FUTURELAB+

AG/ENVIRONMENTAL

Solution Seeking Microbes

Microbes and Food (Menu)

Developed in partnership with:

Discovery Education and Ignited

In this Lesson Plan:

Print the **Teacher Section** →

Print the **Student Section** →

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

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Single Pages (use a comma): T3, T6

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Cover Image
Lactobacillus casei is one of many friendly bacteria in your gut microbiome.

AG/ENVIRONMENTAL / SOLUTION SEEKING MICROBES

Microbes and Food (Menu)

ACTIVITY DURATION

Three class sessions
(45 minutes each)

DRIVING QUESTION

How are microbes used in food production?

ESSENTIAL QUESTIONS

How are microbes used to create alternative proteins?

How are microbes used in the production of renewable feedstock?

How can these techniques be combined to improve food production?

OVERVIEW

Humans have relied on microbes in food production for thousands of years. As students learned in Lesson 2, microbes have been used in fermentation processes for foods, such as yogurt, cheese, beer, and bread. But, what new relationships can we have with microbes that might lead to a more sustainable future of food?

In this lesson, students will learn about how microbes contribute to producing food and food alternatives, comparing and contrasting with traditional approaches. Ultimately they will create a food item that will be featured on the menu that could be served at "Microgrub" and explain how microbes were used in the creation of their food on their menu poster. By advertising their product and explaining where it will be marketed and why, students will incorporate various stakeholders to ensure their product meets the needs of the community they aim to serve.

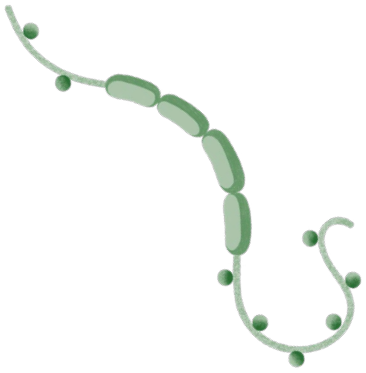
OBJECTIVES

Students will be able to:

Identify how genetically engineered (GE) microbe-influenced food is more environmentally friendly than traditional industry foods.

BACKGROUND INFORMATION

Students should be familiar with the four macromolecules found in food: carbohydrates, proteins, lipids, and nucleic acids, along with their monomers.



Materials
Poster Paper
Markers/Colored Pencils
Internet Access/Computers
Example household goods to physically show students: lipstick, instant noodles, soap, detergent, cookies, chocolate, detergent, shampoo etc.
Microgrub Research Capture Sheet
Microgrub Research Capture Sheet Key
Synthetic Biology Article
Toolkit
Microgrub Poster Checklist
Career Profile: Chelsey Spriggs

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 focus on self and social awareness in this lesson. They will integrate their personal feelings about food choices, giving them a sense of confidence and purpose as they contribute to their group's menu item. Students will think about others' perspectives and demonstrate empathy and compassion as they learn about those who might not have access to newly marketed foods.

CULTURALLY AND LINGUISTICALLY RESPONSIVE INSTRUCTION

Students will bring real-world problems into the classroom as they discuss solving the problem of being able to make and provide enough food for growing populations, regardless of cultural or financial background. Students' cultures will help shape curriculum as they will be asked to focus on food items they are familiar with, or a culturally relevant food item, as they construct their "Menu Item." Also, accessibility and availability of high-quality, nutritious food for all citizens regardless of financial background is a focus.

ADVANCING INCLUSIVE RESEARCH

Students will investigate and discuss communities that do not have access to affordable high-quality, nutritious food. They will discuss the cultural and historical factors that are involved, as well as the structural factors, and will reflect on how considering the needs of more diverse populations can lead to more equitable health outcomes.

COMPUTATIONAL THINKING PRACTICES

In this lesson, students research the emerging field of synthetic food production. As they collect data on microbe-inspired products, such as protease and synthetic honey, they utilize the computational thinking strategy of collecting data. This fundamental skill in computer science helps programmers design applications that are able to identify useful information and disregard irrelevant or unreliable data. Students put that skill into practice by gathering data from verifiable sources and displaying it in a useful format.

CONNECTION TO THE PRODUCT LIFE CYCLE

In this lesson, students research ways that microbes can be used to create more sustainable food products, and ultimately design a menu using their re-engineered food ideas. As students are identifying a sustainable microbe product alternative to current food, this connects to the **development** phase of the product life cycle.

Have you ever wondered…

How is it possible to feed a growing world population?

It has been forecasted that an exponentially growing human population will require 70% more food by 2050. With limitations on traditional agriculture, such as space and environmental impact, what new microbial technologies can we invest in to help accommodate the need for food?

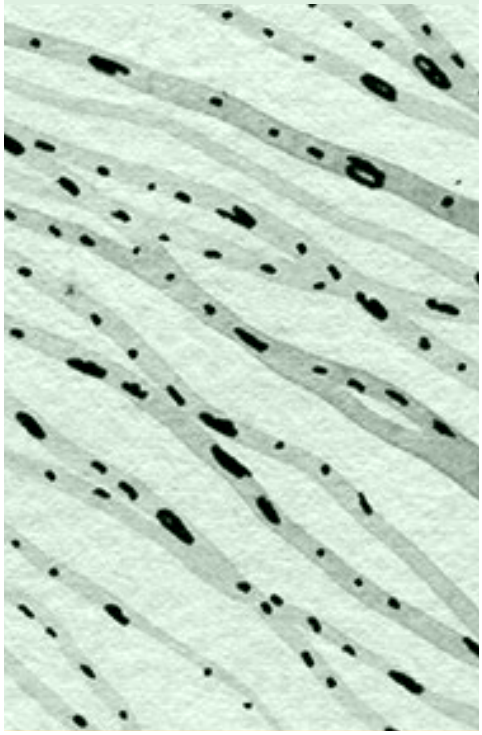
Why may microbes be called the superheroes of the food industry?

