AG/ENVIRONMENTAL

Solution Seeking Microbes

Superhero Microbes

Developed in partnership with:

Discovery Education and Ignited

In this Lesson Plan:

Print the **Teacher Section** →

Print the **Student Section** →

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

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

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

Single Pages (use a comma): T3, T6	
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Cover Image
Lactobacillus casei is one of many friendly bacteria in your gut microbiome.

AG/ENVIRONMENTAL / SOLUTION SEEKING MICROBES

Superhero Microbes

ACTIVITY DURATION

Five class sessions
(45 minutes each)

DRIVING QUESTION

Why are some microbes considered superheroes?

ESSENTIAL QUESTIONS

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

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

How do bacteria and other microbes impact the environment, food production, or human health?

OVERVIEW

Microbes, although unseen by the unaided eye, make up 15% of the total biomass on Earth (humans, for reference, make up only 0.01%), and 99.99% of microbes remain undiscovered. They are significant in the sustainability of the environment, human health, and our food supply. Humans have related to microbes for centuries through their use in food production. They have plagued us as pathogens, but also play an important role in our health as essential symbionts. They are crucial to research as a model organism in the testing of new potential medicines, which have been used in the biotechnology industry since the 1970s to create alternative proteins. Furthermore, their relationships and role in ecosystems is paramount to a sustainable and healthy environment. These very important organisms will be explored in this lesson and over the course of this unit.

In this lesson, students will choose and research specific microbes known to have an impact on the environment, food production, or human health. Students will create a cartoon/comic strip illustrating their microbes as superheroes.

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OBJECTIVES

Students will be able to:

Explain why studying microbes is important to humans and the sustainability of the environment.

Identify how microbes maintain their relationships with other living things.

Describe how microbes are diverse due to their genetic components.

Analyze how microbes have influenced human culture.

Evaluate microbial metabolic processes (anaerobic, aerobic), enzymes, biosynthesis, chemo/autotrophs, gene regulation, and how these add to their microbial superpower.

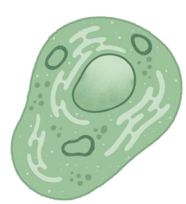
Create a model illustrating the structure and function of microbial components.

Continued

Cartoon/comic strips should include: 1. the origin of the microbe, 2. its superpower (how it helps others), and 3. how it overcomes adversity (villain's "kryptonite"/chemical/ pollution/ etc.). These cartoon/comic strips could potentially be showcased during Lesson 10 (the final assessment of the unit) during Micro-Con.

This lesson will also introduce students to their *Toolkit*, a document in which they will keep a record of what they have learned about microbes, scientists, and the role scientists play in solving real-world challenges. This *Toolkit* will be very important as a reference for students as they design a microbe-influenced solution to a real-world challenge and showcase their designs and prototypes in Lesson 10 when they attend and present at a conference called Micro-Con.

Materials
Computers
Modeling Clay
Blocks
Microscopes (optional)
Colored Pencils/Markers/Pens
Construction Paper
Prepared slides of different types of microbes (or use the images provided in SEM Bacterial Pictures) including: coccus, bacillus, spiral, coryneform, and filamentous
String
Toolkit
Which Superhero Are You?
Career Profile: Holly Lutz, PhD
Bacteria Size Capture Sheet
Microscope Slide Capture Sheet
SEM Bacterial Pictures
Superhero/Anime/Fantasy Creature Analogy Capture Sheet
Superhero Microbe Storyboard
Superhero Microbe Comic Rubric



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 communicate effectively with each other as they work collaboratively, developing positive relationships as they practice teamwork in discussions and in the creation of a cartoon/comic strip. Students will also connect emotionally with the people (citizens the superheroes can save) as they identify superhero microbes that can help solve problems and analyze community impacts. Students will self-manage using planning and organizational skills as they design their storyboards outlining their cartoon/comic strips.

CULTURALLY AND LINGUISTICALLY RESPONSIVE INSTRUCTION

Students will brainstorm “real” superheroes and historical mythological beings that relate best to their culture and heritage. They will use these superheroes as a starting point to relate to superhero microbes. This lesson will lay a foundation for students to harness the power of microbes in order to see themselves as agents of change that can right the injustices that exist in the world in food scarcity, health-related issues, and the sustainability of the environment.

ADVANCING INCLUSIVE RESEARCH

In this unit, students will engage in an explicit and thoughtful process to connect with their community as they develop solutions to community struggles. As students learn about a variety of cultures and spaces where microbes are used to improve the quality of human life, and ultimately pitch their own designs to solve a global problem, they have the chance to empathize with diverse stakeholders and recognize the importance of incorporating these perspectives into potential solutions. In this lesson, students will begin their research process by exploring the special “superhero” abilities of various microbes that could be harnessed to help address community challenges.

COMPUTATIONAL THINKING PRACTICES

In this lesson, students practice the computational skill of decomposition by breaking down a bacterium into its component parts. Decomposition is a skill that computer programmers use to separate a computer program into smaller sub-pieces. Decomposition is a computational thinking strategy that helps students understand how each component contributes to the whole. Students also gain experience with the computational thinking strategies of abstraction and building models by making a concept map and developing a model of a bacterium.

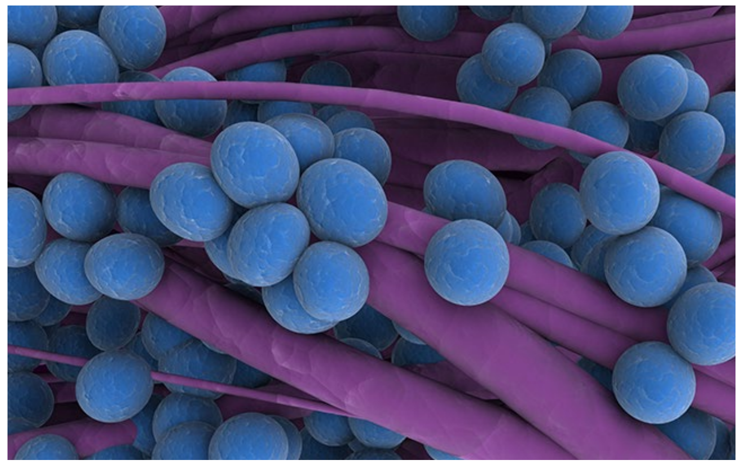
CONNECTION TO THE PRODUCT LIFE CYCLE

In this lesson, students identify structures and functions of microbes and their relationships with other organisms, and begin to think about how microbes can be used to solve challenges in our environment. This type of research, which explores areas of promise, connects to the **discovery** stage of the product life cycle.

Have you ever wondered…

Can microbes be beneficial?

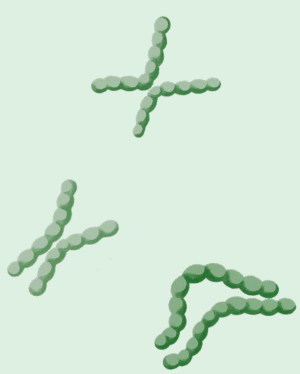
Can you eat plastic or metal? Or make rain? No? Microbes can! Microbes have amazing abilities to do things we would consider superpowers. They have adapted to their environments—from making snow to being the strongest organisms on the planet. Thanks to their superpowers, these amazing organisms can even help solve some of our local or global struggles.



MAKE CONNECTIONS!

How does this connect to the larger unit storyline?

Ultimately students will attend "Micro-Con" where they will showcase how they might use microbes to solve a real-world problem. This lesson highlights "superhero" microbes that already use their superpowers for the good of the environment, human health, or food production.



How does this connect to careers?

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

Microbiologists use genetic and microscopy tools to study microorganisms, such as fungi, viruses, bacteria, and other small eukaryotes. They apply their knowledge of small organisms to questions about health, food science, agriculture, and production.

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

How does this connect to our world?

Each bacterial example that students research is one that has had historical human interactions and future problem-solving potential.

Life as we know it would not exist without microbes. Although many are aware of bacteria and viruses as "germs," this lesson connects students to our dependence on microbes for survival.

Day 1

Procedure

LEARNING OUTCOMES

Students will be able to:

Create a concept map illustrating similarities and differences among bacteria.

Teacher Note > *The Toolkit introduced in this lesson (Day 4) is essential for students to be able to produce a genuine solution to a real-world problem. Teachers may wish to take some time to become familiar with it and how it will be used in each lesson of the unit. Today, as students proceed to making their concept maps, you may wish to introduce the Toolkit.*

There are different types of microbes, and bacteria are a type of microbe (along with fungi, protozoa, and algae). This unit focuses specifically on bacteria, although the term "microbe" is sometimes used for aesthetics (e.g. Bacteria Con vs. Micro-Con).

Individual Work (10 minutes)

Teacher Note > *Prior to class, print the signs for What Superhero Microbe Are You? and post them throughout the room (all examples are bacterial). Teachers may wish to have the numbers 8–15 on one side of the page, but when students come to that number to identify with their microbe, they flip the sign over to see the one with which they identified. You may also wish to provide students with poster paper and markers to create their concept maps in Step 2 below (they can then photograph the concept map and transfer it to their Toolkit when it is introduced on Day 4). An example of a concept map a student group may come up with can be found in the Toolkit Key.*

Digital Option: Teachers may choose to make the signs into a Google Form to avoid student contact and movement.

