooperate-to-save-birds-prairies/
- https://denver.cbslocal.com/2017/03/26/study-livestock-grazing-can-benefit-struggling-bird-species/
- https://www.beefresearch.org/CMDocs/BeefResearch/Sustainability_Home/Ecosystem_Services_ES.pdf
- https://www.beefresearch.org/CMDocs/BeefResearch/Sustainability_FactSheet_TopicBriefs/ToughQA/FS16EcosystemServices.pdf

Questions to Drive Instruction:

- How does grazing impact the songbird community?
- Why is the composition of the songbird community an important factor in the Great Plains ecosystem?

Phenomenon: Cattle grazing can improve rangeland by reducing invasive species.

Make It Visible:

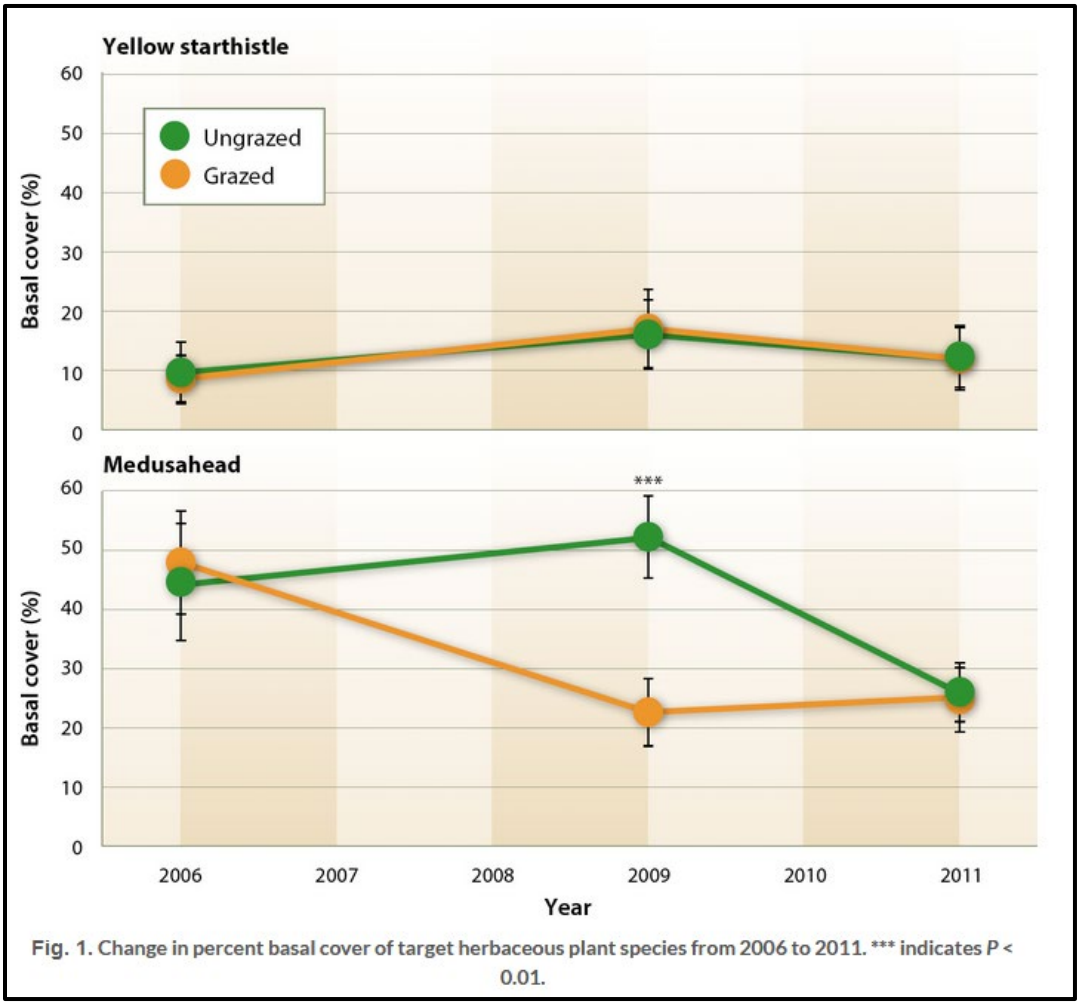


Fig. 1. Change in percent basal cover of target herbaceous plant species from 2006 to 2011. *** indicates $P < 0.01$.

http://calag.ucanr.edu/Archive/?article=ca.v069n04p230

Summary:
"Proper grazing management may suppress invasive plant populations by: reducing invasive plant seed production, and stressing invasive plants and allowing native plants to compete more effectively." (fws.gov)

Related Standards:

- MS-LS1-4 Use argument based on empirical evidence and scientific reasoning to support an explanation for how characteristic animal behaviors and specialized plant structures affect the probability of successful reproduction of animals and plants respectively.
- MS-LS2-5 Evaluate competing design solutions for maintaining biodiversity and ecosystem services.
- MS-ETS1-1 Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
- MS-ETS1-2 Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.
- MS-LS2-1 Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.

