WHERE WILD MICROBES GROW

The Search for Life Under the Seafloor

KEVIN KURTZ ALICE FEAGAN

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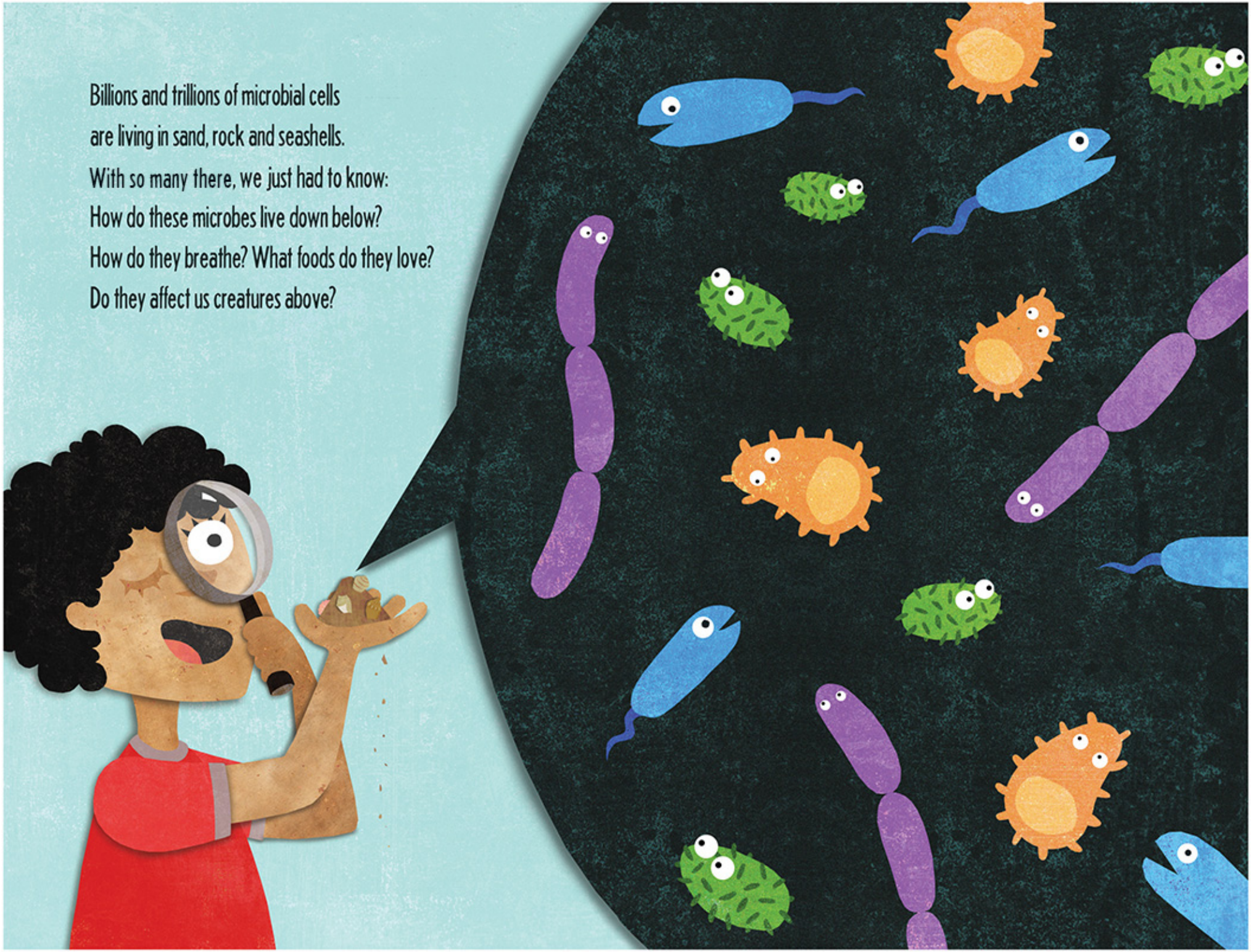
Our planet Earth is special indeed.
It has all the stuff that living things need.
Its water, food, and breathable air
create habitats that living things share.

