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SMILE Program

Hazelnuts and Genetics
Oregon Hazelnuts
Language Booster

Have you ever wondered how scientists can help farmers grow healthier hazelnut trees?

Hazelnuts have become an important part of Oregon's history and agriculture. Farmers began growing hazelnut trees in the Willamette Valley because the region's mild climate and rich soil helped the trees thrive. Over time, Oregon became one of the leading producers of hazelnuts in the United States.

Hazelnut trees can be affected by diseases such as **Eastern Filbert Blight**, which can damage orchards and reduce harvests. To protect the trees and improve production, scientists and farmers study plant **genetics** to better understand traits such as nut size, flavor, tree growth, and disease resistance.

By studying the **DNA** of hazelnut trees, researchers can develop new varieties that grow better in Oregon's climate and are more resistant to the disease. Scientists at OSU are using **gene-editing technology** to explore ways to improve **crops** more quickly and efficiently. Understanding genetics helps farmers produce healthier hazelnut trees and more reliable harvests in the future.

Hazelnuts are used in many different ways around the world. People eat them as a snack, roast them, or add them to foods such as chocolate, cookies, cakes, cereals, and ice cream. Hazelnuts are also used to make spreads, oils, coffee flavorings, and dairy-free milk products. In Oregon, hazelnuts are an important agricultural crop that supports farmers and local businesses. Beyond food, hazelnut shells can also be used for **mulch**, fuel, and crafts.

The story of hazelnuts shows how science, agriculture, and genetics work together to help farmers grow healthy **crops** and provide food for people around the world.

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Hazelnuts and Genetics

Watch the video Nature in Harmony: Hazel Tree, and talk to your team about these questions:

How are hazelnut tree flowers pollinated, and what makes their pollination method different from that of flowers that rely on insects?

What is unique about the fertilization of the hazelnut tree?

What does it mean that hazelnuts are monoecious trees?

Resources:

- **Ferrero Invests in U.S. Hazelnut Farming**

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Hazelnuts and Genetics
Science Investigation

In this investigation, you will explore how DNA carries the instructions that determine the traits of living things, including hazelnut plants. You will discover how genes and amino acids help build proteins that influence characteristics such as disease resistance, growth, and nut quality. By learning how scientists use genetics to develop stronger and healthier plants, you will see how biology and agriculture work together to improve crops that are important to Oregon and the world. This investigation has two parts, building a DNA model and transcribing DNA to determine expressed traits.

Part 1 - DNA Model

In this activity, you will build a simple model of a DNA molecule using popsicle sticks of different colors. Each color will represent one of the four DNA bases—adenine (A), thymine (T), cytosine (C), and guanine (G). As you connect the matching base pairs and assemble the model, you will discover how DNA forms a double-stranded structure that stores instructions for living things. Building the model will help you visualize how the sequence of DNA bases forms the genetic code that determines traits and provides the information needed to make proteins.

Materials:

- 4 half sticks of blue
- 4 half sticks of red
- 4 half sticks of yellow
- 4 half sticks of green
- 8 pieces of Velcro
- 4 long pieces of colored insulating tape
- 14 stickers of the same color

Procedure:

Remember that you are building a ladder!

1. First, take a blue half-stick and a red half-stick. Place them end to end so they form a full stick. Do the same with a yellow half-stick and a green half-stick. Repeat this until you have 8 pairs of half-sticks that will be the bars of your ladder. **The order of the colors of your bars in the scale does not matter.**
2. Second, write the words Adenine on the blue sticks, Thymine on the red sticks, Cytosine on the yellow sticks, and Guanine on the green sticks.
3. Third, use your 8 pieces of Velcro to attach your red half-sticks to the blues and your green half-sticks to the yellows, so that they make 8 full sticks. Your piece of Velcro has two parts. Attach one part of Velcro to the tip of a stick, and the other to the tip of its

corresponding color. Attach the Velcro parts together. Repeat for the other Velcro pieces and half-sticks. You now have 8 sticks, with two colors. They are the bars of your ladder.

4. To make the sides of the ladder, you will need your 4 pieces of tape. Place two of the pieces at a distance equal to the length of the bars, the sticky part upwards. Place one end of the bars on one ribbon and the other end on the second ribbon. Repeat with the other 7 bars at an equal distance from each other, along the ribbon, to complete your ladder. Lay the other two pieces of insulating tape, the sticky part down, over the first two pieces.
5. Finally, you will write the word Phosphate on the stickers. Then stick each of your 14 stickers onto the insulating tape between the bars of the ladder. On the insulating tape, in line with the bars of the ladder, write "D Sugar."

