## Biotechnology Unit Overview

**Disclaimer**: The charts included in this unit make one set of connections between the lessons outlined in the unit and the NGSS performance expectations. Other valid connections are likely; however, space and time restrictions prevent us from listing all possibilities.

This middle school unit on Biotechnology exposes students to several methods and techniques of artificial selection and genetic modification as applied in agriculture. The Science and Engineering Practices covered in these lessons include: **Constructing Explanations and Designing Solutions**, **Analyzing and Interpreting Data, Developing and Using Models, Obtaining, Evaluating and Communicating Information,** and **Asking Questions and Defining Problems**, in order to explain the nature of science and make decisions about important issues in the practice of science.

Much of this unit centers around the Nature of Science. These four aspects are closely aligned with the practices:

Scientific Investigations Use a Variety of Methods
Scientific Knowledge is Based on Empirical Evidence
Scientific Knowledge is Open to Revision in Light of New Evidence
Scientific Models, Laws, Mechanisms, and Theories Explain Natural Phenomena

While these four are more closely aligned with crosscutting concepts:

Science is a Way of Knowing
Scientific Knowledge Assumes an Order and Consistency in Natural Systems
Science is a Human Endeavor
Science Addresses Questions About the Natural and Material World

Lesson 1 *Environment or Genetics* introduces the phenomena of the unit through a big question, ***What accounts for differences among members of the same species?*** then encourages students to begin to compare environment and genetics and their effects on physical characteristics. Lesson 2 *DNA Extraction* introduces students to the possibility that we can use the physical properties of cells and cell materials to extract DNA to make it visible while asking them to test out ideas then analyze the results.

Lesson 3 *DNA Sentences* asks students to use a model to illustrate transcription and translation in the synthesis of proteins from DNA using words for sentences. Lesson 4 *Punnett Squares* illustrates a way to explain how Punnett Squares work. Lesson 5 *Selective Breeding vs Genetic Modification* tests assumptions about how many traits influence a characteristic and challenge students to get the best offspring results through traditional breeding, then introduces a more precise tool for breeding.

Lesson 6A *Plasmid Modeling*, asks students to create a model of a plasmid to mimic the actual process of developing a plasmid with a gene of interest. 6B *Transform Bacteria* appliess the model through the use of a kit from BioRad Explorer™ that has been modified to use fewer control checks yet still allows students to transform bacteria using the pGLO plasmid. Lesson 7 *Design Challenge* asks students to design a way to modify corn or other crops to resist drought conditions using a design process.

Biotechnology is a set of techniques that have been developed to help improve medicine, agriculture and fuel production. Taking natural traits of organisms and selecting for them has been a method used for centuries (a.k.a. selective breeding or artificial selection). New tools have been discovered in the past 30 years that have changed the way scientists can manipulate a species and have sped up the process, making it much more precise. Students have a chance to learn about those techniques through this unit and design some of their own solutions.

**Science and Engineering Practices**

Lesson 1: Environment or Genetics
**Constructing Explanations and Designing Solutions**

Lesson 2: DNA Extraction
**Analyzing and Interpreting Data**

Lesson 3: DNA Sentences
**Developing and Using Models**

Lesson 4: Punnett Squares
**Developing and Using Models**

Lesson 5: Selective Breeding vs Genetic Modification
**Developing and Using Models**

Lesson 6A: Plasmid Modeling
**Developing and Using Models**

Lesson 6B: Transform Bacteria
**Constructing Explanations**
**Obtaining, Evaluating, and Communicating Information**

Lesson 7: Design Challenge
**Analyzing and Interpreting Data**

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Feed the World - HS Biotechnology Unit Storyline

Phenomenon: Environment or genetics: Not everything is due to genetics...slideshow that shows examples of various "traits" that are dependent on environmental factors and genetics. The goal is for students to address a Design Challenge around how to make plants more drought resistant.

| Lesson<br>Focus Question | Overview | What should students be able to explain? | How does this add to their explanatory model? |
|---|---|---|---|
| **Lesson 1 Slideshow**<br>*"Are differences due to genetics?"* | Students watch a slide show showing various "traits."<br><br>Brainstorm questions to drive investigations. | All differences are not due to genetics, i.e. could be environmental (fat vs skinny dogs, flower color due to pH) or combined with genetics, (temperature changes, etc.) | Traits could be either genetic or environmentally influenced, or both.<br><br>What do we need to know in order to decide? |
| **Lesson 2**<br>**DNA Extraction**<br>*"How might we see the raw material of life, DNA?"* | Students determine the effects of common household materials on corn in an attempt to understand the effect of each material. | DNA can be extracted from corn or other plants as well as other organisms; how to extract DNA; the function of each of the products used in the extraction. | DNA is present in all living things, and can be extracted. However, there is more to the story! |
| **Lesson 3**<br>**DNA Sentences**<br>*"How are proteins coded for by DNA?"* | Students translate and transcribe DNA to model protein "sentences." | How DNA communicates traits by coding for proteins. DNA works to produce visible traits through transcription and translation (may use this activity as formative assessment to assess student understanding of DNA). | Pieces of DNA that are transcribed and translated determine the traits in living things. |
| **Lesson 4**<br>**Punnett squares**<br>*"Why do scientists use biotechnology? What are the advantages?"* | Students use a model to learn about Punnett squares, then complete Punnett squares of crosses to show predictability in breeding. | What are the limitations of conventional breeding? (Traditional breeding takes more time and results are not always specific to the traits desired.) | Traditional techniques have some disadvantages. |
| **Lesson 5**<br>**Selective Breeding vs Genetic Modification** | Students learn the traits that help corn resist drought and determine how to breed corn that has those | The current practice of selective breeding does not always produce the set of desirable traits | Multi-gene combinations are more difficult to manage using traditional methods. |

| | | | |
|---|---|---|---|
| *"What are the advantages of selective breeding? How does selective breeding differ from genetic modification?"* | traits. | in offspring. | |
| **Lesson 6A**<br>**Plasmid Modeling**<br>*"How does genetic modification work?"*<br>*How does DNA work in bacteria? How can we use that to aid in genetic modification?* | Students model a plasmid with a gene of interest and a way to select to determine if the plasmid was added to bacteria. | How DNA in the form of plasmids determine the traits of the bacteria. By using these plasmids, bacteria can be modified easily. | Students see that DNA can be modeled and show modifications easily. |
| **Lesson 6B**<br>**BioRad pGLO™ Lab**<br>*"How can we genetically modify bacteria? What are the results of gene insertion?"* | Students "transform" bacteria to glow in UV light. | DNA gets moved from one organism to another through genetic engineering. | Students analyze their results to determine if they transformed bacteria and explain how it happened. |
| **Lesson 7**<br>**Design Challenge**<br>*If there are plants out there that are adapted to resist drought can we use that trait to modify other plants to prevent water loss?* | Students use knowledge gained to determine how to adapt another plant to prevent water loss. | | |

**Biotechnology Unit Vocabulary**

**Lesson 1**

**Genetics** - a branch of biology that deals with the heredity and variation of organisms.
**Traits** - an inherited characteristic.
**Drought** - lack of rain or moisture
**Meiosis** - the process of chromosomal mixing that occurs when organisms create gametes for reproduction
**Genetic modification** - the process of changing genes either through mutation or selective breeding; can be natural, human-driven by selecting for certain traits or engineered by adding a gene for a trait from a specific organism.
**Adaptation** - a characteristic of a plant or animal that makes it able to adjust to the conditions of a particular environment.
**pH** - the measure of acidity or basicity of a substance.
**Heredity** - the natural process by which parents pass on to their offspring through their genes the characteristics that make them related.

**Lesson 2**

**Phospholipid bilayer** - the material a cell membrane is made of.
**Enzyme** - a protein that speeds up or enhances a chemical reaction.
**Hydrophobic** - from the roots “water” and “hating”; something that will not dissolve in water
**Hydrophilic** - from the roots “water” and “loving”; something that easily dissolves in water
**Surfactant** - a substance that helps hydrophobic substances dissolve in water.

**Lesson 3**

**DNA -** deoxyribonucleic acid
**mRNA** - messenger RNA
**tRNA** - transfer RNA
**Transcription** - when used to refer to gene expression, it is the process of making a complementary strand of mRNA to DNA
**Translation** - mRNA is decoded to determine an amino acid sequence to synthesize a protein
**Mutation** - A mutation, which may arise during replication and/or recombination, is a permanent change in the nucleotide sequence of DNA. Damaged DNA can be mutated either by *substitution*, *deletion* or *insertion* of base pairs.

**Lesson 4**

**Gamete** - a male or female sex cell with half the number of choromosomes from the organism
**Chromosomes** - strands of DNA that contain cells. The number of chromosomes is specific to an organism (i.e. humans have 23 pairs or 46.)
**Phenotype** - observable traits of an organism
**Genotype** - set of genes in an organism
**Alleles** - different forms of a gene (i.e. a gene for smooth seed coat is an allele for seed coat, so is a gene for wrinkled seed coat)

**Homozygous** - a genotype in which both genes (one from each parent) is the same allele
**Heterozygous** - a genotype in which both genes are different alleles
**Dominant** - a gene that when present its trait will be expressed in the offspring
**Recessive** - both alleles for the trait must be present for the trait to be expressed
**Monohybrid cross** - a cross between two organisms where only one trait of interest is predicted
**Dihybrid cross** - a cross between two organisms in which two traits that are on two different chromosomes are predicted

**Lesson 5**
**See lesson 1 vocabulary**

**Lesson 6A**
**Restriction enzyme -** one of several enzymes that will cut a strand of DNA at a specific point.
**Plasmid** - an extrachromosomal ring of DNA especially of bacteria that replicates autonomously.
**Nucleotides** - any of several compounds that consist of a ribose or deoxyribose sugar joined to a purine or pyrimidine base and a phosphate group and that are the basic structural units of nucleic acids (such as RNA and DNA).

**Lesson 6B**
**Sterile technique** - a set of skills that reduce the potential for contamination by bacteria, mold or fungi.

**Lesson 7**
**LAUNCH** - a design process created to help engineer new solutions to problems.

Biotechnology Pre-/Post-Test

Choose the best answer

1. DNA extraction uses the __________ properties of cell parts and the ___________ properties of common household materials to break down the cell and allow the DNA to clump together.
    a. physical/chemical
    b. biological/chemical
    c. chemical/biological
    d. chemical/physical

2. DNA transcription and translation results in the formation of:
    a. Amino acids from proteins
    b. mRNA and tRNA
    c. Proteins from amino acids
    d. New cells

3. Punnett squares are used to
    a. Predict offspring ratios from parent crosses
    b. Determine the dominance of a gene
    c. Create new genotypes
    d. Show recessiveness

4. A plasmid is:
    a. Only human-made and inserted in bacteria
    b. A piece of the cell membrane
    c. A tool used in selective breeding
    d. A circular piece of DNA that occurs naturally in bacteria

5. Which of the following occurred due to a genetic transformation where a gene was transferred from one organism to another organism performed by humans?
    a. Resistance of papaya to ringspot virus
    b. Growth of square watermelons
    c. Jellyfish ability to fluoresce in UV light
    d. Resistance of bacteria to antibiotics

**Complete the sentences below…**

6. Selective breeding is a process of breeding where:

7. Genetic modification differs from selective breeding in that:

8. An example of a design challenge model is:

9. Sterile environments are critical when working with bacteria because:

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**Complete the sentences below…**

6. Selective breeding is a process of breeding where:

- *Organisms of the same species (or those that can mate i.e. donkey and horses to get mules) with the preferred traits are crossed.*

7. Genetic modification differs from selective breeding in that:
- *Only the specific genes for a trait are isolated, and added to a new organism.*

8. An example of a design challenge model is:
- *LAUNCH: Look, listen and learn; Ask tons of questions; Understand the process or problem; Navigate ideas; Create a prototype; Highlight and fix; Present to a real audience.*

9. Sterile environments are critical when working with bacteria because:
- *Bacteria is everywhere, so the chances of contamination by bacteria, mold or fungi that you do not want growing is great if sterile techniques are not used.*

## Lesson #1

## Environment or Genetics - Teacher

Focus Question: *What accounts for differences among members of the same species?*
Learning Target: Students will be exposed to different traits that may be influenced by genetics, environmental factors of both.
New Vocabulary: *adaptation, pH, heredity*

**MS-LS1-5 From Molecules to Organisms: Structures and Processes**

| Performance Expectation | Connections to Activity |
|---|---|
| **MS-LS1-5**. Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms. | Students watch a slideshow that has several examples of environmental adaptations. |
| Science & Engineering Practice | |
| **Constructing Explanations and Designing Solutions**<br>● Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. | Students construct an explanation based on evidence from their own lives or from research, for the phenomena they see. |
| Disciplinary Core Idea | |
| **LS1.B: Growth and Development of Organisms**<br>● Genetic factors as well as local conditions affect the growth of the adult plant. | Genetics play a role in all of these photos, but, students will determine the "cause" of these variations. |
| Cross Cutting Concept | |
| **Cause and Effect**<br>● Phenomena may have more than one cause, and some cause and effect relationships in systems can | After the final slide, students will research if there are other plants that exhibit leaf rolling or some other adaptation to loss of water. |

| | |
|---|---|
| only be described using probability. | |

**Prior Knowledge**

This slideshow is designed to be the introduction to a unit on biotechnology that includes skill building, constructing explanations and designing solutions and modeling.

Teachers may access students' prior knowledge by asking the following:

- Have you seen two dogs of the same breed that look very different?
- Look around the classroom, we are all the same species but have many differing traits.
- If an organism has access to food shelter and water its entire life, will it look the same as another of the same species, that has not had that same access.
- What animals/plants can you think of that have different traits, even though they may be the same species?

**Materials**

Slide show

Notebook paper 1/student

**Teacher Background**

This set of slides includes only a few different traits. Each student may be assigned to find an additional example of a genetic trait that is influenced by the environment. Another area for discussion is the topic of epigenetics, the study of how genes are activated or silenced by environmental factors. See https://www.whatisepigenetics.com/what-is-epigenetics/ This is an area of research that may lead to breakthrough methods of disease treatment and research into how lifestyle affects gene expression.

Have students take note of each of the examples then find out additional information about how that trait is expressed. Students might be assigned to research a different trait to discover a new trait that is affected by the environment. Students then are given the task to amass skills throughout the unit in order to design a drought tolerant plant.

