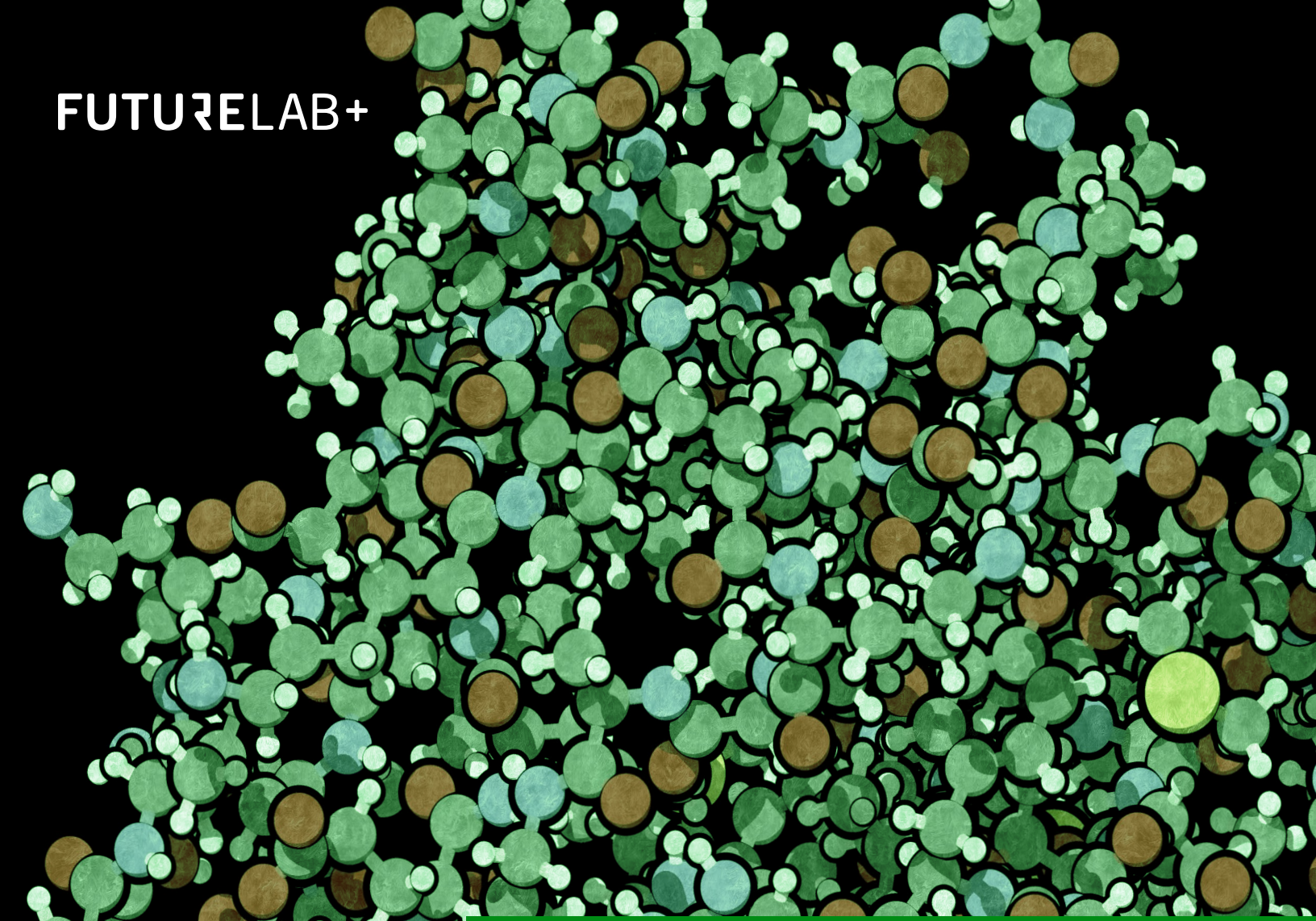
FUTURELAB+



AG/ENVIRONMENTAL

Alternative Proteins

DNA to Alternative Proteins

Developed in partnership with:

Discovery Education and Ignited

In this Lesson Plan:

Print the **Teacher Section** →

Print the **Student Section** →

This document is separated into two sections, For Teachers [T] *and* Student Resources [S]*, which can be printed independently.*

Select the appropriate printer icon above to print either section in its entirety.

Follow the tips below in the Range field of your Print panel to print single pages or page ranges:

Single Pages (use a comma): T3, T6

Page Range (use a hyphen): T3–T6

Cover Image
This model of a protein in cow's milk is a common allergen. Could a genetically engineered modification help?

AG/ENVIRONMENTAL / ALTERNATIVE PROTEINS

DNA to Alternative Proteins

ACTIVITY DURATION

Four class sessions
(45–50 minutes each)

DRIVING QUESTION

How are GE products produced from genes for proteins?

ESSENTIAL QUESTIONS

How is DNA expressed and what is the function of the protein product?

What altered genes and protein products are currently on the market?

What is the history of genetic modification, including some advantages and disadvantages of each method?

What genetic technology techniques are used to create GE crops currently on the market?

OVERVIEW

Genetic engineering (GE) refers to various techniques used to modify and manipulate the genome of a living organism. Recombinant DNA technology, more specifically, encompasses laboratory techniques that involve joining together DNA sequences of two or more organisms. The history of genetic engineering shows how far we have come as a species, from selective breeding to CRISPR technology.

In this lesson, students will explore GE products on a genetic and alternative protein level. After learning more about the history of genetic engineering and recombinant DNA technology, students will gain first-hand experience in the lab where they will test the presence of a GE product protein. To conclude, students will select a GE product of interest and develop a stakeholder-focused ad that communicates the biotechnology process, gene, and alternative protein of the selected product.

OBJECTIVES

Students will be able to:

Identify the relationship between gene and protein (expression of the gene).

Describe the various genetic engineering techniques currently available for modification.

Assess the presence of an altered gene in a laboratory activity.

Identify the genetic engineering technique used to produce a GE product of interest.

Market a GE product of interest for a specific stakeholder.

Communicate scientific information about gene-editing techniques.

Materials

- **Computer**
- **GE Product Profile Capture Sheet**
- **GE Product Analysis**
- **Codon Chart**
- **Protein Slide Capture Sheet**
- **Protein Slide Rubric**
- **Alternative Proteins Exit Ticket**
- **Exploring Genetic Engineering Infographic**
- **Exploring Genetic Engineering Methods Capture Sheet**
- **GE Product Spotlight PSA Ad**
- **Advertising Development Tips 101**
- **Target Audience**
- **Spotlight PSA Ad Exit Ticket**
- **Alternative Protein Speed Dating Protocol Capture Sheet**
- **PSA Ad Grading Rubric**
- **Project Notebook**

Pedagogical Framing

Instructional materials are designed to meet national education and industry standards to focus on in-demand skills needed across the full product development life cycle—from molecule to medicine—which will also expose students and educators to the breadth of education and career pathways across biotechnology.

Through this collection, educators are equipped with strategies to engage students from diverse racial, ethnic, and cultural groups, providing them with quality, equitable, and liberating educational experiences that validate and affirm student identity.

Units are designed to be problem-based and focus on workforce skill development to empower students with the knowledge and tools to be the change in reducing health disparities in communities.

SOCIAL-EMOTIONAL LEARNING

Students engage in responsible decision-making as they build their ad around a stakeholder client. Students will be taking on other perspectives as they market their final ad about a genetic modification product.

CULTURALLY AND LINGUISTICALLY RESPONSIVE INSTRUCTION

Students will communicate in linguistically and culturally responsive ways as they will be presenting an ad to various community members, including those within the native community. Additionally, students will recognize and redress bias in the system in an optional activity to explore bias in marketing and development.

ADVANCING INCLUSIVE RESEARCH

Students will take into account diverse populations and cultural perspectives in their local community when developing advertisements. These ads will communicate the biotech process, as well as the gene and protein of students' products.

COMPUTATIONAL THINKING PRACTICES

Students will communicate complex ideas clearly and effectively by creating an advertisement for a specific stakeholder. They will also plan and employ effective research strategies to locate information and other resources for their intellectual or creative pursuits as they research a current GE product.

CONNECTION TO THE PRODUCT LIFE CYCLE

In this lesson, students research existing technologies used in gene editing, deep dive into a particular GE product, and create a public service announcement (PSA) campaign around the science and problem solving involved with the product. This fits into both the **discover** portion of the product life cycle as students research existing technology, and the **commercialize** stage as they develop targeted ads for a specified consumer.

Have you ever wondered…

How does GE technology result in alternative proteins?

GE technology has evolved immensely throughout the 21st century. Recognizing the advantages and disadvantages of specific gene editing methods, as well as the history of each technique, is important for understanding the bigger picture of genetic modification. Through teacher-directed instruction, students will acquire content knowledge about specific methods and then apply this knowledge to commercialized GE products.

What is the role of alternative proteins in producing GE products?

Students will participate in a lab activity during this lesson that will assess GE product efficacy through protein identification. Genes are expressed through protein products that interact with the environment in some way. Alternative proteins drive GE products and need to be identified before the products can be commercialized.

How can current GE technology methods be communicated to the public?

Students will acquire content knowledge about specific genetic engineering methods and then apply this knowledge to commercialized GE products. They will then create an ad geared to a specific target audience and determine if the role of the GE product is necessary to solve a community challenge.

MAKE CONNECTIONS!

How does this connect to the larger unit storyline?

This unit digs deeper into the biotechnology methods used in the production of GE products.

In the final project, students will be asked to identify the preferred biotechnology method for producing their product.

Students will be practicing marketing and ad development in this lesson to prepare for their final learning artifact.

The skills students use in this lesson, including taking stakeholder opinions to develop an ad, will carry into the final project.

How does this connect to careers?

Research scientists design and carry out experiments to test new ideas, and report their findings in written journals and presentations. To focus their research, they review existing journal articles to generate new questions that have not been addressed before. In this lesson, students research existing gene editing technologies.

