Amplify Science

Microbiome

Investigation Notebook with Article Compilation

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Microbiome

Investigation Notebook

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Safety Guidelines for Science Investigations

1. **Follow instructions.** Listen carefully to your teacher's instructions. Ask questions if you don't know what to do.
2. **Don't taste things.** No tasting anything or putting it near your mouth unless your teacher says it is safe to do so.
3. **Smell substances like a chemist.** When you smell a substance, don't put your nose near it. Instead, gently move the air from above the substance to your nose. This is how chemists smell substances.
4. **Protect your eyes.** Wear safety goggles if something wet could splash into your eyes, if powder or dust might get in your eyes, or if something sharp could fly into your eyes.
5. **Protect your hands.** Wear gloves if you are working with materials or chemicals that could irritate your skin.
6. **Keep your hands away from your face.** Do not touch your face, mouth, ears, eyes, or nose while working with chemicals, plants, or animals.
7. **Tell your teacher if you have allergies.** This will keep you safe and comfortable during science class.
8. **Be calm and careful.** Move carefully and slowly around the classroom. Save your outdoor behavior for recess.
9. **Report all spills, accidents, and injuries to your teacher.** Tell your teacher if something spills, if there is an accident, or if someone gets injured.
10. **Avoid anything that could cause a burn.** Allow your teacher to work with hot water or hot equipment.
11. **Wash your hands after class.** Make sure to wash your hands thoroughly with soap and water after handling plants, animals, or science materials.

Name: ____________________ Date: ____________

Microbiome
Unit Overview

How can having 100 trillion microorganisms on and in the human body keep us healthy? How can fecal transplants cure patients infected with harmful bacteria? That's what your classmates and you will set out to discover! Stepping into the role of a student researcher, you will interpret a case study about a very ill patient to find out how a fecal transplant played a role in his recovery. Your understanding of the tiny microorganisms living on and in the human body will help you determine whether a cutting-edge medical procedure, called a fecal transplant, deserves public money for more research.

Name: ______________________ Date: ______________

Chapter 1: Microorganisms On and In the Human Body
Chapter Overview

In just a few days, you'll be waging a war against harmful bacteria that are too small to see! It may be hard to imagine fighting a problem that exists in a world full of the invisible. How do you get started? First, you will need to investigate more about the 100 trillion creatures that call the human body home, especially focusing on these creatures' very tiny sizes. They aren't on the human body to infect us—in fact, we couldn't survive without them! Soon, you'll be ready to step into the role of a microbiome student researcher to take on the harmful bacteria that endanger our microbiomes.

Name: ______________________________ Date: ____________________

Lesson 1.1: Introduction to the Scale of Living Things

Welcome to an exciting new year of science! Over the next few weeks, you will learn to think like a life scientist as you investigate the world around you. In your role as a student researcher, you will help the Microbiome Research Institute work to increase funding for new medical treatments that depend on microorganisms found on and in the human body. The head scientist at the Institute will explain more about this research in a video. Then, you'll view some amazing pictures of tiny objects that live on and in the human body, which will help you begin to think about the actual sizes and scale of all different types of living things.

Unit Question

- How can having 100 trillion microorganisms on and in the human body keep us healthy?

Chapter 1 Question

- How small are the microorganisms that live on and in the human body?

Vocabulary

- microorganism
- organism
- scale

Digital Tools

- Scale Tool

Name: ______________________ Date: ______________

Quick-Write: Initial Ideas

Chapter 1 Question: *How small are the microorganisms that live on and in the human body?*

What initial ideas do you have about the Chapter 1 Question? Record some of your ideas below.

- Don’t worry if you don’t have a lot of ideas yet. These are just your initial ideas about the question.
- If you need help getting started, use some of the sentence starters below to help you record your ideas.

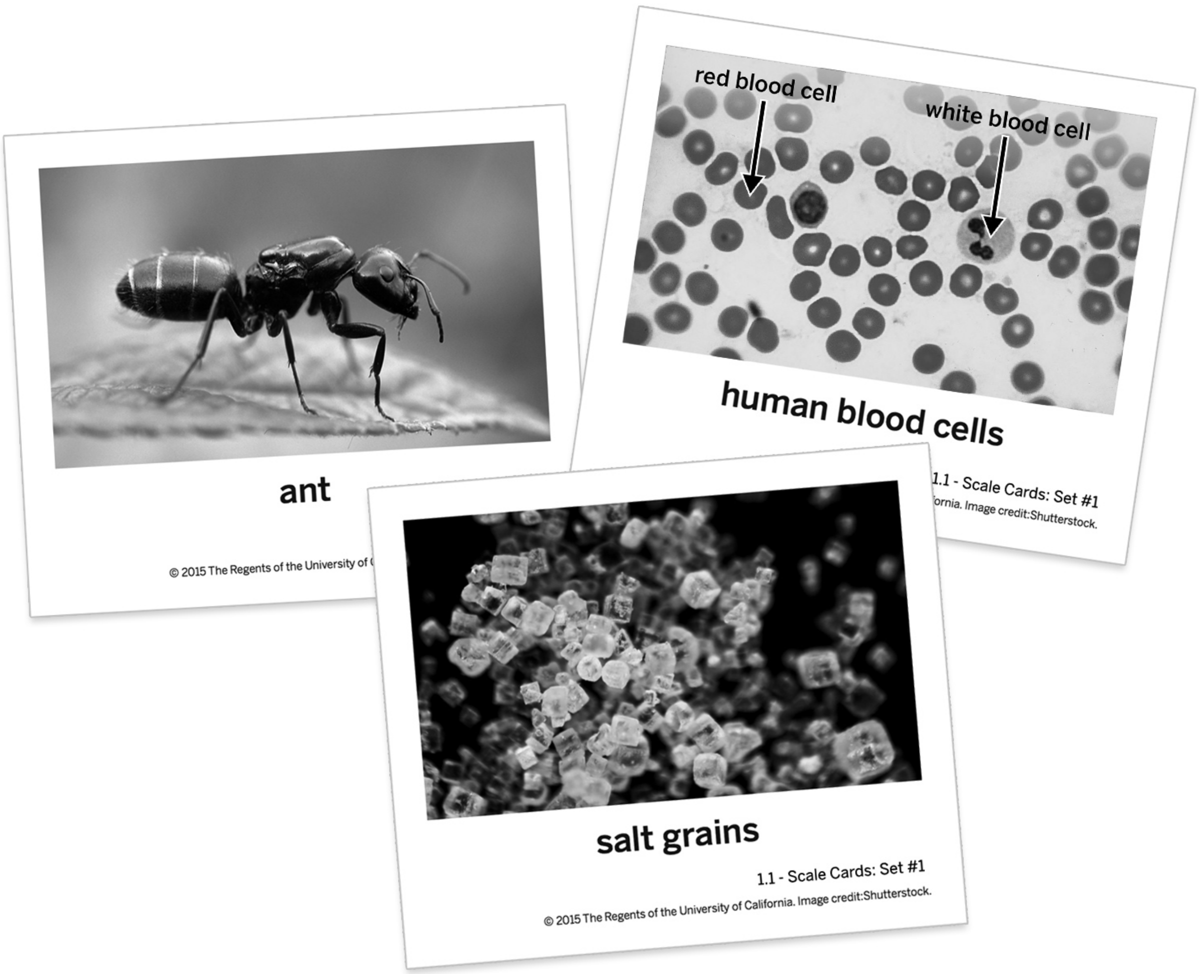
I think a microorganism is smaller than a . . .

I think this because . . .

Name: ______________________ Date: ______________

Exploring Scale

Sort the organisms and objects on the Scale Cards: Set #1 from smallest to largest (left to right). Remember to discuss your ideas as you work!



Name: ______________________ Date: ______________

Reflection

Below are some of the objects featured on the Scale Cards: Set #1.

1. Rewrite the objects to order them from smallest to largest (top to bottom).
2. Use the Scale Tool to help you order the objects, if needed.

Smallest

Objects	Order
grain of salt	______________
E. coli bacteria	______________
human	______________
water molecule	______________
skin cell	______________

Largest

Name: ______________________________ Date: ________________

Homework: Reflecting About Microorganisms

Respond to the two questions below. Try to use some of the words below that you heard today.

- bacteria
- cell
- microorganism
- microscopic
- organism
- scale

1. What was surprising or interesting to learn about the very small organisms and objects in today's lesson?

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2. What other questions do you have about microorganisms?

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Name: ______________________________ Date: ____________________

Lesson 1.2: How Small Is Small?

In the previous lesson, you learned that there are microorganisms living on and in the human body. You also compared the sizes of microorganisms to other tiny things. In this lesson, you will think very carefully about the small sizes of these microorganisms.

Unit Question

- How can having 100 trillion microorganisms on and in the human body keep us healthy?

Chapter 1 Question

- How small are the microorganisms that live on and in the human body?

Key Concepts

- Many organisms are microscopic—so small that they cannot be seen with the naked eye.

Vocabulary

- cells
- microorganism
- microscopic
- organism
- scale

Digital Tools

- Scale Tool

Name: ______________________________ Date: ____________________

Warm-Up

Check each statement below that is true. **Note:** You can select more than one statement.

- ☐ Cells come in different sizes and shapes.
- ☐ All organisms are made of many cells.
- ☐ Some organisms are made of just one cell.
- ☐ All cells are the same size and shape.
- ☐ Most cells are too small to see with the naked eye.

What else do you know about cells? Record your ideas or any questions you have about cells.

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Name: ______________________________ Date: ________________

Understanding the Scale of Cells

Launch the Scale Tool to help you gather evidence about the objects on the new Scale Cards in Set #2.

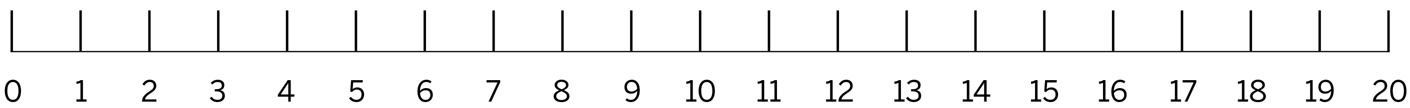
- Ringworm fungus
- *C. difficile* bacteria
- Human liver cell

You won't find these items in the Scale Tool, but you can use the measurements on the Scale Cards: Set #2 and the measurements of other objects in the Scale Tool to help you place these items in the Scale Card Sort!

Name: ______________________________ Date: ____________________

Supersized Microorganisms

1. Choose two microorganisms from the Scale Cards or the Scale Tool.
2. Draw your microorganisms at 20,000 times their actual size.
3. Label each microorganism with its size and name.



scale: 20,000 times actual size
2 centimeters (cm) = 1 micrometer (μm)

Name: ____________________ Date: ____________

Reflection

Check each statement below that is true. **Note:** You can select more than one statement.

- ☐ Cells come in different sizes and shapes.
- ☐ All organisms are made of many cells.
- ☐ Some organisms are made of just one cell.
- ☐ All cells are the same size and shape.
- ☐ Most cells are too small to see with the naked eye.

Refer back to your Warm-Up on page 11. Did any of your answers change from your Warm-Up response? If so, why? Record your changes and your explanations below.

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Name: ______________________________ Date: ____________________

Homework: Comparing Objects at Different Scales

In this lesson, you learned that:

- Living things are made of cells.
- Cells are very small—in fact, almost all cells are microscopic.
- Some living things are made of just one cell.

Think about how the scale of cells compares to the scale of other objects. Launch the Scale Tool and complete the table below by finding examples of objects at each scale that is listed. Some parts of the table have been completed for you.

Scale	**Objects at this scale**	**Size of object**
thousands of kilometers		
thousands of meters	depth of the Grand Canyon	
meters	orca	8 meters
centimeters		
micrometers	red blood cell	8 micrometers
nanometers		

Name: ____________________ Date: ____________

Homework: Reading "Cells"

You have learned a lot about cells, but there is so much more to know! Read and annotate the article "Cells" and answer the questions below.

1. What is one new thing you learned about cells from this article?

2. What are organelles and why are they important?

3. How are cells, tissues, organs, and systems related?

Name: ______________________________ Date: ________________

Lesson 1.3: Observing Microorganisms

Microorganisms are tiny, but there are some things that are even smaller! In today's lesson, you'll think about things that are even smaller than microorganisms, and you'll also learn how scientists observe microorganisms without a microscope. Also, using a routine called Word Relationships and what you've learned in the last few lessons, you will talk and work like a scientist to revise your initial response to the Chapter 1 Question: *How small are the microorganisms that live on and in the human body?*

Unit Question

- How can having 100 trillion microorganisms on and in the human body keep us healthy?

Chapter 1 Question

- How small are the microorganisms that live on and in the human body?

Key Concepts

- Many organisms are microscopic—so small that they cannot be seen with the naked eye.
- All living things are made of cells.
- Almost all cells are microscopic.
- Even though they are both too small to see, cells are much bigger than molecules.

Vocabulary

- cells
- microorganism
- microscopic
- scale

Name: ______________________ Date: ______________

Warm-Up

You've been learning about tiny organisms that are made of a single cell! But are there objects even **smaller** than a cell?

Circle "agree" or "disagree" for each statement below. It's okay if you aren't sure.

Cells are the smallest things that exist.	**agree**	**disagree**
Molecules are smaller than cells.	**agree**	**disagree**
Cells are smaller than molecules.	**agree**	**disagree**
Molecules are made of cells.	**agree**	**disagree**
Cells are made of molecules.	**agree**	**disagree**

Explain why you agree with some of the statements.

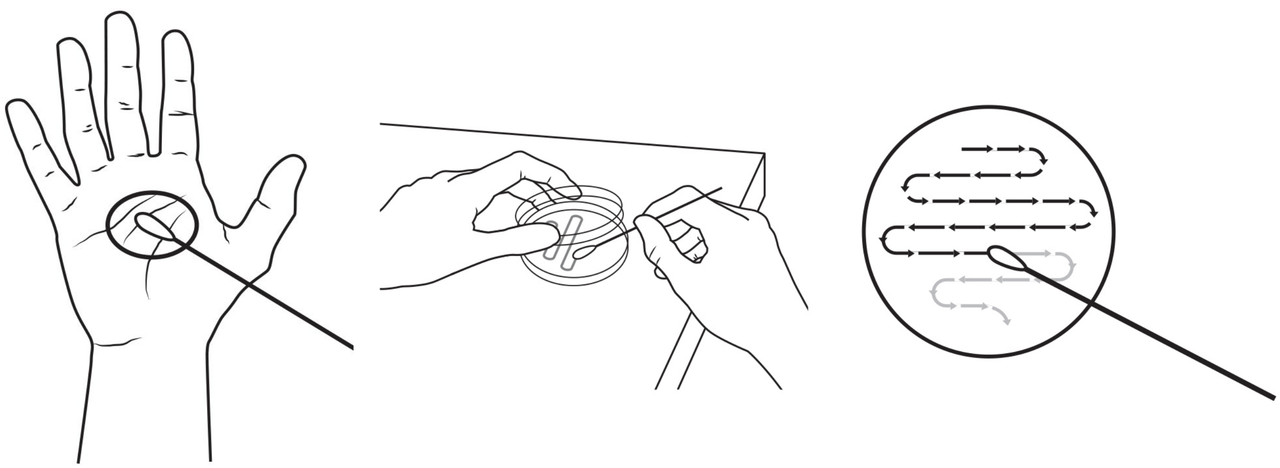
Name: ____________________ Date: ____________________

Investigating Microorganisms

Observing Microorganisms

1. Can you observe microorganisms on your hand? (circle one) **yes** **no**
2. Do you think there are any microorganisms on your hand? (circle one) **yes** **no**

The images below show how a microbiologist could prepare a culture in order to grow and observe the microorganisms found on a person's hand.



Name: ______________________________ Date: ________________

Observing Microorganisms: Day 1

Refer to the Day 1 image of the petri dish that your teacher projected, and answer the questions below.

Can you see evidence of microorganisms? (circle one) **yes** **no**

Describe what you observe in the petri dish.

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Make a prediction: What do you think the petri dish will look like on Day 5?

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Name: ______________________________ Date: ________________

Observing Microorganisms: Day 5

Refer to the Day 5 image of the petri dish that your teacher projected, and answer the questions below.

Can you see evidence of microorganisms? (circle one) **yes** **no**

Describe what you observe in the petri dish.

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Make a prediction: What do you think the petri dish will look like on Day 9?

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Name: ____________________ Date: ____________

Homework: Revising Responses to the Chapter 1 Question

Chapter 1 Question: *How small are the microorganisms that live on and in the human body?*

1. Turn back to page 6 and read over your previous response to the Chapter 1 Question.
2. Revise your response below so it includes what you have learned in the last few lessons. You may wish to use the following science words in your revised response.
    - cell
    - micrometer
    - microorganism
    - microscopic
    - molecule
    - nanometer

Name: ______________________________ Date: ____________________

Chapter 2: Arguing for the Benefits of Fecal Transplants
Chapter Overview

The tiny microorganisms that live on and in the human body are tiny but powerful. They can be helpful or they can be deadly. You'll be using what you've learned about the microbiome to investigate a promising but controversial new treatment that involves transplanting microorganisms from a healthy person into a sick person. By the end of this unit, you'll be able to write a scientific argument explaining how this treatment works.

