FUTURELAB+

AG/ENVIRONMENTAL

Solution Seeking Microbes

Toolkit

Developed in partnership with:

Discovery Education and Ignited

In this Toolkit:

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Lesson 1: Superhero Microbes

ANSWER KEY **Do not share with students**

What did we figure out?
Which parts of what we figured out can help us with our model or concept map? *(bullet point or highlight key terms)*

1. **What is the structure and function of the components that make up bacteria?**

Students should include: capsule, flagella, nucleoid, plasmid, ribosomes, plasma membrane, fimbria, and their functions.

2. **How can we relate the components of bacteria to superhero powers?**

Superheroes usually have an origin story. This includes how they got their superpower and identifies their sidekick, evil villain or competitor, mentor, and how they help humans. This analogy can be compared to microbes because they have adaptations that allow them to survive in an environment where others do not thrive, they have symbiotic relationships with other organisms, and humans have related to them in ways that improve human lives.

3. **How do microbes impact the environment, food production, or human health in this lesson?**

Answers will vary.

4. **Based on the career profile in this lesson, what does this tell you about the types of people that do science?**

Answers will vary. Holly Lutz, PhD: Research Associate at the Field Museum of Natural History's Integrative Research Center & Project Scientist, UC San Diego's Center for Microbiome Innovation

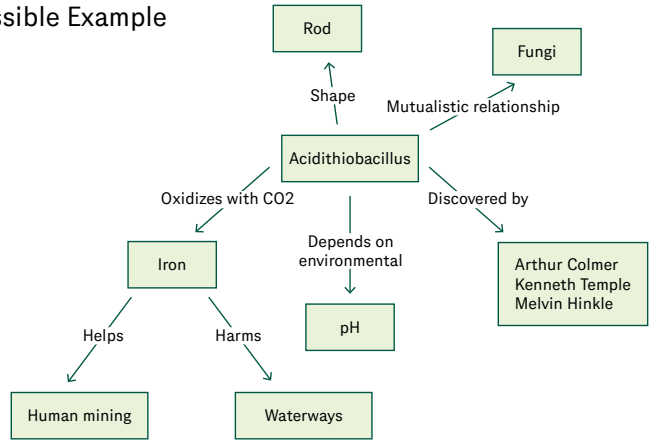
5. **What did you find most relatable?**

Answers will vary.

Based on our progress through this lesson, how can we visually represent what we learned?
Create a model or concept map, drawing, symbols, etc. to help answer our Unit question "How can microbes help solve real-world challenges?" *(highlight structures and relationships)*

Answers will vary.

Possible Example



Lesson 2: Yogurt Fermentation

ANSWER KEY **Do not share with students**

What did we figure out?
Which parts of what we figured out can help us with our model or concept map? *(bullet point or highlight key terms)*

1. **Explain how yogurt is made, including fermentation steps performed by microbes.**

Yogurt is made from the bacterial fermentation of a liquid, typically milk. When a bacterial culture is added to milk at optimal temperatures, it ferments the milk sugar, known as lactose, into lactic acid. The lactic acid makes the milk more acidic (lower pH), causing the proteins to coagulate and thicken, and giving yogurt its tangy taste.

2. **Based on the career profile in this lesson, what does this tell you about the types of people that do science?**

Answers will vary. Celeste Allaband, veterinarian and researcher

3. **What did you find most relatable?**

Answers will vary.

Based on our progress through this lesson, how can we visually represent what we learned?
Create a model or concept map, drawing, symbols, etc. to help answer our Unit question "How can microbes help solve real-world challenges?" *(highlight structures and relationships)*

Answers will vary.

Lesson 3: Microbes and Food (Menu)

ANSWER KEY **Do not share with students**

What did we figure out?
Which parts of what we figured out can help us with our model or concept map? *(bullet point or highlight key terms)*

1. **How are microbes used in food production?**

We can utilize the adaptability of microbes to engineer them to create food or molecules we desire by giving them new genes to synthesize these products.

2. **How do microbes impact the environment, food production, or human health in this lesson?**

Microbes can be used to reduce agricultural strain on the environment and reduce the energy or emissions associated with traditional agriculture.

3. **Based on the career profile in this lesson, what does this tell you about the types of people that do science?**

Answers will vary. Chelsey Spriggs: Research Fellow Tsai Lab, Virology researcher, Postdoc at University of Michigan, Diversity advocate

4. **What did you find most relatable?**

Answers will vary.