Slide 2: These dogs have been fed different amounts of food. They appear to have the same genetics (same breed of dog). https://www.rover.com/blog/dog-fat-skinny-just-right

Slide 3: Hydrangeas petal color is determined by the pH of the soil they have been planted in. According to Better Homes and Gardens:

> For true blue flowers, the **hydrangeas** need to be grown in acidic soil (**pH**5.5 and lower). For pink flowers, the plants need neutral to alkaline soils (**pH** 6.5 and higher). For purple blooms (or a mix of blue and pink flowers on the same plant), the **pH** of the soil must be [between] 5.5 and **pH** 6.5.

https://www.bhg.com/gardening/trees-shrubs-vines/shrubs/how-to-get-blue-hydrangeas/

Slide 4: These rabbits show the difference in pigmentation due to temperature. The gene for pigmentation is only active below 25ºC.
https://www.nature.com/scitable/topicpage/environmental-influences-on-gene-expression-536#

Slide 5: On the left is non-transformed *E. coli* growing on agar. On the right is one of the results from the Bio-Rad pGLO™ Genetic Transformation Kit: transformed *E.coli* bacteria growing on agar containing an antibiotic and a form of sugar, that indicates that all cells here were transformed (are antibiotic resistant and have the gene for Green Fluorescent Protein).

Slide 6: Corn leaves roll when the amount of water leaving the plant through evapotranspiration is greater than the amount entering from the roots. This adaptation helps the plant reduce water loss. Prolonged periods of this stress may affect yield (the amount of corn the plant will produce). https://www.dtnpf.com/agriculture/web/ag/news/article/2016/06/15/corn-leaves-rolling

There are many ways to use this slide show. Student research could lead to a discussion of leaf shapes, internal structures of leaves, other water saving/conserving traits (from cactus to maple leaves). The focus of this activity is to show students the favorable adaptation of leaf rolling and help students to think about how this characteristic may be enhanced or transferred to other plants or how corn may benefit from another adaptation found in a different plant.

Slide 7: The final slide presents the design challenge: How might we limit drought-stress in other plants?
Design a way to use the adaptations plants use to reduce water loss and add it to plants that do not have that adaptation.

**Differentiation**
Other ways to connect with students with various needs:

i. **Local community**: students may investigate local plants that resist drought for additional testing.

ii. **Students with special needs** (language/reading/auditory/visual): Students may watch *Genotype Expression* *https://www.youtube.com/watch?v=fPCtvQIStSg* which describes how the environment affects gene expression.

iii. **Extra support**: Students might read: “Pioneer Research to Develop Drought-tolerant Corn Hybrids”
https://www.pioneer.com/CMRoot/Pioneer/US/products/seed_trait_technology/see_the_difference/corn_drought.pdf or
“Drought-Tolerant Corn Hybrids Yield More in Drought-Stressed Environments with No Penalty in Non-stressed Environments”
https://www.frontiersin.org/articles/10.3389/fpls.2016.01534/full

iv. **Extensions**: Students can research the development of corn by viewing: *Popped Secret: The Mysterious Origin of Corn* from HHMI Biointeractive: https://www.hhmi.org/biointeractive/popped-secret-mysterious-origin-corn to determine how corn might be bred to be more drought resistant. Another option would be to have students listen to this example of how genetic modification is being researched: https://www.npr.org/sections/thesalt/2019/01/03/681941779/scientists-have-hacked-photosynthesis-in-search-of-more-productive-crops This story highlights the critical importance of the protein Rubisco and how researchers have engineered a better, more efficient pathway for $CO_2$ to be grabbed and transformed into energy for tobacco plants.

**Rubric for Assessment**

| Skill | Developing | Satisfactory | Exemplary |
|---|---|---|---|
| Constructing explanations | Student can give an example of an environmentally influenced genetic trait, but does not provide evidence to support how the environment affects the trait. | Student can give an example of an environmentally influenced genetic trait, and can provide evidence to support how the environment affects the trait. | Student can give an example of an environmentally influenced genetic trait, can provide evidence to support how the environment affects the trait and discusses how that trait may be exhibited by one organism, while not by another. |

**Rubric for Self-Assessment**

| Skill | Yes | No |
|---|---|---|
| I can give an example of an environmentally influenced trait in an organism. | | |
| I can provide evidence to support how the environment affects a trait. | | |
| I can determine how a trait might be exhibited by one organism, while not by another. | | |

# Are differences due to genetics?

Feed the World Biotechnology
Lesson 1


https://www.rover.com/blog/dog-fat-skinny-just-right

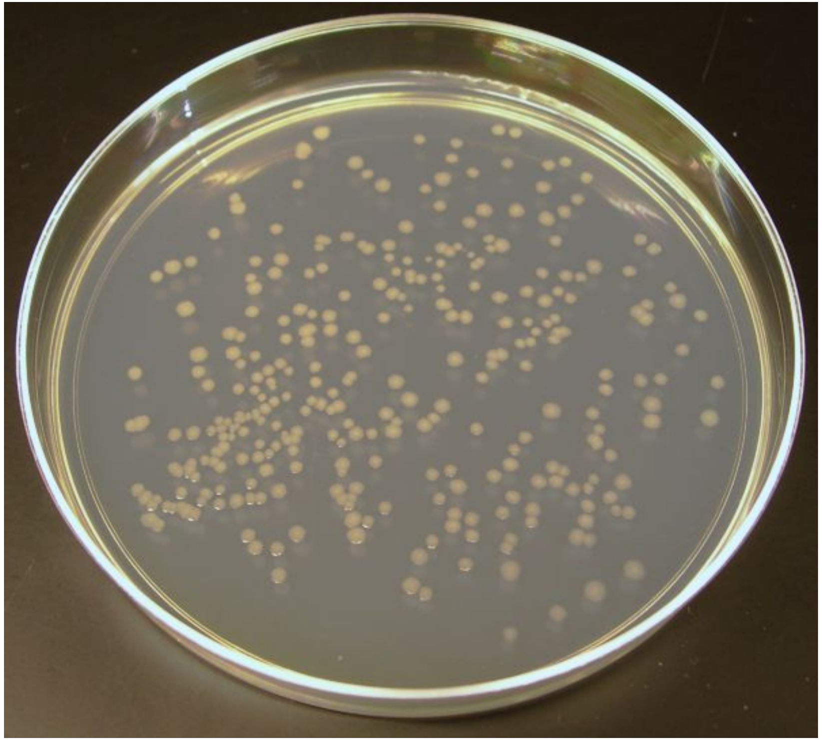
# Hydrangea colors




**Figure 1 : A pigment gene is influenced by temperature.**

Gene C controls fur pigmentation in Himalayan rabbits. Because the gene is active when environmental temperatures are between 15 and 25°C, the rabbit reared at 20°C (left) has pigmentation on its ears, nose, and feet, where its body loses the most heat. The rabbit reared at temperatures above 30°C (right) has no fur pigmentation, because gene C is inactive at these higher temperatures.

# *E.coli* bacteria



https://commons.wikimedia.org/wiki/File:Ecoli_colonies.png

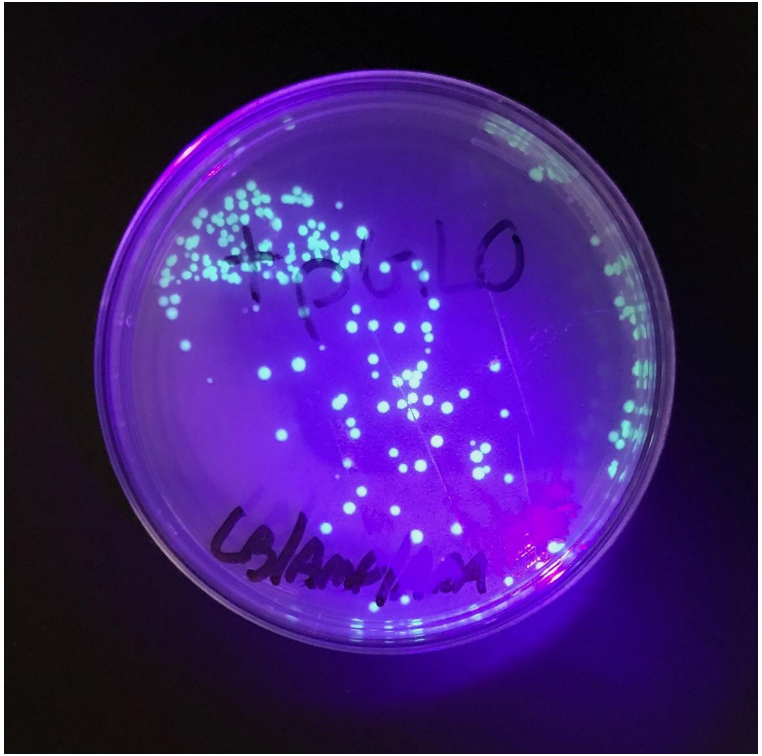



Photo by J. Hunt; taken: June 2017

# Corn leaves curling vs not curling


https://www.ag.ndsu.edu/cpr/plant-science/drought-stress-beginning-to-impact-corn-growth-7-5-12

https://pxhere.com/en/photo/913745

# How might we limit drought-stress in other plants?

Your challenge is to design a way to use the adaptations corn plants use to reduce water loss and add it to plants that do not have that adaptation.

# Potential Questions

Is it natural?
How does that happen?
How do bacteria reproduce?
Could it be genetic?
Is it environmental?

What does DNA look like?
How does DNA work to produce visible traits?
How does DNA work in bacteria?
How can we control/manipulate DNA?
How can we generalize this action of DNA to genetic modification?

# Lesson 2
# DNA Extraction from Corn

Focus Question: *How can we see the raw material of life?*
Learning Target: *Students predict, test, then research the materials necessary to extract DNA, then follow a procedure to extract it.*
Vocabulary: *phospholipid bilayer, enzyme, pH, hydrophobic, hydrophilic, surfactant*

**MS-PS1-2. Matter and its Interactions**

<table>
<tr><th>Performance Expectation</th><th>Classroom Connection</th></tr>
<tr><td>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.</td><td>Students research the properties of cell membranes and cell parts. They expose cells to the chemicals provided for DNA extraction to see the effects.</td></tr>
<tr><th colspan="2">Science and Engineering Practice</th></tr>
<tr><td>Analyzing and Interpreting Data<br>● Analyze and interpret data to determine similarities and differences in findings.</td><td>Students collect and analyze data from their experiments. Interpreting the data helps them to make decisions about what to do next.</td></tr>
<tr><th colspan="2">Disciplinary Core Ideas</th></tr>
<tr><td>PS1.A: Structure and Properties of Matter<br>● Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it.<br><br>PS1.B: Chemical Reactions<br>● Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants.</td><td>Students will predict the function of common materials on cell parts.<br><br>Students will test the materials to see observable effects.<br><br>Students will research those materials to determine the known effects.<br><br>Students will use the materials to extract DNA following an established process.</td></tr>
<tr><th colspan="2">Cross Cutting Concept</th></tr>
<tr><td>Patterns<br>● Macroscopic patterns are related to the nature of microscopic and atomic-level structure.</td><td>Students will observe how the materials work together to allow them to extract DNA, then compare the functions of the materials to other known uses (i.e. how dishwashing liquid removes grease from dishes, how enzymes break down proteins in stains, etc).</td></tr>
</table>

**Teacher Background**

DNA extraction is a first step in many biotechnology processes. Although many teachers do this in their classrooms, students may not understand the function of each of the materials used. This lesson is designed to follow the identification of cell parts and the structures of which cell parts are made, so that students can test materials that will help them break down the cell and make DNA available for extraction, taking advantage of the physical and chemical effects of each of those materials.

In order to release DNA from the cell, several things must happen. A review of cell structures may be necessary and an overview of how we use products to remove grease and proteins from clothing to make the comparison to cell parts and how they may be broken down.

**Prior Knowledge**

In order to be successful in this activity, students must know cell structure including membrane components and the physical properties of parts of the cell. Start by asking these questions:

1. Where is DNA found inside the cell?
2. What is that structure surrounded by?
3. What is that structure composed of?
4. How might we dissolve fats? Proteins? (think of washing dishes with greasy residue or pants with grass stains)
5. What is the structure of DNA? Are the strands long or short? How might we cut the strands?

**Teacher Preparation**

1. Place 100 g of corn, 1 g of salt and 200 ml of water in a blender. Blend on high for 30 seconds.
2. Pour the thin corn soup through a strainer into a 500 ml beaker.

Students will first predict the function of each of a set of materials (salt, meat tenderizer, detergent and alcohol) then test the effect of these by using about 10 ml of this liquified corn and 1 g (solid) to 1mL (liquid) materials provided in order to collect data (to make observations).

## Lesson 2
## DNA Extraction from Corn

Focus Question: *How can we see the raw material of life?*
Vocabulary: *phospholipid bilayer, enzyme, pH, hydrophobic, hydrophilic, surfactant*

Deoxyribose nucleic acid, or DNA, is the backbone of every living thing. The greatest amount of DNA is found in the nucleus of cells; it contains the genetic information that determines each organism's traits since it holds the instructions for proteins manufactured by the cell.

**Questions for Review**

1. Where is DNA found inside the cell?
2. What is that structure surrounded by?
3. What is that structure composed of?
4. How might we dissolve fats? Proteins? (think of washing dishes with greasy residue or pants with grass stains)
5. What is the structure of DNA? Are the strands long or short? How might we cut the strands?

Now that you have answered the questions above, how might the ingredients in this list help to "show" DNA?

- Table salt,
- Liquid detergent,
- Meat tenderizer,
- Isopropyl/Ethyl Alcohol

1. Make a prediction about the function of each of the ingredients.
2. Using 1 g of solid or 1 mL of liquid, test each of these ingredients on 10 mL of liquified corn (provided by your teacher) to see what effect, if any, is visible. Try again in a different order. Research each material after testing. Fill in the table below.

| Ingredient | Prediction | Observed result | Researched function |
|---|---|---|---|
| Meat Tenderizer | | | |
| Liquid detergent | | | |
| Table salt | | | |
| Alcohol | | | |

## Extract DNA

### Materials

Canned yellow sweet corn
Table salt
Blender
Beakers (500 ml)
Metal strainer
Scale
Graduated cylinder
Test tubes
Test tube rack
70-95% Isopropyl or Ethyl Alcohol
Liquid detergent
Microtubes
Meat tenderizer
Coffee stir sticks

### Procedure

1. Obtain 30 mL of liquified corn in a glass test tube
2. Add 3 mL of liquid detergent to the corn soup mixture and let sit for 10 minutes.
3. Add 1 g of meat tenderizer (enzyme) to each test tube and stir gently (be careful, if you stir too hard you will break up the DNA strands).
4. Tilt your test tube to the side and slowly add cold isopropyl alcohol down the side of the tube so that it sits on top of the corn mixture. Pour until you have about the same amount of alcohol as you do corn mixture.
5. Look for layers of white stringy stuff (DNA) where the layers of alcohol and corn mixture meet.
6. Use a stir stick, cotton swab or pipette, to collect the DNA and transfer it to a microtube two-thirds full of isopropyl alcohol. Cap the microtube.

### Reflection

1. How does the liquid detergent help to extract the DNA from the corn cells?

2. The meat tenderizer that you add to the test tube in step 5 acts as an enzyme on the corn DNA. What does this enzyme do to the DNA?