Name: ________________________________ Date: ________________

Lesson 2.1: Reading “The Human Microbiome”

Today, you will return to your bacteria culture to see more evidence about microorganisms that came from your body! Then, you’ll read more about these microorganisms in “The Human Microbiome” article. Using this article, you will begin to learn how to read like a scientist, carefully and actively, making sure you understand the text and images. You will record your questions and ideas as you read, and you’ll have a chance to discuss your thoughts about the article with others. After reading today, you’ll have a better understanding of what the human microbiome is and how it is possible to have trillions of microorganisms on and in the human body.

Unit Question

- How can having 100 trillion microorganisms on and in the human body keep us healthy?

Chapter 2 Question

- How can fecal transplants cure patients infected with harmful bacteria?

Vocabulary

- cells
- microbiome
- microorganism
- microscopic
- organism
- scale

Name: ______________________________ Date: ____________________

Warm-Up

Observing Microorganisms: Day 9

Refer to the Day 9 image of the petri dish that your teacher projected, and answer the questions below.

Can you see evidence of microorganisms? (circle one) **yes** **no**

Describe what you observe in the petri dish.

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Name: ______________________________ Date: ________________

Introducing Active Reading

Analyzing Example Annotations

- What do you notice about this student's annotations?
- How do you know that she was thinking carefully while reading and trying to understand the text?

They are so tiny, but so important!

that are incredibly powerful, and you can't see them, and they're everywhere," says Lynch. "And they dictate, in my book, pretty much everything that goes on on this planet."

The crosscutting concept of Systems

Today, at the University of California, San Francisco, Lynch works with many different types of scientists to study the human microbiome and how it affects the body as a system—which requires building bridges between different areas of science. To study the interactions between microorganisms and the body as a whole, scientists have to think and learn about topics outside of their usual areas of study. "In that way, we're kind of like our own little microbiome," she says. "Everybody brings different knowledge and skills to the table."

How long have scientists studied microbiome?

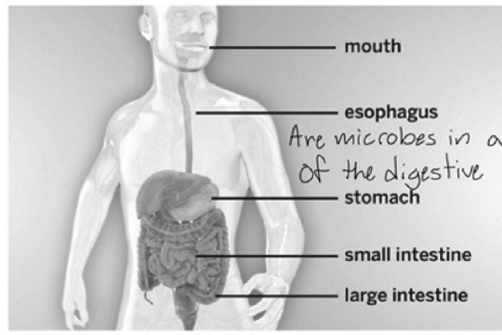
The study of the human microbiome is still in its early stages: scientists are trying to find out and describe the basics of how the microbiome works. Someday, scientists hope to understand exactly what happens during each interaction—and that could open up whole new fields of study.

Interactions seem really important, What does that mean?

What are the challenges?

Studying the human microbiome has its challenges, but Lynch says she loves learning new things—and she encourages young people to find something they love, too. "Go after something that you really enjoy, something that isn't a chore," she says. "I've ended up where I am because I've always gone after things that interest me. I eat, breathe, and sleep this stuff, and I love it."

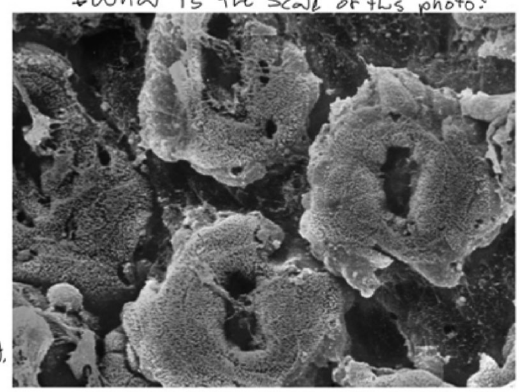
gross



Are microbes in all parts of the digestive system?

Many of the microbes Dr. Susan Lynch studies are found in the human digestive system.

What is the scale of this photo?



This photo, taken with a microscope, shows the wall of a gut infected with ulcerative colitis, a digestive problem that may be caused by the interaction between microorganisms. Lynch's work may someday help heal people with this condition. (Colors were added to the photo to make it easier to see.)

BIG IDEA: The microbiome interacts with and affects lots of things even though it's not visible

Name: ________________________________ Date: ________________

Reading "The Human Microbiome"

1. Read and annotate the article "The Human Microbiome."
2. Choose and mark annotations to discuss with your partner. Once you have discussed these annotations, mark them as discussed.
3. Now, choose and mark a question or connection, either one you already discussed or a different one you still want to discuss with the class.
4. Answer the reflection questions below.

How similar is Active Reading to the way you normally read?

- ☐ I always read this way.
- ☐ It is somewhat similar to how I normally read.
- ☐ It is very different from the way I normally read.

As I read, I paid attention to my own understanding and recorded my thoughts and questions.

- ☐ Never
- ☐ Almost never
- ☐ Sometimes
- ☐ Frequently/often
- ☐ All the time

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Name: ______________________________ Date: ________________

Lesson 2.2: Beginning a Case Study of Patient 23

Here's the deal: A politician wants to cut funding for research on a new treatment that's being used to cure patients infected with a harmful bacteria called *C. difficile.* The treatment involves transplanting helpful bacteria from the poop of a healthy person into the gut of a sick person. Is this an amazing medical breakthrough, or is it just crazy?

The Microbiome Research Institute needs your help to build an argument about how this treatment isn't crazy. (In fact, it actually saves lives.) You'll start to construct this argument by learning more about helpful and harmful bacteria. Then, you'll examine data from a patient who actually received this treatment.

Unit Question

- How can having 100 trillion microorganisms on and in the human body keep us healthy?

Chapter 2 Question

- How can fecal transplants cure patients infected with harmful bacteria?

Vocabulary

- bacteria
- cells
- microbiome
- microorganism
- scale

Name: ______________________________ Date: ______________

Warm-Up

After reading "The Human Microbiome" article, you learned that there are trillions of bacteria in the human microbiome. Which of these statements do you agree with most right now? (check one)

- ☐ Bacteria are disgusting! Most bacteria in the human microbiome are harmful.
- ☐ Bacteria are great! Most bacteria in the human microbiome are helpful.
- ☐ I'm not sure! Bacteria are kind of disgusting, but some of them might be helpful.

What other interesting things did you learn from reading "The Human Microbiome" article?

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What questions do you still have about the article?

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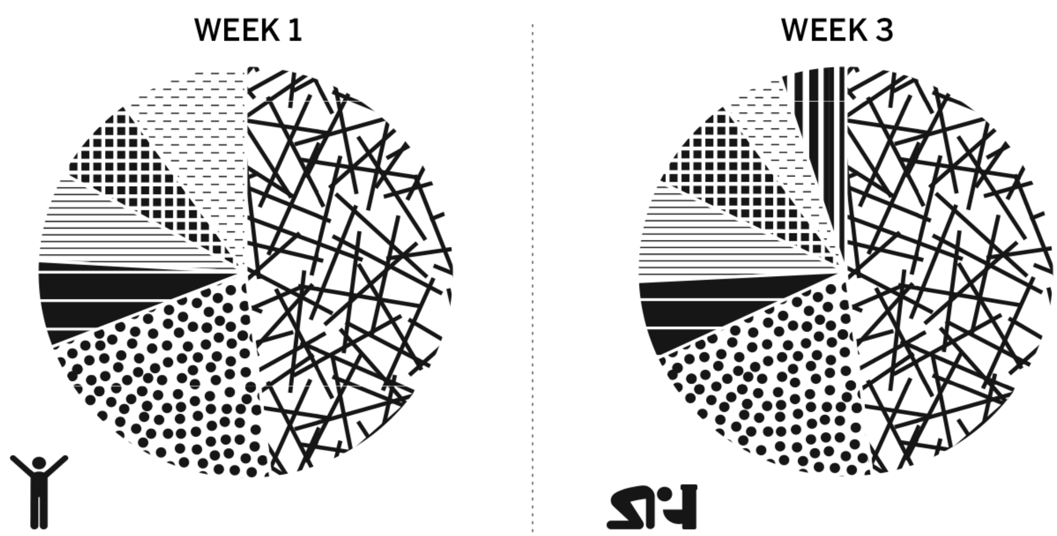
Name: ____________________ Date: ____________

Introducing Patient 23's Case Study

Analyzing Data in Pie Charts

1. Annotate the case study pie charts below with your comments and questions.
2. Then, discuss the following questions with your partner:
   - What is the **same** about the patient's gut microbiome data from week 1 to week 3?
   - What is **different** about the patient's gut microbiome data from week 1 to week 3?
3. When you are finished discussing with a partner, answer the questions about the patient on the next page.

Patient 23's Gut Bacteria



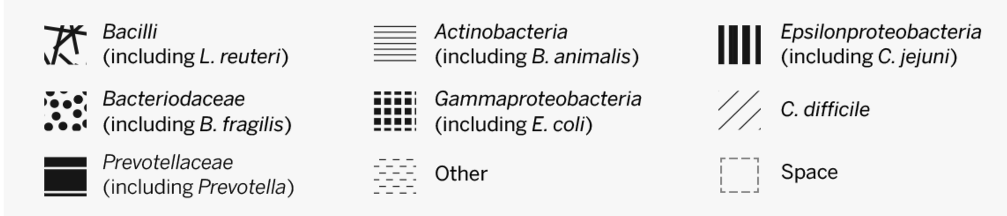
Doctor's Notes

Patient reports feeling normal.

Doctor's Notes

Patient reports vomiting, diarrhea, and a fever.

Gut Bacteria Key



Name: ______________________________ Date: ____________________

Introducing Patient 23's Case Study (continued)

After your discussion, record your ideas below about why you think Patient 23 feels normal during week 1 but sick during week 3.

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The evidence that supports my ideas is . . .

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Name: ______________________________ Date: ________________

Second Read of “The Human Microbiome”

Reread the sections: “Your Body: Home Sweet Home for Bacteria,” “Helpful Bacteria and Alien Invaders,” and “Antibiotics and the Microbiome” from “The Human Microbiome” article. Then, highlight or add annotations with your ideas to parts of the text that relate to Patient 23. Using your annotations, answer the questions below.

1. What do bacteria do in a healthy gut microbiome?

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2. What is one type of bacteria found in a healthy gut microbiome?

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3. What is a type of harmful bacteria found in the human gut microbiome?

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4. What do harmful bacteria do in the gut microbiome?

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Name: ________________________________ Date: ________________

Reflection: Revising Explanations About Patient 23

Refer back to your initial explanation on page 31 about why Patient 23 felt sick during week 3. Use what you learned from your second read of "The Human Microbiome" to revise your explanation.

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Name: ______________________________ Date: ________________

Lesson 2.3: Investigating Antibiotics

Poor Patient 23! We've analyzed data about his gut microbiome and now have strong evidence that he is a victim of food poisoning (or a *C. jejuni* bacteria infection). This type of food poisoning is often treated with antibiotics, so today you'll evaluate evidence about the effects of antibiotics on the human microbiome, while also learning more about how to argue like a scientist.

Unit Question

- How can having 100 trillion microorganisms on and in the human body keep us healthy?

Chapter 2 Question

- How can fecal transplants cure patients infected with harmful bacteria?

Key Concepts

- The human microbiome contains approximately 100 trillion microorganisms. Most of these are bacteria.
- The human body provides an environment (food and space) for bacteria to survive.

Vocabulary

- antibiotics
- bacteria
- claim
- evidence
- microorganism
- reasoning
- scale
- scientific argument

Name: ______________________ Date: ______________

Warm-Up

1. Read the arguments below.
2. Then, answer the question about the arguments.

Argument One: Patient 23 felt sick during week 3 because he was infected with the *C. jejuni* bacteria. From "The Human Microbiome" article, I know that "this kind of *C. jejuni* infection can cause diarrhea, vomiting, and fever—all the symptoms of food poisoning." These symptoms match the doctor's note for Patient 23 for week 3. When Patient 23 felt healthy during week 1, the *C. jejuni* bacteria was not present in his gut microbiome. In week 3, when he felt sick, *C. jejuni* was present. Therefore, *C. jejuni* is probably the cause of his sickness.

Argument Two: Patient 23 felt sick during week 3 because he was infected with the *C. jejuni* bacteria. *C. jejuni* is very bad for you. He probably ate something spoiled. My sister got food poisoning once.

These two arguments both answer the question *Why did Patient 23 feel sick during week 3?* Which of these arguments is more convincing? Explain your thinking below.

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Name: ______________________________ Date: ____________________

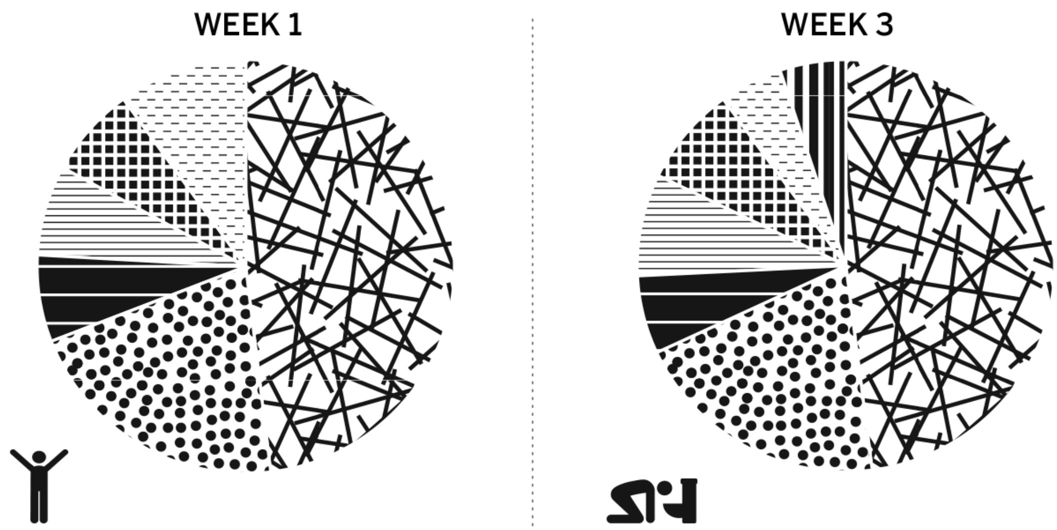
Evaluating Evidence About Antibiotics

Antibiotics Card Sort

How do antibiotics affect the microbiome?

1. Place the Claim card at the top of your desk and the Relevant and Irrelevant headers underneath it.
2. With your partner, discuss each evidence card and decide if it is relevant or irrelevant to the claim.
3. Place each evidence card under the appropriate header on your desk.

Patient 23's Gut Bacteria



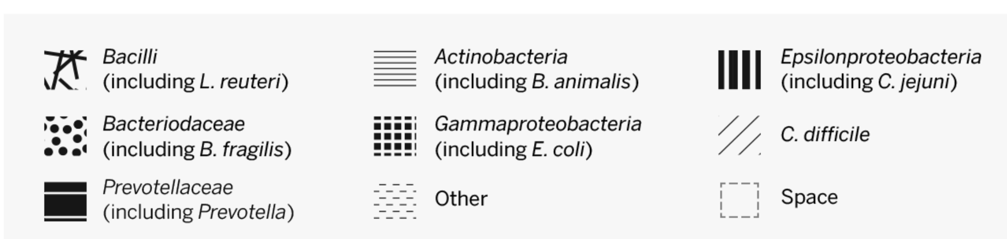
Doctor's Notes

Patient reports feeling normal.

Doctor's Notes

Patient reports vomiting, diarrhea, and a fever.

Gut Bacteria Key



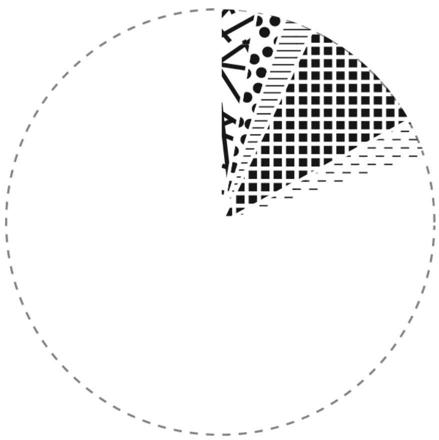
Name: ______________________ Date: ______________

Returning to Patient 23

Analyzing Data for Patient 23 During Week 5

1. Analyze the new pie chart for week 5.
2. Then, answer the question below.

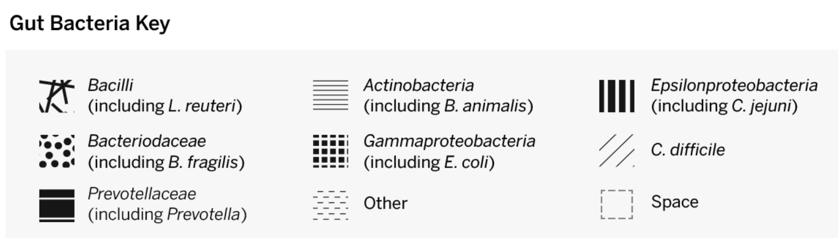
Treatment: antibiotics



WEEK 5

Doctor's Notes

Patient feeling well again.



Observe what happened to Patient 23 during week 5 (after he was treated with antibiotics). What do you notice? How do you think antibiotics affected his microbiome?