Part 2 - Growing the Best Hazelnuts

Materials:

1. 1 Pencil, pen, or marker.
2. 1 Growing the Best Hazelnuts in Oregon Worksheet.
3. Transcription, Translation, Expression Worksheet
4. My Hazelnut Tree and Fruit Traits Summary Sheet

Procedure:

1. Work as a team to create a hazelnut tree from the DNA provided.
2. The DNA you will use is determined by your birth month and what county in Oregon your Hazelnut is grown in.
    a. You will use 10 genes to make your hazelnut tree.
    b. Each gene will need to be transcribed, translated, and expressed.
    c. Use the codon wheel to transcribe and translate your gene.
    d. Record if your hazelnut tree traits are desirable to consumers.
    e. Record if your hazelnut tree traits are disease resistant or drought tolerant.
    f. Create a drawing of your tree.
3. Argue if your Hazelnut tree is desirable or not to consumers.
5. Share your tree, drawing, and reasoning with your classmate

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Hazelnuts and Genetics

Growing The Best Hazelnut in Oregon

Introduction: You are in search of the best hazelnut to grow in Oregon. You have focused on specific genes that the Hazelnut industry, growers, harvesters, processors, and consumers desire. Genes are like assembly instructions for molecules called amino acids, which are strung together and folded to form proteins, the building blocks of life. Different proteins are associated with distinct phenotypic traits, as shown in the table below. In our example, each trait is either desired or not desired by the Hazelnut Industry.

Hazelnut Fruit Traits - These Impact Processing and Harvesting Yield				
Genes	**Amino Acid Sequence**	**Protein**	**Description**	**Desired**
Nut Size	val - ser - leu	A	Large	Desired
	val - ser - lys	B	Small	Not Desired
Kernel Size	tyr - pro - gln - gln - lys	C	Large	Desired
	val - pro - thr - glu - lys	D	Small	Not Desired
Nut Shape	leu - leu - leu - pro	E	Rounded	Desired
	leu - leu - ser - ala	F	Elongated	Not Desired
Shell Tickness	ala - val - val	G	Thin	Desired
	val - ala - ala	H	Thick	Not Desired
Nut Weight	his - ile	I	Heavy	Desired

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	his - his	J	Light	Not Desired

What top traits would you want in a hazelnut? (include not listed ones, like taste, oily, etc.)

Which nut traits do you think are the most important for ease of hazelnut processing?

Which traits do you think are the most important for easy hazelnut eating?

Which traits do you think are the most important for increasing the amount of Hazelnut fruit produced (high yield)?

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Hazelnut Leaves, Roots, Bark Traits - Impact Hazelnut Growing					
Genes	**Amino Acid Sequence**	**Protein**	**Description**	**Desired**	**Tolerance or Resistance**
Root Length	ser - pro - val	K	Shallow roots	Not Desired	No
	val - phe - tyr	L	Average roots	Desired	No
	ser – gly - val	M	Deep roots	Desired	Drought Tolerant
	val – phe - asp	N	Very deep roots	Desired	Very Drought Tolerant
Hairy Leaves	asp - ile - leu - leu - pro - thr	O	Trichomes on leaves	Desired	Insect Resistant
	asp - ile - pro - pro - pro - thr	P	No trichomes on leaves	Not Desired	No

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Single Stem Tree	val - asp - asp - ala	Q	Only one central stem	Desired	Cold Tolerant
	asp - asp - asp - ala	R	More than one central stem	Not Desired	No
Leaf Size	phe - ser - gly	S	Small leaves	Desired	Heat Tolerant
	phe - phe - gly	T	Large leaves	Not Desired	No
Leaf Color	arg - tyr - cys - lys	U	Dark green leaves	Desired	Shade Tolerant
	arg - arg - asp - thr	V	Light green leaves	Not Desired	No

Which top 3 traits do you think would be most important for helping a Hazelnut tree grow in your area?

How does your area compare to the climate in Oregon's Willamette Valley, where most hazelnuts in Oregon are grown?