- MS-LS2-3 Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem.
- MS-LS2-4 Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.
- HS-LS2-1 Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales.
- HS-LS2-2 Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.
- HS-LS2-7 Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.
- HS-LS4-6 Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.
- HS-ESS3-3 Create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity.
- HS-ESS3-4 Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.

Selected Resources:

- https://binged.it/2PXNJLE
- https://www.fws.gov/invasives/staffTrainingModule/methods/grazing/impacts.html
- http://www.ebparks.org/about/stewardship/grazing/benefits.htm
- https://www.beefresearch.org/CMDocs/BeefResearch/Sustainability_Home/Ecosystem_Services_ES.pdf
- https://www.beefresearch.org/CMDocs/BeefResearch/Sustainability_FactSheet_TopicBriefs/ToughQA/FS16EcosystemServices.pdf

Questions to Drive Instruction:

- How can cattle be used to combat invasive species?
- How do invasive species affect ecosystem dynamics?

Phenomenon: Knickers is significantly larger than other cows in the herd.

Make It Visible:

For an actual image of Knickers, check this article: https://www.perthnow.com.au/business/agriculture/big-knickers-a-standout-on-myalup-farm-ng-b881032899z

Summary:
Biotechnology plays an essential role in beef production in the areas of reproduction, genetics, and breeding; animal nutrition; and animal health. Students explore bio-agriculture, genetics, ethics, and bio-engineering and how these concepts create a culture of food production and nutritional value.

Related Standards:

- HS-ETS1-1 Engineering Design: Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.
- HS-ETS1-2 Engineering Design: Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.
- HS-LS2-3 Ecosystems: Interactions, Energy, and Dynamics: Construct and revise an explanation based on evidence for the cycling of matter and flow of energy in aerobic and anaerobic conditions.
- HS-LS3-1 Heredity: Inheritance and Variation of Traits: Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring.
  HS-ESS3-4 Earth and Human Activity: Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.
- MS-LS4-5 Gather and synthesize information about the technologies that have changed the way humans influence the inheritance of desired traits in organisms.
- MS-LS3-2 Develop and use a model to describe why asexual reproduction results in offspring with identical genetic information and sexual reproduction results in offspring with genetic variation.

- MS-LS1-5 Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms.

Selected Resources:

- https://www.beefmagazine.com/mag/beef_improving_genetics_reproductive
- http://www.fao.org/biotech/sectoral-overviews/biotech-livestock/en/
- https://www.youtube.com/watch?v=WoKEk87Q88U
- https://www.washingtonpost.com/science/2018/11/28/meet-knickers-giant-cow-that-is-neither-cow-nor-giant/?noredirect=on&utm_term=.b697c4eb1043
- https://www.beefresearch.org/CMDocs/BeefResearch/PE_Project_Summaries/FY04Determine_the_Genetic_and_Phenotypic_Variances.pdf

Questions to Drive Instruction:

- What is biotechnology?
- How can biotechnology be used in raising cows?
- How can we increase beef's nutritional value using biotechnology?
- What are the ethics involved (e.g., risks and benefits)?

Phenomenon: Biotechnology allows for the development of more efficient beef cattle.

Make It Visible:

For a detailed image of the biotechnology process in the beef industry, check out this image:
https://media.springernature.com/lw785/springer-static/image/art%3A10.1186%2Fs13059-018-1583-1/MediaObjects/13059_2018_1583_Fig1_HTML.png

Summary:
Artificial insemination allows producers to breed more efficient beef cattle by selecting for particular traits.

Related Standards:

- HS-LS3-1 Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring.
- HS-LS3-2 Make and defend a claim based on evidence that inheritable genetic variations may result from: (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors.
- HS-LS3-3 Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population.
- HS-ESS3-4 Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.
- MS-LS4-5 Gather and synthesize information about the technologies that have changed the way humans influence the inheritance of desired traits in organisms.
- MS-LS3-2 Develop and use a model to describe why asexual reproduction results in offspring with identical genetic information and sexual reproduction results in offspring with genetic variation.
- MS-LS1-5 Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms.