Microbes not only allow for the preservation of foods, but they improve the nutritional qualities and organoleptic qualities (taste, sight, smell, and texture). Additionally, synthetic biology is allowing for sustainable microbe- and plant-based protein products as traditional methods of raising livestock are not sustainable for a growing world population. In this way, bacteria can be programmed into efficient, customized macromolecule factories.

MAKE CONNECTIONS!

How does this connect to the larger unit storyline?

Microbes are being used to create alternative proteins and nutrients in foods for humans and feedstocks for animals. This is a way that microbes are contributing to human health, the environment, and food production.



How does this connect to careers?

Food scientists use lab and field studies to improve the safety, quality, and production of food. They use microbiology, engineering, and chemistry to meet the food safety requirements of the FDA and the needs of consumers and food manufacturers.

Environmental scientists conduct field and lab research around how to protect and improve human health and the health of our environment. They design research studies, review existing literature, and advocate for changes in their communities and our planet overall based on their work.

Financial analysts help their organizations see potential costs and benefits of programs and products. They use and create data reports in order to offer financial advice, risk assessment, budgeting guidelines, and they help companies make sense of the finances for projects.

Non-Governmental Organization (NGO) food aid employees may take on a wide range of roles (project manager, human resources, financial adviser) that ultimately serve the goal of the organization; in this lesson, the goal is around food aid and delivery logistics.

How does this connect to our world?

Alternative food sources are becoming more prevalent in our society (meatless ground beef and similar products) and people are recognizing that we will need new food sources.

Day 1

LEARNING OUTCOMES

Students will be able to:

Describe traditional agriculture methods used to produce various food items.

Explain values of various roles, including an environmentalist, a financial analyst, a non-governmental organization (NGO) worker, and a food scientist.

The image shows meatless burgers on a cutting board.

The image shows a palm oil plantation in Malaysia.

Procedure

Teacher Note > *Students will be using the internet to research throughout this lesson. You may wish to review with students researching tips.*

Whole Group (5 minutes)

1. Remind students that in the previous lesson they observed a natural, traditional way of using microbes to make food. Now they will explore how we can use biotechnology to exploit microbes in new ways to make new foods.

2. Ask students if they have heard of or have tried any plant-based meat products. Ask them to discuss with their partner the following (you may wish to project these questions for students to view while discussing):

   a. What is your comfort level with this?

   b. If given the opportunity, would you try it?

   c. What is it?

   d. Why do you think plant-based meat products were made in the first place?

   e. Why would it make sense to have something like this on the market?

   Ask a few groups to share what they discussed. Students may relate that they have noticed that plant-based meat products are expensive or they sound “weird” or that they have not even heard of them. They may relate that they have heard that raising cattle is not sustainable in its current practice. Address that our goal in this lesson is to understand how and why microbes are the superheroes of the food industry with the potential to make food production more sustainable.

3. Show an example of food with palm oil in it and ask students if they know why palm oil might be in these products. Do not give too many details as a student group may choose to focus on this for their group work, but tell students there are pluses and minuses to growing a product. For instance, 86% of the world’s palm oil is produced in Indonesia, which contributes to its economy. Tell students they will look for microbe-influenced alternatives to current food production practices that are more sustainable and can be made available to all.

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Day 1

Continued

Procedure

Small Group (35 minutes)

1 Hand out and introduce the *Microgrub Research Capture Sheet* to students. Explain that to complete this capture sheet, students will be working in groups to research the roles of related careers in the development of microbe-influenced food and assessing environmental and human influence.

2 Split students into groups we will call "Menu" groups, as they will eventually be producing a menu item together for a company called "Microgrub" that is being hired to cater a venue at the end of this unit at an event called "Micro-Con" where microbes will be showcased for how they address real-world struggles. Each group will identify a food item that uses the food product they have been researching as an ingredient. Groups can be either eight students per group or four students per group at your discretion, and groups may choose which microbial-influenced food product they would like to research. Keep in mind, these are examples of foods that are synthetically produced or manufactured using microbes.

a. Palm oil

b. Synthetic honey

c. Biovanillin—vanilla made from microbes

d. Feed additives (vitamins B2, B12) for cattle

e. Hemoglobin from soy (burger)

f. Protease (enzymes)—infant formula

g. Chymosin—cheese making

Group members will each take on a chosen role: Environmentalist, Financial analysis, Food scientist, or NGO worker. It is from this viewpoint that they will focus on the traditional trends in food production to compare and contrast those with microbial-influenced food production.