Hazelnuts and Genetics

Select Your Hazelnut Tree and Fruit DNA Sequence:
The hazelnut tree you will make depends upon the month of your birthday, as follows:

January-March: Marion Hazelnuts

April-June: Clackamas Hazelnuts

July-September: Yamhill Hazelnuts

October-December: Linn-Benton Hazelnuts

DNA Sequences:
Each of the following DNA samples was taken from local hazelnut farmers. Your job is to analyze each DNA sample and determine the phenotype (how the tree and fruit look) from its sequence. You'll act as a molecular biologist, following the steps of the "central dogma": how DNA is converted to RNA through transcription, and from RNA to amino acids (the building blocks of proteins) through translation.

***Note*: Each line represents a new gene. Circle the gene sequence that corresponds to your birthday month.**

Marion Hazelnuts

5' TAC | CAG TCG TTT | ATG GGG GTT GTC TTT | GAG AAT TCA CGC| CGA CAA CAC | GTA GTA | CAA AAA ATG | CTA TAG AAT GAC GGG TGG | CAA

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CTA CTA CGG | AAA AGA CCT | GCA ATG ACA TTT | ATT 3'

Clackamas Hazelnuts

5' TAC | CAT AGA TTT | CAA GGA TGA CTC TTC | GAA GAG GAG GGG | CAA CGC CGA | GTA GTG | CAT AAA TTA | CTA TAA GAA GAC GGG TGT | CTA CTA CTA CGT | AAG AGC CCT | GCC GCA CTG TGT | ATT 3'

Yamhill Hazelnuts

5' TAC | CAG TCG TTT | ATG GGG GTT GTC TTT | GAG AAT TCA CGC| CAA CGC CGA| GTG TAA | AGA CCC CAT | CTA TAA GGA GGC GGG TGG| CAA CTA CTA CGT | AAG AAA CCT | GCG GCA CTG TGT| ATT 3'

Linn-Benton Hazelnuts
5' TAC | CAT AGG GAG| ATG GGG GTT GTC TTT | AAT AAT GAC GGG | CAC CGT CGA| GTA TAA| AGA GGG CAT | CTG TAA GGA GGC GGG TGT | CTA CTA CTA CGG| AAA AGA CCT | GCA ATG ACA TTT | ATT 3'

Transcription, Translation, Expression Example

Transcribing & Translating your DNA sequence

In molecular biology, transcription is the first step of gene expression, where genetic instructions are copied from DNA to a messenger RNA (mRNA) molecule. For each letter in the DNA sequence, you'll write the matching letter for the RNA sequence. (A→U, T→A, C→G, G→C). (Remember that AUG is a start codon, and it signifies the beginning of the protein sequence. UAA is a stop codon and signifies the end of a gene!)

Translation is the process by which cells use the genetic instructions carried by messenger RNA (mRNA) to string together amino acids, the building blocks of proteins. Once you have an RNA sequence, use the codon wheel to translate each codon into an amino acid. Then, look up which protein is made by that combination of amino acids. Each gene sequence codes for a protein that is expressed as a tree trait.

Example: Clackamas Hazelnuts

5' TAC (Start) | CAT AGA TTT (Gene 1)| CAA GGA TGA CTC TTC (Gene 2)| GAA

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GAG GAG GGG (Gene 3)| CAA CGC CGA (Gene 4)| GTA GTG (Gene 5)| CAT AAA TTA (Gene 6)| CTA TAA GAA GAC GGG TGT (Gene 7)| CTA CTA CTA CGT (Gene 8)| AAG AGC CCT (Gene 9)| GCC GCA CTG TGT (Gene 10)|ATT 3' (Stop)

Transcription, Translation, Expression Example

Gene 3	Example from	
Transcription	DNA	GAG AAT TCA CGC
	DNA→RNA = A→U, T→A, C→G, G→C	
Translation	mRNA	CUC - UUA - AGU - GCG
	Use the codon wheel to determine what amino acid is made	
	Amino Acid Sequence	Leu - Leu - Ser – Ala
	Use Hazelnut Trait tables to determine which protein is made	
	Protein	F
Expressed	Record trait expressed	
	Trait	Nut Shape, Elongated, Not Desired

Transcription, Translation, Expression Worksheet

Start Codon	Transcription Starts	
Transcription	DNA	TAC
	DNA→RNA = A→U, T→A, C→G, G→C	