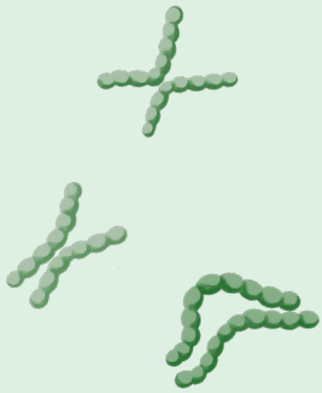
Marketing and public relations (PR) experts help companies to sell their product to a target consumer. They talk with consumers to learn about the customers' needs, and influence the direction and production of products accordingly.

Digital artists use multimedia to communicate creative and complex ideas. Varied physical and digital tools help these artists develop virtual reality and online art, communicate information to consumers, and create virtual ads.

How does this connect to our world?

Genetic engineering and the production of GE products is a global endeavor wherein products are designed to solve global problems.

Students will use the input of global stakeholders when developing their GE product ad.



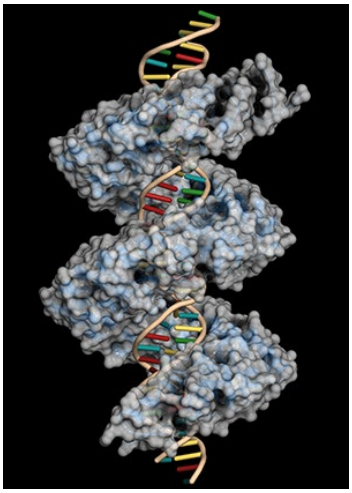
Day 1

Procedure

LEARNING OUTCOMES

Students will be able to:

Explain how the structure of DNA determines the structure of proteins.



Whole Group (10 minutes)

1. Assign students a partner to collaborate with throughout this lesson.

2. Re-introduce the driving question for the unit: *What novel GE product concept is worth creating to solve a local community challenge?* Also, remind students of the overall goal of the unit: to create a novel GE product that will solve a local community challenge.

3. Refer students to the Project Phase Chart Capture Sheet from their **Project Notebook** and share with students that they will be filling out the GE Technology and Protein Product section of the chart this week.

4. Set students up for their learning sequence this week by reviewing the *Essential Questions* and *Overview* of this lesson. Discuss the following with students after showing them a review video of transcription and translation, such as videos from Cold Spring Harbor Laboratory's *Biology Animations*.

   a. Q: What is a protein and what role does it play in the cell?

   A: Proteins are required for the structure, function and regulation of cells. Each protein has a specific function, which is determined by shape. The building blocks of proteins are amino acids.

   b. Q: What molecule in the body has instructions for how to build a protein?

   A: DNA

   c. Q: If new DNA or genes are introduced into an organism, what impact would this make?

   A: This would introduce alternative proteins that would carry out a new, novel function in the cells. This alternative protein would result in new structures or functions.

Continues next page >

Day 1

Continued

Procedure

5	Share with students that the focus of this week is to explore proteins within genetically modified products. In order to do so, they must learn the definition of *alternative protein* and *alternative protein markets*. Display the definitions for students.
	a. *Alternative Protein*: An introduced protein product (or absent protein) within an organism that provides an alternative function that was not originally present; derived from the introduction of an altered gene
	b. *Alternative Protein Market*: Market for alternative proteins to eggs, meat, seafood, and dairy; explored through genetic modification and testing alternative proteins
6	Pass out or assign one *GE Product Profile Capture Sheet* to each group. Share with students that these profiles are highlighting a snapshot of the genetic make-up and protein product of one real GE product. Students will be investigating these GE products this week and filling in the missing information from the cards.

INDUSTRY AND CAREER CONNECTION

This is a good point to mention to students the role of Research Scientists. They are playing this role by researching existing gene editing technologies, and will report their findings by presenting these to their classmates.

Teacher Note > *Other suggestions of GE products include: GE zucchini, GE alfalfa, GE squash, GE soybeans, GE microorganisms for renin product used in cheese, or GE sugar beet. A blank product profile is provided for creation of more profiles. Answers to this assignment can be found in the GE Product Spotlight PSA Ad Answer Key.*

7	Ask students to complete the *GE Product Analysis* with their partners. They will need to use the *Codon Chart* to complete this assignment.
8	Ask students to complete the *Protein Slide Capture Sheet* with their partners.
9	Teams will be using information from these two assignments to share to a small group afterwards.

Teacher Note > *When students are searching for their protein product, some protein names and functions are easier to find in the provided resource than others. This could be used as an opportunity for differentiation. For struggling students, encourage the use of the ctrl+f feature on their keyboard—accessible in all major Internet browsers—to research the word "protein" or the provided target gene name. This will help them orient a good reference point for locating the information. Open-ended Google research may be more difficult than using the provided resource. The teacher key will also be useful when helping students locate the information. As an extension topic, Genetically Modified Foods from* Time *provides some great context into the vast amount of seed varieties that are available by farmers for purchase.*

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Day 1

Continued

Procedure

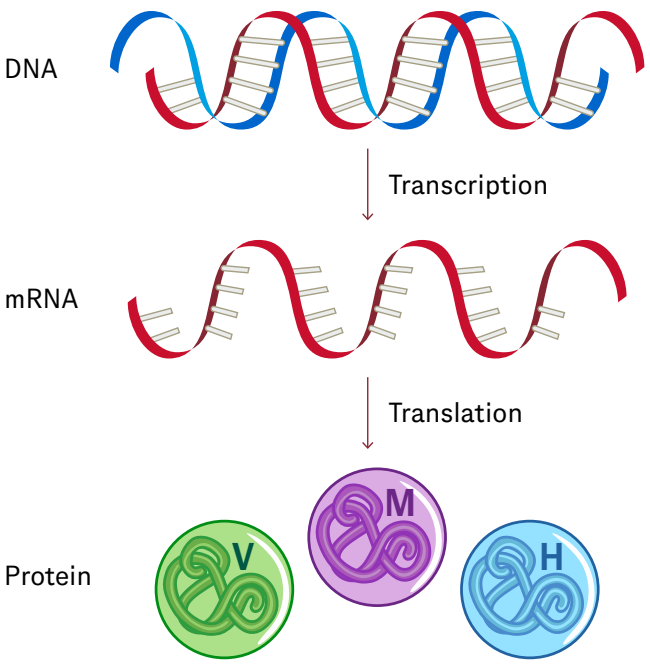
Small Group (30 minutes)

Allow students time to work in their groups to conduct research for their *GE Product Analysis* and *Protein Slide Capture Sheet*.

Teacher Note > *The beginning of the GE Product Analysis is a very brief review of the central dogma of biology (DNA to mRNA to Protein) and the role of proteins in the cell. More time can be spent on this review to emphasize NGSS standards more thoroughly. To build their Protein Slide Capture Sheet, students can use Google Slides or another online platform. Use the Protein Slide Rubric to assess student mastery of today's lesson. Reminder: students are not researching how the protein is necessarily made at this stage. Instead, they are identifying the protein and its function.*

Whole Group (5 minutes)

Assess students with the *Alternative Proteins Exit Ticket*. Students will need to use the *Codon Chart* to complete this assignment. Students may need to speak with another group member to complete this.



Day 2

Procedure

LEARNING OUTCOMES

Students will be able to:

Describe the various genetic engineering techniques currently available for modification.

Whole Group (5 minutes)

1 Discuss with the class the following:

a. Q: What methods have you heard of that are used to create or domesticate genetically modified crops?

A: Possible student answers could include mutating the DNA, cross breeding the desired traits, etc.

b. Q: What are some possible advantages and disadvantages of genetic modification?

A: Possible advantages could include having better food products that last longer and more sustainable farming. Disadvantages might include big corporations taking over crops and concerns about health.

c. Q: Are all methods of achieving desired traits in crops considered genetic modification?

A: Genetic modification is defined as any modification to genes using biotechnology.

Teacher Note > *Use What Is the Difference Between Genetically Modified Organisms and Genetically Engineered Organisms? as a tool when discussing student answers to methods of achieving desired traits in crops considered for genetic modification.*

2 Pass out the *Exploring Genetic Engineering Infographic*.

3 Share with the class that today they will be exploring all of the methods used by scientists to modify plants.

Small Group (35 minutes)

Allow partners time to explore each type of genetic modification using the infographic provided and their own research. Point to the *Exploring Genetic Engineering Methods Capture Sheet* worksheet for students to record a summary of each method. Resources are provided in the links.

Teacher Note > *To speed up the lesson, each student pair could be assigned one box to explore and then information can be presented to the rest of the class. Another extension opportunity is to put the information on a large poster board for one method and complete a Gallery Walk. Another suggestion is to do the Traditional Breeding box as a model for students.*

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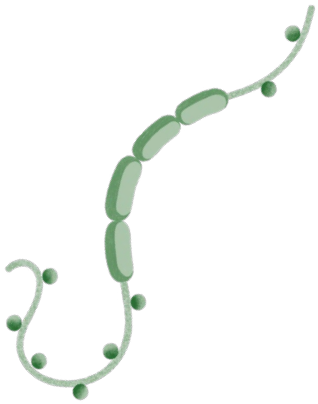
Day 2

Continued

Procedure

Whole Group (5 minutes)	
1	Ask students to get out the *GE Product Profile Capture Sheet* and remind them of the product they were assigned to on Day 1.
2	Share with students that they will eventually be completing a *GE Product Spotlight PSA Ad* for a GE product of interest using the *Advertising Development Tips 101* as a guide.
3	Tell students that their homework assignment is an overview of the genetic engineering technology used to make the GE product they were assigned in their *GE Product Profile Capture Sheet*.

Homework	
1	Allow students time to research the biotechnology method that was used for the production of the GE product they selected Day 1.
2	By Day 3 of Lesson 3, students should be able to identify the details of the genetic engineering technique used to produce their assigned GE product. Have students add these details to their *GE Product Profile Capture Sheet*.



Teacher Note > *The Lab Break is suggested to be placed between Days 2 and 3 of Lesson 3. This homework will not be needed until Day 3 of Lesson 3.*

Lab Break

Procedure

Teacher Note > *Before students proceed onto Day 3 of Lesson 3, they should do Days 4–5 of the Lab. In this lab, students will complete a lateral protein test (Lab Day 4) and a data analysis (Lab Day 5). This lab will be essential for students' understanding of the Lesson 3 activities on Days 3 and 4, during which they will create their PSA highlighting the alternative protein.*

Day 3

LEARNING OUTCOMES

Students will be able to:

Identify the genetic engineering technique used to produce a GE product of interest.