3. Why does the alcohol allow us to see the white stringy DNA molecules? What is a precipitate?

Rubric for Self-Assessment

| Skill | Yes | No |
|---|---|---|
| I was able to see the effect of the common household materials on the corn. | | |
| I predicted what each material would do to the DNA. | | |
| I observed what happened during each step. | | |
| I researched the effect of each of the materials. | | |
| When we completed the DNA extraction, I was successful in removing a piece of it. | | |
| I can analyze the data we collected and interpret that a chemical change occurred. | | |

**Lesson 3**
**DNA Sentences - Teacher**
Focus Question: *How are proteins coded for by DNA?*
Learning Target: Students use DNA, codons and anticodons to transcribe and translate sentences related to information about corn.
Vocabulary: *deoxyribonucleic acid (DNA), messenger RNA (mRNA), transfer RNA (tRNA), transcription, translation, mutation*

**MS-LS3: Heredity: Inheritance and Variation of Traits**

| Performance Expectation | Connections to Activity |
|---|---|
| **MS-LS3-1**. Develop and use a model to describe why structural changes to genes (mutations) located on chromosomes may affect proteins and may result in harmful, beneficial, or neutral effects on the structure and function of the organism. | Students use DNA, codons and anticodons to transcribe and translate sentences related to information about corn.<br><br>Students are tasked to use this model to show how deletions and insertions would affect the "sentence." |
| **Science & Engineering Practice** | |
| **Constructing Explanations and Designing Solutions**<br>● Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.<br>**Developing and Using Models**<br>● Develop and use a model to describe phenomena. | Students *construct an explanation* by writing out the processes of transcription and translation for proteins after completing their groups' two sentences (proteins) from words (amino acids) correctly using the terms: DNA, mRNA and tRNA. (Students will need to correct the sentences if they are incorrect before constructing their explanation).<br><br>Students *design solutions* and use modeling to show the effect of mutated DNA on the sentence. |
| **Disciplinary Core Idea** | |
| **LS3.A: Inheritance of traits**<br>● Genes are located in the chromosomes of cells, with each chromosome pair containing two variants of each of many distinct genes. Each distinct gene chiefly controls the production of specific proteins, which in turn affects the | DNA is shown as the guide for the creation of proteins; changes in DNA create changes in the mRNA and tRNA, therefore the words (amino acids) of the sentences (proteins). |

| | |
|---|---|
| traits of the individual. Changes (mutations) to genes can result in changes to proteins, which can affect the structures and functions of the organism and thereby change traits. | |
| Cross Cutting Concept | |
| **Cause and Effect**<br>● Cause and effect relationships may be used to predict phenomena in natural or designed systems. | Students will try to transcribe and translate sentences with mutations then explain the issue. |

*Student handout information is indicated in light gray print. Answer keys are imbedded in the student handout section.

**Materials**

DNA strand cards and tRNA cards with words on the back
Transcription/Translation Data Sheet
Large sheet of paper for each group
Markers

**Prior Knowledge**

In order to successfully complete this activity, students must know that DNA bases match according to the following table:

| DNA | mRNA | tRNA |
|---|---|---|
| A | U | A |
| C | G | C |
| T | A | U |
| G | C | G |

In addition, those three letter codes actually match up with amino acids to make proteins just as the words in this activity make sentences. The order and number of the amino acids determine the protein. Students need to be aware of the three types of mutations: base substitutions, insertions and deletions.

**Teacher preparation**

1. Copy the DNA strips and cut into separate strands.
2. Modify ¼ of the strands to show a mutation. (i.e. Remove one or more nucleotides, substitute one or more nucleotides, or add one or more nucleotides.)
3. Copy the tRNA cards front to back so anticodons are on one side with words on the other.
4. Set out DNA strands at a central location in the room. (This location represents the nucleus; remember DNA does not leave the nucleus.)
5. Set out tRNA cards around the perimeter of the room, grouped by first letters of the anticodons (A's together, C's together, etc)

6. Group students by four's; provide each group with a copy of the **Transcription/Translation data sheet** copied front to back so each group has enough for the number of sentences assigned. **Note**: Each box in the grid is for a codon or anticodon (three-letter code).
7. Assign sentences to groups. (If all students will practice all roles, each group of four should have four sentences assigned.)
   a. Students will send their transcriber to the nucleus to transcribe the DNA to mRNA.
   b. After transcription, the student returns to the group table and hands the transcription to the translator (tRNA).
   c. After translation, the runners go to find the matching translated tRNA anticodons around the room and once they find the match, they copy the word to their data sheet. STUDENTS MUST NOT TAKE THE tRNA CARDS as they are used in multiple sentences.
   d. Together, the group determines the sentence looking for errors.
   e. Students switch roles (transcriber becomes translator, translator becomes a runner, one runner becomes the transcriber)
   f. Repeat these steps for the number of sentences assigned.
8. Have students *construct an explanation* (orally, on video, or written) of the process they used to transcribe and translate the sentences correctly using the words: DNA, mRNA, tRNA, amino acids and proteins.
9. Have students describe the effect of the mutation on the sentences.

**Student Handout**

**Background**

Deoxyribonucleic acid (DNA) is the molecule of life. DNA is one of the most recognizable nucleic acids, a double-stranded helix. The process by which DNA codes for proteins involves enzymes and additional single-stranded nucleic acids, specifically messenger ribonucleic acid (mRNA) and transfer ribonucleic acid (tRNA). The steps in protein synthesis, transcription from DNA to mRNA, and translation from mRNA to tRNA can be demonstrated by modeling. In this activity, each triplet code of DNA will represent a word in a sentence rather than a code for an amino acid. Introns and exons are omitted. The words can be found by transcribing the DNA into mRNA, then translating mRNA into tRNA.

1. Choose one person to be the transcriber. Find the DNA strand assigned to your group located at the table in the center of the room. (This will represent the nucleus.)

**Note:** The first triplet code is a "start" code, which in eukaryotes, represents the amino acid methionine. For this activity, it is the same triplet code for all and is denoted by the word "START." Each punctuation symbol is represented by a different "stop" anticodon.

2. On the data sheet provided, transcribe the mRNA codons from the DNA strand (without moving the DNA).
3. At your group's table, choose a different person to translate the mRNA codons to tRNA anticodons.
4. Write these anticodons on your data sheet.

5. Choose two people to go find the tRNA anticodons around the room. Turn over the anticodons to find the words of the sentence and write the words on your data sheet.
6. Write your sentence in large print/script on the large sheet or white board at your table.
7. Switch roles and repeat for each additional DNA strand you are assigned.

**Extension:**
After your group has translated your assigned sentences, determine which DNA strands contained a mutation, identify it and explain the consequences of the mutation on the meaning of the sentence. Compare that to an actual mutation.

**Reflection**
1. How are chromosomes, DNA, genes and proteins related?
- *Chromosomes are strands of DNA, they contain genes, which are portions of the DNA strands. The bases of DNA that are contained in a gene code for amino acids in a specific order to create proteins that create a trait.*

2. What area of the cell does the table holding DNA represent in this modeling activity?Why can't the DNA strand be brought back to your group?
- *The nucleus is where DNA is located in a cell. DNA does not leave the nucleus.*

4. What area of the cell does your table represent?
- *The table represents the ribosome. The ribosome is the location of protein synthesis.*

5. What do the words represent? The completed sentences?
- *The words represent amino acids, and the completed sentences represent the proteins.*

6. What do you think the consequences might be if an error occurred in the cell as it goes through the process of protein synthesis?
- *If an error occurs in the transcription or translation process, different codons and anticodons would be produced. This might result in different amino acids that might change the function of the protein and/or prevent a protein from being formed at all.*

**Differentiation**
Other ways to connect with students with various needs:

i. **Local community**: Students may visit a local ethanol plant or invite an extension person or member of the state corn board to their classroom to hear about the benefits of ethanol and the uses of corn.
ii. **Students with special needs (language/reading/auditory/visual)**: Cards can be enlarged for the visually impaired, or spoken so one can participate in the activity.
iii. **Extra support**: If students are struggling, they may watch *Transcription and Translation: From DNA to Protein* https://www.youtube.com/watch?v=bKIpDtJdK8Q
iv. **Extensions**: After completing transcription and translation of the assigned sentences, students may research the evidence for or against the statements.

**Rubric for Constructing Explanations and Designing Solutions**

| Skill | Beginning | Satisfactory | Exemplar |
|---|---|---|---|
| Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins.<br><br>Develop and use a model for how DNA codes for proteins | Participated in the DNA sentence activity. Explanation of the function of DNA and the roles DNA, mRNA and tRNA in transcription and translation of DNA into proteins does not accurately or completely explain the process.<br><br>Mutated sentence was not adequately explained. | Participated in the DNA sentence activity. Explanation of the function of DNA and the roles DNA, mRNA and tRNA in transcription and translation of DNA into proteins is complete and accurate.<br><br>Mutated sentence was explained using proper terminology. | Participated in the DNA sentence activity. Explanation of the function of DNA and the roles DNA, mRNA and tRNA in transcription and translation of DNA into proteins is complete and accurate.<br><br>Mutation was explained and modeled and compared to an actual example of a mutation. |

**Rubric for Self-Assessment**

| Skill | Yes | No |
|---|---|---|
| I participated in each role during the DNA activity. | | |
| I can explain the function of DNA and the roles of DNA, mRNA and tRNA in transcription and translation of DNA into proteins. | | |
| I used the model to determine when and where a mutation occurred that had an outcome on the sentence. | | |

1. Ethanol decreases CO2 production.
   TAC AGT CCG TAG TGA ATT
2. Ethanol is clean energy from corn.
   TAC AGT TCC GAC ATC ATG AGG ATT
3. GMOs improve nutrition.
   TAC AAA CCC AGC ATT
4. DNA is the molecule of life.
   TAC TTA TCC TCG TGG TTT TAA ATT
5. Biotechnology increases yield.
   TAC CGG CCC CGT ATT
6. Biotechnology decreases pesticide use.
   TAC CGG CCG AAC AGA ATT
7. GMOs will meet the increasing demand for food.
   TAC AAA GCG CGA TCG CCC ATA TAT CAA ATT
8. GMOs decrease poverty and increase sustainability.
   TAC AAA CCG TGC GAG CCC AAG ATT
9. GMOs can grow on marginal land
   TAC AAA ACG TGT TTT GCA CCT ATT
10. Some corn is drought tolerant.
    TAC ACT AGG TCC CAC TTC AAT
11. One bushel of corn used for ethanol makes 17.5 pounds of distiller's dried grains.
    TAC CTT GAT TTT AGG AGA TAT AGT CAG TTG ACC TTT CCA ATT
12. Corn ethanol meets the demand for fuel and food.
    TAC AGG AGT CGA TCG ATA TAT ATC GAG CAA ATT
13. One bushel of corn equals 56 pounds.
    TAC CTT GAT TTT AGG CAG TTG ACC ATT
14. One bushel of corn makes 2.8 gallons of ethanol.
    TAC CTT GAT TTT AGG CAG TTG ACC TTT AGT ATT
15. GMOs grow more food on less land.
    TAC AAA TGT CCC CAA TTT CCG CCT ATT
16. Biotechnology decreases energy use.
    TAC CGG CCG ATC AGA ATT
17. Biotechnology decreases CO2 production.
    TAC CGG CCG TAG TGA ATT
18. Biotechnology improves water and soil quality.
    TAC CGG CCC GTT GAG AAT GCT ATT
19. 40% of corn is used to produce ethanol.
    TAC TTG ACC TTT AGG TCC AGA CAT TGA AGT ATT
20. Dent corn produces most corn products.
    TAC GAA AGG TGA ACA AGG TGA ATT



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AAA

AAC

AAG

AAU

ACA

ACC

ACG

ACU

Feed the World

DRAFT

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PESTICIDE

GMOs

SOIL

SUSTAINABILITY

POUNDS/GALLONS/
PERCENT

MOST

SOME

CAN

AGA

AGC

AGG

AGU

AUA

AUC

AUG

AUU

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DRAFT

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NUTRITION

USE(D)/USING

ETHANOL

CORN

ENERGY/FUEL

DEMAND

•

FROM

CAA

CAC

CAG

CAU

CCA

CCC

CCG

CCU

DROUGHT

FOOD

TO

MAKES/EQUALS

INCREASE(ING)/
IMPROVE(ING)/
MORE

DISTILLER'S
DRIED GRAINS

LAND

DECREASE(S)/
DECREASING/
LESS

CGA

CGG

CGU

CUU

GAA

GAC

GAG

GAU

BIOTECHNOLOGY

MEET(S)

ONE

YIELD

CLEAN

DENT

BUSHEL

AND

GCA

GCG

GCU

GUA

GUU

UAA

UAC

UAG

Feed the World

DRAFT

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WILL

MARGINAL

OUR

QUALITY

LIFE

WATER

$CO_2$

START

UAU

UCC

UCG

UGA

UGC

UGG

UGU

UUA

Feed the World

DRAFT

IS/ARE

FOR

PRODUCE(S)/
PRODUCTS/
PRODUCTION

THE

MOLECULE

POVERTY

DNA

GROW

UUC

UUG

UUU

DRAFT

17.5/56/2.8/40

TOLERANT

OF/ON

1 TAC AGT CCG TAG TGA ATT

2 TAC AGT TCC GAC ATC ATG AGG ATT

3 TAC AAA CCC AGC ATT

4 TAC TTA TCC TCG TGG TTT TAA ATT

5 TAC CGG CCC CGT ATT





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6 TAC CGG CCG AAC AGA ATT

7 TAC AAA GCG CGA TCG CCC ATA TAT CAA ATT

8 TAC AAA CCG TGC GAG CCC AAG ATT

9 TAC AAA ACG TGT TTT GCA CCT ATT

10 TAC ACT AGG TCC CAC TTC ATT


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11 TAC CTT GAT TTT AGG AGA TAT AGT CAG TTG ACC TTT CCA ATT

12 TAC AGG AGT CGA TCG ATA TAT ATC GAG CAA ATT

13 TAC CTT GAT TTT AGG CAG TTG ACC ATT

14 TAC CTT GAT TTT AGG CAG TTG ACC TTT AGT ATT

15 TAC AAA TGT CCC CAA TTT CCG CCT ATT


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16 TAC CGG CCG ATC AGA ATT

17 TAC CGG CCG TAG TGA ATT

18 TAC CGG CCC GTT GAG GTT GCT ATT

19 TAC TTG ACC TTT AGG TCC AGA CAT TGA AGT ATT

20 TAC GAA AGG TGA ACA AGG TGA ATT

**Lesson 3**
**DNA Sentences**

Focus Question: *How are proteins coded for by DNA?*
Vocabulary: *deoxyribonucleic acid (DNA), messenger RNA (mRNA), transfer RNA (tRNA), CRISPR, transcription, translation, mutation*

**Background**

Deoxyribonucleic acid (DNA) is the molecule of life. DNA is one of the most recognizable nucleic acids, a double-stranded helix. The process by which DNA codes for proteins involves enzymes and additional single-stranded nucleic acids, specifically messenger ribonucleic acid (mRNA) and transfer ribonucleic acid (tRNA). The steps in protein synthesis, transcription from DNA to mRNA, and translation from mRNA to tRNA can be demonstrated by modeling.