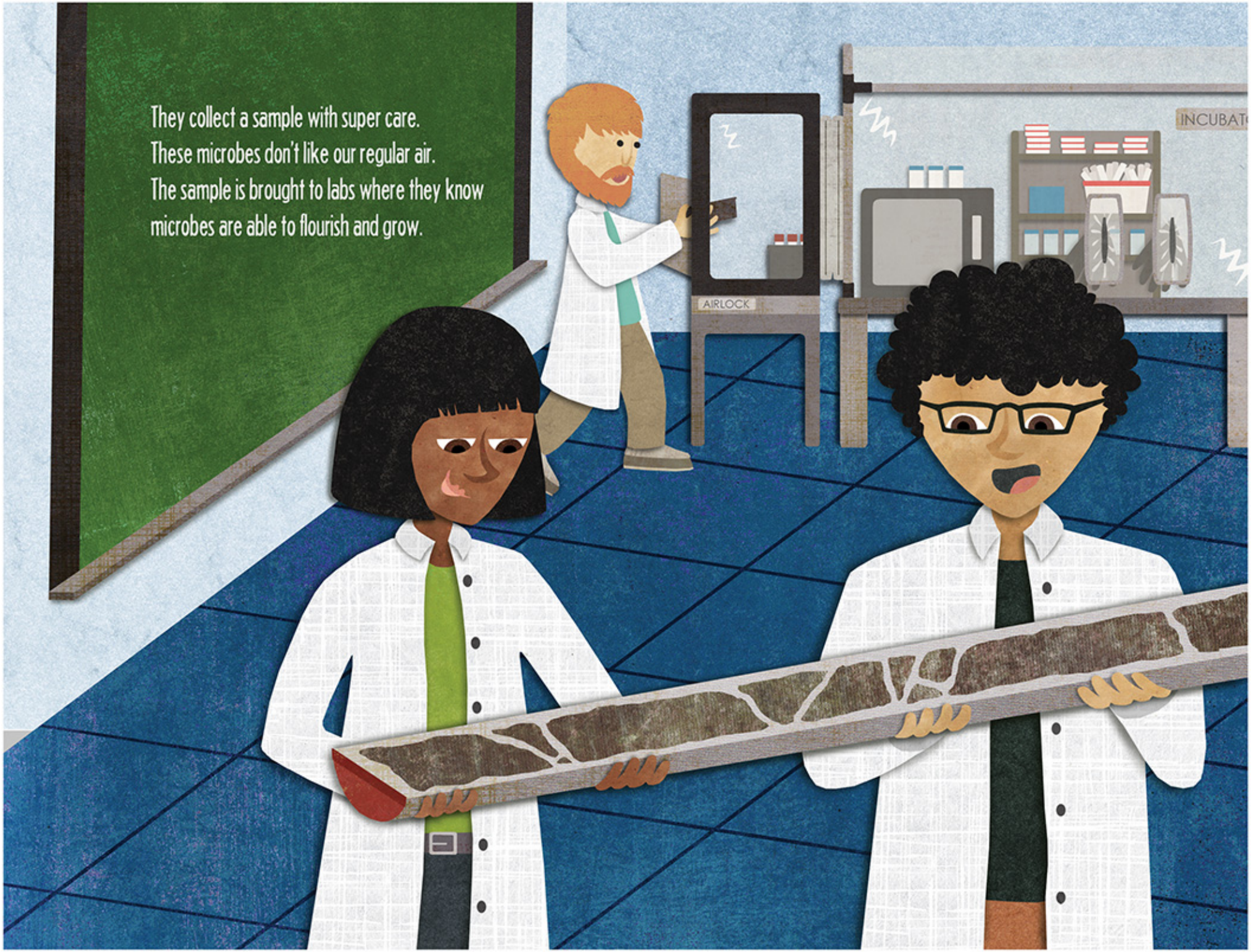
Habitats exist all the world round,
like forests, grasslands, and inside the ground.
We've found living things where water will boil,
deep under ice, and feeding on oil.

The world is so full of critters galore,
scientists wondered, "What's in the seafloor?"
They drilled down, collected some mud and some rock
and what they discovered came as a shock.



