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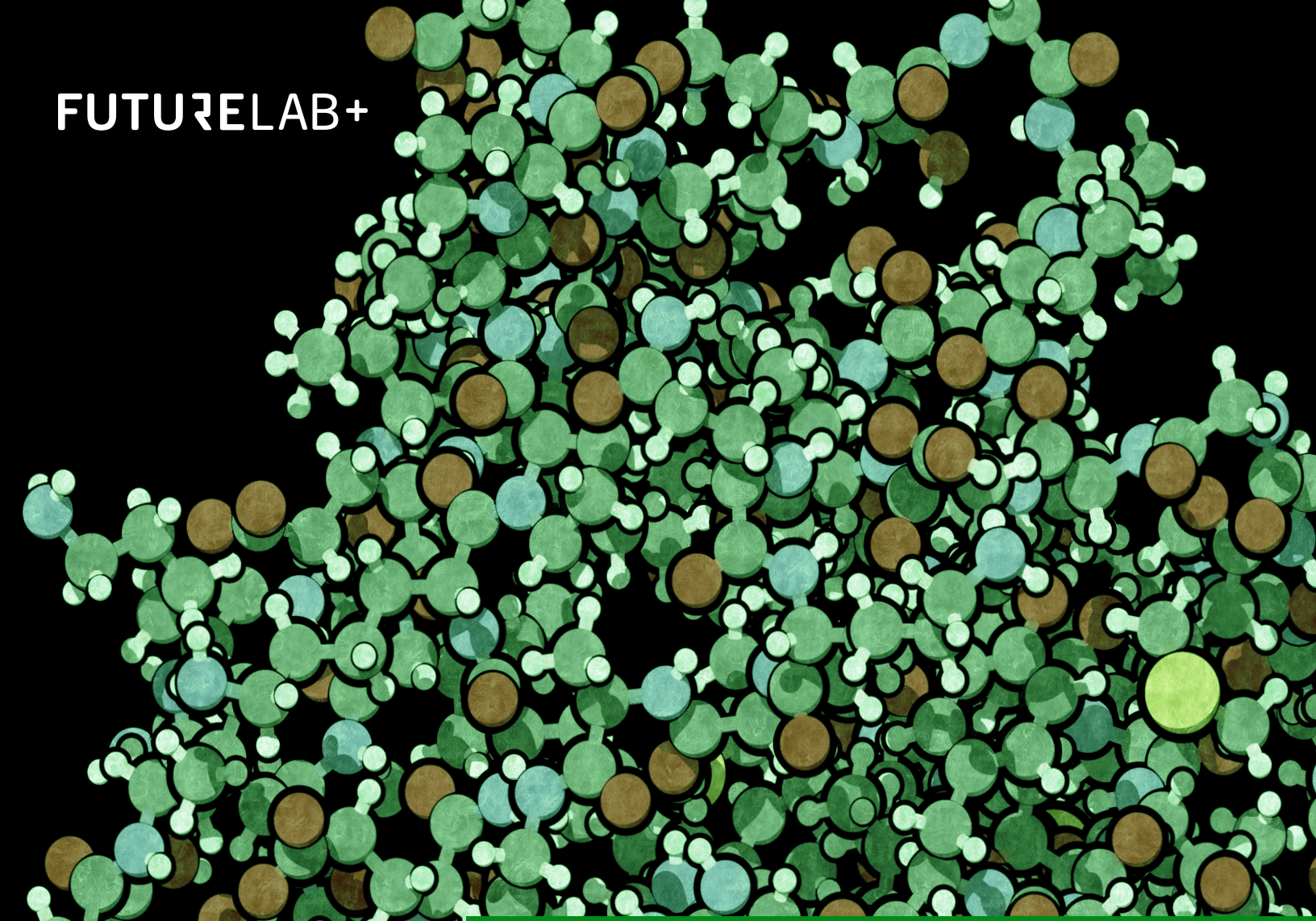

AG/ENVIRONMENTAL

Alternative Proteins

Golden Rice Case Study

Developed in partnership with:

Discovery Education and Ignited

In this Lesson Plan:

Print the **Teacher Section** →

Print the **Student Section** →

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

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

AG/ENVIRONMENTAL / ALTERNATIVE PROTEINS

Golden Rice Case Study

ACTIVITY DURATION

Four class sessions
(45–50 minutes each)

DRIVING QUESTION

How can GE technology help solve a community challenge?

ESSENTIAL QUESTIONS

How can we solve the public health crisis of malnutrition with genetic modification?

What genetic engineering techniques were practiced to produce Golden Rice?

What conversations are taking place among stakeholders involved in the production of Golden Rice?

OVERVIEW

Vitamin A, found in food products such as carrots, leafy greens, and eggs, is essential for maintaining eyesight and a healthy immune system. Despite being an avoidable illness, Vitamin A deficiency remains a severe public health problem in many countries that do not have easy access to foods rich in Vitamin A. Genetic engineering technology can help communities address nutritional deficits such as Vitamin A deficiency. Golden Rice is one well-known food product that is genetically modified for this purpose.

During this lesson, students will investigate Golden Rice as a case study into how GE technology can impact a community on a local level. Students will discover the product through case study files, dig deeper into their discovery by exploring the GE technology through a cultural lens, and then collaboratively illustrate how the product is manufactured and commercialized in a final flowchart artifact.

OBJECTIVES

Students will be able to:

Construct an explanation on how Golden Rice is used to solve a community problem.

Recognize key players and community impact of Golden Rice production.

Describe the GE technology used to make Golden Rice.

Illustrate and **communicate** Golden Rice production from farm to consumer.

Materials
Discover Golden Rice Capture Sheet
Case Files A
Day 1 Exit Ticket
Careers Highlight Capture Sheet
Case Files B
Knowledge Profiles Capture Sheet
Recap Assessment Capture Sheet
GE Product Production Pipeline Infographic
Manufacturing and Commercialization Flowchart Capture Sheet
Analysis of Other Group Work Capture Sheet
Golden Rice Case Study Rubric
Projector with Sound for Videos
Poster Board
Markers or Colored Pencils
Sticky Notes or Whiteboard

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 will be developing social-awareness as they practice empathy and compassion toward a community other than their own. Students will additionally be practicing relationship skills as they communicate the rice production process and discuss the impacts of this genetically modified crop with their peer groups.

CULTURALLY AND LINGUISTICALLY RESPONSIVE INSTRUCTION

Students will assess Golden Rice versus regular rice from a cultural lens. Filipino culture is integrated into the case study, as well as in a student reflection on how their own cultures and experiences connect to this topic.

ADVANCING INCLUSIVE RESEARCH

Students will investigate and discuss the disparity of communities that suffer from Vitamin A deficiency (VAD) despite it being an avoidable illness. They will reflect on how considering the needs of more diverse populations can lead to more equitable health outcomes. Students will also determine how genetic engineering can be utilized to help struggling communities obtain equitable access to foods rich in Vitamin A.

COMPUTATIONAL THINKING PRACTICES

Students will practice analyzing data that can help solve discipline-specific problems such as VAD. Additionally, students will collaborate within groups as they complete tasks around computing, including working in varying group roles, ensuring equitable workload distribution, and managing a project.

CONNECTION TO THE PRODUCT LIFE CYCLE

Students will be walking through the production pipeline throughout this lesson as they gain a deeper understanding of how Golden Rice is produced. Students will **discover** Golden Rice background information and the public health crisis of Vitamin A deficiency. Groups will also investigate the safety of Golden Rice, find out about the **manufacturing** of the product, and touch upon **commercialization** as they explore community values.

Have you ever wondered…

How has GE technology been used to solve a global and local health problem?

Vitamin A deficiency (VAD) is a global problem that can result in blindness and infant mortality. This community struggle could be solved by modifying rice, a common food staple in many developing countries. This global problem can be explored on a local level by investigating the impacts of Golden Rice on Filipino communities.

How can GE technology impact a community?

GE technology can create uncertainty in a community, especially if safety data are not clearly communicated. Students will explore safety regulations, economic impacts, and cultural impacts to address this question.

What is the life cycle of a GE product?

GE products go through a series of steps to become effective at solving a global or local community problem. From target genes and their alternative protein products to private companies that brand and market the product, much more is involved in the production and sale of GE products than meets the eye.

MAKE CONNECTIONS!

How does this connect to the larger unit storyline?

This case study on Golden Rice manufacturing and commercialization serves as an example of how GE technology can solve a global (or local to the Philippines) health crisis. This example and the investigative skills involved in the process will be used for the final website.

How does this connect to careers?

Sociologists assist diverse community members, solve social problems, and formulate public policy. Sociologists specialize in a range of social topics, such as education, public health, poverty, and race relations.

Plant and food scientists use chemistry, biology, and other sciences to research ways to improve agricultural product safety and quality.

Food science technicians collect food samples and conduct tests on food safety, food additives, and food containers to ensure they comply with established safety standards.

Economists collect and analyze data, research trends, and evaluate economic issues for resources, goods, and services.

How does this connect to our world?

The case study is focused on an issue that is considered global, as more than one country is facing the health crisis of Vitamin A deficiency. While it is global, it will be explored at a local level in the Philippines.

Day 1

LEARNING OUTCOMES

Students will be able to:

Discuss the components of proteins and fatty acids and their role within the cell.

Describe the GE technology used to make Golden Rice.

Construct an explanation on how Golden Rice is used to solve a community problem.

Procedure

Whole Group (20 minutes)

Teacher Note > *Prior to the start of this lesson, students should be seated in groups of four. Students will remain in these groups throughout the remainder of the unit and will complete the final novel GE product website together.*

1. Display the picture of regular rice and Golden Rice found on the *Discover Golden Rice Capture Sheet*. Ask students to independently answer the first two questions, making a claim about which type of rice seems genetically modified. Have students share their responses with a neighbor and then discuss as a class.

Teacher note > *As a possible extension to touch upon NGSS standards, review with students the biochemistry behind how atoms used to make sugar molecules are then used to build amino acids and thus, proteins. Discuss the purpose of proteins in a living organism and the role of fatty acids in the cell.*

2. Conduct an informal class vote on which product is genetically modified—do not tell students if they are correct at this point.

3. Display the Vitamin A Deficiency World Map found in the *Discover Golden Rice Capture Sheet*. Ask students to answer the reflection questions verbally.

4. Highlight the Philippines on the map. Ask students the following:
   - **a.** What do you know about the Philippines?
   - **b.** How might the climate compare to the climate in our community?
   - **c.** How might the culture compare to the culture in our community?

5. Show students this video introducing *Rice fortification and hidden hunger*. Discuss with students:
   - **a.** What problem is highlighted in the video?
   - **b.** What GE product is being produced?
   - **c.** What questions do you have about food fortification?

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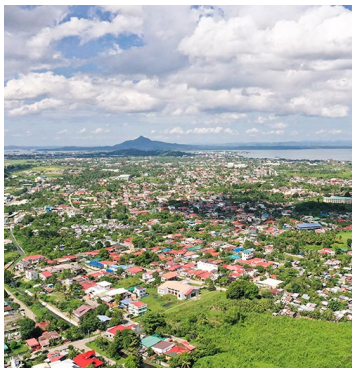
Day 1

Continued



Procedure

6 Introduce the specific biofortified food that will be highlighted this week in a way that works for your students. Options include showing an introductory video on Golden Rice, an introductory article such as portions of this *Good as Gold* article that highlight Golden Rice, or a student-friendly infographic containing key information that sparks an interest in Golden Rice.

7 Share with students that picture A on the *Discover Golden Rice Capture Sheet* was in fact genetically modified.

8 Explain to students that over the next few days they will be exploring this case study in depth, beginning with a "deep dive" into the GE technology used to develop this product and how it has impacted communities in the Philippines.

9 To prepare students for cultural competency, address misconceptions that may arise when exploring a community through a cultural lens by facilitating a student discussion on unconscious bias. For those who are not a part of the culture, it is important to be self-reflective when drawing conclusions.

a. Q: Do only poor families experience health struggles? How may the struggle between an impoverished and financially stable family differ?

A: Example response: Poverty does create more challenges, but these challenges can also impact people who are not impoverished. For example, Vitamin A deficiency can impact a wealthy family just as much as it can an impoverished family. Those living in poverty are considered more vulnerable.

b. Q: Unconscious biases are social stereotypes of a group of people in a way that is usually considered unfair. Everyone holds unconscious beliefs about various groups as we all tend to organize social worlds by categorizing. When exploring another culture, how might our experiences influence how we view the community?

A: Example response: As someone who is not in poverty, one may think a culture needs to be "saved" or is not capable of getting out of poverty, but the reality is much more complicated than this. Certain social constructs tend to keep families in poverty.

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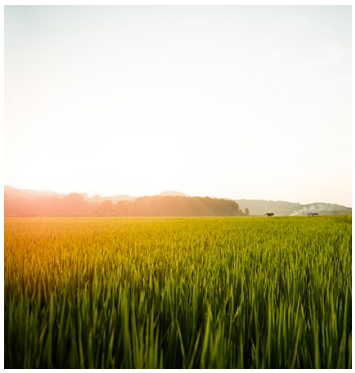
Day 1

Continued

Procedure



Small Group (20–25 minutes)	
1	Pass out student *Case Files A* to each group.
2	Have groups explore artifacts of Golden Rice and fill out the Discover Section of their *Discover Golden Rice Capture Sheet*. This can be done by dividing up the work among groups. Group members can then work together or research independently.

Teacher Note > *Encourage students to collaborate as they work through this section. At some point during this activity, they will need to educate the other group members on the information they have learned, and each individual student should be able to explain each of the four sections before the end of the class.*

Individual Work (2 minutes)

Pass out *Day 1 Exit Ticket* to check for student understanding.

Day 2

LEARNING OUTCOMES

Students will be able to:

Analyze necessary skills for applicable careers.

Create a knowledge profile using data on the impact of Golden Rice from the viewpoint of career professionals.

Integrate citizen viewpoints on Golden Rice and **develop** their own opinion.

Procedure

Small Group (10 minutes)

Assign each group a guiding question from the table in the Discover Section of the *Discover Golden Rice Capture Sheet*. Give each group two minutes to come up with a quick 30-second summary of what they learned. Have each group nominate a spokesperson and allow each group 30 seconds to recap their section aloud to the class.

Whole Group (5 minutes)

1. Describe the goal for today: to explore the Golden Rice case study from a cultural, safety, and economic perspective. There will be four research roles today: sociologist, plant and food scientist, food science technician, and economist.