Have students walk the room as they answer a series of questions (i.e., Do you like to eat out or stay in?) to use a dichotomous key to determine the superhero microbe to which they relate, and to read a short description of each microbe. Invite students to partner with other students who have the same microbe once they all "land" on their microbe by using the dichotomous key. (As an alternative, after students find their microbes, teachers can allow students to read all choices to pick any microbe from the list, but you may want to limit group size to no more than four, adjusting the groups so there are no single students unless students want to work independently.) They will read about the origin story and superpower of their microbes. Students may wish to take a photo of the posted description, or you may wish to send these to students digitally. Direct students to sit next to their group members for the next activity or to gather around lab tables if available.

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Day 1

Continued

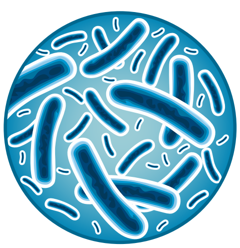
INDUSTRY & CAREER CONNECTION

This is a good time to point out to students that microbiologists use genetic and microscopy tools to study microorganisms such as fungi, viruses, bacteria, and other small eukaryotes. They apply their knowledge of small organisms to health questions, to food science, and to agriculture and production.

Invite students to read Career Profile: Holly Lutz, PhD, a microbiologist.

COMPUTATIONAL THINKING IN ACTION

By developing their concept maps, students are utilizing the computational thinking strategy of abstraction. This skill helps students to sort through large amounts of information and hone in on just the core elements.



Archaea

Procedure

Small Group (25 minutes)

1 Explain to students that concept maps are a way to visually display information quickly and clearly. By showing a model of "structures" in boxes and "relationships" as arrows connecting these boxes, other student groups will be able to see the similarities and differences among the superhero microbes with which they identify. Ideally, you would have four students per group (or two students can work together) to create concept maps using the Group Concept Maps template (see below). Students should use the readings they were given as well as researching additional information to create their concept maps. If students are using a hands-on version (paper and pens), they should take a picture of it. If students create digital concept maps, tell students they will take a screenshot and insert this into the *Toolkit* on Day 4 of this lesson. Teachers may wish to show the following concept map to help students understand what they are being asked to create. Tell students to include the following terms, as well as five terms of their choosing that relate to the microbes and their superpowers:

- **a.** Microbe
- **b.** Bacteria
- **c.** Archaea
- **d.** Weakness
- **e.** Superpower
- **f.** Thrives in environment
- **g.** Mentor/Who discovered

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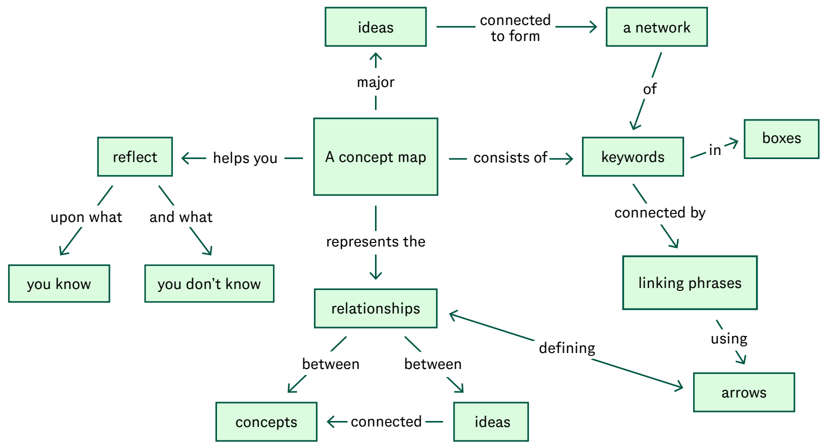
Day 1

Continued

Procedure

2 Students should then write the relationships among these terms over the arrows in their concept maps.



3 After student groups create their concept maps, a group spokesperson will share the logic of that group's concept map with one other group. Students can discuss similarities and differences they found in their maps and hypothesize why these similarities and differences exist.

Whole Group (10 minutes)

1 What similarities and differences were seen among microbe groups? Did everyone really feel like they "identified" with the microbe? What made your group's microbe unique when compared to others? Where do these unique characteristics come from? Push for students to discuss differences in DNA, the environment where the microbe is found, etc. Tell students that these unique characteristics are what you will focus on in this lesson.

Teacher Note > *If students have not learned microscopy yet, this is a good time to insert a lesson on that topic. Since prepared slides will be used for this lesson, wet mount procedures do not need to be taught or reviewed. About 30-45 minutes may be dedicated to having students practice using the microscope with other prepared slides such as "the letter e," three colors of string, and other basic materials. An online Microscope Tutorial could also be used for review. You may wish to have students list each component of the microscope and explain the function of each.*

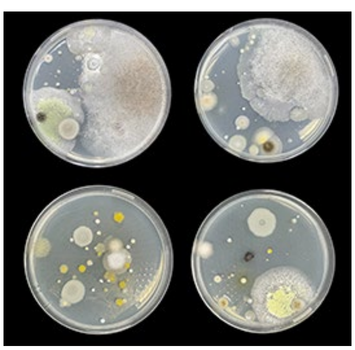


Image of bacteria on agar plate isolated from air.

Day 2

Procedure

LEARNING OUTCOMES

Students will be able to:

Classify bacteria based on structural similarities.

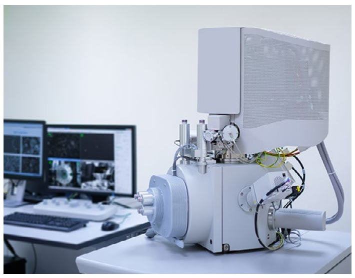


Image of a scanning Electron Microscope (SEM) machine in laboratory.

INDUSTRY & CAREER CONNECTION

Remind students that they are playing the role of a microbiologist.

Teacher Note > *Teachers should set up microscopes and prepare slides for student groups. If you do not have microscopes and slides, you may wish to show students five SEM images (see SEM Bacteria Pictures) of different types of bacteria or other microbes and have them create groups based on the images. Depending on your student comfort level with using microscopes, more time may be required. You may want to briefly review with students the parts of a microscope and how to use each.*

Individual Work (10 minutes)

1 Using the *Bacteria Size Capture Sheet*, have students make predictions and cut out or circle the appropriate size X-chromosome, bacteriophage, *E. coli*, mitochondrion, and skin cell in relation to the width of a human hair pictured.

2 Direct students to *Cell Size and Scale* to visualize the size and scale of bacteria and viruses and discuss how their predictions were similar or different from the actual size and scale of the objects. Relate to students that the point is to recognize and anticipate how small microbes actually are before viewing them under the microscope, which they will do in the next activity.

Small Group (25 minutes)

1 Tell students that they will be looking at bacteria under the microscope with a partner, and are going to group them based on any characteristics they find appropriate in the *Microscope Slide Capture Sheet*.

2 Encourage students to communicate with their partners as they view the prepared slides under the microscope of types of bacteria (coccus, bacillus, spiral, coryneform, and filamentous) about characteristics they might find appropriate (shape, color, etc.). Tell students they will view five slides under the microscope and five SEM images online or on *SEM Bacteria Pictures* for a total of 10 bacterial samples. Remind students that there are no "wrong" answers here, but that they should explain and justify the relationships they found.

3 There are many strategies students may use to approach this. You can encourage them to try different strategies, or let them find ways that work for them. For instance, they might write down the names of the bacteria and characteristics they see in the bacteria as they view them, and then create categories. Encourage students to view the images more than once to create as many or as few categories as they feel appropriate.

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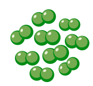
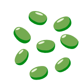
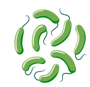
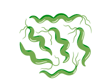
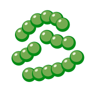
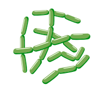
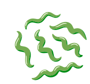
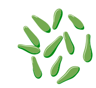
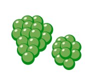
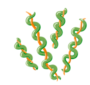
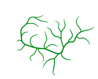
Day 2

Continued

Procedure

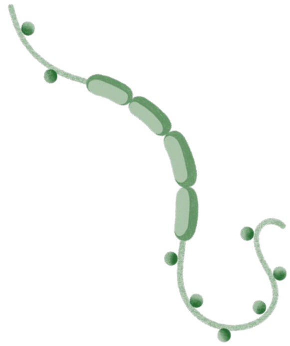
Whole Group (10 minutes)

1 Have students share and explain their groupings, and then reveal the actual types of structures (coccus, bacillus, spiral, coryneform, and filamentous, or simplify to sphere, rods, curved or spiral, and other shapes).

Circular	Rod-Shaped	Curved Forms	Other Shapes
 Diplo- (in pairs)	 Coccobacilli (oval)	 Vibrio (curved rod)	 Helicobacter (helical)
 Strepto- (in chains)	 Streptobacilli	 Spirilla (coli)	 Corynebacter (club)
 Staphylo- (clusters)	 Mycobacteria	 Spirochete (spiral)	 Streptomyces

2 Students can generate a question based on what they observed (for instance, why are some red vs. purple, why are they different sizes, why are they spread out or clumped together, etc.). Show students the short clip, *Gram Staining*, from Amrita University illustrating the staining process and differences between Gram +/- structure. Tell students to write a short answer to the question “Why do bacteria adhere to stains differently?” in their capture sheet.