Market a GE product of interest for a specific stakeholder.

Communicate scientific information about gene editing techniques.

Procedure

Whole Group (15–20 minutes)

1. Recap the previous day's lab activity by emphasizing the importance of alternative protein assessment in GE product production.

2. Quickly assess students on what they learned on Day 2 of Lesson 3 by asking the following:

   a. Q: What type of genetic modification technique is used to modify genes without directly influencing the DNA?

   A: traditional breeding

   b. Q: What type of genetic modification technique(s) involve enzymes that cut DNA like scissors?

   A: TALNs, ZFNs, and CRISPR

   c. Q: What types of considerations are assessed when determining how effective a genetic engineering technique is?

   A: Possible answers: accuracy, impact on other genes, amount of base pairs it can edit, cost, how "natural" it is

3. Share with students the following:

   a. Most of breeding is the selection of favorable traits and phenotypes. Those phenotypes come from genotypic diversity. That diversity can exist naturally and be selected through classical breeding, or be created using tools like mutagenesis.

4. Remind students that GMO is the recognized term for genetically engineered crops and products, and GE is the scientifically accurate and industry accepted terminology.

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Day 3

Continued

Procedure

INDUSTRY AND CAREER CONNECTION

This is a good time to share with students that they are playing the role of a Marketing Expert by learning about customers' needs and working with companies to influence the direction and production of products accordingly.

5 Review the *Advertising Development Tips 101* and discuss the importance of keeping your target audience in mind when it comes to advertising. Possible discussion questions:

a. Q: Have you seen GMOs being advertised in the store?

A: The answer is most likely no. GMOs are not required to be labeled.

b. Q: Have you seen non-GMO products labeled in stores?

A: There is an official non-GMO verified label for products in stores.

c. Q: Could ads or infographics about GE foods help our community? Why or why not?

A: Answers will vary.

Teacher Note > *Support discussion with relevant photos, such as a photo of the official non-GMO verified label.*

5 Display the *GE Product Spotlight PSA Ad* and review assignment requirements. Give students time to look over the example product.

Teacher Note > *If time allows, take the opportunity to discuss bias in marketing. Many resources can be found online that discuss behavioral, gender, and racial bias in advertising.*

INDUSTRY AND CAREER CONNECTION

This is a good time to note the role of a Digital artist, who uses multimedia to communicate creative and complex ideas through visuals formats such as advertisements.

Small Group (30 minutes)

1 Assign one *Target Audience* to each pair of students. Share with students that this is the audience for their PSA. They must communicate information in a way to reach this audience.

2 Allow students time to create their *GE Product Spotlight PSA Ad* using their assigned *Target Audience* to guide their work. They should do some background research on their target audience as part of this process.

3 Give students the *Spotlight PSA Ad Exit Ticket* to help guide the next day's instruction.

Homework

Finish *GE Product Spotlight PSA Ad*.

Day 4

LEARNING OUTCOMES

Students will be able to:

Market a GE product of interest for a specific stakeholder.

Communicate scientific information about gene editing techniques.

Procedure

Small Group (10 minutes)

1 Structure the seats in the room so that student pairs can sit across from one another in the continuous row. One row will shift to the right or left for four rounds of discussion.

2 Start class by allowing students more time to complete their *GE Product Spotlight PSA Ad*.

Whole Group (10 minutes)

1 Have each student display his or her ad in an area of the room for others to see.

2 Assign each student a *different Target Audience* from the one used to develop the ad (Day 3). This is the role students will be taking on as prospective buyers.

Teacher Note > *Students may need some time to research their new stakeholder role. Provide some time for students to gain some perspective into this new role prior to proceeding.*

3 Share with students that there will be two speed dating rounds: one where they are the salesperson for their GE Product and one where they will be a potential buyer from the perspective of their new stakeholder role.

4 Students will use the *Alternative Protein Speed Dating Protocol Capture Sheet* to guide them through this activity.

Teacher Note > *Speed dating activities can be as quick or long as you feel necessary. The protocol recommends at least five minutes per round.*

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Day 4

Continued

Procedure

Small Group (20 minutes)

1 Facilitate two rounds of speed dating and help arrange students according to the provided scenarios.

Teacher Note > *Students will be completing two rounds in this activity and should manage their own conversations using the protocol provided (times are listed). Student pairs will be the same in round one and round two. It may be helpful to model a round for students prior to beginning.*

2 Ensure that students are completing their *Alternative Protein Speed Dating Protocol Capture Sheet* as they rotate.

3 Collect all learning artifacts at the end of the class period and use the *PSA Ad Grading Rubric* to assess students.

Whole Group (5 minutes)

1 Have students turn in their final *GE Product Spotlight PSA Ad*.

2 Refer students to the Project Phase Chart Capture Sheet from the **Project Notebook** and ask them to fill out the Discover sections titled GE Technology and Protein Product to conclude the lesson this week.

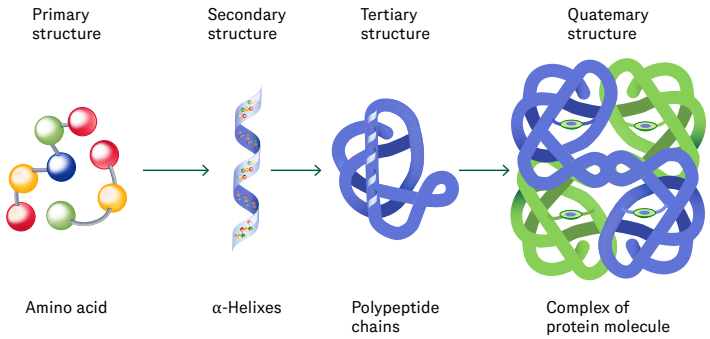
3 Discuss the following with the class (or use as an Exit Ticket to save time):

a. How did you feel about communicating information about GE products?

b. What were some successes and challenges?

c. Would you have created your ad differently after talking to your target audience? Why or why not?

Protein structure



National Standards

Next Generation Science Standards

LS1-1 From Molecules to Organisms: Structures and Processes
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.

Science and Engineering Practices
Constructing Explanations and Designing Solutions
Construct and revise 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.

Career and Technical Education (CTE)

A3.1
Define and describe the structure and function of DNA ribonucleic acid (RNA) and proteins, explain the consequences of DNA mutations on proteins.

A5.1
Use the Internet and World Wide Web to collect and share scientific information.

A8.1
Follow written protocols and oral directions to perform a variety of laboratory and technical tasks.

A9.2
Identify several products obtained through recombinant DNA technology.

A9.3
Outline the steps in production and delivery of a product made through recombinant DNA technology.

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National Standards

CTE *Continued*	**2.5** Communicate information and ideas effectively to multiple audiences using a variety of media and formats.
	5.6 Read, interpret, and extract information from documents.
	10.1 Interpret and explain terminology and practices specific to the Health Science and Medical Technology sector.

GE Product Analysis

ANSWER KEY **Do not share with students**

Directions
With your partner, define the terms and answer the questions. You will be using this information to communicate information to a small group later.

1. Define the following terms:

   a. Genetic engineering:

   A type of genetic modification; the process of using recombinant DNA (rDNA) technology to alter the genetic makeup of an organism.

   b. Genetic modification:

   Involves a range of methods, such as selective breeding; used to alter the genetic composition of plants and animals to achieve a desired result.

   c. Genetically modified organism (GMO):

   This is not a scientific term, but was created by the public; refers to any organism whose genome was changed by genetic engineering.

2. What is the connection among DNA, chromosomes, genes, and protein?

   Use these terms in your description below.

Answers will vary. Possible answer: A gene is a section of DNA on a chromosome that codes for a specific protein. This protein carries out a specific function in organisms, such as building structures or making enzymes.

3. Go from DNA to mRNA to Protein, starting with the DNA sequence below:

DNA	A T A C G G A A T T A A G G T A T G
mRNA	U A U G C C U U A A U U C C A U A C
Protein Product	CYS–ALA–LEU–ISO–PRO–TYR

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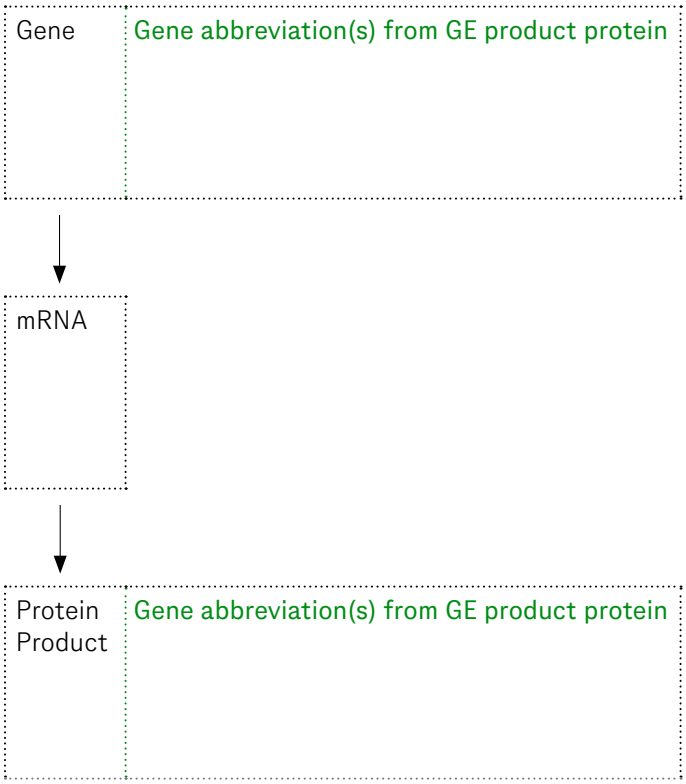
GE Product Analysis

ANSWER KEY **Do not share with students**

Continued

4. Describe the gene-to-protein connection for the GE Product Profile assigned to you.



5. Proteins are produced in cells and are used by the body to make enzymes and to build structures.

   a. What are the building blocks of proteins?