2. Display the *Careers Highlight Capture Sheet* to the class and discuss how these careers connect with Golden Rice.

3. Ask students to divide these roles among their group members, then pass out the corresponding student handouts from *Case Files B* to those members.

Teacher Note > *Take a moment to encourage students to brainstorm soft skills and technical skills involved in these careers. This can be a long activity or a short activity, depending on time. A link is provided within the worksheet for students to obtain the information. Soft Skills That Are Highly Valued in Biotech Candidates has a good list.*

4. Share with students that the purpose of the activity today is to use the *Case Files B*, as well as any individual research findings, to create a profile of their knowledge through illustrations or descriptions.

Small Group (35 minutes)

1. Have groups explore artifacts of Golden Rice and fill out the *Knowledge Profiles Capture Sheet*. This can be done by dividing up the work among groups; group members can then share work together or research independently.

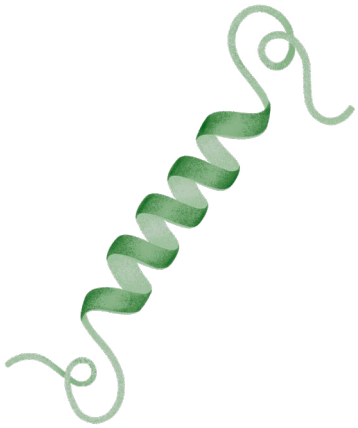
2. Ask students to turn in their capture sheets to check for understanding. These profiles can be displayed at the start of class the next day.

Day 3

LEARNING OUTCOMES

Students will be able to:

Illustrate and **communicate** Golden Rice production from farm to consumer.



Procedure

Whole Group (25 minutes)	
1	Assemble students' work from the previous day's activity into sections around the room, with the same careers grouped together (i.e., all sociologists grouped together). Facilitate a Gallery Walk and ask students to write questions they have on sticky notes as they walk around the room. (This can also be done with a large whiteboard.)
2	Ask students to retrieve their own work. Give time for students to share their findings with the rest of their group. Group members should record important notes on their own knowledge profile for future reference.
3	Pass out the *Recap Assessment Capture Sheet* to check for group and individual student understanding, as well as to encourage student reflection on how they connect to the case study on a cultural level.
4	Introduce the *GE Product Production Pipeline Infographic* to students and discuss the following:
	a. Is the production of GE products a fast or slow process? Include evidence in your response.
	b. What role does failure play in this process?
	c. Think about our Golden Rice case study. What stages of this production pipeline have we explored thus far? Use evidence in your explanation.
5	Inform students that assigned groups will be working together on the *Manufacturing and Commercialization Flowchart Capture Sheet* to produce one final product. Students can either create their product on the handout or on a poster board.
6	Describe the goal of the assignment: to illustrate Golden Rice production from farm to consumer.

Teacher Note > *There will be more time on Day 4 to complete this flowchart. Emphasize to students that this infographic does not discuss Golden Rice specifically, but can be used as a model for how Golden Rice could be produced from farm to consumer. This activity will require synthesizing information acquired from earlier in the lesson, as well as Internet research, to complete a flowchart of Golden Rice production. The skills developed in the design of this flowchart will be used for the final product in this unit as students will design a novel GE product concept and brainstorm possible production cycles.*

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Day 3

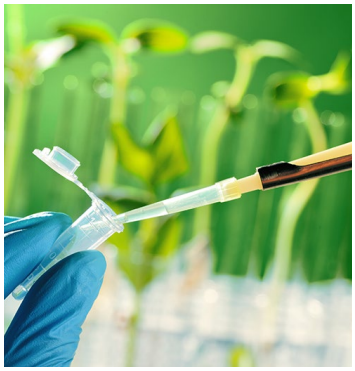
Continued

Procedure

7 Define the words *manufacture* and *commercialization* (*manufacture*: the production of products; *commercialization*: the process of introducing a new product into the market).

Small Group (25 minutes)

Allow students time to work and encourage them to use both the *GE Product Production Pipeline Infographic* provided and their own research to create their flowchart product.



Day 4

LEARNING OUTCOMES

Students will be able to:

Illustrate and **communicate** Golden Rice production from farm to consumer.

Procedure

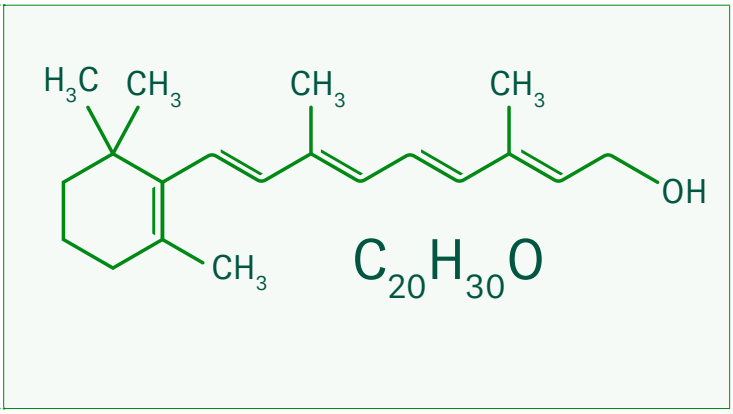
Small Group (30 minutes)

Allow students time to work and encourage them to use both the artifacts provided and their own research to create their product. Remind them of the requirements of the product (listed at the top of the *Manufacturing and Commercialization Flowchart Capture Sheet*).

Whole Group (20 minutes)

1	Have students display their products at their work stations or work areas.
2	Hand out the *Analysis of Other Group Work Capture Sheet*. Have groups rotate to at least three other stations and brainstorm answers to the Rounds 1, 2 and 3 questions, as a group. Have students write answers to Round 4 questions as a group. Each round should take 5 minutes.
3	Take a class vote at the very end on whether Golden Rice is the best solution to the problem of Vitamin A deficiency.
4	Display a list of careers discussed in this lesson on a whiteboard or other available means. These careers will be explored in more detail in the next lesson.
5	Have students gather all handouts to add to their unit portfolio. Collect these and assess work using the *Golden Rice Case Study Rubric*. Return work to students at the start of next week.

Vitamin A



National Standards

Next Generation Science Standards

LS1.C Organization for Matter and Energy Flow in Organisms

The sugar molecules thus formed contain carbon, hydrogen, and oxygen: their hydrocarbon backbones are used to make amino acids and other carbon-based molecules that can be assembled into larger molecules (such as proteins or DNA), used for example to form new cells.

Science and Engineering Practices

Developing and Using Models

Develop a complex model that allows for manipulation and testing of a proposed process or system.

Career and Technical Education (CTE)

A1.1

Use data to explain how biotechnology fields such as pharmaceuticals, agriculture, diagnostics, industrial products, instrumentation, and research and development are impacting human life.

A1.6

Explore and outline the various science and non-science fields and careers associated with biotechnology.

A2.4

Understand the critical need for ethical policies and procedures for institutions engaged in biotechnology research and product development.

A5.1

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

A9.1

Describe the major steps of a product's move through a company's product pipeline.

3.4

Research the scope of career opportunities available and the requirements for education, training, certification, and licensure.

4.1

Use electronic reference materials to gather information and produce products and services.

Discover Golden Rice Capture Sheet

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

Directions
Answer the questions below to discover some information about Golden Rice.

1. Review the graphic below and make a claim about which type of rice in the photos below, A or B, is genetically modified.

Picture A is genetically modified (answers may vary based on student hypothesis).

A	B	Comparisons
		**Proximates, Fibers and Minerals** No statistically significant difference **Fatty acids** Within combined literature range **Vitamins** No statistically significant difference **Anti-nutrients** No statistically significant difference **Beta carotene (All-trans-beta-carotene)** A) 1.96–8.31 ppm B) Below limits of quantification

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Discover Golden Rice Capture Sheet

ANSWER KEY **Do not share with students**

Continued

2. Provide two pieces of evidence for your claim by stating:
    a. observational differences between the two types of rice,
    b. differences in nutritional value, or
    c. your own experiences with rice.

Answers may vary. Example response: An observational difference is that due to Picture A's yellow color, it is most likely genetically modified. Normal rice is often white. Another detail that suggests that Picture A is genetically modified is that the Golden Rice has more beta carotene (1.96–7.31ppm) as opposed to the white rice.

3. What do fatty acids and proteins do for the body? Conduct online research for help.

Fatty acids are building blocks of fat in our body. They provide energy and make up the cell wall. Proteins are essential for enzymes and building structures in the body such as muscle, bone, etc.

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Discover Golden Rice Capture Sheet

ANSWER KEY **Do not share with students**

Continued

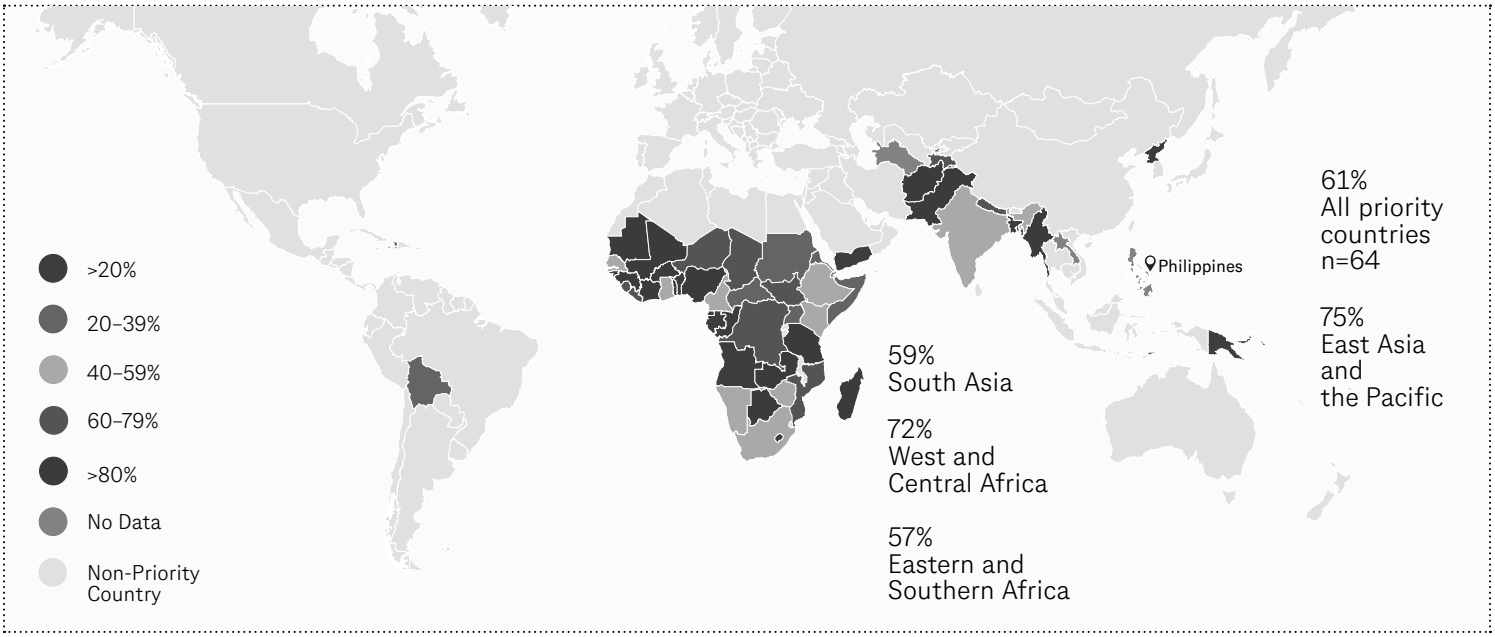
4. Read the text, study the diagram, and answer the question on the following page.

The Community Struggle

In adults, and especially pregnant people, *Vitamin A deficiency* (VAD) can cause night blindness (a condition in which it is difficult to see in low levels of light) or even total blindness. In children, VAD is the leading cause of preventable childhood blindness. VAD in children also diminishes the ability to fight infections, and so it increases the risk from common illnesses, such as diarrhea. According to the World Health Organization, VAD affects about one third of preschool children—that is an estimated 250 million children, mostly in low-income countries. VAD causes about 250,000 to 500,000 malnourished children to go blind each year, around half of whom die within a year. Regular supplements of Vitamin A is a proven intervention that reduces mortality by 12 to 24 percent.

East Asia and the Pacific achieved the highest two-dose coverage with Vitamin A supplements of all regions in 2018

Percentage of children aged 6–59 months that received two high-dose Vitamin A supplements



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Discover Golden Rice Capture Sheet

ANSWER KEY **Do not share with students**

Continued

5. Make a claim about the health crisis that will be explored in this case study. Be as detailed as possible and write in your own words.

Answers may vary. Example response: The Vitamin A deficiency health crisis heavily affects children in the Eastern Hemisphere and can be resolved by providing youth with Vitamin A supplements.

6. What part of the world is most impacted by this health crisis? Include data from the graph above in your response.

Answers may vary. Example response: The Eastern Hemisphere is significantly impacted by this health crisis, specifically third-world countries in Africa and Asia.

7. Brainstorm: Are people in the United States impacted by VAD or vitamin deficiency in general? Yes or No?

Answers will be yes or no.

8. Explore CDC's *A comprehensive biochemical assessment of the nutrition status of the U.S. population* to make a claim about vitamin deficiency in the United States:

Answers will vary. Below is an example.

Claim
People in the United States are impacted by vitamin deficiency.
Evidence
State data from graph in infographic.

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Discover Golden Rice Capture Sheet

ANSWER KEY **Do not share with students**

Continued

9. Discover. Use research artifacts provided by your teacher to explore more about Golden Rice.

	Guiding Question	Your Answer
A	What is Golden Rice, when was it developed, and who contributed to developing it? Use Artifact 1 from Case Files A to answer this.	Golden Rice is a genetically modified form of rice which alternatively produces beta carotene, which further becomes Vitamin A when metabolized in humans. It was engineered in the 1990s by Ingo Potrykus and Peter Beyer.
B	Summarize the genetic engineering process used to make Golden Rice from *Erwinia bacteria* to rice product. Be sure to mention the alternative protein product. Use Artifacts 1 and 2 from Case Files A to answer this.	— Three genes are isolated from a daffodil plant and *Erwinia bacteria*. These genes produce a protein product that allows the rice to produce beta carotene (and in turn, Vitamin A). — The isolated genes, along with promoters that activate the genes, are inserted into plasmids of *Agrobacterium*. — *Agrobacterium* are put into a petri dish with rice embryos and "infect" the rice with the genes that will produce beta carotene. — The rice plants are crossed with locally-grown rice to ensure the transgenic Golden Rice plant can grow under local conditions.