Teacher Note > *Possible extension using this staining virtual lab from New Mexico State University if teachers would like to go more in depth on the staining process.*



Day 3

LEARNING OUTCOMES

Students will be able to:

Design a model of a bacterial cell.

Create an analogy to explain the functions of bacterial structures.

Procedure

Whole Group (10 minutes)	
1	Show students a video that depicts a superhero. You may search "supersuit" for example. Perhaps a two-minute clip would be appropriate.
2	Based on the short video, students should discuss with partners what a superhero is, what powers it might possess, what tool it may have (for instance, spider silk for a spider-themed superhero), and what villain is its enemy. They should find a common superhero or fantasy creature they both know, or can introduce each other to a superhero or fantasy creature that may be less well known, but culturally relevant or important to them.

Small Group (35 minutes)	
1	Hand out the *Superhero/Anime/Fantasy Creature Analogy Capture Sheet*, and have students complete a three-part assignment in groups of two (detailed below). These can be similar groups from Day 1.
2	**Part 1:** Using the concept map students made on Day 1, they should fill in information about their microbe's origin story, superpower, and research about how the microbe overcomes adversity (each student should have chosen a bacteria rather than any other type of microbe).

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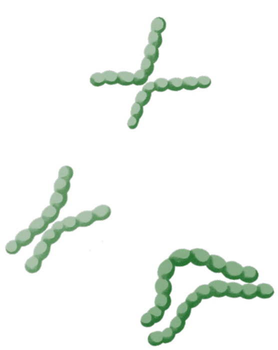


Day 3

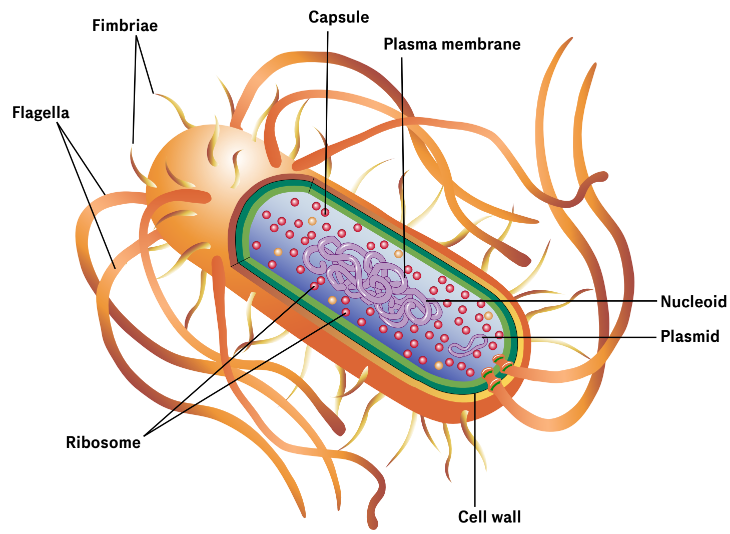
Continued

COMPUTATIONAL THINKING IN ACTION

As students learn about the component parts of a bacterium, they are using the computational thinking strategy of decomposition.

Procedure

3 **Part 2:** Using an image like this one, students should fill out an analogy chart to make connections between the components of their bacteria and those of a superhero. (Examples: jetpack, car, utility belt, force field, sticky gloves, secret phone, mind reading cap, thermal jacket.)



Cell wall	In addition to the plasma membrane, bacterial cells have a cell wall that is more rigid to provide additional protection. Plant cells also have a cell wall.
Capsule	Some bacteria have a capsule—a sticky coating outside the cell wall that helps the bacteria attach to surfaces.
Fimbriae	Fimbriae are often found on the surface of bacterial cells. These hair-like projections can help bacteria attach to other cells.
Flagella	Many bacteria have a whip-like flagellum, a whip-like tail that aids in movement.
Nucleoid	Bacterial genetic material is stored in a nucleoid that floats in the cytoplasm. A nucleoid is not surrounded by a separate membrane.
Plasmid	Plasmids are small, circular strings of DNA that can replicate independently of the chromosomes. Plasmids are also used by scientists to manipulate genes.

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Day 3
Continued

Procedure

Plasma Membrane	The plasma membrane (or cell membrane) is a lipid bilayer that separates the interior of the cell (the cytoplasm) from the outside environment. It is semipermeable and regulates the transport of materials in and out.
Ribosome	The ribosomes are made of RNA and proteins, and are found in the cytoplasm. They use messenger RNA to synthesize proteins.

4 After 10 minutes, discuss a few of the analogies that students identified with the class (you may ask students to volunteer).

5 **Part 3:** Students will research the following components of their bacteria and use various materials provided (paper, modeling clay, string, blocks, etc.) to make a model illustrating the structures of their bacteria. If these tools are not available, household items or items around the classroom can be used to construct the model. A photo of the model should be taken and uploaded to the capture sheet.

COMPUTATIONAL THINKING IN ACTION

Here, students are using the computational thinking strategy of building models to construct a model of a bacterium.

Teacher Note > *You may wish to explain to students that they will not have a lot of time to make their models and that creativity is born through constraints. The time constraint is purposeful. Alternatively, if you do not wish to have the time constraint on students, this activity could be extended. Teachers can Google search "bacteria models" for examples to show students.*

Day 4

Procedure

LEARNING OUTCOMES

Students will be able to:

Create a cartoon/comic strip that illustrates an analogy between unique bacterial properties and superheroes.

INDUSTRY & CAREER CONNECTION

Students will be identifying how their superhero microbe helps others. This is playing the role of Marketing and PR experts, whose job it is to help companies to sell their product to a target consumer. They talk with consumers to learn about the customers' needs, and influence the direction and production of products accordingly.

Small Group (45 minutes)	
1	The *Toolkit*: Tell students that they will have a "Toolkit" that they will add to during each lesson. The information gathered in the *Toolkit* is a vital piece to helping them in the final activity for this unit, where they will attend "Micro-Con"—a fun conference similar to Comic-Con (if they have heard of it, if not, feel free to bring up other conferences that may be more appropriate, or you may wish to show a short clip showing what Comic-Con looks like to get students excited).
2	Have students regroup with their partners to add the Concept Map from Day 1 to their *Toolkit*, elaborating on the Concept Map using information from Parts 1-3 of the *Superhero/Anime/Fantasy Creature Analogy Capture Sheet*. See Example in Toolkit Key.
3	Have students create a cartoon/comic strip of their superhero microbe (bacteria) to illustrate the origin, its superpower or how it helps others, and how it overcomes adversity (villain's "kryptonite," chemical, pollution, etc.). They will start this process by researching and first creating a storyboard to sketch out their ideas, and then use their storyboards to make an illustrated cartoon or comic strip. Teachers should instruct students that they need to get their storyboard approved by the teacher before they can start illustrating. Show students the grading rubric so they understand what components need to be in their cartoon/comic strip. Students can use a premade *Superhero Microbe Storyboard* or be creative and develop their own.

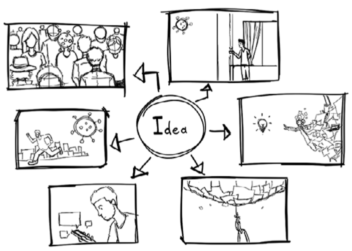
Teacher Note > *Teachers may opt to work cross-curricular with their English peers!*

Day 5

LEARNING OUTCOMES

Students will be able to:

Create a cartoon/comic strip that illustrates an analogy between unique bacterial properties and superheroes.



Procedure

Small Group (25 minutes)	
1	Allow students to finish illustrating their cartoon/comic strips. These can be drawn by hand or in an online storyboarding tool.
2	To expose students to other superhero microbes and to receive feedback, students will partner with another group and explain their superhero microbes. Changes can be made prior to turning in assignments. Students should look over the *Superhero Microbe Comic Rubric* and give the other group an initial "grade."
3	Cartoon/comic strips will be graded based on a rubric that ensures the items from the storyboard are included in the final product. These products can be showcased in a "program" or pamphlet during the final assessment of the unit, Micro-Con.
4	Ask students to add to their *Toolkit* by completing the questions for Lesson 1.

Whole Group (15 minutes)	
1	Teachers should lead the class in a short discussion about the two important questions: • What is the structure and function of the components that make up bacteria? • How can we relate the components of bacteria to superhero powers?
2	Tell students that as we relate bacteria to superheroes, we will also look at some superhero scientists in each lesson. Give students an opportunity to read the *Career Profile: Holly Lutz, PhD* if they have not already, focusing on what she does in her field, and what might be most relatable or what resonates most with students. They should log their thoughts under Questions 4-5 in the *Toolkit*: *Based on the career profile in this lesson, what does this tell you about the types of people who do science? What did you find most relatable?* If time permits, you may ask students to share their thoughts.

Teacher Note > *At the end of the unit, this Toolkit will be used to answer the Mission Objective for the Superhero: How can we harness the power of microbes to help provide solutions to a local or global problem?*

National Standards

Next Generation Science Standards

LS1.A: Structure and Function

Systems of specialized cells within organisms help them perform the essential functions of life.

Multicellular organisms have a hierarchical structural organization, in which any one system is made up of numerous parts and is itself a component of the next level.

Science and Engineering Practices

Developing and Using Models

Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.