   Amino acids

   b. All of your cells contain the same exact DNA, but are all genes expressed in every cell? That is, do bone cells express the same genes into protein as skin cells? Why or why not?

   No, because these cells carry out different functions and express specific genes into proteins that help these functions.

Protein Slide Capture Sheet

ANSWER KEY **Do not share with students**

Directions

Create a slide about the GE Product Profile assigned to you, using the template, Google Slides, or another program.

Be sure to include the following:

a. *Name of GE product at top*

b. *Altered gene and protein details*

c. *Protein function (or protein function that is silenced)*

d. *Picture of protein*
Remember: Shape determines protein function. The picture you identify is important because it shows the shape that will carry out an alternative function in the organism.

e. *Statement of safety (for humans or the environment)*

Product name
Bt Corn

Protein picture of Bt delta endotoxin (Bt Protein); specifically *Cry1Ac* delta endotoxin

1 Gene name
Bt gene, specifically *Cry1Ac*

2 Alternative protein product name
Bt delta endotoxin (Bt Protein); specifically *Cry1Ac* delta endotoxin

3 Protein Function
Paralyzes the larvae of some harmful insects, including the corn borers (moth family).

4 Statement of Safety
Excellent safety record because they are only selective toxins with insects and a specific gut receptor; humans do not have the receptor.

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Protein Slide Capture Sheet

ANSWER KEY **Do not share with students**

Continued

Product name
Biosteel (Spider Silk)

1 ↓	Gene name *MaSp1* and *MaSp2* synthetic genes
2	Alternative protein product name Major ampullate dragline silk protein 1 (MaSp1) and major ampullate dragline silk protein 2 (MaSp2)
3	Protein Function Protein makes up the toughest biopolymer on Earth; can be produced in high quantities through transgenics.

Protein picture of major ampullate dragline silk protein 1 (MaSp1) and major ampullate dragline silk protein 2 (MaSp2)

MaSp2 can be found more easily than *MaSp1*.

4	Statement of Safety The product is biodegradable and has been tested to be environmentally safe.

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Protein Slide Capture Sheet

ANSWER KEY **Do not share with students**

Continued

Product name
Bt Cotton

Protein picture of Bt delta endotoxin (Bt Protein); specifically *Cry1Ac* delta endotoxin

1 Gene name
Bt gene (from bacteria), specifically *Cry1Ab*

2 Alternative protein product name
Bt delta endotoxin (Bt Protein), specifically *Cry1Ab* delta endotoxin

3 Protein Function
Paralyzes the larvae of some harmful insects, including the cotton bollworm.

4 Statement of Safety

Excellent safety record because they are only selective toxins with insects and a specific gut receptor; humans do not have the receptor.

Continues next page >

Protein Slide Capture Sheet

ANSWER KEY **Do not share with students**

Continued

Product name
Golden Rice

1 Gene name
psy gene, *crtI* gene, and *lcy* gene

2 Alternative protein product name
Beta carotene is the end metabolized product, but three enzymes are the protein products through genetic modification:

— Phytoene synthase (from *psy*)
— Phytoene desaturase (from *crtI*)
— Lycopene beta-cyclase (from *lcy*)

3 Protein Function
These enzymes allow rice to synthesize the beta carotene that will be metabolized into Vitamin A in humans.

Protein picture of one of these Beta carotene enzymes:

— Phytoene synthase (from *psy*)
— Phytoene desaturase (from *crtI*)
— Lycopene beta-cyclase (from *lcy*)

4 Statement of Safety

Beta carotene is considered a safe source for obtaining Vitamin A.

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Protein Slide Capture Sheet

ANSWER KEY **Do not share with students**

Continued

Product name
AquaAdvantage Salmon

Protein picture of OP5a antifreeze protein and Growth Hormone (GH) protein

1 ↓ Gene name
opAFP-GHc2 (antifreeze promoto sequence from ocean pout) and growth hormone (GH) gene from Chinook salmon

2 Alternative protein product name
OP5a antifreeze protein and Growth Hormone (GH) protein

3 Protein Function
Allows salmon to grow year round; the fish grow quicker and larger, and so are much more cost effective to farm.

4 Statement of Safety

An allergy database and the Structural Database of Allergenic Proteins were reviewed and less than 35 percent of the amino acid sequence matched; no direct hazards identified; no unintended genetic mutations.

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Protein Slide Capture Sheet

ANSWER KEY **Do not share with students**

Continued

Product name
Biofortified Cassava

Protein picture of Iron transporter and ferritin

1 Gene name
IRT1 and *FER1*

2 Alternative protein product name
Iron transporter and ferritin

3 Protein Function
Found in cassava storage roots and with elevated iron and zinc levels that may provide additional nutrients to consumers.

4 Statement of Safety

Toxic metals are a concern in fortified food. Field safety tests showed higher magnesium and copper levels, but no toxic metals were taken up by the plant.

Continues next page >

Protein Slide Capture Sheet

ANSWER KEY **Do not share with students**

Continued

Product name
Iron-Fortified Beans

Protein picture of Ferritin

1 Gene name
FER1 gene

2 Alternative protein product name
Ferritin

3 Protein Function
Iron storage protein; offers a higher level of iron

4 Statement of Safety

Created to help communities in Rwanda with anemia and cognitive disabilities from malnutrition; iron is imperative for good health.

Continues next page >

Protein Slide Capture Sheet

ANSWER KEY **Do not share with students**

Continued

Product name
Impossible Burger

Protein picture of Leghemoglobin

1 Gene name
legHB gene from soy

2 Alternative protein product name
Leghemoglobin

3 Protein Function
Reddens root nodules of soybean plants; it provides oxygen to its symbiotic bacteria and gives a meatless burger the taste, look, and smell of a real burger.
Source: *Anatomy of an Impossible Burger*

4 Statement of Safety

To reduce the environmental impacts of beef in the United States diet, novel protein sources that mimic meat have been introduced. These beef substitutes can be produced at a fraction of the environmental and resource costs of traditional beef.

Continues next page >

Protein Slide Capture Sheet

ANSWER KEY **Do not share with students**

Continued

Product name
Virus Resistant Papaya

Protein picture of Papaya ringspot virus (PRV) coat protein

1 Gene name
Coat protein gene

2 Alternative protein product name
Papaya ringspot virus (PRV) coat protein

3 Protein Function
This protein provides immune protection against the ringspot virus, similar to a vaccine.

4 Statement of Safety

Data from safety tests have made this one of the most well characterized GE plants available on the market. It has passed the FDA's safety, nutritional, and regulatory reviews.

Source: *Papaya Ringspot Virus*

Continues next page >

Protein Slide Capture Sheet

ANSWER KEY **Do not share with students**

Continued

Product name
Late Blight Resistant Potatoes

Protein picture of Ribose-5-phosphate isomerase 2 (enzyme) or R Proteins

1 Gene name
Rpi2 gene from a Mexican potato variety or R genes

2 Alternative protein product name
Ribose-5-phosphate isomerase 2 (enzyme) or R Proteins

3 Protein Function
Responsible for the recognition of pathogens proteins, which lead to the hypersensitive reaction and prevention of the infection.
Source: *Expression of the Potato Late Blight Resistance Gene*

4 Statement of Safety
Protein does not share sequence identity with known allergens. Expression levels of R-proteins are generally low, and VNT1 was not detected in potato varieties expressing the Rpi-vnt1 gene. With minimal hazard and negligible exposure, the risks associated with consumption of R-proteins in late blight protected potatoes are exceedingly low.
Source: *Food safety evaluation for R-proteins introduced by biotechnology*

Continues next page >

Protein Slide Capture Sheet

ANSWER KEY **Do not share with students**

Continued

Product name
Arctic Apple

1 Gene name
Anti-PPO gene

2 Alternative protein product name
Inhibits the production of polyphenol oxidase enzymes (PPO enzymes)

3 Protein Function
The anti-PPO gene creates anti-PPO RNA. This RNA destroys the PPO RNA before it can be used to make PPO enzymes. The function of the PPO enzyme is to create with polyphenols, which, when the apple is cut, interacts with oxygen to create the browning reaction.

Protein picture of PPO enzyme

Student responses may vary. This gene prevents the production of a protein. This gene is not formed into a protein itself, but remains in the RNA form to preform its function.

4 Statement of Safety

There is no evidence that this process is unsafe for humans or the environment.

Continues next page >

Alternative Proteins Exit Ticket

ANSWER KEY **Do not share with students**

Directions
Reflect on today's learning by answering the questions about alternative proteins.

1. Describe a protein product discussed other than your own. You may need to ask someone from another group to complete this. Why was this alternative protein created?

Answers will vary. Use the answers from the Protein Slide and PSA Ad key for possible answers to this question.

2. What role do alternative proteins play in GE product production? Would GE products be able to solve the same problem without altering genes, and thus, protein products in plants?

The alternative protein allows the organism to carry out a different function, such as grow larger or have more nutrients. Without genetically modified (GE) products, there would be fewer solutions to malnutrition, affordable food, sustainable food choices to combat climate change, or high crop yields.

3. Go from DNA to mRNA to Protein, starting with the DNA sequence below. Use the Codon Chart to complete the protein product.

DNA	T T A C G G T A T C G C T A T
mRNA	A A U G C C A U A G C G A U A
Protein Product	A S P – A L A – I S O – A L A – I S O

Exploring Genetic Engineering Methods Capture Sheet

ANSWER KEY **Do not share with students**

Directions
Use the Exploring Genetic Engineering Infographic and resource links provided to research and record a summary of each GE method.

Traditional Plant Breeding (Non-GMO)

1	Resource *Conventional Plant Breeding Principles and Techniques*
2	Brief summary or illustration of this method This method involves manipulating plant genomes within the natural genetic boundaries of the species.

3	How does this compare to genetic modification using biotechnology? This is a more traditional process that has been used for centuries. Scientists cross-pollinate and select specific parents and progeny to achieve the desired trait. There is no introduction or editing of DNA using biotechnology.