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Translation	**mRNA**	**AUG**
	Use the codon wheel to determine what amino acid is made	
	Amino Acid Sequence	**Methionine**
	Use Hazelnut Trait tables to determine which protein is made	
	Protein	**Start**
Expressed	**Record trait expressed**	
	Trait	**None. DNA transcription starts.**

Gene 1		
Transcription	**DNA**	

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Translation	**DNA→RNA = A→U, T→A, C→G, G→C**	
	mRNA	
	Use the codon wheel to determine what amino acid is made	
	Amino Acid Sequence	
	Use Hazelnut Trait tables to determine which protein is made	
	Protein	
Expressed	**Record trait expressed**	
	Trait	

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Gene 2		
Transcription	**DNA**	
	DNA→RNA = A→U, T→A, C→G, G→C	
Translation	**mRNA**	
	Use the codon wheel to determine what amino acid is made	
	Amino Acid Sequence	
	Use Hazelnut Trait tables to determine which protein is made	
	Protein	
Expressed	**Record trait expressed**	
	Trait	

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Gene 3		
Transcription	**DNA**	
	DNA→RNA = A→U, T→A, C→G, G→C	
Translation	**mRNA**	
	Use the codon wheel to determine what amino acid is made	
	Amino Acid Sequence	
	Use Hazelnut Trait tables to determine which protein is made	
	Protein	
Expressed	**Record trait expressed**	
	Trait	

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Gene 4		
Transcription	**DNA**	
	DNA→RNA = A→U, T→A, C→G, G→C	
Translation	**mRNA**	
	Use the codon wheel to determine what amino acid is made	
	Amino Acid Sequence	
	Use Hazelnut Trait tables to determine which protein is made	
	Protein	
Expressed	**Record trait expressed**	
	Trait	

Hazelnuts and Genetics

Gene 5		
Transcription	**DNA**	
	DNA→RNA = A→U, T→A, C→G, G→C	
Translation	**mRNA**	
	Use the codon wheel to determine what amino acid is made	
	Amino Acid Sequence	
	Use Hazelnut Trait tables to determine which protein is made	
	Protein	
Expressed	**Record trait expressed**	
	Trait	

Hazelnuts and Genetics

Gene 6		
Transcription	**DNA**	
	DNA→RNA = A→U, T→A, C→G, G→C	
Translation	**mRNA**	
	Use the codon wheel to determine what amino acid is made	
	Amino Acid Sequence	
	Use Hazelnut Trait tables to determine which protein is made	
	Protein	

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Expressed	**Record trait expressed**	
	Trait	

Gene 7		
Transcription	**DNA**	
	DNA→RNA = A→U, T→A, C→G, G→C	
Translation	**mRNA**	
	Use the codon wheel to determine what amino acid is made	
	Amino Acid Sequence	

	Use Hazelnut Trait tables to determine which protein is made	
	Protein	
Expressed	**Record trait expressed**	
	Trait	

Gene 8		
Transcription	**DNA**	
	DNA→RNA = A→U, T→A, C→G, G→C	

Translation	**mRNA**	
	Use the codon wheel to determine what amino acid is made	
	Amino Acid Sequence	
	Use Hazelnut Trait tables to determine which protein is made	
	Protein	
Expressed	**Record trait expressed**	
	Trait	

Gene 9		
Transcription	**DNA**	

Hazelnuts and Genetics

Translation	DNA→RNA = A→U, T→A, C→G, G→C	
	mRNA	
	Use the codon wheel to determine what amino acid is made	
	Amino Acid Sequence	
	Use Hazelnut Trait tables to determine which protein is made	
	Protein	
Expressed	**Record trait expressed**	
	Trait	

Hazelnuts and Genetics

Gene 10		
Transcription	**DNA**	
	DNA→RNA = A→U, T→A, C→G, G→C	
Translation	**mRNA**	
	Use the codon wheel to determine what amino acid is made	
	Amino Acid Sequence	
	Use Hazelnut Trait tables to determine which protein is made	
	Protein	
Expressed	**Record trait expressed**	
	Trait	

