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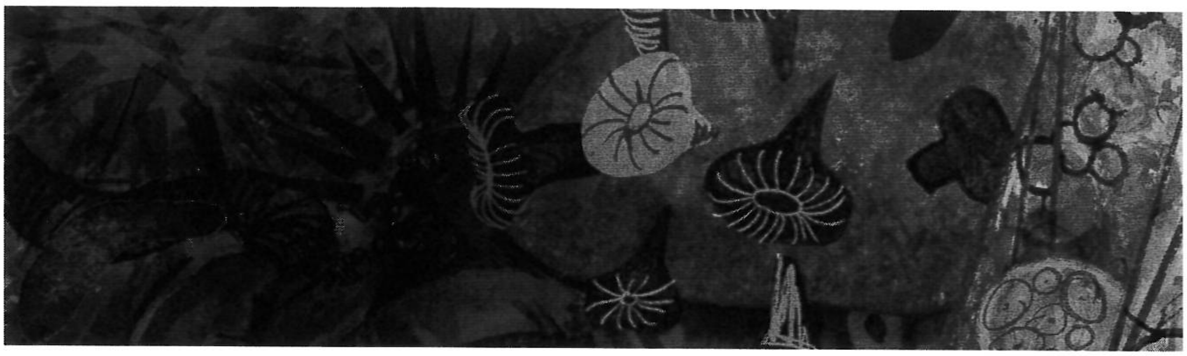

Microbiome

Article Compilation

These materials are based upon work partially supported by the National Science Foundation under grant numbers DRL-1119584, DRL-1417939, ESI-0242733, ESI-0628272, and ESI-0822119. The Federal Government has certain rights in this material. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

These materials are based upon work partially supported by the Institute of Education Sciences, U.S. Department of Education, through Grant R305A130610 to The Regents of the University of California. The opinions expressed are those of the authors and do not represent views of the Institute or the U.S. Department of Education.

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UNIVERSITY OF CALIFORNIA, BERKELEY

Developed by the Learning Design Group at the University of California, Berkeley's Lawrence Hall of Science.

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Microbiome
ISBN: 978-1-64276-821-3
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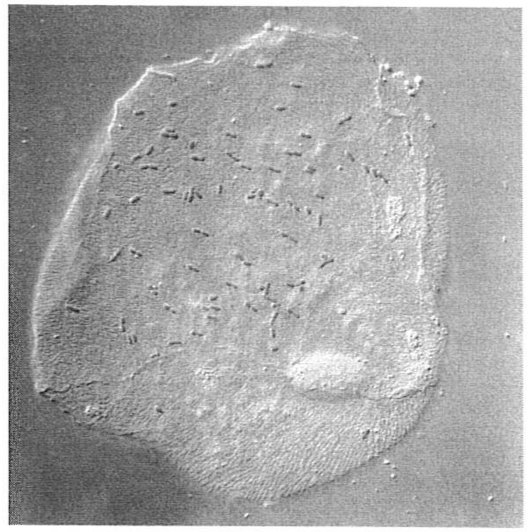
Cells: The Basic Unit of Life

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.



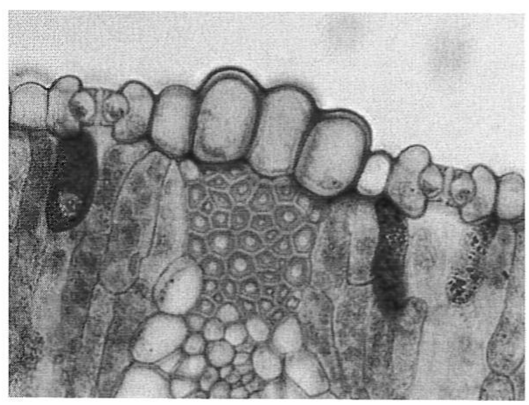
This photo was taken through a microscope. It shows one cell from the cheek of a human, with almost 100 bacteria on it. Each one of those bacteria is a single cell. The bacteria and cheek cell all appear 945 times larger than actual size. Each one of the bacteria is about 1 micrometer long. The cheek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

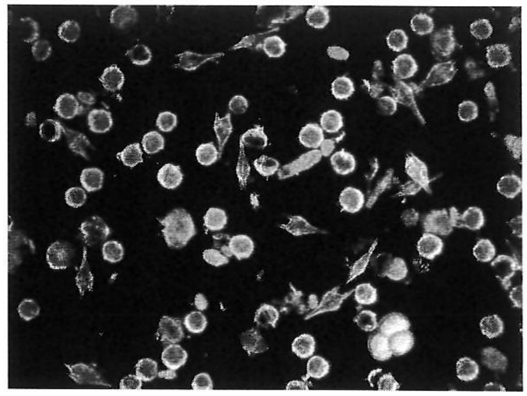
The Basic Unit of Life

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.

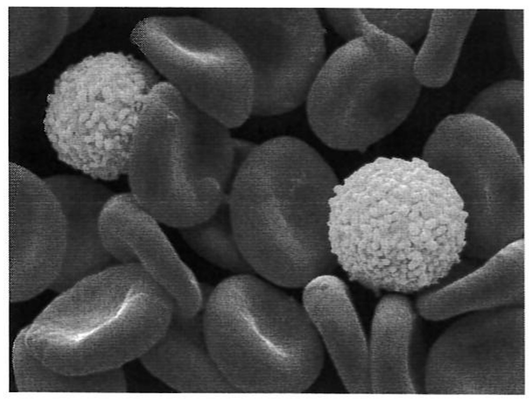
All cells have some things in common. For example, all cells are filled with a jellylike fluid called cytoplasm and enclosed by a cell membrane. This cell membrane controls which substances are allowed in and out of the cell. All cells also have tiny structures called ribosomes that make proteins using 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!