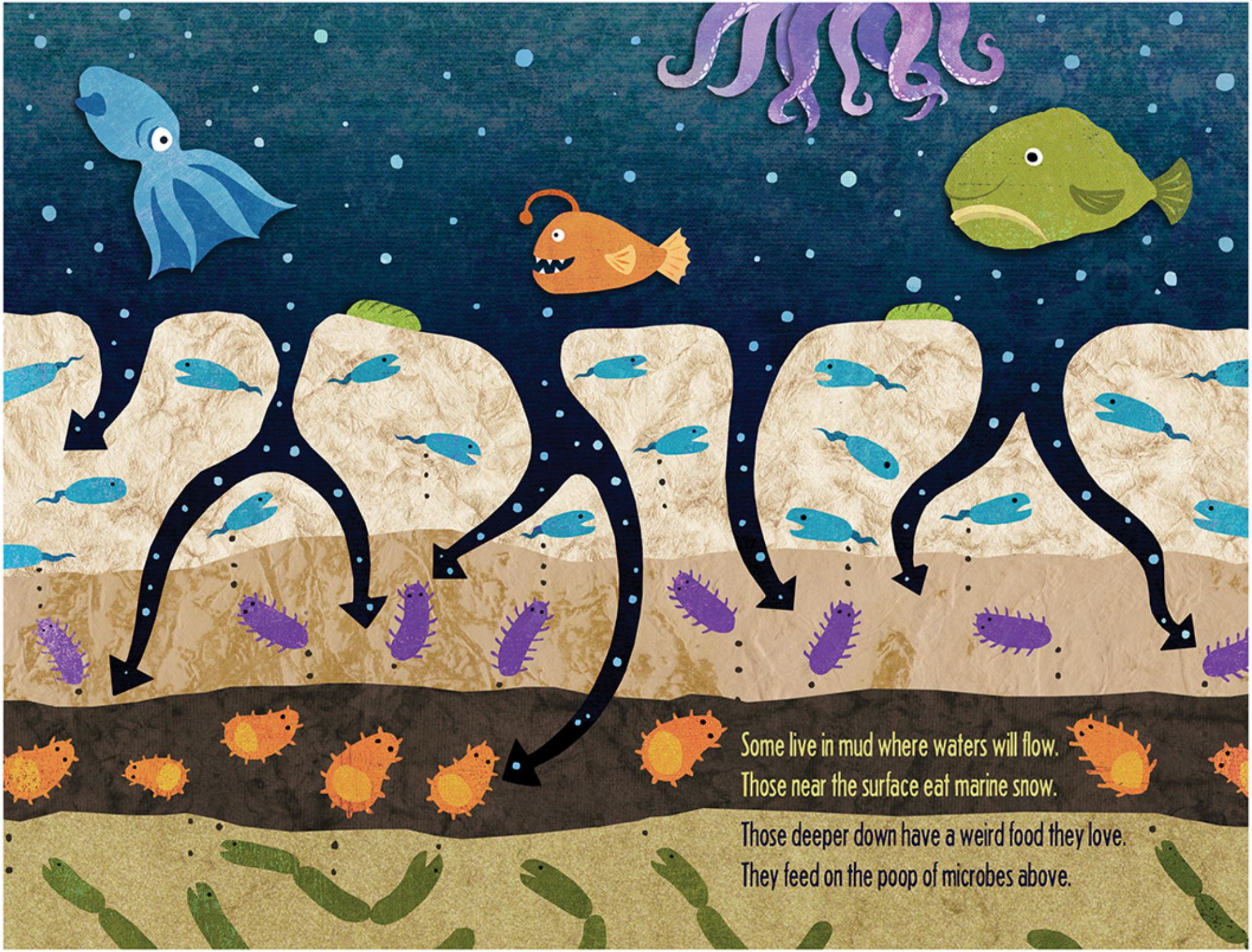
Billions and trillions of microbial cells
are living in sand, rock and seashells.
With so many there, we just had to know:
How do these microbes live down below?
How do they breathe? What foods do they love?
Do they affect us creatures above?

Microbes are tiny, too small to see.
Billions could fit inside of a flea.
Though you won't spot one, even if you stare,
scientists know how to tell that they're there.