Hazelnuts and Genetics

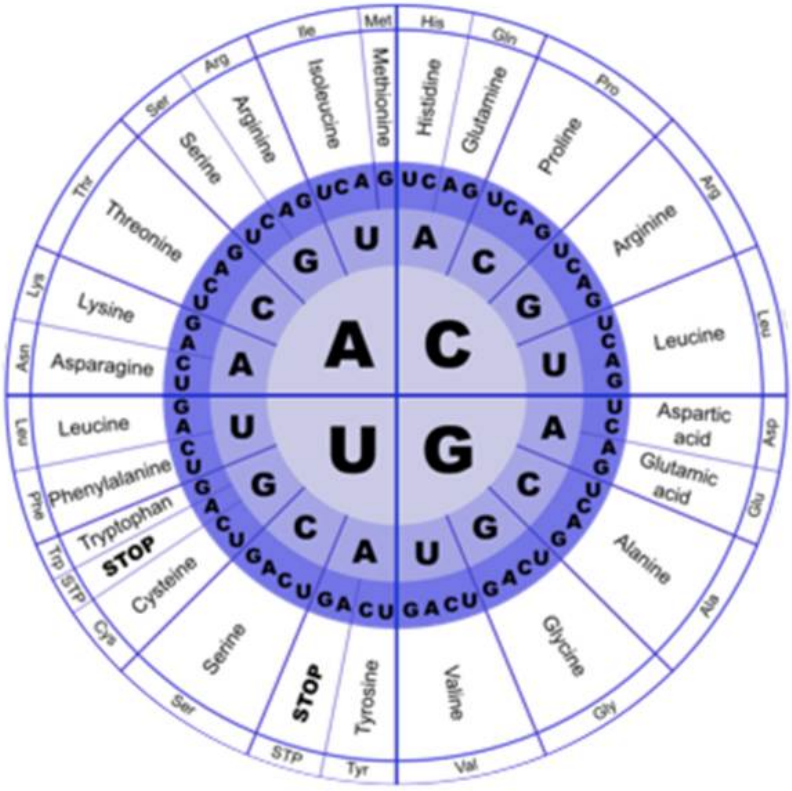
Stop Codon	**Transcription Starts**	
Transcription	**DNA**	**ATT**
	DNA→RNA = A→U, T→A, C→G, G→C	
Translation	**mRNA**	**UAA**
	Use the codon wheel to determine what amino acid is made	
	Amino Acid Sequence	**None.**
	Use Hazelnut Trait tables to determine which protein is made	
	Protein	**Stop (no amino acid is created, stopping transcription)**
Expressed	**Record trait expressed**	
	Trait	**None. DNA transcription stops.**

Hazelnuts and Genetics

Use the Codon Wheel to identify each acid in the Amino Acid Sequence.

Use the wheel by going First Letter (Center) → Second Letter (Inner Ring) → Third Letter (Outer Ring) → Amino Acid

mRNA Codon Wheel



How to use the codon wheel to find amino acids from mRNA:

Start at center. Move outwards, reading each letter of the mRNA codon.

Examples:
AGC = serine
CGA = arginine

Stop codons do not code for any amino acid: UAA, UAG, and UGA.

My Hazelnut Tree and Fruit Traits Sheet

List the protein and trait descriptions that your tree expresses, and circle (yes or no) showing whether or not those traits are desirable to the Hazelnut industry, and circle (yes or no) showing your tree's tolerances and resistance.

Protein	Trait Description	Desired for Harvesting and Processing	Tolerance or Resistance
		Yes / No	Yes / No
		Yes / No	Yes / No
		Yes / No	Yes / No
		Yes / No	Yes / No
		Yes / No	Yes / No
		Yes / No	Yes / No
		Yes / No	Yes / No
		Yes / No	Yes / No
		Yes / No	Yes / No

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		Yes / No	**Yes / No**
Total of YES from each column			

What do you notice about your Hazelnut tree? List 3 observations below.

1.

2.

3.

My Hazelnut Tree and Fruit Traits Summary Sheet

Draw your nut and tree below. Be sure to include all the traits.