In this activity, each triplet code of DNA will represent a word in a sentence rather than a code for an amino acid. Introns and exons are omitted. The words can be found by transcribing the DNA into mRNA, then translating mRNA into tRNA.

1. Choose one person to be the transcriber. Find the DNA strand assigned to your group located at the table in the center of the room. (This will represent the nucleus.)

**Note:** The first triplet code is a “start” code, which in eukaryotes, represents the amino acid methionine. For this activity, it is the same triplet code for all and is denoted by the word “START.” Each punctuation symbol is represented by a different “stop” anticodon.

2. On the data sheet provided, transcribe the mRNA codons from the DNA strand (without moving the DNA).
3. At your group’s table, choose a different person to translate the mRNA codons to tRNA anticodons.
4. Write these anticodons on your data sheet.
5. Choose two people to go find the tRNA anticodons around the room. Turn over the anticodons to find the words of the sentence and write the words on your data sheet.
6. Write your sentence in large print/script on the large sheet or white board at your table.
7. Switch roles and repeat for each additional DNA strand you are assigned.

**Extension:**

After your group has translated your assigned sentences, determine which DNA strands contained a mutation, identify it and explain the consequences of the mutation on the meaning of the sentence. Compare that to an actual mutation.

**Reflection**

1. How are chromosomes, DNA, genes and proteins related?

2. What area of the cell does the table holding DNA represent in this modeling activity? Why can't the DNA strand be brought back to your group?

4. What area of the cell does your table represent?

5. What do the words represent? The completed sentences?

6. What do you think the consequences might be if an error occurred in the cell as it goes through the process of protein synthesis?

**Rubric for Self-Assessment**

| Skill | Yes | No |
|---|---|---|
| I participated in each role during the DNA activity. | | |
| I can explain the function of DNA and the roles of DNA, mRNA and tRNA in transcription and translation of DNA into proteins. | | |
| I used the model to determine when and where a mutation occurred and whether it had an outcome on the sentence. | | |

# Transcription/translation group data sheet

Sentence number: ___________

Transcriber name: ___________________________

mRNA codons:

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | |

Translator: ___________________________

tRNA codons:

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | |

Sentence: ___________________________________________

tRNA runner name: ______________

tRNA runner name: __________________

# Transcription/translation group data sheet

Sentence number: ___________

Transcriber name: ___________________________

mRNA codons:

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | |

Translator: ___________________________

tRNA codons:

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | |

Sentence: ___________________________________________

tRNA runner name: ______________

tRNA runner name: __________________

# Lesson 4
## Modeling Punnett Squares - Teacher

**Focus Question:** *How do breeders predict which traits will be in offspring? How might biotechnology methods improve the process?*
**Learning Target:** *Students observe a model in order to construct an explanation about how Punnett squares work to predict offspring ratios.*
Vocabulary: *gamete, chromosomes, alleles, dominant, recessive, homozygous, heterozygous*

**MS-LS3: Heredity: Inheritance and Variation of Traits**

| **Performance Expectation** | **Classroom Connections** |
|---|---|
| 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. | Students observe a model of offspring possibilities from two "parents" and are asked to explain their observations. |
| **Science and Engineering Practice** | |
| Developing and Using Models<br>● Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system. | Students use cards as models of genetic crosses to explain patterns |
| **Disciplinary Core Idea** | |
| LS3.B: Variation of Traits<br>• In sexually reproducing organisms, each parent contributes half of the genes acquired (at random) by the offspring. Individuals have two of each chromosome and hence two alleles of each gene, one acquired from each parent. These versions may be identical or may differ from each other. | Students answer the following questions:<br>• You noted that some cards have both a blue and white component. Why might using two letters help show the two components more clearly?<br>• How do you think the alleles of each card interact with the alleles of the other card? |
| **Crosscutting Concept** | |
| Cause and Effect<br>● Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. | Students develop cause-and-effect relationships to predict outcomes of genetic crosses by answering questions such as, "If we mix two strong blues, what will be the result using your ideas about how the letters interact?" |

**Prior Knowledge**
Students need not have seen a Punnett square nor have any experience with predicting ratios. However, they do need to know that a gamete contains only one set of chromosomes from one parent that then is fertilized by the gamete from the other parent with another set of chromosomes. So half of the chromosomes come from each parent.

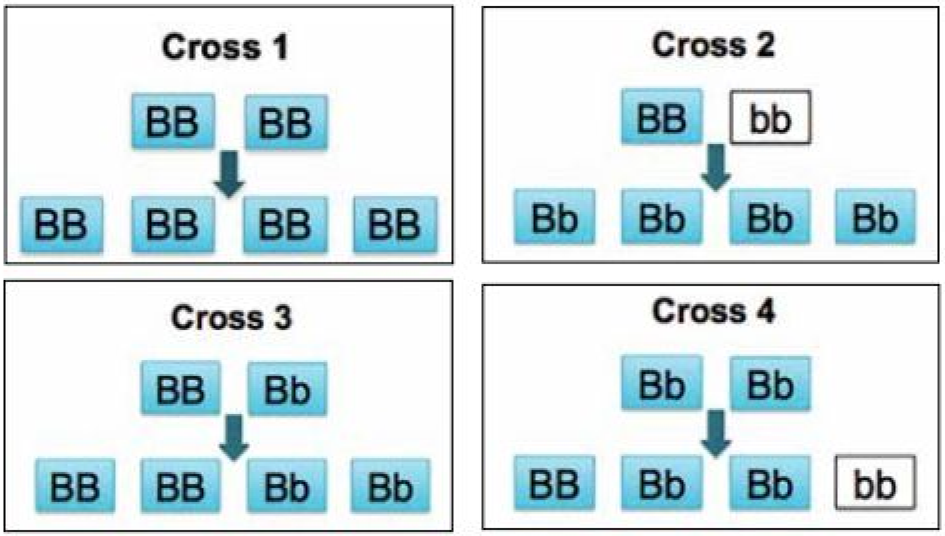
**Teacher instructions**
Teaching Punnett squares in Biology class results in many students who may be able to memorize the probabilities, but often students are unable to describe the patterns of heredity in any deeper way. This activity requires students to observe and make sense of their observations while vocabulary can be introduced to describe their observations.

**Suggested Time Table**
2- 45 minute periods

**Materials**
Shoebox with lid
Square cards - 20 blue and 20 white unmarked cards

**Method**: Throughout this exercise, students should be sitting in pairs or fours of collaborative groups, sharing answers and discussing/defending their thoughts with their classmates. They record results in their notebooks to keep track of what is happening. At times, they will need to explain their thinking.

1. Show students two blue cards. Tell them that by putting the cards in the box, other cards will come out. Place the cards in a shoebox. Keep the lid tipped or keep the box at a height that students cannot see into the box. (This is cross 1)
2. Before pulling four cards out of the box, encourage students to make predictions about the color of those cards. Pull four blue cards out of the box.
3. Ask: "Why do you think the results turned out the way they did?"
4. Encourage students to make a note about their thinking and the results.
5. Set Cross 1 aside with the original two blue "parents" above a row of the four blue offspring that resulted.
6. You may need to use a sticky note to keep track of what is going on with the crosses, or student observations.
7. In Cross 2, put one blue card and one white card in the box. Ask students to predict what color cards will come out and share their reasoning.
8. Draw 4 blue cards out of the box. Ask students to explain. Many students will say blue "wins," or whenever there is a blue card all results will be blue. Ask: "Why do you think that might be?"
9. Set aside Cross 2, ask students to write down their thoughts at this point. Move on to Cross 3.




https://s3.amazonaws.com/nstacontent/ss1704_50.pdf?AWSAccessKeyId=AKIAIMRSQAV7P6X4QIKQ&Expires=1550844999&Signature=j%2fxodPtlj99KQ7rnXMu4sZeZhNM%3d

10. Use one card from the results of Cross 1 and one card from the results of Cross 2 to create a new cross. Ask students to predict the outcome.
11. Ask: "Why do you think you'll get all blue cards again?" and "Why do you think white might show up now?"
12. Perform Cross 4 by using two of the results of Cross 2. Ask for predictions. Pull out 3 blue and 1 white. Discuss the outcome and their reasoning for it.
13. Let students choose two of the cards you have (drawn previously) to cross. So, one member of the group will have to make a suggestion for a cross and explain why the group wants to complete that cross.
14. If students suggest two blue cards, ask: "To what extent does it matter which two blue cards we cross?" Remember that Cross 3 and 4 were both blue cards, but the results were different. Have students choose the specific cards they want to cross.
15. Keep track of the student crosses on a note paper for yourself.
16. Students begin to realize that some cards have both a blue and white component. Or a strong blue and a weak blue. Ask: "How could we label the cards to show that they might have both a white and a blue component?" After listening to student responses, ask: "If we marked each card with letters, in this case we'd use "B" for blue; how could we show that some blue cards are pure blue while others have a white component?" Most student groups will come up with using an uppercase and lowercase b.
17. This may be a time to remind students that organisms have one set of chromosomes from each parent. So one letter is not sufficient to describe both genes for a trait. Ask: "You noted that some cards have both a blue and white component; why might using two letters help show the two components more clearly?"
18. Suggest using a "B" for blue components and a "b" for the white components if students do not make the suggestion on their own.

19. Briefly explain that the letters are called **alleles**. Ask: “Why do you think a ‘B’ mixed with a ‘b’ results in a blue card?” When students explain that the “‘B’ is stronger than the ‘b,’’ introduce the terms **dominant** and **recessive**.
20. Ask: “How can we explain that two cards produce four new cards?” or “How might the numbers of each color help us explain why we get certain results?” Some students compare the mixing to the distributive property in mathematics. That is, each allele from one card pairs with each allele from the other card, making four new card combinations representing the gametes.
21. If they do not make this association, ask: “How do you think the alleles of each card interact with the alleles of the other card?” and “Why would this produce four cards?”
22. Test their ideas. Ask: “If we mix two strong blues, what will be the result if your ideas about how the letters interact are correct?” Encourage additional predictions such as white with strong blue and weak blue with weak blue.
23. When students claim that two weak blues will make three blue and one white, look skeptical and ask them to explain why.
24. Draw a 2 x 2 grid on the board and ask students how the grid may help you predict offspring as they have been doing.

**Assessment** (this set of questions can be woven into the conversation throughout the session)

- Notice how your thinking changed over time. What might cause scientists’ thinking to change? Why is the ability for science ideas to change a good thing?
- You had to create an explanation to account for your observations. How does this illustrate that science is not based solely on evidence?
- You tested your ideas by making predictions. Why might scientists use predictions to test their ideas?
- In what way did your investigation require creativity? How might scientists use creativity?
- We talked in small groups and as a whole class. Why do you think collaboration is so important in science?

**Differentiation**

Other ways to connect with students with various needs:

i. **Local community**: Students may contact a local plant breeder or someone from the state extension office to discuss how these predictions help to inform crosses made with seed.

ii. **Students with special needs (language/reading/auditory/visual)**: Cards may need to a different color for students who have color-blindness. Students working in groups may need an interpreter or another instructional aide to support those who have difficulty communicating.

iii. **Extra support**: If students are struggling, they may watch *Learn Biology: How to draw a Punnett square.* https://www.youtube.com/watch?v=prkHKjfUmMs

iv. **Extensions**: Students may want to attempt a dihybrid cross for corn. These predictions work only if the two traits are on different chromosomes. See Biology

Junction for a sample cross.
https://www.biologyjunction.com/dihybrid_cross_in_corn.htm

**Rubric for Assessment**

| Skill | Developing | Satisfactory | Exemplary |
|---|---|---|---|
| Explanation of model and how it works to predict offspring of various crosses. | Student can follow model rules but cannot explain the mechanism of alleles and how they combine. | Student follows model rules and can explain combination of alleles; determines cause and effect from observing crosses made. | Student follows model rules and can explain combination of alleles; determines cause and effect from observing crosses made; can extend allele combinations to a dihybrid cross. |

**Rubric for Self-Assessment**

| Skill | Yes | Not yet |
|---|---|---|
| I understand the model and was able to make predictions based on it. | | |
| I am able to complete Punnett squares for single traits and predict the outcomes. | | |

## Lesson 4
## Modeling Punnett Squares

Focus Question*: How do breeders predict which traits will be in offspring? How might biotechnology methods improve the process?*
Vocabulary: *gamete, chromosomes, alleles, dominant, recessive, homozygous, heterozygous*

After completing the modeling activity with your instructor, complete these questions to see how traits in corn can be predicted. If a plant breeder is interested in creating a better corn plant, one with some traits from one variety and some traits from another, the traditional method is to cross these two varieties and look for the plants that exhibit the combination of traits desired.

**Instructions**
**Monohybrid Cross - a cross looking at one gene for a trait**
**Use the model (Carolina Biological Supply 17-6810 Monohybrid cross) to complete the activity below.**

1. Cross Colored Aleurone with the genotype (RR) corn with Colorless Aleurone, genotype (rr), in the Punnett square below to show the $F_1$ results.
   a. Circle the correct words below: The **R R** genotype is homozygous / hetrerozygous dominant / recessive.

| | **R** | **R** |
|---|---|---|
| **R** | | |
| **r** | | |

**R R x r r**

a. What are the resulting genotypes? What is the percent?

b. What are the resulting phenotypes? What is the percent?

2. When you cross two of the offspring from above, what will be the result in the F2 generation?
   b. Circle the correct word in the sentence below: The **R r** genotype is homozygous / heterozygous.

| | **R** | **r** |
|---|---|---|
| **R** | | |
| **r** | | |

**R r x R r**

a. What are the resulting genotypes? What are the percents?

b. What are the resulting phenotypes? What are the percents?

3. Count the kernels on the cob to determine the actual ratio.

**Rubric for Self-Assessment**

| Skill | Yes | Not yet |
|---|---|---|

| | | |
|---|---|---|
| I understand the model and was able to make predictions based on it. | | |
| I am able to complete Punnett squares for single traits and predict the outcomes. | | |

## Lesson 5
## Selective Breeding vs Genetic Modification - Teacher

Focus Questions: *What are the advantages of selective breeding? How does selective breeding differ from genetic modification?*
Learning Target: *Students model selective breeding and evaluate the strengths and weaknesses.*
Vocabulary: *genetics, trait, drought, meiosis, genetic modification*

**MS-LS3: Heredity: Inheritance and Variation of Traits**
**MS-ESS3: Earth and Human Activity**

| Performance Expectation | Connections to Activity |
|---|---|
| **MS-LS3-1**. Develop and use a model to describe why structural changes to genes (mutations) located on chromosomes may affect proteins and may result in harmful, beneficial, or neutral effects on the structure and function of the organism. | Students are given three traits of corn. They are challenged to make the most drought resistant corn. DNA codes for the traits that help corn to be drought resistant. They construct an explanation of the best way to obtain offspring with the drought-resistant corn traits. |
| **Science & Engineering Practice** | |
| **Developing and Using Models**<br>● Develop and use a model to describe phenomena. | Students explain the process they followed in the activity, then describe/develop a model for another method that may be more precise (genetic modification). |
| **Disciplinary Core Idea** | |
| **LS3.A: Inheritance of traits**<br>● Variations of inherited traits between parent and offspring arise from genetic differences that result from the subset of chromosomes (and therefore genes) inherited. | Students realize that there are many traits and chromosomes that are involved in this particular characteristic (drought resistance). They are encouraged to determine how the process of meiosis may impact plant breeding and efficiency of obtaining the desired traits.<br><br>Students review these results with the Punnett squares activity in mind.<br><br>Students see why GMO crops have been modified and gain a better understanding of the process. |

| Cross Cutting Concept | |
|---|---|
| **Cause and Effect**<br>● Cause and effect relationships may be used to predict phenomena in natural systems.<br><br>**Structure and Function**<br>● Complex and microscopic structures and systems can be visualized, modeled, and used to describe how their function depends on the shapes, composition, and relationships among its parts, therefore complex natural and designed structures/systems can be analyzed to determine how they function. | Students are asked to determine the outcomes of their crosses and consider the costs and benefits of the modifications. |

*Student handout information is indicated in light gray print. Answer keys are imbedded in the student handout section.