Selected Resources:

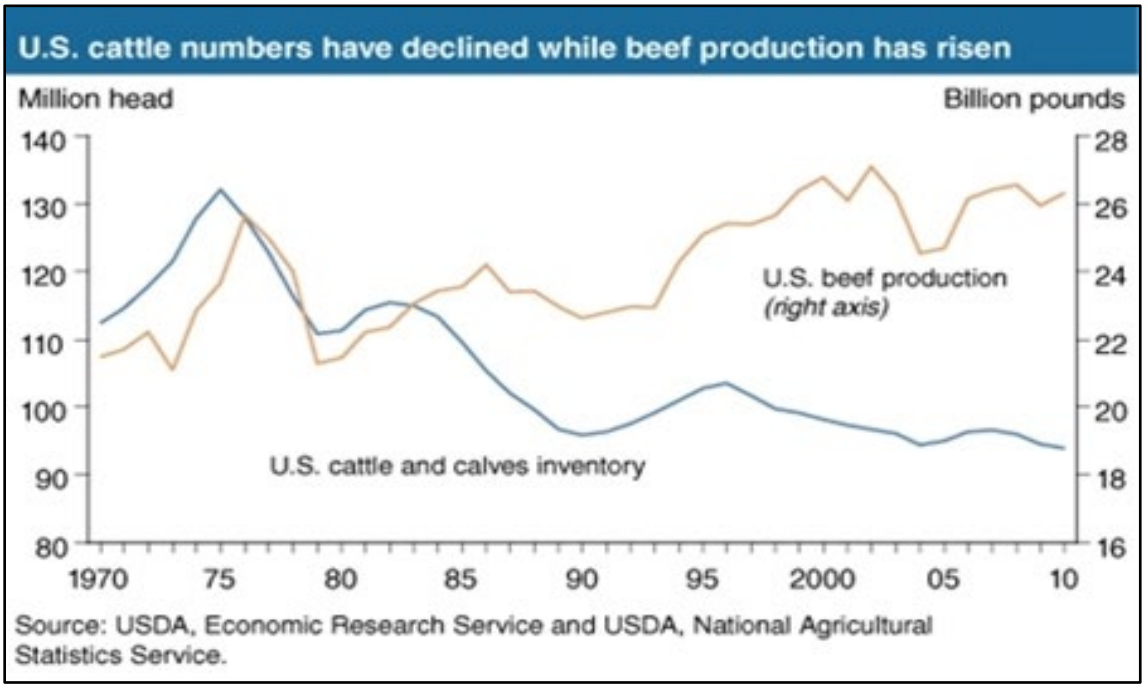
- Lesson: https://www-tc.pbs.org/wnet/nature/files/2008/12/the-perfect-cow.pdf
  https://www.uaex.edu/farm-ranch/animals-forages/beef-cattle/breeding-genetic-selection.aspx
- https://www.bbc.com/bitesize/guides/z6trd2p/revision/3
  https://www.beefresearch.org/CMDocs/BeefResearch/PE_Project_Summaries/FY04Determine_the_Genetic_and_Phenotypic_Variances.pdf

Questions to Drive Instruction:

- How can we engineer a more efficient beef cow?
- Why do cattle today look so much different from cattle 20 years ago?
- What traits are desirable in efficient beef cattle?
- How do cattle producers engineer beef cattle?

Phenomenon: Beef producers produce more beef today per cow than in the past.

Make It Visible:



https://www.ers.usda.gov/webdocs/charts/54960/u.s._cattle_numbers_have_declined_while_beef_production_has_risen_243_450px.jpg?v=6498.9

Summary:
In 2013, the U.S. produced almost the same amount of beef as it did in 1976 — about 13 million tons. It achieved this while slaughtering 10 million fewer cattle from a herd that was almost 40 million head smaller.

Related Standards:

- HS-LS3-1 Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring.
- HS-LS3-2 Make and defend a claim based on evidence that inheritable genetic variations may result from: (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors.
- HS-LS3-3 Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population.
- HS-ESS3-4 Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.
- MS-LS4-5 Gather and synthesize information about the technologies that have changed the way humans influence the inheritance of desired traits in organisms.
- MS-LS3-2 Develop and use a model to describe why asexual reproduction results in offspring with identical genetic information and sexual reproduction results in offspring with genetic variation.
- MS-LS1-5 Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms.
- MS-ETS1-1 Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

Selected Resources:

- https://www.nationalgeographic.com/foodfeatures/meat/
- https://www.ers.usda.gov/data-products/charts-of-note/charts-of-note/?topicId=14842
- https://www.npr.org/sections/thesalt/2012/06/27/155527365/visualizing-a-nation-of-meat-eaters
- https://www.beefresearch.org/CMDocs/BeefResearch/PE_Project_Summaries/FY04Determine_the_Genetic_and_Phenotypic_Variances.pdf

Questions to Drive Instruction:

- What factors have allowed beef producers to develop more efficient beef cattle?
- What traits contribute to efficiency?
- How are beef cattle made more efficient?