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Day 1

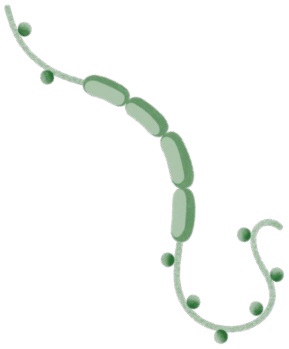
Continued

Procedure

Tell students they will spend some time individually researching information on the career role they chose and the traditional means of the food produced, which they will later present to their groups.

- Tell students to first find a short description on the internet for their role. Suggest that students search the terms “career profile” or “career zone” followed by the name of their chosen role.
- They will research the traditional means of food production from the lens of their chosen career role. Using palm oil as an example, the Environmentalist will look at the environmental impact of traditional farming production for palm oil, the Financial analyst will research associated costs (benefits and losses), the Food scientist would focus on how the palm oil is processed or the biological production in trees, and the NGO workers will focus on accessibility of the traditionally produced food.

3 Tell students to return to their Menu groups. They will first identify their roles and explain what a day in the life of someone with each career is like. After explaining their careers, students will take turns explaining traditional trends in the food industry of their assigned topic to their group members. Students should take notes (short summaries) on their *Microgrub Research Capture Sheet*.



Day 2

LEARNING OUTCOMES

Students will be able to:

Describe microbe-influenced agriculture methods used to produce various food items.

Procedure

Teacher Note > *For more information on the Green Revolution, visit this article. You may wish to show students this video to see how the Green Revolution impacted India.*

Whole Group (20 minutes)

1 With a constantly growing world population, agricultural methods have had to drastically improve to meet demands. As our world population continues to increase, agricultural technologies are once again falling behind. Tell students that it is estimated that the world's food production must double by 2050 to meet the food needs of the world's population. Tell students that now that they have a general understanding of the traditional ways these foods have been made, you will turn your attention to microbes, and how they can be used to make the same or similar food item, potentially in a more environmentally sustainable way. Show students the TedED video *A global food crisis may be less than a decade away* explaining global food production and population growth. Ask students to discuss in pairs the following:

a. What is needed to grow the food item you studied on Day 1 in the traditional method? What is a limitation of this method?

b. What, if any, are alternatives to the traditional method on Day 1 that you may have heard about?

2 Tell students to read the *Synthetic Biology Article* to get them thinking about how modified microbes might help make the foods from Day 1 in a more sustainable way. Tell them to read and annotate the passage, and then answer the questions. For more directions on how to close read, visit *How to Do a Close Reading* from Harvard College Writing Center.

3 Discuss the questions with the class, calling on student volunteers to share their answers. See the provided answer key to help direct student discussion.

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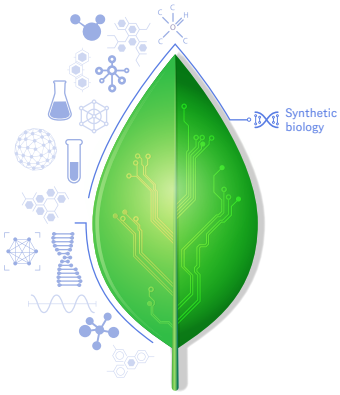
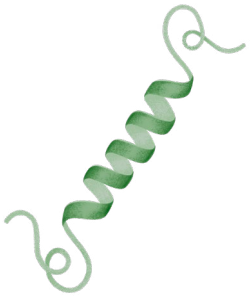
Day 2

Continued

Procedure



Small Group (25 minutes)	
1	Have students regroup with their "Menu" groups. Tell students they will take on the same roles from the previous day, however they will now focus on a microbe-influenced version of their food item.
2	After students finish researching, have them teach their partners what they learned about the microbe-influenced item through their role, recording bullet point notes on their *Microgrub Research Capture Sheet* as they listen.
3	Tell students that tomorrow they will be making a Menu Item poster that includes the microbe-influenced food item marketed to a wide variety of consumers. Their Exit Ticket is to brainstorm three foods that might contain their food item. Encourage students to list foods that are culturally significant to them or their peers.
4	Tell students to visit their **Toolkit** and answer the following questions: • How are microbes used in food production? • How do microbes impact the environment, food production, or human health in this lesson?



Day 3

Procedure

LEARNING OUTCOMES

Students will be able to:

Design a Menu Item poster advertising a microbe-influenced food item.

Small Group (35 minutes)	
1	Students will now choose one food from the three food items they brainstormed on Day 2 to showcase on the "Microgrub Menu." This menu item will be showcased in a poster and will contain the following information that each member will add (see the *Microgrub Poster Checklist*):
	a. illustration of the food item containing microbe-influenced ingredients (for instance, vanilla ice cream cone made with biovanillin)
	b. nutritional information, including macromolecule breakdown and calorie count
	c. discussion of how the item's environmental impact differs from traditional methods
	d. brief discussion or illustration of the biological process used to create this item
	e. identification of the agency that regulates the production of this item
	f. comparison between the cost of the traditional method and that of the microbe-influenced item
	g. explanation of how this menu item will be accessible to a large audience, e.g., where food will be sold beyond the "Microgrub Menu" and why
2	Hand out poster paper and markers to students, and allow time to work on the poster. Each student is given a different colored marker so that it is obvious that all four students contributed to the poster.
3	Students will share with another student or group in the class, explaining their food items. Students will take turns representing their posters during the time permitted.
4	Students should now go back to their **Toolkit** and fill in the information for the microbial impact.