**Teacher Background**

Humans have been selectively breeding animals and plants for thousands of years, choosing the ones with the most favorable characteristics and breeding them to achieve amazing results. Look around at the various dog breeds that have resulted from domesticating wolves or watch the video *Popped Secret: The Mysterious Origin of Corn* at https://www.hhmi.org/biointeractive/popped-secret-mysterious-origin-corn. Up until the late 1970's, that was the only way to get desired traits, but many other traits come along due to the sorting of chromosomes and crossing over that takes place during meiosis during sexual reproduction. Plant breeders have been able to overcome some of these obstacles by using genetic modification to improve crop characteristics, making them insect resistant, herbicide resistant, less prone to enzymatic browning, disease resistant or provide them with a health benefit.

The lesson, ***Selective Breeding vs Genetic Modification***, and the accompanying slide deck, leads students through a modeling activity to allow them to see how trying to get a specific set of traits is not as easy as it seems, even when they are allowed to select for the traits by choosing the offspring they want to cross.

**Materials**

*Starburst® candies Red, Yellow and Pink - these have no allergens and are individually wrapped - 3 per student
Opaque cups (foam cups or colored plastic that students cannot see through) - 1 per every 2 students
Slide deck
Electronic device for researching information

***Each candy represents a trait or phenotype. This activity does not intend to model allele combinations.**

**Prior knowledge**

In order to successfully understand this activity, students need to have some background in the process of meiosis and a general familiarity with the idea of selective breeding. Additional material can be supplemented by showing Lesson 1 Environment or Genetics slide deck from the middle school Biotechnology unit.

**Student Handout**

The purpose of this activity is to simulate selective breeding as it is accomplished by plant scientists. The Starburst® candies in the cup represent different traits that are desirable in corn to provide drought resistance. A *strong root system* is important to drought resistance since strong roots support a healthy stem and plant and make it easier for water and nutrients to enter the plant. *Seedling disease resistance* will add to drought resistance if the corn has some natural immunity to fungi, bacteria, nematodes and root feeding insects. One of the root feeding insects is called rootworm, which becomes a beetle as an adult. The larvae feed on the roots during the early part of the growing season. If the corn has *rootworm resistance*, it is more likely to survive drought as well.

https://commons.wikimedia.org/wiki/File:Diabrotica_virgifera_virgifera_larvae.jpg

1. You have three Starburst® candies. Which characteristics does your corn plant have? Circle the combination of traits you have.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| R | R | R | R | R | R | P | P | P | Y |
| R | R | Y | R | P | P | P | Y | P | Y |
| R | Y | Y | P | P | Y | Y | Y | P | Y |
| Strong root system | Strong root system<br><br>Seedling diseases resistance | Strong root system<br><br>Seedling diseases resistance | Strong root system<br><br>Rootworm resistance | Strong root system<br><br>Root-worm resis-tance | Strong root system<br><br>Rootworm resistance<br><br>Seedling diseases resistance | Rootworm resistance<br><br>Seedling diseases resistance | Rootworm resistance<br><br>Seedling diseases resistance | Root-worm resis-tance | Seedling diseases resistance |

2. Combine your Starburst® with those of someone else at your table. Place your six traits in the cup.
3. Shake the cup.
4. Draw out three Starburst® (traits). This represents the offspring from your cross.
5. Which characteristics does your new corn plant have? Circle the combination of traits you have.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| R | R | R | R | R | R | P | P | P | Y |
| R | R | Y | R | P | P | P | Y | P | Y |
| R | Y | Y | P | P | Y | Y | Y | P | Y |
| Strong root system | Strong root system<br><br>Seedling diseases resistance | Strong root system<br><br>Seedling diseases resistance | Strong root system<br><br>Rootworm resistance | Strong root system<br><br>Root-worm resis-tance | Strong root system<br><br>Rootworm resistance<br><br>Seedling diseases resistance | Rootworm resistance<br><br>Seedling diseases resistance | Rootworm resistance<br><br>Seedling diseases resistance | Root-worm resis-tance | Seedling diseases resistance |

6. Select another corn plant at your table that has some or all of the desired traits. Cross your plant with that plant by repeating steps 2-4. How many offspring in the class, have all three of the desired traits? (Report as the number that do out of the total possible.)

- *There will be less than 100% that have all three of the desired traits (unless they choose while looking).*

7. Why didn't choosing the parents result in all of the offspring having the desired traits?

- *There will be six candies in the cups and the probability of drawing out one of each color will be determined by the number of each color and the mixing that will take place.*

8. How does meiosis affect the outcome? What are the limitations of this model?

- *Meiosis allows for different chromosomes from the parents to end up in different gametes, one from each parent, but not all gametes will have all the same information. Unless the parents are genetically identical, the offspring will show some traits from both parents.*
- *This model does not allow for the separation of these traits to show up on separate chromosomes (i.e. the colors represent different traits, but these traits are on different chromosomes or are influenced by multiple genes. The candies do not represent genes, just the resulting traits.*

9. How might plant breeders overcome these obstacles?

- *Research on which genes influence these traits can be done. Scientists may be able to isolate which genes and modify the genes through gene editing (CRISPR) or they may find the trait in different species, isolate and transfer those genes to plants to give them the traits to make them drought resistant.*

10. How much might it cost (in dollars and time) to make these modifications? What are the environmental costs and benefits?

- *Economic and time: On average, GMOs take 13 years and $130 million of research and development before coming to market*. See more info about the costs at: https://gmoanswers.com/ask/what-average-cost-associated-research-production-and-testing-single-genetically-modified.
- *Environmental costs are: 1) a monocrop with the same genetic modifications can be more susceptible to a disease due to the lack of genetic diversity in the crop, 2) some weeds in fields have become resistant to the use of herbicides after many years of use of that herbicide, 3) some crops that do not have resistance to an herbicide may be harmed if the herbicide is used in an adjacent field.*
- *Benefits: 1) the amount and concentration of harmful herbicides has decreased, 2) the amount of harmful insecticides is greatly reduced since the plants make their own insecticide, 3) some crops are disease resistant which saved the industry of rainbow papaya (research papaya and ringspot virus), and is also used in potatoes and zucchini, 4) health benefits have been added to some plants, such as, high oleic oil from soybeans is more similar to olive oil, but still have the ability to fry for longer periods with less residue than regular soybean oil (soybean oil is sold as vegetable oil).*

**Differentiation**

Other ways to connect with students with various needs:

i. **Local community**: students may investigate local plants that resist drought for additional testing.

ii. **Students with special needs (language/reading/auditory/visual)**: students may plant different seeds and water with various amounts to determine the characteristics that lead to drought resistance.

iii. **Extra support**: Students might read: “Pioneer Research to Develop Drought-tolerant Corn Hybrids” https://www.pioneer.com/CMRoot/Pioneer/US/products/seed_trait_technology/see_the_difference/corn_drought.pdf or “Drought-Tolerant Corn Hybrids Yield More in Drought-Stressed Environments with No Penalty in Non-stressed Environments” https://www.frontiersin.org/articles/10.3389/fpls.2016.01534/full

iv. **Extensions**: Students can research the development of corn by viewing: *Popped Secret: The Mysterious Origin of Corn* from HHMI Biointeractive: https://www.hhmi.org/biointeractive/popped-secret-mysterious-origin-corn to determine how corn might be bred to be more drought resistant.

**Rubric for Assessment**

| Skill | Developing | Satisfactory | Exemplary |
|---|---|---|---|
| **Develop and use a model** | Student can describe the activity but does not make a connection to selective breeding. | Student can describe the activity and explain how it connects to selective breeding. | Student can describe the activity and explain how it connects to selective breeding. Student can describe limitations within the simulation. |

**Rubric for Student Self-Assessment**

| Skill | Description | Yes | No |
|---|---|---|---|
| **Develop and use a model** | I used the model of the selective breeding process to determine advantages and limitations to the process. | | |

## Lesson 5

## Selective Breeding vs Genetic Modification

Focus Questions: *What are the advantages of selective breeding? How does selective breeding differ from genetic modification?*

Vocabulary: *genetics, trait, drought, meiosis, genetic modification*

The purpose of this activity is to simulate selective breeding as it is accomplished by plant scientists. The Starburst® candies in the cup represent different traits that are desirable in corn to provide drought resistance. A *strong root system* is important to drought resistance since strong roots support a healthy stem and plant and make it easier for water and nutrients to enter the plant. *Seedling disease resistance* will add to drought resistance if the corn has some natural immunity to fungi, bacteria, nematodes and root feeding insects. One of the root-feeding insects is called rootworm, which becomes a beetle as an adult. The larvae feed on the roots during the early part of the growing season. If the corn has *rootworm resistance*, it is more likely to survive drought as well.

https://commons.wikimedia.org/wiki/File:Diabrotica_virgifera_virgifera_larvae.jpg

1. You have three Starburst® candies. Which characteristics does your corn plant have? Circle the combination of traits you have.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| R | R | R | R | R | R | P | P | P | Y |
| R | R | Y | R | P | P | P | Y | P | Y |
| R | Y | Y | P | P | Y | Y | Y | P | Y |
| Strong root system | Strong root system<br><br>Seedling diseases resistance | Strong root system<br><br>Seedling diseases resistance | Strong root system<br><br>Rootworm resistance | Strong root system<br><br>Root-worm resis-tance | Strong root system<br><br>Rootworm resistance<br><br>Seedling diseases resistance | Rootworm resistance<br><br>Seedling diseases resistance | Rootworm resistance<br><br>Seedling diseases resistance | Root-worm resis-tance | Seedling diseases resistance |

2. Combine your Starburst® with those of someone else at your table. Place your six traits in the cup.
3. Shake the cup.
4. Draw out three Starburst® (traits). This represents the offspring from your cross.
5. Which characteristics does your new corn plant have? Circle the combination of traits you have.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| R | R | R | R | R | R | P | P | P | Y |
| R | R | Y | R | P | P | P | Y | P | Y |
| R | Y | Y | P | P | Y | Y | Y | P | Y |
| Strong root system | Strong root system<br><br>Seedling diseases resistance | Strong root system<br><br>Seedling diseases resistance | Strong root system<br><br>Rootworm resistance | Strong root system<br><br>Root-worm resis-tance | Strong root system<br><br>Rootworm resistance<br><br>Seedling diseases resistance | Rootworm resistance<br><br>Seedling diseases resistance | Rootworm resistance<br><br>Seedling diseases resistance | Root-worm resis-tance | Seedling diseases resistance |

6. Select another corn plant at your table that has some or all of the desired traits. Cross your plant with that plant by repeating steps 2-4. How many offspring in the class, have all three of the desired traits? (Report as the number that do out of the total possible.)

7. Why didn't choosing the parents result in all of the offspring having the desired traits?

8. How does meiosis affect the outcome? What are the limitations of this model?

9. How might plant breeders overcome these obstacles?

10. How much might it cost (in dollars and time) to make these modifications? What are the environmental costs and benefits?

**Rubric for Self-Assessment**

| Skill | Description | Yes | No |
|---|---|---|---|
| **Develop and use a model** | I used the model of the selective breeding process to determine advantages and limitations to the process. | | |

# Selective Breeding vs Genetic Modification

Feed the World Biotechnology

# Case Study

- According to Pioneer, the yield loss due to drought ranges from 40–80 bu/acre in Nebraska, with higher ranges in the west.
- Economic effects of drought can be up to $9 billion in a drought year.
- Economic impacts may include farmers who lose money because drought destroyed or lowered the yield of their crops.
- These economic impacts can be both direct, such as decreases in corn production, and indirect, as seen by increases in the price of animal feed.
- The traits that will help reduce the effects of drought in corn include: a strong root system, resistance to root worm, and resistance to seedling diseases.

# Selective Breeding Activity

- You have three Starburst® candies. These candies represent the traits that determine resistance to drought.
- Stack your three Starburst® and determine your trait combinations using the following key...
  - Red for strong root system
  - Pink for rootworm resistance
  - Yellow for seedling diseases resistance

# Table of traits for drought resistance

Make note of what characteristics your plant has.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| R | R | R | R | R | R | P | P | P | Y |
| R | R | Y | R | P | P | P | Y | P | Y |
| R | Y | Y | P | P | Y | Y | Y | P | Y |
| Strong root system | Strong root system<br><br>Seedling diseases resistance | Strong root system<br><br>Seedling diseases resistance | Strong root system<br><br>Rootworm resistance | Strong root system<br><br>Rootworm resistance | Strong root system<br><br>Rootworm resistance<br><br>Seedling diseases resistance | Rootworm resistance<br><br>Seedling diseases resistance | Rootworm resistance<br><br>Seedling diseases resistance | Root-worm resis-tance | Seedling diseases resistance |

# Find another person at your table and combine your Starburst®

- Place your six traits in the cup
- Shake the cup
- Draw out three Starburst® (traits)
- This represents the offspring from your cross

# Table of traits for drought resistance

What characteristics does your offspring have?

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| R | R | R | R | R | R | P | P | P | Y |
| R | R | Y | R | P | P | P | Y | P | Y |
| R | Y | Y | P | P | Y | Y | Y | P | Y |
| Strong root system | Strong root system<br><br>Seedling diseases resistance | Strong root system<br><br>Seedling diseases resistance | Strong root system<br><br>Rootworm resistance | Strong root system<br><br>Rootworm resistance | Strong root system<br><br>Rootworm resistance<br><br>Seedling diseases resistance | Rootworm resistance<br><br>Seedling diseases resistance | Rootworm resistance<br><br>Seedling diseases resistance | Root-worm resis-tance | Seedling diseases resistance |

# Choose another person to cross plants with.

- Plant breeders do not rely on random combinations to see what happens.
- Find another plant with traits that you would like. Put the traits in the cup and see what the offspring results are.
- How many plants result with all of the desired traits?