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Discover Golden Rice Capture Sheet

ANSWER KEY **Do not share with students**

Continued

	Guiding Question	Your Answer
C	What is Vitamin A deficiency? Describe why it is prominent in the Philippines using data from the Top 20 food chart. Use Artifact 3 from Case Files A to answer this.	Vitamin A deficiency is a serious problem affecting many people in the developing world. This condition can cause many problems in the human body, including blindness or acute eye symptoms, and a weakening of the immune system. In addition, VAD aggravates conditions in pregnant and lactating women. This deficiency is prominent in the Philippines because the most consumed food is rice, meaning that most of the food being consumed has no Vitamin A, leading to the deficiency.
D	What potential does Golden Rice have to solve Vitamin A deficiency (VAD)? Explore Artifact 4 to figure out if people in this community eat enough rice to prevent VAD. Is Golden Rice currently available to the Filipino community? Use Artifacts 3 and 4 from Case Files A to answer this.	Golden Rice has vast potential to solve VAD. It is estimated that 40 grams of rice for children and 100 grams of rice for adults is enough to combat VAD. In the Philippines, children consume an average of 76.8 grams of rice a day, which exceeds the amount of Golden Rice needed to combat VAD. Golden Rice is not currently available in the Philippines.

Day 1 Exit Ticket

ANSWER KEY **Do not share with students**

Directions
Answer the questions that follow based on your readings and research.

1. What agricultural product is being explored during this case study? How has it been genetically modified?

Rice is the agricultural product being explored during this case study. It has been genetically modified by using three genes (two from a daffodil and one from bacteria).

2. What health crisis inspired the development of Golden Rice? What impacts does the health crisis have on children and adults?

Vitamin A Deficiency (VAD); not having enough Vitamin A in children can cause blindness and increased susceptibility to disease. In adult women, death during childbirth can be a consequence of VAD.

3. What GE technology was used to make Golden Rice? Summarize the process and include the alternative protein product in your response.

Agrobacterium was used to "infect" the plant embryo with three isolated genes that produce beta carotene, which is metabolized into Vitamin A.

4. CONNECT!
   a. What experience do you have, if any, with vitamin deficiencies and access to nutritious food?

Answers will vary.

   b. What experience do you have, if any, with Filipino culture?

Answers will vary.

   c. What typical foods do you eat on a daily basis?

Answers will vary.

Knowledge Profiles Capture Sheet

ANSWER KEY **Do not share with students**

Sociologist: Profile of the Philippines from a Social Lens

Directions
Using the provided artifacts, illustrate or describe answers to the following prompts. Use Artifacts 7, 8 and 9 from Case Files B to answer these questions.

1. What is the most consumed crop in the Philippines?

The most consumed crop in the Philippines is rice.

2. What does rice mean to the Filipino community?

Rice holds a lot of symbolic value for the Filipino community. For example, in weddings, rice is thrown over the couple, the couple is united hand in hand over raw rice, and the couple is advised to eat sticky rice before entering the house or reception area to bless the devotion in the marriage. Furthermore, rice is a socioeconomic symbol. Households in poor areas can be distinguished by rice pots and rice is a staple of holidays, festivals, and almost every Filipino meal regardless of social class.

3. Which citizen spotlight did you connect with the most and why?

Answers will vary.

4. Describe wealth disparities in the Philippines; do all Filipinos have access to healthcare, education, and nutritious food?

There are many wealth disparities in the Philippines. In education, Filipino children are suffering from the low investment in education, leading to outdated teaching methods, an underdevelopment of social and emotional skills, and poor facilities due to a lack of clean water. This disparity heightens when taking into account indigenous and disabled children. There are also inequities in healthcare, with private healthcare facilities being more equipped and supplied than public ones, even though healthcare generally throughout the Philippines is of a high standard.

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Knowledge Profiles Capture Sheet

ANSWER KEY **Do not share with students**

Plant and Food Scientist: Profile of Golden Rice from a farming/production lens

Directions
Using the provided artifacts, illustrate or describe answers to the following prompts. Use Artifact 10 and the two videos from Case Files B to answer these questions.

1. In the space below, describe how rice is grown. Use the artifact provided to formulate your response.

Rice is grown through a series of stages. The seeds are selected to maximize crop emergence and reduce replanting while the land is prepared for the rice to be planted. Then the rice crop is established by transplanting or direct seeding. Due to the crop's sensitivity to water shortages, water is managed during growth, along with nutrient management and an attention to crop health. Finally, the crop is harvested either manually or mechanically.

2. In which climate does rice grow? Describe the environment.

Rice can grow in many climates, from warm and dry climates in Saudi Arabia to colder and wetter environments such as Myanmar's Arakan Coast. However, rice is primarily grown in the environments of South, Southeast, and East Asia, where there are alternating wet and dry seasonal cycles and a bounty of water in major rivers.

3. Describe the anatomy of rice. This is discussed in the second video resource.

Rice crop is made of rice bran, white rice, hull, and rice germ.

4. Describe a *Filipino rice farmer* as discussed in this video. You can also include information from the *first-hand account of rice production.*

Eight average years of schooling; five family members on average; about 2,000 United States dollars made per year; 89 percent are male and rely on farming for income; almost half attend farming seminars. (Other responses may be included.)

5. How many species of rice are there world-wide? You may need to do your own research on this!

There are 40,000 types of rice in the world.

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Knowledge Profiles Capture Sheet

ANSWER KEY **Do not share with students**

Food Science Technician: Describe the safety testing of Golden Rice.

Directions
Using the provided artifacts, illustrate or describe answers to the following prompts. Use Artifact 11 from Case Files B to answer these questions.

1. What safety testing has been done with Golden Rice? Summarize.

Example response: The safety testing done with Golden Rice includes an in-depth investigation on the endosperm carotenoid biosynthetic pathway modification (contributes to the golden color of the rice), gene expression profiling of thousands of genes to show any unexpected changes in expression material, testing on allergenic potential using bioinformatic analysis of transgene proteins, taste trials to detect taste differences to the parent material, and tests on beta carotene bioavailability and bioconversion to retinol.

2. What key things do food science technicians look for in regards to safety? What would be some red flags that would result in a STOP in production?

Example response: The key things food science technicians look for in regards to safety are the potentially harmful side effects that come with consumption and resulting changes in the body.

3. Why is safety testing important in GE product production?

Example response: Safety testing is important in GE product production because of the potential risks that new products can cause to humans and animals. Testing identifies any unwanted effects of genetically modified products that need to be resolved.

Knowledge Profiles Capture Sheet

ANSWER KEY **Do not share with students**

Economist: Profile of Golden Rice from an economic lens.

Directions
Using the provided artifacts, illustrate or describe answers to the following prompts. Use Artifact 12 from Case Files B to answer these questions.

1. Where does the profit made from selling Golden Rice go? Back to the community, private companies, etc.?

While many companies have allowed access to Golden Rice for humanitarian use, the private company Syngenta is the sole owner of the Golden Rice commercial rights and arguably holds a monopoly over Golden Rice in the market.

2. How does the cost of Golden Rice compare to regular rice?

The cost of Golden Rice has a high fee which puts it at a disadvantage as a product in a competitive market.

3. What are some economic advantages and disadvantages of Golden Rice?

Some economic advantages of Golden Rice include the widening of the market of GE products which are beneficial to the development of new markets and economic growth. Also, the most obvious economic advantage of Golden Rice is that it can feed and nourish more people, leading to a larger workforce. An economic disadvantage of Golden Rice is that the cost of production, maintenance, and distribution is too expensive for developing countries that need it. First-world and developed countries can afford the product, but they have no market for Golden Rice. Another economic disadvantage of Golden Rice is that it encourages monopolistic behavior as one company, Syngenta, essentially holds all the rights to the product.

Recap Assessment Capture Sheet

ANSWER KEY **Do not share with students**

Directions
Answer these questions to check your understanding.

1. What are two things you found interesting in the *Knowledge Profiles Capture Sheet* you just explored?

Answers will vary.

Example response: I found the value and symbolism of rice in Asian cultures, specifically in the Philippines, quite interesting as it extends past the immediate meal and there is a great value the crop holds in festivals, traditions, holidays, etc. Another interesting point is the variety of climates and environments where rice can grow. It can thrive at different temperatures, levels of precipitation, and levels of sunlight.

2. What pictures or topics resonated with you the most and were most interesting?

Answers will vary.

Example response: I believe the topic that resonated most with me was how profound Vitamin A deficiency is in the Eastern Hemisphere, despite there being many solutions to resolve the problem. The chart showing Vitamin A deficiency as a public health crisis was both interesting and shocking.

3. What food or crop (such as rice, corn, taro, tea, etc.) do you connect to on a cultural level? In other words, what food do you think of when you think of family or home?

Answers will vary.

Manufacturing and Commercialization Flowchart Capture Sheet

ANSWER KEY **Do not share with students**

Directions

Answer the questions that follow based on your readings and research to illustrate the production of Golden Rice, from farm to consumer. Using the next page or a poster board, be sure to:

1	Include the title: Manufacturing And Commercialization of Golden Rice.
2	Create a flowchart that illustrates and describes in detail how Golden Rice is manufactured and commercialized.
3	Start the process with GE technology/agricultural production and end with consumption of rice by at-risk communities.
4	List and highlight any professions or careers that come in contact with the GE product along the way.
5	List and highlight any big businesses that may profit from the production of Golden Rice along the way.
6	Illustrate or describe how Golden Rice could be branded or marketed at the end of your illustration.

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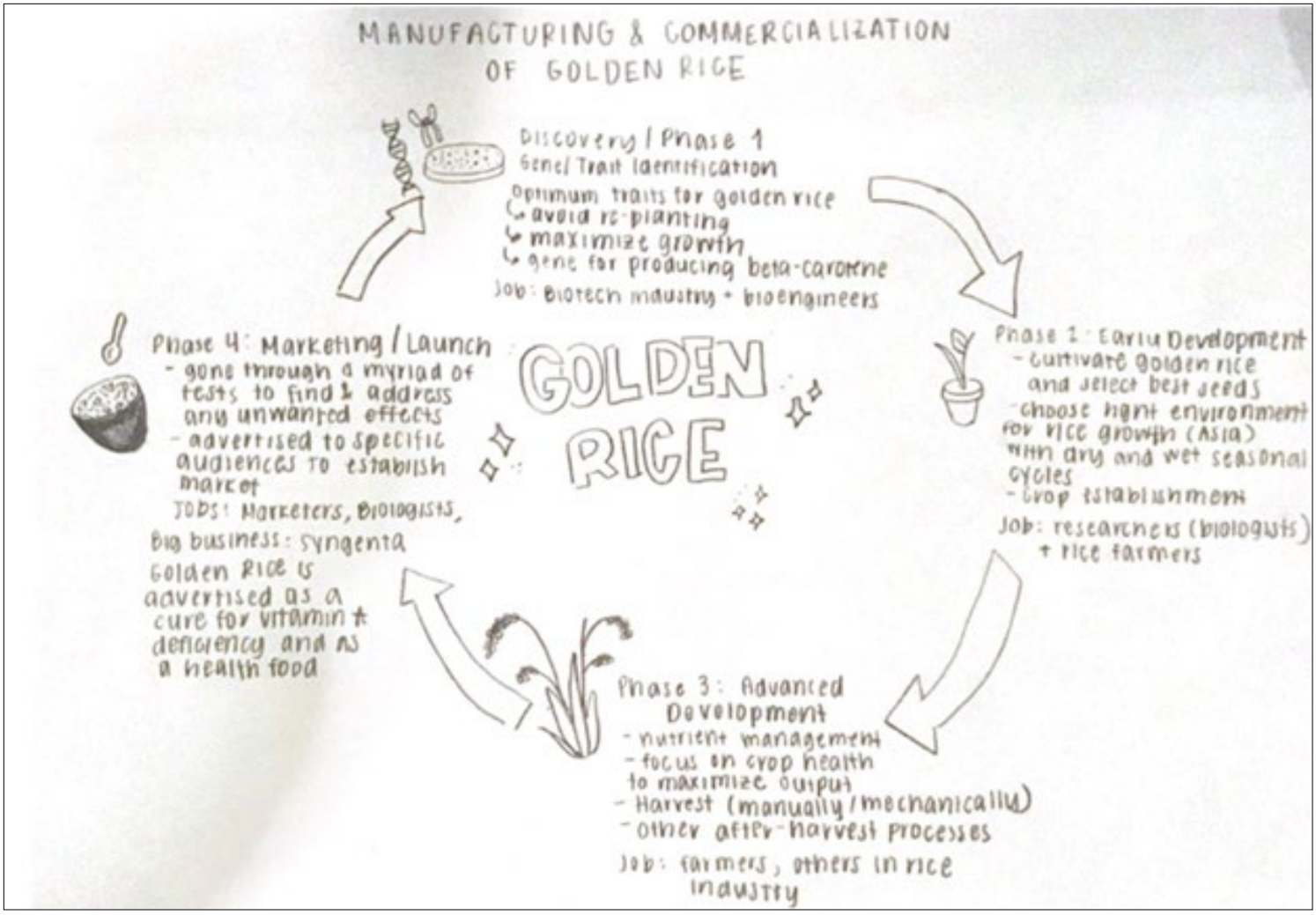
Manufacturing and Commercialization Flowchart Capture Sheet

ANSWER KEY **Do not share with students**

Continued

Below is an example of Student Flowchart.



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Discover Golden Rice Capture Sheet

Directions
Answer the questions below to discover some information about Golden Rice.

1. Review the graphic below and make a claim about which type of rice in the photos below, A or B, is genetically modified.

A	B	Comparisons
		**Proximates, Fibers and Minerals** No statistically significant difference **Fatty acids** Within combined literature range **Vitamins** No statistically significant difference **Anti-nutrients** No statistically significant difference **Beta carotene (All-trans-beta-carotene)** A) 1.96–8.31 ppm B) Below limits of quantification

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Discover Golden Rice Capture Sheet

Continued

2. Provide two pieces of evidence for your claim by stating:
   a. observational differences between the two types of rice,
   b. differences in nutritional value, or
   c. your own experiences with rice.