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Day 3

Continued

Procedure

Whole Class (10 min)	
1	Have students read the *Career Profile* on Chelsey Spriggs. As students read, you may wish to read it too and model for students the ideas that resonate for you with the scientist. Allow students time to answer the question on their **Toolkit**: • Based on the career profile in this lesson, what does this tell you about the types of people that do science? • What did you find most relatable?
2	Ask students to share their responses to either question above in a whole class discussion.

Teacher Note > *If time permits, students can engage in a Gallery walk. One student from each group can be standing in front of the poster, giving a minute-long "About Us" elevator pitch as other student groups visit and review the poster. This student might be considered the "Scientific Communications Specialist" for "Microgrub." Students could then vote on the best food item that will be featured at Microgrub! Votes should be cast based on how well the menu item matches the grading checklist criteria, and is also based on student interest.*

National Standards

Next Generation Science Standards

LS1.C: Organization for Matter and Energy Flow in Organisms

The hydrocarbon backbones of sugars produced through photosynthesis are used to make amino acids and other molecules that can be assembled into proteins or DNA. Through cellular respiration, matter and energy flow through different organizational levels of an organism as elements are recombined to form different products and transfer energy.

Science and Engineering Practices

Obtaining, Evaluating, and Communicating Information

Communicate scientific and/or technical information or ideas (e.g., about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (i.e., orally, graphically, textually, mathematically).

Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source.

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.

A1.3

Recognize the role of innovation in creation of emerging biotechnology careers, including those in nanotechnology, biofuels, and forensics.

A1.6

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

A5.1

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

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National Standards

CTE *Continued*	**A7.1** Identify agencies at the local, state, and federal levels.
	2.5 Communicate information and ideas effectively to multiple audiences using a variety of media and formats.
	4.1 Use electronic reference materials to gather information and produce products and services.
	4.3 Use information and communication technologies to synthesize, summarize, compare, and contrast information from multiple sources.
	4.5 Research past, present, and projected technological advances as they impact a particular pathway.
	5.6 Read, interpret, and extract information from documents.
	7.4 Practice time management and efficiency to fulfill responsibilities.
	7.6 Demonstrate knowledge and practice of responsible financial management.
	9.3 Understand the characteristics and benefits of teamwork, leadership, and citizenship in the school, community, and workplace setting.
	9.5 Understand that the modern world is an international community and requires an expanded global view.

Microgrub Research Capture Sheet

Production Cost Research: Role Assignment

ANSWER KEY **Do not share with students**

Directions

Assign each member of your group to one of the roles described below, and do a bit of research to understand what someone in that role might value.

1. Note the group's assigned food item below.

Answers will vary.

2. Assign roles as described below.

Role	Focus Questions	What would someone in this role value?	Group Member Assigned
Environmentalist	What are the environmental impacts of producing this food?	Answers will vary.	
Food Scientist	What is the process used to create this food? What agency regulates the human health and safety impacts of this item?	Answers will vary.	
Financial Analyst	How large of a market is there for this food (what is the monetary value of the food)?	Answers will vary.	
NGO Worker	Where in the world is this food item produced? Where is it available for purchase?	Answers will vary.	

Microgrub Research Capture Sheet

Production Cost Research: Environmentalist

ANSWER KEY **Do not share with students**

Directions

Research the production "cost" of your food according to the identified focus of an Environmentalist.

Example student responses are for Biovanillin.

	Focus Question	What are the environmental impacts of producing this food?
1	On the first day, research the traditional production costs of your food.	— Water footprint: HIGH 126,505 L/kg of vanilla bean (equivalent to 15,159 gal/lb) — Carbon footprint: LOW 1.6 kg of CO2/kg of beans — High Destruction: Deforestation Erosion Endangering wildlife Greenhouse gas emissions — In general, natural extraction of vanillin is unsustainable. Source: *Is Vanilla Good Or Bad? | 2021 Ingredient Guide For Health, Environment, Animals, Laborers — HEALabel*
2	On the second day, research the "microbe-influenced" production of your food item, and describe its costs.	— Requires use of crops for fermentation: wheat, rice, maize, tea leaves, etc. — Reduces water waste and water footprint-not as much water needed to produce biovanillin as needed for regular vanillin harvesting. — Relatively low destruction of nature/environment: only need crops/land for crops to grow. — In general, biovanillin is more sustainable than natural vanillin. Sources: *Is Vanilla Good Or Bad? | 2021 Ingredient Guide For Health, Environment, Animals, Laborers —HEALabel* *Bio Vanillin Industry Trends and Opportunities* *Vanillin–Bioconversion and Bioengineering of the Most Popular Plant Flavor and Its De Novo Biosynthesis in the Vanilla Orchid*

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Microgrub Research Capture Sheet

Production Cost Research: Food Scientist

ANSWER KEY **Do not share with students**

Directions

Research the production "cost" of your food according to the identified focus of a Food Scientist.

Example student responses are for Biovanillin.

