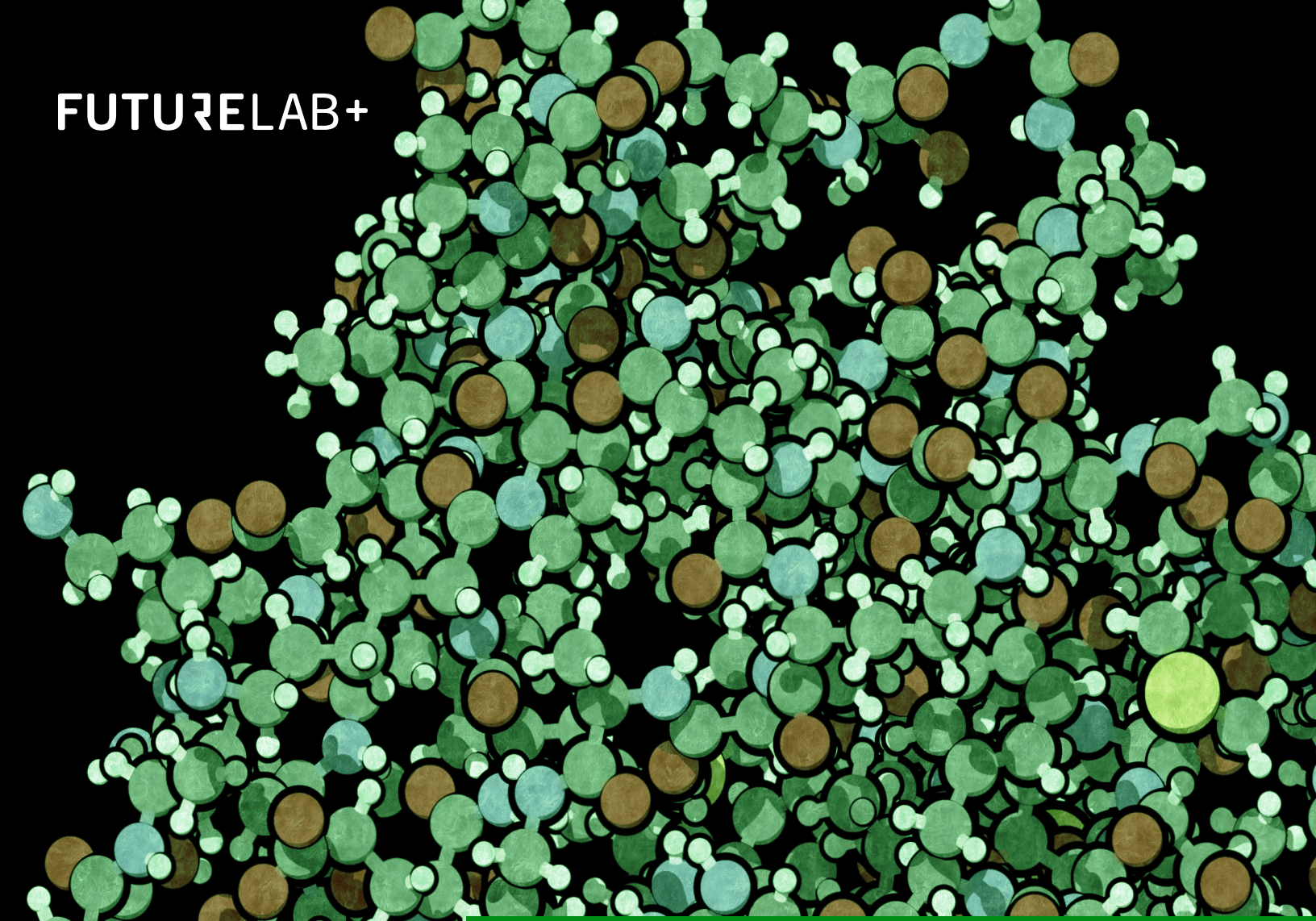
FUTURELAB+



AG/ENVIRONMENTAL

Alternative Proteins

Identifying GMOs

Developed in partnership with:

Discovery Education and Ignited

In this Lesson Plan:

Print the **Teacher Section** →

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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

Identifying GMOs

ACTIVITY DURATION

Four class sessions
(40–50 minutes each)

DRIVING QUESTION

Why might someone buy a GE Product over a non-GE product?

OVERVIEW

The variation that exists among genetically modified organisms (GMOs) and genetically engineered (GE) products in general is vast. GMOs range from modified corn with no outward indication of modification to kittens that glow in the dark and are easily recognizable as genetically engineered. With so many examples of genetic modification—some of which are commercialized and others that merely exist as a concept waiting to start production—the purpose of this lesson is to expose students to the complexity of GMOs and GE products. After categorizing product pictures, students will be given the chance to work with Polymerase Chain Reaction (PCR), a lab tool widely used in the genetic engineering of organisms.

The goal of this unit is for students to develop a novel GE product based upon community needs and stakeholder input. Students will later create an ad campaign to educate the public on their product. In this lesson, the foundation is laid for students to identify differences between GE and non-GE products and to build a claim based on evidence to argue for or against the validity of certain GE products.

ESSENTIAL QUESTIONS

What is a GMO?

How do we know what is and is not a GMO?

Should some GMOs not be created?

OBJECTIVES

Students will be able to:

Identify GMOs and non-GMOs both in images and in real life.

Conduct and **analyze** PCR tests.

Understand how genetics can help identify GE products.

Argue whether a GE product should or should not have been created.

BACKGROUND INFORMATION

This lesson uses GMO (genetically modified organism) as it is the recognized term for genetically engineered crops and products. The remaining lessons in this unit will use genetically engineered (GE) as it is the scientifically accurate terminology and industry standard term.

Materials

- **(Optional) Slices of apple**
- **GMO Cards to Sort**
- **GMO Card Sort Reflection Capture Sheet**
- **GMO vs. Non-GMO Ad Sheets**
- **CER Initial Capture Sheet**
- **GMO Notes Capture Sheet**
- **Project Notebook**
- **PCR Results Sheet**
- **CER Draft Capture Sheet**
- **CER Final Capture Sheet**
- **Poster paper**
- **Sticky notes**

Have you ever wondered…

Have you ever wondered if a GMO is healthier than a non-GMO product?

The term GMO is recognizable, but often misunderstood or confusing to stakeholders. Health impacts of genetic modification is a focus of public debate, and safety testing is monitored by regulatory agencies. Substantial evidence suggests no significant health changes after the introduction of GMO crops into a community, but consequences of GMOs in agriculture, such as increased herbicide use, cause concern (Source: *Genetically Engineered Crops: Experiences and Prospects*).

Should some GMOs not be created?

This is a hotly debated ethical question. All GMOs are created to solve a problem. The question becomes: Was the specific GMO the correct solution to the specific problem? Some GMOs were created to solve problems involving the transfer of a gene into an organism. Other GMOs were created to solve global problems, such as nutritional deficiencies. The ethical dilemma is introduced when deciding which problem should be fixed with a GMO.

How do we know what is and is not genetically modified?

The only way to truly know if something has modified genetic information is to test the genetics and compare them to a known non-GMO. This can be done by looking for the specific marker using Polymerase Chain Reaction (PCR). At the grocery store, many non-GMO products are labeled as such but many GMO products are not.

MAKE CONNECTIONS!

How does this connect to the larger unit storyline?

This lesson starts the storyline by introducing students to the concept of genetically modifying products. Students are asked to find genetically engineered products in real life, and to think about the ethical questions of creating them.

How does this connect to careers?

Grocery or produce managers are responsible for the visual layout and ordering of products, as well as the overall customer experience in a grocery store. Key skills involve being responsive to customer needs and expectations. They must also be able to interpret data on product sales to determine what products sell the best and to order accordingly.

How does this connect to our world?

Students will identify existing genetically modified products, including those that impact their daily lives.

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

Working in groups to achieve a common goal, students will use compassion and empathy to assess their own position on the production of GMOs and evaluate the purpose of GMOs in our society. They will be provided opportunities to evaluate other perspectives during class discussions of genetic modification.

CULTURALLY AND LINGUISTICALLY RESPONSIVE INSTRUCTION

During class discussions, students will share their own experiences with GMO products and related community challenges, such as food preservation.

ADVANCING INCLUSIVE RESEARCH

A lack of diverse representation is a limitation in clinical research. Prior to starting a unit on genetic modification, it is imperative that students understand the diverse perspectives and experiences of their classmates in relation to the topic of genetic modification. This will set the stage for respect, as well as inclusive research, as students have an inventory of classmate cultural perspectives moving forward. These perspectives can be utilized in the design of their final product.

COMPUTATIONAL THINKING PRACTICES

Classroom culture will be assessed by educators to foster opportunities for students to have a deeper reflection on the unit topic. Students will be completing experiments that involve following a laboratory procedure to collect and eventually analyze data to draw scientific conclusions.

CONNECTION TO THE PRODUCT LIFE CYCLE

In this lesson, students focus on existing GMOs to launch the discussion around genetic modification and the scientific processes and ethics behind it. This connects to the **discover** phase of the product life cycle, as students are learning about current advances in genetic engineering and are acting as researchers to test for the presence of certain genes.