3. What do fatty acids and proteins do for the body? Conduct online research for help.

Continues next page >

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Discover Golden Rice Capture Sheet

Continued

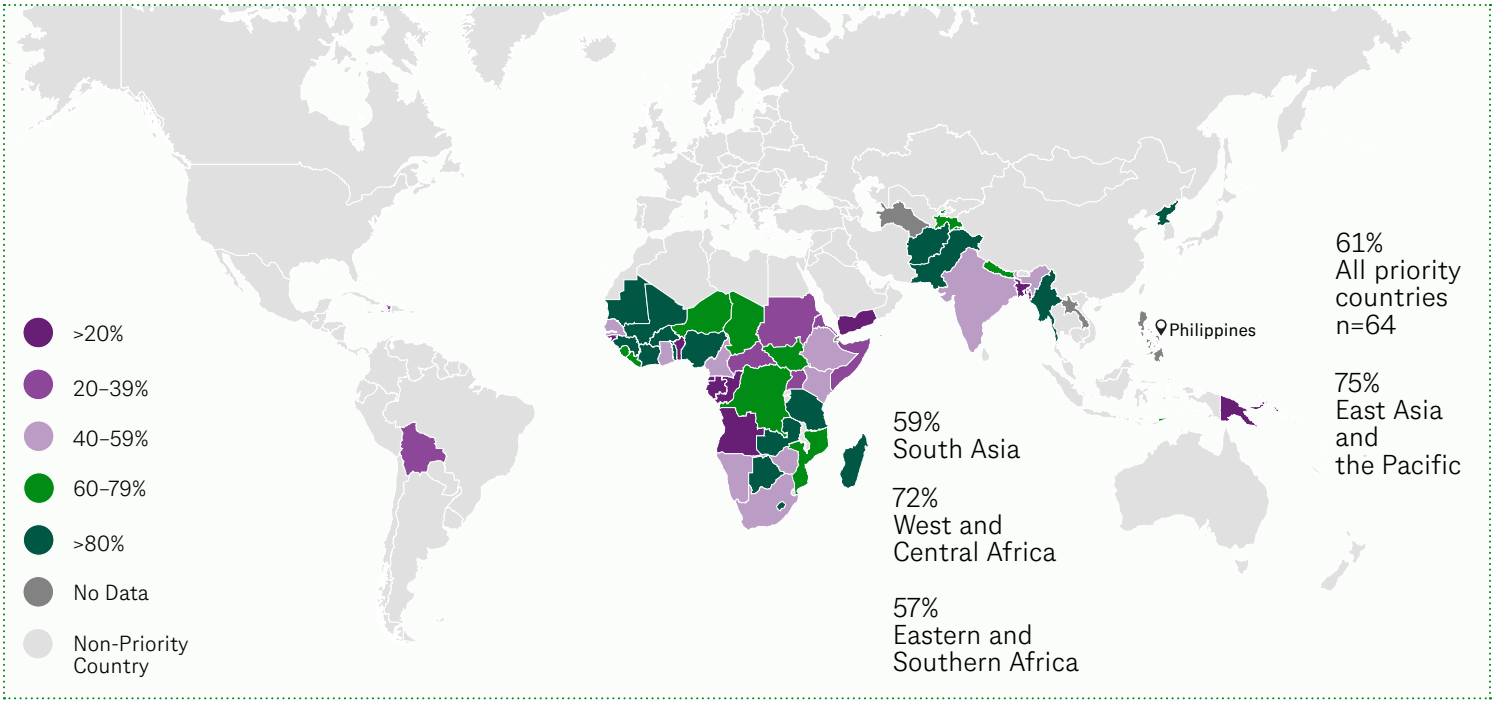
4. Read the text, study the diagram, and answer the question on the following page.

The Community Struggle

In adults, and especially pregnant people, *Vitamin A deficiency* (VAD) can cause night blindness (a condition in which it is difficult to see in low levels of light) or even total blindness. In children, VAD is the leading cause of preventable childhood blindness. VAD in children also diminishes the ability to fight infections, and so it increases the risk from common illnesses, such as diarrhea. According to the World Health Organization, VAD affects about one third of preschool children—that is an estimated 250 million children, mostly in low-income countries. VAD causes about 250,000 to 500,000 malnourished children to go blind each year, around half of whom die within a year. Regular supplements of Vitamin A is a proven intervention that reduces mortality by 12 to 24 percent.

East Asia and the Pacific achieved the highest two-dose coverage with Vitamin A supplements of all regions in 2018

Percentage of children aged 6–59 months that received two high-dose Vitamin A supplements



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Discover Golden Rice Capture Sheet

Continued

5. Make a claim about the health crisis that will be explored in this case study. Be as detailed as possible and write in your own words.

6. What part of the world is most impacted by this health crisis? Include data from the graph above in your response.

7. Brainstorm: Are people in the United States impacted by VAD or vitamin deficiency in general? Yes or No?

8. Explore CDC's *A comprehensive biochemical assessment of the nutrition status of the U.S. population* to make a claim about vitamin deficiency in the United States:

Claim

Evidence

Continues next page >

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Discover Golden Rice Capture Sheet

Continued

9. Discover. Use research artifacts provided by your teacher to explore more about Golden Rice.

	Guiding Question	Your Answer
A	What is Golden Rice, when was it developed, and who contributed to developing it? Use Artifact 1 from Case Files A to answer this.	
B	Summarize the genetic engineering process used to make Golden Rice from *Erwinia bacteria* to rice product. Be sure to mention the alternative protein product. Use Artifacts 1 and 2 from Case Files A to answer this.	

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Discover Golden Rice Capture Sheet

Continued

	Guiding Question	Your Answer
C	**What is Vitamin A deficiency?** Describe why it is prominent in the Philippines using data from the Top 20 food chart. Use Artifact 3 from Case Files A to answer this.	
D	**What potential does Golden Rice have to solve Vitamin A deficiency (VAD)?** Explore Artifact 4 to figure out if people in this community eat enough rice to prevent VAD. Is Golden Rice currently available to the Filipino community? Use Artifacts 3 and 4 from Case Files A to answer this.	

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Case Files A

Directions
Review the artifacts below to help formulate responses to Guiding Questions.

Artifact 1

Resource for Guiding Questions A and B

Source: *Golden Rice*, The Embryo Project Encyclopedia, 2013

Golden Rice was engineered from normal rice by Ingo Potrykus and Peter Beyer in the 1990s to help improve human health. Golden Rice has an engineered multi-gene biochemical pathway in its genome. This pathway produces beta carotene, a molecule that becomes Vitamin A when metabolized by humans. The scientists and their collaborators first succeeded in expressing beta carotene in rice in 1999, and they published the results in 2000. Since then, scientists have improved Golden Rice through laboratory and field trials, but as of 2013 no countries have grown it commercially. Golden Rice is a technology that intersects scientific and ethical debates that extend beyond a grain of rice.

Golden Rice is named for its golden color, which is caused by beta carotene (β-carotene). Normal rice does not express beta carotene in the starchy and biggest part of the rice seed, which is usually an off-white color. Beta carotene is part of a class of molecules called carotenoids, —one of hundreds that plants naturally produce—and it has a yellow-orange hue. Carotenoids are essential nutrients for humans because they are precursors to molecules needed in metabolism. The human body transforms beta carotene, also known as pro-Vitamin A, into Vitamin A, which is necessary to produce retinol and retinoic acid. When people lack access to foods containing beta carotene, because they eat mostly cereal crops such as rice, wheat, or sorghum, they are at risk of blindness and disease.

The creation of much plant biotechnology involves at least three steps: 1) researchers transfer related genes into the plant embryos; 2) the embryos incorporate the new genes into their DNA, produce the desired proteins, and grow and produce seeds; and 3) the offspring (which is known as successful heritability of the new genes modified plants) pass on the inserted genes to their offspring. Potrykus was an early proponent of scientific rigor in biotechnology; maintaining that scientists must show that the engineered plants pass all three steps. In the development of Golden Rice, there was one further step: researchers had to get all three of the inserted genes to work in concert. By coordinating the different genes, rice endosperm can create beta carotene.

Because no one had previously successfully expressed three genes in a food crop, Potrykus' lab attempted multiple methods for the transformation. The first step was to insert the genes into the rice embryo through particle bombardment or bacterial transfer. Potrykus' lab used an Agrobacterium-mediated transformation, where engineered bacteria inserted its DNA into the targeted rice plant embryos. This DNA contained all three genes—phytoene synthase (protein from psy gene, from daffodil), phytoene desaturase (protein from crtI gene from bacteria), and lycopene beta-cyclase (protein from lcy gene, from daffodil). Scientists also inserted other pieces of DNA that the genes needed to function in the cell, and they inserted marker genes to help them track the inserted DNA. Then the scientists grew, selected, and tested the embryos for beta carotene. When full-grown, the rice plants produced and stored beta carotene in their starch. The resulting paper in 2000, "Engineering the Pro-Vitamin A (beta carotene) Biosynthetic Pathway into (CarotenoidFree) Rice Endosperm," had more than 1,300 citations as of 2013. Since the initial experiments with rice, scientists have engineered other crops to produce beta carotene using different biochemical pathways, including maize and potato.

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Case Files A

Continued

Rather than commercializing their invention, the inventors, especially Potrykus, worked to legally secure Golden Rice as a humanitarian project. They licensed Golden Rice to Syngenta, a biopharmaceutical company headquartered in Basel, Switzerland. Potrykus and Beyer then established a "Golden Rice Humanitarian Board" to oversee the development of the technology and grant noncommercial licenses to public research institutes. These national and international research organizations would adapt Golden Rice to local environmental and climate conditions. The International Rice Research Institute (IRRI) gained a license for non-commercial use from the Golden Rice Project in 2001, aiming to spread the use of Golden Rice throughout Asia. The Golden Rice Humanitarian Board oversees that these research institutes can acquire their licenses at low costs and in short periods to better promote the development of Golden Rice.

As of 2013, tests of Golden Rice remained in field trials. IRRI, partnered with Helen Keller International, plans to introduce Golden Rice in Bangladesh and in the Philippines by crossing it with local, high-yielding rice varieties. While IRRI has participated in the Golden Rice Project nearly since its invention, Helen Keller International, headquartered in New York City joined the project in 2011 to support the public health benefits of Vitamin A, which can prevent blindness. In the United States, the Rockefeller Foundation, the United States Agency for International Development, and the Bill & Melinda Gates Foundation supported the Golden Rice Project at IRRI. The Bill & Melinda Gates Foundation, headquartered in Seattle, Washington, became a supporter of the Golden Rice Project in 2011. Furthermore, the government of Bangladesh approved field trials of Golden Rice, and in 2012 estimated that varieties would be available for consumption by 2015.

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Case Files A

Continued

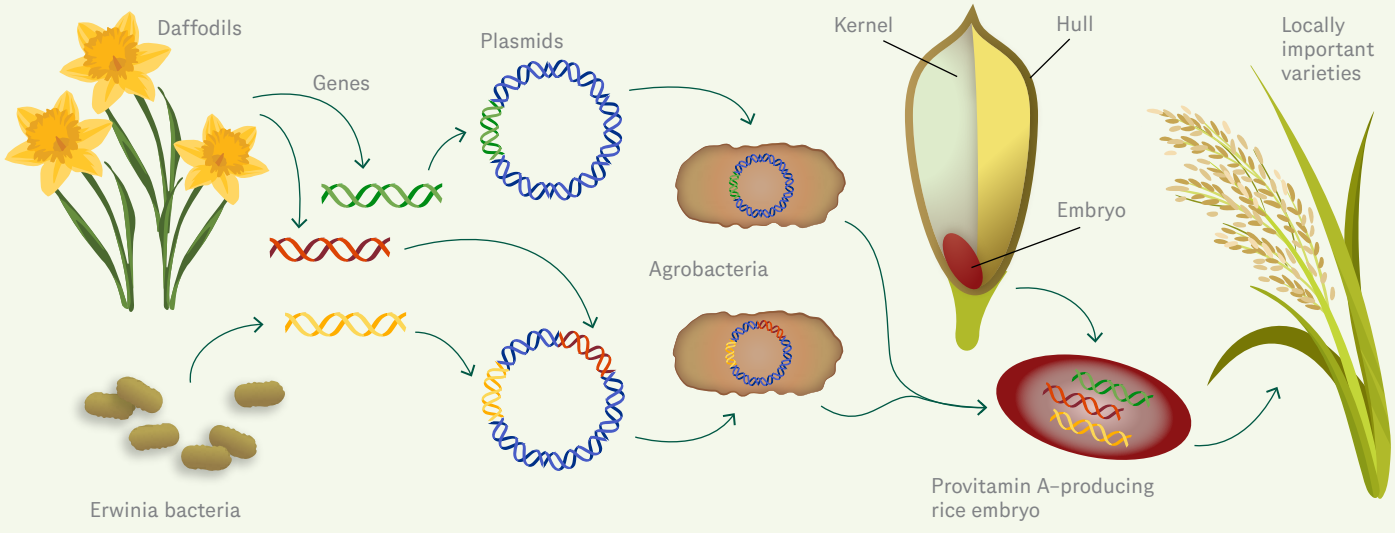
Artifact 2

Resource for Guiding Questions A and B.

Review The Golden Rice Technology infographic demonstrating the gene editing process.

Source: *The Golden Rice Technology*, International Service for the Acquisition of Agri-biotech Applications, 2006

1	2	3	4
			
The genes that give Golden Rice its ability to make beta carotene in its endosperm (the interior of the kernel) come from daffodils and a bacterium called *Erwinia uredovora*.	These genes, along with promoters (segments of DNA that activate genes), are inserted into plasmids (small loops of DNA) that occur inside a species of bacterium known as *Agrobacterium tumefaciens*.	These agrobacteria are then added to a Petri dish containing rice embryos. As they "infect" the embryos, they also transfer the genes that encode the instructions for making beta carotene.	The transgenic rice plants must now be crossed with strains of rice that are grown locally and are suited to a particular region's climate and growing conditions.