Career and Technical Education (CTE)

A4.1

List and describe the structure and function of cellular organelle.

A5.1

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

A5.2

Use a variety of methods, including literature searches in libraries, computer databases, and online for gathering background information, making observations, and collecting and organizing data.

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.

5.6

Read, interpret, and extract information from documents.

7.4

Practice time management and efficiency to fulfill responsibilities.

Educator Resources

Which Superhero Microbe Are You?

Directions

Print these signs and post them around the classroom. Students should walk around the room as they answer the series of questions, landing on one microbe that they identify most with at the end.

Which Superhero Microbe Are You?

Continues next page >

Educator Resources

Which Superhero Microbe Are You?

Continued

1	I am a people person. (go to 2)
	I prefer long walks on the beach by myself. (go to 5)
2	I would rather paint a self portrait. (go to 2)
	I would rather paint flowers or plants. (go to 2)

Continues next page >

Educator Resources

Which Superhero Microbe Are You?

Continued

3	I think of myself as a strong leader. (go to 8)
	I prefer to work in the background. (go to 9)
4	I like water-related sports. (go to 10)
	I like land-related sports. (go to 11)

Continues next page >

Educator Resources

Which Superhero Microbe Are You?

Continued

5	I prefer short sprints. (go to 6)
	I prefer long-distance running. (go to 7)
6	I prefer going out to eat. (go to 12)
	I prefer to eat at home. (go to 13)

Continues next page >

Educator Resources

Which Superhero Microbe Are You?

Continued

7	I prefer to go to the beach (and pick up plastic). (go to 14)
	I prefer to go to the mountains (and raise forest fire awareness). (go to 15)

Continues next page >

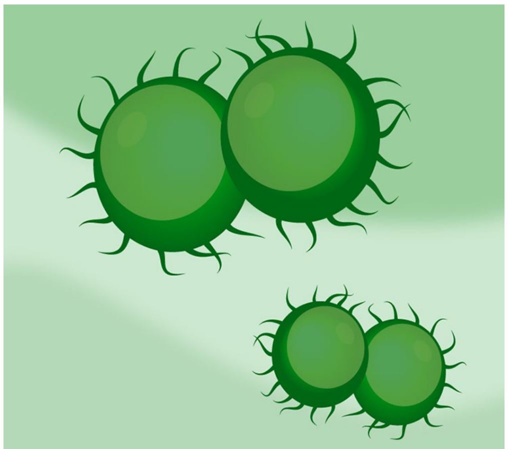
Educator Resources

Which Superhero Microbe Are You?

Continued

8

Neisseria gonorrhoeae



— Coccus-shaped, Gram-negative

— Aerobic

— Fimbriae

N. gonorrhoeae is the cause of the sexually transmitted disease gonorrhea. Its natural environment is in the human body, specifically intracellularly in white blood cells with humans as its only natural host. *N. gonorrhoeae* is not used for any known biotechnology. It was first discovered in 1879 by German physician Albert Ludwig Sigesmund.

N. gonorrhoeae often moves in a jerky fashion called twitching. It uses a "grappling hook" mechanism, which extends, attaches to a surface, and then is retraced to pull the cell forward.

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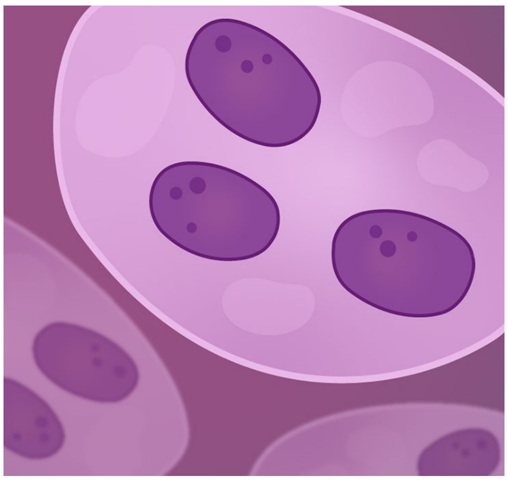
Educator Resources

Which Superhero Microbe Are You?

Continued

9	***Wolbachia***



— Gram-negative
— Symbiotically dependent

Wolbachia form relationships with a number of arthropods, such as *Drosophila* (fruit flies), and it is hypothesized that 70% of all insect species contain *Wolbachia*. *Wolbachia* affect the reproductive abilities of arthropods in order to increase their own numbers.

Wolbachia obtains nutrients through symbiotic relationships, where host organisms provide its nutritional needs. In some hosts, *Wolbachia* produce enzymes that its host does not have.

While a great deal is known about their symbiotic relationships, these bacteria are difficult to study as they are challenging to cultivate independently of their host organisms.

Continues next page >

Educator Resources

Which Superhero Microbe Are You?

Continued

10	***Aquifex***

— Heat-loving (extreme thermophile) from 85–95°C
— Rod shaped, Gram-negative
— Autotrophs
— Flagella
— Name means “water-maker” in Latin

This extremophile, or organism that is able to live in extreme environments, is typically found growing near volcanoes or hot springs. They are thought to have been one of the earliest bacteria to diverge from eubacteria.

Aquifex can use oxygen or sulfur as an energy source, and can make water (when using oxygen) or sulfuric acid (when using sulfur). They grow together in large cell aggregates of up to 100 cells.

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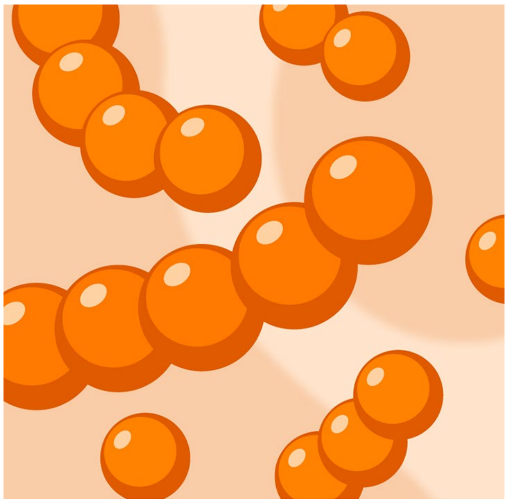
Educator Resources

Which Superhero Microbe Are You?

Continued

11	***Azotobacter***



- Aerobic
- Diazotrophic
- Single, chains, or clumps
- May or may not be mobile by flagella

Azotobacter spp. (spp. is an abbreviation that indicates “several species”) is primarily found in soil and on plants. It is a bacterium that has the ability to fix atmospheric nitrogen, making it available to other organisms. Nitrogen is of utmost importance in agriculture, as it is among the top three vital nutrients for crop development. Its nitrogen fixation abilities make *Azotobacter* spp. of particular interest to scientists who want to improve agricultural productivity.

Azotobacter spp. are found worldwide in climates ranging from extremely northern Siberia to Egypt and India.

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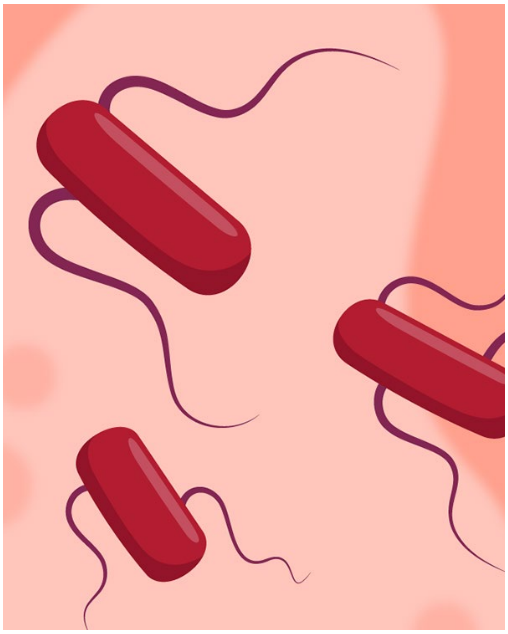
Educator Resources

Which Superhero Microbe Are You?

Continued

12

Geobacter metallireducens



- Found in freshwater
- Does not use oxygen (anaerobic)
- Gains energy by reducing metals, such as iron, manganese, or uranium
- Can use uranium to grow
- Can make flagella when needed
- Rod shaped, Gram-negative

G. metallireducens eats metal! This makes it useful for clean up—it can metabolize harmful contaminants into harmless forms. For example, it can turn metals dissolved in water into a solid form that can easily be removed.

G. metallireducens moves towards environments with more metals by chemotaxis, by moving towards a chemical gradient. It can grow a flagella to help it move.

When it finds metals, it binds to them using pili; a hair-like structure on the outside of the membrane. These pili are of interest to scientists as they could be used to engineer living conductive materials.

Continues next page >

Educator Resources

Which Superhero Microbe Are You?

Continued

13	***Lactobacillus acidophilus***
	— Anaerobic — Rod-shaped, Gram-positive — Involved in fermentation *L. acidophilus* is a probiotic that primarily lives in the gastrointestinal tract of humans and animals. In industry, they are used to help produce cheese and yogurt. *L. acidophilus* ferments carbohydrates to create lactic acid. This lowers the pH, inhibiting the growth of other, unwanted organisms. It also contributes to the flavor of the final food product.