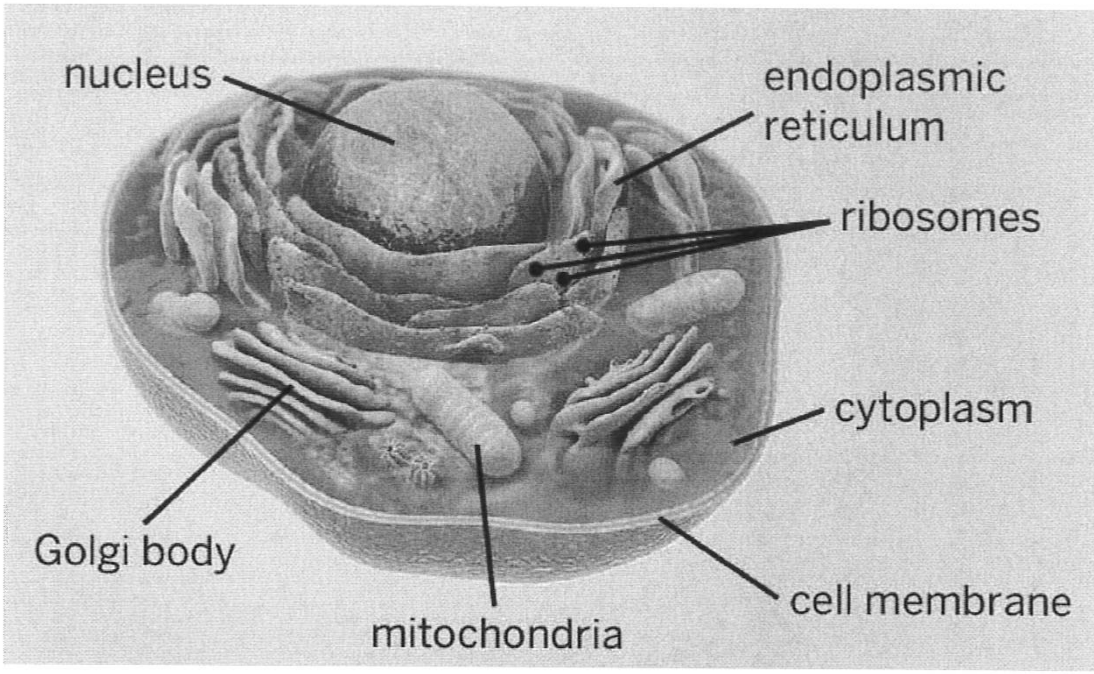
At the same time, many cells put together make much larger structures. A bunch of the same type of cells working together is called a tissue, like muscle tissue or nerve tissue. Different types of tissues working together are called an organ, like the brain or the liver—or the stem and leaves of a plant. 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 surrounds the cell and is in charge of keeping helpful molecules inside the cell and keeping out molecules that are not helpful. 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, whic 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

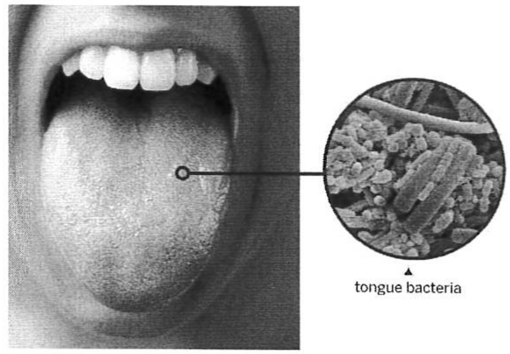
There's a world filled with strange creatures. The creatures of this world are invisible, and they're not human. Aliens sometimes threaten to invade the world these creatures call home. . . .

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.

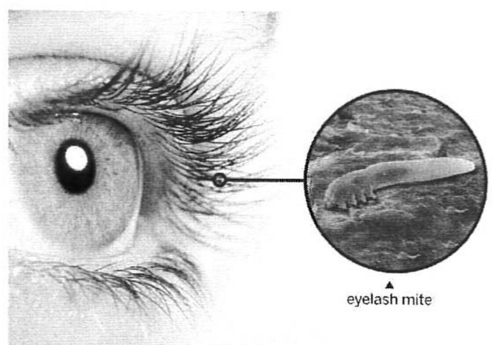
Your Body: Home Sweet Home for Bacteria

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

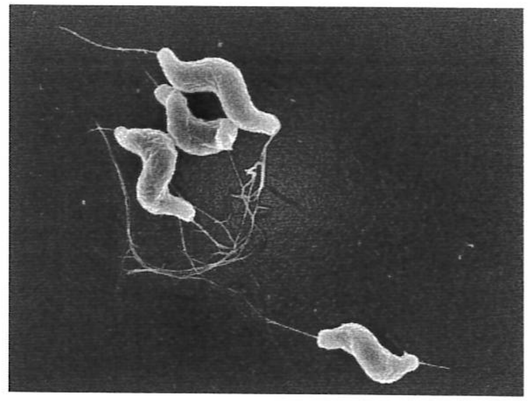
Most bacteria in the human microbiome won't hurt you. In fact, the opposite is true. Many bacteria do important jobs for the human body. For example, bacteria living in your gut help break down food that your body couldn't digest otherwise. Other bacteria help protect your body from infection, which 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.