Day 1

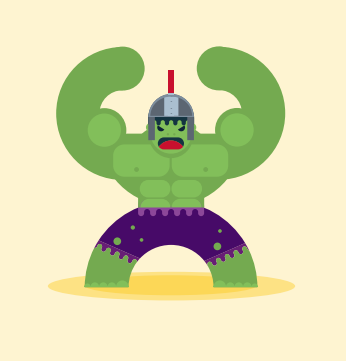
Procedure

LEARNING OUTCOMES

Students will be able to:

Apply their knowledge of GMOs by classifying organisms as GMO or non-GMO.

Identify products that have been created using recombinant DNA technology.



Whole Group (10–15 minutes)

1 Digitally display an image of a green muscular superhero (an Internet search of this term should provide a good image to use). Lead the class in a discussion about this superhero using the following prompts:

- **a.** Who is this?
- **b.** How did this superhero go from being a normal human to a superhuman?
- **c.** What did the gamma radiation do to this superhero?
- **d.** Would you want gamma radiation to alter your genetic code? What are the pros and cons of being altered?

Teacher Note > *This lesson uses GMO as it is the recognized term for genetically engineered crops and products. The remaining lessons in this unit will use genetically engineered (GE) as it is the scientifically accurate terminology and industry standard term.*

2 Show an image of browned apples.

3 Lead a class discussion about the image using the following prompts:

- **a.** What is this?
- **b.** How are browned apples different from non-browned apples?

Teacher Note > *Consider showing students a freshly sliced apple and a sliced apple that has browned rather than the image above.*

Continues next page >

Day 1

Continued

Procedure

c. Why do apples turn brown?

d. If I told you about an apple that did not turn brown, how would you feel about that? Would you want to buy it? Eat it? Let it grow in your yard?

Teacher Note > *These questions will connect into students' final CER for the lesson as they decide if they would purchase a GMO at the grocery store.*

e. Is an anti-browning apple needed in our community?

Teacher Note > *This question will connect to the final learning artifact for this unit in which students explore a local community struggle that will frame an idea for a GE product.*

Small Group (25–30 minutes)	
1	Give each set of partners a pack of *GMO Cards to Sort.*
2	Have students sort the cards into piles based on whether they are real (this organism exists in the world) or not real (this organism does not exist in the world).
	a. Ask students to complete *GMO Card Sort Reflection Capture Sheet, Part 1*, Questions 1 and 2.
3	Check real and not-real piles and correct placement of individual cards as necessary.
	a. Ask students to complete *GMO Card Sort Reflection Capture Sheet, Part 1*, Question 3.
4	Have students sort the real cards further into GMO (genetically changed) and non-GMO (genetically unchanged) piles.
	a. Ask students to complete *GMO Card Sort Reflection Capture Sheet, Part 2*, Questions 1 and 2.
5	Check GMO and non-GMO piles and correct placement of individual cards as necessary.
	a. Ask students to complete *GMO Card Sort Reflection Capture Sheet, Part 2*, Question 3.

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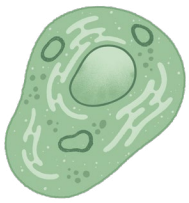
Day 1

Continued

6 Have students sort the GMO and non-GMO cards further into "should be made" (helpful to society and serves a needed purpose) and "should not have been made" (not helpful, apparently dangerous, or does not serve a purpose) piles.

a. Ask students to complete *GMO Card Sort Reflection Capture Sheet, Part 3*, Questions 1 and 2.

Teacher Note > *See table below for answers to the above activity.*



Real GMOs	
Web-Spinning Goats	Developed with spider dragline silk gene to produce large quantities of spider web, which has a high tensile strength, for military use
Fast-Growing Salmon	Created with a gene from Chinook Salmon for protein-coding and a gene from Ocean Pout for anti-freezing to grow faster and allow supply to keep up with the increased demand for more salmon and seafood across the world
Flavr Savr Tomato	Created using an antisense gene to slow the ripening process of the tomato
Cancer-Fighting Tomatoes	Created using a gene from a blueberry to increase antioxidants in the tomato, which are known to help fight cancer
Less Poop Pigs	Created with an *E. coli* gene that decreases the pigs' phosphorous output, meaning each pigs' manure will be less likely to cause environmentally harmful algae blooms
Glow-in-the-Dark Kittens	Developed as proof of concept for inserting genes into mammals; a clear phenotype was used to allow identification of gene insertion success
Leafy Broccoli	Also known as Cabbage, ancient Romans selectively bred *Brassica oleracea italica* to have larger leaves and to increase the amount of food each plant produced

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Day 1

Continued

Real	
GMOs	
Ruby Red Grapefruit	Created by treating with atomic radiation to increase mutations; those with desirable genetic traits, such as thinner skin and fewer or smaller seeds, were further selectively bred to enhance these traits
Miniature Corgi	Created through selective breeding by crossing litter runts or through introduction of a dwarfism gene into the breeding line
Non-GMOs	
Blue Eggs	Produced by chicken breeds that lay white eggs that get a coat of special bile early in the laying process, the pigment, “oocyanin” goes through the shell making the inside blue as well
Land Mine Detecting Spinach	Developed by engineers who added carbon nanotubes to spinach that can detect explosives; not a GMO as it is not changing the genetics, but it is an altered plant
Meaty Avocado	Produced as a native fruit to South Africa, these avocados are making their debut in Australia to be shipped around the world
Antifreeze Frogs	Naturally occurring frogs produce extra sugars or starches to turn their blood into an antifreeze-like substance, thus protecting their organs while the rest of their body freezes during winter months
Long-Lasting Flowers	Currently there is a preservation process that can be used to extend the life of cut flowers, but no flower can last indefinitely

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Day 1

Continued

Not-real	
Venomous Cabbage	Development proposed by using a gene from scorpions that could keep caterpillars off the cabbage without harming humans, but not a tested product
Water-Retention Coconut	Coconuts have been modified to not only be insect-resistant, but to also increase nutrients for coconut oils; however, they have not been modified to increase water retention as of 2022
Human with Spider-like Abilities	Created as a character for entertainment, not a real product
Non-Molding Bread	No bread product has been produced as of 2022 that can prevent molding

Whole Group (5–10 minutes)

1 Lead a class discussion about the activity using the following prompts:

a. Which cards surprised you the most?

b. Which real GMO had the biggest impact on our community? (Explain with reasoning.)

Teacher Note > *As homework or a possible extension, have students pay attention to (and take pictures of) items in the grocery store the next time they go. If going to a real store is not an option, students can look around other local stores or at online websites with food ordering options.*

– Are products labeled as GMOs or non-GMOs?
– Is there a price difference between GMOs, non-GMOs, or unlabeled products?

Students will most likely not be able to find GMO-labeled products, but they might find "non-GMO" labeled products in the store. They might find that non-GMO products are priced higher than unlabeled products, which may be GMO. This can lead to a good conversation on the last day of the lesson around why students may or may or not choose to buy a GMO, and also a moment to raise awareness about the fact that shoppers may not know they are buying GMOs.

Day 2

LEARNING OUTCOMES

Students will be able to:

Describe how GMO technology has evolved through history.

Connect prior knowledge on gene expression to the observed similarities and differences between GMOs and non-GMOs.

Identify and **describe** similarities and differences between GMO and non-GMOs that have been used in agriculture.

Procedure

Whole Group (5 minutes)

1 To prepare, organize the *GMO vs. Non-GMO Ad Sheets* such that the product pairs are displayed together (i.e., Corn A is with Corn B, etc.) at various stations around the classroom. Allow enough space between pairs of ad sheets for groups to look at both cards in the pair.

2 Review what students learned about GMOs from the previous day's activity by adding comments to a class brainstorm on the board.

Teacher Note > *There are two types of tomato and two types of corn presented in these Ad Sheets. The genetic differences between these two types are explained in the PRC Results Sheet that student will review on Day 3.*

Small Group (15–20 minutes)

1 Invite students to walk around the room looking at each pair of information sheets. They should not read the full sheets but make original, brief, comparative observations between the two similar products.

Teacher Note > *It might be helpful to have students think in terms of "Spot the Difference" pictures. Encourage students to find the differences between the products, including appearance, nutritional information, and availability. Differences might be small, but can have a large impact on health, family budget, and food security.*

2 Ask students to make observations about the two different products. What do they have in common? What is different about them?

3 Have students end on the pair that they think is most interesting. For this one pair of Ad Sheets, have students complete the *CER Initial Capture Sheet* after completing the lab. Students will have time to revisit their claim about which is the GMO after completing the lab.