Hazelnut Fruit	
	Must have: ● **Nut Size** ● **Kernel Size** ● **Nut Shape** ● **Shell Thickness** ● **Nut Weight**
Hazelnut Tree, Roots, and Leaves	

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	Must have: ● **Root Length** ● **Stem Type** ● **Trichome leaves** ● **Leaf Size** ● **Leaf Color**
Based on your total YES for desired traits, do you think your Hazelnut would be good to grow, harvest, and process in your local community? Explain why or why not. Is it too dry? Is it too sunny? Is it just right?	**Total YES** **Desired Traits for Processing and Harvesting:** _____
	Total YES **Desired Traits for Growing:** _____

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Completed Hazelnut Tree Traits Sheets

Marion Hazelnuts

Protein	Trait Description	Desired	Tolerance/Resistance
A	Large nut size	Yes	No
C	Large kernel size	Yes	No
F	Elongated nut shape	No	No
G	Thin shell	Yes	No
I	Heavy nut weight	Yes	No
M	Deep roots	Yes	Yes (Drought Tolerant)
O	Trichomes on leaves	Yes	Yes (Insect Resistant)
Q	Single stem tree	Yes	Yes (Cold Tolerant)
S	Small leaves	Yes	Yes (Heat Tolerant)
U	Dark green leaves	Yes	Yes (Shade Tolerant)
Totals		9	5

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Clackamas Hazelnuts

Protein	Trait Description	Desired	Tolerance/Resistance
B	Small nut size	No	No
D	Small kernel size	No	No
E	Rounded nut shape	Yes	No
G	Thin shell	Yes	No
I	Heavy nut weight	Yes	No
N	Very deep roots	Yes	Yes (Very Drought Tolerant)
O	Trichomes on leaves	Yes	Yes (Insect Resistant)
R	Multiple stems	No	No
S	Small leaves	Yes	Yes (Heat Tolerant)
U	Dark green leaves	Yes	Yes (Shade Tolerant)
Totals		7	4

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Yamhill Hazelnuts

Protein	Trait Description	Desired	Tolerance/Resistance
A	Large nut size	Yes	No
C	Large kernel size	Yes	No
F	Elongated nut shape	No	No
G	Thin shell	Yes	No
J	Light nut weight	No	No
L	Average roots	Yes	No
P	No trichomes on leaves	No	No
Q	Single stem tree	Yes	Yes (Cold Tolerant)
S	Small leaves	Yes	Yes (Heat Tolerant)
U	Dark green leaves	Yes	Yes (Shade Tolerant)
Totals		7	3

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Hazelnuts and Genetics

Family Activity: Learning About Bioengineered (BE) Crops

Learning Goal:

Learn what bioengineered (BE) organisms (formerly called genetically modified organisms, GMOs) are, why some crops are genetically modified, and how scientists use genetics to help plants grow better, resist pests, or survive diseases.

Materials (use what you have at home):

- Grocery items or food labels (corn chips, soy products, papaya, cereal, etc.)
- Paper and pencils
- Two bowls or baskets labeled "BE Crop" and "Non-BE Crop."
- Printed pictures of crops (corn, soybeans, apples, papaya, potatoes, tomatoes) and trait cards

What is a BE food?

A BE food, or bioengineered food, is food that contains genetic material that has been modified through certain laboratory techniques and for which the modification could not be obtained through conventional breeding or found in nature.

Activity Part 1: Food Detective (10–15 minutes)

Look at food packages and ingredient lists to identify foods that may contain ingredients from BE crops, such as corn or soybeans.

Look for foods that contain corn or soy and think about why you think these crops are commonly modified.

Activity Part 2: Trait Match Game (10 minutes)

Use the pictures of crops and cards with traits to match each trait to the crop you think could benefit from it.

- Why would farmers want crops with these traits?
- How could these traits help feed more people?

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Papayas

Soybean

Corn

Apples

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 Potatoes	 Tomatoes

Resistant to insects	**Needs less water**
Stays fresh longer	**Resistant to disease**
Grows better in salty soil	**Produces more nutritious food**

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Resources:

[GMO Crops, Animal Food, and Beyond]

[List of Bioengineered Foods]

Eastern filbert blight/ Tizón oriental de los avellanos

A fungus that has infected hazelnut orchards throughout the Pacific Northwest.

Un hongo que ha infectado los huertos de avellanos en todo el Noroeste del Pacífico.

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Eastern Filbert Blight slowly girdles the tree's stems.

Concept Card

DNA/ADN

DNA is a short nickname for deoxyribonucleic (say: dee-OK-see-ri-bo-new-klee-ik) acid. DNA is the genetic information inside the cells of living things. It's the instructions for making the body, like the code for a video game or the blueprints for a house.