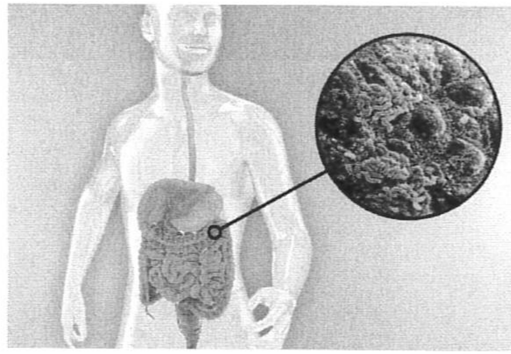
However, antibiotics don't just kill harmful bacteria—they kill helpful bacteria, too. A person who has just taken antibiotics has fewer bacteria than normal. Helpful bacteria will grow back in time, but often the bacteria that return are different from the ones that were there before. Taking antibiotics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

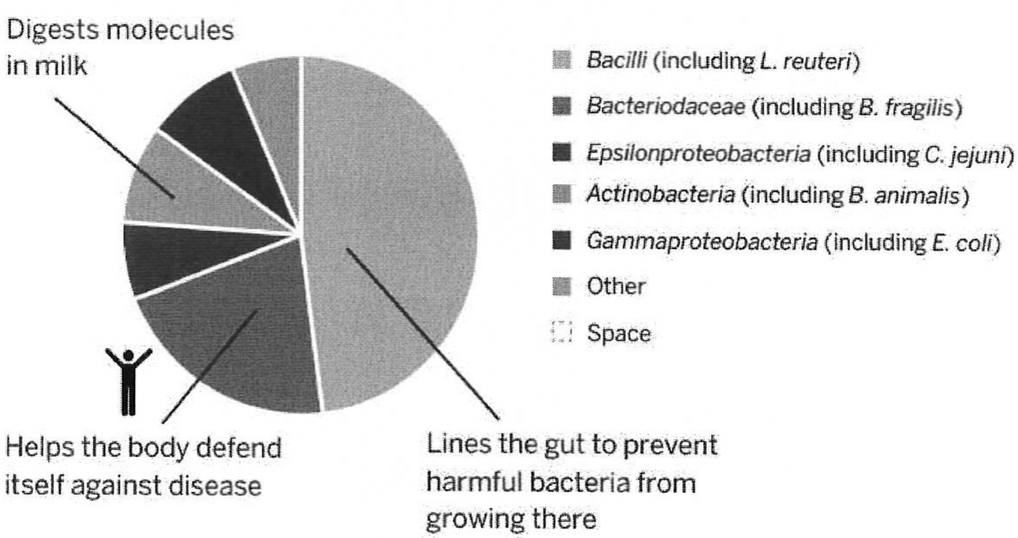
Your body is the whole world to the bacteria of your microbiome. It's an environment that provides microorganisms with everything they need, including food and space to live. What you do affects your bacteria, and they affect you, too. Your body is a world in miniature—a microbiome.



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."

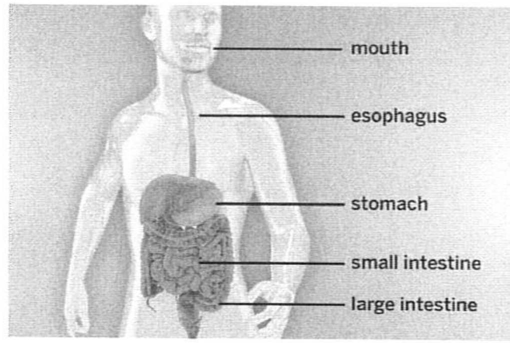
Certain combinations of bacteria, fungi, and other microorganisms in the human microbiome can cause health problems, but other combinations may be able to keep people healthy. By identifying which combinations make people sick, scientists might be able to tell what changes to the microbiome could treat 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."

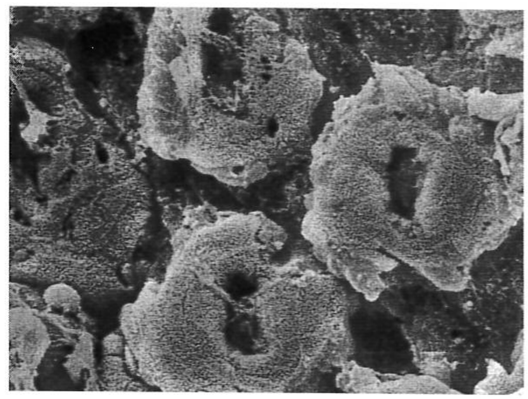
Today, at the University of California, San Francisco, Lynch works with many different types of scientists to study the human microbiome and how it affects the body as a system—which requires building bridges between different areas of science. To study the interactions between microorganisms and the 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

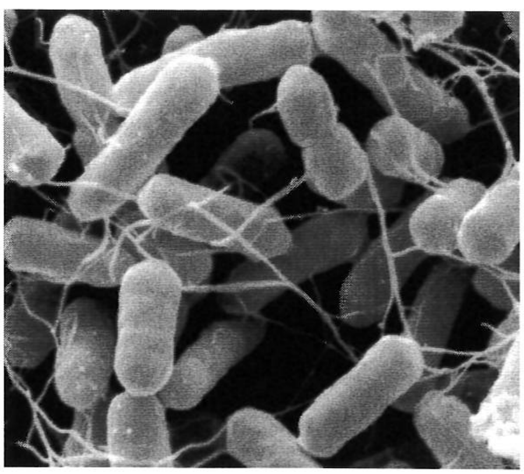
Salmonella lives in the guts of all kinds of animals, especially birds and reptiles, and usually gets passed around through animal waste. Whether a person gets sick from ingesting certain kinds of *Salmonella* can depend on the amount of food and space available in his or her gut microbiome. If the gut 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