Teacher Note > *Golden Rice will be looked at in later lessons as a GE product designed to solve a specific community problem. The rice Ad Sheet is a good resource to assign or suggest to a group that could use a preview of later material. The "Apple" is the challenge product, as the GMO is altered by removing a gene, unlike the expected addition of a gene (which is true for the other products). At this point, students will be making a minimally educated guess on which product is a GMO, but they can determine which they would want to buy. They will be receiving PCR results after completing the lab and will have time to revise their claim about which is the GMO.*

Continues next page >

Day 2

Continued

Procedure

Individual Work (15–20 minutes)

1 Have students read *Science and History of GMOs and Other Food Modification Processes*.

2 Then have students complete the *GMO Notes Capture Sheet* based on what they learn.

Teacher Note > *Question 7 asks students about something learned in the Solution Seeking Microbes unit (genome editing and CRISPR). If you have not done this unit with the class, you may wish to have them skip this question.*

Whole Group (5–10 minutes)

1 Ask students if they have any experience with GMOs in their life, or if they were aware that they might have had experience with GMOs without realizing it. Remind them of the homework at the grocery store.

a. What did you notice about GMO labeling (or more accurately, non-GMO labeling)?

b. Why might companies label non-GMOs and not label GMOs?

c. What did you notice about the price of GMOs vs. non-GMOs? What did you notice about non-GMOs versus other foods?

d. What could explain this price difference?

e. Did anything surprise you in your observations?

Lab Break

Procedure

Teacher Note > *Before students proceed on to Day 3, they should do Days 1–3 of the lab. In this lab, students will perform the techniques of DNA extraction, PCR, and gel electrophoresis. They will describe how these techniques can be used to detect the presence of GE crops, e.g., Bt-corn gene in a food product. This lab will be essential for students' understanding of Day 3–4 activities, where they will analyze PCR results for their two product options.*

Loading a DNA tube into a PCR (polymerase chain reaction) thermocycler machine in a bioscience laboratory.

Day 3

LEARNING OUTCOMES

Students will be able to:

Identify products containing GMOs and **compare** them to products that are non-GMO in terms of availability and price.

Create an argument for or against the use of GMOs based on observations and evidence from lab results.

Procedure

Whole Group (20–25 minutes)

1. Lead a discussion about GMOs in supermarkets based on homework from Day 1.
   - **a.** What did you notice about GMOs vs. non-GMOs in the supermarket?
   - **b.** What questions does this raise for you?
   - **c.** What conversations do you think the advertising groups have around GMO products? How are these different from the conversations around non-GMO products?
   - **d.** What did you notice about the prices?

2. Explain that at the end of this unit students will be assuming the role of a GMO influencer promoting a new GMO in their community. This includes the whole process, from research and development of the GMO, to community buy-in, to marketing.

3. Introduce the *Project Notebook*. Inform students that they will be adding to the Project Phase Chart Capture Sheet each week during the unit.

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Day 3

Continued

Procedure

Teacher Note > *Students will be adding to the chart as they move through the lessons and then will draw from it to design their informational website and ads for their novel GE product. Below is a chart of when they will add each component:*

Project Phase		Lesson to be added
Discover	Problem Descriptions	Lesson 7
	Industry Spotlights	Lesson 6
	Current GE products	Lesson 6
	Solution GE product	Lesson 7
Develop	Community Background	Lesson 8
	GE Technology	Lesson 3
	Protein Products	Lesson 3
	Safety	Lesson 5
Manufacture	Farm-to-Store Process	Lesson 9
	Sustainability	Lesson 9
	Equity	Lesson 9
Commercialize	Community Impact	Lesson 7

Small Group (25–35 minutes)

1 Give groups their GMO vs. Non-GMO Ad Sheets and the *PCR Results Sheet*.

Teacher Note > *DNA is the focus of most GMO curriculum. In the next lesson, we will be focusing on the protein product to complete the central dogma understanding around GE products. Mentioning the protein products here will help connect the idea for students in the next lesson.*

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Day 3

Continued

Procedure

2 Ask groups to work with all the data they now have to complete the *CER Draft Capture Sheet*.

a. Introduce the sentence structure for Claim: *I (would/would not) buy product (A/B), which is a GMO.*

b. Introduce the Evidence prompt: Evidence statements should be data, either qualitative or quantitative. Tell students to be sure there is evidence to prove that the product is the GMO and evidence for why they would or would not purchase it.

Examples of evidence types:

- Price difference
- PCR results
- Nutritional differences (anything from caloric intake to a specific vitamin or mineral content)
- Image comparison
- Shelf life (ability to store at home after purchase)

INDUSTRY AND CAREER CONNECTION

This is a good time to point out that inventory managers are responsible for the layout and ordering of products in a grocery store. Key skills involve being able to interpret data on the sales of products in stores to figure out what sells the best and to order accordingly.

Teacher Note > *While students may not initially think about this, shelf life does connect to the product life cycle, the price point, and the availability in store. Bringing this up with students might help them understand later in this unit why GMOs are in so many stores.*

c. Introduce the reasoning prompt: For each piece of evidence, students should provide a reasoning statement explaining why they would or would not purchase the GMO with the following considerations: cost, advantages of increased nutritional value, family values, or personal beliefs on genetic engineering.

Teacher Note > *This conversation could and should help students understand each other's values and start them thinking about potential challenges in their local community. This primer will be helpful for Lesson 6 when students start identifying community challenges their novel GMO can help solve.*

3 Approve groups' ideas before they move forward with the CER poster creation.

4 Ask groups to create a poster of their CER for a Gallery Walk in next class, based on the PCR results page and example ads.

Teacher Note > *The CER poster is an enlarged version of the CER Draft Capture Sheet with the groups' agreed-upon evidence and reasoning. These ads can be an example or draft model to refer back to in Lesson 10 when they are working on their print ad campaigns.*

Day 4

Procedure

LEARNING OUTCOMES

Students will be able to:

Argue whether a GE product should or should not have been created.

Peer review scientific claims on the use of GMOs and provide feedback for strengthening evidence for argumentation.

Modify argumentation based on peer review.

Small Group (5 minutes)

Give groups five minutes to finalize their posters and place posters around the classroom for the Gallery Walk.

Individual Work (20–25 minutes)

1. Give each group member two sticky notes for each group in the room. Students should write their class number, ID number, or initials on each sticky note for accountability.

2. Invite students to walk the classroom gallery, examining other groups' posters. They should leave one sticky note with at least one clarifying question on it, and another sticky note with one or more positive comments.

3. Project the following list of prompts:

   a. Remember that the most useful feedback is kind, specific, and helpful.

   b. Clarifying questions prompts:

   - Can you expand on _____?
   - How does _____ support your claim specifically?
   - What specifically did you mean by _____?
   - Do you have numbers to support _____?
   - Can you further explain your reasoning about _____?
   - Your evidence, _____ , seems to support your claim but can you re-explain your reasoning for it?
   - _____ does not necessarily support your claim.
   - Have you thought of changing it to _____?

Continues next page >

Day 4

Continued

Procedure

c. Celebration prompts:

- I can clearly understand how your claim is supported by _____.
- I appreciate how detailed your reasoning around _____ is.
- I like how you expanded on _____ beyond just the basic evidence.
- It was really helpful that you included _____ in your evidence.

Small Group (10–15 minutes)

As a group, have students review feedback and revisit their *CER Draft Capture Sheet*. Students can add evidence, revise claims, and clarify reasoning based on the feedback received.

Individual Work (5–10 minutes)

Have students take all the information they have gained from this lesson and write their *CER Final Capture Sheet*.

Teacher Note > *This can be done on the CER Final Capture Sheet or as a complete paragraph putting the evidence and reasoning into a persuasive paragraph.*

National Standards

Next Generation Science Standards	**LS1-2 From Molecules to Organisms: Structures and Processes** Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.
	LS3-1 Heredity: Inheritance and Variation of Traits Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring.
	Science and Engineering Practices Engaging in Argument from Evidence Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge and student-generated evidence.
Career and Technical Education (CTE)	**A1.4** Research and identify public misunderstandings related to biotechnology and discern the source of these misunderstandings
	A9.2 Identify several products obtained through recombinant DNA technology.
	5.4 Interpret information and draw conclusions, based on the best analysis, to make informed decisions.

GMO Card Sort Reflection Capture Sheet, Part 1

ANSWER KEY — **Do not share with students**

Directions
Short your GMO Cards in to "real" and "not real" piles, and answer questions 1 and 2. Have your teacher check your piles, and then answer question 3.

1. How did you decide how to sort the organisms? What made you believe certain organisms were not real?

Answers will vary.

2. Of the cards that you sorted as "not real," are there any that you think should be real? Why?

Answers will vary.

3. After your teacher gave you the correct answers, were any of the real GMOs a surprise? Explain.

Answers will vary.

GMO Card Sort Reflection Capture Sheet, Part 2

ANSWER KEY **Do not share with students**

Directions
Sort your pile of "real" cards into organisms that were intentionally genetically changed to ones that were not intentionally changed, and answer questions 1 and 2. Have your teacher check your piles, and then answer question 3.

1. How did you define Genetically-Modified Organism (GMO) for this sort activity?

I defined GMO as an organism that has been changed genetically in some way.

2. Were you unsure of how to sort any cards? Why?

Answers will vary.

3. Were any GMOs surprising to you? Why?

Answers will vary.

GMO Card Sort Reflection Capture Sheet, Part 3

ANSWER KEY **Do not share with students**

Directions
Sort your pile of "real" cards that were intentionally genetically changed into organisms you think should be made and ones you feel should not be made, then answer questions 1–2.

1. Which GMOs did you think should be created? Why?

Answers will vary.

2. Why should the other GMOs not have been created?

Answers will vary.

CER Draft Capture Sheet

ANSWER KEY **Do not share with students**

Directions
Look at the two sheets of information about similar products and answer the following questions based on your initial observations.