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Name: ______________________________ Date: ________________

Homework: Reading "Meet a Scientist Who Studies the Human Microbiome"

Learn more about a scientist who studies the human microbiome. Read and annotate the article "Meet a Scientist Who Studies the Human Microbiome" and answer the question below.

What do scientists who study the human microbiome hope to achieve?

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Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Name: ______________________________ Date: ________________

Lesson 2.4: Analyzing Experiments with Mice

Did you know that mice have microbiomes, too? Today, you will analyze data from an experiment conducted on laboratory mice. This experiment provides information about how a healthy gut microbiome full of different types of bacteria could be important to the overall health of an organism's body. By the end of this lesson, you will be able to use what you learned from the mouse experiment to figure out why Patient 23 got a different infection after being treated with antibiotics in week 5 of his case study.

Unit Question

- How can having 100 trillion microorganisms on and in the human body keep us healthy?

Chapter 2 Question

- How can fecal transplants cure patients infected with harmful bacteria?

Key Concepts

- The human microbiome contains approximately 100 trillion microorganisms. Most of these are bacteria.
- The human body provides an environment (food and space) for bacteria to survive.
- A healthy microbiome has various helpful types of bacteria.
- An infection of harmful bacteria in the human microbiome can make a person sick.

Vocabulary

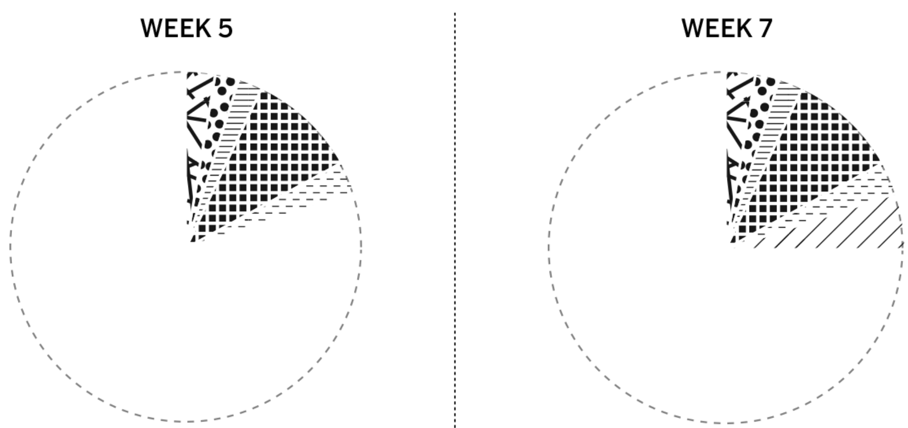
- antibiotics
- bacteria
- claim
- evidence
- microorganism
- scale

Name: ______________________________ Date: ________________

Warm-Up

The pie charts below show data about Patient 23 during weeks 5 and 7 of the case study. Using the Gut Bacteria Key, determine which new type of bacteria has been introduced to Patient 23's gut microbiome. Then, answer the questions below.

Treatment: antibiotics



Doctor's Notes (Week 5)

Patient feeling well again.

Doctor's Notes (Week 7)

Patient reports stomach pains, diarrhea, and bloating.

Gut Bacteria Key

Bacilli (including *L. reuteri*)	*Actinobacteria* (including *B. animalis*)	*Epsilonproteobacteria* (including *C. jejuni*)
Bacteriodaceae (including *B. fragilis*)	*Gammaproteobacteria* (including *E. coli*)	*C. difficile*
Prevotellaceae (including *Prevotella*)	Other	Space

Which new type of bacteria was introduced to Patient 23's gut microbiome?

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What effect do you think this new bacteria will have on Patient 23's overall health?

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Name: ____________________ Date: ____________

Analyzing an Experiment About the Microbiome

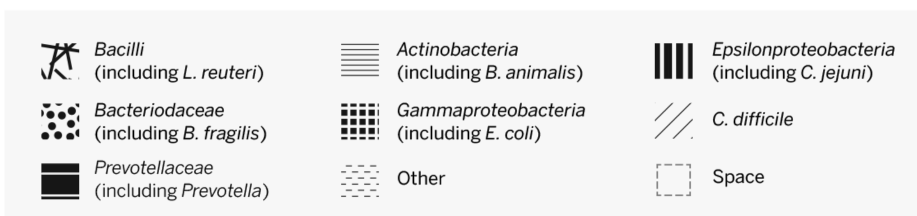
With your partner, discuss the similarities and differences between the healthy gut microbiomes of a mouse and a human.

Human and Mouse Gut Microbiomes

Normal Human Gut Microbiome

Normal Mouse Gut Microbiome

Gut Bacteria Key



Name: ______________________________ Date: ________________

Analyzing an Experiment About the Microbiome (continued)

Recording Observations About New Data

Record your observations about the mouse data by annotating the image below.

Experiment 1: *Salmonella* Bacteria

Normal Gut Microbiomes of 20 Healthy Mice Before Experiment

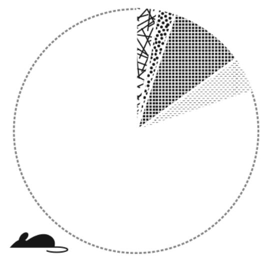
Mice ingest the same amount of *Salmonella* bacteria

Test Results

5 mice are unaffected and remain healthy

12 get slightly sick from *Salmonella* infection

3 get really sick from *Salmonella* infection



Low-Bacteria Gut Microbiomes of 20 Healthy Mice Before Experiment

Mice ingest the same amount of *Salmonella* bacteria

Test Results

20 get really sick from *Salmonella* infection

Gut Bacteria Key

- *Bacilli* (including *L. reuteri*)
- *Bacteriodaceae* (including *B. fragilis*)
- *Prevotellaceae* (including *Prevotella*)
- *Actinobacteria* (including *B. animalis*)
- *Gammaproteobacteria* (including *E. coli*)
- Other
- *Epsilonproteobacteria* (including *C. jejuni*)
- *C. difficile*
- Space

Name: ______________________________ Date: ______________

Reading "Bacteria: *Salmonella*"

Carefully read the "Environment" section from the "Bacteria: *Salmonella*" article. Pay attention to your own understanding while you read.

As you read, think about how the information presented in the text could help you answer the following two discussion questions. Record your notes on the lines underneath the questions.

1. How do *Salmonella* bacteria in the gut microbiome affect the body?

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2. Why were the low-bacteria mice in the experiment more likely to get a *Salmonella* bacteria infection?

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Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

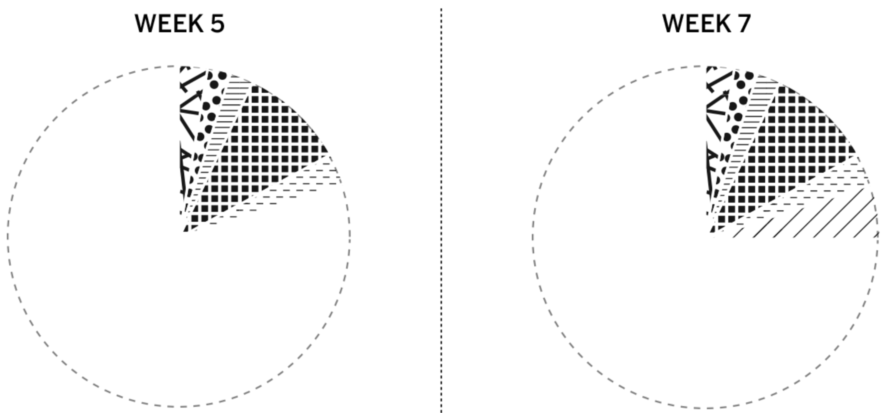
Name: ____________________ Date: ____________

Applying New Understanding to Patient 23

Why did Patient 23 get a* C. difficile *infection after his treatment with antibiotics?

1. Use evidence from Experiment 1: *Salmonella* Bacteria, the "Bacteria: *Salmonella*" article, and the other case study data to support your ideas as you discuss the question above with your partner.
2. If you are having trouble expressing your ideas, use these sentence starters:
   - Patient 23 got a *C. difficile* infection after his treatment with antibiotics because . . .
   - The evidence that supports my idea is . . .

Treatment: antibiotics



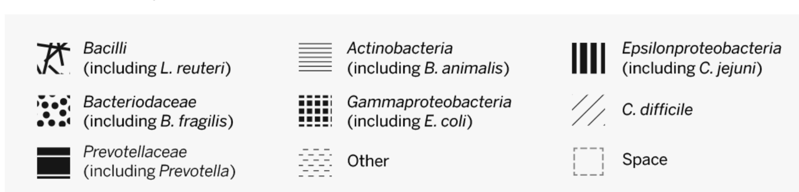
Doctor's Notes (Week 5)

Patient feeling well again.

Doctor's Notes (Week 7)

Patient reports stomach pains, diarrhea, and bloating.

Gut Bacteria Key



Name: ____________________ Date: ____________

Homework: Reading "Bacteria: *C. difficile*"

The week 7 data shows that Patient 23 is infected with the *C. difficile* bacteria. Read and annotate the article to learn more about this very harmful bacteria.

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Name: ______________________ Date: ______________

Lesson 2.5: Analyzing Evidence About Fecal Transplants

The Microbiome Research Institute needs your help and expertise! In order to fight the senator's efforts to cut their funding, they are preparing a press release about the benefits of fecal transplants. Specifically, they need your help writing a scientific argument about how fecal transplants work, which they will include in the press release. You'll start by analyzing new data about Patient 23. Then, by relooking at all of the evidence you have gathered about fecal transplants, you can begin to reason about this evidence and write the first part of your argument.

Unit Question

- How can having 100 trillion microorganisms on and in the human body keep us healthy?

Chapter 2 Question

- How can fecal transplants cure patients infected with harmful bacteria?

Key Concepts

- The human microbiome contains approximately 100 trillion microorganisms. Most of these are bacteria.
- The human body provides an environment (food and space) for bacteria to survive.
- A healthy microbiome has various helpful types of bacteria.
- An infection of harmful bacteria in the human microbiome can make a person sick.
- Antibiotics reduce the number of helpful and harmful bacteria in the microbiome.
- Living things with fewer than normal helpful bacteria in their guts can become infected more easily because there is more food and space available for harmful bacteria.

Vocabulary

- antibiotics
- bacteria
- claim
- evidence
- microorganism
- scale

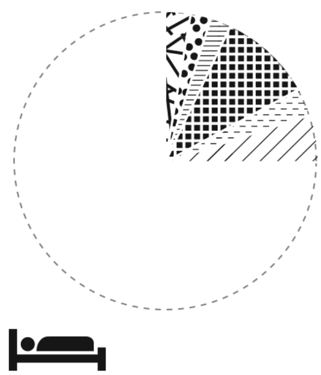
Name: ______________________ Date: ______________

Warm-Up

1. Review the new data about Patient 23.
2. Then, answer the question below.

Treatment: fecal transplant

WEEK 7



Doctor's Notes

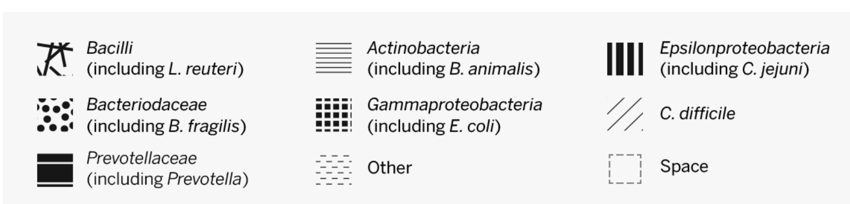
Patient reports stomach pains, diarrhea, and bloating.

WEEK 9

Doctor's Notes

Patient reports feeling normal again.

Gut Bacteria Key



What differences do you notice in Patient 23's gut microbiome between weeks 7 and 9? Record at least two observations.

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Name: ______________________ Date: ______________

Message from the Microbiome Research Institute

To: Student Researchers
From: Mara, Head Scientist
Subject: Fecal Transplant Procedure Presentation
Attachment: FT Procedure

MRI Microbiome Research Institute

Thank you for your careful work analyzing the data for Patient 23. As you know from the politician's speech, the fecal transplant procedure has something to do with feces. I've sent you a slideshow presentation to review that includes a detailed explanation of how the procedure works. I think this information will help you understand more about how a fecal transplant helps cure a patient infected with harmful bacteria.

We also want to include your research in a press release in which we will publicly present our arguments against the senator's effort to cut our funding. In this press release, we are going to present our evidence in support of this claim: A fecal transplant can work to cure a patient infected with a very harmful bacteria, such as *C. difficile*, in many different ways. We think we have strong evidence to support this claim, but we will need your help to research and write a convincing scientific argument.

Name: ______________________________ Date: ________________

Discussing Evidence and Reasoning

Explaining Evidence

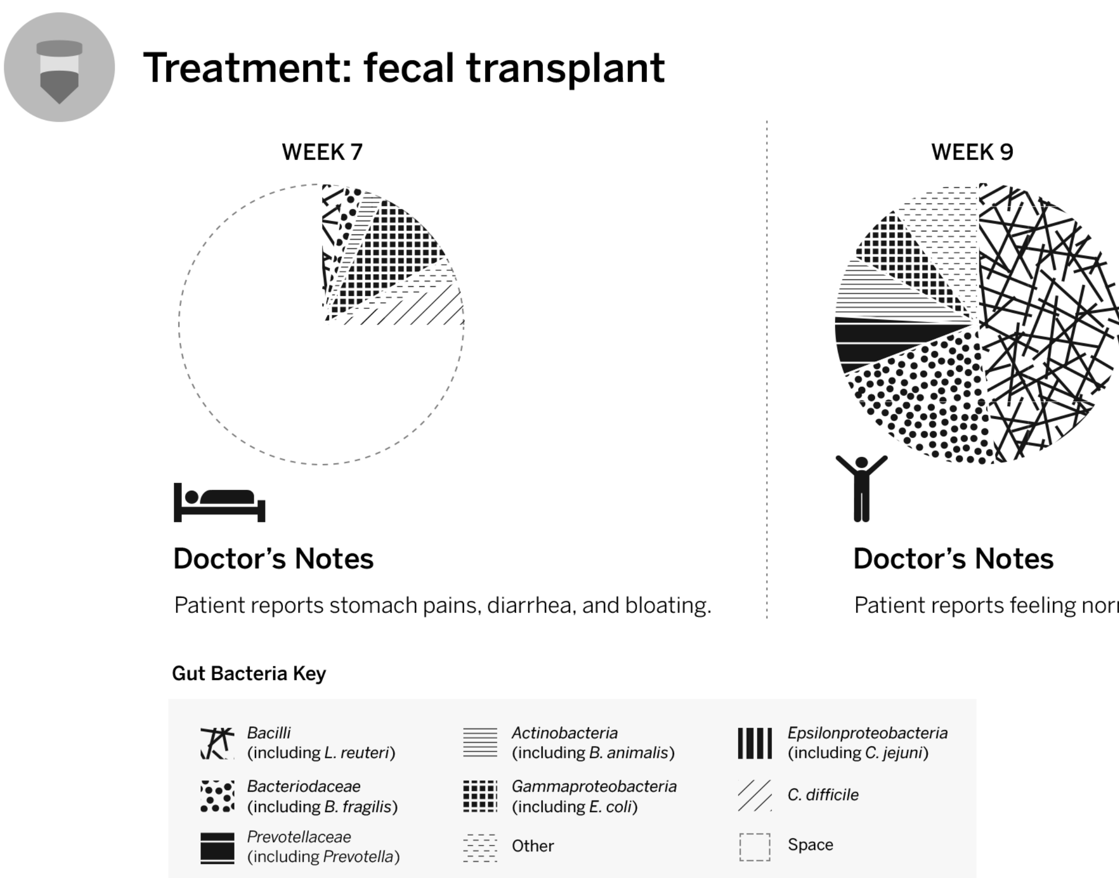
With a partner, take turns explaining how each piece of evidence helps support the subclaim.

- Partner A describes the evidence below.
- Partner B asks "Why does this evidence matter?"
- Partner A explains how this evidence supports the claim.
- Partners switch roles, using a new piece of evidence (see chart on the next page).

How can fecal transplants cure patients infected with harmful bacteria?

Subclaim 1: Bacteria from the fecal transplant can fill up the space in the gut, limiting the food and space for invading harmful bacteria.

Evidence from Patient 23's Case Study, Week 7 and Week 9



Name: ______________________________ Date: ____________________

Discussing Evidence and Reasoning (continued)

Explaining Evidence

With a partner, take turns explaining how each piece of evidence helps support the subclaim.

- Partner B describes the evidence below.
- Partner A asks "Why does this evidence matter?"
- Partner B explains how this evidence supports the claim.
- Partners switch roles, using a new piece of evidence (on the next page).

How can fecal transplants cure patients infected with harmful bacteria?

Subclaim 1: Bacteria from the fecal transplant can fill up the space in the gut, limiting the food and space for invading harmful bacteria.