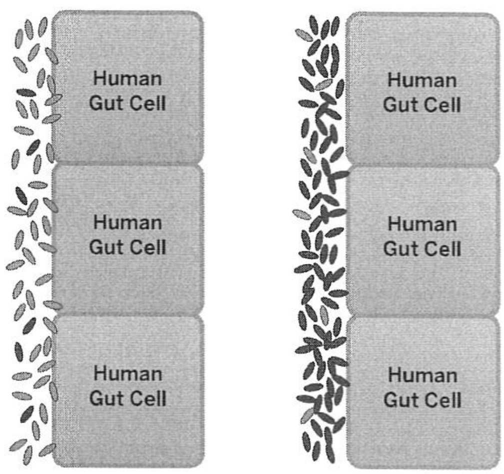
Salmonella can sometimes be found in small amounts in the guts of healthy humans, but is more likely to be found in the microbiomes of people who have recently become sick from *Salmonella* infection.

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."

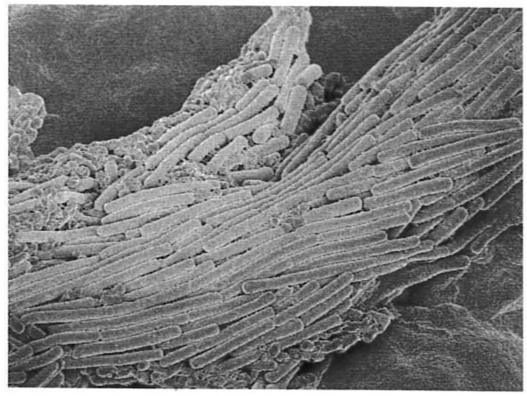
Environment

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.

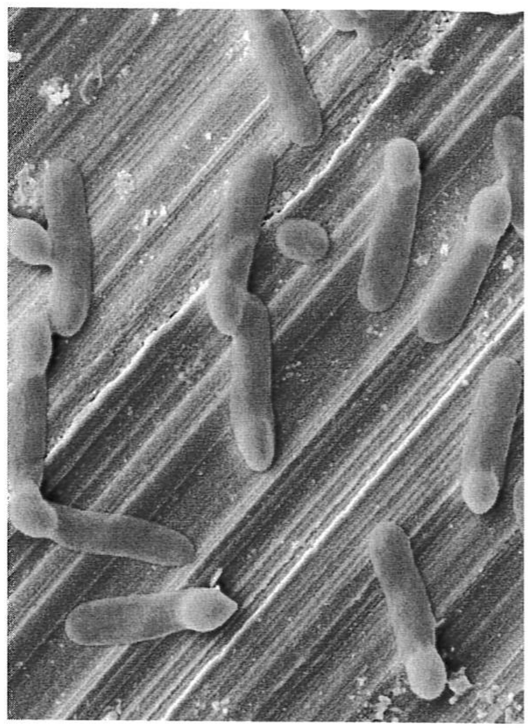
C. difficile has a surprising weakness: oxygen can kill it. However, it also has an amazing defense. When *C. difficile* is exposed to oxygen in the air or other dangers, it shrinks and forms a tough outer covering. In this state, *C. difficile* can survive oxygen, hand cleaners, acids, and even many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



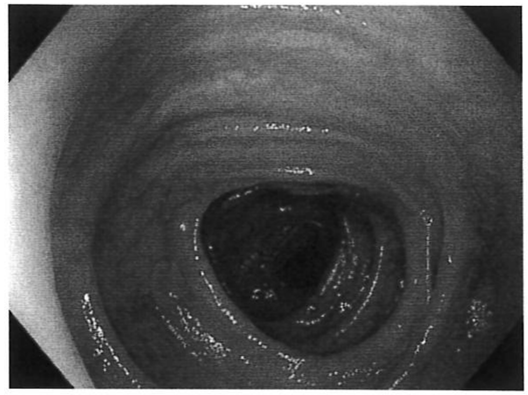
***C. difficile* bacteria can cause dangerous infections in humans. They are between 1 and 4 micrometers long. (This photo was taken in black and white; colors were added to make it easier to see.)**



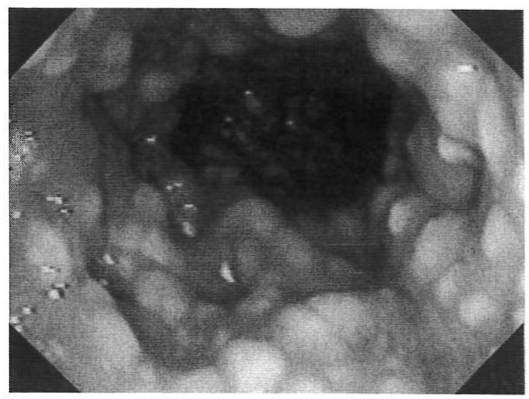
Exposed to the air on a steel surface, these *C. difficile* bacteria are shrinking and forming protective coverings. (This photo is zoomed in much closer than the previous photo.)

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.