- How might plant breeders increase the chances they will get the desired traits in their offspring?

# Reflection

- How did the offspring from your cross differ from the “parents”?
- What traits did your offspring have?
- The first process we used is random and the offspring are not easily predictable. However, scientists can select for traits they desire and there are predictable results, but the ratios of offspring rarely produce 100% of the traits desired each time. The second time, we were more selective...did all of the offspring have the desired traits?
- Seed researchers can selectively breed for resistance.
- How long might it take to get the desired traits?

# If it were only that easy...

- These traits (drought resistance) are controlled by many genes on different areas of several chromosomes.

- How might the process of meiosis affect the breeding of different plants to create the traits desired?

- How might plant breeders overcome these obstacles?

- How much might it cost (economically and time) to make these modifications? What are the environmental costs and benefits?

# Which crops are GMO in the United States? (Only 10!)

- Corn (field and sweet)
- Alfalfa
- Canola
- Cotton
- Soybeans
- Sugar beets
- Rainbow Papaya
- Potatoes
- Summer squash (zucchini)
- Arctic Apples

# What are the modifications?

- Corn (field and sweet) - drought and herbicide tolerance; insect resistance
- Alfalfa - herbicide tolerance
- Canola - herbicide tolerance
- Cotton - herbicide tolerance and insect resistance
- Soybeans - herbicide tolerance and insect resistance; health benefit
- Sugar beets - herbicide tolerance
- Rainbow Papaya - disease resistance
- Potatoes - insect and disease resistance; reduce food waste
- Summer squash (zucchini) - disease resistance
- Arctic Apples - reduce food waste

# Costs and benefits...

What are the costs of making these genetic modifications (both economic and environmental)?

What are the benefits of these genetic modifications?

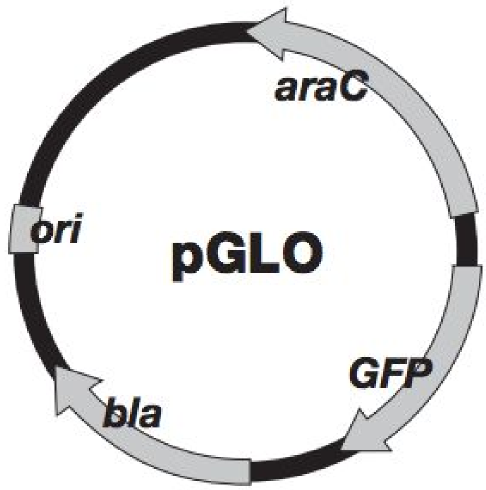
# Lesson 6A
# Plasmid modeling MS - Teacher

Focus Questions: *How does genetic modification work? How does DNA work in bacteria? How might we use that to aid in genetic modification?*
Learning Target: *Students will model the process of plasmid creation and uptake by bacteria.*
Vocabulary: *restriction enzymes, plasmid, nucleotides*

**MS-LS3: Heredity: Inheritance and Variation of Traits**

| Performance Expectation | Classroom Connection |
|---|---|
| **MS-LS3-1.** Develop and use a model to describe why structural changes to genes (mutations) located on chromosomes may affect proteins and may result in harmful, beneficial, or neutral effects on the structure and function of the organism**.** | Students create a model of a plasmid that contains genes to synthesize a specific protein for a desired trait. |
| **Science and Engineering Practice** | |
| **Developing and Using Models**<br>● Use a model based on evidence to illustrate the relationships between systems or between components of a system. | Student models will show the process of finding a gene of interest, cutting DNA with restriction enzymes, inserting the gene of interest into a plasmid and the process of DNA repair to add that gene to a plasmid. |
| **Disciplinary Core Idea** | |
| **LS3.A: Inheritance of Traits**<br>● Genes are located in the chromosomes of cells, with each chromosome pair containing two variants of each of many distinct genes. Each distinct gene chiefly controls the production of specific proteins, which in turn affects the traits of the individual. Changes (mutations) to genes can result in changes to proteins, which can affect the structures and functions of the organism and thereby change traits. | Plasmids are circular pieces of DNA; students will insert a gene of interest to show how the plasmid can be engineered. Students will *develop a model* to show which genes will be inserted to change the trait. |
| **Cross Cutting Concept** | |
| **Structure and Function**<br>● Complex and microscopic structures and systems can be visualized, modeled, and used to describe how their function depends on the shapes, composition, and relationships among its parts, therefore complex natural structures/systems can be analyzed to determine how they function. | Enzymes have various functions; restriction enzymes can be used to remove DNA or insert DNA into plasmids. |

*Student handout information is indicated in light gray print. Answer keys are imbedded in the student handout section.




**pGLO plasmid.** Sequence and map are available at http://explorer.bio-rad.com under "Teaching Resources"

Potential final model: http://www.bio-rad.com/webroot/web/pdf/lse/literature/1660033.pdf (page 10)

**Teacher Background**
Genetic modification is different than crossing different varieties of the same plant species. It is taking a gene from one species and inserting it into the genetic material of another, different species. This is what makes it so specific. We have been able to modify bacteria to produce insulin for humans that is genetically identical to the insulin produced in a human pancreas. How is this possible?

Scientists have been able to isolate genes that code for specific traits through genome studies (discovering the DNA sequence of an entire organism). Proteins, called restriction enzymes, have been discovered and used to cut out the desired gene from the strand of DNA. Scientists have also used various bacteria to act as vectors that can carry genetic material.

Bacteria are ideal species for these vectors, as they contain chromosomal DNA and plasmid DNA. A plasmid is a circular piece of DNA that is found naturally in bacteria. These plasmids can replicate when the bacterium replicates and may be composed of as few as 1,000 or up to 20,000 nucleotides. The genes on the plasmid are part of the traits expressed by the bacterium, perhaps helping it to resist antibiotics, or produce a toxin.

**Prior Knowledge**
This activity asks students model the creation of the plasmid, and describes how to illustrate a potential method of uptake by the plasmid by bacteria. Students need to know about the structures of bacteria: chromosomal DNA and plasmid DNA, the composition of the cell

membrane, and how heat may affect it. This lesson will help prepare them for **Lesson 6B Transform Bacteria**

**Materials**
Pop beads
Mini marshmallows and toothpicks
Blocks
Or other similar materials for making sets of nucleotides and a strand of DNA

**Teacher Preparation**
Gather materials for student use to make models.

PART I
In this activity, you will create a model to show
1) how a gene may be removed from a strand of DNA, then
2) inserted into a plasmid, to be taken into bacteria.
This will demonstrate the process that was used to make the plasmid in the Bio-Rad pGLO™ Bacterial Transformation Kit.

Use beads or other materials (mini marshmallows, blocks, toothpicks, etc.) to create a model to show the process of genetic modification. Your model must include:
- the gene or genes of interest from the original species within the DNA strand;
- a gene to allow for the selection of the transformed cells (often this is an antibiotic resistance gene);
- the action of the restriction enzyme to “cut” out the gene(s) of interest;
- the addition of the gene or genes of interest into the existing DNA of the organism you are trying to modify; and
- the action of the DNA ligase that “attaches” the DNA nucleotides together in place.

**Note:** A process called PCR (polymerase chain reaction) makes hundreds of thousands of copies of the desired gene(s) to create copies that are inserted into bacteria or another vector. The transformed cells can be selected for replication (for example, another gene for antibiotic resistance is added to the plasmid along with the gene of interest; when the cells grow on a plate that has the antibiotic, the transformed cells are the only ones that grow.) These transformed vectors are used to transfer the gene to the desired species. (We will not include this aspect in this model.)

Ask students to connect their model to the phenomenon by explaining how genetic modification may allow for the species that is modified to have better survival chances.

**PART II**
Now that you have your model, how might we get the bacteria to uptake the plasmid you made?

1. If a plastic bottle or balloon acts as the bacteria model, how might we get the genes inside the bottle?

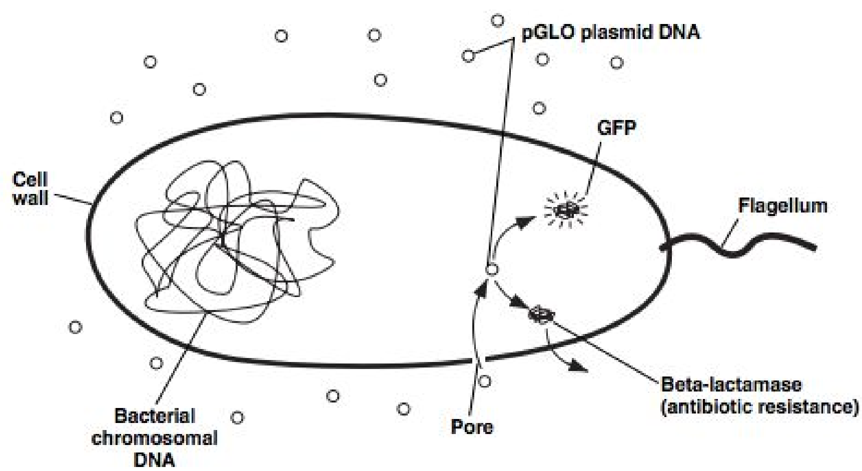
- *Allow students to discuss in their lab group, then ask for ideas. If students are struggling, remind them that they might need to use the physical properties of the cell materials (membrane, cytoplasm) and they might need to be reminded of the processes they have learned (osmosis, diffusion, charge differential, etc)*

2. What will happen to the cell membrane if we heat the bacteria a bit? (Think of yourself in a hot tub or sauna.) What will happen to the cell membrane if we put it in ice water? (Think of yourself on a chilly day without a coat on.)

- *Although this may seem like a silly analogy, this is exactly what scientists are doing to the bacteria: warming it to allow the pore spaces to open, then chilling it to encourage them to close.*

3. How could the conditions in #2 help us get the plasmid in the bottle or balloon?

- *Help students visualize what might happen to the pore spaces when warm and then when cold.*




http://www.bio-rad.com/webroot/web/pdf/lse/literature/1660033.pdf (page 35)

This diagram shows the bacteria and what is happening during the transformation. This helps students visualize how a plasmid may enter a bacterium and how many plasmids there are inside their vials during the experiment.

**Differentiation**

i. **Local community**: Students may do a search to see what genetic modification resources are available in their community. Medical labs are using genetic modification techniques to target specific diseases, agriculture companies (Corteva, Bayer, Syngenta, BASF) may have education and outreach departments that would send a speaker to your class. The county extension service or land grant university in your area may also offer speakers or programs to help consumers understand genetic modification. See also: *GMOs 101* from Michigan State University: https://msutoday.msu.edu/feature/2018/gmos-101/

ii. **Students with special needs (language/reading/auditory/visual)**: Since this lesson is primarily tactile and/or kinesthetic, it could be modified to have students draw the model in a series of comic book frames. Or one student could verbally describe the action while another creates the model and takes it through the steps of the process.

iii. **Extra support**: Students may watch *Genetic Engineering* at: https://www.youtube.com/watch?v=nfC689ElUVk and *Plasmid Rap* at: https://www.youtube.com/watch?v=QFfUFyUvP-w

iv. **Extensions**: New technology is available that will change the way genetic modification works. The technique is called CRISPR and there are various videos and articles about it. To learn the science behind CRISPR, visit HHMI BIointeractive: Click and Learn *CRISPR-Cas 9: Mechanisms and Applications* at https://www.hhmi.org/biointeractive/crispr-cas-9-mechanism-applications or watch *What is CRISPR-Cas?* at https://www.youtube.com/watch?v=52jOEPzhpzc&t=2s

**Rubric for Assessment**

| Skill | Beginning | Satisfactory | Exemplar |
|---|---|---|---|
| Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects. | Explanation for how the model represents the plasmid contains only some of the parts to be transferred to a bacteria to make the proteins of interest. | Explanation for how the model represents the plasmid contains all the parts to be transferred to a bacteria to make the proteins of interest. | Explanation for how the model represents the plasmid contains all the parts to be transferred to a bacteria to make the proteins of interest and the reason why those proteins are of interest. |

**Rubric for Self-Assessment**

| Skill | Yes | No |
|---|---|---|
| My model showed all five aspects of the plasmid required. | | |
| I was able to explain how my model operated in writing or orally to my classmates. | | |

# Lesson 6A
# Plasmid modeling

Focus Questions: *How does genetic modification work? How does DNA work in bacteria? How might we use that to aid in genetic modification?*

Vocabulary: *restriction enzymes, plasmid vectors, nucleotides*

**Background**

Genetic modification is different than crossing different varieties of the same plant species. It is taking a gene from one species and inserting it into the genetic material of another, different species. This is what makes it so specific. Scientists have been able to modify bacteria to produce insulin for humans that is genetically identical to the insulin produced in a human pancreas. How is this possible?

Scientists have been able to isolate genes that code for specific proteins that determine traits through genomic studies (discovering the DNA sequence of an entire organism). Proteins, called restriction enzymes, have been discovered and have been used to cut out the desired gene from a strand of DNA. Scientists have also used various bacterial species to act as vectors that can carry genetic material.

Bacteria are ideal species for these vectors, as they contain chromosomal DNA and plasmid DNA. A plasmid is a circular piece of DNA that is found naturally in bacteria. These plasmids can replicate when the bacterium replicates and may be composed of as few as 1,000 or up to 20,000 nucleotides. The genes in the plasmid are expressed by the bacterium, perhaps helping it to resist antibiotics, or produce a toxin.

**PART I**

In this activity, you will create a model to show

1) how a gene may be removed from a strand of DNA, then
2) inserted into a plasmid, to be taken up by bacteria.

This will demonstrate the process that was used to make the plasmid in the Bio-Rad pGLO™ Bacterial Transformation Kit.

Use beads or other materials (mini marshmallows, blocks, toothpicks, etc.) to create a model to show the process of genetic modification. Your model must include:

- the gene or genes of interest from the original species within the DNA strand;
- a gene to allow for the selection of the transformed cells (often this is an antibiotic resistance gene);
- the action of the restriction enzyme to “cut” out the gene(s) of interest;
- the addition of the gene or genes of interest into the existing DNA of the organism you are trying to modify; and
- the action of the DNA ligase that “attaches” the DNA nucleotides together in place.

Your model is just that. There is no need to make strings of genes with the exact numbers of bases, otherwise, you would need many more beads (materials).

Use your model to explain how genetic modification (by inserting a trait from another organism) may allow for the species that is modified to have better survival chances.

**PART II**

Now that you have your model, how might we get the bacteria to uptake the plasmid you made?

1. If a plastic bottle or balloon acts as the bacteria model, how might we get the genes inside the bottle?

2. What will happen to the cell membrane if we heat the bacteria a bit? (Think of yourself in a hot tub or sauna.) What will happen to the cell membrane if we put it in ice water? (Think of yourself on a chilly day without a coat on.)