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Case Files A

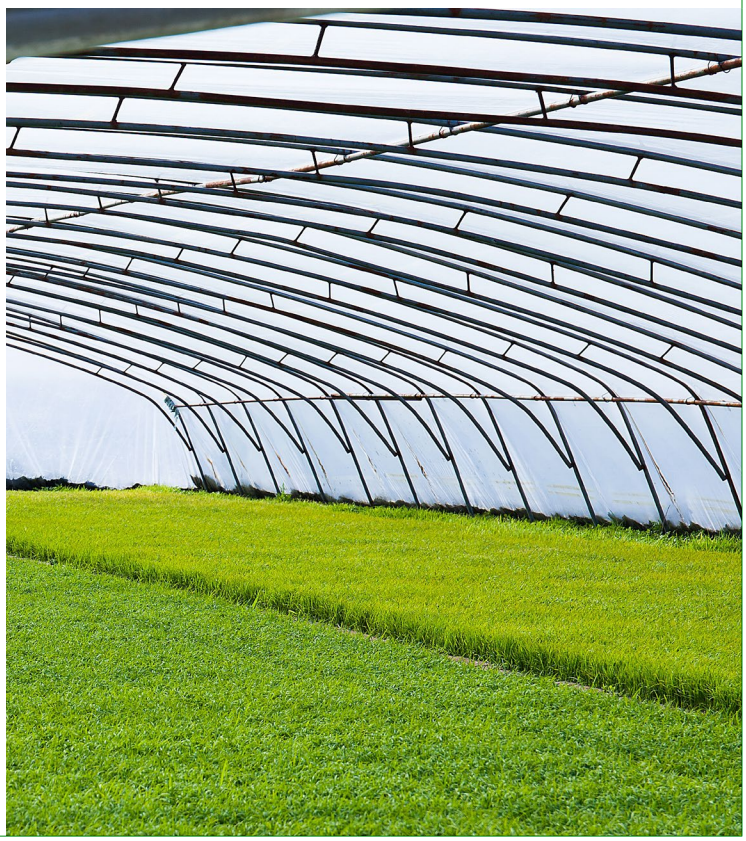
Continued

Artifact 3

Resource for Guiding Question C.

Source: *Vitamin A Deficiency Disorders in Children and Women*, from the journal Food and Nutrition Bulletin, 2003

Vitamin A deficiency (VAD) is a major problem in large parts of the developing world. An estimated 250,000–500,000 VA-deficient children go blind every year. Apart from acute eye symptoms, VAD also weakens the immune system, thus increasing the incidence and severity of infectious diseases. For adults, the implications can be serious too, especially for pregnant and lactating women. Nearly 600,000 women die from childbirth-related causes each year, many of them from complications which could be reduced through better provision of Vitamin A. The most vulnerable are those fighting poverty because their diets commonly consist of less nutritious staple foods, and barriers to education. VAD constitutes a serious problem in the Philippines. Moreover, in 2001, Golden Rice technology was transferred to the Philippine-based International Rice Research Institute (IRRI), where adaptive research is now being carried out. Scientists are currently working on verifying and improving the gene constructs and incorporating them into popular indica rice varieties. After that, a testing phase will follow. Golden Rice could become commercially available in 2007 [1].



[1] *Since the article above was written, Golden Rice was declared "as safe as conventional rice" by the United States Department of Agriculture in 2018 and by regulators in the Philippines in 2019.*

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Case Files A

Continued

Artifact 4

Resource for Guiding Question C.

Top-20 most consumed food groups and their contribution to the diet of toddlers in the Philippines. The table below is abridged. Please visit the source for the complete version.

Source: *Nutrient Intakes and Food Sources of Filipino Infants, Toddlers and Young Children are Inadequate: Findings from the National Nutrition Survey 2013*, from the journal Nutrients, 2018

Rank	Food Groups	% of Children	Mean Intake	Macronutrients				Vitamins				Minerals		
				Energy	Carbs	Protein	Total Fat	Thiamine	Riboflavin	Vitamin A	Vitamin C	Calcium	Iron	Zinc
1	Rice	96	76.8 (2.1)	33.1 (1)	47.6 (1)	20.9 (1)	1.8	15.3 (1)	5.0 (4)	0	0	5.2 (4)	15.7 (1)	18.5 (1)
2	Fish	50	16.9 (1.1)	2.3	0.1	12.8 (3)	2.6	2.5	3.2	5.8	0	5.5 (3)	4.4	4.7
3	Vegetables	39	13.9 (1.2)	1.2	1.6	1.0	0.3	2.4	1.5	8.3 (5)	11.7 (5)	1.9	3.0	1.1
4	Cow's milk	38	25.4 (2.3)[1]	12.6 (2)	6.4 (2)	19.4 (2)	25.0 (1)	13.0 (3)	45.9 (1)	34.8 (1)	11.8 (4)	43.4 (1)	2.3	11.7 (3)
5	Sugary drinks	33	29.8 (3.4)[2]	3.6	4.9	1.3	1.4	16.6 (3)	7.2 (3)	10.1 (3)	23.6 (1)	5.1 (5)	8.7 (3)	7.9 (4)
6	Table sugar	29	3.3 (0.5)	1.6	2.5	0	0	0	0.2	0	0	0.9	0.2	0
7	Bread	28	12.0 (1.1)	4.9 (4)	5.9 (3)	4.7	2.2	6.0	2.3	1.0	0	1.5	7.7 (4)	3.3
8	Noodles	27	7.6 (0.9)	3.9 (5)	3.8 (5)	2.8	5.1 (5)	6.6 (5)	1.6	0.2	0.2	0.4	2.8	2.6
9	Eggs	25	5.3 (0.7)	1.3	3.1	3.5	3.3	1.1	4.0 (5)	3.9	0	0.6	2.6	3.0
10	Cookies	20	5.3 (0.7)	3.1	2.1	1.3	4.0	1.3	1.0	0.8	0	0.9	1.8	0.9
11	Fruits	17	11.0 (2.0)	1.1	1.7	0.4	0.2	1.2	0.7	0.7	17.0 (3)	0.8	1.5	0.5
12	Pork	16	7.4 (1.4)	2.7	0.1	4.7	8.2 (3)	5.7	2.9	12.1 (2)	0.6	0.4	2.8	7.2 (5)
13	Chicken	16	7.4 (1.4)	1.3	0	5.6 (5)	2.5	0.8	1.7	3.4	0.6	1.1	2.0	3.3
14	Formula	15	12.6 (2.2)	5.8 (3)	4.7 (4)	5.7 (4)	8.7 (2)	11.2 (4)	12.5 (2)	9.3 (4)	22.0 (2)	20.5 (2)	15.7 (2)	18.1 (2)
15	Luncheon meats	14	7.3 (1.4)	2.3	0.5	3.8	6.5 (4)	1.4	1.2	1.9	0	0.5	6.5 (5)	4.2
16	Crackers	14	3.5 (0.5)	2.1	1.8	1.2	3.4	1.5	0.8	0	0	0.5	1.3	0.8
17	Human milk	11	9.9 (0.4)	0.8	0.6	0.5	1.6	0.2	0.1	0.2	1.8	0.6	0.6	0.5
18	Cakes	11	4.5 (1.2)	2.1	2.1	1.0	2.7	1.7	0.5	1.7	0	1.0	2.1	0.9
19	Candy	10	2.2 (0.5)	1.3	1.3	0.5	1.6	0.3	0.4	0.2	0	1.0	0.7	1.0
20	Beans, nuts and peas	6	1.6 (1.4)	0.6	0.5	1.1	0.4	1.3	0.3	0	0.3	0.7	1.0	0.6
	Total contribution of top 20 foods		87.7	91.3	92.2	81.5	90.1	93.0	94.4	89.6	92.5	83.4	90.8	—

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Case Files A

Continued

Artifact 5

Resource for Guiding Question D.

The potential for Golden Rice to deliver the estimated average requirement of β-carotene, as a source of Vitamin A, to 1–3-year-old children and adults.

Source: *Golden Rice: To Combat Vitamin A Deficiency for Public Health*, from the book Vitamin A, 2019

The data indicated that, given the β-carotene content of Golden Rice, a single serving of it could provide more than 50 percent of the recommended daily intake of Vitamin A, or estimated average requirement (EAR), and sufficiently combat VAD. As Golden Rice is typically not the only source of β-carotene in the diet, many nutritionists think that the EAR could be less than 50 percent.

		Amount of β-carotene in Golden Rice µg/g	Rice Consumption Per Day g of dry rice before cooking	Percentage of EAR Provided
To a child	β-carotene to circulating retinol bioconversion rate: 2.1:1	4.0	40	36%
		4.0	100	91%
		6.0	40	54%
		6.0	100	136%
		11.2	40	102%
		11.2	100	254%
To an adult	β-carotene to circulating retinol bioconversion rate: 3.8:1	4.0	40	20%
		4.0	100	50%
		6.0	40	30%
		6.0	100	75%
		11.2	40	56%
		11.2	100	140%

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Case Files A

Continued

Artifact 6

Resource for Guiding Question D.

Potential health benefits of Golden Rice: Rice Biofortification: High Iron, Zinc, and Vitamin-A to Fight against "Hidden Hunger".

Source: *Rice Biofortification: High Iron, Zinc, and Vitamin-A to Fight against "Hidden Hunger"*, from the journal Agronomy, 2019

1997	*Burkhardt et al [89]*	This is first time that pro-Vitamin A biosynthesis has been engineered in rice endosperm, which normally is carotenoid-lacking. Using recombinant daffodil phytoene synthase cDNA, scientists were able to introduce genes that are precursors in the Vitamin A signaling pathway.
2000	*Ye et al [90]*	Recombinant DNA technology was used to improve the nutritional value of rice by introducing phytoene transgenes in effort to combat Vitamin A deficiency in Taipei 309 rice.
2003	*Datta et al [91]*	Introduction of carotenogenic pathway in rice cultivars in Bangladesh, Myanmar, and Vietnam, as well as the promise of engineering transgenic lines to serve farmers in a specific region and agro-ecological zone.
	Hoa et al [108]	Improved Golden Rice lines of the initial "proof-of-concept" Japonica rice including IR64, MTL250, and Japonica variety Taipei 309. These were promising because they were expected to receive approval for follow up studies for nutritional and risk assessments.
2005	*Parkhi et al [95]*	Molecular characterization and first use of co-transformation two bacterial plasmids in rice to develop a marker-free transgenic rice.
	Paine et al [93]	Providing pro-Vitamin A in rice is a simple and effective complement to supplementation initiatives. By direct comparison of gene orthologs (similar genes in different organisms), scientists were able to identify an effective means to increase pro-Vitamin A content in rice.
2006	*Datta et al [92]*	Improved Golden Rice metabolic target products of carotenoids in two transgenic varieties, IR64 and BR29. Post-transgeneration enhancement of carotenoids in any plant species including Golden Rice may provide new insights into their metabolic pathways.
	Baisakh et al [96]	This study reports the development of a marker-free transgenic near-isogenic (same genetics) lines of Golden Rice in an elite indica rice cultivar IR64. The removal of the marker gene from the transgenic plant has been considered 'good laboratory practice' by many institutions.
2007	*Rai et al [109]*	This study analyzed the inheritance of carotenoid accumulation, measured in terms of total carotenoid and β-carotenoid levels, in transgenic Golden Rice lines.
	Datta et al [102]	This study reported higher carotenoid levels in the T3 generation, analogous to F3 generation, compared to T0–T1 seeds, which showed a positive transgenerational effect. These findings may have contributed to the growing conditions, greenhouse versus field conditions, however introducing transgenes into their genome did not affect agronomic characteristics of rice.

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Case Files A

Continued

2014	*Datta et al [88]*	This study reports the development of dihaploid transgenic lines containing two copies of the chromosomes. Using this technique, they were able to create a genetically stable transgenic line, BR29, with complete homozygosity.
2015	*Gayen et al [107]*	Down-regulation of lipoxygenase enzymatic activity reduces degradation of carotenoids in transgenic rice seeds. This is implicated in prolonged post-harvest storage to prevent quality deterioration, which is common in carotenoid-introduced transgenic crops.
2016	*Gayen et al [103]*	In this study, proteome, or protein expression levels, and metabolite analyses were carried out to characterize metabolic regulatory factors in transgenic Golden Rice after introducing transgenes to upregulate carotenoid-specific pathways.
	Bai et al [94]	Developing transgenic rice lines expressing genes implicated in the carotenoid pathway, including ZmPSY1, paCRTI, atDXS, or AtOR, increased carotenoid content and provided a greater insight into regulation of the carotenoid pathway.
2018	*IRRI, Philippines*	Golden Rice received three successive positive food safety evaluations from leading regulatory agencies.
2019	*Daily Star, Bangladesh*	Field evaluation of Golden Rice is successfully completed and it is expected to be released as a commercial variety for cultivation and consumption in Bangladesh.
	Swamy et al [104]	This study reported that no differences were found in the compositional analysis of Golden Rice 2 and its control apart from the levels of carotenoids. The compositional evaluation of genetically modified crops is to determine any significant changes in nutrient composition and safety of the intended and unintended changes.

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Day 1 Exit Ticket

Directions
Answer the questions that follow based on your readings and research.

1. What agricultural product is being explored during this case study? How has it been genetically modified?

2. What health crisis inspired the development of Golden Rice? What impacts does the health crisis have on children and adults?

3. What GE technology was used to make Golden Rice? Summarize the process and include the alternative protein product in your response.

4. CONNECT!
   a. What experience do you have, if any, with vitamin deficiencies and access to nutritious food?

   b. What experience do you have, if any, with Filipino culture?

   c. What typical foods do you eat on a daily basis?

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Careers Highlight Capture Sheet

Directions
As a group, explore the artifacts about Golden Rice and complete these Knowledge Profiles.