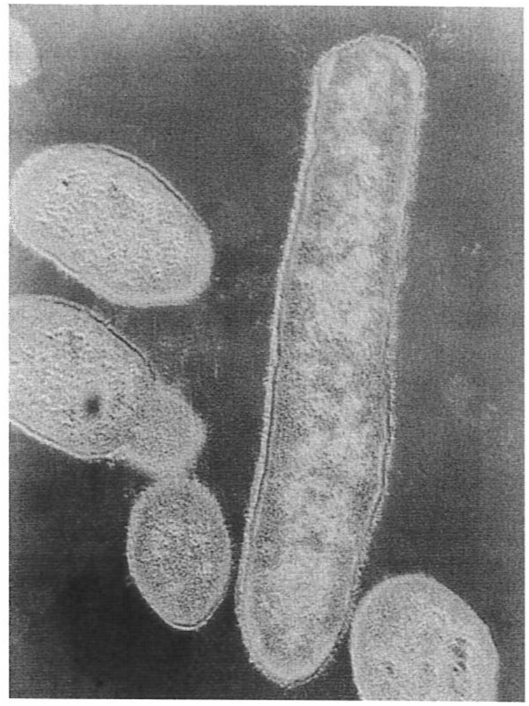
Environment

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.

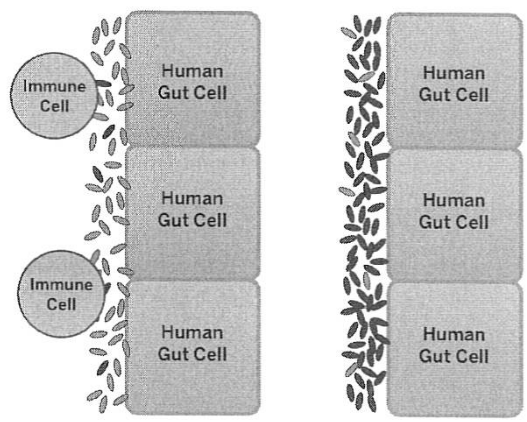
Normal Role in Humans

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.



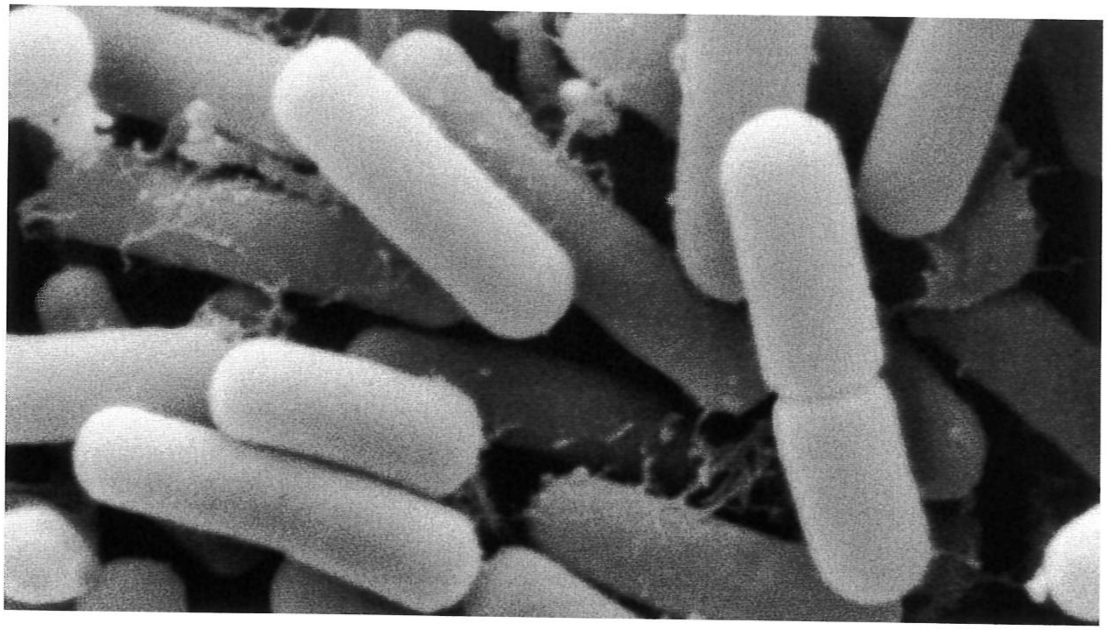
When they escape the gut, *B. fragilis* bacteria can cause dangerous infections. They use human cells as food! (People added the colors in this photo to make the bacteria easier to see.)



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

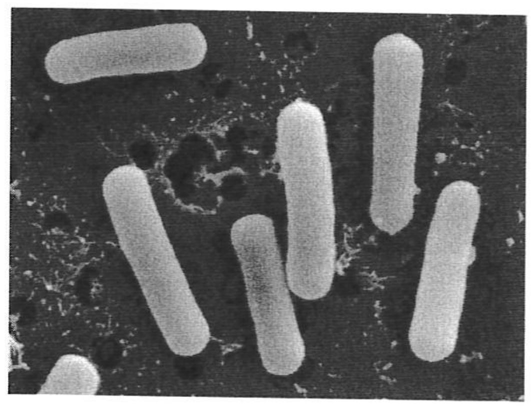
Even though they are usually helpful, *B. fragilis* bacteria can sometimes cause disease. Often, this happens after the gut wall has been damaged in some way. As *B. fragilis* escapes from the gut, it becomes dangerous. *B. fragilis* does not usually hurt the cells in the gut because of the mucus that 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.



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.)