They collect a sample with super care.
These microbes don't like our regular air.
The sample is brought to labs where they know
microbes are able to flourish and grow.
AIRLOCK
INCUBAT

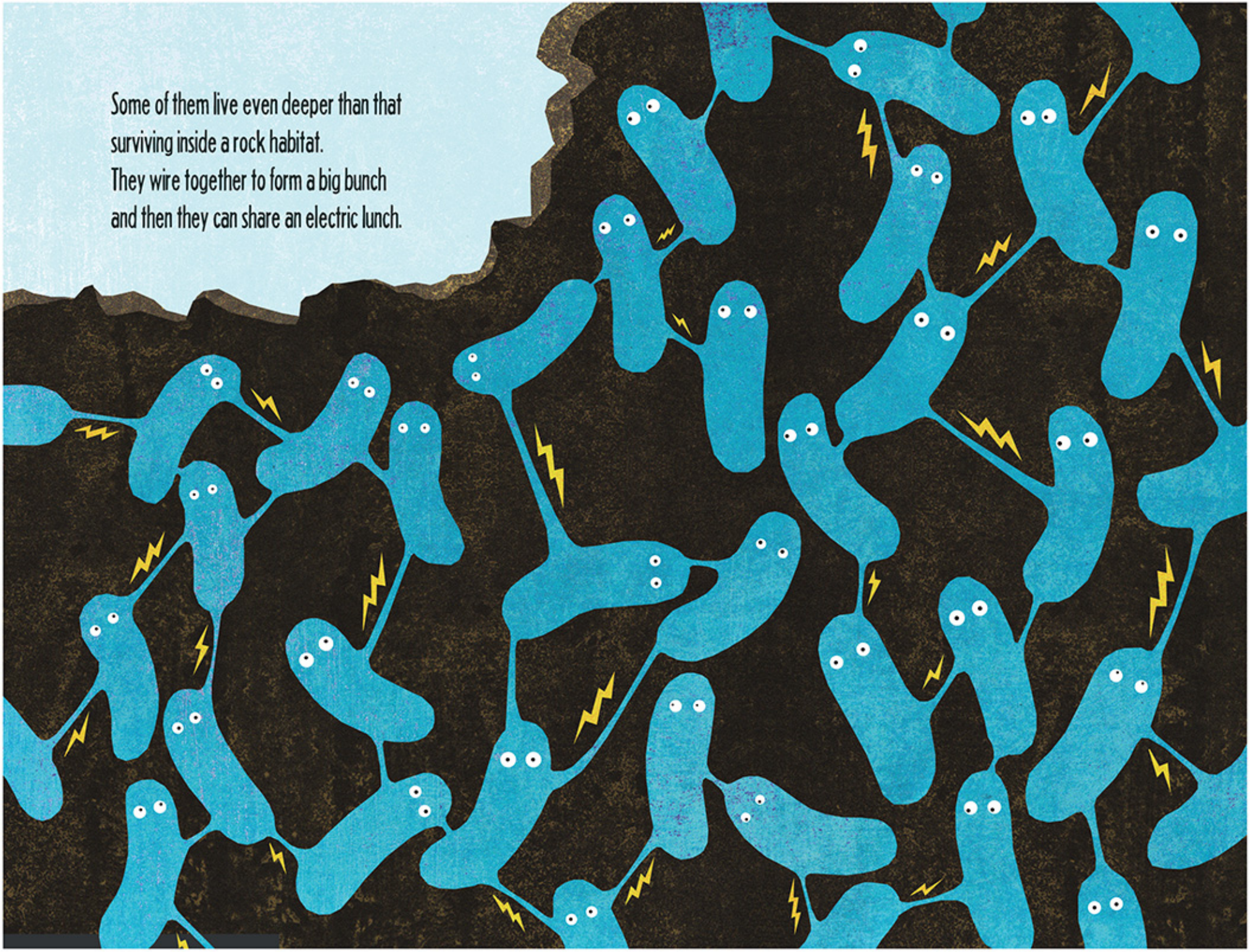
Inside the labs, the scientists work
to find the microbes wherever they lurk.
They I.D. each species they find alive
and try to determine how they survive.

In some ways microbes are kind of like you.
They all need to eat, and breathe and drink too.
The seafloor is not a place we could stay
but microbes live there in so many ways.