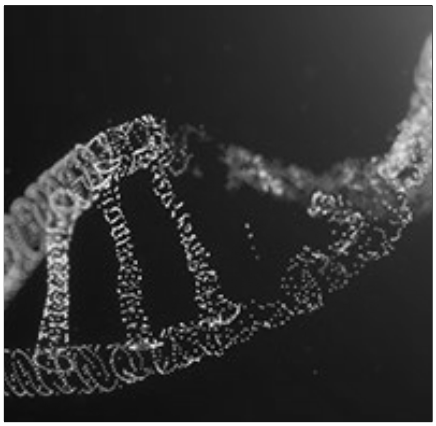
Continues next page >

GE Product Analysis and Protein Slide Capture Sheet

ANSWER KEY **Do not share with students**

Continued

Mutagenesis (Non-GMO; introduced in 1920s)



1	Resource *What are mutagenized crops and why they are not labeled and regulated?*
2	Brief summary or illustration of this method Mutagenesis involves exposing plants to ionizing radiation or chemicals to mutate their genes, then growing them for multiple generations to isolate desirable traits.
3	What are some disadvantages of this method? — Activists are concerned about unintended mutations that could result. — Mutations are random and unpredictable. — Studies must be completed to determine what changes were made. — This method rarely affects one trait or region.
4	What are some advantages of this method? Include examples of improved crops. Advantages include improved nutritional profile of important food crops and increased protein content of nuts, corn, and soybeans. In addition, this method has been used to develop diabetic-friendly rice that does not dramatically spike blood sugar. According to a 2016 study, dozens of staple crops have been nutritionally enhanced by mutation breeding.
5	Overall, is this method recognized as safe? Explain. Overwhelming evidence suggests this method is safe.

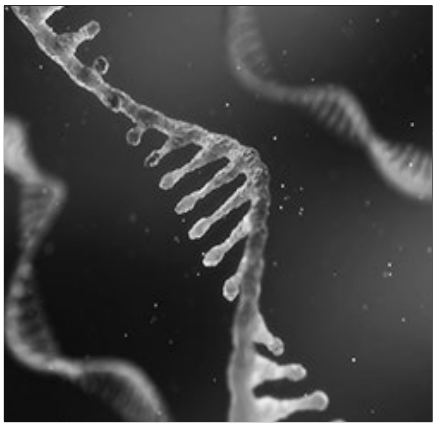
Continues next page >

GE Product Analysis and Protein Slide Capture Sheet

ANSWER KEY **Do not share with students**

Continued

RNA Interference (RNAi) using double-stranded RNA (dsRNA) and small interfering RNA (siRNA)



1	Resource *Genetically Modified Organism-Free RNA Interference; How RNAi Works; RNAi for Crop Improvement*
2	Brief summary or illustration of this method and how it is used to control gene expression The term RNA interference (RNAi) was coined to describe a cellular mechanism that uses the gene's own DNA sequence to turn off the mRNA prior to protein production, a process that researchers call silencing. In other words, this is post transcriptional gene silencing. In a wide variety of organisms, including animals, plants, and fungi, RNAi is triggered by double-stranded RNA (dsRNA).
3	What is the main benefit of using RNAi technology in plants? RNAi has great potential against invading pests and pathogens.
4	Identify potential downfalls of using RNAi technology in plants. Epigenetics still exist for dsRNA-treated plants that are considered GMO-free. These newly silenced genes could turn on at some point.

Continues next page >

GE Product Analysis and Protein Slide Capture Sheet

ANSWER KEY **Do not share with students**

Continued

Transgenics (most used method for GMOs)

1	Resource *Recombinant DNA Technology and Transgenic Animals*
2	Brief summary or illustration of this method and how it is used to control gene expression Transgenics is the alteration of an organism's genome through recombinant DNA technology, which involves either the combining of DNA from different genomes or the insertion of foreign DNA into a genome.

3	What is recombinant DNA? DNA that has been formed artificially by combining genes from different organisms
4	Describe how each of these two transgenic methods work.
a	Gene Gun (particle bombardment; low success): *Gene gun explainer from UW Medicine scientist* A device used to deliver exogenous DNA (transgenes), RNA, or protein to cells; a heavy metal particle, such as gold, is coated with a gene and blasted at high pressure into a plant tissue.
b	*Agrobacterium mediated transformation technique; Making a transgenic plant* In nature, agrobacterium is able to integrate its own DNA into plants. A cultured strain of agrobacterium is modified to insert the desired DNA sequence into the plant genome. Plant tissues are infected with the agrobacterium. The bacteria randomly inserts the recombinant DNA into the plant genome. This recombinant DNA will enter the nucleus and begin producing alternative proteins.

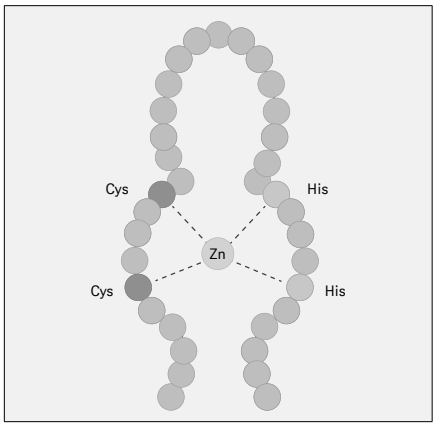
Continues next page >

GE Product Analysis and Protein Slide Capture Sheet

ANSWER KEY **Do not share with students**

Continued

Zinc Finger Proteins (ZFNs)

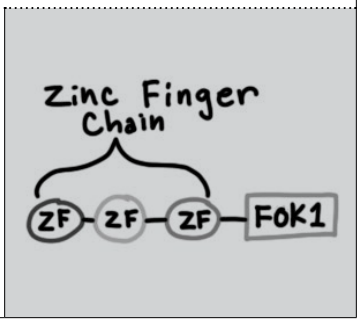


1 Resource
Gene Editing Techniques: ZFNs, TALENs or CRISPR?

2 Brief summary or illustration of this method and how it is used to control gene expression

First genome editing nuclease (enzyme) able to cut DNA with precision at certain recognized areas

Made up of a protein (zinc finger chain) with an enzyme attached called FOK1;
this enzyme comes from bacteria.



3 What is a downfall of this method?

— It can only cut sequences at a certain length.

— It only recognizes triplet nucleotides.

— This significantly limits what sequences can be targeted. Efficiency is also fairly low.

4 What crops have been modified using this method?
Use the table from *Applications and potential of genome editing in crop improvement*.

Plants related to cabbage and mustard, tobacco, corn, petunia, soybean, rapeseed, rice, apple, and fig.

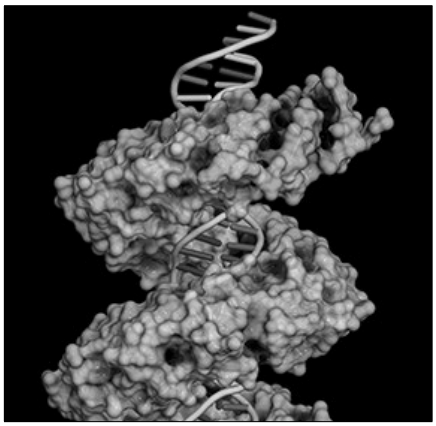
Continues next page >

GE Product Analysis and Protein Slide Capture Sheet

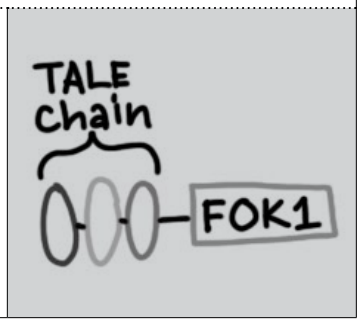
ANSWER KEY **Do not share with students**

Continued

Transcription activator-like effector nucleases (TALNs) Zinc Finger Proteins (ZFNs)



1	Resource *Gene Editing Techniques: ZFNs, TALENs or CRISPR?*
2	Brief summary or illustration of this method and how it is used to control gene expression Second genome editing nuclease (enzyme) able to cut DNA with precision at certain recognized areas Made up of TALE chain protein and FOK1 enzyme from bacteria



3	What is an advantage of this type of gene-editing technology compared to others? It is able to recognize single DNA nucleotides instead of groups of three; increased potential in target sites.
4	What crops have been modified using this method? Use the table from *Applications and potential of genome editing in crop improvement*. Barley, potato, tomato, sugarcane, flax, rapeseed, soybean, rice, maize, and wheat

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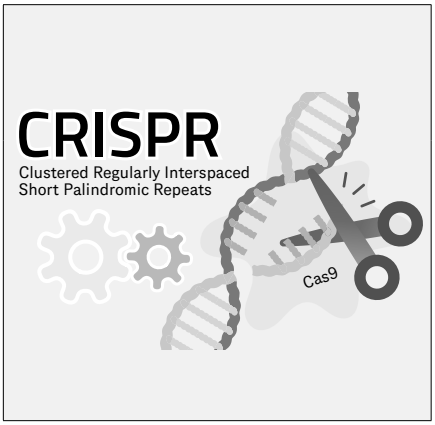
GE Product Analysis and Protein Slide Capture Sheet

ANSWER KEY **Do not share with students**

Continued

CRISPR-Cas9



1	Resource *CRISPR Explained; Gene Editing Techniques: ZFNs, TALENs or CRISPR?; CRISPR Plants)*
2	Brief summary or illustration of this method and how it is used to control gene expression Method involves Cas protein (enzyme) that can cut DNA and a guide RNA that can recognize the sequence of DNA to be edited. This involves identifying a desired gene, creating an RNA sequence that will locate that sequence, and then sending the CaS protein in to cut it. DNA can be deleted, edited, or added at the point that was cut.
3	What is an advantage of this type of gene-editing technology compared to others? CRISPR is revolutionary because of its simplicity, effectiveness, and low cost. It also has the ability to target multiple genes. This system has been an effective solution to challenges in plant breeding. Another advantage is the ability to target a mutation or insertion. If you know where the new DNA goes, you can minimize the impact of unintended effects.
4	What crops have been modified using this method? Use the table from *Applications and potential of genome editing in crop improvement*. Rice, maize, wheat, soybean, barley, potato, tomato, flax, rapeseed, cotton, cucumber, lettuce, grapes, grapefruit, apple, oranges, and watermelon

GE Product Spotlight PSA Ad

ANSWER KEY **Do not share with students**

Directions

Create a PSA Ad to share your GE product with the Target Audience your teacher assigned you in a way that is approachable and easy to understand.

