FDA U.S. FOOD & DRUG ADMINISTRATION

LifeSmarts
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BIOTECHNOLOGY

FOUNDATIONS OF AGRICULTURE

In the "Foundations of Agriculture" module, students will explore the vital role that agriculture plays in our world, focusing on the fascinating science behind crop development and food production. This module offers an exciting introduction to the genetic modification and selective breeding techniques that have revolutionized farming practices, enabling us to meet the growing demands of a global population. Students will learn how these innovations are directly linked to LifeSmarts topics such as sustainability, food safety, and consumer awareness. Developed by educators and FDA experts, the lesson is packed with engaging videos, interactive discussions, and real-world examples like the development of the Cosmic Crisp® apple, making it a must-review for anyone interested in the intersection of science and everyday life. Teachers will find the vocabulary and enrichment activities especially valuable for reinforcing key concepts and preparing students for LifeSmarts competitions.

DISCUSSION QUESTIONS

- Discuss the impact of selective breeding on modern agriculture. How has this practice evolved from early plant domestication to the development of new apple cultivars like the Cosmic Crisp®?
- Explain the significance of the Green Revolution and its relation to the advancements in agricultural practices discussed in the "Foundations of Agriculture" module.

CHALLENGE QUESTION

- Research another modern crop, besides the Cosmic Crisp® apple, that has been developed through selective breeding or genetic modification. Describe the process used to develop this crop and discuss its impact on agriculture and consumers.

See this lesson and more at LifeSmarts U.

This lesson was developed by educators and experts in conjunction with the U.S. Food & Drug Administration

VOCABULARY

- Domestication
- Selective Breeding
- Grafting
- Genetic Modification
- Mendelian Inheritance
- Hybridization
- Angiosperm
- Phenotype
- Cultivar
- Precision Agriculture

ACTIVITIES

- The Making of a New Apple Cultivar
- Strawberry DNA Extraction

VIDEOS

* See reverse side for list

U.S. FOOD & DRUG ADMINISTRATION

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VIDEO LINKS

APPLE – How Does It Grow? (5:32)
https://www.youtube.com/watch?v=UWLmEh1HIBw

How to extract DNA from strawberries (9:45)
https://www.youtube.com/watch?v=hOpu4iN5Bh4

The Seed Bank (12:24)
https://vimeo.com/309965169

A Rare Look Inside the Doomsday Seed Vault Deep In The Arctic (5:24)
http://www.youtube.com/watch?v=uAl8dSpkNWs

Why are there so many types of apples? (5:24)
http://www.youtube.com/watch?v=mQePz62zkqA

Farmweek – New Apple (4:10)
http://www.youtube.com/watch?v=jZsu-_EGa_M

Strawberry DNA Extraction Lab Explanation
www.youtube.com/watch?v=vnjwNiJktZk

Growing Strawberries: Strawberry Fields Forever
www.youtube.com/watch?v=CnQgSXrYo6Q

What is DNA and How Does It Work?
www.youtube.com/watch?v=zwibgNGe4aY

OTHER WEB LINKS

Orange Pippin (Apple Varieties Information)
http://www.orangepippin.com

Cosmic Crisp® Apple Information
http://www.cosmiccrisp.com/the-facts

USDA – National Apple Rootstock Breeding Program
https://www.ars.usda.gov/northeast-area/geneva-ny/plant-genetic-resources-unit-pgru/docs/about-pgru/national-apple-rootstock-breeding-program/

Apple Tree Propagation: Grafting
https://apples.extension.org/apple-tree-propagation-grafting/

DISCUSSION QUESTIONS (SAMPLE ANSWERS)

- A: Selective breeding has been a cornerstone of agricultural development, beginning with the early domestication of plants. Early farmers selected plants with desirable traits, such as better yield or climate tolerance, and bred them to improve the next generation. Over time, this practice became more scientific, with advances like Mendel's work on genetic inheritance laying the groundwork for modern genetics. Today, selective breeding is highly refined, allowing scientists to develop new plant varieties like the Cosmic Crisp® apple. This apple was created through a deliberate process of cross-breeding, selection, and evaluation over many years, resulting in a cultivar that meets specific consumer and grower needs, such as resistance to browning and improved storage life.

- A: The Green Revolution was a period of significant agricultural advancement during the mid-20th century, characterized by the introduction of high-yielding crop varieties, synthetic fertilizers, and advanced irrigation techniques. This revolution greatly increased global food production, particularly in developing countries, helping to alleviate hunger and improve food security. The advancements in selective breeding and biotechnology discussed in the "Foundations of Agriculture" module are direct continuations of the innovations that began during the Green Revolution. For example, the development of the Cosmic Crisp® apple through selective breeding reflects the ongoing effort to optimize crop yields and quality, ensuring that agriculture can meet the demands of a growing global population.

CHALLENGE QUESTION (SAMPLE ANSWER)

- **A well-known example is Bt corn**
  https://www.nature.com/scitable/knowledge/library/use-and-impact-of-bt-maize-46975413/

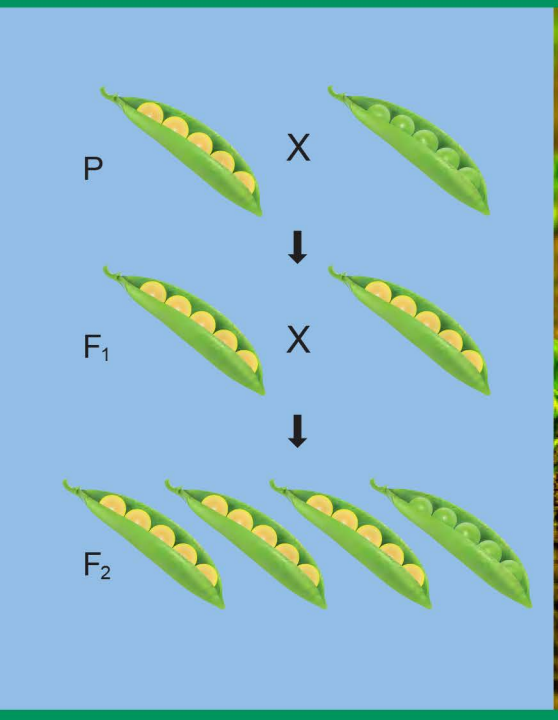
  Key Points:
  Development Process: Bt corn is a genetically modified crop that has been engineered to express a gene from the bacterium Bacillus thuringiensis (Bt), which produces a protein toxic to certain insect pests, such as the European corn borer. This genetic modification was introduced into the corn genome through biotechnology techniques in the laboratory. The Bt gene allows the corn to produce the insecticidal protein throughout the plant, providing constant protection against pests.

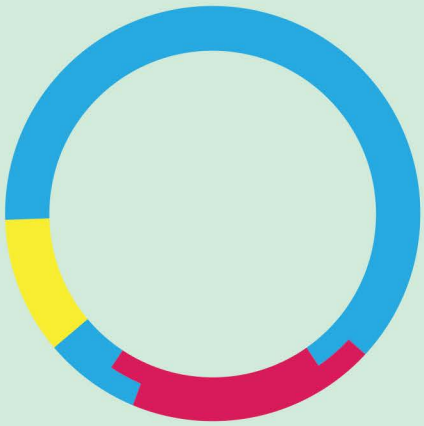
  Impact on Agriculture: The introduction of Bt corn has significantly reduced the need for chemical insecticides in corn production, leading to lower production costs for farmers and reduced environmental impact. The consistent protection against pests has also helped increase crop yields and improve food security in regions where corn is a staple crop.

  Impact on Consumers: For consumers, Bt corn has contributed to the availability of more affordable and abundant corn-based products. However, the use of genetically modified organisms (GMOs) like Bt corn has also sparked debates over food safety, environmental concerns, and labeling transparency. While scientific consensus holds that Bt corn is safe for consumption, some consumers remain cautious about GMOs, leading to calls for clearer labeling and the availability of non-GMO options.

SCIENCE AND OUR FOOD SUPPLY

Biotechnology - Foundations of Agriculture



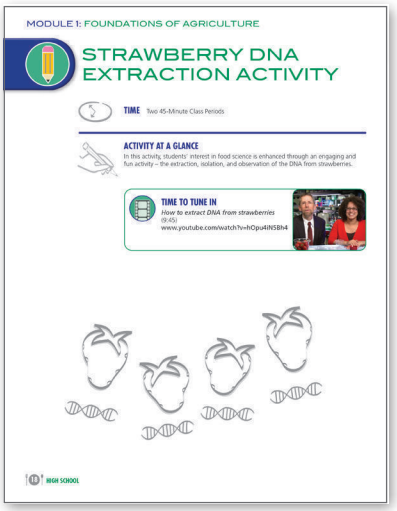


Teacher's Guide for High School Classrooms

1st Edition

OVERVIEW OF ACTIVITIES

The activities are written in this easy-to-understand format.


MODULE 1: FOUNDATIONS OF AGRICULTURE

STRAWBERRY DNA EXTRACTION ACTIVITY

TIME Two 45-Minute Class Periods

ACTIVITY AT A GLANCE

In this activity, students' interest in food science is enhanced through an engaging and fun activity – the extraction, isolation, and observation of the DNA from strawberries.