Answers will vary with the organism observed. Below is an example.

1. Which organisms did you decide to observe?

Corn A vs. B

2. What do they have in common? Give at least three examples.

Both have the same shelf life, between 5–7 days. Both have the same caloric value of 125 calories per cup. And both have the same DV % for iron (4%) and potassium (8%).

3. What is different about them? Give at least three examples.

Corn A costs .88 cents per unit and Corn B costs $1.10 per unit. Corn A has all yellow kernels and Corn B has mixed colors.

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CER Draft Capture Sheet

ANSWER KEY **Do not share with students**

Continued

4. Why might there be differences between A and B?

Answers will vary but students might think that they are different organisms or have different genetics.

5. Which of the two (A or B) do you think is a GMO?

I think that Corn A is a GMO.

6. What evidence do you have to support that claim? (This does not need to be in-depth, just what you are basing your claim off of at this point in time.)

Because when I looked for GMOs and Non-GMOs at the store, the non-GMOs were more expensive. Corn A is cheaper than Corn B, so it could be a GMO.

GMO Notes Capture Sheet

ANSWER KEY **Do not share with students**

Directions
Read the FDA article "Science and History of GMOs and Other Food Modification Processes" and answer the following questions.

1. Based on your previous knowledge, what is selective breeding?

Selective breeding is the process of breeding organisms with desirable traits. Dog breeding is one example of this.

2. Based on the video, what is cross-breeding?

Cross-breeding is when two different species or varieties of organisms with certain traits are bred together.

3. Based on the video, what are the two new ways to genetically modify crops?

Genetic engineering is when a gene with a desired trait from one organism is copied and then put into a different organism. Genome editing is more specific and creates new varieties of crops.

4. Open the Timeline of *Genetic Modification in Modern Agriculture*. What are four things that surprised you or were of interest to you on the timeline?

Students are asked to identify four things. Answers will vary, but will likely include how humans have been cross-breeding plants and animals for a long time, and how recently some GMO products have become available.

a. _____

b. _____

c. _____

d. _____

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GMO Notes Capture Sheet

ANSWER KEY **Do not share with students**

Continued

5. What does GMO stand for? Explain what it means in your own words.

GMO stands for Genetically Modified Organism, and it means that the gene for a desired trait in one organism is copied and inserted into the DNA of another organism. Then the new organism with the copied gene is grown.

6. Summarize each step of the current GMO process for plants:

   a. Identify:

   Determine what trait the plant should have, and then find another organism that already has that trait in its DNA.

   b. Copy:

   Copy the gene that has the desired trait.

   c. Insert:

   Insert the copied gene into the DNA of the plant.

   d. Grow:

   The altered plant is grown in a lab first to make sure the plant actually has the desired trait. If the plant does have the trait, then it is grown in a greenhouse, and then in small quantities in field tests, then in larger field tests. If it is determined to be safe and effective, then it will be ready to sell to farmers.

Continues next page >

GMO Notes Capture Sheet

ANSWER KEY **Do not share with students**

Continued

7. Summarize what you learned about genome editing and CRISPR from the last unit.

Answers will vary.

8. How do you think genome editing is helping to advance agriculture?

Crops that are developed using CRISPR can be more nutritious or drought resistant, which can increase the amount of crops that ultimately get to the consumer.

Educator Resources

GMO vs. Non-GMO Ad Sheets

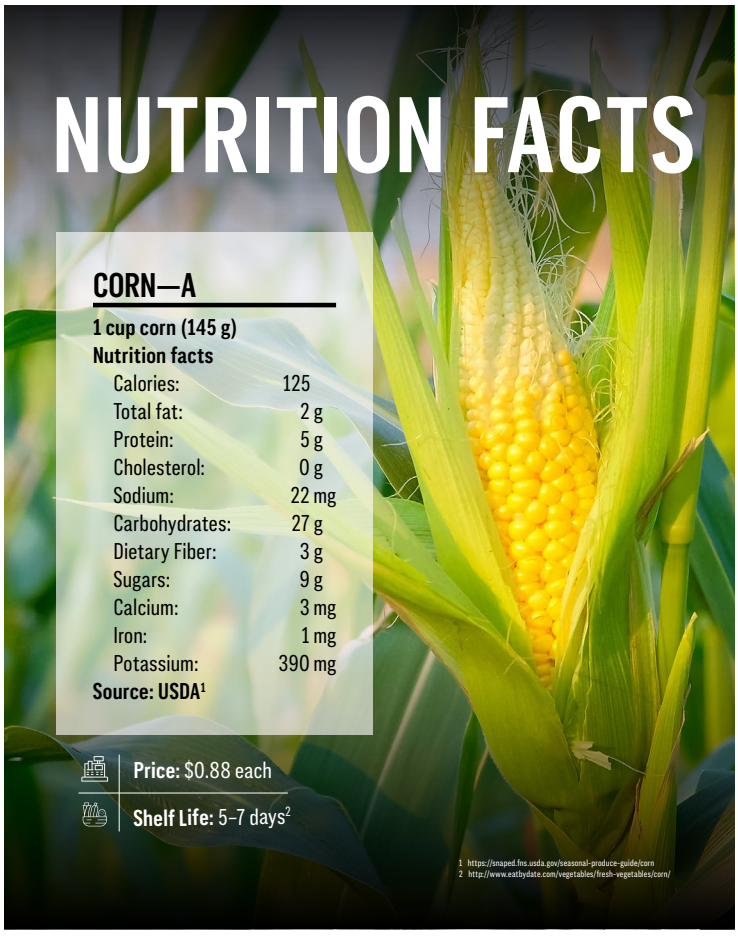
Directions

Organize these ad sheets such that the product pairs are displayed together (i.e., Corn A is with Corn B, etc.) at various stations around the classroom. Allow enough space between pairs of ad sheets for groups to look at both cards in the pair.

Invite students to walk around the room looking at each pair of sheets. They should not read all the text but make brief, comparative observations between the two similar organisms.

It might be helpful to have students think in terms of "Spot the Difference" pictures. Small differences can have a large impact on health, family budget, and food security.

Thumbnail Example of an Ad Sheet



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NUTRITION FACTS

CORN—A

1 cup corn (145 g)

Nutrition facts

Calories:	125
Total fat:	2 g
Protein:	5 g
Cholesterol:	0 g
Sodium:	22 mg
Carbohydrates:	27 g
Dietary Fiber:	3 g
Sugars:	9 g
Calcium:	3 mg
Iron:	1 mg
Potassium:	390 mg

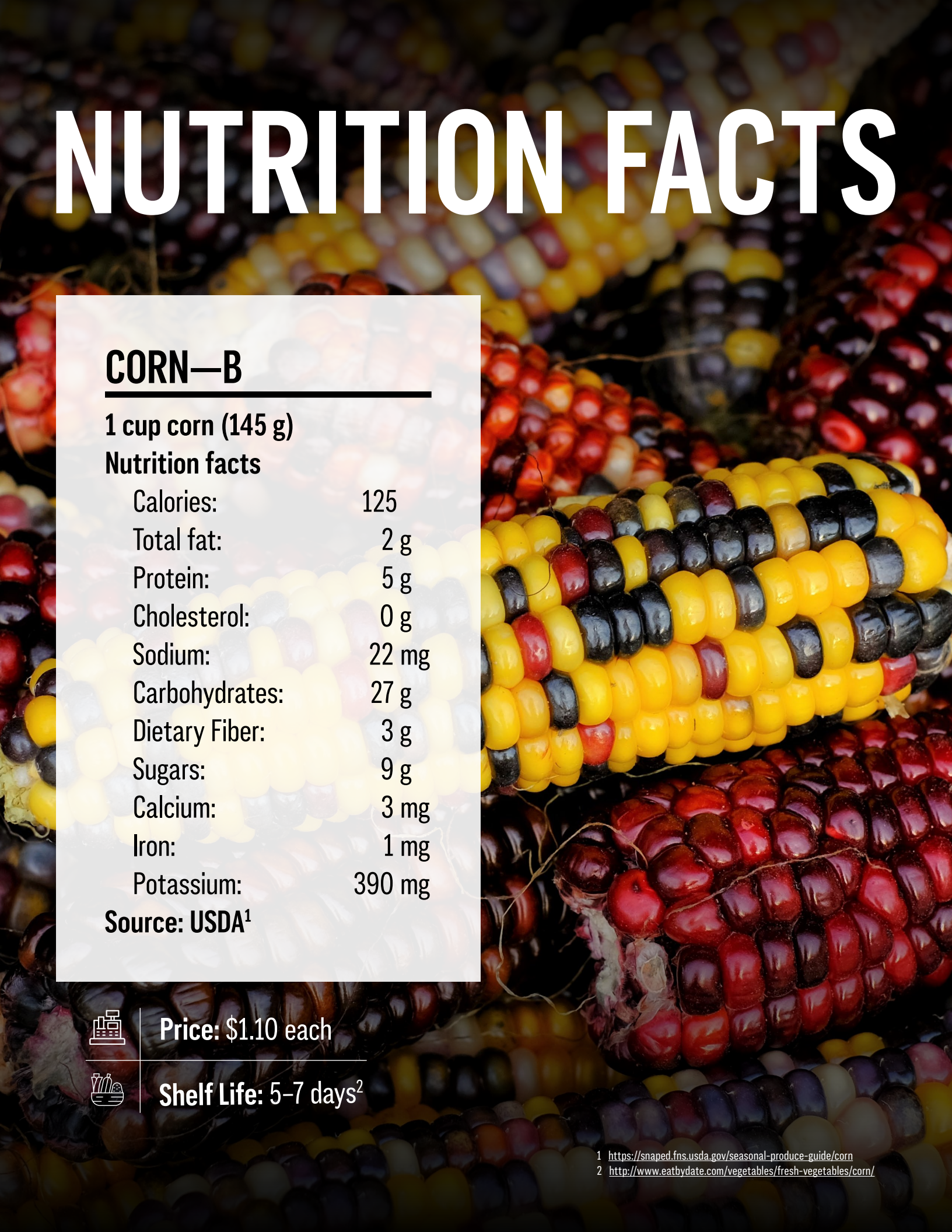
Source: USDA[1]