Evidence from Experiment 1: *Salmonella* Bacteria

Normal Gut Microbiomes of 20 Healthy Mice Before Experiment

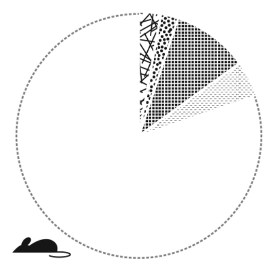
Mice ingest the same amount of *Salmonella* bacteria

Test Results

5 mice are unaffected and remain healthy

12 get slightly sick from *Salmonella* infection

3 get really sick from *Salmonella* infection



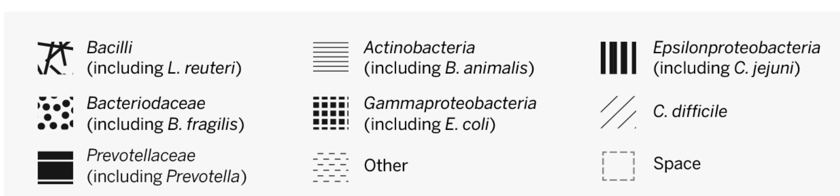
Low-Bacteria Gut Microbiomes of 20 Healthy Mice Before Experiment

Mice ingest the same amount of *Salmonella* bacteria

Test Results

20 get really sick from *Salmonella* infection

Gut Bacteria Key



Name: ______________________ Date: ______________

Discussing Evidence and Reasoning (continued)

Explaining Evidence

With a partner, take turns explaining how each piece of evidence helps support the subclaim.

- Partner A describes the evidence below.
- Partner B asks "Why does this evidence matter?"
- Partner A explains how this evidence supports the claim.

How can fecal transplants cure patients infected with harmful bacteria?

Subclaim 1: Bacteria from the fecal transplant can fill up the space in the gut, limiting the food and space for invading harmful bacteria.

Evidence from "The Human Microbiome"

"Even though they are tiny, bacteria are living things with the same basic needs that all living things share. The human body provides bacteria with the food and living space they need—that's what makes our bodies such a good environment for bacteria."

Name: ______________________________ Date: ____________________

Reasoning Tool

How can fecal transplants cure patients infected with harmful bacteria?

Subclaim 1: Bacteria from the fecal transplant can fill up the space in the gut, limiting the food and space for invading harmful bacteria.

Evidence	**This matters because . . .**	**Therefore, . . .**
From Patient 23's case study data for weeks 7 and 9		
From Experiment 1: *Salmonella* Bacteria		
From "The Human Microbiome" "Even though they are tiny, bacteria are living things with the same basic needs that all living things share. The human body provides bacteria with the food and living space they need—that's what makes our bodies such a good environment for bacteria."		

Name: ____________________ Date: ____________________

Homework: Press Release

PRESS RELEASE

MRI Microbiome Research Institute

A fecal transplant can work to cure a patient infected with a very harmful bacteria, such as *C. difficile,* in many different ways.

Write a paragraph that supports Subclaim 1. Include evidence and explain how your evidence supports this subclaim.

Subclaim 1: Bacteria from the fecal transplant can fill up the space in the gut, limiting the food and space for invading harmful bacteria.

- To help you write, review your work from this lesson, including the Reasoning Tool.
- To help you organize your thinking and construct your ideas, refer to the Argumentation Sentence Starters.
- The Microbiome Research Institute will publish this press release as a way to inform the public and defend their funding.

Argumentation Sentence Starters

- I think this evidence supports this claim because . . .
- I don't think this evidence supports this claim because . . .
- I agree because . . .
- I disagree because . . .
- Why do you think that?

Name: ______________________ Date: ______________

Homework: Press Release (continued)

Name: ______________________________ Date: ________________

Lesson 2.6: Evaluating Evidence About Bacteria

As we already discovered, bacteria from a fecal transplant can take up food and space in the gut, which leaves very little room for harmful bacteria. Now, we want to know if there are other ways the added bacteria from a fecal transplant can help a patient, as well. Today, you'll analyze experiments and read about two new types of bacteria that are added to the gut microbiome during a fecal transplant: *B. fragilis* and *L. reuteri.* You will select one of these types of bacteria to study in this lesson, and you'll evaluate evidence about the bacteria you choose. This will prepare you to write one more argument about this bacteria to add to the press release.

Unit Question

- How can having 100 trillion microorganisms on and in the human body keep us healthy?

Chapter 2 Question

- How can fecal transplants cure patients infected with harmful bacteria?

Key Concepts

- The human microbiome contains approximately 100 trillion microorganisms. Most of these are bacteria.
- The human body provides an environment (food and space) for bacteria to survive.
- A healthy microbiome has various helpful types of bacteria.
- An infection of harmful bacteria in the human microbiome can make a person sick.
- Antibiotics reduce the number of helpful and harmful bacteria in the microbiome.
- Living things with fewer than normal helpful bacteria in their guts can become infected more easily because there is more food and space available for harmful bacteria.

Vocabulary

- antibiotics
- bacteria
- claim
- evidence
- microorganism
- scale

Name: ______________________________ Date: ____________________

Warm-Up

Read your draft of your initial argument (on page 53) and evaluate it based on the criteria below. Select how well you completed each task.

I stated my claim clearly.

- ☐ Definitely
- ☐ Somewhat
- ☐ Not really
- ☐ Not at all

I included evidence to support my claim.

- ☐ Definitely
- ☐ Somewhat
- ☐ Not really
- ☐ Not at all

I made my reasoning clear by explaining how the evidence supports the claim.

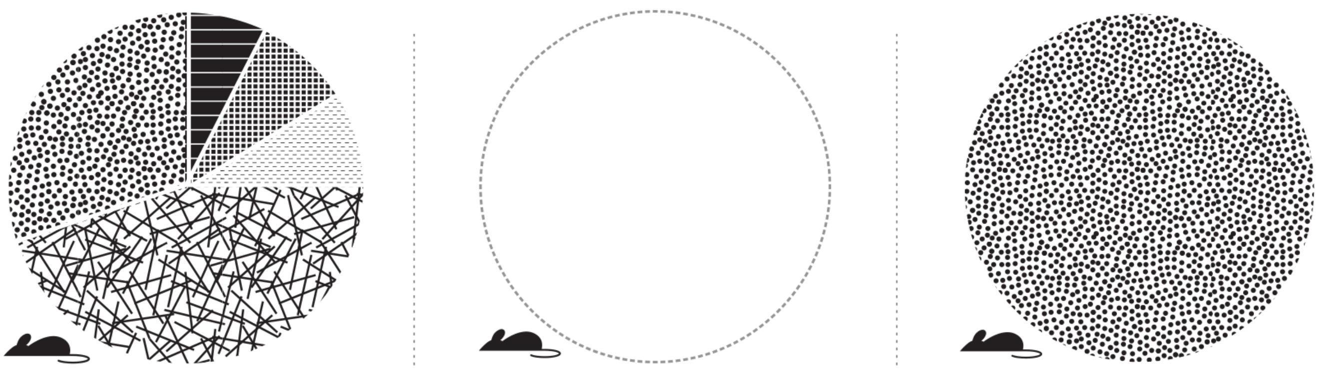
- ☐ Definitely
- ☐ Somewhat
- ☐ Not really
- ☐ Not at all

Name: ______________________ Date: ______________

Analyzing Experiments About Bacteria

1. Choose an experiment to focus on in this lesson, either from this page or the next page.
2. Work with your partner to observe and analyze the results of the experiment you chose.
3. Add annotations to the experiment data.

Experiment 2: *B. fragilis* Bacteria



Normal mouse gut microbiome

Test Results

- Immune Cells: High
- Gut Mucus: High

Mouse with no bacteria in gut

Test Results

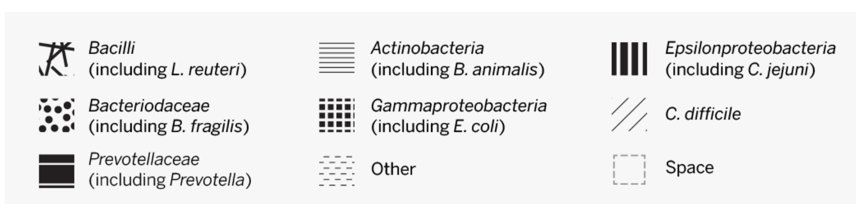
- Immune Cells: Low
- Gut Mucus: Low

Mouse with only *B. fragilis* in gut

Test Results

- Immune Cells: High
- Gut Mucus: Low

Gut Bacteria Key

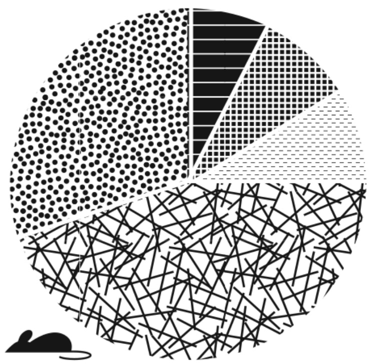


Question: *How does* B. fragilis *bacteria in the gut microbiome affect mouse gut health?*

Name: ______________________ Date: ______________

Analyzing Experiments About Bacteria (continued)

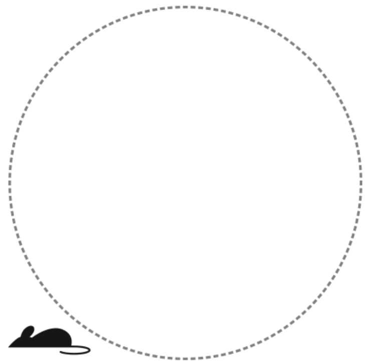
Experiment 3: *L. reuteri* Bacteria



Normal mouse gut microbiome

Test Results

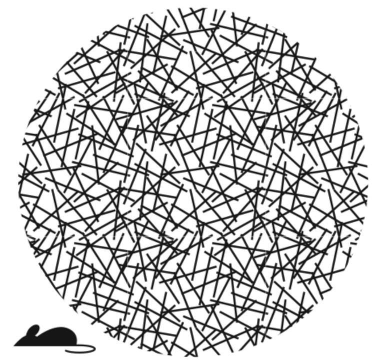
- Immune Cells: High
- Gut Mucus: High



Mouse with no bacteria in gut

Test Results

- Immune Cells: Low
- Gut Mucus: Low

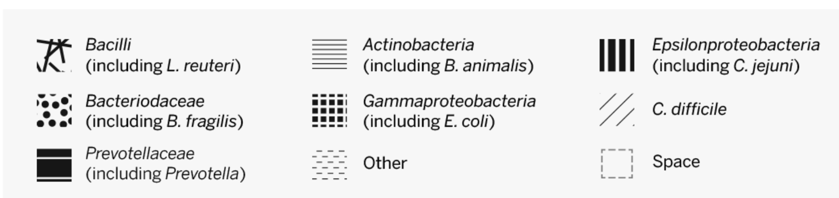


Mouse with only *L. reuteri* in gut

Test Results

- Immune Cells: Low
- Gut Mucus: High

Gut Bacteria Key



Question: *How does* L. reuteri *bacteria in the gut microbiome affect mouse gut health?*

Name: ______________________________ Date: ____________________

Reading About Bacteria

1. Read the article about the bacteria you analyzed in the previous experiment:
   - "Bacteria: *B. fragilis*"
   - "Bacteria: *L. reuteri*"

2. Highlight or make notes about specific parts of the article that could be supporting evidence for your argument.

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Name: ________________________________ Date: ____________________

Evaluating Evidence with the Evidence Gradient

Which experiment did you analyze? (check one)

- ☐ **Experiment 2:** *B. fragilis* Bacteria
- ☐ **Experiment 3:** *L. reuteri* Bacteria

Which claim do you think the evidence from the experiment helps support? (check one)

- ☐ **Subclaim 2:** Bacteria from the fecal transplant can help the patient's body produce immune cells that kill invading bacteria.
- ☐ **Subclaim 3:** Bacteria from the fecal transplant can help the patient's body produce mucus that protects the gut from invading bacteria.
- ☐ Both claims.
- ☐ Neither claim.

Bacteria Evidence Card Sort

1. Choose the claim that is best supported by the evidence in your experiment and article and clip it to the top of your Evidence Gradient. Write your names on the claim you chose.
2. Discuss each Bacteria Evidence Card with your partner. Remove any irrelevant cards.
3. Discuss the relevant Bacteria Evidence Cards. Place each one on the Evidence Gradient, according to how strongly it supports your subclaim.

Name: ______________________________ Date: ____________________

Homework: Revising Your Argument

1. Look back to your initial argument on page 53 and the evaluation of your argument that you completed in today's Warm-Up on page 56.
2. Then, revise your argument to make it more convincing.

PRESS RELEASE

MRI Microbiome Research Institute

A fecal transplant can work to cure a patient infected with a very harmful bacteria, such as *C. difficile,* in many different ways.

Subclaim 1: Bacteria from the fecal transplant can fill up the space in the gut, limiting the food and space for invading harmful bacteria.

Revise your paragraph that supports the subclaim above. Include evidence and explain how your evidence supports this subclaim.

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Name: ______________________ Date: ______________

Homework: Revising Your Argument (continued)

Name: ______________________ Date: ______________

Lesson 2.7: Writing a Final Argument

Today is the last day of your Microbiome Research Institute mission! The Institute is anxious for you to help them create their press release in support of funding for fecal transplant research. You have already written a short argument about one way that fecal transplants help battle dangerous infections. Today, you will complete your contributions to the press release by writing another argument about a different way the bacteria transferred during a fecal transplant can help cure a patient. Make sure your argument is clear and convincing!

Unit Question

- How can having 100 trillion microorganisms on and in the human body keep us healthy?

Chapter 2 Question

- How can fecal transplants cure patients infected with harmful bacteria?

Key Concepts

- Many organisms are microscopic—so small that they cannot be seen with the naked eye.
- All living things are made of cells.
- Almost all cells are microscopic.
- The human microbiome contains approximately 100 trillion microorganisms. Most of these are bacteria.
- The human body provides an environment (food and space) for bacteria to survive.
- A healthy microbiome has various helpful types of bacteria.
- An infection of harmful bacteria in the human microbiome can make a person sick.
- Antibiotics reduce the number of helpful and harmful bacteria in the microbiome.
- Living things with fewer than normal helpful bacteria in their guts can become infected more easily because there is more food and space available for harmful bacteria.

Vocabulary

- antibiotics
- bacteria
- claim
- evidence
- microorganism
- reasoning
- scale
- scientific argument

Name: ______________________ Date: ______________

Warm-Up

A Convincing Argument?

Read the following statement from Senator Naismith, and then answer the question.

> *Fecal transplants will make people sick. My evidence is that I think poop is gross, and everyone knows that poop does not contain anything healthy.*
>
> **— Senator Naismith**

Is Senator Naismith making a convincing argument? Why or why not?

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Name: ______________________________ Date: ________________

Reasoning Tool

Choose the subclaim that you will support with evidence in order to answer the question:

How can fecal transplants cure patients infected with harmful bacteria?

- ☐ **Subclaim 2:** Bacteria from the fecal transplant can help the patient's body produce immune cells that kill invading bacteria.
- ☐ **Subclaim 3:** Bacteria from the fecal transplant can help the patient's body produce mucus that protects the gut from invading bacteria.

Fill out the Reasoning Tool with evidence that supports the subclaim you selected.

Evidence	**This matters because . . .**	**Therefore, . . .**

Name: ______________________________ Date: ________________

Reasoning Tool (continued)

Evidence	This matters because . . .	Therefore, . . .

Name: ______________________________ Date: ________________

Writing Final Argument Paragraphs

PRESS RELEASE

MRI Microbiome Research Institute

Select the subclaim that you will use in your argument:

- ☐ **Subclaim 2:** Bacteria from the fecal transplant can help the patient's body produce immune cells that kill invading bacteria.
- ☐ **Subclaim 3:** Bacteria from the fecal transplant can help the patient's body produce mucus that protects the gut from invading bacteria.

Write a new argument that supports the subclaim you chose above. This argument will be the second part of the press release, so make sure it is clear and convincing.

- Include evidence and explain how this evidence supports this subclaim.
- Look back at your work from this lesson.
- You may also want to use the Argumentation Sentence Starters for help with organizing your thinking and constructing your argument.

Argumentation Sentence Starters

- I think this evidence supports this claim because . . .
- I don't think this evidence supports this claim because . . .
- I agree because . . .
- I disagree because . . .
- Why do you think that?

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Name: ______________________ Date: ______________

Writing Final Argument Paragraphs (continued)

Name: ______________________________ Date: ________________

Homework: Revising Your Final Argument

Read your new argument and evaluate it based on the criteria below. Select how well you completed each task by checking off one option for each statement.

I stated my claim clearly.

- ☐ Definitely
- ☐ Somewhat
- ☐ Not really
- ☐ Not at all

I included evidence to support my claim.

- ☐ Definitely
- ☐ Somewhat
- ☐ Not really
- ☐ Not at all

Revise your new argument below. Remember, this argument will be the second part of the press release, so make sure it is clear and convincing.

Name: ______________________ Date: ______________

Homework: Revising Your Final Argument (continued)

Name: ______________________________ Date: ________________

Homework: Reading “Viruses: On the Edge of Life”

Find out what a virus is and how it is different from bacteria. Read and annotate the article “Viruses: On the Edge of Life” and answer the questions below.

1. How is a virus different from bacteria?

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2. Do you think a virus should be considered a living thing? Why or why not?