Based on our progress through this lesson, how can we visually represent what we learned?
Create a model or concept map, drawing, symbols, etc. to help answer our Unit question "How can microbes help solve real-world challenges?" *(highlight structures and relationships)*

Answers will vary.

Lesson 4: Antibiotics, Resistance, and Combating Disease

ANSWER KEY **Do not share with students**

What did we figure out?
Which parts of what we figured out can help us with our model or concept map? *(bullet point or highlight key terms)*

1. **How are clinical trials designed so new medicines and therapies can be tested with minimal risk to patients?**

Trials are guided by rigorous criteria to reduce risk to patients. Patients are also informed of possible risk and benefits.

2. **How do microbes impact the environment, food production, or human health in this lesson?**

Microbes have a delicate balance with humans. Although some are critical in maintaining a healthy system, others pose a serious risk, especially when medications are not taken as prescribed.

3. **Based on the career profile in this lesson, what does this tell you about the types of people that do science?**

Answers will vary. Ariangela J. Kozik, PhD: Research Fellow at the University of Michigan Medical School: Division of Pulmonary and Critical Care

4. **What did you find most relatable?**

Answers will vary.

Based on our progress through this lesson, how can we visually represent what we learned?
Create a model or concept map, drawing, symbols, etc. to help answer our Unit question "How can microbes help solve real-world challenges?" *(highlight structures and relationships)*

Answers will vary.

Lesson 5: Bacterial Defense

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

What did we figure out?
Which parts of what we figured out can help us with our model or concept map? *(bullet point or highlight key terms)*

1. **What are types of bacterial strategies for defending against phages?**

Each phase of the phage life cycle is targeted: preventative absorption, inhibiting injection, lysosome inhibition, CRISPR, restriction enzymes, assembly interference, and toxins.

2. **What are the components of CRISPR and what is the function of each?**

Guide RNA leads Cas9 to the cut site, Cas9 cleaves DNA, PAM, target

3. **How do restriction enzymes work?**

Restriction enzymes cleave phage DNA. They can be used to cut any DNA that matches.

4. **What are potential uses of CRISPR for humans?**

As discussed in the interactive activity, CRISPR can be used to make modifications to DNA to change shapes of proteins.

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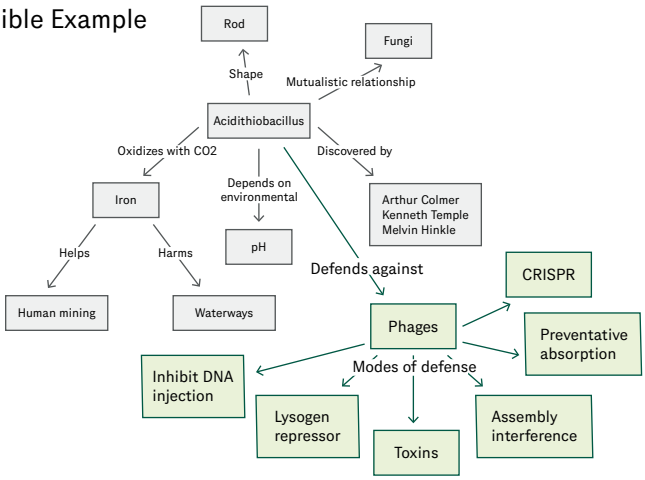
Based on our progress through this lesson, how can we visually represent what we learned?
Create a model or concept map, drawing, symbols, etc. to help answer our Unit question "How can microbes help solve real-world challenges?" *(highlight structures and relationships)*

Answers will vary.

Possible Example



Lesson 5: Bacterial Defense

Continued

ANSWER KEY **Do not share with students**

5. How do microbes impact the environment, food production, or human health in this lesson?

a. Identify the problem in the scenario.

This depends on the article read. For example, if focused on Scenario 1, the phages would be defended against because they are killing the bacteria used in fermentation.

b. Decide which you would want to see thrive, the bacteria or the phage, in order to improve conditions?

In scenarios 1-3, students should identify that they would want the bacteria to thrive, but in scenario 4 students should identify they would want the phage to thrive.

c. Explain how the bacteria would try to defend against the phage using at least three defense mechanisms, one needing to be CRISPR.