TIME TO TUNE IN

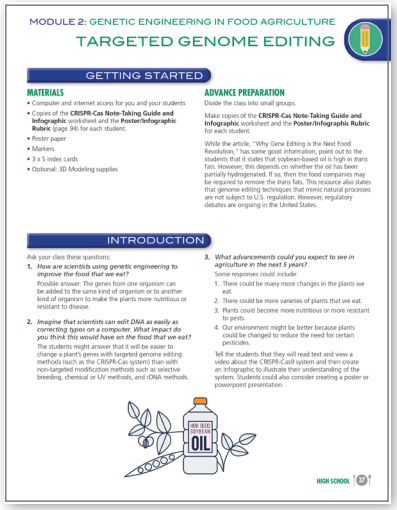
How to extract DNA from strawberries (9:45)
www.youtube.com/watch?v=hOpu4iN5Bh4

HIGH SCHOOL

TIME: The approximate amount of time needed to perform the activity.

ACTIVITY AT A GLANCE: Briefly summarizes the activity.

TIME TO TUNE IN: Shows the URL for an online video related to that activity.


MODULE 2: GENETIC ENGINEERING IN FOOD AGRICULTURE

TARGETED GENOME EDITING

GETTING STARTED

MATERIALS

- Computer and internet access for you and your students
- Copies of the **CRISPR-Cas Note-Taking Guide and Infographic** worksheet and the **Poster/Infographic Rubric** (page 94) for each student.
- Poster paper
- Markers
- 3 x 5 index cards
- Optional: 3D Modeling supplies

ADVANCE PREPARATION

Divide the class into small groups.

Make copies of the **CRISPR-Cas Note-Taking Guide and Infographic** worksheet and the **Poster/Infographic Rubric** for each student.

While the article, "Why Gene Editing is the Next Food Revolution," has some good information, point out to the students that it states that soybean-based oil is high in *trans* fats. However, this depends on whether the oil has been partially hydrogenated. If so, then the food companies may be required to remove the *trans* fats. This resource also states that genome editing techniques that mimic natural processes are not subject to U.S. regulation. However, regulatory debates are ongoing in the United States.

INTRODUCTION

Ask your class these questions:

1. ***How are scientists using genetic engineering to improve the food that we eat?***
   Possible answer: The genes from one organism can be added to the same kind of organism or to another kind of organism to make the plants more nutritious or resistant to disease.
2. ***Imagine that scientists can edit DNA as easily as correcting typos on a computer. What impact do you think this would have on the food that we eat?***
   The students might answer that it will be easier to change a plant's genes with targeted genome editing methods (such as the CRISPR-Cas system) than with non-targeted modification methods such as selective breeding, chemical or UV methods, and rDNA methods.
3. ***What advancements could you expect to see in agriculture in the next 5 years?***
   Some responses could include:
   1. There could be many more changes in the plants we eat.
   2. There could be more varieties of plants that we eat.
   3. Plants could become more nutritious or more resistant to pests.
   4. Our environment might be better because plants could be changed to reduce the need for certain pesticides.

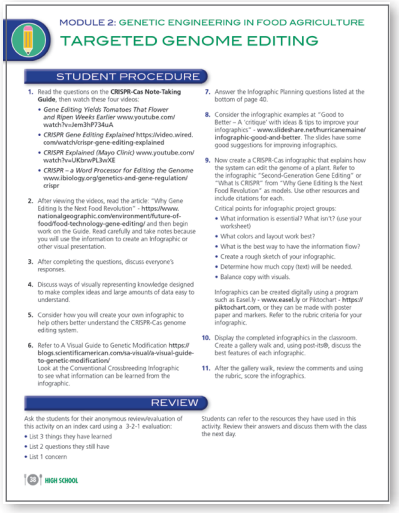
Tell the students that they will read text and view a video about the CRISPR-Cas9 system and then create an infographic to illustrate their understanding of the system. Students could also consider creating a poster or powerpoint presentation.

HIGH SCHOOL

MATERIALS: Includes the items needed to perform the activity.

ADVANCE PREPARATION: Indicates what you need to do before conducting the activity.

INTRODUCTION: Provides fun, innovative suggestions for introducing the activity. Where provided, suggested teacher dialogue is indicated by ***boldface italics***.


MODULE 2: GENETIC ENGINEERING IN FOOD AGRICULTURE

TARGETED GENOME EDITING

STUDENT PROCEDURE

1. Read the questions on the **CRISPR-Cas Note-Taking Guide**, then watch these four videos:
   - *Gene Editing Yields Tomatoes That Flower and Ripen Weeks Earlier* www.youtube.com/watch?v=Jem3hP734uA
   - *CRISPR Gene Editing Explained* https://video.wired.com/watch/crispr-gene-editing-explained
   - *CRISPR Explained (Mayo Clinic)* www.youtube.com/watch?v=JKbrvePLJvXE
   - *CRISPR – a Word Processor for Editing the Genome* www.ibiology.org/genetics-and-gene-regulation/crispr
2. After viewing the videos, read the article: "Why Gene Editing Is the Next Food Revolution" – **https://www.nationalgeographic.com/environment/future-of-food/food-technology-gene-editing/** and then begin work on the Guide. Read carefully and take notes because you will use the information to create an infographic or other visual presentation.
3. After completing the questions, discuss everyone's responses.
4. Discuss ways of visually representing knowledge designed to make complex ideas and large amounts of data easy to understand.
5. Consider how you will create your own infographic to help others better understand the CRISPR-Cas genome editing system.
6. Refer to A Visual Guide to Genetic Modification **https://blogs.scientificamerican.com/sa-visual/a-visual-guide-to-genetic-modification/**
   Look at the Conventional Crossbreeding Infographic to see what information can be learned from the infographic.
7. Answer the Infographic Planning questions listed at the bottom of page 40.
8. Consider the infographic examples at "Good to Better – A 'critique' with ideas & tips to improve your infographics" – **www.slideshare.net/hurricanemaine/infographic-good-and-better**. The slides have some good suggestions for improving infographics.
9. Now create a CRISPR-Cas infographic that explains how the system can edit the genome of a plant. Refer to the infographic "Second-Generation Gene Editing" or "What Is CRISPR" from "Why Gene Editing Is the Next Food Revolution" as models. Use other resources and include citations for each.
   Critical points for infographic project groups:
   - What information is essential? What isn't? (use your worksheet)
   - What colors and layout work best?
   - What is the best way to have the information flow?
   - Create a rough sketch of your infographic.
   - Determine how much copy (text) will be needed.
   - Balance copy with visuals.

   Infographics can be created digitally using a program such as Easel.ly – **www.easel.ly** or Piktochart – **https://piktochart.com**, or they can be made with poster paper and markers. Refer to the rubric criteria for your infographic.
10. Display the completed infographics in the classroom. Create a gallery walk and, using post-its®, discuss the best features of each infographic.
11. After the gallery walk, review the comments and using the rubric, score the infographics.

REVIEW

Ask the students for their anonymous review/evaluation of this activity on an index card using a 3-2-1 evaluation:

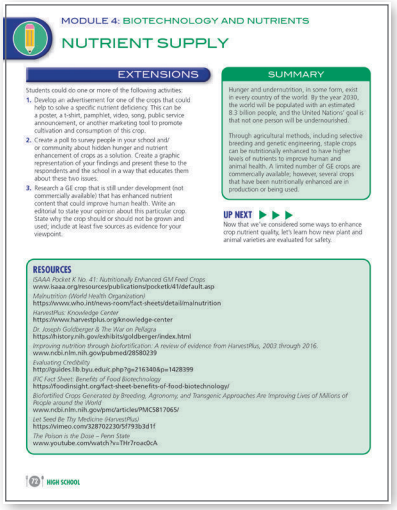
- List 3 things they have learned
- List 2 questions they still have
- List 1 concern

Students can refer to the resources they have used in this activity. Review their answers and discuss them with the class the next day.

HIGH SCHOOL

STUDENT PROCEDURE: Gives the step-by-step process for the activity.

REVIEW: Uses interesting questions to guide students through a review of what they learned in the activity.


MODULE 4: BIOTECHNOLOGY AND NUTRIENTS

NUTRIENT SUPPLY

EXTENSIONS

Students could do one or more of the following activities:

1. Develop an advertisement for one of the crops that could help to solve a specific nutrient deficiency. This can be a poster, a t-shirt, pamphlet, video, song, public service announcement, or another marketing tool to promote cultivation and consumption of this crop.
2. Create a poll to survey people in your school and/or community about hidden hunger and nutrient enhancement of crops as a solution. Create a graphic representation of your findings and present these to the respondents and the school in a way that educates them about these two issues.
3. Research a GE crop that is still under development (not commercially available) that has enhanced nutrient content that could improve human health. Write an editorial to state your opinion about this particular crop. State why the crop should or should not be grown and used, include at least five sources as evidence for your viewpoint.

SUMMARY

Hunger and undernutrition, in some form, exist in every country of the world. By the year 2030, the world will be populated with an estimated 8.3 billion people, and the United Nations' goal is that not one person will be undernourished.

Through agricultural methods, including selective breeding and genetic engineering, staple crops can be nutritionally enhanced to have higher levels of nutrients to improve human and animal health. A limited number of GE crops are commercially available; however, several crops that have been nutritionally enhanced are in production or being used.

UP NEXT ▶ ▶ ▶

Now that we've considered some ways to enhance crop nutrient quality, let's learn how new plant and animal varieties are evaluated for safety.