Phenomenon: Most of the world buys their milk at room temperature.

Make It Visible:

Buying milk in the U.S.

Buying milk in Europe

Summary:
Milk is pasteurized at high temperatures to kill bacteria that are pathogenic and spoilage bacteria (e.g., lactobacillus). In Europe, the pasteurization process uses ultra-high temperatures, killing more bacteria than the process used in the United States.

Related Standards:

- HS-LS1-6 Construct and revise an explanation based on evidence for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large carbon-based molecules.
- HS-LS1-7 Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed resulting in a net transfer of energy.
- MS-LS1-1 Conduct an investigation to provide evidence that living things are made of cells; either one cell or many different numbers and types of cells.
- MS-LS1-2 Develop and use a model to describe the function of a cell as a whole and ways parts of cells contribute to the function.

Selected Resources:

- https://curiosity.com/topics/why-most-of-the-world-buys-their-milk-at-room-temperature-curiosity/
- http://dairyknowledge.in/article/pasteurization
- https://melscience.com/en/articles/why-does-milk-go-sour/

Questions to Drive Instruction:

- Why causes milk to sour?
- What are bacteria?

Phenomenon: Hamburger turns brown when cooked.

Make It Visible:

Summary:
The Maillard reaction is a chemical reaction between an amino acid and a reducing sugar usually requiring the addition of heat. Like caramelization, it is a form of non-enzymatic browning. The reactive carbonyl group of the sugar interacts with the nucleophilic amino group of the amino acid and, interesting but poorly characterized, odor and flavor molecules result. This process accelerates in an alkaline environment because the amino groups do not neutralize.

Related Standards:

- HS: This lies outside NGSS standards and would be more appropriate for an advanced chemistry course that includes concepts from organic chemistry.
- MS: MS-PS1-2 Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.
- ES: This phenomenon could be presented as an instructionally embedded assessment when working toward 2-PS1-4 Construct an argument with evidence that some changes caused by heating or cooling can be reversed and some cannot.

Selected Resources:

- https://www.beefresearch.org/CMDocs/BeefResearch/PE_Fact_Sheets/Color_Changes_in_Cooked_Beef.pdf
- https://www.youtube.com/watch?v=SLAz3oiMi8Q
- https://www.scienceofcooking.com/maillard_reaction.htm
- http://www.chm.bris.ac.uk/webprojects2002/rakotomalala/maillard.htm

Questions to Drive Instruction:

- Why does ground beef turn brown as it cooks?
- Why does the smell change as it cooks?

Phenomenon: Red meat turns brown when vacuum sealed.

Make It Visible:

Red Beef

Vacuumed Packed Beef

Summary:
Meat is red when the pigment myoglobin that is contained in blood is bound to oxygen. When oxygen is released from myoglobin there is a change in spectral properties of the myoglobin molecule, resulting in a brownish color. The strong vacuum pulls out air and draws oxygen molecules off the surface of the meat.

Related Standards:

- MS-PS1-2 Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.
- HS-PS1-2 Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties.
- HS-PS1-7 Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.

Selected Resources:

- http://www.canr.msu.edu/news/the_color_of_meat_depends_on_myoglobin_part_1
- https://www.scienceofcooking.com/why_red_meat_turns_brown.htm
- https://study.com/academy/lesson/what-is-oxidation-definition-process-examples.html

Questions to Drive Instruction:

- What chemical reaction causes red meat to turn brown when vacuum sealed?
- What happens during the vacuum sealing process?

Phenomenon: Billy the Pui O cow, who ran with the local buffalo at Pui O on Lantau Island has died and the cause of death has been announced as eating plastic. The AFCD stated that an autopsy had found the plastic inside the cow was enough to fill two rubbish bags.

Make It Visible:

Summary:
According to the results of an autopsy carried out by the Agriculture Fisheries and Conservation Department (ACFD), Billy died from complications relating to heavy ingestion of plastic bags and garbage. Billy had developed this habit after being fed by humans from bags leading him to associate plastic with food.