Environment

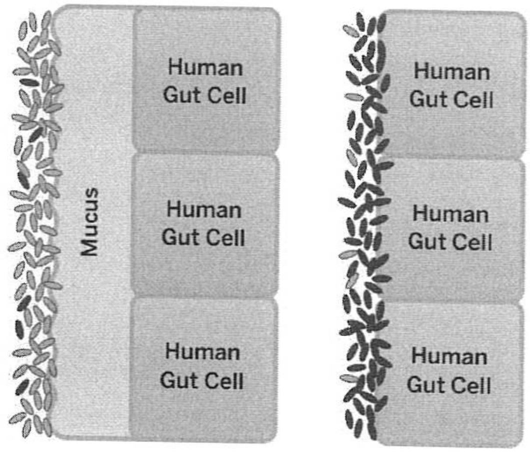
L. reuteri is found in the microbiomes of many animals, including most humans. These bacteria are extremely good at capturing food in the gut: they digest substances in food that humans are often unable to break down. They make a home for themselves by sticking to the gut wall. *L. reuteri* thrives in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

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.

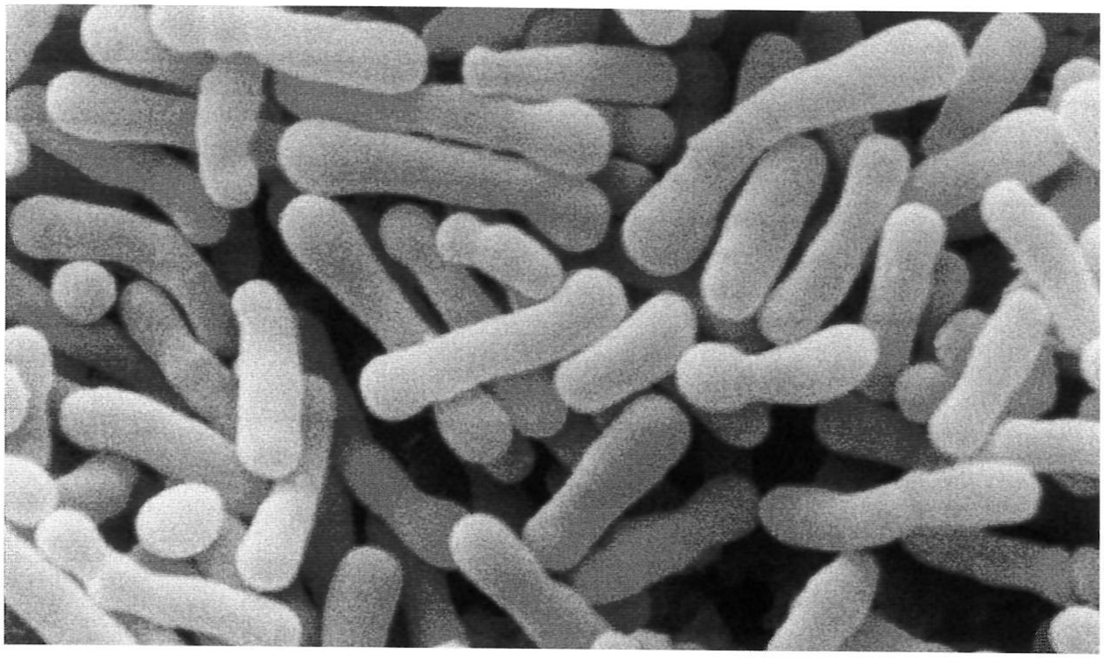
Role in Disease

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.

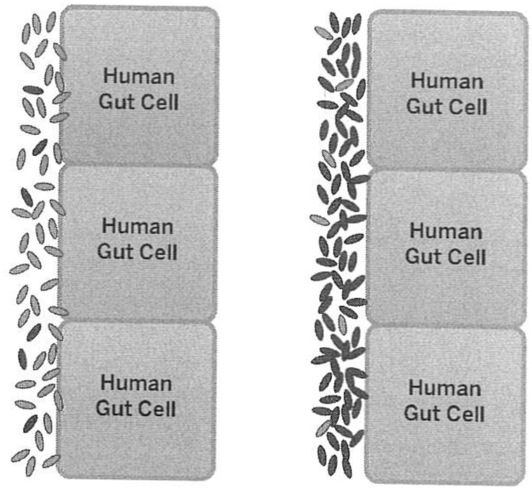
Yogurt often contains billions of _B. animalis_ bacteria.

Normal Role in Humans

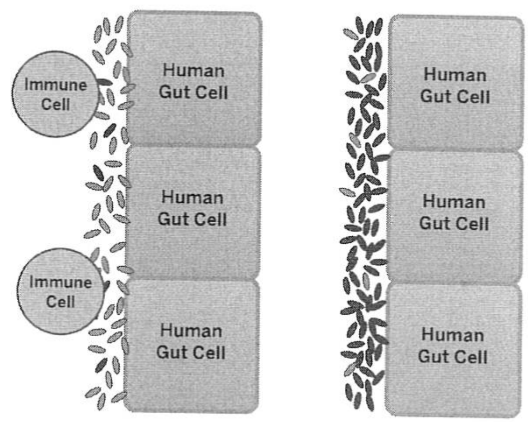
Bacteria like *B. animalis* are some of the first microorganisms to settle in our gut microbiomes—mothers pass them on to their newborn babies in their milk. *B. animalis* bacteria make up a relatively small part of the gut microbiome in adults. However, these bacteria still play a large role in keeping 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