Project Sections

1. Create an eye-catching title and state the product you are highlighting.
2. Provide some background on the product by stating one or two interesting facts about the crop or product production.
3. Summarize your statement of safety into one sentence that highlights safety or environmental testing.
4. Briefly describe the gene-to-alternative-protein relationship.
5. Briefly describe the biotechnology technique used for this GE product.
6. Include sources.

Please reference the Protein Slide Capture Sheet Answer Key for Project Section 3 (Statement of Safety) and information used for Project Section 4 (gene-to-alternative-protein relationship). In the table below, find the answers for Project Section 5 (technique used). This table can also be used to grade the GE Product Profile Capture Sheet.

Name	Genetic Engineering Technique
Bt Corn	This technique involves identifying a gene and understanding how it is regulated. Once the gene has been isolated, it is cloned into a bacterial vector. And finally, the new genetic material is transformed into the plant using the gene gun method (useful in rice and corn) or the Agrobacterium method.
BioSteel (Spider Silk)	This technique is a combination of host systems that have been used to produce recombinant silks, including *E. coli*, yeast, insects (silkworm larvae), plants (tobacco, soybean, potato, Arabidopsis), mammalian cell lines (BHT/hamster), and transgenic animals (mice, goats). The production of this method follows four main steps— design and assembly of synthetic silk-like genes, insertion of this segment into a DNA vector, transformation into a host cell, and expression and purification of selected clones.
Bt Cotton	Bt cotton was created by inserting DNA from Bt bacterium into the plant's genome. There are three primary components of the genetic package inserted in the cotton plant genome: the protein encoding the Bt gene, a promoter region to regulate the amount and location where Bt toxin is produced, and a genetic market to allow researchers to identify successful insertion of the gene into the plant's genome.

Continues next page >

GE Product Spotlight PSA Ad

ANSWER KEY **Do not share with students**

Continued

Name	Genetic Engineering Technique
Golden Rice	Golden Rice is engineered by introducing four plant enzymes in the beta carotene pathway. These genes are introduced using Agrobacterium-mediated transformation into rice endosperm.
AquaAdvantage Salmon	This technique involves microinjecting a growth hormone gene from Chinook salmon, coupled to a promoter sequence from an antifreeze protein gene from ocean pout, into fertilized Atlantic salmon eggs. Of the resulting fish, several grew much faster than their siblings. Testing confirmed that these fish had integrated the transgene into their genomes. Source: *AquaAdvantage Salmon*
Biofortified Cassava	This coexpression of mutant A. thaliana iron transporter (IRT1) and ferritin (FER1) generates cassava that accumulate iron and zinc in storage roots. The expression cassettes for these two genes were achieved by playing *AtIRT1* under control of the A14 promoter. The genetic construct was electroporated into *Agrobacterium* strain LBA4404 and transformed into the cassava cultivar.
Iron-Fortified Beans	HarvestPlus used selective breeding approaches to breed high-iron beans. They developed a high-iron bean line by an advanced breeding approach that includes backcrossing, recurrent selection, and various permutations of gamete and pedigree selection. Source: *The Potential of the Common Bean*

Name	Genetic Engineering Technique
Impossible Burger	The Impossible Burger is made by engineering the leghemoglobin (legHB) gene in yeast Picchia pastoris. This gene is naturally occurring in the root nodules of soybean plants and shares a similar role in transporting oxygen in our blood and myoglobin in our muscles. The legHB can be purified from yeast using polypeptide purification techniques and used to create an Impossible Burger.
Virus Resistant Papaya	The papaya ringspot virus (PRSV) gene is inserted into the papaya and acts as somewhat of a vaccine for the virus. Source: *Papaya Ringspot Virus*
Late Blight Resistant Potatoes	This technique involves taking recombinant DNA from one potato variety and integrating it into another.
Arctic Apple	RNAi technology lowers levels of PPO enzyme in the apple so the polyphenols are not produced in high quantities and thus, no browning. To do this, the anti-PPO gene produces anti-PPO RNA that blocks production.

Spotlight PSA Ad Exit Ticket

ANSWER KEY **Do not share with students**

Directions
Answer the following questions about progress on your GE Product Spotlight PSA Ad.

1. How is your ad development going? What are some successes and challenges?

Answers will vary.

2. How have you incorporated your target audience into your ad development?

Answers will vary. Possible answers include tone or phrasing of sentences, pictures that appeal more toward a type of community, title that is eye-catching to the target audience (i.e., a question that may make them stop and read).

3. List one method of genetic engineering you learned this week and describe how it works.

Answers will vary. See *Exploring Genetic Engineering Methods Capture Sheet*.

4. Describe your target audience.

Answers will vary, but make note of students who may be generalizing populations through bias.

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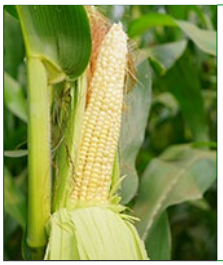
GE Product Profile Capture Sheet

Directions

These profiles indicate the genetic make-up and altered protein of real GE (genetically engineered) products. Use the link provided to fill in the missing information from one the products, as assigned by your teacher.

GE Product Information

Image	Name and Origin	Purpose	Target Gene and Source
	Bt Corn *United States*	Bt corn reduces the need for spraying insecticides while still preventing insect damage.	cry1Ab (Bt gene from bacteria) *Bt-Corn: What It Is and How It Works*
	BioSteel fiber (spider web silk) via Web Spinning Goats *Canada and United States*	Spider silk is five times stronger than regular steel and much more elastic than rubber. This product is used in material science, such as bulletproof vests in the military.	MaSp1 and MaSp2 from *Nephila clavipes* *Recombinant DNA production of spider silk*
	Bt Cotton *United States*	This cotton is resistant to bollworm pest in the southern United States.	Bt gene (from bacteria) *Bt Cotton*
	Golden Rice *Philippines*	This biofortified rice can provide beta carotene, and thus Vitamin A, to developing countries.	*psy gene, crtI gene, and lcy gene* *Golden Rice*

Questions

Protein Product	Genetic Engineering Technique

Continues next page >

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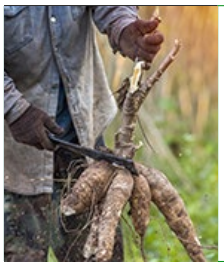
GE Product Profile Capture Sheet

Continued

GE Product Information

Image	Name and Origin	Purpose	Target Gene and Source
	AquAdvantage Salmon *Canada and United States*	This is a fast-growing salmon that reaches a growth marker more quickly than regular salmon; important to the aquaculture industry.	*opAFP-GHc2* (GH Gene) *AquAdvantage Salmon Summary*
	Biofortified Cassava *Nigeria*	This cassava plant has been biofortified to increase iron and zinc for consumers; has potential to prevent nutrient-deficient illnesses.	*IRT1* and *FER1* *Biofortification of field-grown cassava by engineering expression of an iron transporter and ferritin*
	Iron-Fortified Beans *Colombia*	These iron-fortified beans provide more iron to consumers and prevent iron deficiency anemia (IDA).	*FER1* gene *Common Bean Fe Biofortification Using Model Species' Lessons*
	Impossible Burger *United States*	This meat-like burger that is 100% meat-free; great option for vegetarians or those who want to eat less meat.	*legHB* gene from soy *Anatomy of an Impossible Burger*

Questions

Protein Product	Genetic Engineering Technique

Continues next page >

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GE Product Profile Capture Sheet

Continued

GE Product Information

Image	Name and Origin	Purpose	Target Gene and Source
	Virus Resistant Papaya *Hawaii and parts of China*	Papaya that is resistant to the ringspot virus; helps ensure successful production of the fruit.	coat protein gene *Virus Resistant Papaya Plants Derived from Tissues Bombarded with the Coat Protein Gene of Papaya Ringspot Virus*
	Late Blight Resistant Potatoes *United States*	Potato genetically modified to prevent late blight fungal disease, which caused the Irish Potato famine in the 19th century; maintains high crop yield.	*Rpi2* gene from a Mexican potato variety *A New Resistance Gene against Potato Late Blight Originating from Solanum pinnatisectum Located on Potato Chromosome 7*
	Arctic Apple *United States*	This apple can help prevent food waste by not browning when exposed to air.	anti-PPO gene *Arctic Apples: A fresh new take on genetic engineering*

Questions

Protein Product	Genetic Engineering Technique

Additional Profile

GE Product Information

Image	Name and Origin	Purpose	Target Gene and Source

Questions

Protein Product	Genetic Engineering Technique

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GE Product Analysis

Directions
With your partner, define the terms and answer the questions. You will be using this information to communicate information to a small group later.

1. Define the following terms:

   a. Genetic engineering:

   b. Genetic modification:

   c. Genetically modified organism (GMO):

2. What is the connection among DNA, chromosomes, genes, and protein?

   Use these terms in your description below.

3. Go from DNA to mRNA to Protein, starting with the DNA sequence below. Use the *Codon Chart* to complete the protein product.

DNA	A T A C G G A A T T A A G G T A T G
mRNA	
Protein Product	

Continues next page >

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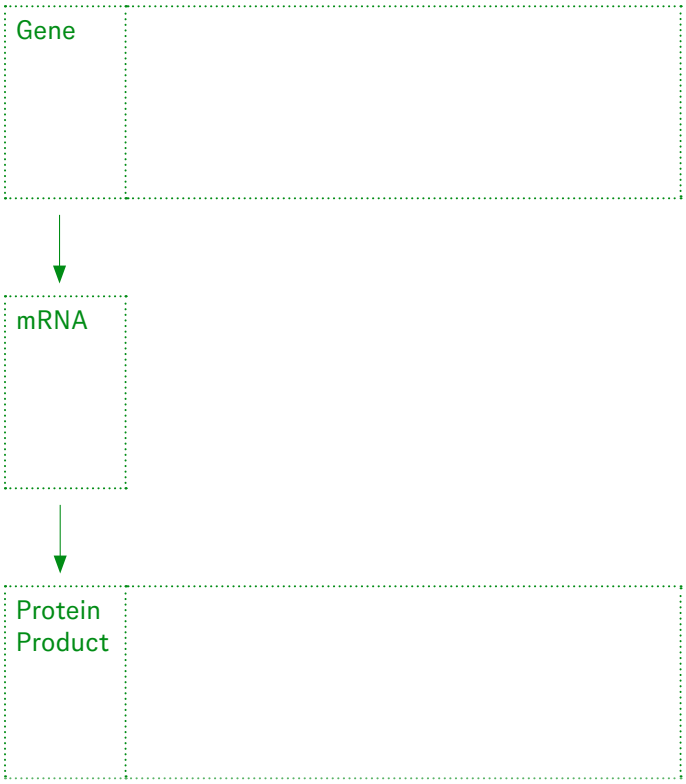
GE Product Analysis

Continued

4. Describe the gene-to-protein connection for the GE product assigned to you.



5. Proteins are produced in cells and are used by the body to make enzymes and to build structures.

   a. What are the building blocks of proteins?

   b. All of your cells contain the same exact DNA, but are all genes expressed in every cell? That is, do bone cells express the same genes into protein as skin cells? Why or why not?