Any of the defensive systems could work (see concept map in lesson). Students will also need to describe how the bacteria use CRISPR to fight phage infections using CRISPR and Cas9, and also methylation to protect bacterial DNA.

d. Defend your argument in part b with a justification as to why the bacteria or the phage should be favored.

Students should justify that the bacteria/phage is the microbe that is helping with the desired outcome, therefore they want it favored.

e. Predict the impact on the scenario and potential evolutionary consequences.

Scenario 1: bacteria in food production and phages: better/more sustainably produced food

Scenario 2: bacteria in ecosystems and phages: prevent changes in ecosystems

Scenario 3: microbiome bacteria and phages: maintain balance of microbiome

Scenario 4: phages are good (A discussion of COVID-19 and where phages could actually be a good thing): example phage therapy

6. Based on the career profile in this lesson, what does this tell you about the types of people that do science?

Answers will vary. Kevin V. Solomon, PhD: Assistant Professor at the University of Delaware's Chemical and Biomolecular Engineering department

7. What did you find most relatable?

Answers will vary.

Lesson 6: The Use of CRISPR and Bioethical Decision-Making

ANSWER KEY **Do not share with students**

What did we figure out?
Which parts of what we figured out can help us with our model or concept map? *(bullet point or highlight key terms)*

1. **What are potential uses of CRISPR for humans?**

CRISPR can be used to selectively disable undesirable mutations.

2. **What are the bioethical consequences of using CRISPR technology?**

CRISPR therapies are expensive and we need to ensure equal access for all people.

3. **How do microbes impact the environment, food production, or human health in this lesson?**

CRISPR technology has been developed thanks to microbes utilizing bacteria's CRISPR. We can selectively target and disable genes in humans, plants, anything with DNA. This has endless potential to be used in all fields where DNA is involved.

4. **Based on the career profile in this lesson, what does this tell you about the types of people that do science?**

Answers will vary. Lydia M. Contreras, PhD: Associate Professor of Chemical Engineering at The University of Texas at Austin

5. **What did you find most relatable?**

Answers will vary.

Based on our progress through this lesson, how can we visually represent what we learned?
Create a model or concept map, drawing, symbols, etc. to help answer our Unit question "How can microbes help solve real-world challenges?" *(highlight structures and relationships)*

Answers will vary.

Lesson 7: Detecting Wolbachia: Microbial Disease Control

ANSWER KEY **Do not share with students**

What did we figure out?
Which parts of what we figured out can help us with our model or concept map? *(bullet point or highlight key terms)*

1. **How do microbes impact the environment, food production, or human health in this lesson?**

Microbes can be used to modify mosquito populations to reduce disease transmission.

2. **Based on the career profile in this lesson, what does this tell you about the types of people that do science?**

Answers will vary. Rusty Lowe, PhD: Lead Scientist, Globe Observer Mosquito Habitat Mapper

3. **What did you find most relatable?**

Answers will vary.

Based on our progress through this lesson, how can we visually represent what we learned?
Create a model or concept map, drawing, symbols, etc. to help answer our Unit question "How can microbes help solve real-world challenges?" *(highlight structures and relationships)*

Answers will vary.

Lesson 8: Microbes and Balance in the Environment

ANSWER KEY **Do not share with students**

What did we figure out?
Which parts of what we figured out can help us with our model or concept map? *(bullet point or highlight key terms)*

1. **How do greenhouse gases, such as CO_2, play a role in climate change?**

CO_2 concentrations have a direct relationship with global temperature. Higher concentrations result in a higher temperature.

2. **How can microbes be used to reduce waste produced in industry by converting these wastes into less harmful or even useful products?**

Microbes can be used to reduce CO_2 emissions in local industries by storing gaseous CO_2 in special compartments and eventually be used to create useful products, such as bioplastic or microbe food!

3. **Based on the career profile in this lesson, what does this tell you about the types of people that do science?**

Answers will vary. Ryan Tappel, PhD Senior Scientist of Synthetic Biology and Entomology at LanzaTech

4. **What did you find most relatable?**

Answers will vary.

Based on our progress through this lesson, how can we visually represent what we learned?
Create a model or concept map, drawing, symbols, etc. to help answer our Unit question "How can microbes help solve real-world challenges?" *(highlight structures and relationships)*

Models should describe three structures and their relationships. The following are examples of structures, but not an exhaustive list.