Sociologist

Job Description	Sociologists specialize in a wide range of social topics, including, but not limited to education and health; crime and poverty; families and population; and gender, racial, and ethnic relations.
Average Salary	2019 Median Pay: $83,420 per year $40.10 per hour
Tasks	— Study human behavior, interaction, and organization. They examine the effect of social influences on different individuals and groups. — Use both quantitative and qualitative methods when conducting research. — Help administrators, educators, lawmakers, and social workers solve social problems and formulate public policy.
Source	*Sociologists, United States Bureau of Labor Statistics*

1. Brainstorm potential soft skills in this career using *21st Century Learning Skills Progression*.

2. Brainstorm potential technical skills in this career using *21st Century Learning Skills Progression*.

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Careers Highlight Capture Sheet

Continued

Plant, Agricultural and Food Scientist

Job Description	Plant/agricultural and food scientists play an important role in the nation's food supply. Some research to understand the biological and chemical processes by which crops and livestock grow. Others seek to discover ways to improve the quality, quantity, and safety of agricultural products. Many agricultural and food scientists work with teams of technicians or students who help in their research.
Average Salary	2019 Median Pay: $65,160 per year $31.33 per hour
Tasks	— Conduct research to improve the productivity of field crops and farm animals. — Create new food products and develop new and better ways to process them. — Study the composition of soil as it relates to plant growth, and research ways to improve it.
Source	*Agricultural and Food Scientists, United States Bureau of Labor Statistics*

1. Brainstorm potential soft skills in this career using *21st Century Learning Skills Progression*.

2. Brainstorm potential technical skills in this career using *21st Century Learning Skills Progression*.

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Careers Highlight Capture Sheet

Continued

Food Science Technician

Job Description	Food science technicians may focus on animal health, farm machinery, fertilizers, agricultural chemicals, or processing technology. Many food science technicians spend time inspecting foodstuffs, chemicals, and additives to determine whether they are safe and have the proper combination of ingredients.
Average Salary	2019 Median Pay: $41,230 per year $19.82 per hour
Tasks	— Analyze chemical properties of food to determine ingredients and to ensure that they comply with established safety standards. — Collect and prepare samples of food, food additives and food containers in accordance with established procedures. — Compile test results, and prepare charts and reports describing them.
Source	*Food Science Technician, United States Bureau of Labor Statistics*

1. Brainstorm potential soft skills in this career using *21st Century Learning Skills Progression*.

2. Brainstorm potential technical skills in this career using *21st Century Learning Skills Progression*.

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Careers Highlight Capture Sheet

Continued

Economist

Job Description	Economists apply economic analysis to various areas, such as education, health, and the environment. Some economists study the cost of products, while others examine employment levels. Economists often study historical trends and use them to make forecasts.
Average Salary	2019 Median Pay: $105,020 per year $50.49 per hour
Tasks	— Conduct surveys and collect data around economic issues, analyze data, and share results through reports, tables, and charts in academic journals and other media. — Interpret and forecast market trends to recommend solutions and approaches to businesses, governments, and individuals.
Source	*Economists, United States Bureau of Labor Statistics*

1. Brainstorm potential soft skills in this career using *21st Century Learning Skills Progression*.

2. Brainstorm potential technical skills in this career using *21st Century Learning Skills Progression*.

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Case Files B

Directions
Review the artifacts in Case Files B to help formulate responses to the Knowledge Profile Capture Sheets.

Artifact 1

Resource for Sociologist Knowledge Profile: Filipino Traditions and Rice

Source: *Rice in the Filipino Diet and Culture*, from the PIUS Research Paper Series Number 2008-03, 2008

Rice is the most consumed crop in the Philippines. Although marginalized in the formal world of ritual, rice retains symbolic significance for Filipinos, at least within small groups. This is evident in weddings. Even if the practice has been banned in many churches (to conserve the economic value of rice), grains of milled rice are showered upon newlywed couples as they leave the church, ostensibly as a sign of blessing. Interestingly, this practice is a vestige (and seeming inversion) of a precolonial wedding ceremony during which an elder united the hands of the bride and groom "over a bowl of raw rice, which he then threw over the guests" (Scott 1994). Also in some rural places today, it is still believed that newlywed couples should eat sticky rice before entering a house or reception area so that their love for, and devotion to each other, would be as sticky as the rice. Rice is featured in fast food and restaurant innovations, such as rice toppings (with the viand placed on top of a bowl of rice) and separately wrapped servings of rice are in harmony with individualism and the ideology of consumer sovereignty. Parenthetically, the precolonial practice may be read as a form of blessing given by the newlyweds to the social group, because the rice emanated from the couple's hands. In the colonial and postcolonial wedding ceremony, the social group, in throwing rice to the new couple, blesses the latter.

In other private rites, rice retains its place; for example, the presence of rice (along with salt) to ward off evil spirits from a new house is required before the occupants move in with their belongings. More importantly, various rice delicacies and rice cakes, such as biko, suman, and bibingka, are necessary elements in festivals and town fiestas. In these somewhat elaborate forms, rice transcends its quotidian character. Moreover, even low-income families strive to serve good quality boiled rice during fiestas and family celebrations, which again highlights the importance of rice in a meal.

Rice remains crucial for commensality in Philippine households. Among the poorest, rice will suffice to constitute a meal. Added flavor may come from salt, soy sauce, or instant noodles. A small amount of viand may be rationed, but rice is still taken from a collective plate. Rice, therefore, symbolizes familial togetherness even in the poorest of families. However, any marker of inclusion also implies exclusion. Due to poverty, several households may live in a single dwelling unit. The rice pot prepared and consumed by each household signifies the separateness of these households. The rice pot as a demarcating line is recognized by households as well as by research organizations that conduct surveys and need indicators to define what constitutes a household.

In daily life, the sacredness of rice is affirmed in many households. My father used to instruct me as a child to finish every last bit of rice morsel on the plate as a sign of respect for the grace of God. Other parents point to hunger and famine in this or that place to prod children to finish the food on their plate. Despite the spread of the fast food industry and the increasing substitution of rice by bread, noodles, and other cereal products, rice is still the essential food of Filipinos even in urban centers.

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Case Files B

Continued

Artifact 2

Resource for Sociologist Knowledge Profile: Citizen Spotlights

Source: *Rice in the Filipino Diet and Culture*, from the PIUS Research Paper Series Number 2008-03, 2008

1 Anna
29 years old

Is a part-time student and full-time employee in a research organization. She lives in Laguna, but works and studies in Manila where she rents an apartment with a friend. Anna shares that she orders food from fast food restaurants only when she does not have food for lunch or dinner. Most of the time, Anna orders meals consisting of rice and a choice of chicken, lumpiang shanghai, or burger patties. When these rice meals are not enough, she usually adds a piece of burger or orders spaghetti. However, Anna does not eat a burger or spaghetti alone for dinner or lunch. She has to have rice to complete her meal. Anna prefers having the traditional rice meals, consisting of rice and a viand, over burgers and spaghetti, which she considers snack foods and not as replacements for her preferred rice meals. She also consumes instant noodles and street food such as fish balls and considers these as snacks when eaten alone. To pass these off as lunch or dinner fare, she combines these with rice.

2 Edna
45 years old, mother of seven

Lives in San Jose, Del Monte, Bulacan, and works as a "stay-out" house helper and laundry woman. Edna finished her second year of high school. Edna and her children regularly eat rice with little additions for the main meals and even during snack time. She prefers to have rice during meals because "mabigat ito at matagal kang magutom" (it is heavy and you don't get hungry easily). If they do not have meat or fish at home, they would instead buy instant noodles and mix this with rice. Rice is a staple food in their home: "Hindi puwedeng walang kanin sa bahay," she says. Rarely does she buy food from fast food restaurants. In those few instances when she does, she usually orders spaghetti and soft drinks. This type of meal, she says, can serve as her lunch as long as she would not engage in physically demanding work during the day. Edna says that she and her children do not like eating rice distributed by the National Food Administration because "mabaho na ito, tapos wala ka pang ulam; hindi talaga makakain" (with its foul odor, it cannot be eaten, especially when there is no viand). Although the wagwag rice variety is costlier than NFA rice, she prefers to buy this because, "kahit na anong ulam, kahit hindi masyado masarap, kahit asin o bagoong lang, makakain mo" (regardless of the viand and how simple it is, even with just salt or fish paste, you can eat the rice). Edna has tasted NFA rice when she was younger and clearly remembers its poor smell. Since then, she had never bought or eaten this type of rice. Sometimes, whenever her family craves it, they eat ground corn, or what she calls "bigas ng magsasaka" (the farmer's rice), because this gives a "heavier feeling" in the stomach and costs the same as ground palay. In the end, however, her family still prefers to eat rice paired off with any other food item.

3 Allen
18 years old

Is student at one of the upscale universities in Metro Manila and is the youngest of three children. His mother is a businesswoman while his father works for the Philippine Air Force. Allen consumes rice or bread for breakfast depending on the available viand. When he is in a hurry, he usually opts for bread and then supplements this with a midmorning snack. Eating bread for breakfast, he says, is usually not enough. If he has rice for breakfast, there is no need for him to have a midmorning snack. For lunch, his choice of food at the school canteen depends on his mood at that time. At home, lunch is always served with rice. People at his home, he claims, are meticulous when it comes to food. If rice is not available, they will usually order food with rice. Because he is currently on a diet, Allen only eats bread at dinnertime. "You don't need a lot of sustenance at night because you are resting already. I am also trying to lose fat, which is why I don't eat too much rice," he explains. His sisters, likewise, do not eat rice for dinner because they are on a diet. Occasionally, he can have rice as part of his midnight snack if he likes the food. Allen confesses that he needs to eat rice even for just one meal or else "hindi kumpleto ang araw ko" (my day is not complete). When dining in fast food restaurants, Allen combines non-rice meals (such as spaghetti) with rice. Depending on the pasta, he can eat this separately or with rice.

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Case Files B

Continued

Artifact 3

Resource for Sociologist Knowledge Profile:
Education Outcomes in the Philippines

Source: *Education Outcomes in the Philippines*, from the ADB Economic Working Paper Series, 2010

Filipino parents value education as one of the most important legacies they can impart to their children. They believe that having a better education opens opportunities that would ensure a good future and eventually lift them out of poverty. Thus, they are willing to make enormous sacrifices to send their children to school (Dolan 1991, De Dios 1995, LaRocque 2004). However, with a poor family's severely limited resources, education tends to be less prioritized over more basic needs such as food and shelter. Hence, the chances of the family moving out of poverty are unlikely. It is therefore important that the poor be given equitable access to education.

The 1987 Philippine Constitution declares that education, particularly basic education, is the right of every Filipino. On this basis, government education policies and programs have been primarily geared toward providing access to education for all. The Philippines is committed to the World Declaration on Education for All (EFA)—and the second goal of the Millennium Development Goals (MDG)—to achieve universal primary education by 2015.

EFA's framework of action has six specific goals in the areas of: (i) early childhood care and education (ECCE); (ii) universal primary/basic education; (iii) life skills and lifelong learning; (iv) adult literacy; (v) gender equality; and (vi) quality. In line with this framework of action, the Philippine EFA National Action Plan (UNESCO 2010) adopted in 2006 was formulated as the country's master plan for basic education.

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Case Files B

Continued

As seen from the table below, both the Department of Education and Annual Poverty Indicator Survey (APIS) data across years (2002 to 2007) showed that less than half of 6-year-old children are not yet in primary school. BEIS reported that 63.36% of Grade 1 enrollees are older than 6 years. Of these overaged Grade 1 pupils, 63.44% are 7 years old. Parents appear to postpone enrollment at 6 years old and tend to send their children to school when they get older.

Table 1: Age-Specific Enrollment Rates, APIS 2002, 2004, 2007 (percent)

Source: Authors'computations using APIS 2002, 2004 and 2007.

	2002				2004				2007			
Age	Enrolled	Pre-School	Primary	Secondary	Enrolled	Pre-School	Primary	Secondary	Enrolled	Pre-School	Primary	Secondary
6	78.55	27.18	51.37	—	82.5	25.96	56.54	—	84.8	25.33	59.48	—
7	93.91	2.97	90.94	—	94.02	3.46	90.56	—	94.19	3.07	91.12	—
8	96.78	0.89	95.89	—	96.87	0.69	96.18	—	96.2	0.5	95.7	—
9	97.86	0.33	97.53	—	97.37	0.18	97.19	—	97.32	0.26	97.06	—
10	97.79	0.15	97.53	0.11	96.79	0.18	96.61	—	96.83	0.04	97.79	—
11	97.84	0.01*	93.6	4.23	96.76	—	91.92	4.73	96.26	0.06*	91.3	4.9
12	94.87	0.01*	56.65	38.21	94.16	—	56.23	37.88	94.44	0.1*	52.76	41.58
13	92.41	—	22.37	70.04	90.62	—	23.32	67.21	90.36	0.05*	21.74	68.57
14	88.66	—	10.46	78.1	86.56	—	11.09	75.33	86.76	—	10.29	76.47
15	84.62	—	4.39	79.33	82.85	—	4.76	76.67	82.2	0.04*	4.91	74.09
16	74.32	—	2.3	57.87	70.72	—	2.28	53.45	66.97	—	2.06	43.47
17	60.12	0.03*	0.76	23.73	56.60	—	1.01	23.07	54.38	—	1.16	20.86

— Zero values

* Nonzero values; suspected encoding errors

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Case Files B

Continued

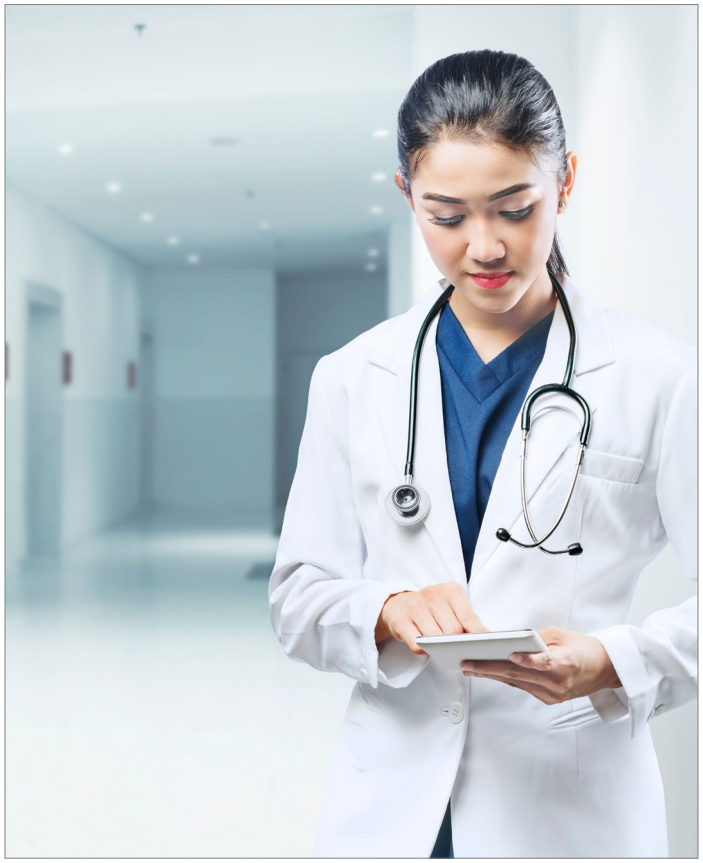
Artifact 4

Resource for Sociologist Knowledge Profile: Healthcare in the Philippines

Source: *Healthcare in the Philippines*, from Allianz Care, 2022

Overall, the healthcare system in the Philippines is of a high standard. Filipino medical staff are expertly trained, but the facilities may not be as impressive as those found in high-end United States or European hospitals.