RESOURCES

ISAAA Pocket K No. 41: Nutritionally Enhanced GM Food Crops:
www.isaaa.org/resources/publications/pocketk41/default.asp

Malnutrition (World Health Organization)
https://www.who.int/news-room/fact-sheets/detail/malnutrition

HarvestPlus: Knowledge Center
https://www.harvestplus.org/knowledge-center

Dr. Joseph Goldberger & The War on Pellagra
https://history.nih.gov/exhibits/goldberger/index.html

Improving nutrition through biofortification: A review of evidence from HarvestPlus, 2003 through 2016.
www.ncbi.nlm.nih.gov/pubmed/28580239

Evaluating Credibility
http://guides.lib.byu.edu/c.php?g=216340&p=1428399

IFIC Fact Sheet: Benefits of Food Biotechnology
https://foodinsight.org/fact-sheet-benefits-of-food-biotechnology/

Biofortified Crops Generated by Breeding, Agronomy, and Transgenic Approaches Are Improving Lives of Millions of People around the World
www.ncbi.nlm.nih.gov/pmc/articles/PMC5817065/

Let Seed Be Thy Medicine (HarvestPlus)
https://vimeo.com/328702230/5f7930d1f

The Poison is the Dose – Penn State
www.youtube.com/watch?v=THr7roaxDcA

HIGH SCHOOL

SUMMARY: Summarizes key concepts learned in the activity.

EXTENSIONS: Suggest activities to help students learn more about the topic.

RESOURCES: Provide references to online resources for the activity or for further study.

UP NEXT: Gives a preview of the next activity.

MODULE 1 FOUNDATIONS OF AGRICULTURE

This module introduces a brief overview of plant domestication, selective breeding, and other agricultural science.

For this module, it is recommended that teachers will have already taught students the following underlying key concepts: cell structure and function; cell division, cellular reproduction, and protein synthesis; plant structures, functions, and life cycles; and basic genetic terminology.

BACKGROUND INFORMATION

This section provides an overview of key stages of plant domestication and early genetic discoveries.

ACTIVITY & LAB

The Making of a New Apple Cultivar activity helps students examine traits chosen by selective breeding using the Cosmic Crisp® apple and its parent apples.

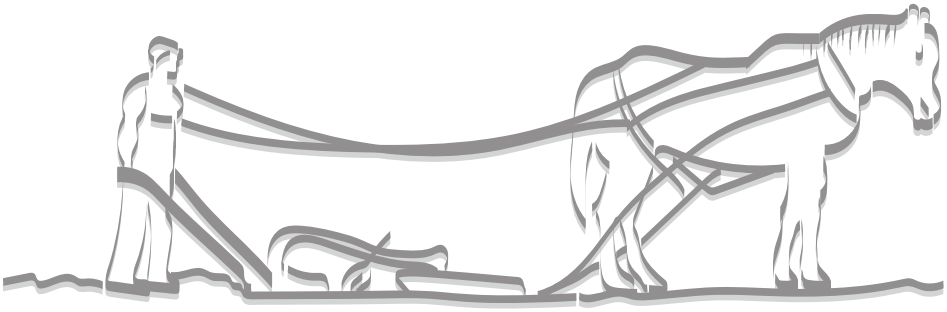
Time to Tune In
This short video shows some techniques (e.g., grafting, pest control) that one farm uses to grow and maintain an apple orchard.

APPLE – How Does It Grow? (5:32)
www.youtube.com/watch?v=UWLmEh1HIBw

Strawberry DNA Extraction lab shows that DNA is found in a commonly consumed fruit, just as it is in food from any living source.

Time to Tune In
In this video, Drs. Eric Green and Carla Easter from the National Human Genome Research Institute of the National Institutes of Health demonstrate how to extract DNA from strawberries using everyday household items.

How to extract DNA from strawberries (9:45)
www.youtube.com/watch?v=hOpu4iN5Bh4



BACKGROUND INFORMATION

PART 1
Early Agriculture

There is clear evidence of early, small-scale farming in the Middle East about 23,000 years ago. The seeds of edible cereals, such as wild emmer, wild barley, and wild oats, along with a grinding slab and sickle blades indicate that early humans harvested cereal along the Sea of Galilee. Low-oxygen lake sediment preserved the early farming evidence for modern archaeologists to study today.

Although exact years are not defined, early agriculture began independently in several areas around the globe.

Different societies selected plants to meet their needs and preferences. Preferred plants could grow to provide sufficient quantities and survive regional climate conditions, including temperature, water availability, and sunlight. Plants that were adapted to local ecosystems and soil were (and still are) most likely to thrive and produce more food for people and livestock.

Civilization progressed through the Middle Ages and across the continents. Intercontinental exchanges after 1492 led to the global distribution of many crops. By the 1850s, railroad expansion supported both U.S. settlement and farming distribution across the country. Irrigation, crop rotation, and fertilizer use also enhanced farm production. With the invention of the gasoline-powered tractor in 1892, crop productivity increased significantly as this machine and others replaced much of the human labor. Recently, synthetic fertilizers and pesticides and more scientific selective breeding have further enhanced agricultural productivity. Throughout time, the goal has been to produce enough food to feed people, livestock, and pets.

Sample Milestones

Time	Region	Crop/Livestock
~ 21,000 B.C.	Levant (Eastern Mediterranean)	Wild emmer, wild barley, and wild oats
~ 9,500 B.C.	Fertile Crescent	Neolithic Founder Crops (emmer wheat, einkorn wheat, hulled barley, peas, lentils, bitter vetch, chick peas, and flax)
~11,000 – 9,000 B.C.	China	Rice, followed by mung, soy, and azuki
~ 11,000 B.C.	Mesopotamia	Pigs, followed by sheep
~ 8,500 B.C.	Turkey and Pakistan	Cattle
~ 8,000 B.C.	North America	Squash, potatoes, and beans
~ 7,000 B.C.	New Guinea	Sugarcane and some root vegetables
~ 5,000 B.C.	Sahel region of Africa	Sorghum
~ 8,000 – 5,000 B.C.	Andes of South America	Potatoes, beans, coca, llamas, alpacas, and guinea pigs
~ 8,000 – 5,000 B.C.	Papua New Guinea	Bananas
~ 4,000 B.C.	Mesoamerica (current Central America)	Maize (teosinte)
~ 3,600 B.C.	Peru	Cotton
~ 3,000 B.C.	Somalia and Arabia	Camels

BACKGROUND INFORMATION

Scientific Advances in Agriculture

Humans have been modifying plants for thousands of years through selective breeding. By saving seeds from plants with the traits they desired, indigenous people played a significant role in domestication of corn with a range of colors, sizes, and uses. As farmers learned more about trait inheritance, they deliberately crossbred and selected plants to improve yield, flavor, and other desirable characteristics.

In 1866, Gregor Mendel published his work on the inheritance of pea plant traits. He grew more than 10,000 plants over 8 years and tracked them by number and offspring. He was the first person to identify that traits can be either dominant or recessive. His work went mostly unnoticed for three decades, but it is considered the beginning of modern genetics.

Refresher: Mendelian Laws of Inheritance

1) *The Law of Segregation*: Each inherited trait is defined by a gene pair. Parental genes are randomly separated to the sex cells so that sex cells contain only one gene of the pair. Offspring therefore inherit one genetic allele from each parent when sex cells unite in fertilization.
2) *The Law of Independent Assortment*: Genes for different traits are sorted separately from one another so that the inheritance of one trait is not dependent on the inheritance of another.
3) *The Law of Dominance*: An organism with alternate forms of a gene will express the form that is dominant.

Although Mendel published his work in 1866, it wasn't until the early 1900's that his work was recognized.

While many advances in agricultural production were historically slow, the **Green Revolution** of the 1950s and 1960s allowed for more rapid increases in food production, specifically using high-yield seed varieties and fertilizer. In the 1960s, Norman Borlaug used selective breeding to significantly increase wheat yields (from 750 kg/hectare to 3,200 kg/hectare). His model was used later for other crops.

Throughout the 20th century, more was learned about genetic inheritance. For example, the garden strawberries that consumers buy today resulted from a cross between a strawberry species native to North America and a strawberry species native to South America.

In recent decades, certain crop improvements have also resulted from modern biotechnology when targeted changes to a plant's genetic makeup give the plant a new desirable trait. The term GE refers to the genetic modification practices that utilize modern biotechnology. This technology has been used to produce a variety of crops, including some new apple varieties that resist browning associated with cuts and bruises by reducing levels of enzymes that cause browning.

DNA in Our Food

We ingest DNA when we eat a plant or animal-derived food. An average meal contains more than 90,000 miles of DNA. Our digestive enzymes break the DNA molecules into smaller molecular components just like they break down proteins, carbohydrates, and fats into smaller molecules that our bodies can use. The DNA in our food does not become our DNA: If we eat an onion, it might give us onion breath, but it won't turn us into an onion.

A Bit About Seeds

Some plants grow from seeds. A seed is a unit of reproduction that includes the genetic material and nutrients needed to start a new plant's development. Seed plants fall into two basic groups: **Gymnosperms** (do not produce flowers) and **angiosperms** (do produce flowers). The angiosperm flowers develop into fruits that contain seeds (e.g., apples, tomatoes, squash). Most of the food that humans eat comes from angiosperms. Examples of food from gymnosperms include pine nuts and ginkgo. Edible seeds (particularly cereals, legumes, and nuts) are a major source of human calories.

Some plants are grown through **vegetative reproduction** (vegetative propagation). This is a form of asexual reproduction. One form is growing a new plant from a part (a cutting) from another plant, essentially making clones. The cuttings can take root and grow into full plants.

DID YOU KNOW?