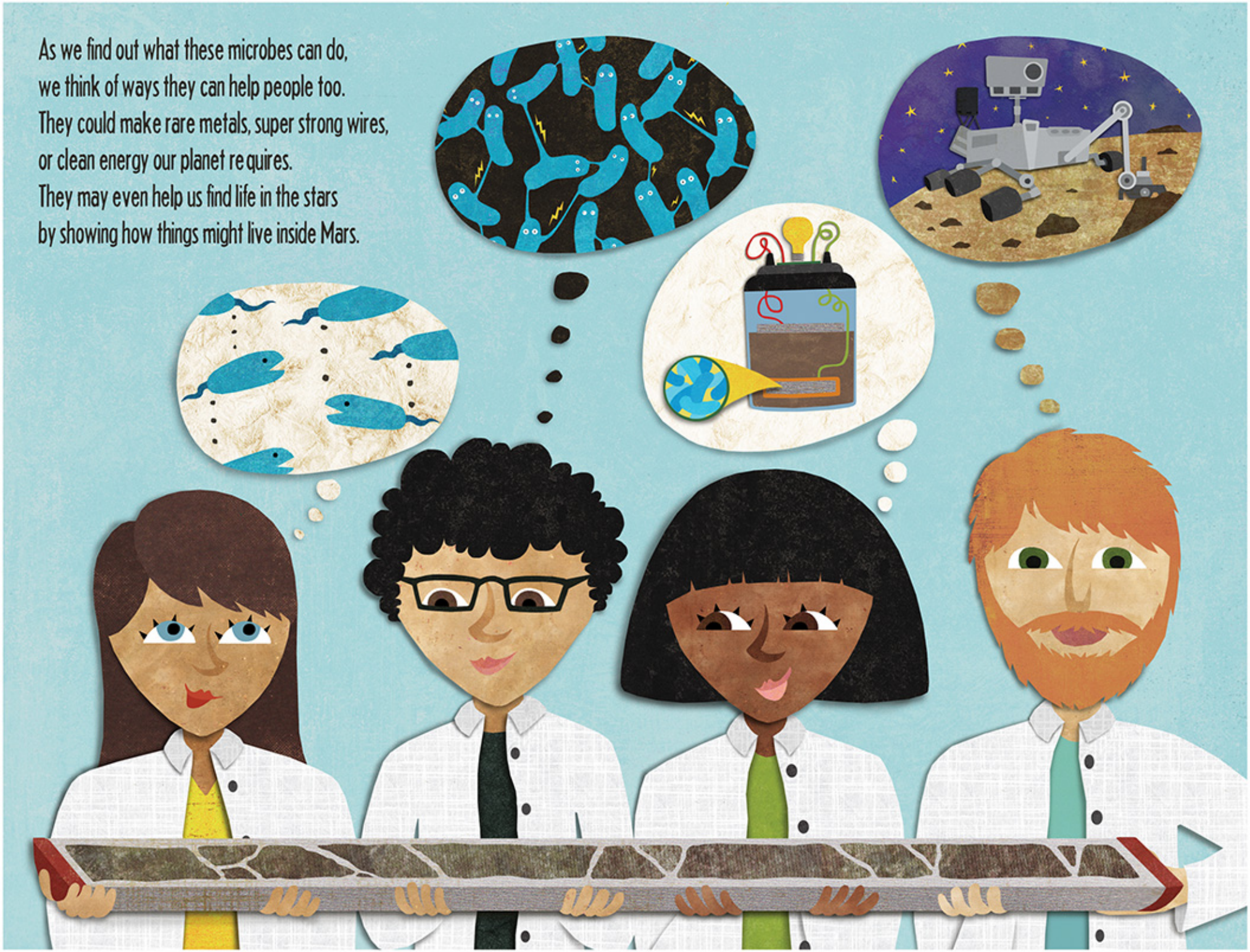


Some live in mud where waters will flow.
Those near the surface eat marine snow.

Those deeper down have a weird food they love.
They feed on the poop of microbes above.



Some of them live even deeper than that
surviving inside a rock habitat.
They wire together to form a big bunch
and then they can share an electric lunch.


As we find out what these microbes can do,
we think of ways they can help people too.
They could make rare metals, super strong wires,
or clean energy our planet requires.
They may even help us find life in the stars
by showing how things might live inside Mars.