	Focus Question	What is the process used to create this food? What agency regulates the human health and safety of this item?
1	On the first day, research the traditional production costs of your food.	— FDA regulates natural vanilla extraction/production. — Vanillin is naturally derived through botanical extraction. — Labor intensive—takes years to grow and pollinate by hand. — After harvesting, beans are cured and blanched, which activates enzyme that develops distinct vanilla flavor. — Beans are then "sweated"—fermented, then dried, and then the process is repeated. — Finally beans are cured and then shipped to an extraction facility. — Beans are crushed and ground to expose different molecules, including vanillin. — Grounds are washed and soaked in a solution of alcohol and water— vanillin is alcohol soluble, so the molecules get absorbed into the alcohol creating vanilla extract. Source: *How Is Pure Vanilla Extract Made?*
2	On the second day, research the "microbe-influenced" production of your food item, and describe its costs.	— Ferulic acid: several different bacteria are able to metabolize ferulic acid→ leads to production of biovanillin. — Different plants are fermented in order to obtain ferulic acid: maize, rice, wheat. — Different strains of bacteria, and also fungi and yeast are used to produce biovanillin. — Microorganisms degrade and metabolize ferulic acid into vanillin/vanillic acid. — Biovanillin does not alter nutritional value of food or beverage products. Sources: *Vanillin–Bioconversion and Bioengineering of the Most Popular Plant Flavor and Its De Novo Biosynthesis in the Vanilla Orchid* *Microbial Production of Biovanillin* *How Vanillin is Made*

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Microgrub Research Capture Sheet

Production Cost Research: Financial Analyst

ANSWER KEY **Do not share with students**

Directions

Research the production "cost" of your food according to the identified focus of a Financial Analyst.

Example student responses are for Biovanillin.

	Focus Question	How large of a market is there for this food (what is the monetary value of the food)?
1	On the first day, research the traditional production costs of your food.	— Global vanillin market is around $760 million (as of 2019). — Traditional vanillin harvesting accounts for $161 million. — Avg cost for pure vanilla extract is around $20/8 oz bottle. — Cost of first-grade vanilla extraction as of 2018 is $600/kg (Madagascar). Source: *Bio Vanillin: A promising nutraceutical ingredient for biotechnology manufacturers* *Vanilla prices slowly drop as crop quality improves.*
2	On the second day, research the "microbe-influenced" production of your food item, and describe its costs.	— Global vanillin market is around $760 million (as of 2019). — Biovanillin production accounts for $19 million as of 2019. — Significantly less costly than traditional vanilla production: less $$ for water and labor needed. — Precultivation and fermentation using yeast and other microorganisms is generally a one-step process, which reduces the cost of production. — Overall, high effectiveness and low cost in comparison to natural vanilla production. Source: *Bio Vanillin: A promising nutraceutical ingredient for biotechnology manufacturers* *Microbial Production of Biovanillin*

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Microgrub Research Capture Sheet

Production Cost Research: NGO Worker

ANSWER KEY **Do not share with students**

Directions

Research the production "cost" of your food according to the identified focus of a NGO Worker.

Example student responses are for Biovanillin.

	Focus Question	Where in the world is this food item produced? Where is it available for purchase?
1	On the first day, research the traditional production costs of your food.	— The largest consumers of vanilla globally are the United States (18%) and Indonesia (13%), followed by Mexico, France, and Papua New Guinea. — Global vanilla market depends highly on Madagascar, and production can fluctuate due to crop shortages there, such as with the 2016 cyclones (2016).t. Source: *Insights into the global vanilla market*
2	On the second day, research the "microbe-influenced" production of your food item, and describe its costs.	— Asia-Pacific expected to be the largest consumer of biovanillin until 2024, due to this region's broad consumer base and rapid industrialization of the food sector. — Exceeded 60 tons in 2015. — Emerging markets in India, China and Malaysia are expected to play key role in biovanillin production. — Extremely useful in baking and confectionery industry.. Sources: *Bio Vanillin Market To Grow On Account Of Rising Awareness Regarding Environment Conservation* *Bio Vanillin Market Analysis, By Application (Food & Beverage, Fragrance, Pharmaceuticals) And Segment Forecasts To 2024*

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Microgrub Research Capture Sheet

Production Cost Research: Group

ANSWER KEY **Do not share with students**

Directions

As a group, compare the traditional vs. microbe-influenced production to determine which method is most efficient.

1. Give each cost a score (with 5 being high and 1 being low), then average the scores to come up with one for each method.

	Environmentalist	Food Scientist	Financial Analyst	NGO Worker	Group
Traditional Production	Answers will vary.	Answers will vary.	Answers will vary.	Answers will vary.	Answers will vary.
Microbe-Influenced Production	Answers will vary.	Answers will vary.	Answers will vary.	Answers will vary.	Answers will vary.

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Microgrub Research Capture Sheet
Production Cost Research: Group

ANSWER KEY **Do not share with students**

Continued

2. As a group, decide which type of food production has a better impact on the environment, human health, and accessibility.

	Environmental impact	Human health impact	Accessibility
Traditional Production	Answers will vary.	Answers will vary.	Answers will vary.
Microbe-Influenced Production	Answers will vary.	Answers will vary.	Answers will vary.

3. Whichever food production (traditional or microbe-influenced) has a higher cost, indicate below how that cost might be reduced without changing the way the food is produced.

Answers will vary.

Synthetic Biology Article

ANSWER KEY **Do not share with students**

Directions
Read and analyze the following article and answer the questions on the next page.