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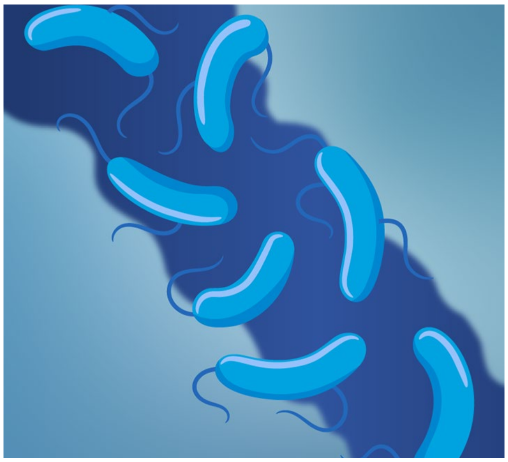
Educator Resources

Which Superhero Microbe Are You?

Continued

14	***Ideonella sakaiensis***



— Metabolizes PET (polyethylene terephthalate), commonly know as plastic
— Aerobic
— Rod-shaped, Gram-negative
— Has flagella

This bacteria eats plastic! It is the only known bacteria that does so. It was found in 2016, by scientists studying sludge from a plastic recycling plant in Japan.

I. sakaiensis uses plastic as its carbon source, and breaks it down using powerful enzymes. This could make it useful to recycle some of the 50 million tons of plastic debris that humans generate annually.

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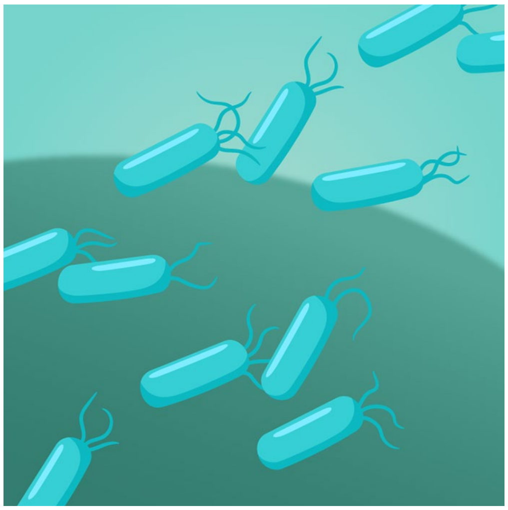
Educator Resources

Which Superhero Microbe Are You?

Continued

15

Pseudomonas syringae



- Rod-shaped, Gram-negative
- Aerobic
- Polar flagella
- Can live off of live or dead plant material (saprophytic)

P. syringae thrives on the surfaces of plant leaves, and in fact is named after the lilac tree (*Syringa vulgaris*). Most of this group of about 50 different species act as pathogens to plants, although some are favorable and have actually been used to deliver antifungal treatments to the plants (almost like a vaccine).

P. syringae has unique proteins on its outer membrane that can make ice form at higher temperatures. When airborne, they are important in helping to produce ice and snow as part of the water cycle.

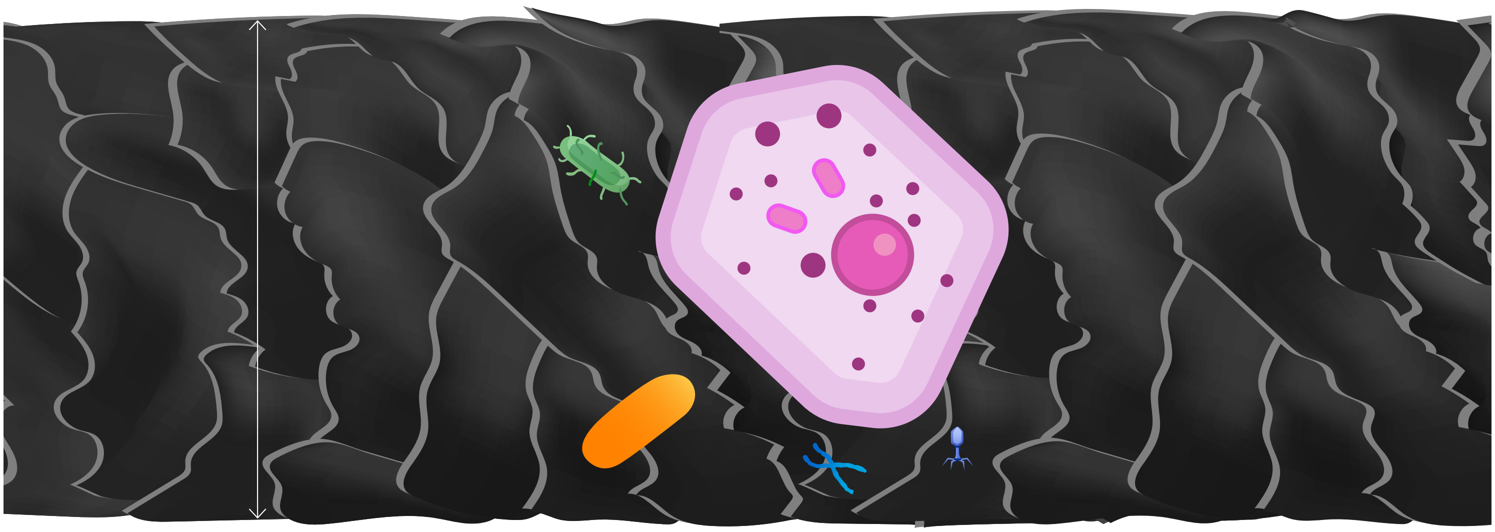
Bacteria Size Capture Sheet

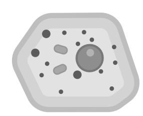
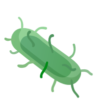
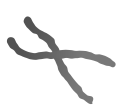
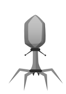
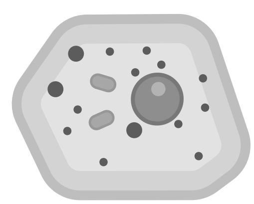
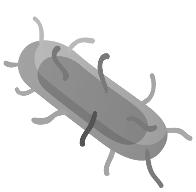
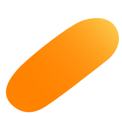
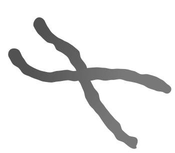
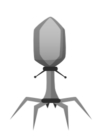
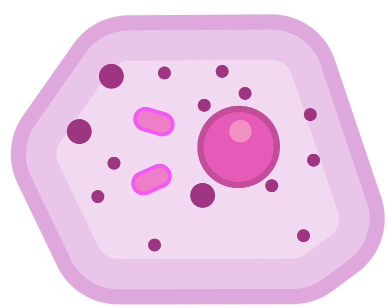
ANSWER KEY **Do not share with students**

Directions

How large are bacteria compared to other microscopic structures? Cut out or circle the appropriate size E. coli, *mitochondrion,* X*-chromosome, bacteriophage, and skin cell in relation to the width of a human hair pictured.*

Width of Human Hair



E. coli	Mitochondrion	*X*-chromosome	Bacteriophage	Skin cell
				
				
				

SEM Bacterial Pictures

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

Directions

Use the combination of your microscope observations and the following SEM (scanning electron microscope) images to make five groupings of bacteria based on structural similarities or differences. Write a short description of each below the image.

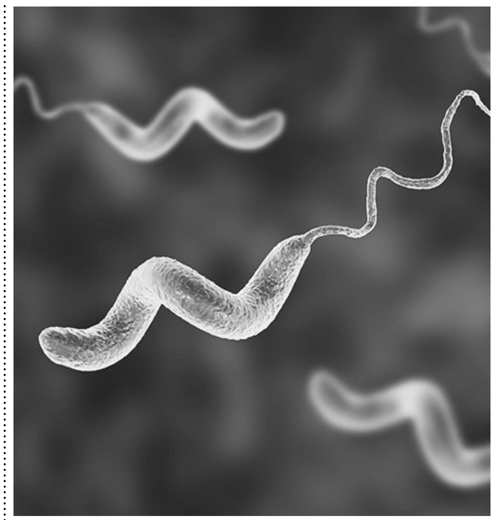
Bacteria No. 1

Sphere shaped

Bacteria No. 2

Long rod shaped

Bacteria No. 3



Spiral shaped

Bacteria No. 4

Long corkscrew shaped

Bacteria No. 5

Rod shaped

Microscope Slide Capture Sheet

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

Directions
Look at bacteria under the microscope, or use the SEM Bacteria Pictures to answer the following questions.

1. Observe the prepared slides.
    a. Create as many groupings as needed (four spaces are given, but you may use less or more).
    b. Give each group a name/title.
    c. Describe similarities and differences in structure for each grouping.
    d. Draw or insert a picture of each slide.

The following groupings may vary, however potential groupings are listed. Students should have distinct groups based on some structural feature of the bacteria.

1	Rod-Shaped	2	Spherically-Shaped
	These are short, straight sausage-like shapes.		These often look like round balls.

Continues next page >

Microscope Slide Capture Sheet

ANSWER KEY **Do not share with students**

Continued

3 Spiral Shaped	4 Comma Shaped
These can look like a spiral or corkscrew.	These are short and have a single curve in their body shape.

Continues next page >

Microscope Slide Capture Sheet

ANSWER KEY **Do not share with students**

Continued

2. Generate a question based on observations from the slides you have just observed.

Answers may vary, but potential questions may be "Why are bacteria shaped differently? What is the purpose of each shape? How does each shape give a type of bacteria an evolutionary advantage?"