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Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Microbiome Glossary

antibiotics: medicines that kill microorganisms, especially bacteria

antibióticos: medicinas que matan los microorganismos, especialmente las bacterias

bacteria: tiny organisms that are made of a single cell

bacterias: organismos diminutos que están hechos de una sola célula

cells: the tiny structures that make up all living things and are the smallest units able to perform life functions

células: las estructuras diminutas que constituyen todos los seres vivientes y que son las más pequeñas unidades capaces de desempeñar las funciones de la vida

claim: a proposed answer to a question about the natural world

afirmación: una respuesta propuesta a una pregunta sobre el mundo natural

evidence: information about the natural world that is used to support or go against (refute) a claim

evidencia: información sobre el mundo natural que se utiliza para respaldar o rechazar (refutar) una afirmación

infection: sickness caused by harmful microorganisms

infección: una enfermedad causada por microorganismos dañinos

microbiome: all of the microorganisms that live in a particular environment, such as a human body

microbioma: todos los microorganismos que viven en un ambiente específico, por ejemplo en un cuerpo humano

microorganism: an organism that is too small to be seen with the naked eye

microorganismo: un organismo que es demasiado pequeño como para ver a simple vista

microscopic: too small to be seen with the naked eye

microscópico: demasiado pequeño como para ver a simple vista

organisms: living things, such as plants, animals, and bacteria

organismos: seres vivientes, como plantas, animales y bacterias

population: a group of the same type of organism living in the same area

población: un grupo del mismo tipo de organismo que vive en la misma área

Microbiome Glossary (continued)

reasoning: the process of making clear how your evidence supports your claim

razonamiento: el proceso de aclarar cómo tu evidencia respalda tu afirmación

scale: the relative size of things

escala: el tamaño relativo de las cosas

scientific argument: a claim supported by evidence

argumento científico: una afirmación respaldada por evidencia

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Microbiome

Article Compilation

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Cells: The Basic Unit of Life

Your entire body is made of cells—trillions of them! Cells are the tiny structures that make up all living organisms, including sharks, plants, cats, insects, bacteria, and you. People often say that cells are the basic building blocks of life. That's true, but the phrase "building blocks" makes it sound as if all cells are the same. In fact, organisms are different from one another because of the *differences* in their cells. There are many types of cells.

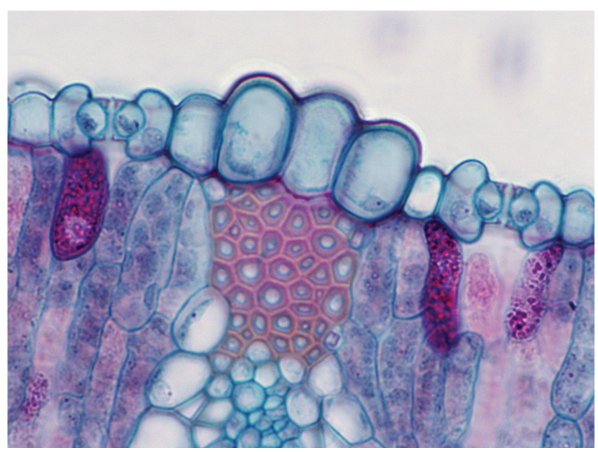
This photo was taken through a microscope. It shows one cell from the cheek of a human, with almost 100 bacteria on it. Each one of those bacteria is a single cell. The bacteria and cheek cell all appear 945 times larger than actual size. Each one of the bacteria is about 1 micrometer long. The cheek cell is 50 to 70 times longer in every direction!

How Do We Know About the Cell?

Cells got their name from a scientist named Robert Hooke way back in 1665. Hooke used a basic microscope to look at thin slices of cork, and saw that they were made of many tiny, hollow structures that looked like rooms. In fact, Hooke thought they looked like the rooms where monks lived, so he called them cells.

The cells Hooke saw weren't actually living cells. Cork is made from the bark of a tree called a cork oak—the cells of the bark are alive when they're on the tree, but they die when they're cut off for people to use.

By the time a scientist named Anton van Leeuwenhoek arrived on the scene in 1680, lenses had improved, making it easier for scientists to see much smaller things. Van Leeuwenhoek put things like blood, rainwater, and scrapings from teeth under a microscope, and what did he see? Tiny organisms moving around! Van Leeuwenhoek argued that motion is a sign of life, and was the first scientist to say that cells are living things.



The plant cells in this photo appear 500 times larger than their actual size. The photo was taken through a microscope and shows the cells that make up the edge of a leaf. Since this photograph shows a cross-section, we can't tell exactly how long these cells are, but they are roughly 10–20 micrometers tall. Plant cells can be very different from one another, but tend to be 20–50 micrometers in length.

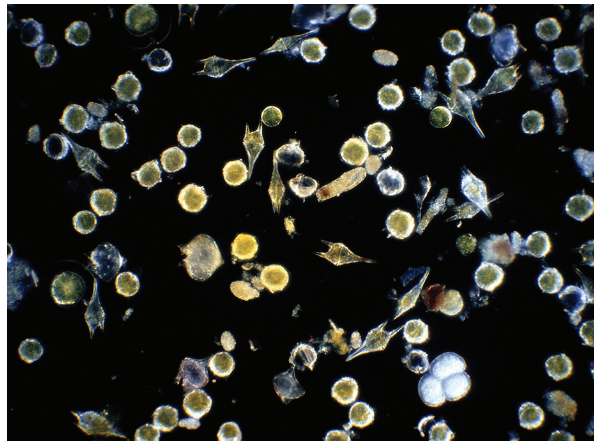
The Basic Unit of Life

All living things are made of cells, including plants and animals and other organisms like bacteria, whether they're made of just one cell or trillions of cells put together. Things that used to be alive but aren't anymore, like wood, are still made of cells—but the cells are dead. Things that were never alive, like glass and water, aren't made of cells at all.

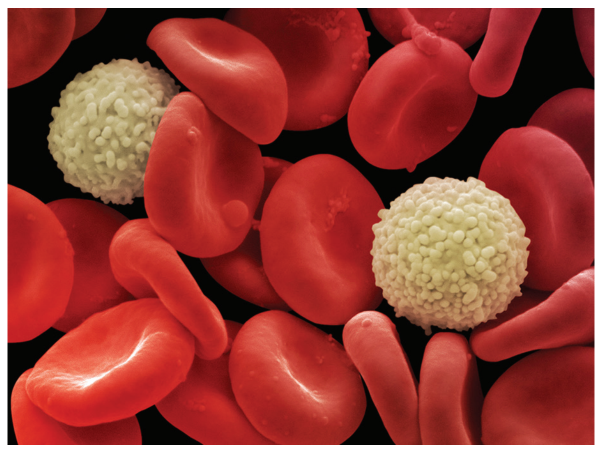
All cells have some things in common. For example, all cells are filled with a jellylike fluid called cytoplasm and enclosed by a cell membrane. This cell membrane controls which substances are allowed in and out of the cell. All cells also have tiny structures called ribosomes that make proteins using instructions from genes. All cells take in food, release energy from the food, and use the energy to do things.

The smallest living organisms are single cells. Most cells are very, very tiny: it takes trillions of them to make a human body. Cells are not the tiniest things in the world, however. Cells are made of molecules, which are much smaller than cells, and molecules are made of atoms, which are even smaller!

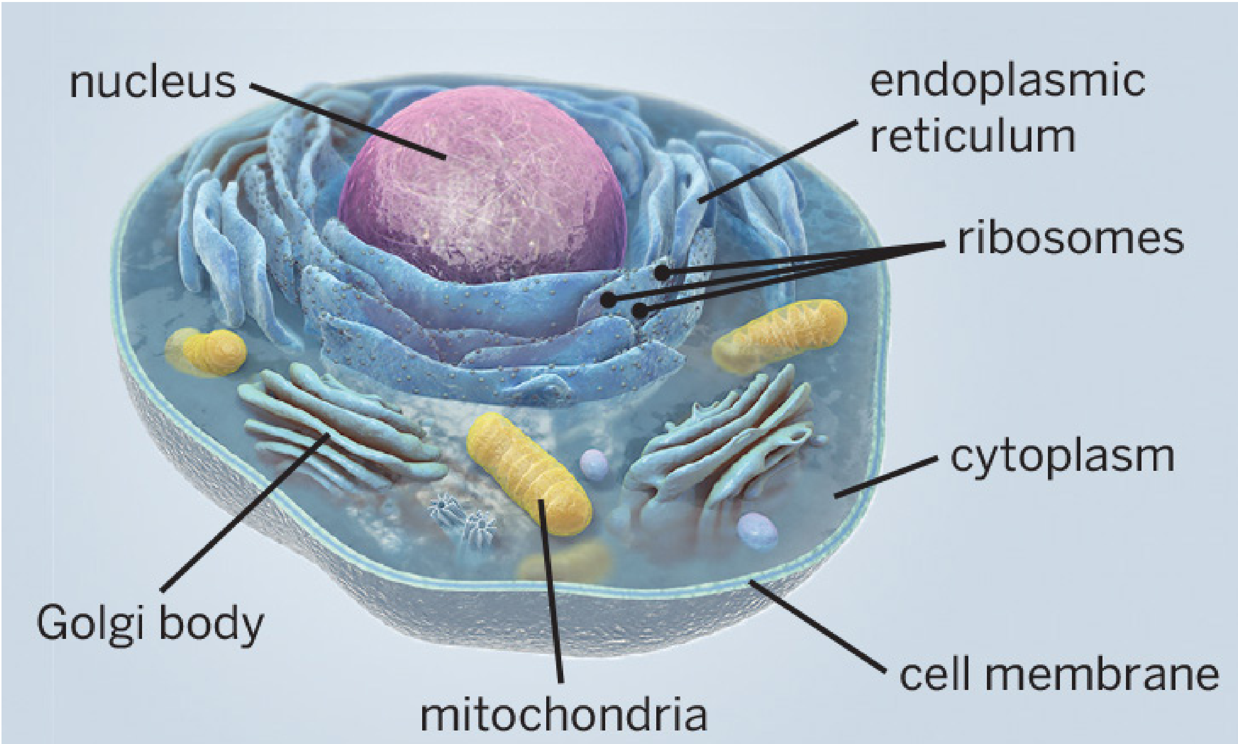
At the same time, many cells put together make much larger structures. A bunch of the same type of cells working together is called a tissue, like muscle tissue or nerve tissue. Different types of tissues working together are called an organ, like the brain or the liver—or the stem and leaves of a plant. Different types of organs working together are called a system, like the circulatory system or the musculoskeletal system. And different systems working together make a body like yours!



These tiny glowing organisms live in the ocean. Each organism is made of just one cell, and they can range in size from 10 micrometers to 2,000 micrometers! Some can even be seen with the naked eye.



There are different types of cells in your blood, including the red blood cells and white blood cells shown in this photo. White blood cells help protect your body from infection. The photo was taken through a powerful microscope, and shows the cells more than 5,000 times larger than their actual size— only about 710 micrometers across.



Organelles are cell parts that perform certain functions. This diagram shows some of the organelles in a typical human body cell. Many other kinds of cells contain the same organelles.

What's in a Cell?

Cells come in all different kinds, from the cells that make up a carrot to the cells in the human brain. However, many cells have some parts in common, called organelles. Here's a list of important organelles found in your body cells and the cells of many other organisms.

- **Nucleus:** The nucleus is a small enclosure inside a cell. It may be small, but it's very important: the nucleus is the command center of the cell, which contains its DNA and tells the cell how to behave and react.
- **Cell membrane:** The cell membrane forms a barrier around the cell and controls the materials that can enter and leave the cell. Substances that the cell needs are allowed to enter (or get pulled in) and waste products are allowed to leave (or get pushed out). This helps the cell to maintain homeostasis. Homeostasis is the stability maintained by an organism's cells and body systems. A cell membrane also protects a cell from its surroundings by keeping harmful substances out. In animal cells, the cell membrane is the outer layer, but plant cells have an extra layer of protection called the cell wall, which is outside of the cell membrane.
- **Mitochondria:** Mitochondria are beanshaped organelles that use glucose and oxygen molecules to release energy that the cell can use.
- **Ribosomes:** Ribosomes are tiny organelles that make proteins. They can be found floating freely in the cell or attached to the rough endoplasmic reticulum.
- **Endoplasmic reticulum:** Endoplasmic reticulum, or E.R., is responsible for making and transporting molecules around the cell. E.R. comes in two types: rough, which is covered in ribosomes, and smooth, which isn't.

- **Golgi body:** The Golgi body is like the post office of the cell—it packs proteins into little packages called vesicles and sends them wherever they're needed in the cell.
- **Cytoplasm:** Cytoplasm isn't an organelle; instead, it's a gel-like substance that fills the cell. The organelles of the cell are suspended in the cytoplasm and can move around in it.

Plant cells usually have all of the same organelles as animal cells, plus a few extra organelles that help them meet the needs of plants. These organelles include:

- **Cell wall:** The cell wall is the waxy outer layer that surrounds plant cells outside of the cell membrane. The cell wall offers extra protection, and its rigid structure helps the plant stand up. The cell wall also keeps the cell from stretching and bursting when too much water flows into the cell.

- **Chloroplasts:** Chloroplasts are organelles that store chlorophyll, a green substance that allows plants to turn sunlight into the molecules they need to release energy.

- **Vacuole:** Plant cells have storage in the form of vacuoles, which are large organelles that allow them to store food, waste, and water. The vacuole can also help maintain the right amount of pressure in the cell and isolate anything that might be a threat to the cell. Some animal cells also have vacuoles, but plant cell vacuoles are bigger and more common.

Using Differences in Cells to Classify Living Things

There are three domains (major types) of living things: eukarya, bacteria, and archaea. These domains are actually based on differences in the structures of cells! All organisms in the domain eukarya are made up of cells with a nucleus that contains genetic information.

Some eukarya are tiny organisms that are each made up of only one cell, but most are made up of trillions of cells. Examples of eukarya include birds, pine trees, dogs, mushrooms, and humans. Almost all bacteria and archaea are tiny organisms that are each made up of only one cell with no nucleus. Instead of being contained in a nucleus, their genetic material just floats around inside the cell. Bacteria and archaea are in different domains because they have different kinds of molecules inside their cells. It turns out that these molecules are important for determining where the organisms can live and what they can use to get energy. For example, one way bacteria and archaea cells are different has to do with their cell membranes, the barriers that separate their insides from the outside environment. The cell membranes of archaea can withstand very high temperatures and harsh chemicals. That is one reason why some archaea can sometimes be found living in places where nothing else can survive.

Cells may be tiny, but there's no life without them—everything that's alive is alive because its cells are taking in molecules, releasing energy, and doing jobs like carrying oxygen through the blood and transmitting electricity through the body. Without them, no living things would exist. So if you're reading this, thank your cells!

The Human Microbiome

A World Inside You

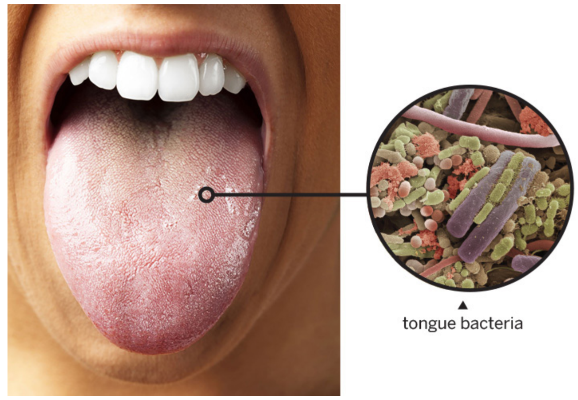
There's a world filled with strange creatures. The creatures of this world are invisible, and they're not human. Aliens sometimes threaten to invade the world these creatures call home. . . .

This world is not a far-off planet: it's your body! The creatures are called microorganisms, and your body is home to more than 100 trillion of them. Microorganisms live on your skin, in your gut, in your nose and mouth, and pretty much everywhere else on and in your body.

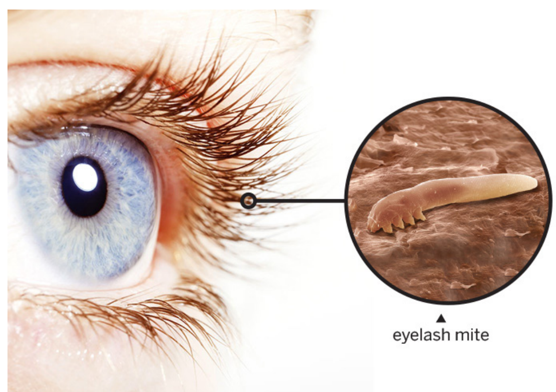
Your Body: Home Sweet Home for Bacteria

The microorganisms living in and on your body range from fungi to eyelash mites, but most of them are bacteria. Bacteria are among the smallest microorganisms on Earth. Most are made of a single cell—that's the tiny structure that makes up all living things. However, bacteria are not all the same. They come in different shapes, use different things as food, and live in different places. Thousands of different kinds of bacteria live in and on your body.

Even though they are tiny, bacteria are living things with the same basic needs that all living things share. The human body provides bacteria with the food and living space they need—that's what makes our bodies such a good environment for bacteria. One word for an environment and the organisms living there is *biome*, so we call the bacteria living in and on the human body "the human microbiome." All together, the bacteria living in an average human's microbiome weigh



Your tongue is covered with bacteria like the ones in this photo, which was taken through a microscope. Bacteria are some of the smallest microorganisms that live in and on your body: these bacteria are actually 10,000 times smaller than they look in this photo! The bacteria colored green in this photo are 1 micrometer long, about 100 times too small to see with the naked eye. (The colors are not real: they were added to make the photo easier to see.)