1. Read, highlight, and annotate the following article.

Synthetic Biology and Hunger	Source: *What Can Synthetic Biology Do Better to Help End Hunger?*
Synthetic biology has the potential to change the way our agriculture systems function, and to usher in a new era of equitable and sustainable nutrition. That is provided the biotech community becomes more aware of obstacles that could lead to greater food disparities. By working together, science, business, and public policy can create unconventional food technologies that can solve global hunger. Agriculture technology (ag-tech) is the combination of traditional farming and modern digital advances. Entrepreneurs need to understand that public policies can be a tremendous help or hindrance to their ag-tech startups if they let them. To ensure policy-makers are more helpful than harmful, entrepreneurs need to communicate through money. For example, with this mindset, entrepreneurs can explain the benefits and risks of deforestation in dollar values. They can also illustrate how their technology could reduce the need for deforestation by helping increase crop yields. Besides money, another communication roadblock that is often overlooked is the outdated and superior mentalities of scientists. The motivation to help others is not typically enough to advance sustainable solutions. Agricultural technologies, including modified seeds and precision farming, are already helping to increase crop yields and reduce resource needs, but new technology is not necessarily accessible to everybody. If implementing this technology requires training, developed nations would likely be in a better position to utilize it, leaving out less-equipped regions. Without effective policies, ag-tech could unintentionally worsen economic and social inequities instead of improving them. Governments can reduce these risks by removing money as a barrier to access to technologies. This is why, in some ways, it is easier and more efficient to create partnerships at the local level than to wait for government aid. Because of how rigid bureaucracies are, the time and effort it takes just to clear a patent application present huge hurdles for new entrepreneurs. Community acceptance is also a significant obstacle. The lack of trust from many farmers stems from a lack of knowledge and understanding about new techniques, since “new” does not always mean “better” to them. Even when the government creates policies to support farmers, many farmers are unwilling to accept them. Governments, startups, and financial institutions must put the interests of individuals and communities above net profit, despite the obvious human tendency to prioritize personal wealth. However, for the synthetic biology industry to fully accept its role in addressing global hunger, partnerships with investors who agree that socially-based business models are investable opportunities need to be created.	*Annotations* Answers will vary.

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Synthetic Biology Article

ANSWER KEY **Do not share with students**

Continued

2. How can entrepreneurs in the ag-tech industry get the help of policymakers?

Entrepreneurs in the ag-tech industry can get the help of policymakers by communicating through money.

3. What evidence would entrepreneurs in the ag-tech industry use to explain why their product is desirable to policymakers?

Entrepreneurs in the ag-tech industry can use the benefits and risks of deforestation in dollar values to explain why their products are desirable to policymakers. They can also illustrate how their technology could reduce the need for deforestation by helping increase crop yields.

4. Where would new technology be most likely implemented? Why is this a problem?

New technology would be most likely implemented in more developed nations. This is a problem because if a new technology requires training, less equipped regions are left behind as more developed nations would likely be in a better position to implement it.

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Synthetic Biology Article

ANSWER KEY **Do not share with students**

Continued

5. Why do we need effective policies?

We need effective policies because without them, ag-tech could unintentionally worsen economic and social inequities instead of improving them. Effective policies made by the government can reduce these risks by removing money as a barrier to access to technologies.

6. Why is community acceptance important?

Community acceptance is important because even when the government creates policies to support the local community, many community members could be unwilling to accept it, making the policies obsolete.

Microgrub Poster Checklist

ANSWER KEY **Do not share with students**

Directions

Select one possible Micro-Con menu item that might contain the microbe-influenced food item you researched with the Microgrub Research Capture Sheet, and showcase it as a poster with the following information:

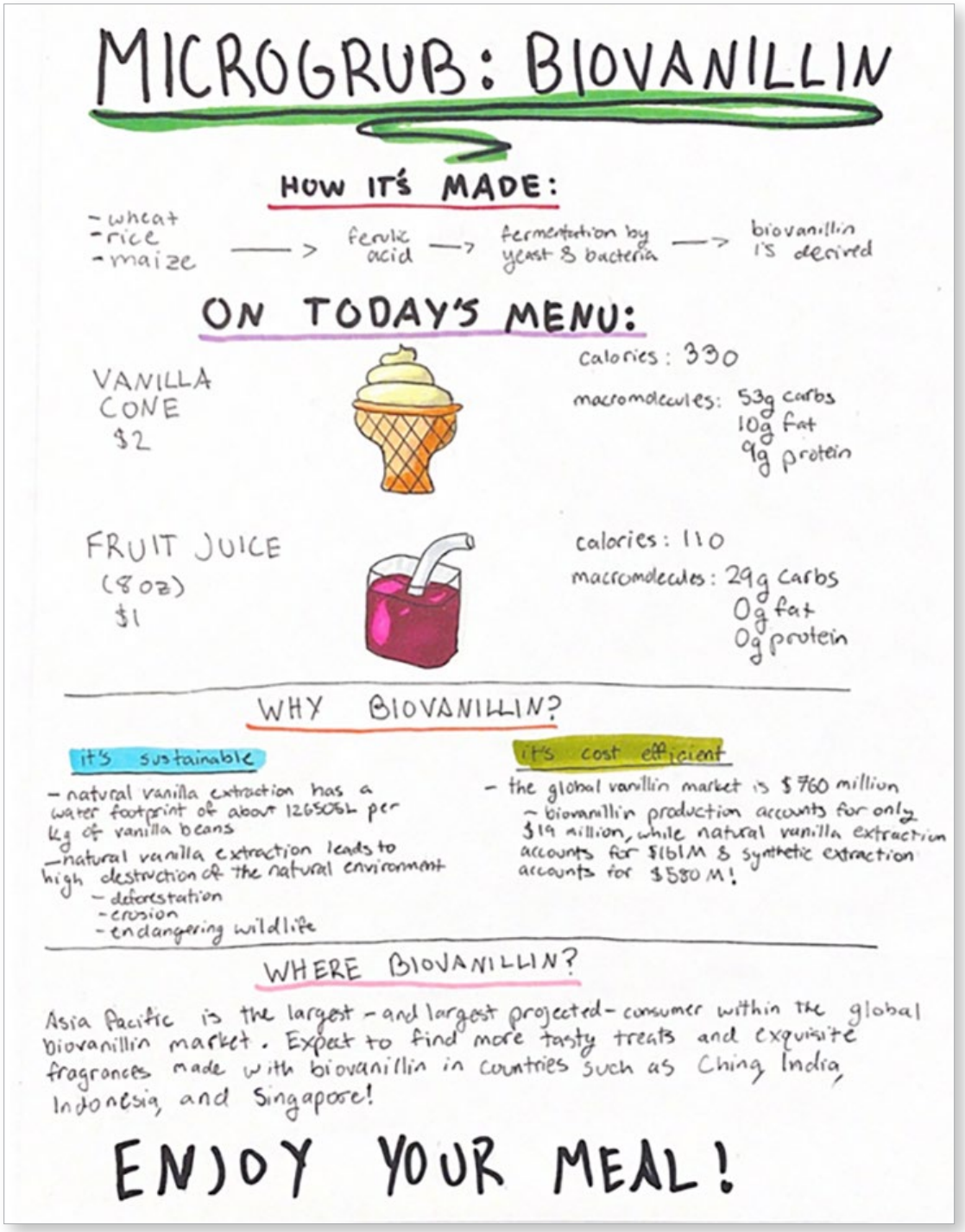
1	Illustration of the food item containing microbe-influenced ingredients (for instance, vanilla ice cream made with biovanillin)
2	Nutritional information of menu item: calories, carbohydrates, fats and protein
3	Discussion of how the item is more or less environmentally friendly than traditional industry item
4	Brief discussion or illustration of the biological process used to create this item
5	Identification of the agency that regulates the production of this item
6	Comparison between the cost of the traditional method and the microbe-influenced method
7	Explanation of how this menu item will be accessible to a large audience, e.g., where this food will be sold beyond the "Microgrub Menu"

Student example shown on the next page.

Microgrub Poster Checklist

ANSWER KEY **Do not share with students**

Continued



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Microgrub Research Capture Sheet

Production Cost Research: Role Assignment

Directions

Assign each member of your group to one of the roles described below, and do a bit of research to understand what someone in that role might value.

1. Note the group's assigned food item below.

_____

2. Assign roles as described below.

Role	Focus Questions	What would someone in this role value?	Group Member Assigned
Environmentalist	What are the environmental impacts of producing this food?		
Food Scientist	What is the process used to create this food? What agency regulates the human health and safety impacts of this item?		
Financial Analyst	How large of a market is there for this food (what is the monetary value of the food)?		
NGO Worker	Where in the world is this food item produced? Where is it available for purchase?		

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Microgrub Research Capture Sheet

Production Cost Research: Environmentalist

Directions

Research the production "cost" of your food according to the identified focus of an Environmentalist.

	Focus Question	What are the environmental impacts of producing this food?
1	On the first day, research the traditional production costs of your food.	
2	On the second day, research the "microbe-influenced" production of your food item, and describe its costs.	

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Microgrub Research Capture Sheet

Production Cost Research: Food Scientist

Directions

Research the production "cost" of your food according to the identified focus of a Food Scientist.

	Focus Question	What is the process used to create this food? What agency regulates the human health and safety of this item?
1	On the first day, research the traditional production costs of your food.	
2	On the second day, research the "microbe-influenced" production of your food item, and describe its costs.	

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Microgrub Research Capture Sheet

Production Cost Research: Financial Analyst

Directions

Research the production "cost" of your food according to the identified focus of a Financial Analyst.

	Focus Question	How large of a market is there for this food (what is the monetary value of the food)?
1	On the first day, research the traditional production costs of your food.	
2	On the second day, research the "microbe-influenced" production of your food item, and describe its costs.	

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Microgrub Research Capture Sheet

Production Cost Research: NGO Worker

Directions

Research the production "cost" of your food according to the identified focus of an NGO Worker.

	Focus Questions	Where in the world is this food item produced? Where is it available for purchase?
1	On the first day, research the traditional production costs of your food.	
2	On the second day, research the "microbe-influenced" production of your food item, and describe its costs.	

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Microgrub Research Capture Sheet

Production Cost Research: Group

Directions

As a group, compare the traditional vs. microbe-influenced production to determine which method is most efficient.

1. Give each cost a score (with 5 being high and 1 being low), then average the scores to come up with one for each method.

	Environmentalist	Food Scientist	Financial Analyst	NGO Worker	Group
Traditional Production					
Microbe-Influenced Production					

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Microgrub Research Capture Sheet

Production Cost Research: Group

Continued

2. As a group, decide which type of food production has a better impact on the environment, human health, and accessibility.