ADN es el nombre abreviado del ácido desoxirribonucleico. El ADN es la información genética que se encuentra dentro de las células de los seres vivos. Son las instrucciones para construir el cuerpo, al igual que el código de un videojuego o los planos de una casa.

Nearly every cell in your body, except your red blood cells, contains a copy of your DNA.

Concept Card

gene editing/edición genética

A method that enables scientists to modify the DNA of many organisms, including plants, bacteria, and animals.

Un método que permite a los científicos modificar el ADN de muchos organismos, incluyendo plantas, bacterias y animales.

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Researchers are using gene editing to potentially cure inherited diseases

Concept Card

crop/
cultivo

The produce of the ground, while growing or when gathered.

Los productos de la tierra, mientras crecen o una vez recolectados.

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Farmers are hoping for a bountiful crop of wheat this autumn.

Concept Card

Teacher Page

Summary

This activity will guide students through creating their own DNA model and then using it to understand how genes code for traits, using hazelnuts as a specific example. This activity is broken down into 2 parts: part 1 is building their DNA model, and part 2 is going through the central dogma process of taking their DNA sample, transcribing it, translating it, and ultimately investigating which traits their hazelnut DNA sample is coding for. They will then analyze whether those traits are desired and finish the activity by drawing their tree with its corresponding traits.

NGSS Standards

3-LS3-1. Analyze and interpret data to provide evidence that plants and animals have traits inherited from parents and that variation of these traits exists in a group of similar organisms.

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3-LS4-2. Use evidence to construct an explanation for how the variations in characteristics among individuals of the same species may provide advantages in surviving, finding mates, and reproducing.

3-LS4-3. Construct an argument with evidence that in a particular habitat some organisms can survive well, some survive less well, and some cannot survive at all.

3-LS4-4. Make a claim about the merit of a solution to a problem caused when the environment changes and the types of plants and animals that live there may change.*

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

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 to the structure and function of the organism.

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.

MS-LS4-5. Gather and synthesize information about the technologies that have changed the way humans influence the inheritance of desired traits in organisms.

HS-LS1-1. Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins which carry out the essential functions of life through systems of specialized cells.

HS-LS3-1. Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring.

Lesson Objectives

1. Students will explore the ladder structure of DNA by building a model.
2. Students will explore the concept of central dogma by learning the directional flow of genetic information within living cells.

Lesson Procedure

1. Read through the Language Booster with groups and have students explore the concept cards. Introduce the vocabulary to ensure understanding of the terminology used on the cards.

Part 1 - DNA Model

1. Guide the students through the procedure on Page 3 as they create their own model of DNA.

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2. Use the DNA Notes in the Supplemental Resources Folder to give a brief overview of DNA and its purpose.
3. Explain that this model represents **one gene** in the entire DNA sequence.
4. Have all students line up together and hold their models next to each other to create a really long sequence! Explain that an actual strand of DNA would measure out to be about 24 miles long!!

Part 2 - Growing the Best Hazelnuts

1. Explore the "Growing the Best Hazelnuts" worksheet with students. Discuss with students what a desirable trait is and how having certain traits mentioned in the worksheet are beneficial to farmers. Have students answer the following questions.
2. Students will complete the worksheet by choosing their hazelnut tree type based on their birthday month. This will tell them which DNA sequence they will use to complete the activity.
3. Students will take that DNA strand and move through the transcription process of each gene. Use the example to explain the process to students.
    a. ES Students - Use the Completed Hazelnut Tree Traits Sheets to quickly move from the translation, transcription, expression example, to analyzing traits and making a drawing.
    b. MS Students - Transcribe one 10 gene DNA strand as a class, then use that strand and the completed worksheets to draw their hazelnut tree and fruit.
    c. HS Students - Complete DNA sample and transcribing and translating the entire 10 gene DNA sequence..
4. Students will finish the activity by completing the My Hazelnut Tree and Fruit Traits Summary Sheet.

Possible Assessments:

1. Have students present to the class about why their tree would be a good fit for your local climate or not.
2. Select a climate where hazelnut trees grow, and argue what tree should be planted there.

Extensions:

1. Students can weigh, measure, and categorize hazelnuts found at the grocery store.
2. Students can compare the hazelnuts they find to the USDA grading system
    a. https://www.ams.usda.gov/grades-standards/filberts-shell-grades-and-standards