This microscopic animal is an eyelash mite. It is harmless, and lives next to the roots of eyelashes. The photo was taken through a microscope, and shows the mite about 300 times larger than its actual size. This mite is about 210 micrometers in length. You might just barely be able to detect an eyelash mite with the naked eye in perfect conditions—if it weren't nearly transparent!

about 2 to 5 pounds. The number of bacteria in the microbiome of one human is millions of times greater than the number of people living on Earth!

Helpful Bacteria and Alien Invaders

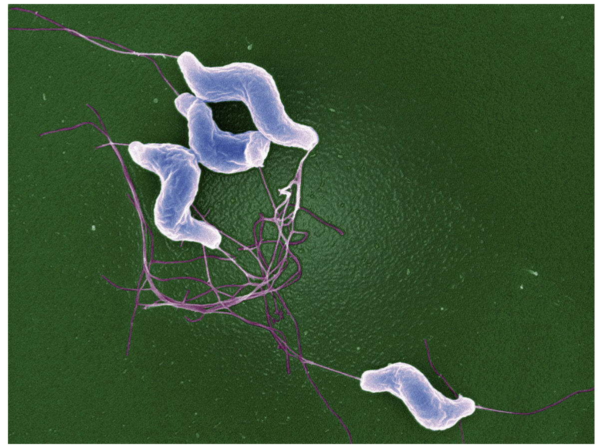
Most bacteria in the human microbiome won't hurt you. In fact, the opposite is true. Many bacteria do important jobs for the human body. For example, bacteria living in your gut help break down food that your body couldn't digest otherwise. Other bacteria help protect your body from infection, which helps to keep you healthy. All these helpful bacteria use the food and shelter your body provides. You depend on these bacteria, and they depend on you.

Unfortunately, not all bacteria are helpful. Harmful bacteria can invade the human microbiome through cuts, spoiled food, and even the air we breathe. An invasion of harmful bacteria or other microorganisms is called an infection, and infections can make people very sick. For example, a type of bacteria called *C. jejuni* produces a poison that harms cells from the human gut. When those cells can't function, the gut can't repair itself. This kind of *C. jejuni* infection can cause diarrhea, vomiting, and fever—all the symptoms of food poisoning.

Antibiotics and the Microbiome

Often, doctors treat infections with antibiotics. Antibiotics are medicines that kill bacteria. Antibiotics can stop dangerous infections, and they save millions of lives every year.

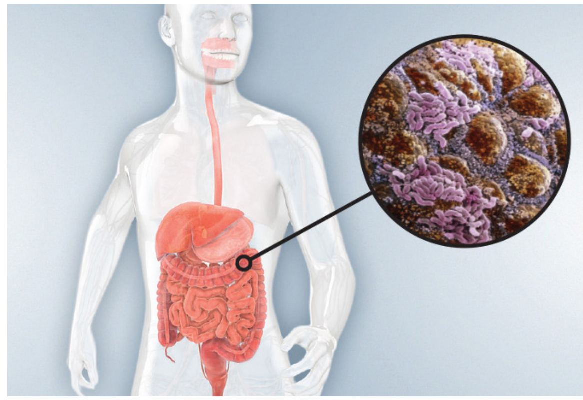
However, antibiotics don't just kill harmful bacteria—they kill helpful bacteria, too. A person who has just taken antibiotics has fewer bacteria than normal. Helpful bacteria will grow back in time, but often the bacteria that return are different from the ones that were there before. Taking antibiotics changes a person's microbiome.



What people call "food poisoning" isn't caused by poisoned food: it's usually an infection with harmful bacteria such as *C. jejuni*. (People added the colors in this photo to make the bacteria easier to see.)

Your Own Little World

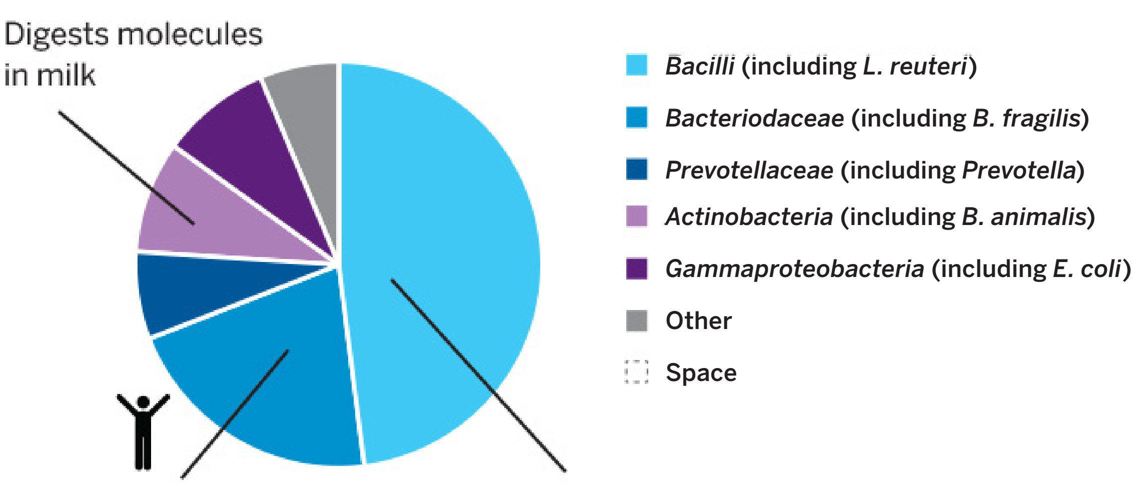
Your body is the whole world to the bacteria of your microbiome. It's an environment that provides microorganisms with everything they need, including food and space to live. What you do affects your bacteria, and they affect you, too. Your body is a world in miniature—a microbiome.



This microscope photo shows some bacteria in their natural environment: the human gut. The gut includes the intestines and stomach. In the photo, the bacteria appear 3,750 times larger than actual size. These bacteria are about 2 micrometers in length—nearly 50 times too small to see. (People added the colors in this photo to make the bacteria easier to see.)

Chart 1: Bacteria in a Healthy Gut Microbiome

Total number of bacteria: about 90 trillion



This pie chart compares the relative amounts of different kinds of bacteria in a typical healthy human's gut.

Meet a Scientist Who Studies the Human Microbiome

Dr. Susan Lynch is a scientist who studies ecosystems—not in the jungle or at the bottom of the ocean, but somewhere much, much closer: in the human body. Research shows that the body isn't just made of human cells—in fact, for every human cell in your body, there may be as many as ten cells belonging to bacteria and other microorganisms! Lynch studies those microorganisms, how they live together in the body, and how their interactions might cause people to get sick.

Dr. Susan Lynch is a microbiologist who studies the human microbiome.

Some illnesses and medical conditions, like asthma, allergies, and some digestive problems, happen when the tissues of the body swell, or become inflamed. Inflammation is one of the body's ways of fighting off something that might be harmful, but it can also be dangerous. For example, during an asthma attack, the tissues of the airways swell up so much that air can't easily get through. The symptoms of allergies are also caused by inflammation: swelling inside the nose, around the eyes, in the skin, and in the airways. According to Lynch's research, some inflammation responses may be caused by the way many types of bacteria and fungi interact in the body, instead of by a single type of microorganism. Lynch says that microorganisms "don't live on their own. They live in communities, much like humans. They interact with one another and they interact with their environment."

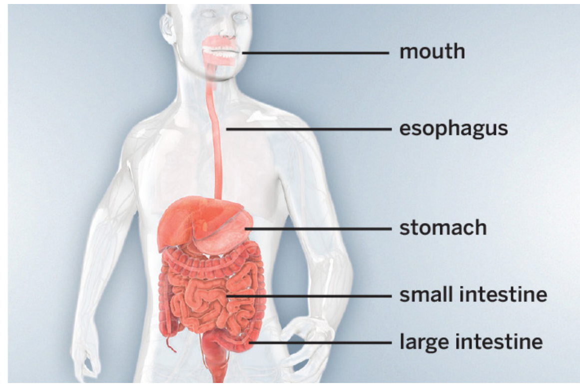
Certain combinations of bacteria, fungi, and other microorganisms in the human microbiome can cause health problems, but other combinations may be able to keep people healthy. By identifying which combinations make people sick, scientists might be able to tell what changes to the microbiome could treat those illnesses or prevent them from happening at all. Someday, Lynch believes that doctors will be able to tell patients exactly what combinations of microorganisms they need in their systems to stay healthy.

Growing up in a small town in Ireland, Lynch went to a tiny school. She always enjoyed science, and her high school biology teacher encouraged her to study microbiology in college. Lynch trained as a microbiologist, studying individual organisms and how they might cause illness. In 2005, she attended a talk in South America on the ways in which more than one microorganism can affect the body at the same time—and she decided to begin studying the whole human microbiome instead. "As soon as I knew about it, it just fascinated me—the idea of these organisms that are incredibly powerful, and you can't see them, and they're everywhere," says Lynch. "And they dictate, in my book, pretty much everything that goes on on this planet."

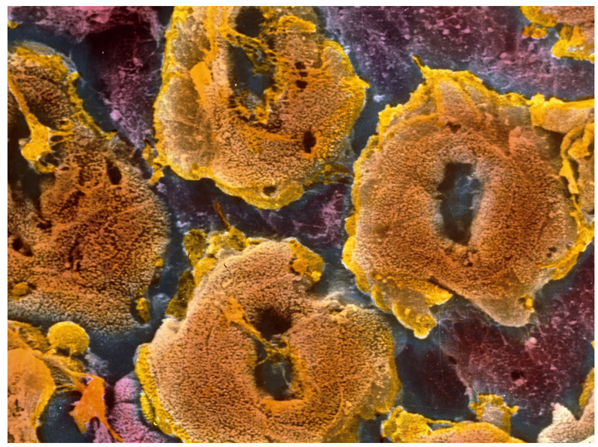
Today, at the University of California, San Francisco, Lynch works with many different types of scientists to study the human microbiome and how it affects the body as a system—which requires building bridges between different areas of science. To study the interactions between microorganisms and the body as a whole, scientists have to think and learn about topics outside of their usual areas of study. "In that way, we're kind of like our own little microbiome," she says. "Everybody brings different knowledge and skills to the table."

The study of the human microbiome is still in its early stages: scientists are trying to find out and describe the basics of how the microbiome works. Someday, scientists hope to understand exactly what happens during each interaction—and that could open up whole new fields of study.

Studying the human microbiome has its challenges, but Lynch says she loves learning new things—and she encourages young people to find something they love, too. "Go after something that you really enjoy, something that isn't a chore," she says. "I've ended up where I am because I've always gone after things that interest me. I eat, breathe, and sleep this stuff, and I love it."



Many of the microbes Dr. Susan Lynch studies are found in the human digestive system.



This photo, taken with a microscope, shows the wall of a gut infected with ulcerative colitis, a digestive problem that may be caused by the interaction between microorganisms. Lynch's work may someday help heal people with this condition. (Colors were added to the photo to make it easier to see.)

Bacteria: *Salmonella*

Food poisoning isn't caused by poison at all. Instead, what we call "food poisoning" is usually caused by bacteria, including *Salmonella*, a type of bacteria commonly found in chickens and other animals. *Salmonella* finds its way into our food and water and causes thousands of cases of food poisoning every year.

Environment

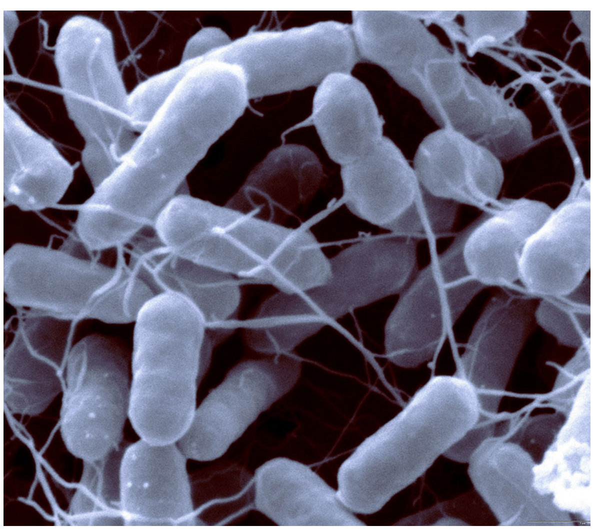
Salmonella lives in the guts of all kinds of animals, especially birds and reptiles, and usually gets passed around through animal waste. Whether a person gets sick from ingesting certain kinds of *Salmonella* can depend on the amount of food and space available in his or her gut microbiome. If the gut is home to lots of beneficial bacteria, the *Salmonella* bacteria can't get enough food and space to reproduce. On the other hand, if there are *not* many beneficial bacteria in the gut, the *Salmonella* population can grow and take over, causing illness—which in this case is more commonly known as food poisoning. *Salmonella* can be killed using heat, so cooking food properly is one way to keep from becoming sick.

Normal Role in Humans

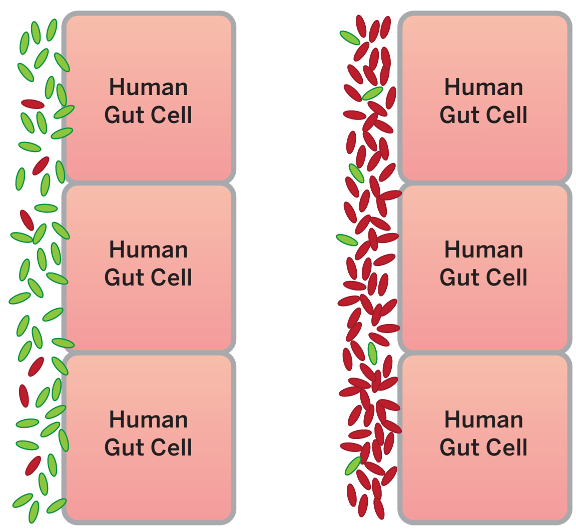
Salmonella can sometimes be found in small amounts in the guts of healthy humans, but is more likely to be found in the microbiomes of people who have recently become sick from *Salmonella* infection.

Role in Disease

In most cases, *Salmonella* causes vomiting, diarrhea, and intestinal pain for up to a week. Most people get better without treatment from a doctor, but in severe cases, *Salmonella* can leave the intestines and move into the blood, where it causes severe disease and even death.



***Salmonella* bacteria can cause the illness that people call "food poisoning."**



When lots of helpful bacteria (shown here in green) are present in the gut, there is little space and food available to harmful bacteria like *Salmonella* (shown here in red). This helps prevent the harmful bacteria from infecting the gut. When there are fewer helpful bacteria in the gut, there is more space and food available for harmful bacteria that can cause disease.

Bacteria: *C. difficile*

When scientists first discovered *C. difficile* (cee-diff-uh-SEEL), they named these bacteria difficile (which means "difficult") because the bacteria were so hard to grow in the lab. Today, *C. difficile* might be considered difficult in another way: it causes hard-to-treat gut infections that kill thousands of people every year. Because it causes potentially deadly infections, *C. difficile* is sometimes referred to as "killer bacteria."

Environment

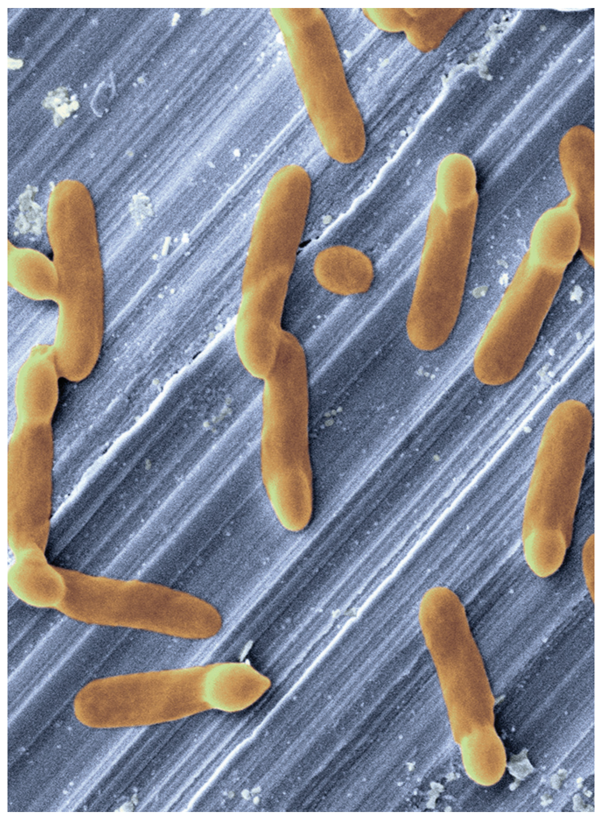
Although difficult to grow in a lab, *C. difficile* bacteria are very common in nature. These microorganisms are especially numerous in soil, where they use nearly anything as food. They can also survive in the environment of the human gut.

C. difficile has a surprising weakness: oxygen can kill it. However, it also has an amazing defense. When *C. difficile* is exposed to oxygen in the air or other dangers, it shrinks and forms a tough outer covering. In this state, *C. difficile* can survive oxygen, hand cleaners, acids, and even many antibiotics. Once the danger passes, the bacteria return to normal and begin multiplying.