Related Standards:

- MS-LS1-8 Gather and synthesize information that sensory receptors respond to stimuli by sending messages to the brain for immediate behavior or storage as memories.
- MS-LS1-4 Use argument based on empirical evidence and scientific reasoning to support an explanation for how characteristic animal behaviors and specialized plant structures affect the probability of successful reproduction of animals and plants respectively.
- MS-ESS3-3 Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.
- MS-ESS3-4 Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems.
- MS-LS1-3 Use argument supported by evidence for how the body is a system of interacting subsystems composed of groups of cells.
- HS-LS1-2 Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.
- HS-LS1-3 Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis.

- HS-LS1-7 Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed resulting in a net transfer of energy.
- HS-LS2-3 Construct and revise an explanation based on evidence for the cycling of matter and flow of energy in aerobic and anaerobic conditions.
- HS-LS2-7 Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.
- HS-LS4-6 Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.

Selected Resources:

- http://www.arounddb.com/news/afcd-urges-public-not-to-feed-feral-cows-after-the-tragic-death-of-billy-the-cow/
- http://acvcsd.org/wp-content/uploads/2016/05/The-Negative-Effects-of-Feeding-Wildlife-with-new-letterhead.pdf
- https://www.nature.com/scitable/knowledge/library/measuring-animal-preferences-and-choice-behavior-23590718
- http://www.bbc.co.uk/newsbeat/article/38063952/the-animals-that-are-being-harmed-by-plastic-bags

Questions to Drive Instruction:

- Why do animals eat human food?
- What causes animals to eat food that isn't good for them?
- What happens to animals when they eat plastic?

Phenomenon: Beef produced in Latin America produces more GHG emissions than beef produced in North America.

Make It Visible:

United States Feedlot

Cattle Operation in Brazil

Summary:
Latin American beef, according to the United Nations' Food and Agriculture Organization (FAO), produces more than twice as many emissions per pound as its North American counterpart because more of the cattle are on pasture, and ranchers have been cutting down rainforest to make pastures and cropland for feed.

Related Standards:

- HS-LS1-6 Construct and revise an explanation based on evidence for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large carbon-based molecules.
- HS-LS1-7 Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed resulting in a net transfer of energy.
- HS-LS2-3 Construct and revise an explanation based on evidence for the cycling of matter and flow of energy in aerobic and anaerobic conditions.
- HS-LS2-4 Use mathematical representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem.
- HS-LS2-5 Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere.
- HS-ESS2-4 Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate.
- HS-ESS3-5 Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems.
- HS-ETS1-3 Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.
- MS-LS1-7 Develop a model to describe how food is rearranged through chemical reactions forming new molecules that support growth and/or release energy as this matter moves through an organism.
- MS-LS2-3 Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem.

- MS-LS2-4 Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.
- MS-ESS3-3 Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.
- MS-ESS3-4 Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems.
- MS-ETS1-2 Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

Selected Resources:

- https://www.nationalgeographic.com/foodfeatures/meat/
- http://www.fao.org/news/story/en/item/197623/icode/
- http://www.fao.org/ag/againfo/resources/en/publications/tackling_climate_change/index.htm
- https://insideclimatenews.org/news/17102016/beef-companies-failing-effort-slow-amazon-rainforest-deforestation-climate-change-mcdonalds-burger-king-walmart

Questions to Drive Instruction:

- Why do cows raised in Latin America have a higher carbon footprint than cows raised in North America?
- What environmental factors contribute to beefs' carbon footprint?
- How is a carbon footprint determined?
- What are the consequences of increased GHG emissions?

Phenomenon: Beef has specific tastes.

Make It Visible:

Summary:
Beef from farm-raised animals contains tendons, blood vessels, fat, nerves, and connective tissues that affect the texture, flavor, and nutritional value.

Related Standards:

- MS-LS1-1 Conduct an investigation to provide evidence that living things are made of cells; either one cell or many different numbers and types of cells.
- MS-LS1-2 Develop and use a model to describe the function of a cell as a whole and ways parts of cells contribute to the function.
- MS-LS1-3 Use argument supported by evidence for how the body is a system of interacting subsystems composed of groups of cells.
- 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.
- HS-LS1-2 Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.
- HS-LS1-4 Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms.