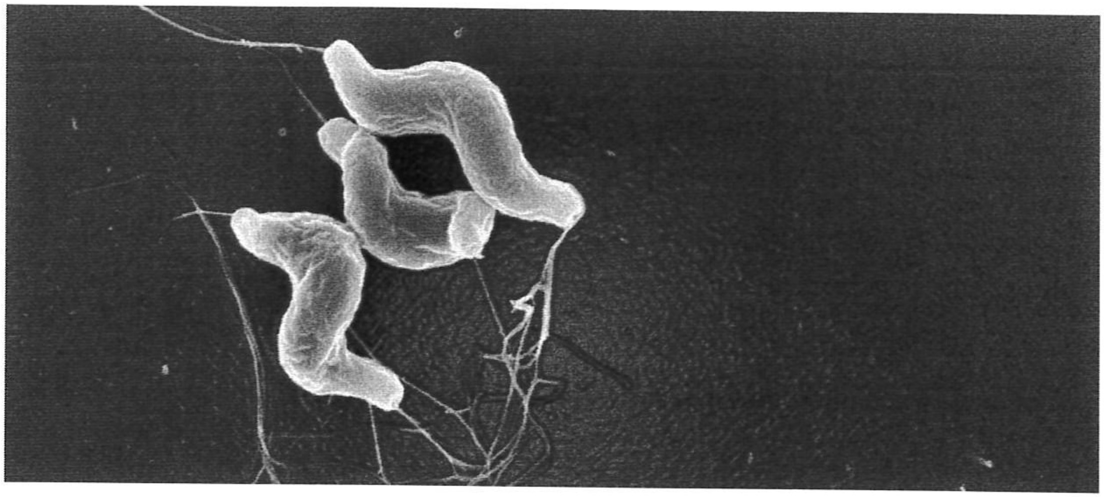
B. animalis bacteria do not cause disease when their population increases in the gut microbiome. In fact, not having enough *B. animalis* can cause problems! Low numbers of bacteria like *B. animalis* may be associated with some digestive problems, as well as problems with the immune system. Many people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

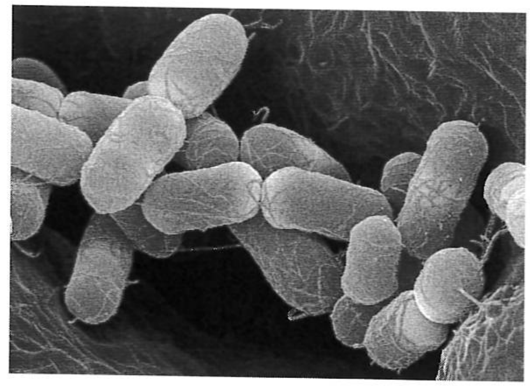
Environment

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.

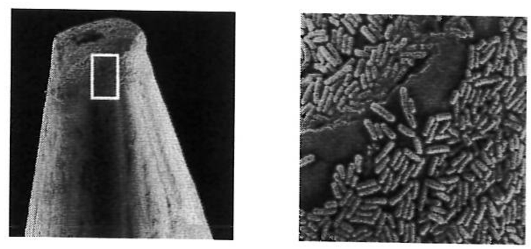
Normal Role in Humans

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.

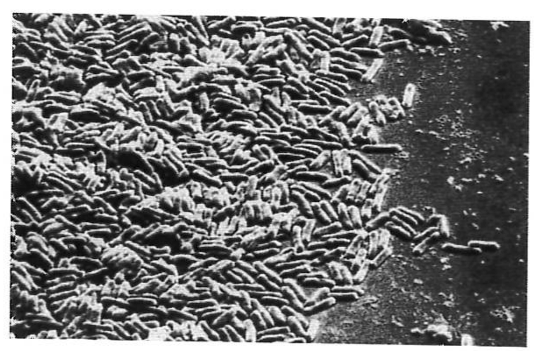
Humans aren't able to digest every part of our food. It's the parts humans can't digest that *E. coli* uses for food. As the *E. coli* bacteria break down this undigested food, they produce vitamin K, a substance that boosts bone growth and helps form scabs to stop bleeding. *E. coli* also causes the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

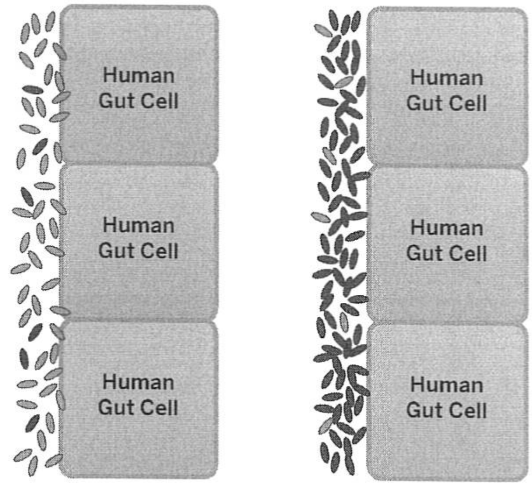


***E. coli* can multiply very quickly under the right conditions. (These bacteria aren't really pink; color was added to the photo to make them easier to see.)**

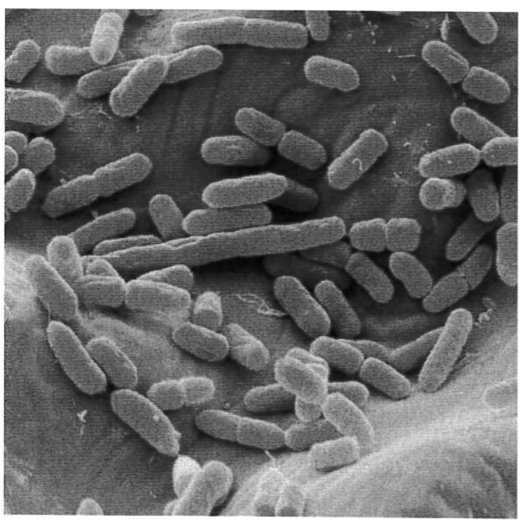
These bacteria stay in our bodies throughout our lives. In fact, within 40 hours of birth, *E. coli* have moved in and multiplied in a newborn baby's gut. It's good that they move so quickly—otherwise, harmful microorganisms could move into a baby's gut without competition, and that could cause the baby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