3. Why do bacteria adhere to stains differently?

Differences in structure. (Gram-positive bacteria have a thick peptidoglycan layer and no outer lipid membrane while Gram-negative bacteria have a thin peptidoglycan layer and have an outer lipid membrane.)

Superhero/Anime/Fantasy Creature Analogy Capture Sheet, Part 1

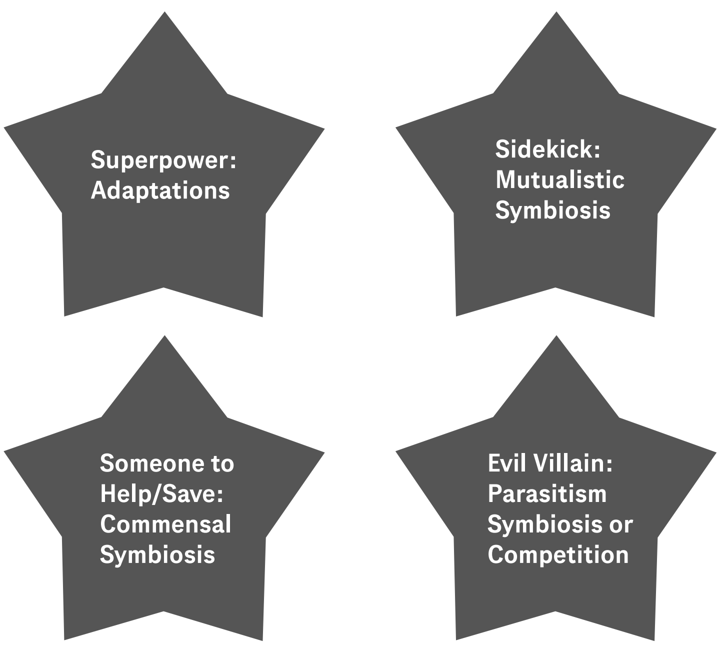
ANSWER KEY — **Do not share with students**

Directions

Using the concept map you completed on Day 1, describe some characteristics of your microbe superhero.

1. Warm-up: Think about the image below and brainstorm with your partner about the superhero analogies to microbes. For instance, what is the analogy of a superpower of “extreme strength” in a superhero to microbes? What is an adaptation?

   Write your notes in the lines provided below.



Student notes will vary.

Continues next page >

Superhero/Anime/Fantasy Creature Analogy Capture Sheet, Part 1

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

Continued

2. Begin your Superhero/Fantasy Creature Life Story by choosing a superhero microbe from the following list (all are bacteria):

1	*Geobacter metallireducens*
2	*Ideonella sakaiensis*
3	*Aquifex*
4	*Pseudomonas syringae*
5	*Lactobacillus acidophilus* or *helveticus*
6	*Neisseria gonorrhoeae*
7	*Wolbachia*
8	*Azotobacter*

3. Using the analogy of a superhero or fantasy creature, answer the following questions about your bacteria by performing some research on your own. If you get stuck, reach out to your partner or instructor who will help guide you.

The following is an example of a student responses based on the bacteria *Acidithiobacillus*.

3a. What is its origin story?
Where does it originate or thrive best? What organisms does it have a close symbiotic relationship with (sidekick)? What is that relationship? Who is its mentor (who discovered it or who works with it closely)?

Acidithiobacillus thrives in acidic locations, which are often in mines. It has a symbiotic relationship, which is mutualistic, with fungi.

Arthur Colmer, Kenneth Temple, and Melvin Hinkle first observed this bacteria.

Continues next page >

Superhero/Anime/Fantasy Creature Analogy Capture Sheet, Part 1

ANSWER KEY **Do not share with students**

Continued

3b. What is its superpower or how does it help others?

What makes it unique from other organisms? How have humans historically related to this bacteria? How has it helped the environment, food production, human health, or other organisms (what symbiotic relationship is this)?

Acidithiobacillus oxidizes substances such as iron. Humans have historically used this bacteria to oxidize ores while mining in order to get purer metals. This bacteria has helped miners in doing this, but its use also has negative effects on the environment. Specifically, it causes acid mine drainage, which causes acidic and toxic fluids to reach waterways.

3c. How does it overcome adversity?

What are its enemies or villains (what symbiotic relationship is this)? What kills it or makes it weak? What might happen if this bacteria superhero ceased to exist?

Agar is an enemy of certain types of *Acidithiobacillus* because its surface does not allow the bacteria to thrive. Also, substances that are basic and increase an area's pH can weaken the bacteria. Without this bacteria, many mining techniques being used today would no longer work, making mining more difficult but also potentially reducing the severity of the effects it has on the environment.

Superhero/Anime/Fantasy Creature Analogy Capture Sheet, Part 2

ANSWER KEY Do not share with students

Directions
Use *What is a prokaryote? A look at bacteria* to make connections between the components of bacterial cells and the characteristics of a superhero. The first one is done for you as an example (you are welcome to change the analogy!).

Bacteria name: *Acidithiobacillus*

	Function	Superhero Component Analogy or Reasoning
Cell wall	*Surrounds the cell, rigid, gives protection*	*Super suit because it protects the superhero*
Capsule	Around the cell wall, allows bacteria to adhere to their surroundings or other cells	Gloves with suction cups that allow the superhero to stick to and climb buildings
Flagella	Whip like structures that aid in movement of the cell	Jetpack that helps the superhero fly through the air
Nucleoid	Clustered genetic material in the cytoplasm	Secret phone that contains the instructions for the superhero's mission
Plasmids	Small circular DNA rings that replicate independently	The text messages with supplemental instructions the superhero receives on the phone in addition to the original instructions
Fimbria	Small hairlike structures that protrude from the capsule that stick the cell to other cells	The mind-reading cap that allows the superhero to "stick to" or understand others' thoughts
Plasma membrane	Membrane that surrounds the cell and allows for select molecules to pass through into the cell	Thermal jacket that keeps the superhero warm and safe from the cold on their missions
Ribosomes	Structures that construct proteins using the genetic instructions in the bacteria	The toolbox the superhero has to build the gadgets described in their instructions

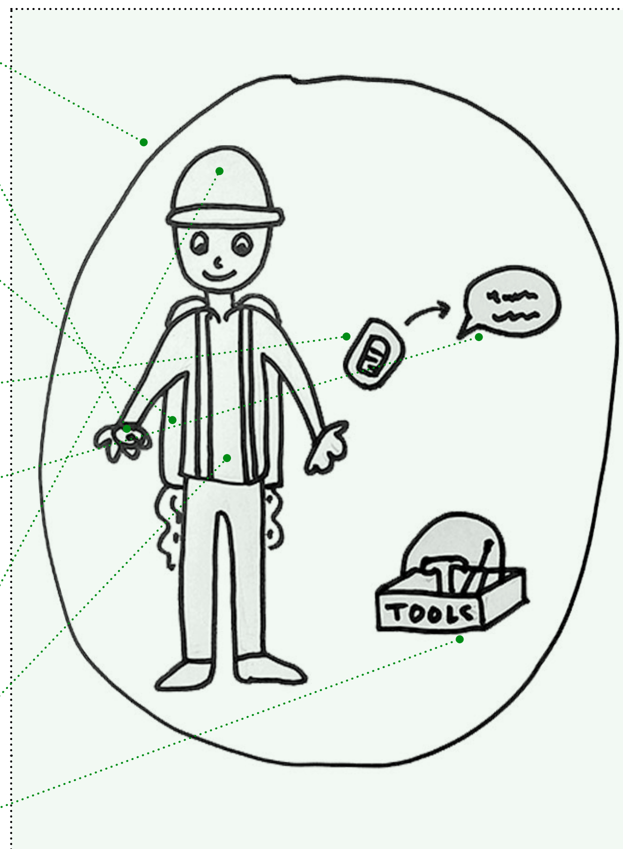
Superhero/Anime/Fantasy Creature Analogy Capture Sheet, Part 3

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

Directions

Follow the three steps below to illustrate your microbe superhero.

1. Find objects in your classroom or at home to help you make a model of your bacteria. For instance, a series of bowls could be used to represent the cell wall and membrane and earbuds to represent the nucleoid. Insert a photo of your bacterial model on the left side of the table below.
2. Using the analogy of a superhero or fantasy creature, draw a representation of what your superhero might look like on the right side of the chart below.
3. Draw a line from the center column to identify where each structural element is represented in both your model and your drawing.

Your Bacterial Model	Structural Elements	Your Superhero or Fantasy Creature Drawing
	Cell wall Capsule Flagella Nucleoid Plasmids Fimbria Plasmid membrane Ribosomes	

Superhero Microbe Storyboard Key

ANSWER KEY **Do not share with students**

Directions

Once your storyboard is approved, create a cartoon/comic strip of your superhero microbe to illustrate its origin, its superpower, and how it overcomes adversity. Check the rubric so you understand what components need to be included.

Here is an example of student storyboard.