The quality of the Philippines' state-subsidized public healthcare, although good, varies widely between rural and urban areas. Private healthcare in the Philippines provides much more consistent care and facilities tend to be better equipped than public ones. English is also spoken throughout the Philippines, meaning that there should be few language barriers preventing expats from accessing healthcare.



Public Healthcare

Doctors and nursing staff in public hospitals are highly proficient; however, public healthcare in the Philippines faces some limitations. Despite having achieved universal healthcare, the Philippines still faces challenges with unequal access to medical care. As such, the standard of public healthcare in the Philippines generally varies from excellent in urban centers to poor in rural areas. Public healthcare also faces strain both from treating the large number of Filipinos who rely on public healthcare and from the trend of Filipino medical staff migrating to Western countries. This has resulted in understaffing in some hospitals and patients may experience delays in treatment.

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Case Files B

Continued

Artifact 5

Resource for Plant and Food Scientist Knowledge Profile: Rice as a Crop

Source: Ricepedia, a project of The *CGIAR Research Program* (CRP) on rice agri-food systems (RICE)

Rice is the most important human food crop in the world, directly feeding more people than any other crop. In 2012, nearly half of the world's population—more than 3 billion people—relied on rice every day. It is also the staple food across Asia where around half of the world's poorest people live and is becoming increasingly important in Africa and Latin America.

Rice has also fed more people over a longer time than has any other crop. It is spectacularly diverse, both in the way it is grown and how it is used by humans. Rice is unique because it can grow in wet environments that other crops cannot survive in. Such wet environments are abundant across Asia. The domestication of rice ranks as one of the most important developments in history and now thousands of rice varieties are cultivated on every continent except Antarctica.

Where is rice grown?

Rice is produced in a wide range of locations and under a variety of climatic conditions, from the wettest areas in the world to the driest deserts. It is produced along Myanmar's Arakan Coast, where the growing season records an average of more than 5,100 mm of rainfall, and at Al Hasa Oasis in Saudi Arabia, where annual rainfall is less than 100 mm. Temperatures, too, vary greatly. In the Upper Sind in Pakistan, the rice season averages 33°C; in Otaru, Japan, the mean temperature for the growing season is 17°C.

The crop is produced at sea level on coastal plains and in delta regions throughout Asia, and to a height of 2,600 m on the slopes of Nepal's mountains.

Rice is also grown under an extremely broad range of solar radiation, ranging from 25% of potential sun exposure during the main rice season in portions of Myanmar, Thailand, and India's Assam State to approximately 95% of potential in southern Egypt and Sudan. Rice occupies an extraordinarily high portion of the total planted area in South, Southeast, and East Asia. This area is subject to an alternating wet and dry seasonal cycle and also contains some of the world's major rivers, each with its own vast delta. Here, enormous areas of flat, low-lying agricultural land are flooded annually during and immediately following the rainy season. Only two major food crops, rice and taro, adapt readily to production under these conditions of saturated soil and high temperatures.

What types of rice are grown?

Two rice species are important cereals for human nutrition: *Oryza sativa*, grown worldwide, and *O. glaberrima*, grown in parts of West Africa. These two cultigens—species known only by cultivated plants—belong to a genus that includes about 25 other species, although the taxonomy is still a matter of research and debate.

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Case Files B

Continued

Stages of rice growth

Rice goes through a series of processes before finally reaching the table. Its production can generally be divided into the following stages: Seed selection, land preparation, crop establishment, water management, nutrient management, crop health, harvesting, and postharvest.

What happens after harvest?

After harvest, the rice grain undergoes a number of processes depending on how it will be used. These include drying, storing, milling, processing, and packing—all before the rice is delivered to markets for sale.

Rice productivity

Global rice production more than tripled between 1961 and 2010, with a compound growth rate of 2.24% per year (2.21% in rice-producing Asia). This increase was slightly greater than that for wheat (2.02% per year), but substantially less than that for maize, which grew at 2.71% per year. Most of the increase in rice production was due to higher yields, which increased at an annual average rate of 1.74%, compared with an annual average growth rate of 0.49% for area harvested. In absolute terms, paddy yields increased at an annual average rate of 51.1 kg/ha per year, although this rate of increase has declined in both percentage and absolute terms.

Who grows rice?

Rice is grown by more people than any other crop in the world. There are more than 144 million rice farms worldwide on a harvested area of about 158 million hectares. It is cultivated in a wide range of climates and terrains, by hand or using massive machinery, by small families or large agricultural corporations. The contrasts in the geographic, economic, and social conditions under which rice is produced are vast.

Watch these videos!

Rice Infographics: Who is the Filipino Rice Farmer from PhilRiceTV

Rice Farming in the Philippines (The Traditional Method) from The Filipina Pea

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Case Files B

Continued

Article 6

Resource for Food Science Technician Knowledge Profile:
Rice as a Crop

Source: Ricepedia, a project of The *CGIAR Research Program* (CRP) on rice agri-food systems (RICE)

Summary

The Golden Rice Project is already working with regulators in some target countries. Regulators allow informed individuals to eat Golden Rice prior to commercial regulatory clearance in a country for research purposes. However, the Golden Rice Project has been careful to restrict usage only to that essential to the objectives of the project. Very few people have tasted Golden Rice so far. Human studies are essential to select lines with optimal nutritional characteristics.

Animal testing is not mandated by FDA, and because animals metabolise beta carotene differently from humans, such a test cannot answer the human bioavailability and bioconversion questions regarding whether Golden Rice is as good or better than beta carotene delivered in capsules or as vegetables.

Golden Rice has gone through many tests since it was first obtained. Among the tests performed are:

1. An in-depth investigation and understanding of the endosperm carotenoid biosynthetic pathway modification has been developed, which accurately explains the source of the golden color of Golden Rice.
2. Less than 10 transgenic events (from about 2,000 created) were carefully selected to be able to fulfill regulatory requirements regarding the genetic structure.
3. Gene expression profiling of thousands of genes was carried out, showing no unexpected changes or disturbances in the expression profile as compared to the parent material.
4. Allergenic potential has been ruled out at the prediction level using bioinformatic analysis of transgene proteins. The report is available online at Allergen Online.
5. High digestibility of the transgenic proteins in simulated gastric fluid has been demonstrated, further substantiating the claim of lack of allergenic potential.
6. It has been shown that Golden Rice diverts only a minuscule amount of carbon into carotenoids, so that changes in compositional analysis are minimal.
7. Various taste trials have been conducted, which have not detected taste differences to the parent material.
8. Tests have been conducted to determine beta carotene bioavailability and bioconversion to retinol (the most significant source of Vitamin A) by feeding deuterium-labeled Golden Rice to adults in the United States, as well as to a small group of children in China. Both trials were highly successful in showing that the human intestine is indeed capable of extracting beta carotene out of Golden Rice in a highly efficient manner. [1] [2]

[1] Tang et al (2009) Golden Rice is an effective source of Vitamin A. American Journal of Clinical Nutrition 89:1776–1783.

[2] Tang et al (2012) β-Carotene in Golden Rice is as good as β-carotene in oil at providing Vitamin A to children. American Journal of Clinical Nutrition 96:658–664.

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Case Files B

Continued

Artifact 7

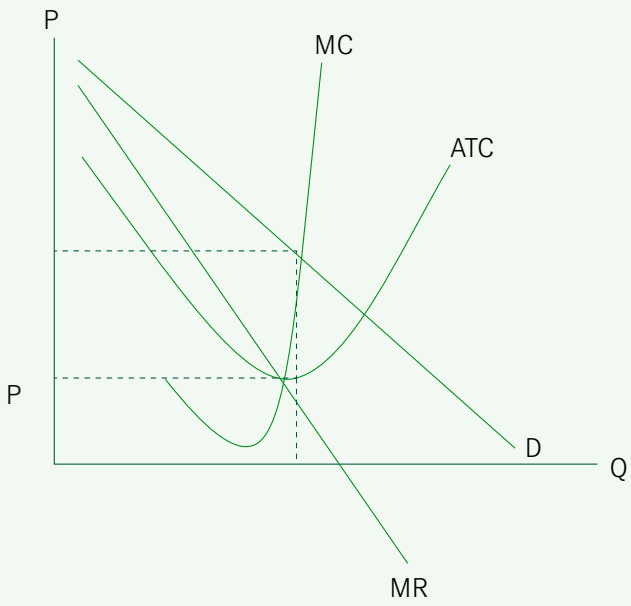
Resource for Economist Knowledge Profile:
The Economic Impact of Golden Rice

Source: *The Economic Impact of Golden Rice* from the Randolph-Macon College faculty microsite of Remy Berinato, 2017

The price of Golden Rice in itself can be considered an economic disadvantage. The cost of production, maintaining, and distributing Golden Rice is too expensive for the developing countries that need it. Currently, the only countries that can afford Golden Rice are first-world and developed countries, but there is no market for this product in those countries because Vitamin A deficiency is not a widespread or detrimental problem.

This high fee for Golden Rice also puts it at a disadvantage as a product on the competitive market. Because it is one of the most expensive solutions to fixing the Vitamin A deficiency problem, developing countries often choose alternatives. Cheaper methods of addressing Vitamin A deficiency, such as reinforcing flour with more Vitamin A through processing methods, increasing the availability of fortified milk and ready-made meals, and simply raising awareness about the consequences of a Vitamin A deficiency, are more appealing to developing countries simply because they cost less than implementing Golden Rice (GM Watch 2013). There has also been speculation that it would take 3 kg of Golden Rice per day for a child to meet their Vitamin A requirement. This is an obscene amount since the average amount of rice eaten in countries where that grain is a staple is 400 g per day. This concern continues to raise the price of Golden Rice (Free Rice 2017).

Monopoly



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Case Files B

Continued

The figure shows the relationship between Marginal Cost (MC), Average Total Cost (ATC), Supply (S), and Marginal Revenue (MR) for a monopoly in the market. The box created by the intersection of the Marginal Cost and Average Total Cost shows the total economic profit of the monopoly. Monopolies do not function on the intersection of supply and demand; they function where Marginal Cost and Average Total Cost intersect, which yields the market price of the product. Additionally, monopolies are harmful to society because they produce Deadweight Loss, a phenomenon in which portions of consumer and producer surplus are lost to the market. Therefore, monopolies are inefficient and often supply less than quantity demanded, requiring higher prices to yield economic profit.

Another economic disadvantage to Golden Rice is the fact that it encourages monopolistic behavior. When Peter Beyer and Ingo Potrykus invented Golden Rice, they needed an industrial partner that would be willing to finance the humanitarian use and commercialization of this product. In 2001, Beyer and Potrykus exclusively signed over the rights to Golden Rice to Syngenta, an agrichemical and seed company located in Switzerland, which effectively gave them a monopoly on Golden Rice (Golden Rice Project 2016).

While Syngenta was the sole owner of the Golden Rice commercial rights, the company had agreed to allow access to Golden Rice for humanitarian uses, free of charge, so that developing countries who would greatly benefit from this genetically modified crop could do so (Golden Rice Project 2016). However, the creation and production of Golden Rice involved several patented technologies, or licenses that conferred the right to exclude others from making, using, or selling a certain type of technology. When Syngenta obtained the rights to Golden Rice, they also managed to obtain a license that allowed them access to all the technology (patented by companies such as Bayer AG, Monsanto Co., Orynova BV, and Zeneca Mogen BV) needed to create Golden Rice, further strengthening their monopoly on Golden Rice in a commercial sense. Fortunately, the companies that owned patents on the technology needed for Golden Rice also allowed access to Golden Rice for humanitarian use.

In spite of allowing humanitarian access to Golden Rice for free, Syngenta has faced opposition over their monopoly on Golden Rice. In the countries where Golden Rice has been planted, groups of farmers have risen up against Syngenta, protesting its monopoly because they want to profit from Golden Rice (Sustainable Pulse 2013). This controversy is detrimental to the market and commercialization of Golden Rice because it presents Syngenta with the potential for huge economic losses.

Economic Advantages of Golden Rice

The most obvious economic advantage of Golden Rice is that it has the potential to feed and nourish more people, which leads to those people having the ability to contribute back to the economy through the workforce. Any type of nutritional deficiency has the possibility to impact labor outcomes by limiting labor productivity and human capital accumulation. The Vitamin A deficiency, which is considered one of the most severe forms of malnutrition, can cause blindness, weaken the body's immune system, and hinder the natural growth rates of individuals, all of which are factors that cripple one's ability to work (Golden Rice Project 2016). This is especially detrimental in developing countries, where most of the workforce is centered around labor. With the introduction of Golden Rice, the percentage of the population affected by malnutrition could decrease, which would allow the potential for capital growth to increase. Because nutrition is positively related to cognitive ability, an increase in nutrition, due to Golden Rice, would result in an increase in labor productivity, which benefits the economy as a whole (Wesseler 2014).

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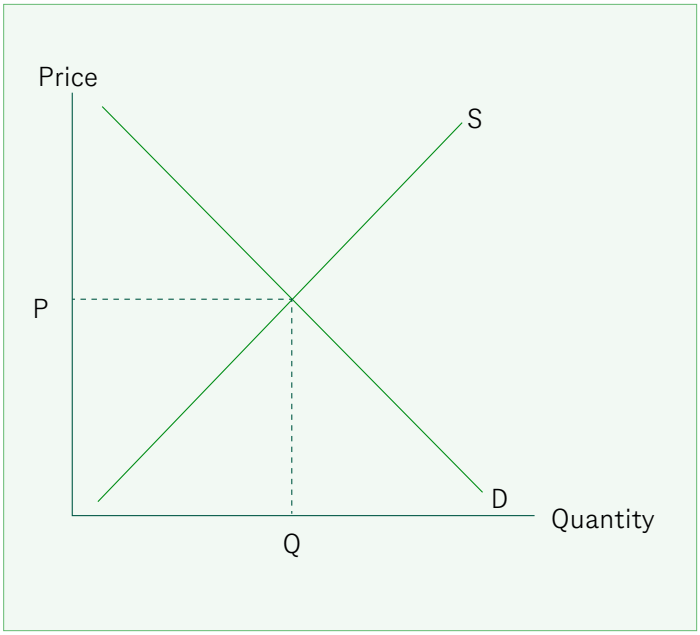
Case Files B

Continued

Another economic advantage of Golden Rice is that it has the possibility to widen the market of GMOs. The development of new markets, with the potential for high returns, is always beneficial to the economy and its growth. If Golden Rice is successful, there would be a dramatic increase in the production of genetically modified foods and crops, which would lead to the development of new GMO companies. This, in turn, would lead to thousands of new jobs that needed to be filled. There would then be a decrease in the unemployment rate; a sure sign of a strong and growing economy. Essentially, Golden Rice has the potential to start a chain of events that are beneficial to the economy, but will only occur if Golden Rice itself takes off.