Price: $0.88 each

Shelf Life: 5–7 days[2]

1 https://snaped.fns.usda.gov/seasonal-produce-guide/corn
2 http://www.eatbydate.com/vegetables/fresh-vegetables/corn/

NUTRITION FACTS



CORN—B

1 cup corn (145 g)

Nutrition facts

Calories:	125
Total fat:	2 g
Protein:	5 g
Cholesterol:	0 g
Sodium:	22 mg
Carbohydrates:	27 g
Dietary Fiber:	3 g
Sugars:	9 g
Calcium:	3 mg
Iron:	1 mg
Potassium:	390 mg

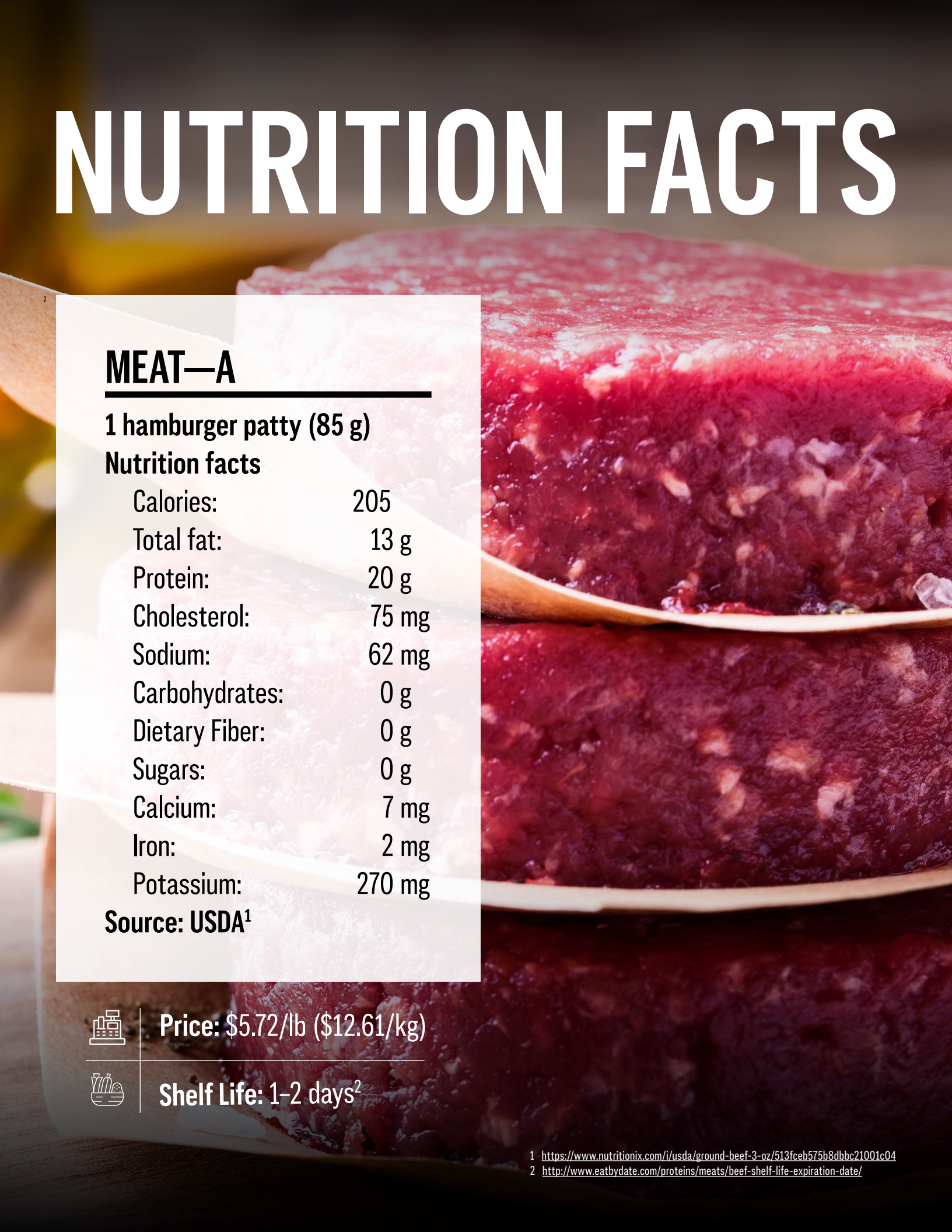
Source: USDA[1]

Price: $1.10 each

Shelf Life: 5–7 days[2]

1 https://snaped.fns.usda.gov/seasonal-produce-guide/corn
2 http://www.eatbydate.com/vegetables/fresh-vegetables/corn/

NUTRITION FACTS



MEAT—A

1 hamburger patty (85 g)

Nutrition facts

Calories:	205
Total fat:	13 g
Protein:	20 g
Cholesterol:	75 mg
Sodium:	62 mg
Carbohydrates:	0 g
Dietary Fiber:	0 g
Sugars:	0 g
Calcium:	7 mg
Iron:	2 mg
Potassium:	270 mg

Source: USDA[1]

Price: $5.72/lb ($12.61/kg)

Shelf Life: 1–2 days[2]

1 https://www.nutritionix.com/i/usda/ground-beef-3-oz/513fceb575b8dbbc21001c04
2 http://www.eatbydate.com/proteins/meats/beef-shelf-life-expiration-date/

NUTRITION FACTS

MEAT—B

1 Plant-Based Protein Patty (113 g)

Nutrition facts

Calories:	240
Total fat:	14 g
Protein:	19 g
Cholesterol:	0 g
Sodium:	370 mg
Carbohydrates:	9 g
Dietary Fiber:	3 g
Sugars:	<1 g
Calcium:	170 mg
Iron:	4.2 mg
Potassium:	610 mg

Source: Impossible Foods[1]

Price: $6.40/lb ($14.11/kg)

Shelf Life: 10 days[2]

1 https://impossiblefoods.com/burger

2 https://assets.ctfassets.net/hhv516v5f7sj/3TSh5cOPT4WyEJ9aL3K7Fg/1e75eb08ba1359ffc0a094291267a607/IF_Bricks_to_Patties_Guide.pdf

NUTRITION FACTS

APPLE—A

1 cup apple slices (109 g)

Nutrition facts

Calories:	57
Total fat:	200 mg
Protein:	300 mg
Cholesterol:	0 g
Sodium:	1 mg
Carbohydrates:	15 g
Dietary Fiber:	3 g
Sugars:	11 g
Added Sugars:	0 g
Calcium:	11 mg
Iron:	0 g
Potassium:	117 mg

Source: USDA[1]