3. How could the conditions in #2 help us get the plasmid in the bottle or balloon?

**Rubric for Self-Assessment**

| Skill | Yes | No |
|---|---|---|
| My model showed all five aspects of the plasmid required. | | |
| I was able to explain how my model operated in writing or orally to my classmates. | | |

## Lesson 6B

## Transform Bacteria to Glow*

Focus Question: *How can we genetically modify bacteria? What are the results of gene insertion?*

Learning Target: *Students will genetically modify (transform) bacteria by inserting a plasmid and examine the results of the transformation.*

Vocabulary: *sterile technique*

*This lesson uses Bio-Rad pGLO™ Bacterial Transformation Kit, Catalog #166-0003EDU available from explorer.bio-rad.com

| Performance Expectation | Classroom Connection |
|---|---|
| **MS-LS1-5**. Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms. | Students genetically modify *E coli* bacteria to glow in the presence of arabinose. They make observations about which bacteria grow best in which condition. |
| **MS-LS4-5**. Gather and synthesize information about the technologies that have changed the way humans influence the inheritance of desired traits in organisms. | Students learn one technique to genetically modify an organism (*E coli*) that influences the inheritance of the trait. |
| **EXTENSION: MS-LS4-4**. Construct an explanation based on evidence that describes how genetic variations of traits in a population increase some individuals' probability of surviving and reproducing in a specific environment. | Students explain the results in each plate related to the genetic differences in the treated vs untreated *E coli*. |
| **EXTENSION**: **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. | Students allow the plates to continue to grow to determine when the resources (nutrient in agar) affect the population. |
| **Science and Engineering Practice** | |
| **MS-LS1-4; MS-LS4-4**<br>Constructing Explanations and Designing Solutions<br>● Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future<br>● Construct an explanation that includes qualitative or quantitative relationships between variables that describe phenomena. | Students construct an explanation to describe why *E coli* is growing (or not growing) on their plates and formulate ideas to design a solution using some of the same principles to address drought in plants. |

| | |
|---|---|
| **MS-LS4-5**<br>Obtaining, Evaluating, and Communicating Information<br>● Gather, read, and synthesize information from multiple appropriate sources and assess the credibility, accuracy, and possible bias of each publication and methods used, and describe how they are supported or not supported by evidence. | Students obtain information about the process they used to transform bacteria and find information from other sources to describe one other method used to genetically engineer an organism, communicate about that method and support their research with evidence. |
| **Disciplinary Core Idea** | |
| **LS1.B: Growth and Development of Organisms**<br>● Genetic factors as well as local conditions affect the growth of organisms.<br><br>**LS4.B: Natural Selection**<br>● In artificial selection, humans have the capacity to influence certain characteristics of organisms by selective breeding. One can choose desired parental traits determined by genes, which are then passed on to their offspring. | Transformed bacteria will grow on plates that non-transformed bacteria will not.<br><br>Students will be able to explain why selective breeding would not have created this bacterial trait. |
| **Crosscutting Concept** | |
| **Cause and Effect**<br>● Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability.<br><br>**Connections to Engineering, Technology, and Applications of Science**<br><br>**Interdependence of Science, Engineering, and Technology**<br>● Engineering advances have led to important discoveries in virtually every field of science, and scientific discoveries have led to the development of entire industries and engineered systems.<br><br>----------------------------<br>**Connections to Nature of Science**<br><br>**Science Addresses Questions About the Natural and Material World**<br>● Scientific knowledge can describe the consequences of actions but does not necessarily prescribe the decisions that society takes. | Adding the plasmid to the bacteria caused the bacteria to glow and grow only under certain environmental conditions.<br><br>Genetic engineering has led to the development of medical and crop advances.<br><br>The science behind genetic modification is used in many applications but there is a mixed reaction to genetically modified organisms among consumers. |

**Teacher Background**

This activity shows in one lab period how bacteria can be genetically modified. Genetic modification is a powerful tool wherein DNA from one organism is added to the DNA of a different species. The results of genetic modification in agriculture have resulted in plants that can make their own pesticides and resist herbicides. In this lesson, green fluorescent protein (GFP) is inserted or added to non-virulent *E. coli* bacteria.

The source of GFP is a jellyfish, *Aequorea victoria*. This protein allows the jellyfish to fluoresce and glow in the dark. The mechanism to transform the bacteria is by the use of a plasmid. The kit comes with a plasmid that contains the GFP, antibiotic resistance and a gene regulation system that turns the production of the protein on in the presence of arabinose, a monosaccharide. The plasmid is added to the bacteria in solution, then conditions are created to encourage the bacteria to uptake the plasmid. The bacteria is then grown overnight on various media that act as controls, and/or select for transformed cells.

As always when using bacteria in the lab, **sterile technique** should be used when transferring materials by sterile pipette or sterile loops. The condition for uptake of the plasmid by the bacteria is critical for success in this lab. The process, called heat shock, can be compared to how skin pores close in extreme cold, open in warmth and close again quickly when exposed to cold once more. Bacteria also have pore spaces that will be closed in the cold, opened in the heat and closed again tightly to hold in the plasmid if it crossed the membrane. The transformation solution used with the bacteria also sets up a charge differential across the membrane that attracts the plasmid to cross the membrane. The colonies in suspension will be held on ice, then in a water bath at 42°C for 50 seconds, then immediately back on ice. Once students complete the procedure, have them complete the table with their predictions about bacteria growth and fluorescence.

Teachers are encouraged to read the manual for the kit before deciding to use this activity. It is available here: [http://www.bio-rad.com/webroot/web/pdf/lse/literature/1660033.pdf](http://www.bio-rad.com/webroot/web/pdf/lse/literature/1660033.pdf)

The kit is designed to provide three controls to test various aspects of the procedure.

1) Grow colonies on LB agar only. This shows that the bacteria are viable even after being subjected to heat shock.
2) Grow untreated colonies on LB agar with added ampicillin. This control provides a check that the original *E coli* bacteria are not ampicillin resistant and die in the presence of ampicillin.
3) Grow treated colonies on LB agar with added ampicillin to show that they actually do grow in the presence of ampicillin, because the plasmid contains an ampicillin resistance gene.

4) The final plate shows that the treated bacteria will grow and glow on LB agar containing ampicillin and the arabinose sugar. The sugar is required to “turn on” the glow.

Adaptation for students in the middle grades: A check for viable bacteria (bacteria growing on an LB plate) compared to the growing and glowing on the LB/ampicillin/arabinose plate may be sufficient, due to the complexity of showing the additional checks. However, it is suggested that the teacher run at least one full set of controls to be sure there is no contamination and to show students the multiple controls that science requires.

**Prior knowledge**

Students should know how to maintain sterile technique. They may need practice:
-unwrapping pipettes just prior to use (not opening then waving them around in the air or laying them down on the table).
-keeping lids closed on petri dishes until ready to pipette into them.
-removing sterile loops one at a time just before the time of use and re-sealing the packages once removed.
-not touching the end of the loop or pipette with their fingers.

**Teacher preparation**

**1. Review safety procedures and lab skills**

**Safety procedures (see pages 5-6 in the lab manual)**

The Escherichia coli bacteria HB101 K-12 strain contained in this kit is not a pathogenic organism like the E. coli strain O157 H7 that has sometimes been implicated in food poisoning. HB101 K-12 has been genetically modified to prevent its growth unless grown on an enriched medium. However, handling of the E. coli K-12 strain requires the use of standard Microbiological Practices. These practices include, but are not limited to, the following. Work surfaces are decontaminated once a day and after any spill of viable material. All contaminated liquid or solid wastes are decontaminated before disposal. All persons must wash their hands: (i) after they handle material containing bacteria, and (ii) before exiting the laboratory. All procedures are performed carefully to minimize the creation of aerosols. Mechanical pipeting devices are used, mouth pipetting is prohibited; eating, drinking, smoking, and applying cosmetics are not permitted in the work area; wearing protective eyewear and gloves is strongly recommended.

If an autoclave is not available, all solutions and components (loops and pipets) that have come in contact with bacteria can be placed in a fresh 10% bleach solution for at least 20 min for sterilization. A shallow pan of this solution should be placed at every lab station. No matter what you choose, all used loops and pipets should be collected for sterilization. Sterilize petri dishes by covering the agar with 10% bleach solution. Let the plate stand for 1 hr or more, and then pour excess plate liquid down the drain. Once sterilized, the agar plates can be double bagged and treated as normal trash. Safety glasses are recommended when using bleach solutions.

Ampicillin may cause allergic reactions or irritation to the eyes, respiratory system, and skin. In case of contact with eyes, rinse immediately with plenty of water and seek medical advice. Wear suitable protective clothing. Ampicillin is a member of the penicillin family of antibiotics. Those with allergies to penicillin or to any other member of the penicillin family of antibiotics should avoid contact with ampicillin.

**Lab skills (See pages 6-7 in the lab manual)**

- Sterile technique
- Use of the pipette
- Decontamination and disposal
- Incubation

**2. Prepare agar plates** - At least 5 days before planning to do the lab in class, the plates should be prepared. **See pages 11-17 in the lab manual for this preparation procedure**. Total preparation time for “cooking” the agar and pouring the plates is about 2 hours.

**Materials**
1000 mL flask
500 mL distilled water
Hot plate with magnetic stir plate
Magnetic stir bar
Long thermometer
1 package of LB agar (included in kit)
1 vial ampicillin (included in kit)
1 vial arabinose (included in kit)
Transformation solution (included in kit)
Sterile pipettes (included in kit)
Sterile petri dishes (included in kit)

**Tips** for agar preparation:

- Boiling the water and agar is easiest on a hot plate with a magnetic stir bar added, even though the procedure suggested is using a microwave.
- It is important to attend to the flask as once boiling it can easily boil over.
- Simmer the agar and water for 5-10 minutes after boiling to sterilize.
- Once the agar has boiled, remove it from heat as it needs to cool to 55$^{o}$C. This gives enough time to re-hydrate the ampicillin and arabinose.
- Once you have added the transformation solution to the ampicillin and arabinose vials, begin to label the bottom of the plates with a permanent marker LB, LB/AMP and LB/AMP/ARA. The number needed for 8 lab groups is 8 LB, 16 LB/AMP and 8 LB/AMP/ARA. The manual calls for a starter LB plate for each lab group, but that is not really necessary. Two to four starter plates should give enough colonies, for all groups to use. The teacher or a lab assistant can distribute the colonies for groups.
- Begin to pour plates once agar is cooled adequately (you can safely handle the flask). The agar will go far if you pour just enough in each plate to cover the bottom of the dish. Quickly replace the lid.

*Note: Stretching materials for 10 groups (2 classes) is doable. You will need to provide additional sterile petri dishes for the starter plates if you choose to do this, but you should have enough agar if the plates are all the small size that come with the kit.

- Store the agar plates on the benchtop for a full day, then invert (bottom side up) to reduce the amount of condensation. Plates should be stored in the refrigerator until use.

**3. Streak the starter plates** - At least 24-36 hours before the lab, re-hydrate the *E. coli* according to the directions on **page 16 of the lab manual**. Streak the starter plates (LB). Incubate the streaked plates at 37ºC overnight or on a countertop for 2-3 days.

**4. Prepare lab solutions (4 students per station)**
Fill one microtube per station with 1mL of transformation solution.
Fill one microtube per station with 1mL of LB broth.
Refrigerate solutions until lab day.

**5. Prepare lab stations -** Day of the lab prepare each lab station with the following materials:
1 foam microtube holder/float with the following 4 microtubes:
 1 empty microtube labeled +
 1 empty microtube labeled -
 1 microtube with 1mL of transformation solution labeled TS
 1 microtube with 1mL of LB broth labeled LB
1 permanent marker
Package of sterile pipettes
Package of sterile loops
Gloves (optional)
2 agar plates:
 1 LB
 1 LB/Amp/Ara
Cup of crushed ice
**For the class:**
LB starter plates
Remaining transformation solution and LB broth

The student portion of the lab manual begins on **page 32** with Lesson 1 and contains several pieces that are not included in this unit. However, teachers may use these to assess student understanding. (It is suggested by this author, that you use *Lesson 6A Plasmid Modeling* to help students visualize the process that was used to prepare the plasmid.) Detailed step-by-step instructions for the lab are included if preferred over the quick guide.

**Differentiation**
***It is suggested that this lab be modified for use with middle school students by only having students transform the bacteria and grow it on the +LB/amp/ara plates to compare to the -LB control plate.**

i. **Local community**: Students may do a search to see if there is a plant genetics lab nearby. Searching for “agriculture research and development” may give a list of facilities in your area. Few of these facilities will be doing genetic modification, but they may be doing PCR and gel electrophoresis, looking for specific genomes or gene sequences to indicate pathogen resistance or the presence of pathogens in soil to diagnose problems farmers have with various diseases.
ii. **Students with special needs (language/reading/auditory/visual)**: Students in cooperative groups can rotate tasks and utilize all students’ strengths.
iii. **Extra support**: Watch *pGLO Transformation Lab* https://www.youtube.com/watch?v=M6Uxrnpy3FM
iv. **Extensions**: Advanced students may complete the lab as explained in the lab guide. This will give them two additional controls.