Across the world, there are more than 1,000 seed banks that protect seed varieties of food crops to safeguard agricultural diversity. The USDA National Plant Germplasm System actively preserves seeds in several U.S. vaults; the largest facility is in the Rocky Mountains at Fort Collins, Colorado. Watch ***The Seed Bank*** to learn more about this important work: **https://vimeo.com/309965169** (12:24)

The largest seed bank in the world is the Svalbard International Seed Vault, located in a mountain on a remote island in Norway. It stores more than 1 million seed varieties. The Svalbard Vault was established to preserve seeds that could be used to restore varieties needed for global food security after natural or human-made disasters. For this reason, it is called the "Doomsday" Vault. To learn more about the Vault, watch this video: ***A Rare Look Inside the Doomsday Seed Vault Deep In The Arctic*** www.youtube.com/watch?v=uAl8dSpkNWs (5:24)

BACKGROUND INFORMATION

A Closer Look at Apples

The earliest apples grew on wild trees in Central Asia and Western China, possibly about 2 to 10 million years ago, around the time early humans were evolving. Although there is some disagreement about who cultivated the first apple trees, most scientists agree that they were cultivated in Kazakhstan by 2,000 B.C.

DID YOU KNOW?

Apples have 17 chromosomes.

Most apples are **diploid** (have two sets of chromosomes), but some are **polyploid** (have more than two sets of homologous chromosomes).

People often tell stories of their ancestors and their traits. Through generations of offspring and migration, how did their family change? If food products could tell you their family stories, what could we learn about their ancestors and where they were raised? How did their family change over time? In the following apple activity, students will learn more about an apple that was developed through selective breeding from two different parent apple varieties.

Farm Facts

- Two million farms dot the U.S. landscape.
- The average farm feeds 166 people annually.
- Farm and ranch families comprise less than 2% of the U.S. population.
- One acre of land can produce different types of crops, depending on the soil type and fertility, how much rain falls, and how much the sun shines. Typically, one acre can grow:
  – 840 pounds of cotton
  – 2,784 pounds of wheat (46.4 bushels)
  – 50,000 pounds of strawberries
- There are many agriculture-related careers, including some working with animals, plants, soil, machines, water resources, environmental studies, or technology, as well as some you might not think about like being a florist or beekeeper.
- 98% of all U.S. farms are owned by individuals, family partnerships, or family corporations. Just 2% of America's farms and ranches are owned by non-family corporations.

from the American Farm Bureau Foundation for Agriculture (2019)

Agricultural Terms (for the purposes of this curriculum)

Agriculture – The science or practice of farming, derived from the Latin words "ager" (field) and "cultura" (cultivation).

Biotechnology – Specific techniques used by scientists to modify DNA or the genetic material of a microorganism, plant, or animal in order to achieve a desired trait. (Source: FDA)

Cloning (e.g., potatoes, sweet potato, sugarcane) – Producing genetically identical offspring.

Cross Breeding – Combining two sexually compatible species, breeds, or varieties to create a new variety with the desired traits of the parents. Example: The Honeycrisp apple gets its famous texture and flavor by blending the traits of the parents.

Cultivar – A contraction of "cultivated variety." It refers to a plant type within a particular cultivated species that is distinguished by one or more characters.

Domestication – The process of breeding for one or more desirable characteristics in plants and animals. This was the first step for humans to move from hunter-gatherer to agricultural societies.

Genetic Modification – The process of altering the genome of an organism. Techniques include those used in traditional breeding as well as newer modification methods like genetic engineering.

Grafting – Inserting a shoot or twig from one plant into part of another rooted plant to selectively grow a specific variety.

Heterosis (hybrid vigor) – The enhanced function of any biological quality in a hybrid offspring.

Hybridization/Hybrid – The offspring of two plants of related species or different varieties.

Precision Agriculture (PA) – An approach to farm management that uses information technology, e.g., drones and GPS data, to ensure that the plants and soil receive the exact amount of water and other nutrients for optimum health and productivity. The goal of PA is to ensure profitability, sustainability, and protection of the environment.

Selective Breeding – A breeding method that uses organisms with specific desired traits to produce the next generation. There is evidence that by 5,000 B.C. humans had some understanding of inheritance and selectively bred more useful varieties of wheat, maize, rice, and dates.

MAKING A NEW APPLE CULTIVAR

TIME Two 45-Minute Class Periods

ACTIVITY AT A GLANCE

The purpose of this lesson is to introduce students to apple growing and show them how selective breeding is used to benefit both the apple grower and consumer by producing a new and better-quality apple.

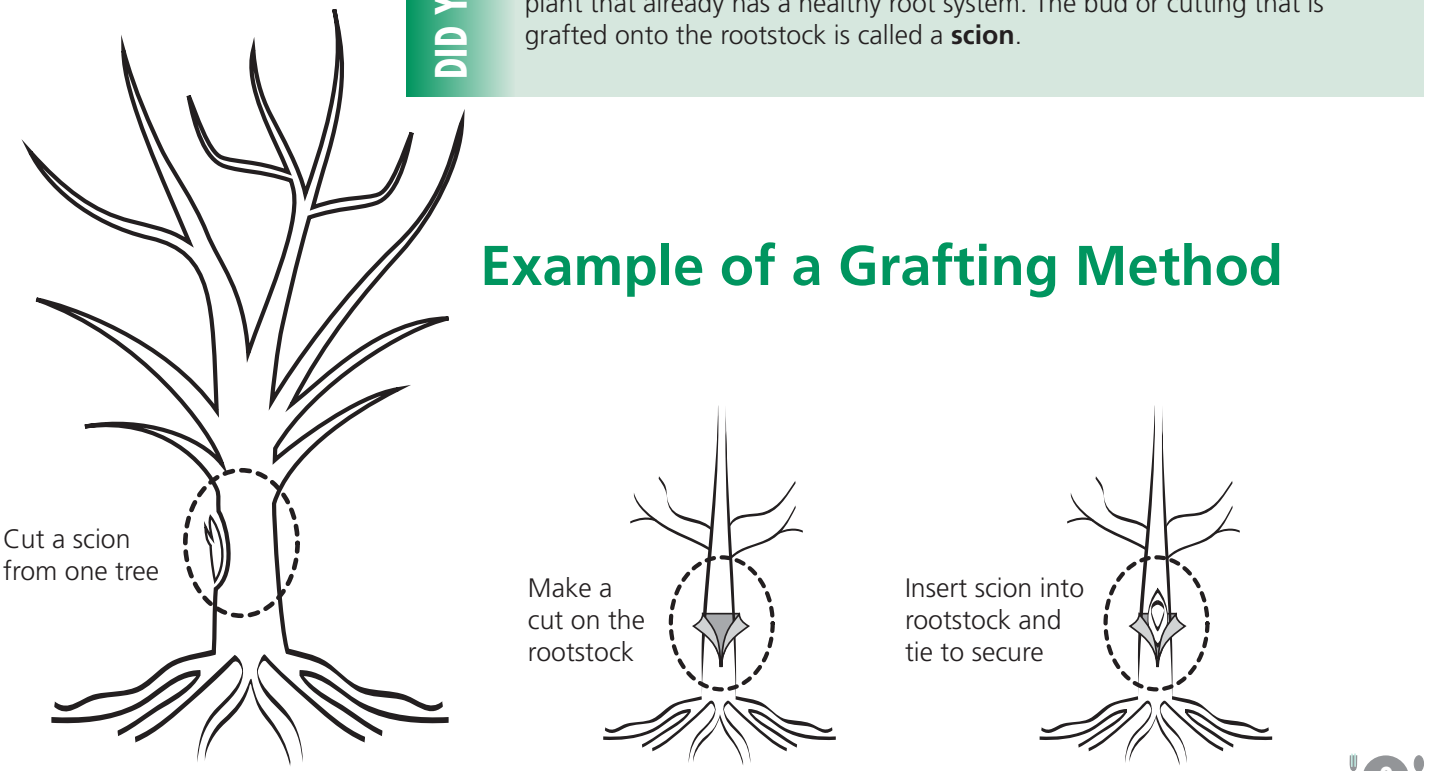
TIME TO TUNE IN

APPLE – How Does It Grow? (5:32)
www.youtube.com/watch?v=UWLmEh1HIBw

DID YOU KNOW?

Apples do not grow "true" from seed. This means that if you plant a seed from one kind of apple, the apple tree that would grow will not be the same variety as the apple that the seed came from. The only way to reproduce a specific desired apple variety is to graft a bud or cutting from a tree that previously yielded that variety onto a rootstock. A rootstock is a compatible plant that already has a healthy root system. The bud or cutting that is grafted onto the rootstock is called a **scion**.

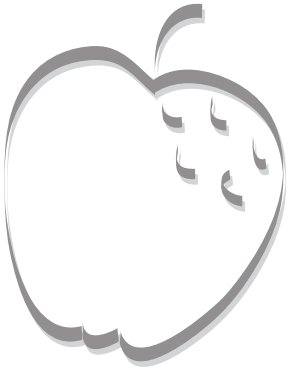
Example of a Grafting Method



BACKGROUND INFORMATION

The Development of the Cosmic Crisp® Apple

The apple is so common that it is very easy to take this fruit for granted. Yet, it has a very rich and interesting history. The wild apple trees that are thought to have come from ancient Asia thousands of years ago are believed to have produced hundreds of tiny fruits that were sour and consisted mostly of numerous dark brown seeds and a core. Over thousands of years, fruits that were more pest resistant and tolerant of geographical climate factors endured through natural selection. These apple trees were the earliest to be cultivated by humans.



Colonial America

In the United States, apples were first planted by colonists from the Massachusetts Bay Colony in the 17th century, and the first apple orchard was planted in Boston in 1625. One of our country's longest surviving apple trees was planted in 1647 in a Manhattan orchard. Unfortunately, the tree died after it was struck by a derailed train in 1866.