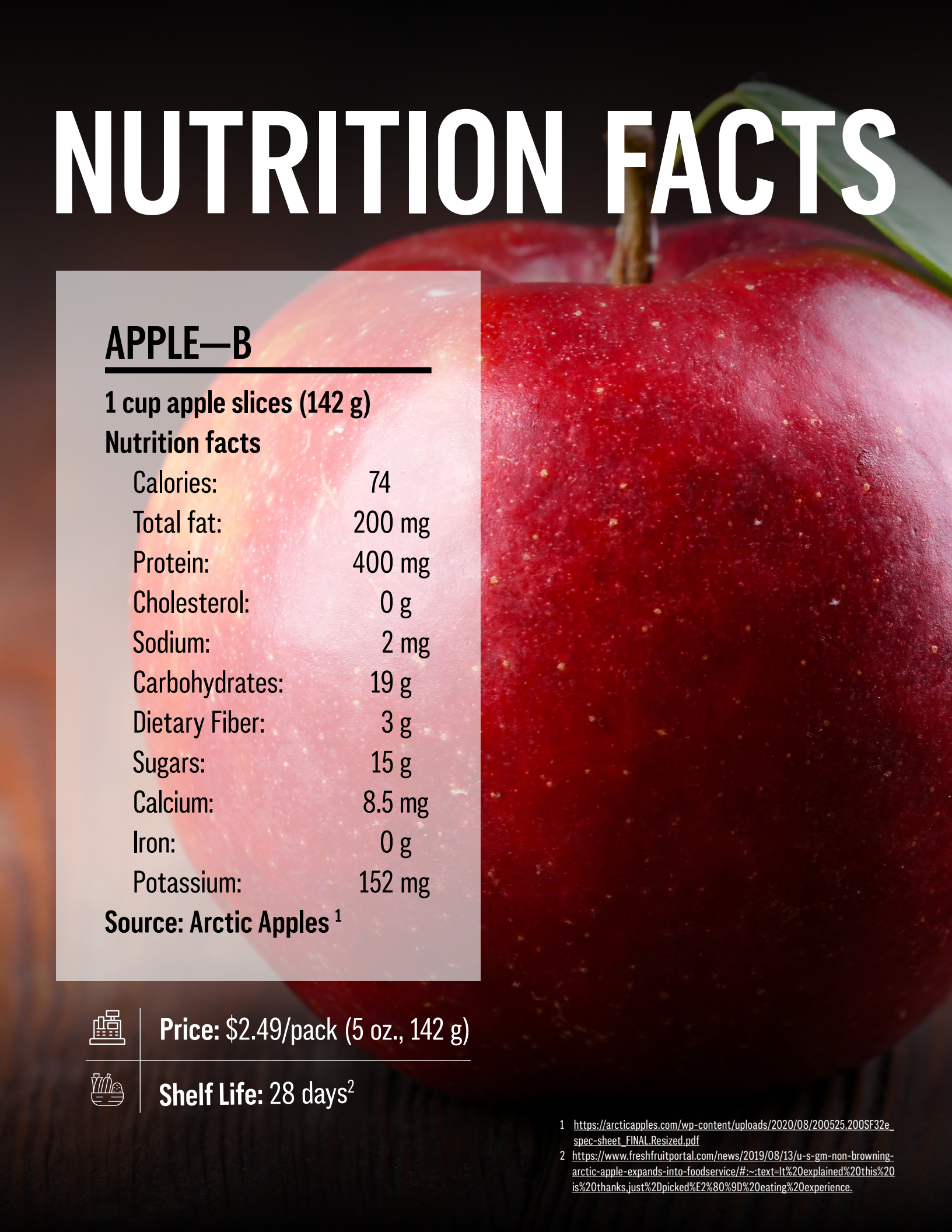
Price: $3.99/pack (5 oz., 142 g)

Shelf Life: 20 days[2]

1 https://www.nutritionix.com/i/usda/apple-1-cup-slices/513fceb475b8dbbc21000f94

2 https://www.freshfruitportal.com/news/2019/08/13/u-s-gm-non-browning-arctic-apple-expands-into-foodservice/#:~:text=It%20explained%20this%20is%20thanks,just%2Dpicked%E2%80%9D%20eating%20experience.

NUTRITION FACTS



APPLE—B

1 cup apple slices (142 g)

Nutrition facts

Calories:	74
Total fat:	200 mg
Protein:	400 mg
Cholesterol:	0 g
Sodium:	2 mg
Carbohydrates:	19 g
Dietary Fiber:	3 g
Sugars:	15 g
Calcium:	8.5 mg
Iron:	0 g
Potassium:	152 mg

Source: Arctic Apples [1]

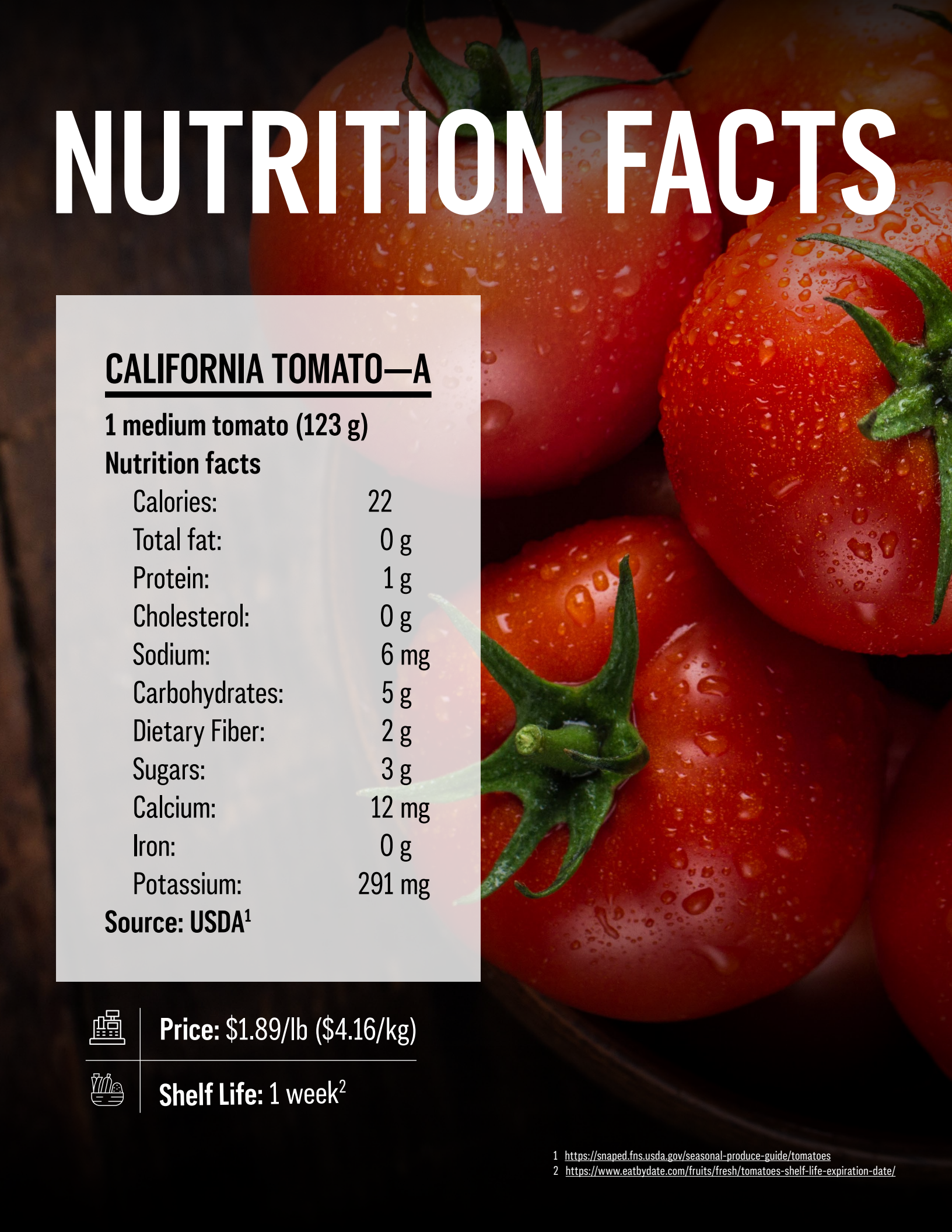
Price: $2.49/pack (5 oz., 142 g)

Shelf Life: 28 days[2]

1 https://arcticapples.com/wp-content/uploads/2020/08/200525.200SF32e_spec-sheet_FINAL.Resized.pdf

2 https://www.freshfruitportal.com/news/2019/08/13/u-s-gm-non-browning-arctic-apple-expands-into-foodservice/#:~:text=It%20explained%20this%20is%20thanks,just%2Dpicked%E2%80%9D%20eating%20experience.

NUTRITION FACTS



CALIFORNIA TOMATO—A

1 medium tomato (123 g)

Nutrition facts

Calories:	22
Total fat:	0 g
Protein:	1 g
Cholesterol:	0 g
Sodium:	6 mg
Carbohydrates:	5 g
Dietary Fiber:	2 g
Sugars:	3 g
Calcium:	12 mg
Iron:	0 g
Potassium:	291 mg

Source: USDA[1]

Price: $1.89/lb ($4.16/kg)

Shelf Life: 1 week[2]

1 https://snaped.fns.usda.gov/seasonal-produce-guide/tomatoes
2 https://www.eatbydate.com/fruits/fresh/tomatoes-shelf-life-expiration-date/

NUTRITION FACTS

CALIFORNIA TOMATO—B

1 medium tomato (123 g)