**Rubric for Assessment**

| Skill | Developing | Satisfactory | Exemplary |
|---|---|---|---|
| Construct an explanation for how environmental and genetic factors influence the growth of organisms | Student can explain how environmental factors influence the growth of bacteria, but not genetic factors. | Student can explain how environmental factors and genetic factors influence the growth of organisms. | Student can explain how environmental factors and genetic factors influence the growth of organisms and the implications of genetic modification changing the survival of GMOs. |
| Gather and synthesize information about the technologies that have changed the way humans influence the inheritance of desired traits in organisms. | Student researched a method of genetic modification, but cannot apply the information to the activity. | Student researched a method of genetic modification, and can apply the information to the activity. | Student researched a method of genetic modification, and can apply the information to the activity as well as generalize to other organisms. |
| **Extension:** Construct an explanation of how genetic variations of traits in a population increase some individuals’ probability of surviving and reproducing in a specific environment. | Student can explain how the *E coli* used in this activity were changed, but cannot determine why they grow on select plates. | Student can explain how the *E coli* used in this activity were changed and which can survive on select plates. | Student can explain how the *E coli* used in this activity were changed, which can survive on select plates and why. |
| **Extension:** Analyze and interpret data to provide evidence for the effects of resource availability on | Student can collect data to determine when bacteria stop growing in the plate, but cannot explain why the growth | Student can collect data to determine when bacteria stop growing in the plate. Student can explain why growth of | Student can collect data to determine when bacteria stop growing in the plate. Student can explain why growth of |

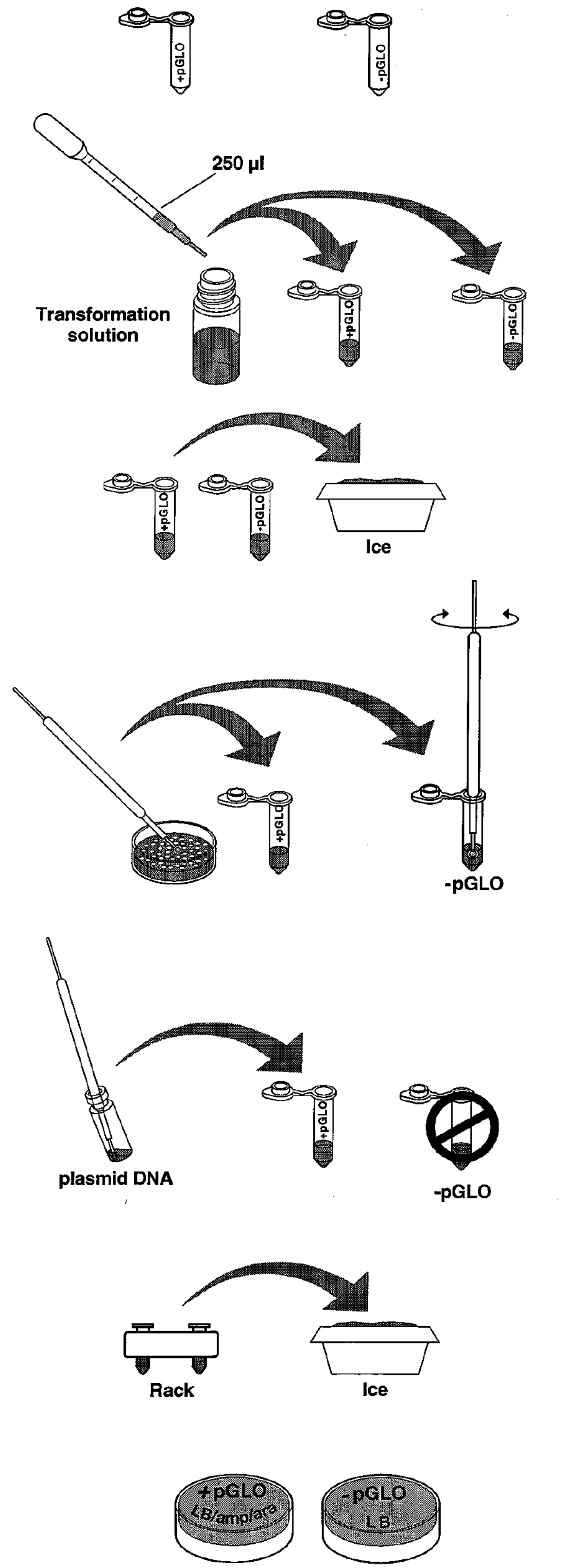
| | | | |
|---|---|---|---|
| organisms and populations of organisms in an ecosystem. | of the bacteria on the plate stops. | the bacteria on the plate stops. | the bacteria on the plate stops. Student can generalize to other situations that may be similar. |

**Rubric for Self-Assessment**

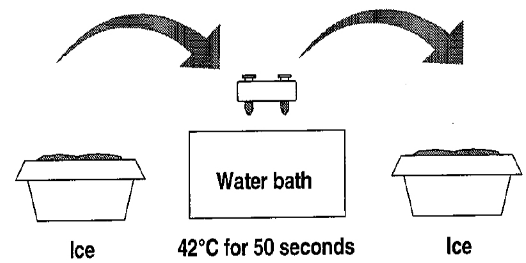
| Skill | Yes | No |
|---|---|---|
| My group completed the lab and grew glowing colonies. | | |
| I can explain the process used in this lab to transform bacteria. | | |
| **Extension**: We determined when the resources (nutrient in agar) affected the population. | | |
| **Extension:** We ran the lab with four plates and can explain how each plate served as a check or control. | | |

# Lesson 6B
# Transform Bacteria

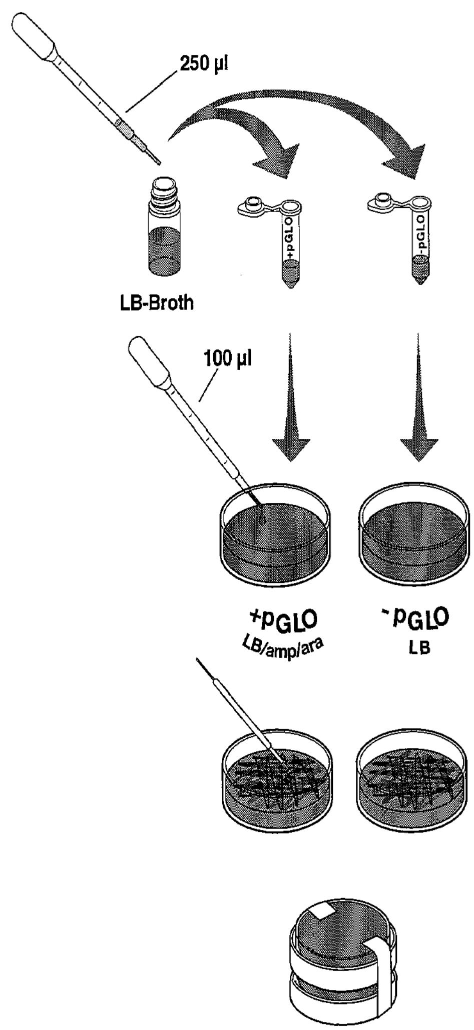
1. Label one closed micro test tube +pGLO and another -pGLO. Label both tubes with your group's name. Place them in the foam tube rack.
2. Open the tubes and using a sterile transfer pipet, transfer 250 µl of transformation solution ($CaC1_2$).
3. Place the tubes on ice.
4. Use a sterile loop to pick up a single colony of bacteria from your starter plate. Pick up the +pGLO tube and immerse the loop into the transformation solution at the bottom of the tube. Spin the loop between your index finger and thumb until the entire colony is dispersed in the transformation solution (with no floating chunks). Place the tube back in the tube rack in the ice. Using a new sterile loop, repeat for the -pGLO tube.
5. Examine the pGLO plasmid DNA solution with the UV lamp. Note your observations. Immerse a new sterile loop into the plasmid DNA stock tube. Withdraw a loopful. There should be a film of plasmid solution across the ring. This is similar to seeing a soapy film across a ring for blowing soap bubbles. Mix the loopful into the cell suspension of the +pGLO tube. Close the tube and return it to the rack on ice. Also close the -pGLO tube. Do not add plasmid DNA to the -pGLO tube. Why not?
6. Incubate the tubes on ice for 10 minutes. Make sure to push the tubes all the way down in the rack so the bottom of the tubes stick out and make contact with the ice.
7. While the tubes are sitting on ice, label your four agar plates on the bottom (not the lid) as follows: Label one LB/amp plate: +pGLO;
   Label the LB/amp/ara plate: +pGLO



8. Heat shock. Using the foam rack as a holder, transfer both the (+) pGLO and (-) pGLO tubes into the water bath, set at 42 °C, for exactly 50 seconds. Make sure to push the tubes all the way down in the rack so the bottom of the tubes stick out and make contact with the warm water. When the 50 seconds are done, place both tubes back on ice. For the best transformation results, the change from the ice (0°C) to 42°C and then back to the ice must be rapid. Incubate tubes on ice for 2 minutes.




9. Remove the rack containing the tubes from the ice and place on the bench top. Open a tube and, using a new sterile pipet, add 250 µl of LB nutrient broth to the tube and reclose it. Repeat with a new sterile pipet for the other tube. Incubate the tubes for 10 minutes at room temperature.
10. Tap the closed tubes with your finger to mix. Using a new sterile pipet for each tube, pipet 100 µl of the transformation and control suspensions onto the appropriate plates.
11. Use a new sterile loop for each plate. Spread the suspensions evenly around the surface of the agar by quickly skating the flat surface of a new sterile loop back and forth across the plate surface.
12. Stack up your plates and tape them together. Put your group name and class period on the bottom of the stack and place the stack upside down in the 37°C incubator until the next day.




- Research one of the genetic modifications that have been made to dent corn in the past 30 years. Create a presentation with data and photographs that explains how this genetic modification has improved any of the following areas:
  - Yield increase
  - Decrease of nutrient requirements for growth
  - Increase of insect resistance
  - Drought Tolerance
  - Resistance to soil pests (nematodes)
  - Decrease of herbicide use
  - Changes in the nutritional composition (protein, moisture, starch, etc.)

| – pGLO | + pGLO |
|---|---|
| LB Amp<br>Prediction:<br>Reason:<br>Observed result: | LB Amp Ara<br>Prediction:<br>Reason:<br>Observed result: |

**Rubric for Self-Assessment**

| Skill | Yes | No |
|---|---|---|
| My group completed the lab and grew glowing colonies. | | |
| I can explain the process used in this lab to transform bacteria. | | |
| **Extension**: We determined when the resources (nutrient in agar) affected the population. | | |
| **Extension:** We ran the lab with four plates and can explain how each plate served as a check or control. | | |

## Lesson 7
## Design Challenge - Teacher

Focus Question: *If there are plants out there that are adapted to resist drought how might we use those traits to modify other plants to prevent water loss?*
Learner Outcome: *Students will engage in the design thinking process to develop a novel solution for plants to resist drought.*
Vocabulary: *LAUNCH framework*

### MS-ETS1. Engineering Design

<table>
<tr><th>Performance Expectation</th><th>Classroom Connections</th></tr>
<tr><td>MS-ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.</td><td>Students use the LAUNCH framework to investigate the ways plants resist drought or prevent water loss.</td></tr>
<tr><th colspan="2">Science and Engineering Practice</th></tr>
<tr><td>Analyzing and Interpreting Data<ul><li>Analyze and interpret data to determine similarities and differences in findings.</li></ul></td><td>Students collect data about different plants, then analyze and interpret to see what traits are favorable in drought conditions.</td></tr>
<tr><th colspan="2">Disciplinary Core Idea</th></tr>
<tr><td>ETS1.B: Developing Possible Solutions<ul><li>There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem.</li><li>Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors.</li></ul>ETS1.C: Optimizing the Design Solution<ul><li>Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process—that is, some of those characteristics may be incorporated into the new design.</li></ul></td><td>Students will systematically:<br>L: Look, Listen, and Learn<br>A: Ask Tons of Questions<br>U: Understanding the Process or Problem<br>N: Navigate Ideas<br><br>C: Create a Prototype<br>H: Highlight and Fix<br>Launch to an Audience</td></tr>
<tr><th colspan="2">Cross Cutting Concept</th></tr>
<tr><td>Scientific Knowledge Assumes an Order and Consistency in Natural Systems</td><td>Students will engage in observation of plants from various habitats and determine which traits will</td></tr>
</table>

| | |
|---|---|
| ● Science assumes that objects and events in natural systems occur in consistent patterns that are understandable through measurement and observation. | help a plant to survive drought. |

*Student handout information is indicated in light gray print. Answer keys are imbedded in the student handout section.

**Prior knowledge**

Students may not have any prior knowledge about plant adaptations to dry habitats. Students need to ask questions, watch videos, look at books, google desert plants, etc. to determine what traits allow a plant to survive with little to no water. Remind them that nearly all plants have some adaptation to lack of adequate water (see: https://kids.frontiersin.org/article/10.3389/frym.2017.00058)

**Teacher preparation**

It is usually more successful if there is a short list of places to begin to look for information about the topic. Spend some time creating a list of videos (always best to preview before adding to the list) and websites that have information they may be able to use. If the library has reference books available, make a list of these or contact the librarian resource person to set aside several books for students to read about various traits plants have.

**Student Handout**

Use the LAUNCH (http://www.spencerauthor.com/the-launch-cycle/) framework design challenge model ( or another design process) to investigate the question.

**L: Look, Listen, and Learn**

In the first phase, look, listen, and learn.The goal here is awareness. It might be a sense of wonder at a process or an awareness of a problem or a sense of empathy toward an audience.

- Make a list of all the things you know about plants and how they maintain water in their cells. (Remember that corn leaves curl, but is that enough to protect them from prolonged periods of drought?)
- Watch videos and read about different plants in different habitats to see what characteristics they have.
- Think about photosynthesis and what the ultimate goal of a corn plant is: to make a lot of kernels on an ear of corn!

**A: Ask Tons of Questions**

Sparked by curiosity, move to the second phase, where you ask tons of questions.

- Make a list of questions about how plants differ and whether those differences are helpful
- Try to determine if different traits are controlled by one gene or multiple genes.

**U: Understanding the Process or Problem**

This leads to understanding the process or problem through an authentic research experience. Conduct interviews or needs assessments, research articles, watch videos, or analyze data to get more information about the process or problem.

- Plants that live in dry areas have adaptations to their habitats. How are those adaptations controlled (genes) and how might crossing plants of different species result in offspring with the desired traits?
- Think back to the activities in this unit...How might the plants get the traits to help them resist drought?

**N: Navigate Ideas**

Apply your newly acquired knowledge to potential solutions. In this phase, navigate ideas. Don't only brainstorm, but also analyze ideas, combine ideas, and generate a concept for what you might create.

- Think about modeling and/or review some ideas from this unit.

**C: Create a Prototype**

Create a prototype. It might be a digital work or a tangible product, a work of art or something you engineer. It might even be an action or an event or a system.

- What might a plant like corn look like if it could resist drought? Would it look different or the same? What traits or characteristics might it have that would be different than a normal corn plant?

**H: Highlight and Fix**

Next, begin to highlight what's working and fix what's failing. The goal here is to view this revision process as an experiment full of iterations, where every mistake takes you closer to success.

- Show your prototype to other people, ask for feedback, look at the prototypes of others to get new ideas on how to refine your prototype.

**Launch to an Audience**

Then, when it's done, it's ready to launch. In the launch phase, send it to an authentic audience. Share your work with the world!

- Make a video, presentation board, slide presentation or use another way to share what you have learned and your ideas.

**Differentiation**

i. **Local community**: Students may ask a local plant specialist (arborist, gardeners, agronomist, botanist) to come to speak about plants adapted to dry climates.
ii. **Students with special needs (language/reading/auditory/visual)**: Students should be in groups that can capitalize on student strengths. Students could be assigned specific roles to contribute to overall ideas and prototype.
iii. **Extra support**: Teacher may provide specific readings, videos, etc for students in order to narrow the search for reliable and relevant information.
iv. **Extensions**: Due to the open ended nature of the task, students will not be limited in their thinking or exploration of this topic.

**Rubric for Assessment**

| Skill | Developing | Satisfactory | Exemplary |
|---|---|---|---|
| Developed a possible solution; optimized the design process | Student did not complete the full process and/or skipped steps within the process | Student followed the LAUNCH design process to address the challenge. | Student followed the LAUNCH design process and addressed the challenge in a novel way. |

**Rubric for Self-Assessment**

| Skill | Yes | No |
|---|---|---|
| I was able to develop a possible solution to protect a plant from water loss. | | |
| I successfully followed a design process to develop the solution. | | |

## Lesson 7
## Design Challenge

Focus Question: *If there are plants out there that are adapted to resist drought how might we use those traits to modify other plants to prevent water loss?*
Vocabulary: *prototype,*

Use the LAUNCH (http://www.spencerauthor.com/the-launch-cycle/) framework design challenge model ( or another design process) to investigate the question.

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