The only apples native to North America are crab apples, which were once called common apples. Apple **cultivars** (varieties) brought as seed from Europe were spread along North American trade routes, as well as cultivated on colonial farms. In 1845, one apple nursery catalogue offered 350 apple cultivars for sale.

Apples as a Crop

Apples are an important agricultural crop. Today, worldwide, there are more than 7,500 known apple cultivars. Over 2,500 different apple cultivars are grown in the United States, but only 100 varieties are grown commercially. Washington and New York are the leading apple-growing states. Only China produces more apples than the United States.

The basic techniques of apple-growing haven't changed much over the years; however, some new technologies, such as using DNA analysis in choosing parents and seedlings, are providing some important new tools in apple propagation. In the wild, apples can grow easily from seeds; however, since the apple fruit is formed through cross-pollination, this fruit can be very different from its parents. For this reason, apples are ordinarily propagated asexually by grafting. Grafting involves inserting a bud or twig from one plant into a small cut in the bark of a rootstock, which is a compatible trunk with established roots.

Most new apple cultivars originate as seedlings, which were either formed by chance or have been bred by deliberately crossing cultivars with promising characteristics, such as flavor and climate tolerance. The Cosmic Crisp® apple was formed by crossing the Enterprise and Honeycrisp apples. This new apple was developed over a period of 20 years by Washington State University's Tree Fruit Research and Extension Center (WSU-TFREC).

DID YOU KNOW?

Why Do Cut Apples Turn Brown? Apple cells contain phenol and phenolase enzymes. When an apple is sliced or damaged in a way that allows the cells to come into contact with air, these chemicals are exposed to oxygen, and the phenol is converted to melanin that gives apples the brown color.

BACKGROUND INFORMATION

Selective Breeding

In 1998, seed resulting from a cross between Enterprise and Honeycrisp apples was germinated and raised in a greenhouse to produce the Cosmic Crisp® apple. The seedling was transferred to a nursery and budded into a rootstock in 1999. The resulting tree was planted in an orchard in 2001. Fruit from this single, budded tree was evaluated in 2002 and 2003, and apples (now called WA 38) were selected. (Note: The WA38 designation means it was WSU's 38th attempt to get a new cultivar.) In 2004, buds from this single seedling were propagated onto rootstock. Two years later, the trees were planted in three different locations in the state of Washington. In 2007, more trees were budded for a much larger scale planting the following year. The fruit from the original tree as well as fruit from the subsequent plantings continue to be evaluated. It takes approximately 2 or more years for a new tree to bear fruit.

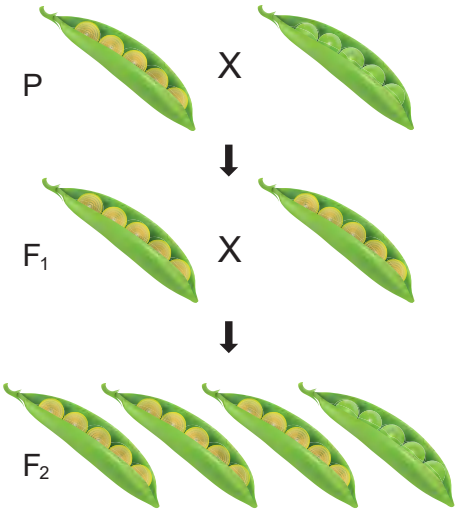
From that single seedling developed in 1998, just over 600,000 Cosmic Crisp® trees were in the ground in 2017, with some 7 million more planted in 2018 and another 6 million planned for planting in 2019. The apples became available to consumers in Fall 2019.

Genetics

The modern science of genetics began during the mid-1800s with the work of Gregor Mendel in what is now the Czech Republic. Mendel experimented with ordinary garden pea plants that were true-breeding, which means that the flowers were mostly self-pollinating, and producing offspring identical to the parents. In other words, the offspring of true-breeding tall pea plants would all be tall, and the offspring of true-breeding short pea plants would all be short. Mendel also discovered that some of the pea plant's alleles were dominant, while others were recessive. A pea plant that was a true-breed for tallness would have two alleles for tallness; and, conversely, one that was a true-breed for shortness would have two alleles for shortness.

To learn more about how traits were passed from parents to offspring, Mendel decided to cross-pollinate true-breeding tall plants with true-breeding short plants. To his surprise, all the offspring were tall. When he crossed these offspring, the plants produced were either tall or short. He observed multiple traits that had two forms, e.g., height (tall or short), pea color (green or yellow), seed shape (smooth or wrinkled). Further study of garden peas and their traits led Mendel to the conclusion that some traits have the ability to mask other traits. He called these traits dominant and those that were masked, recessive.

Pea Color Inheritance



However, in reality, not all traits behave as dominant or recessive. In some cases, the traits may express incomplete dominance where neither trait is dominant or recessive; and, the expressed trait is somewhere between the two traits. For example, some crossbred red and white flowers have pink flower offspring. In other cases, both the dominant and recessive traits may be expressed. This situation is called codominance. A sweet apple variety crossed with a tart apple variety may yield an apple variety that is both sweet and tart.

The techniques that Mendel used in the 19th century in studying genetics are still in use today.

Apple Facts

- Apples are a good source of Vitamin C, potassium, and fiber.
- Apples are fat, sodium, and cholesterol free.
- It takes the energy from approximately 50 leaves to produce one apple.
- Apples ripen 6 to 10 times faster at room temperature than if they were refrigerated.
- Apples have five seed pockets or carpels. Each pocket contains seeds. The number of seeds per carpel is determined by the vigor and health of the plant. Different varieties of apples will have different numbers of seeds.
- The science of apple growing is called **pomology**.

MAKING A NEW APPLE CULTIVAR

GETTING STARTED

MATERIALS

- **The Making of a New Apple Cultivar** worksheet – one for each student
- Internet access for each group of students.
- Optional: Actual apples from your local grocery store, depending on what is available. The *Orange Pippin* website lists places where some apples can be purchased.

ADVANCE PREPARATION

Divide the class into small groups.

Make copies of **The Making of a New Apple Cultivar** worksheet – one for each student.

Make sure students have internet access to view videos and do research.

INTRODUCTION

The United States is the world's second largest producer of apples and next to bananas, the apple is the most consumed fruit in the United States. Yet, if you ask students from where their apples come, they will have limited knowledge of the apples' source. In fact, if you mention apple, the students may think of an electronic device – not the fruit.

STUDENT PROCEDURE

1. Discuss the following questions:
   - How many different varieties of apples can you name?
   - How many of them have you eaten?
   - Which are your favorites and why?

   Think about the different traits apples have and how those traits are determined.

2. Everyone should have a copy of **The Making of a New Apple Variety** worksheet, Parts A, B & C.

3. Watch the video - *APPLE – How Does It Grow?* **www.youtube.com/watch?v=UWLmEh1HIBw**. Complete the Part A worksheet and discuss your responses. This part of the activity will help you to understand apple growing and the many different apple varieties and traits.

4. Now look at your Part B worksheet, and go to the Orange Pippin website (listed on your worksheet) for information to complete the first two columns for the Enterprise and Honeycrisp apples. Use all sections of each apple's webpage to complete the data table.

5. Be sure to:
   - analyze the data.
   - discuss the similarities and differences in the two apples.
   - record the findings in a Venn diagram (Part B Worksheet).
   - review dominant and recessive traits. Is it possible to determine whether any of the traits you have researched are either dominant or recessive?

6. The Cosmic Crisp® apple is a new, non-browning apple developed by Washington State University. This apple is the result of the selective breeding of the Enterprise and Honeycrisp™ apples. To complete the 3rd column of your Part B worksheet, use the following websites: **www.orangepippin.com** and **www.cosmiccrisp.com/the-facts**.

7. Discuss the variety of apple cultivars that have been developed; how are apples bred?

8. As you watch the following videos, complete the Part C worksheet: *Developing the Cosmic Crisp Apple*, and discuss your findings with your group.

   Why are there so many types of apples?
   www.youtube.com/watch?v=mQePz62zkqA

   Farmweek – New Apple
   www.youtube.com/watch?v=jZsu-_EGa_M.

MAKING A NEW APPLE CULTIVAR

REVIEW

Students should now understand

- the difference between dominant and recessive traits
- that creating an apple cultivar is a lengthy process
- the importance of new development to our apple supply

EXTENSIONS

Students could do one or more of the following activities:

1. Research the development of The Opal® apple, another non-browning cultivar developed at the Institute of Experimental Botany in Prague, Czech Republic. It is a cross of the Golden Delicious with the Topaz. Compare it to the Cosmic Crisp® apple.
2. Research the Arctic® apple, also a non-browning apple that was developed through genetic engineering, and compare it to the Cosmic Crisp® apple.

SUMMARY

Apples are one of the most important agricultural crops produced in the United States, and we are the second largest producer in the world. However, this production rate can be challenged by other apple-producing countries. It is important to continue to develop new apple cultivars. Apple breeders use deliberate processes to maintain an apple supply that is both grower and consumer friendly.

UP NEXT

Now that you've learned more about apple trait selection, let's take an inside look at strawberries.