The figure displays the relationship between supply (S) and demand (D) in the short-term market. As quantity demanded decreases or quantity supplied increases, price (P) decreases in response to the shift.

Supply and Demand



Unfortunately, the market for Golden Rice is non-existent; however, predictions regarding the behavior of Golden Rice upon introduction into the market can be speculated. Because price is determined at the intersection of supply and demand, speculating the price of Golden Rice in relation to white rice will provide insight into the potential influence of Golden Rice in the market and the consumers' perceptions of the product.

According to the International Rice Research Institution (IRRI), Golden Rice should not surpass white rice in shelf price (what the consumer pays); in fact, the IRRI predicts that Golden Rice may be slightly less expensive than white rice to the consumer. However, even if the shelf price of Golden Rice is predicted to be less than the shelf price of white rice, the production costs of Golden Rice could be higher than white rice.

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Case Files B

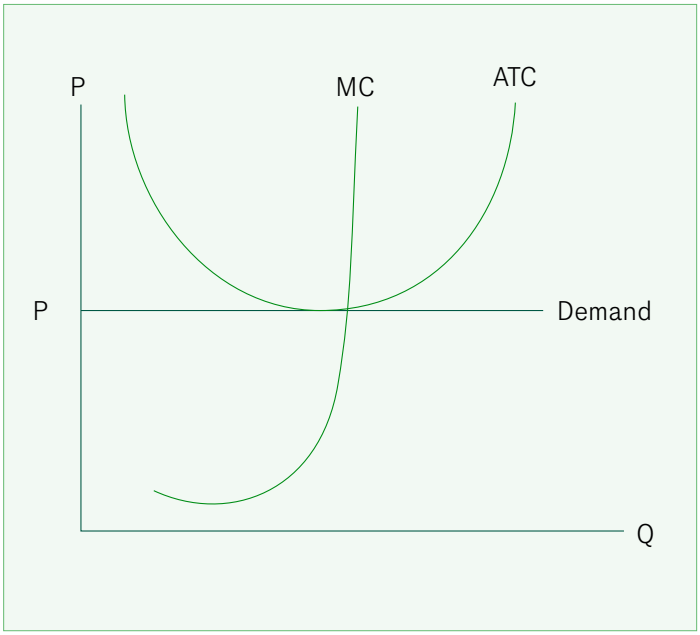
Continued

The figure to the right describes the relationship between Marginal Cost (MC), Average Total Cost (ATC), and the Demand in the rice market. Marginal Cost and Demand are stagnant; however, Average Total Cost moves vertically. If Average Total Cost is below the Demand, farmers in the market for rice will have long-running economic profits, which would encourage prospective farmers to produce rice.

This occurrence causes increased substitutes in production for rice and subsequently lowers the demand for rice. As demand decreases, the Average Total Cost increases to mimic the figure above. Therefore, the introduction of Golden Rice into the rice market would cause an increased Average Total Cost and no economic profit to be made by farmers in the rice market, which makes an unattractive product to the producers.

Even though Golden Rice possesses many benefits to combat the widespread Vitamin A deficiency in developing countries, the fact remains that the demise of Golden Rice in the market is inevitable. In order for Golden Rice to generate demand, it must overcome the substantial production costs and the negative perception of genetically modified foods in each country that opts to implement it. These deterring factors can be combated through educating consumers about genetically modified crops, finding ways to lower production costs, and implementing government subsidies to encourage farming of Golden Rice. However, these efforts are partially impeded by the presence of the Syngenta monopoly over Golden Rice. In order for Golden Rice to become truly beneficial to developing countries, some sort of action (whether in the form of government or competition presented by other GMO companies) must be taken to break up the monopoly. Though Golden Rice holds possible potential in the future, it is currently trapped in economic conditions that make it an implausible product on the market.

No Economic Profit



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Knowledge Profiles Capture Sheet

Sociologist: Profile of the Philippines from a Social Lens

Directions

Using the provided artifacts, illustrate or describe answers to the following prompts. Use Artifacts 1, 2, 3 and 4 from Case Files B to answer these questions.

1. What is the most consumed crop in the Philippines?

2. What does rice mean to the Filipino community?

3. Which citizen spotlight did you connect with the most and why?

4. Describe wealth disparities in the Philippines; do all Filipinos have access to healthcare, education, and nutritious food?

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Knowledge Profiles Capture Sheet

Plant and Food Scientist: Profile of Golden Rice from a farming/production lens

Directions

Using the provided artifacts, illustrate or describe answers to the following prompts. Use Artifact 5 and the two videos from Case Files B to answer these questions.

1. In the space below, describe how rice is grown. Use the artifact provided to formulate your response.

2. In which climate does rice grow? Describe the environment.

3. Describe the anatomy of rice. This is discussed in the second video resource.

Continues next page >

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Knowledge Profiles Capture Sheet

Plant and Food Scientist: Profile of Golden Rice from a farming/production lens

Continued

4. Describe a *Filipino rice farmer* as discussed in this video. You can also include information from the *first-hand account of rice production.*

5. How many species of rice are there worldwide? You may need to do your own research on this!

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Knowledge Profiles Capture Sheet

Food Science Technician: Describe the safety testing of Golden Rice.

Directions

Using the provided artifacts, illustrate or describe answers to the following prompts. Use Artifact 6 from Case Files B to answer these questions.

1. What safety testing has been done with Golden Rice? Summarize.

2. What key things do food science technicians look for in regards to safety? What would be some red flags that would result in a STOP in production?

3. Why is safety testing important in GE product production?

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Knowledge Profiles Capture Sheet

Economist: Profile of Golden Rice from an economic lens.

Directions

Using the provided artifacts, illustrate or describe answers to the following prompts. Use Artifact 7 from Case Files B to answer these questions.

1. Where does the profit made from selling Golden Rice go? Back to the community, private companies, etc.?

2. How does the cost of Golden Rice compare to regular rice?

3. What are some economic advantages and disadvantages of Golden Rice?

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Recap Assessment Capture Sheet

Directions
Answer these questions to check your understanding.

1. What are two things you found interesting in the *Knowledge Profiles Capture Sheet* you just explored?

2. What pictures or topics resonated with you the most and were most interesting?

3. What food or crop (such as rice, corn, taro, tea, etc.) do you connect to on a cultural level? In other words, what food do you think of when you think of family or home?

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GE Product Production Pipeline Infographic

Directions
Use this infographic to explore the Golden Rice process from concept to consumer (read from top to bottom).

Agricultural Biotechnology Pipeline

			Total
Cost	Total expense	~$100M	$M

			Percent of total
Research and Discovery	Gene/trait identification	$2–5M	$M
	Average duration	24 to 48 months	
	Probability of success	5 percent	
	Candidates in this phase	Tens of thousands	
	Phase activities	High-throughput screening and model crop testing	
Phase I	Proof of concept	$5–10M	$M
	Average duration	12 to 24 months	
	Probability of success	25 percent	
	Candidates in this phase	Thousands	
	Phase activities	Gene optimization and crop transformation	
Phase II	Early development	$10–15M	$M
	Average duration	12 to 24 months	
	Probability of success	50 percent	
	Candidates in this phase	10s	
	Phase activities	Trait development, pre-regulatory data and large-scale transformation	

			Total
Duration	Time to market	8–10 years	

			Percent of total
Phase III	Advanced development	$15–30M	$M
	Average duration	12 to 24 months	
	Probability of success	75 percent	
	Candidates in this phase	Less than five	
	Phase activities	Trait development, field testing and regulatory data generation	
Phase IV	Pre-launch	$20–40M	$M
	Average duration	12 to 36 months	
	Probability of success	90 percent	
	Candidates in this phase	Pre-commercial product	
	Phase activities	Regulatory submission, seed bulk-up and pre-marketing	
Market Launch			

Key *Percent of total*

1	5	10	20	30	40	50	75

Source: *A look at product development with genetically modified crops*

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Manufacturing and Commercialization Flowchart Capture Sheet

Directions

Answer the questions that follow based on your readings and research to illustrate the production of Golden Rice, from farm to consumer. Using the next page or a poster board, be sure to:

1	Include the title: Manufacturing And Commercialization of Golden Rice.
2	Create a flowchart that illustrates and describes in detail how Golden Rice is manufactured and commercialized.
3	Start the process with GE technology/agricultural production and end with consumption of rice by at-risk communities.
4	List and highlight any professions or careers that come in contact with the GE product along the way.
5	List and highlight any big businesses that may profit from the production of Golden Rice along the way.
6	Illustrate or describe how Golden Rice could be branded or marketed at the end of your illustration.

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Manufacturing and Commercialization Flowchart Capture Sheet

Continued

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Analysis of Other Group Work Capture Sheet, Round 1

Directions
For this round, look at the product development flowchart from another group. Take on the role of these following careers and brainstorm where they will fit into the production pipeline. Brainstorm skills that these professionals may need to effectively complete their work.

A. Plant Breeder

Job Description	Plant breeders research seed characteristics and aim to improve those characteristics that are most desirable, such as yield, size, quality, maturity, and resistance to frost, drought, disease, and insect pests.
Sources	*Plant Breeder*

1. Which stage of product development involves your work?

2. What skills are needed to effectively complete this work?

Continues next page >

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Analysis of Other Group Work Capture Sheet, Round 1

Continued

B. Plant Geneticists

Job Description	Plant geneticists conduct research to understand, improve, or create new varieties of plants or crops. Looking at a plant's DNA, they can examine ways to isolate and then develop certain plant traits, such as shape, size, production level, pesticide, and disease tolerance.
Sources	*Plant Geneticist*

1. Which stage of product development involves your work?

2. What skills are needed to effectively complete this work?

Continues next page >

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Analysis of Other Group Work Capture Sheet, Round 2

Directions
For this round, look at the product development flowchart from another group. Take on the role of these following careers and brainstorm where they will fit into the production pipeline. Brainstorm skills that these professionals may need to effectively complete their work.

A. Entomologist

Job Description	Entomologists study how insects interact with plants. They are also responsible for researching the growth, nutrition, and behavior of plants. They are considered scientists and their main focus lies in the study and research of insects.
Sources	*Entomologist*

1. Which stage of product development involves your work?

2. What skills are needed to effectively complete this work?

Continues next page >

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Analysis of Other Group Work Capture Sheet, Round 2

Continued

B. Advertising and Marketing Manager

Job Description	These managers work in advertising, promotions, and marketing. They plan programs to generate interest in products or services.
Sources	*Advertising and Marketing Manager*

1. Which stage of product development involves your work?

2. What skills are needed to effectively complete this work?

Continues next page >

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Analysis of Other Group Work Capture Sheet, Round 3

Directions
For this round, look at the product development flowchart from another group. Take on the role of these following careers and brainstorm where they will fit into the production pipeline. Brainstorm skills that these professionals may need to effectively complete their work.

A. Local Rice Farmer

Job Description	A farmer's tasks vary according to the type of operation. A farmer who raises crops will be responsible for preparing land for planting, caring for the crops, and harvesting. Some farmers sell their own crops at market, while others have contracts with processing companies or other organizations.
Sources	*Local Rice Farmer*

1. Which stage of product development involves your work?

2. What skills are needed to effectively complete this work?

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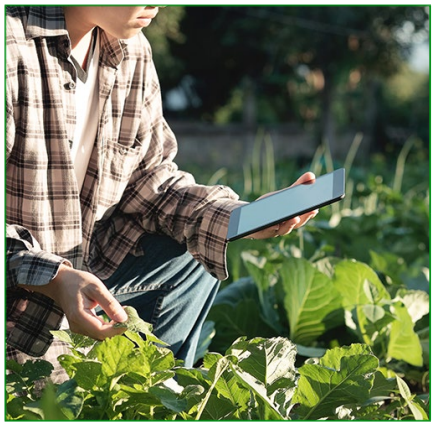
Analysis of Other Group Work Capture Sheet, Round 3

Continued

B. Conservation Ecologist



Job Description	These scientists manage the overall land quality of forests, parks, rangelands, and other natural resources.
Sources	*Conservation Ecologist*

1. Which stage of product development involves your work?

2. What skills are needed to effectively complete this work?

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Analysis of Other Group Work Capture Sheet, Round 4

Directions
Review the following questions and provide your answer to each in the space provided.

1. What questions do you still have about Golden Rice manufacturing and commercialization?

2. Make an initial claim about whether Golden Rice is the best solution to the problem of Vitamin A deficiency.

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Golden Rice Case Study Rubric

Score	3	2	1
Discovery of Golden Rice	Student work is complete, correct, and at a level from which others can learn through collaboration.	Student work lacks one or more of the following criteria: complete, correct, and at a level from which others can learn through collaboration.	Student work is at a level at which more effort and time need to be put forth to master knowledge.
Knowledge Profile	Student work is complete, correct, and at a level from which others can learn through collaboration.	Student work lacks one or more of the following criteria: complete, correct, and at a level from which others can learn through collaboration.	Student work is at a level at which more effort and time need to be put forth to master knowledge.
Manufacturing and Commercialization Flowchart	Flowchart meets all criteria, including information about how Golden Rice is manufactured and commercialized. It also contains information about careers, businesses, and potential marketing plans related to Golden Rice.	Flowchart is missing one or more criteria.	Student work is at a level at which more effort and time need to be put forth to master assignment.
Analysis of Group Work	Ideas from previous activities were clearly integrated into the analysis of group work. Significant thought was put forth in responses. The group collaborated effectively.	Ideas from previous activities were somewhat integrated into the analysis of group work. Some thought was put forth in responses. The group collaborated effectively for the most part.	Group work did not include ideas from previous activities. Little thought was put forth in responses. The group did not collaborate.
Final Score			