Selected Resources:

- http://sitn.hms.harvard.edu/flash/2018/making-steak-spinach-bioengineering-change-meat-production/
- https://www.washingtonpost.com/national/health-science/lab-grown-beef-taste-test-almost-like-a-burger/2013/08/05/921a5996-fdf4-11e2-96a8-d3b921c0924a_story.html?tid=a_inl_manual
- https://courses.lumenlearning.com/boundless-ap/chapter/muscle-development/

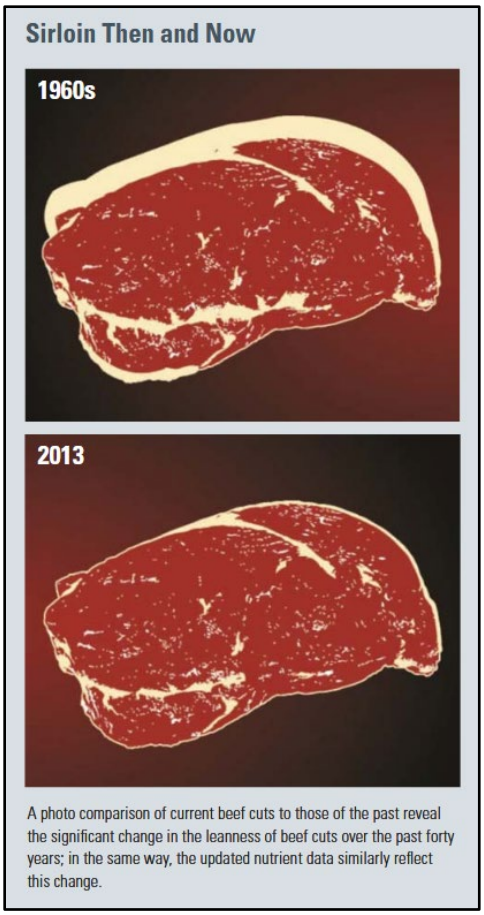
- https://opentextbc.ca/anatomyandphysiology/chapter/10-2-skeletal-muscle/

Questions to Drive Instruction:

- Why could lab-grown beef taste differently than farm-raised beef?
- What does lab-grown beef taste like?
- What does farm-raised beef taste like?
- What is beef made of?
- How is beef grown in a lab?

Phenomenon: A steak from the 1960s looks different from a steak today.

Make It Visible:



https://www.beefresearch.org/CMDocs/BeefResearch/Nutrition/LeanMatters_Web.pdf

Summary:
"During the past four decades, changes in cattle breeding and management along with trimming practices of processors, retailers, and foodservice operators resulted in an estimated 44% reduction in available total fat (from 13% to 7%) and a 29% reduction in saturated fat per capita (from 13% to 9%) contributed by beef as calculated from food disappearance data." (beefboard.org)

Related Standards:

- MS-LS4-5 Gather and synthesize information about the technologies that have changed the way humans influence the inheritance of desired traits in organisms.
- MS-LS3-2 Develop and use a model to describe why asexual reproduction results in offspring with identical genetic information and sexual reproduction results in offspring with genetic variation.
- MS-LS1-5 Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms.
- 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.
- HS-LS1-2 Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.

- HS-LS1-4 Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms.

Selected Resources:

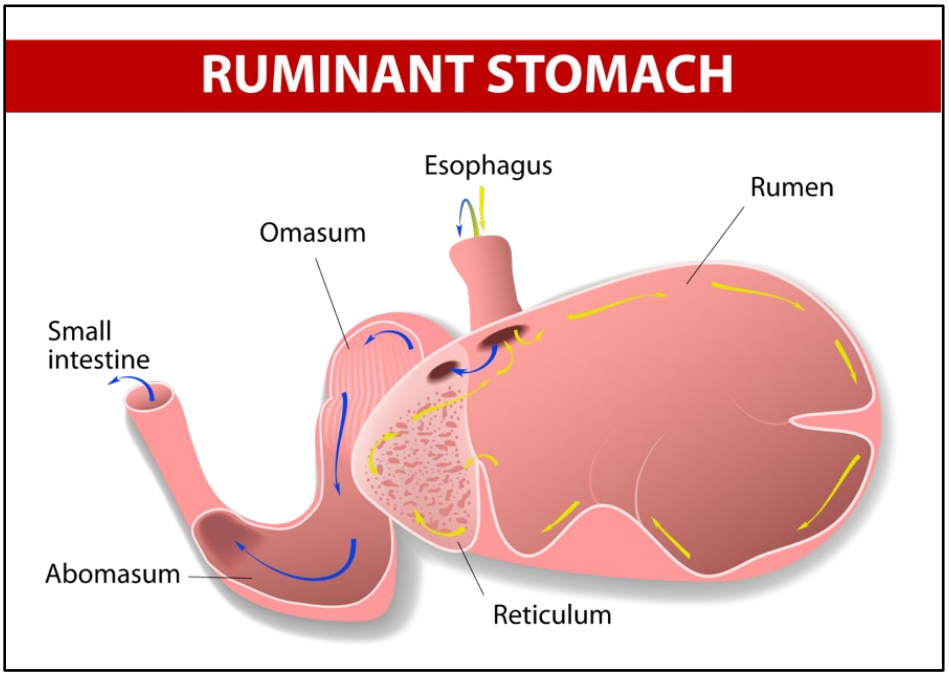
- https://www.beefboard.org/library/files/LeanMattersFinal.pdf
- https://www.beefresearch.org/CMDocs/BeefResearch/Nutrition/BeefCheckoff_Leaner_Pastures_FINAL.pdf