Normal Role in Humans

Most healthy people do not have any *C. difficile* bacteria in their microbiomes. Even if someone accidentally swallows some *C. difficile* bacteria, the other bacteria in the gut keep the number of *C. difficile* low, and therefore safe. *C. difficile* cannot survive when there is a lot of competition from other bacteria for food and space.

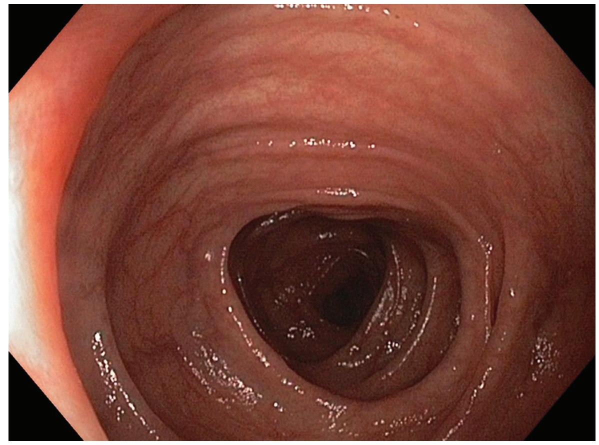
C. difficile **bacteria can cause dangerous infections in humans. They are between 1 and 4 micrometers long. (This photo was taken in black and white; colors were added to make it easier to see.)**



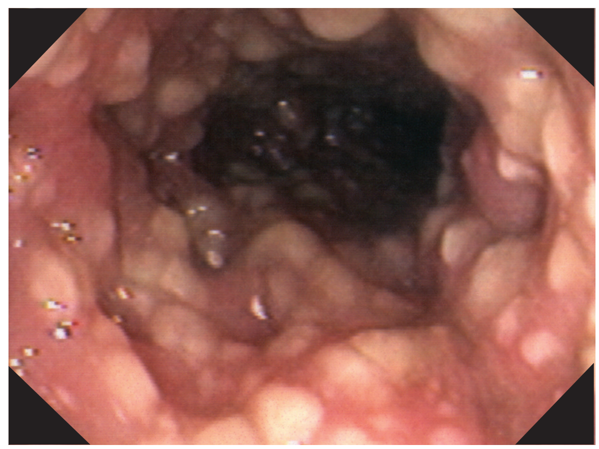
Exposed to the air on a steel surface, these ***C. difficile*** **bacteria are shrinking and forming protective coverings. (This photo is zoomed in much closer than the previous photo.)**

Role in Disease

When sick people take antibiotics, helpful microorganisms in the gut are killed along with the harmful ones. With the helpful gut microorganisms out of the way, *C. difficile* can multiply rapidly and take over the gut microbiome. The growing population of *C. difficile* produces powerful poisons, which irritate the cells of the gut lining and eventually cause the cells to die. *C. difficile* bacteria will then eat the dead cells—and may even escape through the damaged gut into the blood, spreading the infection. *C. difficile* infections can be very dangerous, and in some cases end in death. Bloating, diarrhea, and stomach pain are the most common symptoms. By causing constant irritation, *C. difficile* can make it harder for the immune system to function. Antibiotics can kill *C. difficile*, but until the person's normal microbiome is restored, the infection can come back.



This photo was taken inside a healthy human gut. The gut lining is smooth and healthy. (No bacteria are visible in the photo because they are too small to see in this view.)



This photo shows the gut of a human with a *C. difficile* infection. The gut lining is irritated and damaged. (No bacteria are visible in the photo because they are too small to see in this view.)

Bacteria: *B. fragilis*

Are *B. fragilis* (bee-fruh-JILL-us) bacteria beneficial to humans, or harmful? Without *B. fragilis*, people can have all sorts of health problems. However, these bacteria can also cause dangerous infections.

Environment

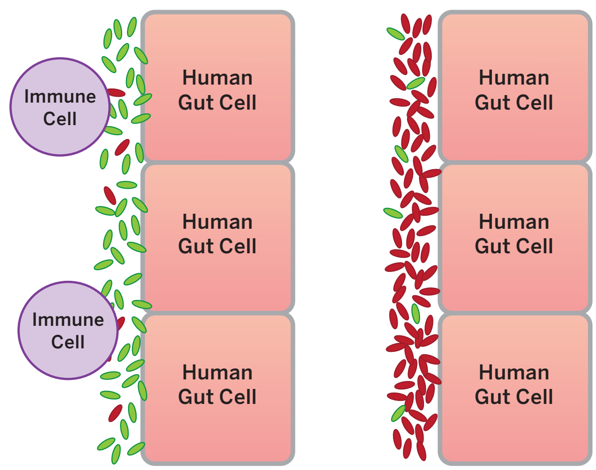
B. fragilis bacteria thrive in the environment of the human gut. In part, this is because *B. fragilis* has the ability to use nearly anything as food, including many substances that humans cannot break down. That means *B. fragilis* can take advantage of undigested food that flows through the gut. *B. fragilis* bacteria are also good at finding living space in the human gut: they stick themselves securely to the gut wall.

Normal Role in Humans

B. fragilis bacteria make up a small but important population in the healthy gut microbiome: usually about 0.5% of the bacteria in the human gut are *B. fragilis*. These bacteria normally help humans in several ways. First, they strengthen the body's defenses by helping the immune system produce enough immune cells to kill harmful invading bacteria.

Another important way *B. fragilis* bacteria help humans is through their habit of sticking to the gut wall. Because they take up living space, *B. fragilis* bacteria prevent harmful microorganisms from moving in. In addition, *B. fragilis* produces substances that help keep the cells of the gut healthy. Human gut cells need these substances to repair and protect themselves.

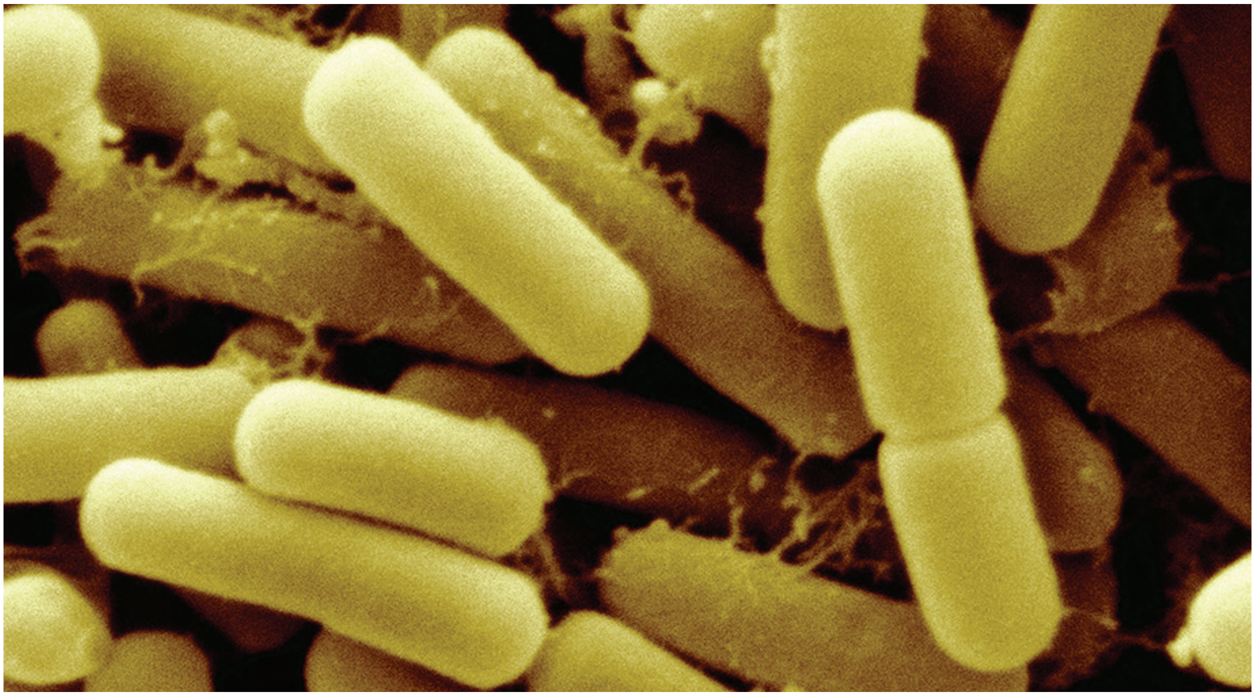
When they escape the gut, *B. fragilis* bacteria can cause dangerous infections. They use human cells as food! (People added the colors in this photo to make the bacteria easier to see.)



Bacteria like *B. fragilis* (shown here in green) help the body produce immune cells that kill harmful bacteria (shown here in red). When there are fewer of these helpful bacteria, there are fewer immune cells. This allows more harmful bacteria to live and cause infection.

Role in Disease

Even though they are usually helpful, *B. fragilis* bacteria can sometimes cause disease. Often, this happens after the gut wall has been damaged in some way. As *B. fragilis* escapes from the gut, it becomes dangerous. *B. fragilis* does not usually hurt the cells in the gut because of the mucus that protects gut cells. Outside the gut, however, these bacteria can attack human cells and use them as food. Once they have infected the body outside the gut, *B. fragilis* bacteria are hard for the body's defenses to fight. To make matters worse, many antibiotics don't work well as treatments for *B. fragilis* infections.



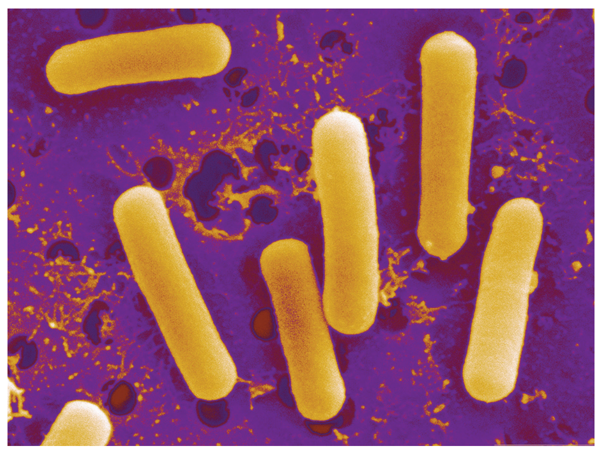
Large numbers of *L. reuteri* bacteria grow in sheets on the walls of the human gut.

Bacteria: *L. reuteri*

Many of the bacteria in our microbiomes help us, but *L. reuteri* (ell ROY-ter-eye) bacteria are some of the most helpful of all. In fact, some people take pills containing billions of *L. reuteri* bacteria to improve digestion. *L. reuteri* is one of the bacteria mothers pass to their babies through their milk. Having plenty of *L. reuteri* helps the babies have healthy gut microbiomes.

Environment

L. reuteri is found in the microbiomes of many animals, including most humans. These bacteria are extremely good at capturing food in the gut: they digest substances in food that humans are often unable to break down. They make a home for themselves by sticking to the gut wall. *L. reuteri* thrives in the gut environment, but it is rarely found living outside animals.



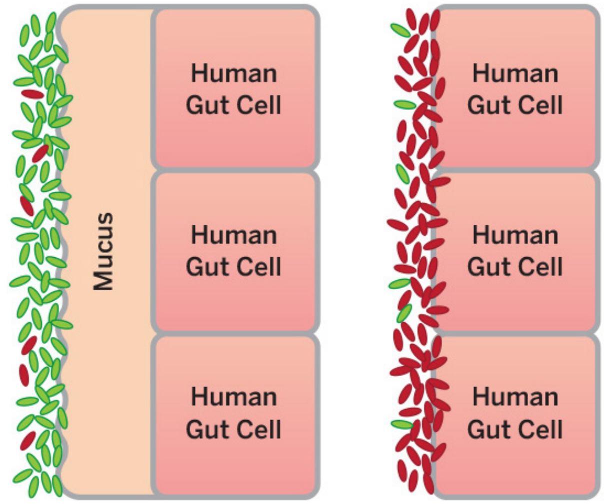
A helpful member of the gut microbiome, *L. reuteri* improves digestion and protects against infection. Each cell is between 2 and 4 micrometers long. (Colors were added to the photo to make the bacteria easier to see.)

Normal Role in Humans

L. reuteri bacteria help us digest food and produce vitamins that aid human health, but that isn't all they do. They also help protect humans from infection. *L. reuteri* helps the gut lining to produce mucus, which protects the gut and keeps it healthy. Large numbers of *L. reuteri* grow together in sheets stuck to the walls of the gut, preventing harmful bacteria from using that living space.

Role in Disease

L. reuteri is not known to cause disease. In fact, it helps cure some diseases! Babies with gut infections that cause diarrhea, for example, will heal more quickly if given *L. reuteri* bacteria. The more scientists learn about *L. reuteri*, the more benefits they discover.



Some helpful bacteria, like *L. reuteri* (shown here in green), help the gut produce mucus that can protect gut cells from infection. When that mucus is not present, the human gut cells can more easily be infected by harmful bacteria (shown here in red).

Mothers pass *L. reuteri* bacteria to their newborn babies in their milk.

***B. animalis* is a helpful type of bacteria found in the human microbiome. Each one is 12 micrometers long.**

Bacteria:
B. animalis

You may have eaten a few billion *B. animalis* bacteria for breakfast this morning! *B. animalis* helps produce yogurt from milk, and a typical yogurt contains billions of these microorganisms. That's a good thing: *B. animalis* can be beneficial to human health. *B. animalis* is found in the guts of dogs, cows, mice, and nearly all other mammals, including humans.

Environment

B. animalis bacteria can be damaged by the oxygen in air. As a result, they thrive in low-oxygen environments like the human gut. There, they break down foods that humans cannot digest alone. Once in the gut, *B. animalis* competes fiercely for food and space, sometimes killing off harmful microorganisms.

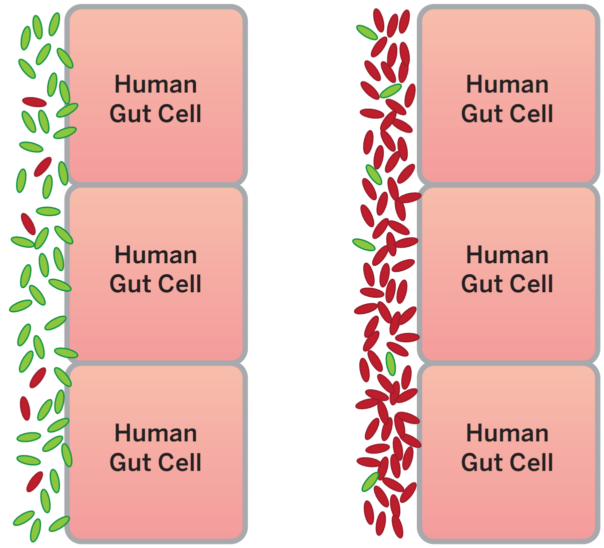
Yogurt often contains billions of *B. animalis* bacteria.

Normal Role in Humans

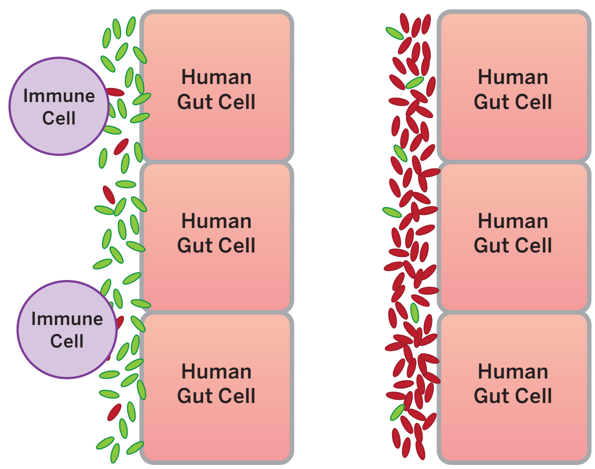
Bacteria like *B. animalis* are some of the first microorganisms to settle in our gut microbiomes—mothers pass them on to their newborn babies in their milk. *B. animalis* bacteria make up a relatively small part of the gut microbiome in adults. However, these bacteria still play a large role in keeping us healthy. As mentioned above, they compete fiercely with harmful bacteria for space and food. Competition from *B. animalis* helps prevent invading bacteria from increasing their populations. *B. animalis* aids in digestion and helps gut cells get the substances they need for repair and growth. It even boosts our immune systems, sending signals to our bodies to make more immune cells that can kill invading bacteria.