Continues next page >

Superhero Microbe Storyboard Key

ANSWER KEY **Do not share with students**

Continued

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Superhero Microbe Storyboard Key

ANSWER KEY **Do not share with students**

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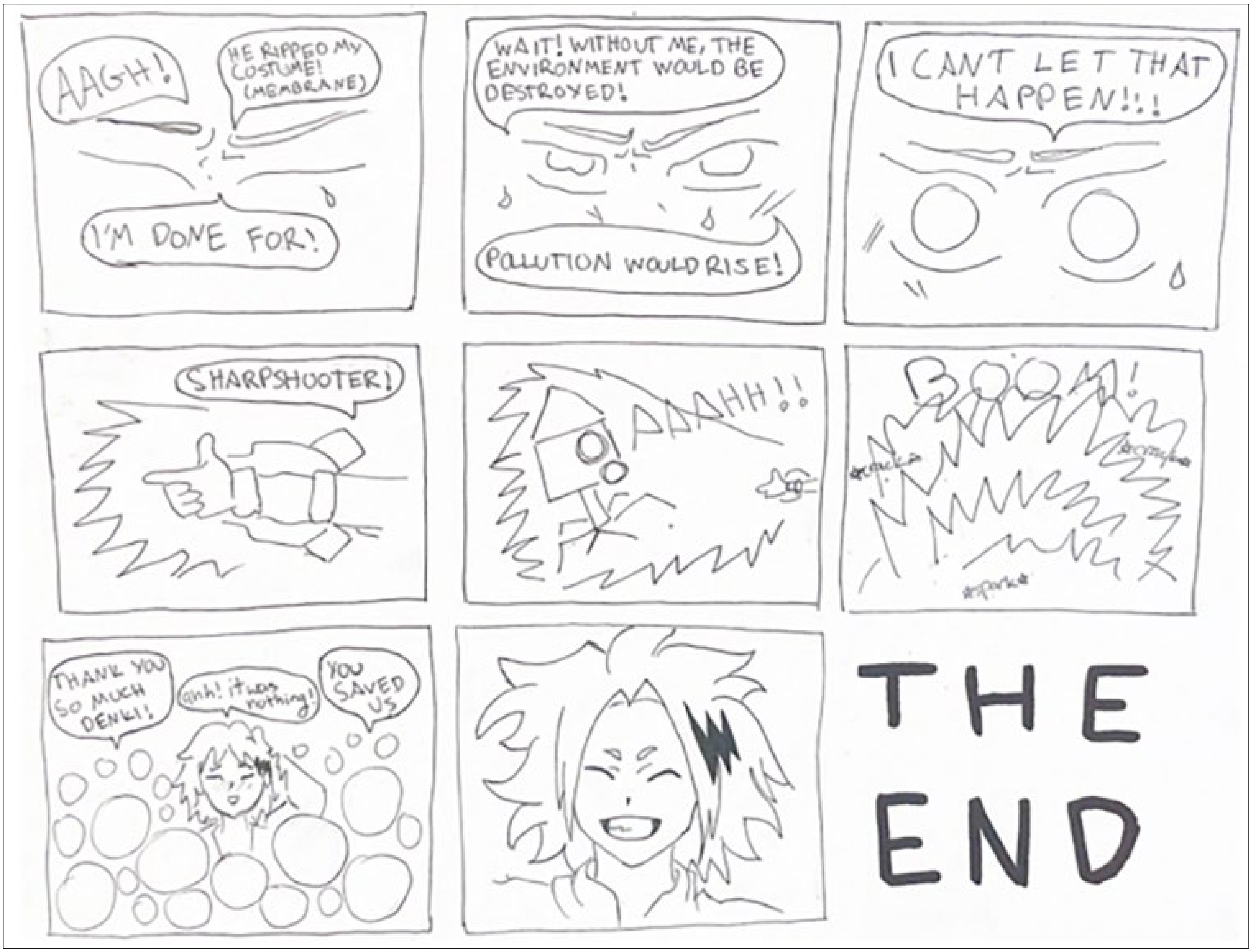


FUTURELAB+

Career Profile

Microbiologist, Project Scientist and Research Associate

Holly Lutz, PhD
UC San Diego's Center for Microbiome Innovation, Field Museum of Natural History's Integrative Research Center

What do you do and how did you get here?

I am currently a project scientist at UCSD and an associate with the Field Museum. After doing my undergraduate work at the University of Chicago, I worked as a research assistant in the museum, and got to do field work, going into caves to observe bats in their natural environment. I got really interested in the skin microbiome, and wrote a proposal to study this with Jack Gilbert's lab. Since then, I've been able to do field work in Africa, where I collected samples from birds, shrews, rodents, and bats. Now I analyze all that data from those field expeditions!

What was your favorite subject in high school, and why did you love it?

I enjoyed my science classes, but I believe my favorite subject was English Literature—I was lucky to have teachers who encouraged critical engagement with the literature we read, and at the time I felt like traveling through stories and time and trying to understand the historical and social contexts in which novels, poetry, etc. were written was really empowering and helped me view the world in a much more engaging way.

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

Learn how to establish boundaries for yourself—with your work, your family, your peers, yourself. If you don't learn how to set your own boundaries, something or someone else will set them for you.

What skills do you use on a daily basis?

Active listening. If you are going to interact with others, it is critical that you truly listen to what they are telling you—whether that is with their words, body language, etc. Perhaps another word for 'active listening' is caring. I have found listening to be the most efficient way to identify problems, find pathways forward, discover new areas for research, and to form meaningful relationships with people both inside and outside of my work. The other, more technical skill I rely on for my research is computer programming. I suppose both are communication skills—the latter is just for machines, while the former is for more sentient beings.

What's most fulfilling about your job?

The complexity and unpredictable nature of the problems I address in my research make it incredibly fulfilling. There are infinite unknowns in the natural world, and I get to play around in what feels like a candy shop of biological novelty. These features also make my work challenging, as new discoveries typically lead to new questions, and working with "big data" means that you have to move between hands-on biology in field conditions (as I practice in my field work with bats and other animals) and working with data files you cannot open or visualize because they are too large. The mental leaps from "this is a bat in my hand" to "these are the genomes of all the microbial symbionts of that bat that was in my hand" can be exhausting, but they are certainly never boring!

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

I truly, deeply wish that I could morph into any animal I choose, so that I could have the ability to communicate with all different types of intelligence that exist in this world!

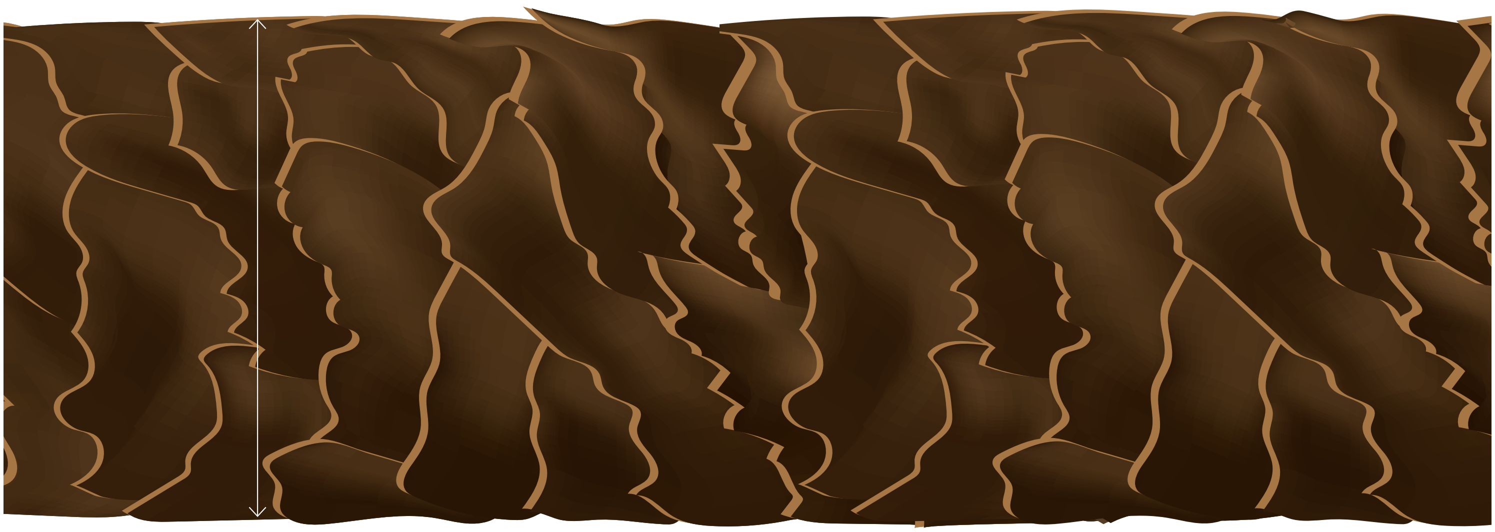
FUTURELAB+

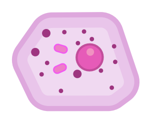
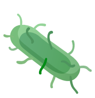
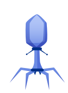
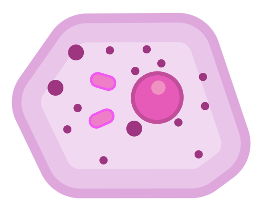
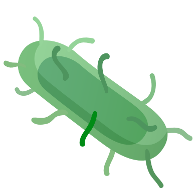
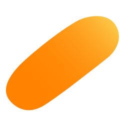
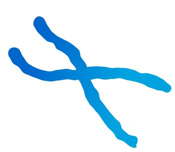
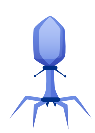
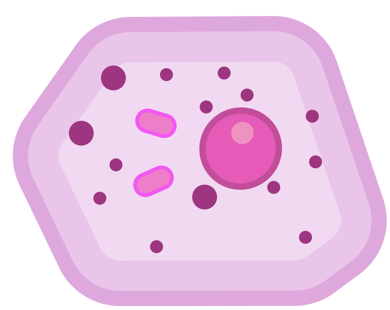
Bacteria Size Capture Sheet