	Environmental impact	Human health impact	Accessibility
Traditional Production			
Microbe-Influenced Production			

3. Whichever food production (traditional or microbe-influenced) has a higher cost, indicate below how that cost might be reduced without changing the way the food is produced.

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Synthetic Biology Article

Directions
Read and analyze the following article and answer the questions on the next page.

1. Read, highlight, and annotate the following article.

Synthetic Biology and Hunger

Source: *What Can Synthetic Biology Do Better to Help End Hunger?*

Annotations

Synthetic biology has the potential to change the way our agriculture systems function, and to usher in a new era of equitable and sustainable nutrition. That is provided the biotech community becomes more aware of obstacles that could lead to greater food disparities. By working together, science, business, and public policy can create unconventional food technologies that can solve global hunger. Agriculture technology (ag-tech) is the combination of traditional farming and modern digital advances. Entrepreneurs need to understand that public policies can be a tremendous help or hindrance to their ag-tech startups if they let them. To ensure policy-makers are more helpful than harmful, entrepreneurs need to communicate through money. For example, with this mindset, entrepreneurs can explain the benefits and risks of deforestation in dollar values. They can also illustrate how their technology could reduce the need for deforestation by helping increase crop yields. Besides money, another communication roadblock that is often overlooked is the outdated and superior mentalities of scientists. The motivation to help others is not typically enough to advance sustainable solutions. Agricultural technologies, including modified seeds and precision farming, are already helping to increase crop yields and reduce resource needs, but new technology is not necessarily accessible to everybody. If implementing this technology requires training, developed nations would likely be in a better position to utilize it, leaving out less-equipped regions. Without effective policies, ag-tech could unintentionally worsen economic and social inequities instead of improving them. Governments can reduce these risks by removing money as a barrier to access to technologies. This is why, in some ways, it is easier and more efficient to create partnerships at the local level than to wait for government aid. Because of how rigid bureaucracies are, the time and effort it takes just to clear a patent application present huge hurdles for new entrepreneurs. Community acceptance is also a significant obstacle. The lack of trust from many farmers stems from a lack of knowledge and understanding about new techniques, since “new” does not always mean “better” to them. Even when the government creates policies to support farmers, many farmers are unwilling to accept them. Governments, startups, and financial institutions must put the interests of individuals and communities above net profit, despite the obvious human tendency to prioritize personal wealth. However, for the synthetic biology industry to fully accept its role in addressing global hunger, partnerships with investors who agree that socially-based business models are investable opportunities need to be created.

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Synthetic Biology Article

Continued

2. How can entrepreneurs in the ag-tech industry get the help of policymakers?

3. What evidence would entrepreneurs in the ag-tech industry use to explain why their product is desirable to policymakers?

4. Where would new technology be most likely implemented? Why is this a problem?

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Synthetic Biology Article

Continued

5. Why do we need effective policies?

6. Why is community acceptance important?

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Microgrub Poster Checklist

Directions
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7	Explanation of how this menu item will be accessible to a large audience, e.g., where this food will be sold beyond the “Microgrub Menu”

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Career Profile

Virology researcher,
Research Fellow
and Diversity advocate

Chelsey Spriggs
Research Fellow at Tsai Lab, Postdoc at University of Michigan

What do you do and how did you get here?

I am a scientist at the University of Michigan where I study how cancer-causing viruses get into cells to cause infection. I always loved science in school, but I had no idea that I could do science when I grew up! I worked in a research lab in college as a part of a degree requirement and learned about viruses and how they can cause cancer. Although I loved science, I thought that the only career options were doctor or veterinarian. I actually went to medical school, but was unhappy and made the difficult decision to leave and pursue biomedical research. My professor helped me to apply for graduate school and the rest is history! I will soon be starting my own lab studying how viruses cause cancer and how they can be used to treat cancer.

What skills do you use on a daily basis?

The skills that I use most are critical thinking and communication. In science, you come up with hypotheses to test and sometimes they work and sometimes they don't. It's VERY cool when they do work, but more often than not, you don't get the result you expected. At that time, it is very important to think critically about what to do next and how to interpret your data. Doing this, you come up with another hypothesis to test and eventually, you get it right! Communication is also extremely important in my daily activities. I have to be able to clearly communicate my findings to others because science is meant to be shared.

What's most fulfilling about your job/career? What's most challenging?

The most fulfilling part about my job is getting good data. If I find something new, for a few minutes, I may be the only person in the world that knows what I know! As a microbiologist, I study things too small to see, so figuring out how they work through science is gratifying. The most challenging thing about my job is that 75% of my experiments fail or do not reveal what I expected them to. At these moments it is important to persevere instead of giving up—eventually I get it right.

If you could give a piece of advice to your younger self, what would it be?

My advice to my younger self would be to follow your passion. Don't do something because you think that is what is expected of you and don't shy away from challenges because people say that it can't be done. You can do what you put your mind to even if you have to be the first one to ever do it!

If you could have any superpower, what would it be?

I would love to be able to fly! Seeing the world from that vantage point would be so awesome... and I'll never be stuck in traffic again!

What is your most used phone app?

My music app. I love listening to music that matches my mood. It can also help me to feel at peace or uplift my spirit. I am always playing music!