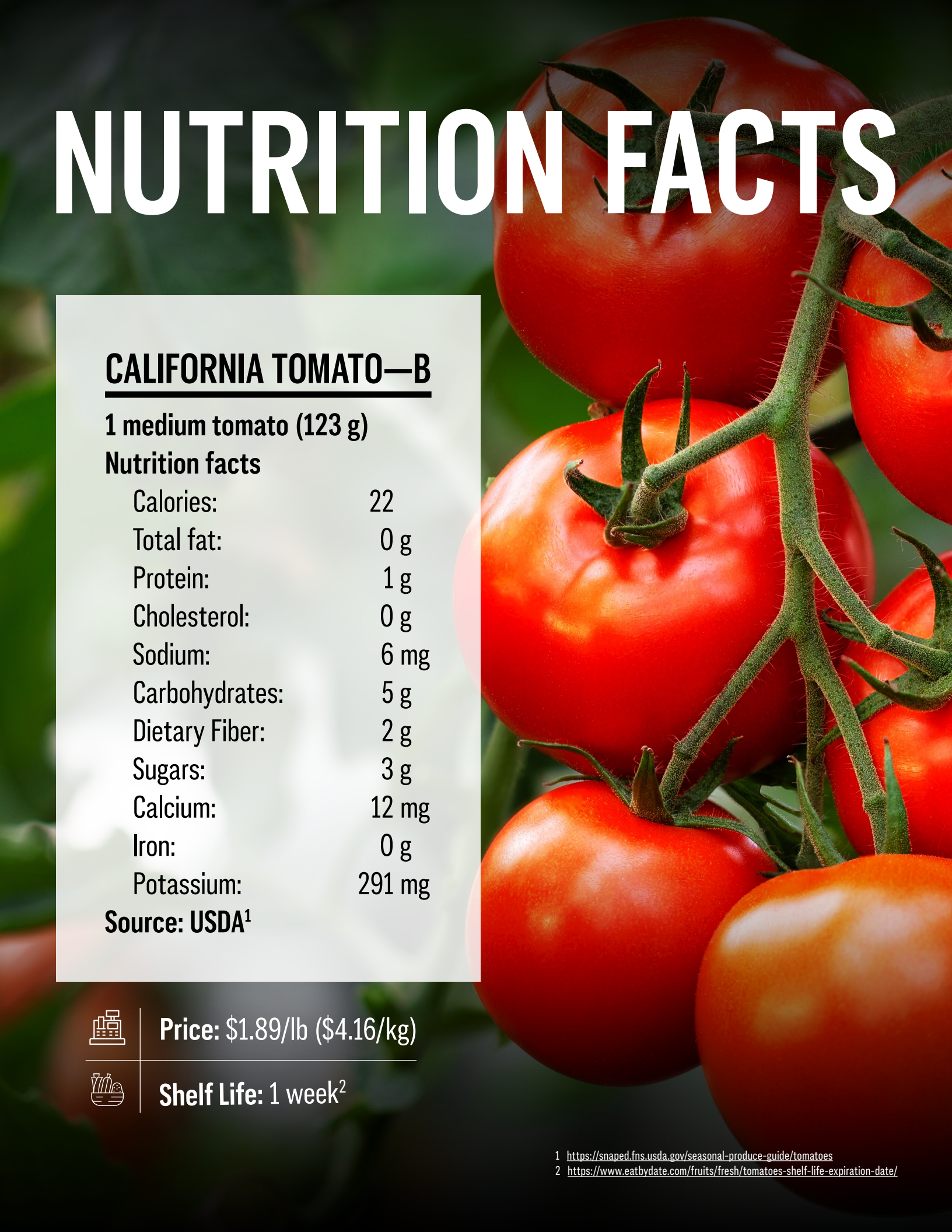
Nutrition facts

Calories:	22
Total fat:	0 g
Protein:	1 g
Cholesterol:	0 g
Sodium:	6 mg
Carbohydrates:	5 g
Dietary Fiber:	2 g
Sugars:	3 g
Calcium:	12 mg
Iron:	0 g
Potassium:	291 mg

Source: USDA[1]

Price: $1.89/lb ($4.16/kg)

Shelf Life: 1 week[2]



1 https://snaped.fns.usda.gov/seasonal-produce-guide/tomatoes
2 https://www.eatbydate.com/fruits/fresh/tomatoes-shelf-life-expiration-date/

NUTRITION FACTS

SALMON—A

1/2 salmon filet (198 g)

Nutrition facts

Calories:	412
Total fat:	12 g
Protein:	39 g
Cholesterol:	109 g
Sodium:	87 mg
Carbohydrates:	0 g
Dietary Fiber:	0 g
Sugars:	0 g
Calcium:	24 mg
Iron:	2 g
Potassium:	970 mg

Source: USDA[1]

Price: $14.99/lb ($33.05/kg)

Shelf Life: 1–2 days

1 https://fdc.nal.usda.gov/fdc-app.html#/food-details/173686/nutrients
2 http://www.eatbydate.com/vegetables/fresh-vegetables/corn/

NUTRITION FACTS

SALMON—B

1/2 salmon filet (198 g)

Nutrition facts

Calories:	412
Total fat:	13 g
Protein:	39 g
Cholesterol:	109 mg
Sodium:	87 g
Carbohydrates:	0 g
Dietary Fiber:	0 g
Sugars:	0 g
Calcium:	24 mg
Iron:	2 mg
Potassium:	970 mg

Source: USDA[1]

Price: $15.99/lb ($35.25/kg)

Shelf Life: 1–2 days[2]

1 https://fdc.nal.usda.gov/fdc-app.html#/food-details/173686/nutrients
2 https://www.eatbydate.com/proteins/seafood/how-long-does-salmon-last-shelf-life/

NUTRITION FACTS

RICE—A

1 cup rice (158 g)

Nutrition facts

Calories:	205
Total fat:	390 mg
Protein:	4 g
Cholesterol:	0 g
Sodium:	0 g
Carbohydrates:	53 g
Dietary Fiber:	600 mg
Sugars:	100 mg
Calcium:	6 mg
Iron:	0 g
Potassium:	54 mg

Source: USDA[1]

Price: $0.49/lb ($1.08/kg)

Shelf Life: 2 years[2]

1 https://fdc.nal.usda.gov/fdc-app.html#/food-details/168930/nutrients

2 https://www.healthline.com/nutrition/does-rice-go-bad#:~:text=Dry%20white%20rice%20has%20a,rancid%2C%20oily%2C%20or%20discolored.

NUTRITION FACTS

RICE—B

1 cup rice (158 g)

Nutrition facts

Calories:	205
Total fat:	390 mg
Protein:	4 g
Cholesterol:	0 g
Sodium:	0 g
Carbohydrates:	53 g
Dietary Fiber:	600 mg
Sugars:	100 mg
Calcium:	6 mg
Iron:	0 g
Potassium:	54 mg

Source: IRRI[1]

Price: $0.70/lb ($1.54/kg)

Shelf Life: 2 years[2]

1 http://news.irri.org/2019/09/compositional-analysis-shows-beta.html
2 https://www.healthline.com/nutrition/does-rice-go-bad#:~:text=Dry%20white%20rice%20has%20a,rancid%2C%20oily%2C%20or%20discolored.

NUTRITION FACTS

TOMATO—A

1 medium tomato (123 g)

Nutrition facts

Calories:	22
Total fat:	0 g
Protein:	1 g
Cholesterol:	0 g
Sodium:	6 mg
Carbohydrates:	5 g
Dietary Fiber:	2 g
Sugars:	3 g
Calcium:	12 mg
Iron:	0 g
Potassium:	291 mg

Source: USDA[1]

Price: $1.36/lb ($2.99/kg)

Shelf Life: 2 weeks [2]

1 https://snaped.fns.usda.gov/seasonal-produce-guide/tomatoes
2 https://www.purdue.edu/newsroom/research/2010/100628HandaTomato.html

NUTRITION FACTS

TOMATO—B

1 medium tomato (123 g)

Nutrition facts

Calories:	22
Total fat:	0 g
Protein:	1 g
Cholesterol:	0 g
Sodium:	6 mg
Carbohydrates:	5 g
Dietary Fiber:	2 g
Sugars:	3 g
Calcium:	12 mg
Iron:	0 g
Potassium:	291 mg

Source: USDA[1]

Price: $1.89/lb ($4.16/kg)

Shelf Life: 1 week[2]

1 https://snaped.fns.usda.gov/seasonal-produce-guide/tomatoes
2 https://www.eatbydate.com/fruits/fresh/tomatoes-shelf-life-expiration-date/

NUTRITION FACTS

MAIZE (CORN)—A

1 cup corn (145 g)

Nutrition facts

Calories:	125
Total fat:	2 g
Protein:	5 g
Cholesterol:	0 g
Sodium:	22 mg
Carbohydrates:	27 g
Dietary Fiber:	3 g
Sugars:	9 g
Calcium:	3 mg
Iron:	1 mg
Potassium:	390 mg

Source: USDA[1]

Price: $0.88 each

Shelf Life: 5–7 days[2]

1 https://snaped.fns.usda.gov/seasonal-produce-guide/corn
2 http://www.eatbydate.com/vegetables/fresh-vegetables/corn/

NUTRITION FACTS

MAIZE (CORN)—B

1 cup corn (145 g)

Nutrition facts

Calories:	125
Total fat:	2 g
Protein:	5 g
Cholesterol:	0 g
Sodium:	22 mg
Carbohydrates:	27 g
Dietary Fiber:	3 g
Sugars:	9 g
Calcium:	3 mg
Iron:	1 mg
Potassium:	390 mg

Source: USDA[1]

Price: $1.10 each

Shelf Life: 5–7 days[2]

1 https://snaped.fns.usda.gov/seasonal-produce-guide/corn
2 http://www.eatbydate.com/vegetables/fresh-vegetables/corn/

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GMO Cards to Sort

Directions

Cut these cards out and then sort into piles based on whether they are real (this organism exists in the world) or not real (this organism does not exist in the world). Make a note of the category you have placed each card into below that card.