RESOURCES

- *APPLE – How Does It Grow?*
  www.youtube.com/watch?v=UWLmEh1HIBw
- *Apple Varieties of the Future from WSU's Apple Breeding Program*
  www.youtube.com/watch?v=GeFCyeeDCYg
- *Cosmic Crisp® Apples*
  www.cosmiccrisp.com/the-facts
- *The Apple That Changed the World*
  www.npr.org/sections/money/2018/05/03/607384579/the-apple-that-changed-the-world; 5:56; May 3, 2018
- *Farmweek – New Apple*
  www.youtube.com/watch?v=jZsu-_EGa_M
- *Apple Tree Propagation: Grafting*
  https://apples.extension.org/apple-tree-propagation-grafting/
- *Incomplete Dominance, Codominance, Polygenic Traits, and Epistasis*
  www.youtube.com/watch?v=YJHGfbW55l0
- *Monohybrids and the Punnett Square Guinea Pigs*
  www.youtube.com/watch?v=i-0rSv6oxSY
- *Orange Pippin*
  www.orangepippin.com
- *USDA – National Apple Rootstock Breeding Program*
  https://www.ars.usda.gov/northeast-area/geneva-ny/plant-genetic-resources-unit-pgru/docs/about-pgru/national-apple-rootstock-breeding-program/
- *Why are there so many types of apples?*
  www.youtube.com/watch?v=mQePz62zkqA
- *National Agriculture in the Classroom*
  www.agclassroom.org

STUDENT WORKSHEET

MAKING A NEW APPLE CULTIVAR

PART A: *APPLE - HOW DOES IT GROW?*

www.youtube.com/watch?v=UWLmEh1HIBw

Name _____ Date _____ Class/Hour _____

1. What is meant by the statement "Each apple seed is genetically unique?" _____

2. Explain how grafting is used to propagate new apple trees. _____

3. Explain the importance of pollinators in the production of the apple crop. _____

4. Describe some methods that apple growers use to control pests? _____

5. If apples are only harvested in the late summer and fall, how are they available to consumers all year round? _____

6. How does the United States compare to other countries in the amount of apples produced? _____

STUDENT WORKSHEET

MAKING A NEW APPLE CULTIVAR

PART B: COMPARING APPLE CULTIVAR TRAITS

Name _____ Date _____ Class/Hour _____

Refer to the following websites for this activity: **www.orangepippin.com** and **www.cosmiccrisp.com/the-facts**

	Enterprise Apple	Honeycrisp™ Apple	Cosmic Crisp® Apple
Fruit Color			
Flesh Color			
Fruit Crispness			
Fruit Size			
Fruit Browning			
Fruit Shape			
Fruit Taste			
Skin Thickness			
Use			
Disease Resistance			
Scab			
Mildew			
Fireblight			
Cedar Apple Rust			
Bitter Pit			

Make a Venn diagram to explain the similarities and differences between the Enterprise and Honeycrisp™ apples.

Using the data you have collected, is there a way to determine if any of the apples' traits are dominant or recessive?

When comparing the Cosmic Crisp® apple to the Enterprise and Honeycrisp™ apples, what do you notice about the taste of the apples? How could the inheritance of taste be explained? Are there any other traits that seem to be similarly inherited? What would you need to do to determine whether or not your ideas for inheritance are correct?

STUDENT WORKSHEET

MAKING A NEW APPLE CULTIVAR

PART C: DEVELOPING THE COSMIC CRISP® APPLE

Name _____ Date _____ Class/Hour _____

Complete this worksheet as you watch the following two videos:

Why are there so many types of apples?
www.youtube.com/watch?v=mQePz62zkqA and
Farmweek – New Apple – **www.youtube.com/watch?v=jZsu-_EGa_M**

1. The Cosmic Crisp® apple was developed through selective breeding. Explain selective breeding and list the steps that apple breeders might use in this process. _____

2. In researching the Cosmic Crisp®, you probably did not find information about the apple's skin thickness. What might you predict the apple's skin thickness to be? What information did you use to make this prediction? _____

3. How long was the WA 38 (Cosmic Crisp®) cultivar in development at Washington State University? _____

4. How do apple breeders ensure that the new apple cultivar is the same as the original seedling? _____

5. How was the public introduction of the Cosmic Crisp® apple different than the way in which new apple cultivars are usually introduced? _____

6. How do apple breeders maintain long-lasting rights over an apple cultivar? _____

7. The breeders of the Cosmic Crisp® apple believe that they have produced an apple that is better than most of the other apples available today in our grocery stores. Explain why you either agree or disagree with this statement.

8. Looking to the future, what would the traits be of your "perfect" new apple cultivar? _____

BACKGROUND INFORMATION

PART 2
Strawberry DNA

Deoxyribonucleic acid (DNA) is a molecule that contains the genetic instructions used in the development and functioning of all organisms and some viruses. Strands of DNA are divided into segments called genes. All organisms have genes that determine various biological traits, some of which are visible and some of which are not. Many genes, in turn, provide the information for making proteins, which carry out specific functions. This incredible molecule can easily be seen with the naked eye when collected from thousands of cells.

In this activity, students will extract strands of DNA from the nuclei of strawberry cells. Strawberry cells are used because their cells are easy to break open and they have lots of DNA. Their cells are **octoploid**, which means they have eight copies of each chromosome. Human cells are **diploid** (have two sets of chromosomes).

First, the students gently mash the strawberries to break the cells' walls and expose the inner membranes. Next the cells are mixed with the DNA extracting buffer, which is a mixture of soap, salt, and water. The soap dissolves the lipid bilayers of the cellular and nuclear membranes, exposing the DNA. The salt breaks up the protein chains that bind around the nucleic acids in the DNA. When the mixture is filtered, the strawberry cell parts that are larger than DNA are separated from the DNA. Adding chilled rubbing alcohol to the filtered solution causes the DNA to precipitate out of the solution and become visible. It is important to keep the alcohol cold, because the colder the alcohol, the less soluble the DNA. The other cell parts are soluble in the chilled alcohol.

How is DNA from Food Used by Scientists?

Scientists can use DNA isolated from food to identify particular traits, a plant or animal species, or potential contamination sources.

- Agricultural researchers use DNA analysis to choose desired traits that can be propagated in plants and animals.

- DNA barcoding is a method that tests DNA in a food source for known DNA sequences that distinguish one species from another. For example, tilapia (fish) DNA has unique sequences that differ from trout DNA, so commercial fish can be analyzed to verify correct labeling.
- Working together, the FDA and the Centers for Disease Control and Prevention can trace the origins of microbial pathogens in food that is a potential source of foodborne pathogens by using DNA samples.

Uses of Genetics in Plant Breeding

- *Backcrossing:* This is a quality control step in the selective breeding process. Because a hybrid cross can result in the inheritance of desired and unwanted traits as well as the loss of desired traits, breeders cross the offspring of hybrid crosses with the preferred parent until the offspring has the desired traits but not the unwanted traits.
- *Inbreeding:* Some plant species may be fertilized by themselves and produce an inbred variety that is identical from generation to generation. The fact that it preserves the original traits make it useful for research, as new true-breeding cultivars, and as the parents of hybrids.
- *Hybrid breeding:* Two different inbred varieties can be crossed to produce offspring with stable characteristics and hybrid vigor, where the offspring is much more productive than either parent.
- *Mutation breeding:* Mutations in a plant's genome occur naturally and can result in desirable traits. Mutation breeding is the induction of genetic mutations by exposing plant cells to radiation or certain chemicals and then selecting for plants with desirable traits.
- *Molecular marker-assisted selection:* Molecular markers are DNA sequences that 'mark' locations on a genome. Breeders use molecular markers linked to desirable traits to genetically screen and select plants for breeding.
- *Genetic engineering:* Techniques that will be covered in Module 2.

STRAWBERRY DNA EXTRACTION ACTIVITY

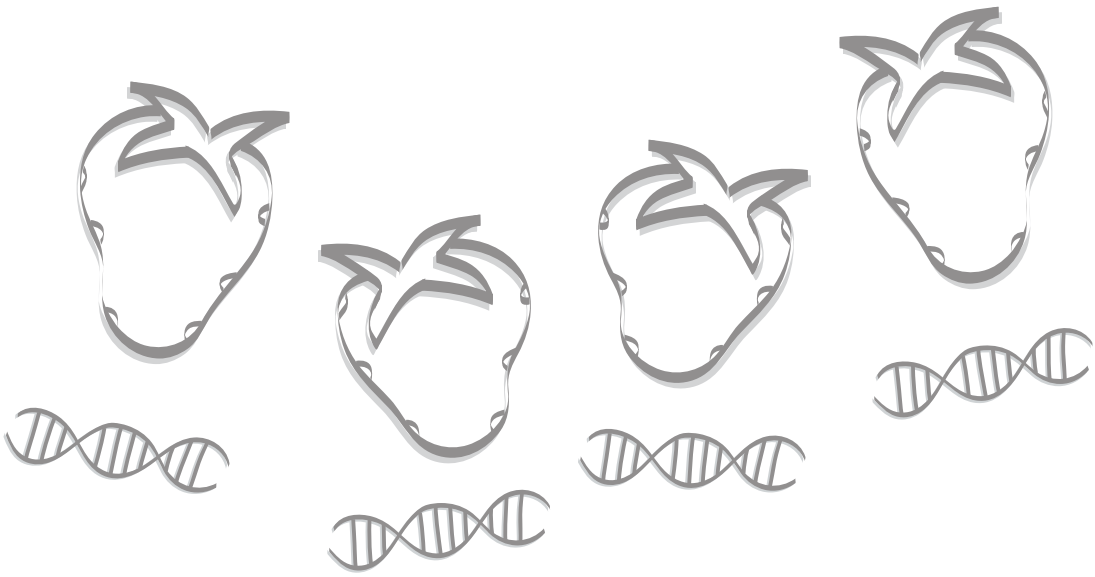
TIME Two 45-Minute Class Periods

ACTIVITY AT A GLANCE

In this activity, students' interest in food science is enhanced through an engaging and fun activity – the extraction, isolation, and observation of the DNA from strawberries.