Driving Questions to Drive Instruction:

- Why does steak look so much different today than it did 30 years ago?
- Why did steaks have so much fat 30 years ago compared to today?

Phenomenon: Cows rely on fermentation by microbes in their gut to survive.

Make It Visible:



Summary:
Ruminants, such as cattle, eat a plant diet which is high in structural sugar (i.e., cellulose). Because of this, they have a ruminant stomach with four chambers. The first chamber, the Rumen, contains high levels of microbes including bacteria, protozoa, and fungi which help in the chemical digestion of the plant material. Bacteria that break down structural carbohydrates are an important source for volatile fatty acids (VFAs). VFAs provide 70% of a cow's energy and are used for the production of milk. Interestingly, the Ammonia produced by the microbial fermentation of carbohydrates is used to produce more microbes, which are the primary source of protein for the ruminant.

Related Standards:

- MS-LS2-1 Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.
- MS-LS2-3 Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem.
- MS-LS2-4 Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.
- HS-LS2-1 Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales.
- HS-LS2-2 Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.
- HS-PS1-4 Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy.
- HS-PS1-6 Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium.
- HS-PS1-7 Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.

- HS-LS1-2 Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts. Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.
- HS-LS1-3 Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis.
- HS-LS1-6 Construct and revise an explanation based on evidence for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large carbon-based molecules.
- HS-LS1-7 Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed resulting in a net transfer of energy.
- HS-LS2-3 Construct and revise an explanation based on evidence for the cycling of matter and flow of energy in aerobic and anaerobic conditions.
- HS-LS2-4 Use mathematical representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem.
- HS-LS2-5 Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere.

Selected Resources:

- https://www.beefresearch.org/CMDocs/BeefResearch/Sustainability_FactSheet_TopicBriefs/ToughQA/FS17Methane.pdf
- https://www.sciencedirect.com/science/article/pii/S0309174013004944
- https://www.progressivecattle.com/topics/feed-nutrition/rumen-bugs-101-feeding-the-microbes-not-just-the-cow

Questions to Drive Instruction:

- How does the rumen function?
- What are the components of the ecosystem within the rumen?
- What are the chemical reactions taking place in the rumen?
- How does changing a cow's diet affect the microorganisms in its' rumen?

Phenomenon: About 65% of cow manure is methane.

Make It Visible:

Summary:
Through the process of anaerobic digestion an animal waste product can be converted into a renewable energy source. Students can follow a visual representation, video, or lesson explaining how taking the manure from a dairy cow, and processing it through a methane digester, converts that organic matter into a usable gas that can be used to power machinery or generate electricity. Deeply exploring the micro-ecosystem within a methane digester provides opportunities to look at population dynamics.

Related Standards:

- MS-LS2-3 Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem.
- MS-LS1-7 Develop a model to describe how food is rearranged through chemical reactions forming new molecules that support growth and/or release energy as this matter moves through an organism.
- MS-ESS3-3 Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.
- MS-ESS3-4 Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems.
- MS-ETS1-1 Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
- MS-ETS1-2 Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.
- HS-PS1-4 Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy.

- HS-PS1-7 Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.
- HS-LS1-6 Construct and revise an explanation based on evidence for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large carbon-based molecules.
- HS-LS2-3 Construct and revise an explanation based on evidence for the cycling of matter and flow of energy in aerobic and anaerobic conditions.
- HS-LS2-5 Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere.
- HS-ESS2-6 Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere.