- Microbes
- Carbon dioxide/waste products
- Climate/pollution

Lesson 9: Design Thinking to Identify Challenges

ANSWER KEY **Do not share with students**

What did we figure out?
Which parts of what we figured out can help us with our model or concept map? *(bullet point or highlight key terms)*

1. **What is a local or global problem that involves one of the following: climate change, disease, pollution, or food production?**

Answers will vary, but global may include climate change, food scarcity, or access to healthcare for new treatments.

2. **How can we develop empathy for people in our community?**

By listening to others and taking into consideration hardships that you yourself may not encounter

3. **How can microbes be utilized to solve a local or global problem?**

Answers will vary, but should include a brainstorm toward their final project.

4. **Based on the career profile in this lesson, what does this tell you about the types of people that do science?**

Answers will vary. Aditya Kunjapur, PhD Assistant Professor of Chemical and Biomolecular Engineering, University of Delaware

5. **What did you find most relatable?**

Answers will vary.

Based on our progress through this lesson, how can we visually represent what we learned?
Create a model or concept map, drawing, symbols, etc. to help answer our Unit question "How can microbes help solve real-world challenges?" *(highlight structures and relationships)*

Students should insert a picture of their prototype from the beginning of the lesson.

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Toolkit

OVERVIEW

There are so many challenges in our world, but microbes have many powers that can help us solve these challenges. By the end of this unit, you will be designing a solution to a real-world challenge using microbes as part of your solution. In order to remember all these amazing microbial powers, you will want to record these superpowers as you learn about them! Ultimately, you will look back to your Toolkit to create innovative ideas to solve a challenge.

MISSION OBJECTIVE

How can we harness the power of microbes to help provide solutions to a local or global problem?

ESSENTIAL QUESTIONS

How do microbes impact human health, the availability of food, and the environment?

How can we use the principles of design thinking to drive our decision-making process?

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Lesson 1: Superhero Microbes

What did we figure out?
Which parts of what we figured out can help us with our model or concept map? *(bullet point or highlight key terms)*

1. **What is the structure and function of the components that make up bacteria?**

2. **How can we relate the components of bacteria to superhero powers?**

Continues next page >

Based on our progress through this lesson, how can we visually represent what we learned?
Create a model or concept map, drawing, symbols, etc. to help answer our Unit question "How can microbes help solve real-world challenges?" *(highlight structures and relationships)*

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Lesson 1: Superhero Microbes

Continued

3. How do microbes impact the environment, food production, or human health in this lesson?

4. Based on the career profile in this lesson, what does this tell you about the types of people that do science?

5. What did you find most relatable?

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Lesson 2: Yogurt Fermentation

What did we figure out?
Which parts of what we figured out can help us with our model or concept map? *(bullet point or highlight key terms)*

1. **Explain how yogurt is made, including fermentation steps performed by microbes.**

2. **Based on the career profile in this lesson, what does this tell you about the types of people that do science?**

Continues next page >

Based on our progress through this lesson, how can we visually represent what we learned?
Create a model or concept map, drawing, symbols, etc. to help answer our Unit question "How can microbes help solve real-world challenges?" *(highlight structures and relationships)*

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Lesson 2: Yogurt Fermentation

Continued

3. What did you find most relatable?

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Lesson 3: Microbes and Food (Menu)

What did we figure out?
Which parts of what we figured out can help us with our model or concept map? *(bullet point or highlight key terms)*

1. How are microbes used in food production?

2. How do microbes impact the environment, food production, or human health in this lesson?

Continues next page >

Based on our progress through this lesson, how can we visually represent what we learned?
Create a model or concept map, drawing, symbols, etc. to help answer our Unit question "How can microbes help solve real-world challenges?" *(highlight structures and relationships)*

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Lesson 3: Microbes and Food (Menu)

Continued

3. Based on the career profile in this lesson, what does this tell you about the types of people that do science?

4. What did you find most relatable?

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Lesson 4: Antibiotics, Resistance, and Combating Disease

What did we figure out?
Which parts of what we figured out can help us with our model or concept map? *(bullet point or highlight key terms)*

1. **How are clinical trials designed so new medicines and therapies can be tested with minimal risk to patients?**

2. **How do microbes impact the environment, food production, or human health in this lesson?**

Continues next page >

Based on our progress through this lesson, how can we visually represent what we learned?
Create a model or concept map, drawing, symbols, etc. to help answer our Unit question "How can microbes help solve real-world challenges?" *(highlight structures and relationships)*

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Lesson 4: Antibiotics, Resistance, and Combating Disease