TIME TO TUNE IN

How to extract DNA from strawberries
(9:45)
www.youtube.com/watch?v=hOpu4iN5Bh4



STRAWBERRY DNA EXTRACTION ACTIVITY

GETTING STARTED

MATERIALS FOR EACH GROUP OF TWO STUDENTS

- Isopropyl (rubbing) alcohol – approximately 10 mL
- One-cup measuring cup
- Measuring teaspoon
- Table salt (non-iodized)
- Clear dishwashing liquid
- Water
- Two eight-ounce, clear plastic cups
- Cheese cloth (or coffee filter)
- Funnel
- Three strawberries (fresh or frozen – note: frozen usually work best)
- Resealable, heavy-duty, quart-size plastic bag
- Craft stick or coffee stirrer
- Goggles for each student

ADVANCE PREPARATION

Divide the class into small groups - two is ideal for this activity.

Make a copy of the **Strawberry DNA Extraction** worksheet for each student.

Chill the isopropyl alcohol in the freezer. It is important for the alcohol to be as cold as possible. Note: If ethanol is available, it does not need to be chilled.

If preferred, you can prepare a stock extraction buffer by mixing ½ gallon (2 L) of water with ½ cup (120 mL) of clear, good quality dishwashing liquid and 2 tablespoons (30 mL) of non-iodized table salt. Slowly mix the buffer, being careful not to produce any bubbles. Too many bubbles will prevent the extraction buffer from extracting as much DNA as possible. Each group would need 10 mL of this buffer. It is best if the buffer is made at least a day ahead of time.

INTRODUCTION

Ask your students the following questions, and then discuss their responses.

What is DNA?

Where in the cell is the DNA found?

What does the word extraction mean?

How do you think you could extract the DNA from cells?

Does your food contain DNA; if so, where would that DNA be found?

The next activity will prove that the food we eat contains DNA; the DNA will be clearly visible at the end of this activity!

If students need a review of cell organelles, use a diagram of a plant cell such as the one found at this website: **https://biologydictionary.net/plant-cell/**

Laboratory Safety Reminder!

Remind students not to eat the strawberries at any time during this lab.

STRAWBERRY DNA EXTRACTION ACTIVITY

STUDENT PROCEDURE

How to extract DNA from strawberries

www.youtube.com/watch?v=hOpu4iN5Bh4

The instructions you will follow for this lab are not identical to those in the video, however seeing it done first will clarify some of the concepts.

Pick-up the materials needed for this activity and take them to your workstation; be sure that each person in your group has a **Strawberry DNA Extraction** worksheet.

Everyone must wear their goggles throughout the activity.

Instructions:

If fresh strawberries are being used, remove the green leaves.

1. Place the strawberries in the plastic bag and seal it, being careful to eliminate as much air as possible. Gently smash the berries for about two minutes; be very careful not to crush the bag. Make sure the berries are completely crushed because this starts to break open the cells and release the DNA.

2. Prepare the DNA extraction liquid by mixing together 2 teaspoons (10 mL) of detergent, 1 teaspoon of salt, and ½ cup (100 mL) of water in one of the plastic cups. Stir the mixture very carefully so there are no bubbles; the bubbles might interfere with the precipitation of the DNA.

3. Add 2 teaspoons (10 mL) of the DNA extraction liquid to the bag with the strawberries. This will further break down the membranes and release the DNA strands.

4. Reseal your plastic bags and carefully eliminate as much air as possible. Gently smash the berries for another minute; be sure to avoid creating any bubbles because they will prevent the extracting buffer from extracting as much DNA as possible.

5. Place the funnel inside the second plastic cup and place the cheese cloth inside the funnel. Open the bag and pour the strawberry mixture into the cheese cloth.

6. Twist the cheese cloth just above the liquid and gently squeeze the remaining liquid into the cup. After filtering the mixture, dispose of the cheese cloth and the plastic bag.

7. Note the level of the liquid in the cup; slowly add an equal amount of chilled rubbing alcohol to the cup, layering the alcohol on top of the strawberry liquid. This can be done by tilting the cup and slowly pouring the alcohol down the side of the cup. The DNA has just been isolated from the rest of the material contained in the cells of the strawberry.

8. Wait a few minutes and then carefully observe the line between the strawberry mixture and the alcohol. Notice development of a white, threadlike, cloud at this line. This is the strawberry DNA. The DNA will clump together and float to the top of the alcohol layer.

9. Observe the other groups' DNA samples; are there any differences?

10. Use the craft sticks or spoons to slowly extract the DNA from the cup.

11. Clean up your workstations and complete the worksheet.

STRAWBERRY DNA EXTRACTION ACTIVITY

REVIEW

Explain the importance of each step in the strawberry DNA extraction process by asking the following questions:

Why did you have to mash the strawberries?

What was the purpose of the salt in the DNA extraction solution?

What was the purpose of the soap in the DNA extraction solution?

Explain what happened in the final step when the rubbing alcohol was added to the strawberry extract.

Explain what the DNA looked like.

When the students have completed their responses to the questions, have them share their responses.

If you want to review the DNA extraction process and the purpose for each step, this video might help - *Strawberry DNA Extraction Lab Explanation* - www.youtube.com/watch?v=vnjwNiJktZk

Finally, ask the students to answer the following questions, and, when finished, share their ideas.

Why is it useful for scientists to be able to extract DNA from fruits and vegetables? List at least two reasons.

If you could extract the DNA from any fruit or vegetable, which one would you choose and why would you want to study its DNA?

SUMMARY

While this activity is a very much-simplified process, the isolation, extraction, and observation of DNA are important parts of food agricultural science, allowing scientists to accurately select for the most desirable traits for the fruits and vegetables that we eat.

EXTENSIONS

Students could do one or more of the following activities:

1. Experiment with extracting DNA from other fruits and vegetables and compare the amount of DNA extracted.
2. Perform the experiment and substitute different kinds of soaps and detergents such as powdered soaps, shampoo, or body scrubs in place of the dishwashing liquid.
3. Experiment with changing the quantity of materials used and comparing the amount of DNA extracted.
4. Watch the video – *Growing Strawberries: Strawberry Fields Forever* - www.youtube.com/watch?v=CnQgSXrYo6Q. This 4-minute video shows how California strawberry growers are learning to grow their crops using newer, high-tech tools.

RESOURCES

- *Growing Strawberries: Strawberry Fields Forever* from the CA Department of Food and Agriculture
  www.youtube.com/watch?v=CnQgSXrYo6Q
- *What is DNA and How Does It Work?*
  www.youtube.com/watch?v=zwibgNGe4aY

UP NEXT

Now that you've learned about DNA in food, let's take a look at some more laboratory techniques being used to produce some plant and animal varieties.

STUDENT WORKSHEET

STRAWBERRY DNA EXTRACTION

Name _____ Date _____ Class/Hour _____

1. What is DNA? _____

2. Where in the cell is the DNA found? _____

3. What does the word *extraction* mean? _____

4. How do you think you could extract the DNA from cells? _____

5. Does your food contain DNA, and if so, where would that DNA be found? _____

6. Each step in the extraction process aids in isolating DNA from the other cellular materials. Explain why each step was necessary and put the DNA extraction procedure into context by answering the following questions:

   Why did you have to mash the strawberries? _____

   What was the purpose of the salt in the DNA extracting solution? _____

   What was the purpose of the liquid detergent in the DNA extracting solution? _____

   Explain what happened when you added the alcohol to the strawberry extract. _____

   What did the extracted DNA look like? _____

7. Why is it useful for scientists to be able to extract DNA from fruits and vegetables? List at least two reasons. _____

8. If you could extract the DNA from any fruit or vegetable, which one would you choose and why would you want to study its DNA? _____

FROM MODULE 1

MAKING A NEW APPLE CULTIVAR WORKSHEET

ANSWERS

PART A: *APPLE, HOW DOES IT GROW?*

WWW.YOUTUBE.COM/WATCH?V=UWLMEH1HIBW

1. What is meant by the statement, "Each apple seed is genetically unique?"
   Each seed has the potential to produce a completely different apple than the one from which the seed came.

2. Explain how grafting is used to propagate new apple trees.
   In grafting, the bud from the apple cultivar the farmer wants to grow is placed in a small cut on an apple root stock. The bud and root stock fuse together and a new apple tree is produced.

3. Explain the importance of pollinators in the production of the apple crop.
   Insect pollinators are important in the cross-pollination of the apple blossoms. If the blossoms are not cross-pollinated, apples will not be produced.

4. Describe some methods that apple growers use to control pests?
   A fake apple covered with a sticky material attracts apple maggot flies. When the flies are observed on the apple, the grower knows it is time to spray.

   Insect birth control-twist ties with a pheromone in them are placed in the trees. The pheromone is released over time and sends out a scent that confuses the male insect and he never mates with the female.

5. If apples are only harvested in the late summer and fall, how are they available to consumers all year round?
   Apples are picked when they are half their ripened color and then placed in low oxygen storage, which puts the apples "to sleep."

6. How does the United States compare to other countries in the amount of apples produced?
   The United States is the second largest producer of apples in the world.