Directions

How large are bacteria compared to other microscopic structures? Cut out or circle the appropriate size E. coli, *mitochondrion,* X*-chromosome, bacteriophage, and skin cell in relation to the width of a human hair pictured.*

Width of Human Hair



E. coli	Mitochondrion	*X*-chromosome	Bacteriophage	Skin cell
				
				
				

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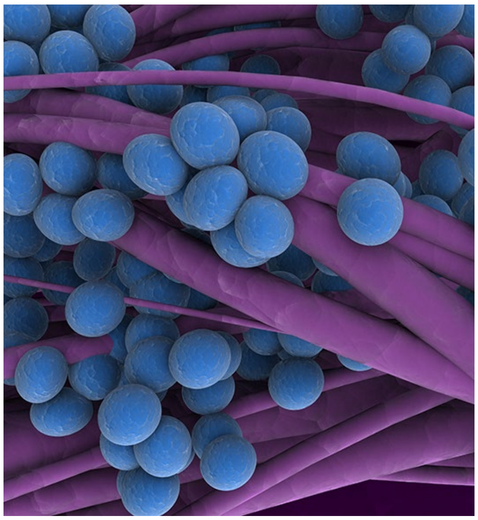
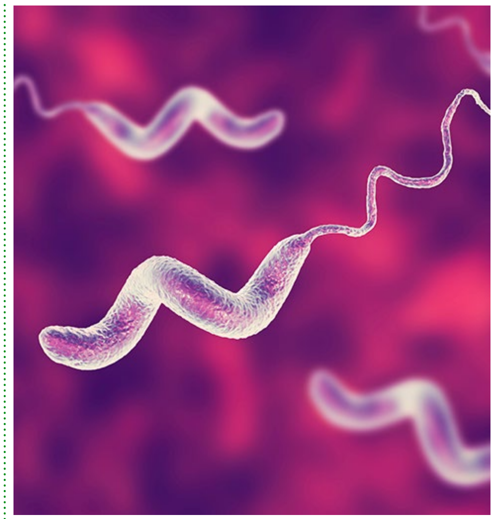
SEM Bacterial Pictures

Directions
Use the combination of your microscope observations and the following SEM (scanning electron microscope) images to make five groupings of bacteria based on structural similarities or differences. Write a short description of each below the image.

Bacteria No. 1	Bacteria No. 2	Bacteria No. 3
		

Bacteria No. 4	Bacteria No. 5
	

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Microscope Slide Capture Sheet

Directions
Look at bacteria under the microscope, or use the SEM Bacteria Pictures to answer the following questions.

1. Observe the prepared slides.
   a. Create as many groupings as needed (four spaces are given, but you may use less or more).
   b. Give each group a name/title.
   c. Describe similarities and differences in structure for each grouping.
   d. Draw or insert a picture of each slide.

1	2

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Microscope Slide Capture Sheet

Continued

3	4

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Microscope Slide Capture Sheet

Continued

2. Generate a question based on observations from the slides you have just observed.

3. Why do bacteria adhere to stains differently?

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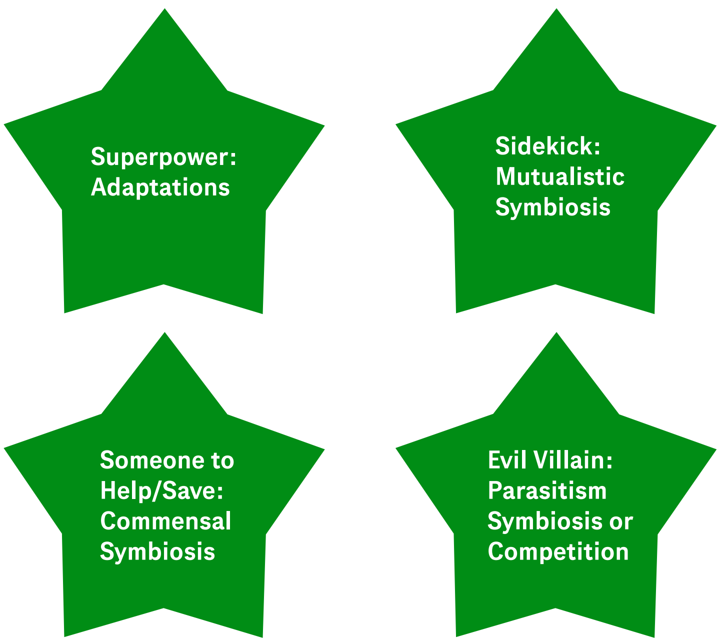
Superhero/Anime/Fantasy Creature Analogy
Capture Sheet, Part 1

Directions

Using the concept map you completed on Day 1, describe some characteristics of your microbe superhero.

1. Warm-up: Think about the image below and brainstorm with your partner about the superhero analogies to microbes. For instance, what is the analogy of a superpower of “extreme strength” in a superhero to microbes? What is an adaptation?

   Write your notes in the lines provided below.



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Superhero/Anime/Fantasy Creature Analogy Capture Sheet, Part 1

Continued

2. Begin your Superhero/Fantasy Creature Life Story by choosing a superhero microbe from the following list (all are bacteria):

1	*Geobacter metallireducens*
2	*Ideonella sakaiensis*
3	*Aquifex*
4	*Pseudomonas syringae*
5	*Lactobacillus acidophilus* or *helveticus*
6	*Neisseria gonorrhoeae*
7	*Wolbachia*
8	*Azotobacter*

3. Using the analogy of a superhero or fantasy creature, answer the following questions about your bacteria by performing some research on your own. If you get stuck, reach out to your partner or instructor who will help guide you.

3a. What is its origin story?

Where does it originate or thrive best? What organisms does it have a close symbiotic relationship with (sidekick)? What is that relationship? Who is its mentor (who discovered it or who works with it closely)?

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Superhero/Anime/Fantasy Creature Analogy Capture Sheet, Part 1

Continued

3b. What is its superpower or how does it help others?

What makes it unique from other organisms? How have humans historically related to this bacteria? How has it helped the environment, food production, human health, or other organisms (what symbiotic relationship is this)?

3c. How does it overcome adversity?

What are its enemies or villains (what symbiotic relationship is this)? What kills it or makes it weak? What might happen if this bacteria superhero ceased to exist?

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Superhero/Anime/Fantasy Creature Analogy
Capture Sheet, Part 2

Directions
Use *What is a prokaryote? A look at bacteria* to make connections between the components of bacterial cells and the characteristics of a superhero. The first one is done for you as an example (you are welcome to change the analogy!).

Bacteria name:

	Function	Superhero Component Analogy or Reasoning
Cell wall	*Surrounds the cell, rigid, gives protection*	*Super suit because it protects the superhero*
Capsule		
Flagella		
Nucleoid		
Plasmids		
Fimbria		
Plasma membrane		
Ribosomes		

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Superhero/Anime/Fantasy Creature Analogy Capture Sheet, Part 3

Directions

Follow the three steps below to illustrate your microbe superhero.

1. Find objects in your classroom or at home to help you make a model of your bacteria. For instance, a series of bowls could be used to represent the cell wall and membrane and earbuds to represent the nucleoid. Insert a photo of your bacterial model on the left side of the table below.
2. Using the analogy of a superhero or fantasy creature, draw a representation of what your superhero might look like on the right side of the chart below.
3. Draw a line from the center column to identify where each structural element is represented in both your model and your drawing.

Your Bacterial Model	Structural Elements	Your Superhero or Fantasy Creature Drawing
	Cell wall	
	Capsule	
	Flagella	
	Nucleoid	
	Plasmids	
	Fimbria	
	Plasmid membrane	
	Ribosomes	

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Superhero Microbe Storyboard

Directions

Once your storyboard is approved, create a cartoon/comic strip of your superhero microbe to illustrate its origin, its superpower, and how it overcomes adversity. Check the rubric so you understand what components need to be included.

Continues next page >

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Superhero Microbe Storyboard

Continued

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Superhero Microbe Comic Rubric

Score	3	2	1
Origin Story Components	Contains three of the five components listed. — Evolutionary history/age — Closest relatives — Symbiotic relationships — Environmental condition where it thrives — Mentor/Superhuman (who discovered it/when)	Contains two of the five components listed.	Contains one of the five components listed.
Description of the Hero's Superpower	Contains two of the three components listed. — Other organisms — How humans historically used/related to this bacteria — How has it helped the environment, food production, or human health	Contains one of the three components listed.	Contains none of the three components listed.
Description of the Hero's Limitations	Contains two of the three components listed. — What kills it/makes it weak? — Is there a villain it fights? — What would happen if this microbe superhero did not exist? (impact on environment, food, human health)	Contains one of the three components listed.	Contains none of the three components listed.
Final Score			