Role in Disease

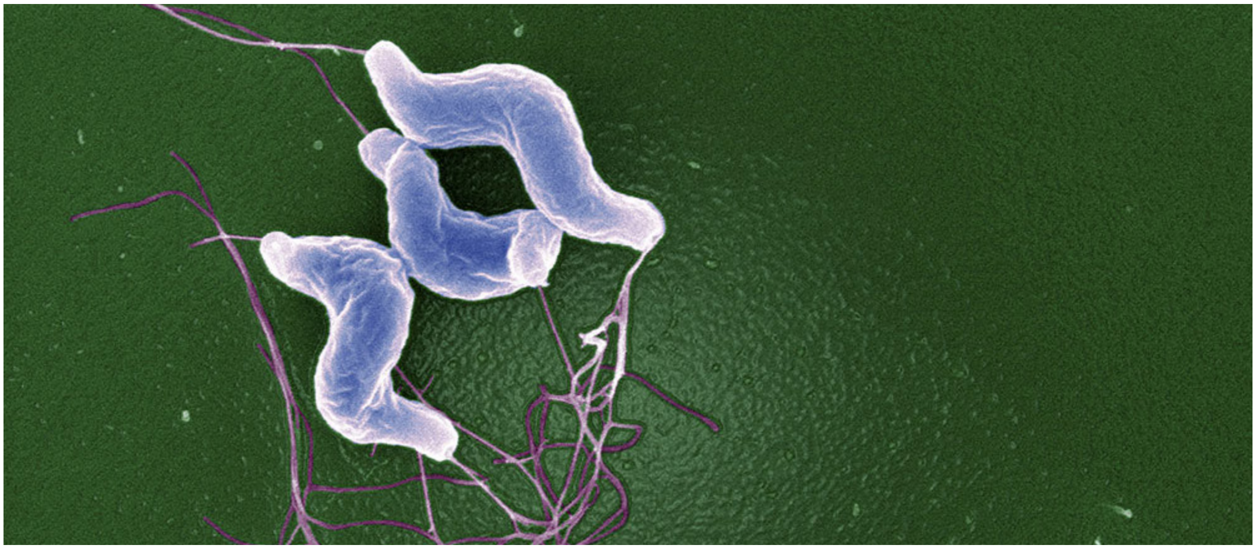
B. animalis bacteria do not cause disease when their population increases in the gut microbiome. In fact, not having enough *B. animalis* can cause problems! Low numbers of bacteria like *B. animalis* may be associated with some digestive problems, as well as problems with the immune system. Many people eat yogurt or take pills containing *B. animalis* bacteria to try to improve their health.



When lots of helpful bacteria like *B. animalis* (shown here in green) are present in the gut, there is little space and food available to harmful bacteria (shown here in red). This helps prevent the harmful bacteria from infecting the gut. When there are fewer helpful bacteria in the gut, there is more space and food available for harmful bacteria that can cause disease.



Bacteria like *B. animalis* (shown here in green) help the body produce immune cells that kill harmful bacteria. When there are fewer of these helpful bacteria, there are fewer immune cells. This allows more harmful bacteria (shown here in red) to live and cause infection.



This photo shows a few C. *jejuni b*acteria together in a group. Infections with *C. jejuni* cause what is known as food poisoning. (Colors were added to the photo to make the bacteria easier to see.)

Bacteria: *C. jejuni*

Have you ever heard people say they got "food poisoning"? What made them sick was probably *C. jejuni* (see-jeh-JUNE-ee) bacteria. *C. jejuni* bacteria are part of the normal microbiome in birds and cattle, but in humans, these bacteria cause more cases of food poisoning than almost any other microorganism! They are only 4 to 6 micrometers long, but *C. jejuni* bacteria can cause serious trouble.

Environment

C. jejuni bacteria can meet all their needs in the human gut, even though they don't ordinarily live in this environment. Unlike helpful gut bacteria, these harmful bacteria don't use our undigested food--instead, they steal from human gut cells. Using their corkscrew shape and two whiplike tails, *C. jejuni* bacteria make their way to the cells of the gut. *C. jejuni* will either grab nutrients from digested food before our cells get them, or invade the gut cells and eat what's inside.

Normal Role in Humans

C. jejuni bacteria are not normally found in humans. In fact, these microorganisms do not benefit humans at all—but they seem to play an important role in the microbiomes of chickens, and many humans enjoy eating chicken. As you might expect, most people who get *C. jejuni* infections get them from chickens, often from eating undercooked meat.

Role in Disease

Once *C. jejuni* bacteria get into humans, they cause diarrhea, vomiting, and fever—all the symptoms of food poisoning. These symptoms result from a toxin that *C. jejuni* produces. The toxin harms gut cells, blocking them from repairing the gut. It also shuts down the body's defenses. Even though Salmonella bacteria is more famous for causing food poisoning, *C. jejuni* is actually responsible for many more infections in the U.S. each year!

Some *C. jejuni* infections clear up in a few days, but others become severe and must be treated with antibiotics. Antibiotics quickly kill the *C. jejuni* invaders, along with most of the other microorganisms in the gut.

Bacteria: *E. coli*

The bacteria called *E. coli* (ee-COLE-eye) have a bad reputation. Most people know about *E. coli* only as harmful bacteria that cause disease and even death. However, there are actually many types of *E. coli*, and most of them play helpful roles in the human microbiome.

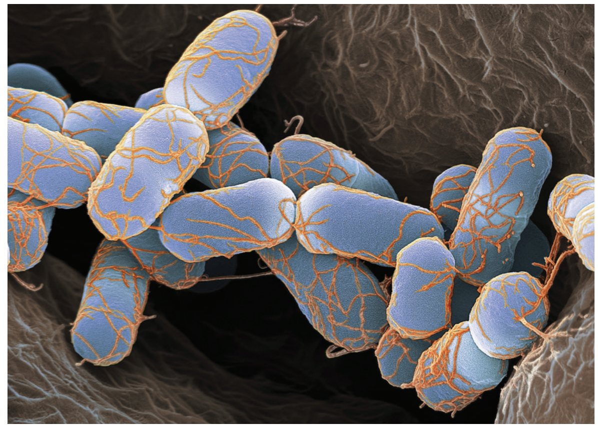
Environment

E. coli bacteria thrive in the guts of humans and other mammals. They grow best at temperatures near 37°C (98.6°F)—the same temperature as our bodies! *E. coli* can use many substances for food, nearly all of which are found in the gut. Unlike many gut bacteria, however, *E. coli* can also survive outside the body.

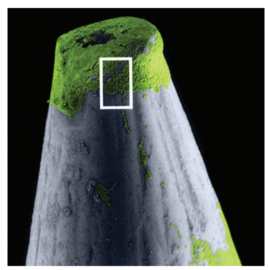
Normal Role in Humans

Healthy humans ordinarily have *E. coli* living in their microbiomes. Because *E. coli* bacteria are good at getting food and living space from the human gut, they multiply quickly when other microorganisms are reduced. In the right conditions, *E. coli* can multiply very fast: a population of *E. coli* bacteria can double in numbers every 20 minutes! *E. coli* benefits humans by taking up food and space that harmful invading microorganisms might use otherwise. Competition from *E. coli* helps prevent invading microorganisms from growing out of control.

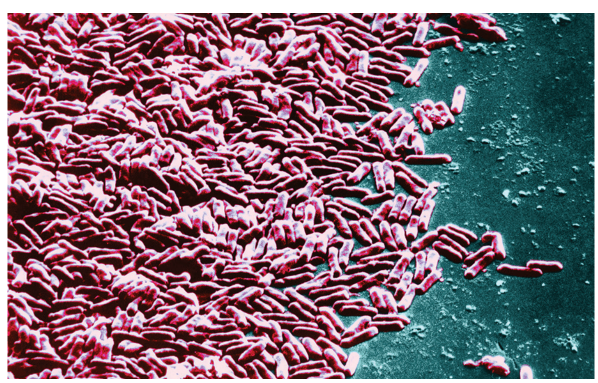
Humans aren't able to digest every part of our food. It's the parts humans can't digest that *E. coli* uses for food. As the *E. coli* bacteria break down this undigested food, they produce vitamin K, a substance that boosts bone growth and helps form scabs to stop bleeding. *E. coli* also causes the gut to produce protective mucus.



This image of *E. coli* bacteria was taken through a powerful microscope. In the photo, the bacteria appear about 15,000 times larger than their actual size of just 2 micrometers! (*E. coli* isn't really blue; color was added to the photo to make the bacteria easier to see.)



The photo at left is a close-up of the sharp tip of a pin, covered with *E. coli* bacteria. The photo at right zooms in even further to show the individual bacteria 3,500 times larger than actual size. (*E. coli* isn't really green; color was added to the photo to make the bacteria easier to see.)

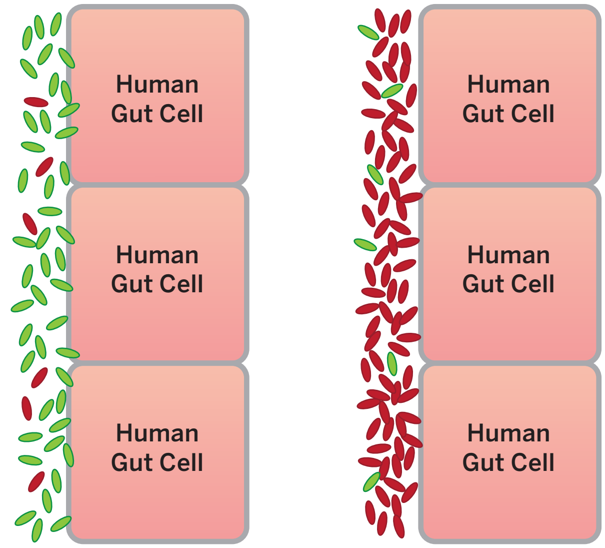


***E. coli* can multiply very quickly under the right conditions. (These bacteria aren't really pink; color was added to the photo to make them easier to see.)**

These bacteria stay in our bodies throughout our lives. In fact, within 40 hours of birth, *E. coli* have moved in and multiplied in a newborn baby's gut. It's good that they move so quickly—otherwise, harmful microorganisms could move into a baby's gut without competition, and that could cause the baby to become very sick.

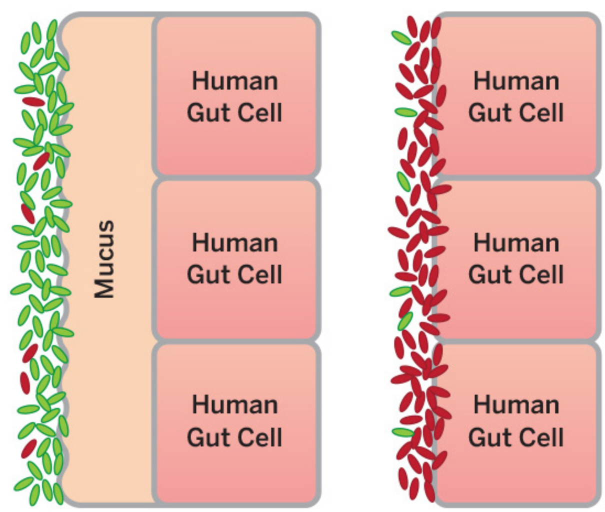
Role in Disease

Even though most types of *E. coli* are beneficial, the harmful types are better known. These *E. coli* bacteria are dangerous. Because *E. coli* can survive outside the gut, harmful *E. coli* bacteria sometimes find their way way into the food people eat. Infections with harmful *E. coli* cause "food poisoning," with severe vomiting and diarrhea. Some of these harmful types of *E. coli* actually turn the safe *E. coli* present in the microbiome into harmful *E. coli*! It's no wonder *E. coli* has a bad reputation. Still, the majority of *E. coli* bacteria are helpful, not harmful.



When lots of helpful bacteria like *E. coli* (shown here in green) are present in the gut, there is little space and food available to harmful bacteria (shown here in red). This helps prevent the harmful bacteria from infecting the gut. When there are fewer helpful bacteria in the gut, there is more space and food available for harmful bacteria that could cause disease.

This piece of lettuce has *E. coli* bacteria on it, viewed through a microscope and shown more than 5,000 times larger than actual size. People can become very sick if they eat food contaminated with harmful types of *E. coli*. (The photo was taken in black and white; colors were added to make it easier to see.)



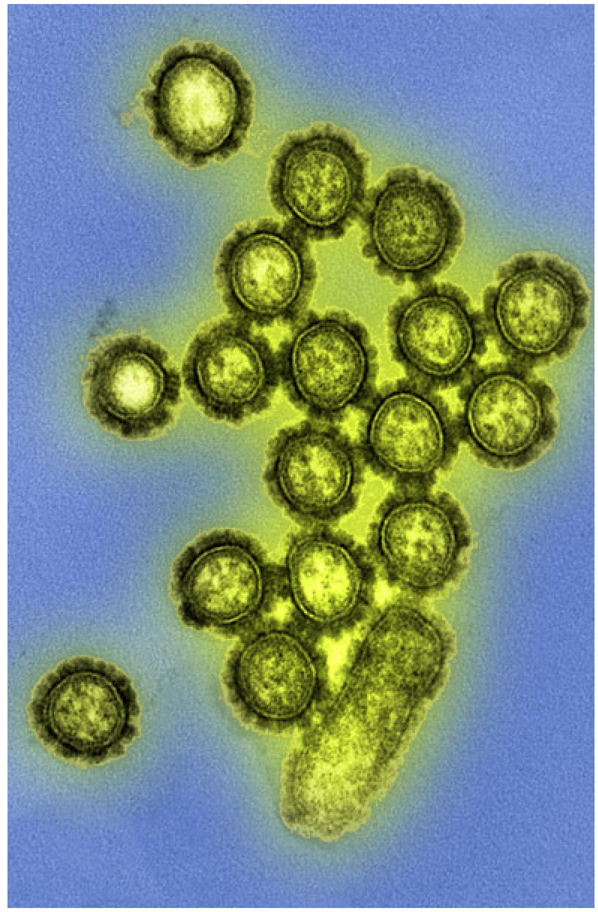
Some helpful bacteria, like *E. coli* (shown here in green), help the gut produce mucus that can protect gut cells from infection. When that mucus is not present, the gut cells can more easily be infected by harmful bacteria (shown here in red).

Viruses: On the Edge of Life

Oh, no: imagine you woke up this morning with a sore throat, an achy body, and skin that feels like it's burning up. You might have influenza, also known as the flu. Influenza is caused by a virus—a tiny structure that infects the living cells of animals, plants, and all kinds of bacteria and microorganisms. Viruses are one of the leading causes of illness in the world.

Viruses are very simple, and they exist on a microscopic scale: they're just tiny bundles of DNA covered in a coat of protein, sometimes with a layer of fat molecules for extra protection, and most of them are about 100 times smaller than the average cell—the largest are about 300 nanometers. Because viruses are so simple, scientists argue about whether they count as living organisms. On one hand, viruses aren't made of cells, which scientists consider the basic unit of life.

On the other hand, they have DNA and are able to reproduce, and they evolve through natural selection—all of which are important qualities of living things. Some scientists say that viruses are "on the edge of life." Viruses may be simple, but they're good at what they do: reproducing. Because viruses don't have cell bodies of their own, they use the living cells of host organisms in order to reproduce. When it's time to reproduce, the virus latches onto a living cell and injects its own DNA into the body of the cell. The virus's DNA takes over the cell and forces it to make more viruses. When the host cell is full of new viruses, they burst out, killing the cell. Each new virus then looks for a new cell to infect, and the cycle begins again. For some viruses, this happens quickly—but some viruses hide their DNA in the host's cells for years, allowing the cells to copy the virus's DNA over

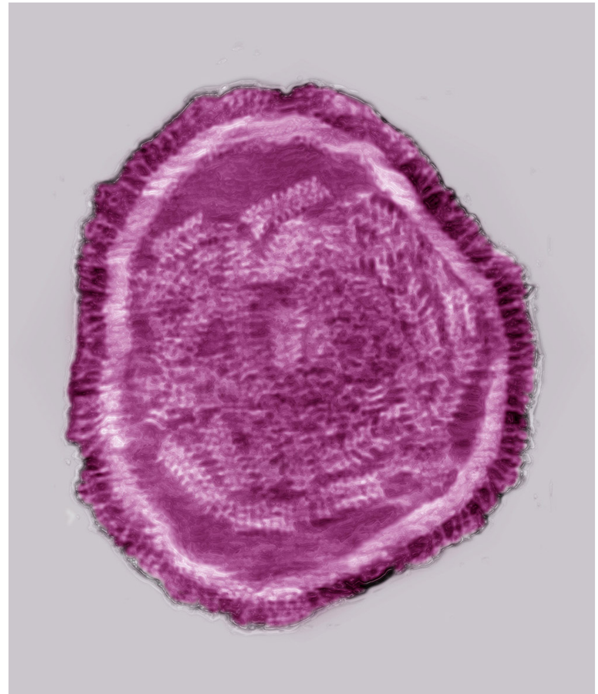


Viruses are tiny biological structures that cause illness in plants, animals, and all kinds of bacteria and microorganisms. (Colors were added to the photo to make it easier to see.)

Viruses share some characteristics with living things, but not all. Some scientists say they're "on the edge of life."

and over as the cells reproduce, but not actually making the host sick. For example, people infected with HIV can have the virus in their cells for years before they develop AIDS, which is a collection of serious symptoms caused by the virus.

Because they infect living cells, viruses are hard to treat without killing the host cells as well. The antibiotic medicines used to treat bacterial infections kill bacteria, but antibiotics don't have an effect on viruses. The best way to fight viruses is to prevent them with vaccines. A vaccine is a weakened version of a virus, which can be injected into a healthy patient. The weakened virus doesn't make the patient sick, but it does prepare the patient's immune system to fight the virus in the future.



Viruses are tiny bundles of DNA covered by layers of protein. (Colors were added to the photo to make it easier to see.)

Microbiome

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