MAKING A NEW APPLE CULTIVAR WORKSHEET

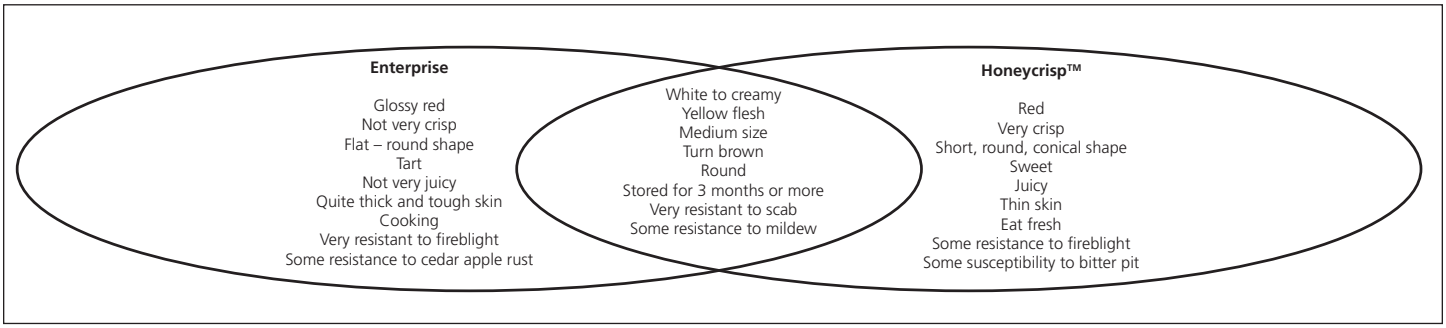
ANSWERS

PART B: COMPARING THE APPLE CULTIVAR TRAITS

Refer to the following websites for this activity: **www.orangepippin.com** and **www.cosmiccrisp.com/the-facts**

	Enterprise Apple	Honeycrisp™ Apple	Cosmic Crisp® Apple
Fruit Color	Glossy red	Red	Red
Flesh Color	White to cream/pale yellow	White to cream/yellow	White
Fruit Crispness	Not very crisp	Very crisp	Very Crisp
Fruit Size	Medium	Medium	Medium to large
Fruit Browning	Browns	Browns easily	Non-browning
Fruit Shape	Flat – round	Short, round, conical	Symmetrical
Fruit Taste	Tart	Sweet	Sweet/tart
Juiciness	Not very juicy	Juicy	Very juicy
Skin Thickness	Quite thick and tough	Thin	Thick
Use	Best for cooking; good for eating fresh	Best if eaten fresh	Eat fresh
Storability	3 months or more	3 months or more	3 months or more – up to a year
Disease Resistance			
Scab	Very resistant	Very resistant	
Mildew	Some resistance	Some resistance	Moderately susceptible
Fireblight	Very resistant	Some resistance	Moderately susceptible
Cedar Apple Rust	Some Resistance		
Bitter Pit		Some susceptibility	Resistant

Make a Venn diagram to explain the similarities and differences between the Enterprise and Honeycrisp™ apples.



Using the data you have collected, is there a way to determine if any of the apples' traits are dominant or recessive?

You need to know the genotypes for the traits to determine if the trait is dominant or recessive.

When comparing the Cosmic Crisp® apple to the Enterprise and Honeycrisp™ apples, what do you notice about the taste of the apples? How could the inheritance of taste be explained? Are there any other traits that seem to be similarly inherited? What would you need to do to determine whether or not your ideas for inheritance are correct?

Answers will vary. Students should notice that the Cosmic Crisp® apple is both tart and sweet. They might explain that this could be because neither trait is dominant or recessive.

Students would need to know more about the genotypes of the apples.

MAKING A NEW APPLE CULTIVAR WORKSHEET ANSWERS

PART C: DEVELOPING THE COSMIC CRISP® APPLE

Complete this worksheet as you watch the following two videos:

Why are there so many types of apples?
www.youtube.com/watch?v=mQePz62zkqA and
Farmweek – New Apple – **www.youtube.com/watch?v=jZsu-_EGa_M**

1. The Cosmic Crisp® apple was developed through selective breeding. Explain selective breeding and list the steps that apple breeders might use in this process.
   Selective breeding is the process of choosing apples with specific traits to produce certain traits in the new apples.
   - Cross-pollinate apple blossoms.
   - Collect seeds from the apples.
   - Grow seedlings from the seeds.
   - Grown trees from the seedlings.
   - Select fruit for further evaluation.
   - Send selected seedlings to different locations to assess how different factors affect the growth.
   - Collect and sample fruit again to ensure consistency.

2. In researching the Cosmic Crisp®, you probably did not find information about the apple's skin thickness. What might you predict the apple's skin thickness to be? What information did you use to make this prediction?
   Skin thickness could be somewhat thin – based on the fact that one parent had thick skin and the other had thin skin.

3. How long was the WA 38 (Cosmic Crisp®) cultivar in development at Washington State University?
   20 years

4. How do apple breeders ensure that the new apple cultivar is the same as the original seedling?
   All the trees are produced from buds taken from the original tree.

5. How was the public introduction of the Cosmic Crisp® apple different than the way in which new apple cultivars are usually introduced?
   There is typically limited, if any, public involvement prior to the introduction of a new cultivar; focus groups and taste testing sessions were held to expose the public to the Cosmic Crisp® apple.

6. How do apple breeders maintain long-lasting rights over an apple cultivar?
   They patent and/or trademark the apple name.

7. The breeders of the Cosmic Crisp® apple believe that they have produced an apple that is better than most of the other apples available today in our grocery stores. Explain why you either agree or disagree with this statement.
   Answers will vary. In their responses, students should include the favorable traits of the apple – easy to grow, stores well, does not bruise, does not turn brown when cut, etc.

8. Looking to the future, what traits would you like to see in new apple cultivars and why are these traits important?
   Answers will vary but students should explain why the traits they mention are important.

STRAWBERRY DNA EXTRACTION WORKSHEET ANSWERS

1. What is DNA?

Answers will vary. DNA is deoxyribonucleic acid – hereditary material passed from parents to offspring.

2. Where in the cell is the DNA found?

Answers will vary. DNA is found in the nucleus of the cell.

3. What does the word extraction mean?

Answers will vary. Extraction is to remove from or to take out of something.

4. How do you think you could extract the DNA from cells?

Answers will vary. Accept all student responses. Students may suggest that certain chemicals are needed.

5. Does your food contain DNA, and if so, where would that DNA be found?

Answers will vary. Students may suggest that the DNA is found in the cells of the food.

6. Each step in the extraction process aids in isolating DNA from the other cellular materials. Explain why each step was necessary and put the DNA extraction procedure into context by answering the following questions:

Why did you have to mash the strawberries?

To spread all the cells out as much as possible and to break down the cell walls

What was the purpose of the salt in the DNA extracting solution?

The salt helps the DNA precipitate out of the solution.

What was the purpose of the liquid detergent in the DNA extracting solution?

The detergent breaks open the cells; it breaks down the cell membrane and nuclear membrane.

Explain what happened when you added the alcohol to the strawberry extract.

The alcohol caused the DNA to precipitate out of the solution.

What did the extracted DNA look like?

It was a white, slimy solid.

7. Why is it useful for scientists to be able to extract DNA from fruits and vegetables? List at least two reasons.

Answers will vary. Scientists can use the DNA to determine which parents to cross to produce a plant with the desired traits.

The DNA can be used to determine if the seedlings produced by the cross breeding have the desired traits.

8. If you could extract the DNA from any fruit or vegetable, which one would you choose and why would you want to study its DNA?

Answers will vary.

Science and Our Food Supply: Exploring Food Agriculture and Biotechnology was brought to you by…

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Center for Food Safety and Applied Nutrition
College Park, MD

Subject Matter Experts

FDA

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- ***International Affairs Staff***

Center for Veterinary Medicine
- ***Office of the Director***
- ***Office of Surveillance and Compliance***

USDA

Office of Pest Management Policy
Biotechnology Regulatory Services

EPA

Office of Pesticide Programs

Curriculum Development Experts

Ken Bingman, M.S.
High School SOFS Advisor
Educational Consultant
Spring Hill, KS

Mimi Cooper, M.Ed.
Lead SOFS Advisor
Educational Consultant
St. Augustine, FL

Lacey L. Dixon, Ed.D.
Animal Science Teacher; FFA Advisor
Dover High School
Dover, DE

Janie Dubois, Ph.D.
International Food Safety Training Specialist
Olney, MD

Susan Hartley
Biomedical Sciences Teacher
Hinkley High School
Aurora, CO

Laurie Hayes
Biomedicine Instructor
The Center for Advanced Research and Technology (CART)
Clovis, CA

Isabelle Howes, M.L.S.
National Training Coordinator for FDA
Food Safety & Nutrition Education Programs
Graduate School USA
Washington, DC

Kristina Ellis Owen, M.Ed.
Assistant Principal
Woodland Heights Elementary School
Former AP/Pre-AP Biology Teacher, Brownwood High School
Brownwood, TX

Jodi Songer Riedel, M.S. NBCT
Agricultural Education Teacher; FFA Advisor
Wakefield High School
Raleigh, NC

Elena Stowell, M.S. NBCT AYA Biology
Biology & Earth Systems; College in the High School Biology Teacher
High School SOFS Advisor
Kentwood High School
Kent, WA

Peter Sykora
Science Instructor 7-12
Middle Level SOFS Advisor
Litchfield-Marion High School
Marion, ND

Kevin Whalen
Agriscience Instructor; Arcadia FFA Advisor
Arcadia High School
Arcadia, WI

Keshia D. Williams, Ed.S. NBCT
AP Biology; AP & General Environmental Science Teacher
Robert E. Lee High School
Montgomery, AL

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