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Protein Slide Capture Sheet

Directions

Create a slide about the GE product assigned to you, using the template, Google Slides, or another program.

Be sure to include the following:

a. *Name of GE product at top*
b. *Altered gene and protein details*
c. *Protein function (or protein function that is silenced)*
d. *Picture of protein*
   Remember: Shape determines protein function. The picture you identify is important because it shows the shape that will carry out an alternative function in the organism.
e. *Statement of safety (for humans or the environment)*

Protein Slide Template

Product name

Paste product picture here	1 Gene name *(from protein profile)*
	2 Alternative protein product name *(if you have more than one, choose one to highlight)*
	3 Protein Function
Paste protein picture here	4 Statement of Safety

Continues next page >

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Protein Slide Capture Sheet

Continued

Protein Slide Example

Product name

GM Alfalfa

1 ↓ Gene name

Soil bacterium gene

2 Alternative protein product name

Glyphosate tolerant form of EPSP synthase (enzyme)

3 Protein Function

Allows plant to be tolerant to herbicides; without alternative protein, the plant would die with herbicides.

4 Statement of Safety

Government regulatory agencies have ruled that crops with herbicide tolerant alternative proteins do not pose any additional environmental and health risks compared to non-GM crops.

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Codon Chart

This tool is called a codon chart. It is used to decipher DNA into the amino acids that will be produced. You will use this chart to answer questions in the *GE Product Analysis* and the *Alternative Proteins Exit Ticket*.

Locate the first letter of your mRNA codon in the vertical column 1, the second in the horizontal column 2, and the third in the vertical column 3. Use the abbreviations below to determine the amino acid for which your codon codes.

1	2				3
	U	**C**	**A**	**G**	
U	UUU, UUC: Phe UUA, UUG: Leu	UCU, UCC, UCA, UCG: Ser	UAU, UAC: Tyr UAA: stop UAG: stop	UGU, UGC: Cys UGA: stop UGG: Trp	**U C A G**
C	CUU, CUC, CUA, CUG: Leu	CCU, CCC, CCA, CCG: Pro	CAU, CAC: His CAA, CAG: Gln	CGU, CGC, CGA, CGG: Pro	**U C A G**
A	AUU, AUC, AUA: Ile AUG: Met	ACU, ACC, ACA, ACG: Thr	AAU, AAC: Asn AAA, AAG: Lys	AGU, AGC: Ser AGA, AGG: Arg	**U C A G**
G	GUU, GUC, GUA, GUG: Val	GCU, GCC, GCA, GCG: Ala	GAU, GAC: Asp GAA, GAG: Glu	GGU, GGC, GGA, GGG: Gly	**U C A G**

Key

Ala = Alanine (A)
Arg = Arginine (R)
Asn = Asparagine (N)
Asp = Aspartate (D)
Cys = Cysteine (C)
Gln = Glutamine (Q)
Glu = Glutamate (E)
Gly = Glycine (G)
His = Histidine (H)
Ile = Isoleucine (I)
Leu = Leucine (L)
Lys = Lysine (K)
Met = Methionine (M)
Phe = Phenylalanine (F)
Pro = Proline (P)
Ser = Serine (S)
Thr = Threonine (T)
Trp = Tryptophan (W)
Tyr = Tyrosine (Y)
Val = Valine (V)

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Protein Slide Rubric

	Score	3	2	1
	Name of GE Product	Name of GE product is listed on the protein slide.	Name of GE product is difficult to find or is shown incorrectly, such as with misspellings or typos.	Component is missing.
	Altered Gene and Proteins Details	Gene to protein—both are correctly identified.	Missing one component, or not entirely accurate.	Component is missing.
	Protein Function	Protein function is correctly identified.	Protein function is only partly identified or identified with errors.	Component is missing.
	Image of Protein Product	An effort was made to identify a picture of the final protein product.	A picture of the final protein product is presented, but the image is unclear or confusing.	Component is missing.
	Statement of Safety	A statement indicating safety, either in terms of humans or the environment, is included.	A partial statement about safety is included, but it is difficult to follow or contains errors.	Component is missing.
	Final Score			

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Alternative Proteins Exit Ticket

Directions
Reflect on today's learning by answering the questions about alternative proteins.

1. Describe a protein product discussed other than your own. You may need to ask someone from another group to complete this. Why was this alternative protein created?

2. What role do alternative proteins play in GE product production? Would GE products be able to solve the same problem without altering genes, and thus, protein products in plants?

3. Go from DNA to mRNA to Protein, starting with the DNA sequence below. Use the *Codon Chart* to complete the protein product.

DNA	T T A C G G T A T C G C T A T
mRNA	
Protein Product	

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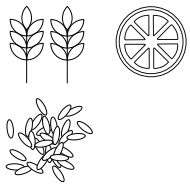
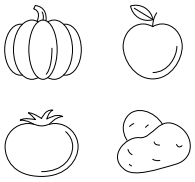
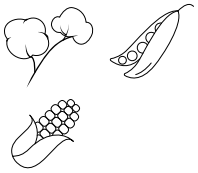
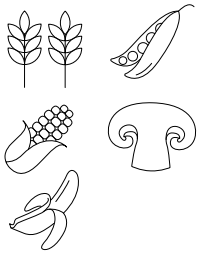
Exploring Genetic Engineering Infographic

Directions
Use this sheet and other Internet sources provided to complete the Exploring Genetic Engineering Methods Capture Sheet.

How Crops are Genetically Modified

Undesirable, unintended effects rarely occur in the final product of any crop, regardless of which process is used.

Name of Method	Traditional Breeding	Mutagenesis	RNA Interference	Transgenics	Gene Editing
Mechanism of genetic modification	Crossing plants and selecting offspring	Exposing seeds to chemicals or radiation	Switching off selected genes with RNA	Inserting selected genes using recombinant DNA methods	Using engineered nucleases (CRISPR, TALENs, SFNs, etc.) when used to delete genes
Outcome of genetic modification	Desired gene(s) inserted with other genetic material	Random changes in genome, usually unpredictable	Targeted gene(s) switched off or "silenced"	Only gene(s) inserted at desired locations selected	Desired gene(s) deleted only at known locations
Commonly used crops affected by this genetic modification	Almost all crops	wheat, grapefruit, rice 	squash, apple, tomato, potato 	cotton, peas, corn 	wheat, peas, corn mushroom, banana 
Number of genes affected	Few to whole genomes	100s–1,000s	1–dozens	1–8	1 or more
Safety regulations	No safety testing required; *Unregulated*	No safety testing required; *Unregulated*	Safety testing required; *Highly regulated*	Safety testing required; *Highly regulated*	Safety testing required depending on jurisdiction; *Mixed regulations*

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Exploring Genetic Engineering Methods Capture Sheet

Directions
Use the Exploring Genetic Engineering Infographic and resource links provided to research and record a summary of each GE method.

Traditional Plant Breeding (Non-GMO)

1	Resource *Conventional Plant Breeding Principles and Techniques*
2	Brief summary or illustration of this method

3	How does this compare to genetic modification using biotechnology?

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Exploring Genetic Engineering Methods Capture Sheet

Continued

Mutagenesis (Non-GMO; introduced in 1920s)

1	Resource *What are mutagenized crops and why they are not labeled and regulated?*
2	Brief summary or illustration of this method
3	What are some disadvantages of this method?
4	What are some advantages of this method? Include examples of improved crops.
5	Overall, is this method recognized as safe? Explain.

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Exploring Genetic Engineering Methods Capture Sheet

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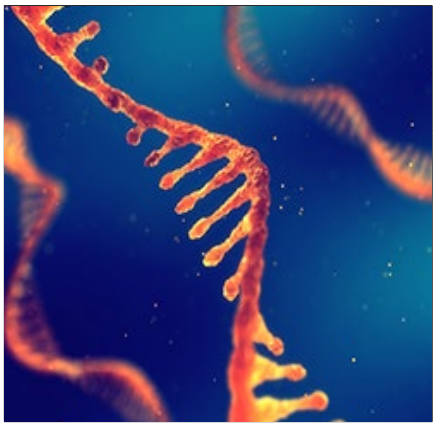
RNA Interference (RNAi) using double-stranded RNA (dsRNA) and small interfering RNA (siRNA)



1	Resource *Genetically Modified Organism-Free RNA Interference; How RNAi Works; RNAi for Crop Improvement*
2	Brief summary or illustration of this method and how it is used to control gene expression
3	What is the main benefit of using RNAi technology in plants?
4	Identify potential downfalls of using RNAi technology in plants.