Web-Spinning Goats

Goat that produces spider web protein in its milk

1

Fast-Growing Salmon

Salmon that grows twice as fast, producing protein faster

2

Flavr Savr Tomato

Tomato with a slower ripening process to prevent softening and rotting, while allowing the tomato to retain its natural flavor and color

3

Cancer-Fighting Tomatoes

Tomato that contains antioxidants that can help fight cancer

4

Continues next page >

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GMO Cards to Sort

Continued

Non-Molding Bread	Bread that will not mold for up to six months without needing to be refrigerated or frozen

5

Less Poop Pigs	Pig that excretes about 40 percent less waste

6

Land Mine Detecting Spinach	Spinach that fluoresces when it detects explosive

7

Glow-in-the-Dark Kittens	Cat that can glow green or red

8

Continues next page >

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GMO Cards to Sort

Continued

Venomous Cabbage

Cabbage that is poisonous to caterpillars but not humans

9

Water-Retention Coconut

Larger coconut that produces more coconut water in the core

10

Blue Eggs

Chicken eggs that have a blue shell and blue egg "whites"

11

Human with Spider-like Abilities

Man that can create spiderwebs to swing from and stick to walls

12

Continues next page >

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GMO Cards to Sort

Continued

Leafy Broccoli

Broccoli with more buds to increase future crops yields and larger leaves

13

Ruby Red Grapefruit

Grapefruit with thinner skin, smaller seeds, and a deeper red color

14

Miniature Corgi

Smaller corgi that produces smaller amounts of waste to be cleaned up

15

Meaty Avocado

Avocado five times the size of regular avocados, increasing the edible portion in each

16

Continues next page >

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GMO Cards to Sort

Continued

Antifreeze Frogs	Frog that has special blood allowing it to freeze solid in the winter and then thaw in the spring without dying

17

Long-Lasting Flowers	Flower that will last a year after being cut without wilting or looking dead

18

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GMO Card Sort Reflection Capture Sheet, Part 1

Directions
Sort your GMO Cards into "real" and "not real" piles, and answer questions 1 and 2. Have your teacher check your piles, and then answer question 3.

1. How did you decide how to sort the organisms? What made you believe certain organisms were not real?

2. Of the cards that you sorted as "not real," are there any that you think should be real? Why?

3. After your teacher gave you the correct answers, were any of the real GMOs a surprise? Explain.

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GMO Card Sort Reflection Capture Sheet, Part 2

Directions

Sort your pile of "real" cards into organisms that were intentionally genetically changed to ones that were not intentionally changed, and answer questions 1 and 2. Have your teacher check your piles, and then answer question 3.

1. How did you define Genetically-Modified Organism (GMO) for this sort activity?

2. Were you unsure of how to sort any cards? Why?

3. Were any GMOs surprising to you? Why?

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GMO Card Sort Reflection Capture Sheet, Part 3

Directions

Sort your pile of "real" cards that were intentionally genetically changed into organisms you think should be made and ones you feel should not be made, then answer questions 1–2.

1. Which GMOs did you think should be created? Why?

2. Why should the other GMOs not have been created?

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CER Draft Capture Sheet

Directions
Look at the two sheets of information about similar products and answer the following questions based on your initial observations.

1. Which organisms did you decide to observe?

2. What do they have in common? Give at least three examples.

3. What is different about them? Give at least three examples.

Continues next page >

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CER Draft Capture Sheet

Continued

4. Why might there be differences between A and B?

5. Which of the two (A or B) do you think is a GMO?

6. What evidence do you have to support that claim? (This does not need to be in-depth, just what you are basing your claim off of at this point in time.)

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GMO Notes Capture Sheet

Directions
Read the FDA article "Science and History of GMOs and Other Food Modification Processes" and answer the following questions.

1. Based on your previous knowledge, what is selective breeding?

2. Based on the video, what is cross-breeding?

3. Based on the video, what are the two new ways to genetically modify crops?

4. Open the Timeline of *Genetic Modification in Modern Agriculture*. What are four things that surprised you or were of interest to you on the timeline?

   a.

   b.

   c.

   d.

Continues next page >

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GMO Notes Capture Sheet

Continued

5. What does GMO stand for? Explain what it means in your own words.

6. Summarize each step of the current GMO process for plants:

   a. Identify:

   b. Copy:

   c. Insert:

   d. Grow:

Continues next page >

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GMO Notes Capture Sheet

Continued

7. Summarize what you learned about genome editing and CRISPR from the last unit.

8. How do you think genome editing is helping to advance agriculture?

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PCR Results Sheet

Directions

Use the information from this sheet, along with the GMO vs Non-GMO Ad Sheets to complete the CER Draft Capture Sheet.

		Results	
		Organism A	Organism B
Corn	PCR test was run for the cry1Ab gene (from Bt bacteria), which encodes for the cry1Ab delta endotoxin protein. The protein Bt delta endotoxin kills Lepidoptera larvae, also known as the European corn borer. European corn borers are a type of moth that eat corn stalks and leaves during their larval stage. A European corn borer infestation is a hazard to crop yield (the amount of corn that is grown and can be sold). Genetically modified corn is therefore insect-resistant.	cry1Ab is Present	cry1Ab is Absent
Meat	PCR test was run for the LegH gene, which encodes for the soy leghemoglobin protein. Soy leghemoglobin is a flavor additive used in ground beef analogue products (plant-based ground beef alternatives). Consuming soy leghemoglobin starts a series of reactions that transform the amino acids, nucleotides, vitamins, and sugars naturally found in animal muscle tissue, into a compound that creates the flavor profile of meat.	LegH is Absent	LegH is Present
Apple	PCR test was run for the PPOa, PPOb, and PPOd genes, which encode for Polyphenol Oxidase proteins. Browning occurs when phenolic compounds are oxidised by the enzyme Polyphenol Oxidase (PPO), which causes brown pigments to be generated. The non-browning trait is given to an apple by silencing the PPO through RNA interference (RNAi), therefore preventing it from oxidising and browning. This results in an apple that retains its color, taste, flavor, and nutritional value even when damaged or cut.	PPOa is Absent PPOb is Absent PPOd is Absent	PPOa is Present PPOb is Present PPOd is Present
California Tomato	PCR test was run for the fs8.1. The exact protein that this encodes for is unknown, but it is believed to play a role in fruit shape. It makes the tomatoes hardier and more bountiful than conventional tomatoes. Its square-ish shape helps it to survive the bruising of mechanical harvesting and transport from field to cannery in huge glass fiber containers.	fs8.1 is Present	fs8.1 is Absent
Salmon	PCR test was run for the GH1 gene, which encodes for the Growth Hormone 1 protein. The added growth hormone gives the Atlantic salmon a rapid growth phenotype, meaning the fish will grow both bigger and faster. This allows more salmon to go to market faster, which means faster and greater profits. Improved metabolic efficiencies associated with low but sustained levels of growth hormone also allow the salmon to be grown in fish farms on land across the country.	GH1 is Present	GH1 is Absent

Continues next page >

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PCR Results Sheet

Continued

		Results	
		Organism A	Organism B
Rice	PCR test was run for the phytoene synthase gene, from daffodils which encodes β-carotene (a provitamin A carotenoid that the body can convert into Vitamin A). Vitamin A is an important nutrient for vision, growth, reproduction, cellular differentiation and proliferation, and the immune system. The addition of β-carotene does not change the life cycle or other nutritional value of the rice.	Phytoene Synthase Gene is Absent	Phytoene Synthase Gene is Present
Tomato	PCR test was run for the ySpdSyn gene, which encodes for the spermidine synthase protein. The spermidine synthase gene (ySpdSyn) comes from yeast. In tomatoes, it extends the post-harvest shelf life without preventing the ripening process. More significantly, the ySpdSyn fruits have reduced shriveling and decay, meaning tomatoes can be in the store longer without needing to be thrown away. This means grocery stores could have less profit loss because the tomatoes are more likely to be purchased instead of thrown away.	ySpdSyn is Present	ySpdSyn is Absent
Maize (corn)	PCR test was run for the Rabies virus G gene which encodes for the Antigen glycoproteins protein. Rabies virus G protein expressed in maize is able to provide protection against rabies. The G protein is used in various viral host vaccines but is now being developed in edible plant vaccines. This will allow livestock to eat the vaccine for rabies instead of needing another injection.	Rabies virus G is Present	Rabies virus G is Absent

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CER Final Capture Sheet

Directions

Use information from the PCR Results Sheet and the GMO vs Non-GMO Ad Sheets to complete this CER as a group.

All questions are informed by the Driving Question: Would you purchase the GMO?

Your Organism

Claim
I *would / would not (circle one)* buy product *A / B (circle one)* which is a GMO.

	Evidence *Evidence needs to support both parts of the claim statement. It should include data from information sheets, observations but not inferences, and data from the PCR lab.*	Reasoning *Each reasoning statement should explain why you would or would not buy a GMO product. You can connect your reasoning to knowledge you gained in this unit from labs, discussions, etc.*
1		
2		
3		
4		

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CER Final Capture Sheet

Directions

Use all the information you have learned from this lesson to complete this CER as an individual.

All questions are informed by the Driving Question: Would you purchase the GMO?

Your Organism

Claim
I *would / would not (circle one)* buy product *A / B (circle one)* which is a GMO.

	Evidence *Evidence needs to support both parts of the claim statement. It should include data from information sheets, observations but not inferences, and data from the PCR lab.*	**Reasoning** *Each reasoning statement should explain why you would or would not buy a GMO product. You can connect your reasoning to knowledge you gained in this unit from labs, discussions, etc.*
1		
2		
3		
4		