Role in Disease

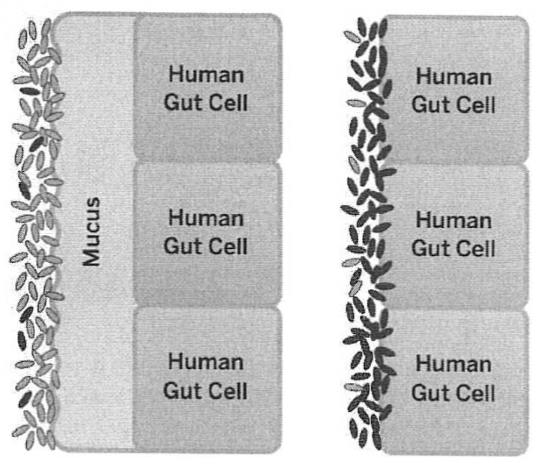
Even though most types of *E. coli* are beneficial, the harmful types are better known. These *E. coli* bacteria are dangerous. Because *E. coli* can survive outside the gut, harmful *E. coli* bacteria sometimes find their way way into the food people eat. Infections with harmful *E. coli* cause "food 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.)



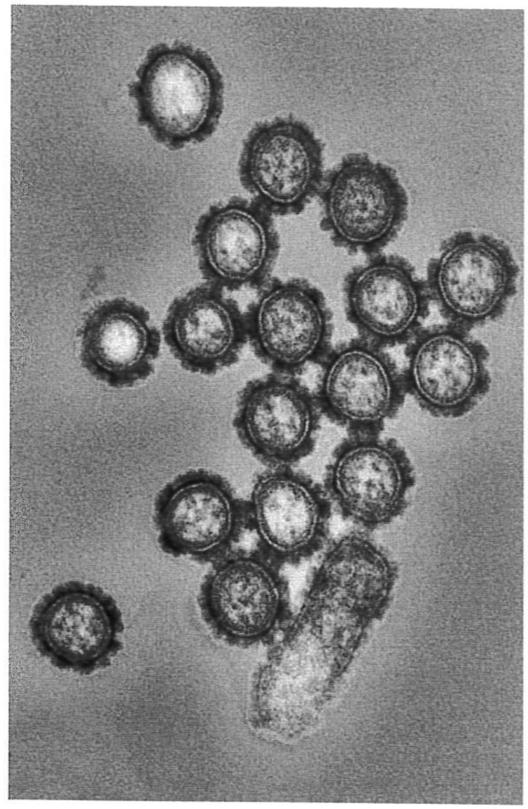
Some helpful bacteria, like *E. coli* (shown here in green), help the gut produce mucus that can protect gut cells from infection. When that mucus is not present, the gut cells can more easily be infected by harmful bacteria (shown here in red).

Viruses: On the Edge of Life

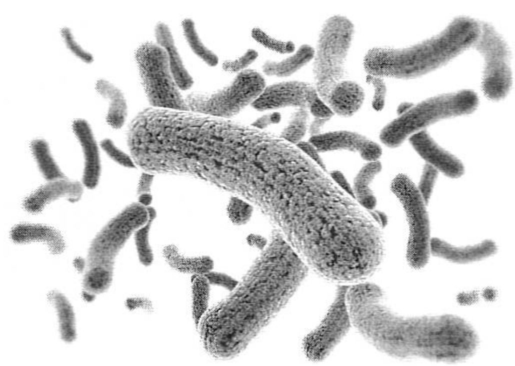
Oh, no: imagine you woke up this morning with a sore throat, an achy body, and skin that feels like it's burning up. You might have influenza, also known as the flu. Influenza is caused by a virus—a tiny structure that infects the living cells of animals, plants, and all kinds of bacteria and microorganisms.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



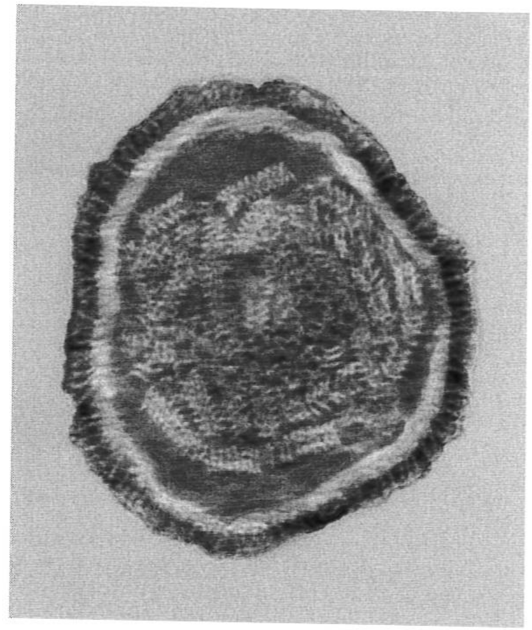
Viruses are tiny biological structures that cause illness in plants, animals, and all kinds of bacteria and microorganisms. (Colors were added to the photo to make it easier to see.)



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.)