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Exploring Genetic Engineering Methods Capture Sheet

Continued

Transgenics (most used method for GMOs)

1	Resource *Recombinant DNA Technology and Transgenic Animals*
2	Brief summary or illustration of this method and how it is used to control gene expression

3	What is recombinant DNA?
4	Describe how each of these two transgenic methods work.
a	Gene Gun *Gene gun explainer from UW Medicine scientist; Gene Gun from Plant and Soil Sciences eLibrary*
b	*Agrobacterium tumefaciens* from *Plant and Soil Sciences eLibrary* *Making a transgenic plant from Science Learning Hub*

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Exploring Genetic Engineering Methods Capture Sheet

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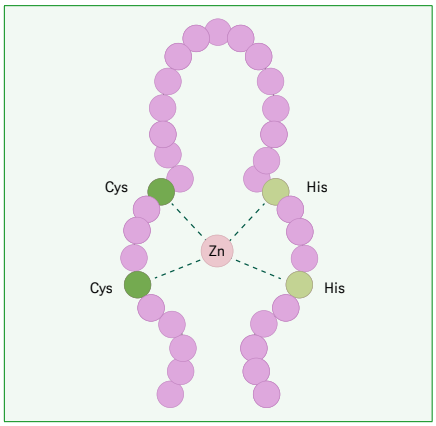
Zinc Finger Proteins (ZFNs)



1	Resource *Gene Editing Techniques: ZFNs, TALENs or CRISPR?*
2	Brief summary or illustration of this method and how it is used to control gene expression
3	What is a downfall of this method?
4	What crops have been modified using this method? Use the table from *Applications and potential of genome editing in crop improvement*.

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Exploring Genetic Engineering Methods Capture Sheet

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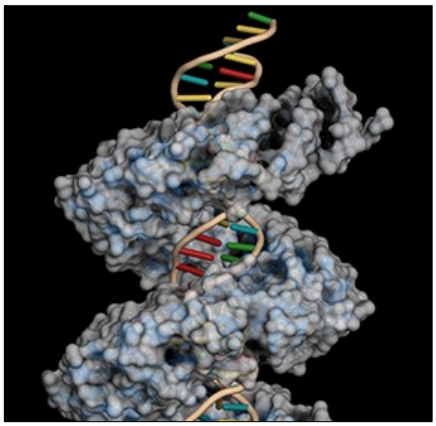
Transcription activator-like effector nucleases (TALNs) Zinc Finger Proteins (ZFNs)



1	Resource *Gene Editing Techniques: ZFNs, TALENs or CRISPR?*
2	Brief summary or illustration of this method and how it is used to control gene expression
3	What is an advantage of this type of gene-editing technology compared to others?
4	What crops have been modified using this method? Use the table from *Applications and potential of genome editing in crop improvement*.

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Exploring Genetic Engineering Methods Capture Sheet

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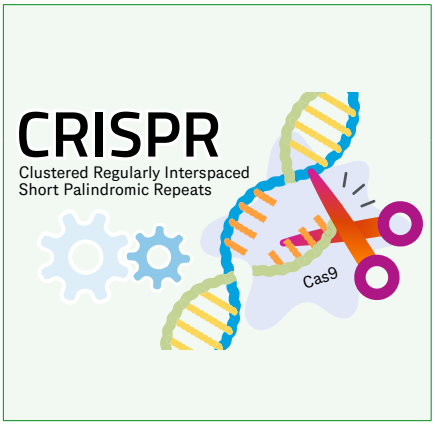
CRISPR-Cas9



1	Resource *CRISPR Explained; Gene Editing Techniques: ZFNs, TALENs or CRISPR?; CRISPR Plants)*
2	Brief summary or illustration of this method and how it is used to control gene expression
3	What is an advantage of this type of gene-editing technology compared to others?
4	What crops have been modified using this method? Use the table from *Applications and potential of genome editing in crop improvement*.

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GE Product Spotlight PSA Ad

Directions

Create a Public Service Announcement (PSA) Ad to share your GE product with the Target Audience your teacher assigned you in a way that is approachable and easy to understand.

Project Sections

1. Create an eye-catching title and state the product you are highlighting.
2. Provide some background on the product by stating one or two interesting facts about the production of the GE product.
3. Summarize your statement of safety into one sentence that highlights safety or environmental testing.
4. Briefly describe the gene-to-alternative-protein relationship.
5. Briefly describe the biotechnology technique used for this GE product.
6. Include sources.

Example PSA Ad—*many other themes can be adopted.*

More than ten million acres of alfalfa are grown in the US.

Target gene from soil bacterium creates an alternative protein product that is resistant to the herbicide glyphosate.

Alfalfa is grown mostly to make hey feed for dairy cows and horses.

Alfalfa is produced using transgenic methods, specifically agrobacterium-mediated transformation, that involves herbicide-resistant recombinant DNA being integrated into alfalfa through a ground bacteria.

GM alfalfa is considered safe and measures are taken to ensure no cross-pollination will occur with organic fields.

Source: doi: 10.17221/46/2017-CJGPB

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Advertising Development Tips 101

Directions
Consider these questions in light of the Target Audience assigned to you to complete your GE Product Spotlight PSA Ad.

1 Understand your target audience.

a	What do they do?
b	What are their values?
c	What would make them want to invest in your GE product?
d	Equity: ensure your ad is inclusive and includes underrepresented populations in your audience.

2 Explain science content in a simplified, easy-to-read way.

a	What will make sense most to your audience: pictures with some words or mostly words?
b	What information is worth explaining? Is there any information that should be left out?
c	Pull out three core reasons why the buyer would want your product and use those to drive your ad production process.

3 Pictures are very important.

a	How could you use pictures to connect with the values of the buyer?
b	How could you use pictures to attract the buyer to learn more?

4 Think about credibility and correctness (ethos).

a	Cite your sources.
b	Be sure your information is correct and research-driven.

5 Consider misinformation in your approach.

a	What misinformation or misconceptions may your audience have when viewing your ad?

6 Consider your own bias and limitations in knowledge.

a	Do you actually know about the community that is your target audience?

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Target Audience Profiles

Directions

Your teacher will assign you a Target Audience for two activities. One of these will be the audience for which you design your PSA Ad. The second will be the audience you represent when you review a classmate's PSA Ad during the Alternative Protein Speed Dating activity. Use the spaces below to note which audience you have been assigned.

Assigned Target Audiences

What target audience are you designing your PSA Ad for?

.....

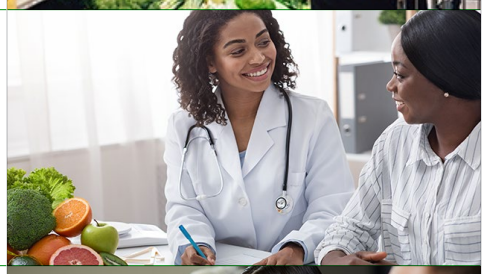
What target audience are you representing as a prospective buyer?

.....

Possible Target Audiences

General public in grocery store

Patients in a nutritionist's office



Uninformed policy maker

Tribal leader who believes in traditional ecological knowledge

Read *Traditional Knowledge Indigenous Perspectives on*

Customers at a farmer's market

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Spotlight PSA Ad Exit Ticket

Directions

Answer the following questions about progress on your GE Product Spotlight PSA Ad.

1. How is your ad development going? What are some successes and challenges?

2. How have you incorporated your target audience into your ad development?

3. List one method of genetic engineering you learned this week and describe how it works.

4. Describe your target audience.

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Alternative Protein Speed Dating Protocol Capture Sheet

Directions

There will be two rounds of speed dating. In one, you will act as a GE product salesperson for the ad you created. For the other, your teacher will assign you to a new Target Audience you should represent when listening to your classmate's pitch.

Round 1

Scenario: Seller of Product (Student A) talking to target audience representative (Student B)

For this round, one student is going to be selling his or her product and the other is going to be acting out the target audience. Make sure the seller displays the ad for their target audience when presenting.

Seller

Target Audience Rep

Protocol		5 min
☐	Seller	1 min
	Present your PSA to your target audience.	
☐	Target Audience Rep	1 min
	State one thing you liked about the product presentation and one thing you are worried or concerned about. Ask a question to your seller.	
☐	Seller	1 min
	Respond to question.	
☐	Target Audience Rep	30 sec
	Ask a follow up question.	
☐	Seller	1 min
	Respond to question.	
☐	Target Audience Rep	30 sec
	State a) whether you want to purchase the product in the future now that you know more about it, b) concerns you may still have, and c) questions that may have been left unanswered.	

Reflection		2 min
☐	Seller	1 min
	Did you feel you designed the ad in a way that reached your target audience? Explain. What were some challenges and successes? Did you feel this GE product was important for solving a community challenge? Explain.	
☐	Target Audience Rep	1 min
	How did the ad help you process your position on GE products? Did you feel this GE product was important for solving a community challenge? Explain.	

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Alternative Protein Speed Dating Protocol Capture Sheet

Continued

Round 2

Scenario: Reverse roles from Round 1

For this round, one student is going to be selling his or her product and the other is going to be acting out the target audience. This target audience representative must be a student who researched this target audience during the activity. Make sure the seller displays the ad for their target audience when presenting.

Seller

Target Audience Rep

Protocol		**5 min**
☐	Seller	1 min
	Present your PSA to your target audience.	
☐	Target Audience Rep	1 min
	State one thing you liked about the product presentation and one thing you are worried or concerned about. Ask a question to your seller.	
☐	Seller	1 min
	Respond to question.	
☐	Target Audience Rep	30 sec
	Ask a follow up question.	
☐	Seller	1 min
	Respond to question.	
☐	Target Audience Rep	30 sec
	State a) whether you want to purchase the product in the future now that you know more about it, b) concerns you may still have, and c) questions that may have been left unanswered.	

Reflection		**2 min**
☐	Seller	1 min
	Did you feel you designed the ad in a way that reached your target audience? Explain. What were some challenges and successes? Did you feel this GE product was important for solving a community challenge? Explain.	
☐	Target Audience Rep	1 min
	How did the ad help you process your position on GE products? Did you feel this GE product was important for solving a community challenge? Explain.	

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PSA Ad Grading Rubric

Observable Features	Meets Expectations 8–10 points	Progressing 5–7 points	No attempt 0 points
Spotlight Ad			
a. Included an eye-catching title and stated the product.			
b. Provided some background on the product by stating one or two interesting facts about the crop or product production.			
c. Summarized statement of safety into one sentence that highlights safety or environmental testing.			
d. Briefly described the gene-to-alternative-protein relationship.			
e. Briefly described the biotechnology technique used for this GE product.			
f. Included sources.			
Protein Speed Dating			
a. Student presented the ad to their target audience with professionalism.			
b. Student's reflection questions were well thought-out.			
c. Target audience questions were answered.			
d. Student followed protocol.			
Final Score			
Grade			