Continued

3. Based on the career profile in this lesson, what does this tell you about the types of people that do science?

4. What did you find most relatable?

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Lesson 5: Bacterial Defense

What did we figure out?
Which parts of what we figured out can help us with our model or concept map? *(bullet point or highlight key terms)*

1. **What are types of bacterial strategies for defending against phages?**

2. **What are the components of CRISPR and what is the function of each?**

Continues next page >

Based on our progress through this lesson, how can we visually represent what we learned?
Create a model or concept map, drawing, symbols, etc. to help answer our Unit question "How can microbes help solve real-world challenges?" *(highlight structures and relationships)*

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Lesson 5: Bacterial Defense

Continued

3. How do restriction enzymes work?

4. What are potential uses of CRISPR for humans?

5. How do microbes impact the environment, food production, or human health in this lesson?

a. Identify the problem in the scenario.

b. Decide which you would want to see thrive, the bacteria or the phage, in order to improve conditions?

c. Explain how the bacteria would try to defend against the phage using at least three defense mechanisms, one needing to be CRISPR.

d. Defend your argument in part b with a justification as to why the bacteria or the phage should be favored.

e. Predict the impact on the scenario and potential evolutionary consequences.

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Lesson 5: Bacterial Defense

Continued

6. Based on the career profile in this lesson, what does this tell you about the types of people that do science?

7. What did you find most relatable?

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Lesson 6: The Use of CRISPR and Bioethical Decision-Making

What did we figure out?
Which parts of what we figured out can help us with our model or concept map? *(bullet point or highlight key terms)*

1. What are potential uses of CRISPR for humans?

2. What are the bioethical consequences of using CRISPR technology?

Continues next page >

Based on our progress through this lesson, how can we visually represent what we learned?
Create a model or concept map, drawing, symbols, etc. to help answer our Unit question "How can microbes help solve real-world challenges?" *(highlight structures and relationships)*

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Lesson 6: The Use of CRISPR and Bioethical Decision-Making

Continued

3. How do microbes impact the environment, food production, or human health in this lesson?

4. Based on the career profile in this lesson, what does this tell you about the types of people that do science?

5. What did you find most relatable?

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Lesson 7: Detecting Wolbachia: Microbial Disease Control

What did we figure out?
Which parts of what we figured out can help us with our model or concept map? *(bullet point or highlight key terms)*

1. **How do microbes impact the environment, food production, or human health in this lesson?**

2. **Based on the career profile in this lesson, what does this tell you about the types of people that do science?**

Continues next page >

Based on our progress through this lesson, how can we visually represent what we learned?
Create a model or concept map, drawing, symbols, etc. to help answer our Unit question "How can microbes help solve real-world challenges?" *(highlight structures and relationships)*

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Lesson 7: Detecting Wolbachia: Microbial Disease Control

Continued

3. What did you find most relatable?

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Lesson 8: Microbes and Balance in the Environment

What did we figure out?
Which parts of what we figured out can help us with our model or concept map? *(bullet point or highlight key terms)*

1. **How do greenhouse gases, such as CO_2, play a role in climate change?**

2. **How can microbes be used to reduce waste produced in industry by converting these wastes into less harmful or even useful products?**

Continues next page >

Based on our progress through this lesson, how can we visually represent what we learned?
Create a model or concept map, drawing, symbols, etc. to help answer our Unit question "How can microbes help solve real-world challenges?" *(highlight structures and relationships)*

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Lesson 8: Microbes and Balance in the Environment

Continued

3. Based on the career profile in this lesson, what does this tell you about the types of people that do science?

4. What did you find most relatable?

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Lesson 9: Design Thinking to Identify Challenges

What did we figure out?
Which parts of what we figured out can help us with our model or concept map? *(bullet point or highlight key terms)*

1. **What is a local or global problem that involves one of the following: climate change, disease, pollution, or food production?**

2. **How can we develop empathy for people in our community?**

Continues next page >

Based on our progress through this lesson, how can we visually represent what we learned?
Create a model or concept map, drawing, symbols, etc. to help answer our Unit question "How can microbes help solve real-world challenges?" *(highlight structures and relationships)*

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Lesson 9: Design Thinking to Identify Challenges

Continued

3. How can microbes be utilized to solve a local or global problem?

4. Based on the career profile in this lesson, what does this tell you about the types of people that do science?

5. What did you find most relatable?