Selected Resources:

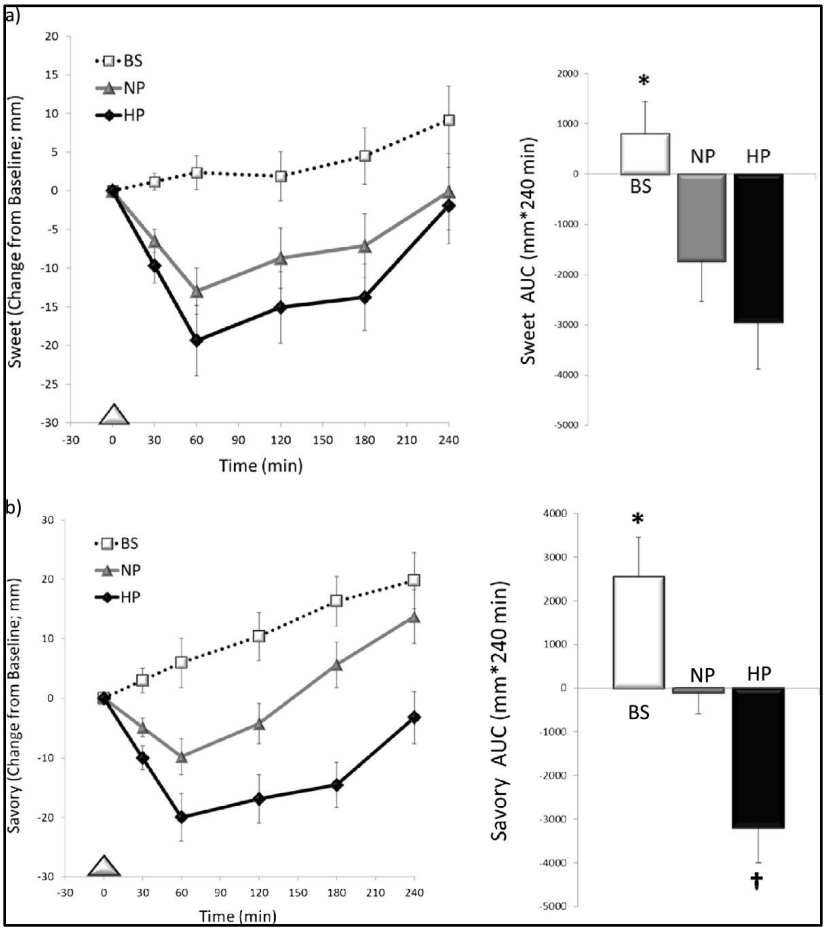
- https://bioproducts.osu.edu/sites/obpic/files/d6/files/dont_waste_the_waste.pdf
- https://myfarmlife.com/livestock/how-a-methane-digester-works/
- https://ww2.kqed.org/quest/2013/08/29/harnessing-the-hidden-power-of-cow-manure/

Questions to Drive Instruction:

- How is the solid waste converted into a gas?
- What are the positives and negatives to using methane gas as an energy source?
- Why is renewable energy important?

Phenomenon: Eating breakfast reduces food cravings; especially one high in protein.

Make It Visible:



https://nutritionj.biomedcentral.com/articles/10.1186/1475-2891-13-80

Summary:
Eating breakfast leads to reductions in food cravings. “These data suggest that the daily addition of breakfast, particularly one high in protein, may be beneficial in reducing food cravings and potentially modulate the underlying substrates that control food hedonics and reward in young overweight/obese people.” (beefresearch.com)

Related Standards:

- MS-LS2-3 Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem.
- MS-LS1-7 Develop a model to describe how food is rearranged through chemical reactions forming new molecules that support growth and/or release energy as this matter moves through an organism.
- MS-LS1-3Use argument supported by evidence for how the body is a system of interacting subsystems composed of groups of cells.
- MS-LS1-8Gather and synthesize information that sensory receptors respond to stimuli by sending messages to the brain for immediate behavior or storage as memories.
- HS-PS1-4Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy.

- HS-PS1-7Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.
- HS-LS1-2 Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.
- HS-LS1-3 Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis.
- HS-LS1-6 Construct and revise an explanation based on evidence for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large carbon-based molecules.

Selected Resources:

- https://www.beefresearch.org/CMDocs/BeefResearch/Nutrition_Research_Brief/Hoertel%20et%20al%202014%20protein%20on%20cravings.pdf
- https://nutritionj.biomedcentral.com/articles/10.1186/1475-2891-13-80
- https://www.sciencedaily.com/releases/2011/05/110519113024.htm

Questions to Drive Instruction:

- What causes hunger sensation?
- How is protein different from other molecules?
- How does our body obtain energy from food?
- How does a protein-rich breakfast affect our bodies?