We've just started learning about life in the seafloor.
Each expedition unearths something more.
The more we discover what the seafloor conceals,
the more possibilities our planet reveals.

GLOSSARY

Atmosphere: The atmosphere is the layer of the Earth that stretches from the ground to about seven miles above us. It contains the air, which is made of gases like oxygen, carbon dioxide and nitrogen.

Cell: Cells are like tiny building blocks that make up living things. Some living things, called microbes, have only one cell in their bodies. Other living things have multiple cells that link together to make-up their bodies. You, for example, have over 37 trillion human cells in your body, plus 100 trillion microbe cells (from the 100 trillion microbes living in your body).

Cell membrane: A cell membrane is basically the outer skin of a cell. The cell membrane holds the cell together and protects the insides. The cell membrane has openings in it that allow food, water and gases (like oxygen) to pass into the cell.

Chemosynthesis: Chemosynthesis is the process some microbes use to turn carbon, nutrients and other chemicals into energy that the microbe can use to live. Chemosynthesis is different from photosynthesis, where living things get the food energy they need from sunlight. Microbes that do chemosynthesis have been found in hydrothermal vents, hot springs, cold seeps, lakes underneath glaciers and inside the seafloor.

Core: Cores are samples that are drilled out of the ground or out of ice. The *JOIDES Resolution* drills the seafloor to collect cores. Its drill fills up a long tube with rocks and sediment. The tube is brought up to the ship and cut into 1.5 meter length pieces (about 5 feet) to make the cores. The science team onboard carefully records the order and location of each core so scientists all over the world can study and learn from them.

Decomposers: Decomposers are microbes (like bacteria) and multi-cellular fungi (like mushrooms) that feed on poop and dead stuff. Decomposers breakdown the cells found in poop and dead stuff to release the cells' energy and nutrients. Other living things can then use those energy and nutrients.

Food chain: A food chain is a diagram that shows which living things eat which other living things in a habitat. It is a quick way to show how energy travels from one living thing to another. Food chains always start with photosynthesizers getting energy from the sun or chemosynthesizers getting energy from carbon, nutrients or other chemicals. One example of a food chain is: (1) grass gets energy from the sun, then (2) a cow gets energy by eating the grass, and then (3) you get energy by eating the cow as a hamburger.

Genes: Genes are like the computer programs inside of the cells of living things. Genes tell the cell what to do. The type of genes a living thing has determines what type of species it is. When living things have babies, their genes are automatically passed onto their babies.

GLOSSARY

Habitat: A habitat is a place where a living thing is able to find the food, water, space and other things it needs to survive. A habitat can be a place like a forest, a desert, a coral reef or a pond. A habitat can also be on or inside another living thing's body. Some of the things habitats provide living things with are:
Water - Energy - Nutrients - Stuff to breathe - Enough space to live - Shelter - The right temperatures

Magma: Magma is what we call hot, molten rock inside the Earth. If magma comes out of the ground, then it is called lava.

Marine snow: Marine snow is the stuff that falls down through the ocean from all the animals and other living things that make the ocean their habitat. Marine snow gets its name because it falls in such large amounts deep in the ocean, marine snow looks like falling snow. Marine snow flakes are made mainly of poop and the remains of dead fish, algae, plankton, bacteria and other ocean creatures.

Microbe: A microbe is a living thing that only has one cell in its entire body. They are so tiny that we can only see them with a powerful microscope. Bacteria, viruses, amoeba, archaea and yeast are all types of microbes.

Microbiology: Microbiology is the scientific study of microbes.

Microbiologist: A microbiologist is a scientist who studies microbes. They specialize in studying living things that cannot be seen with the naked eye, like bacteria, viruses and fungi. They try to understand how microbes live, grow, and survive in their habitats, and how they affect the world around them.

Photosynthesis: Photosynthesis is the process plants, algae and some microbes use to turn water, carbon dioxide and sunlight into sugar and oxygen. The sugar stores energy the plant can use later to live and grow. Animals also get energy from these sugars when they eat plants. Most of the oxygen made during photosynthesis is released in the atmosphere. Humans actually could not survive if it were not for plants and microbes doing photosynthesis. There would not be enough food energy to eat or oxygen to breathe without them.

Sediment: Sediment is made of tiny bits of rock and microscopic fossils. The tiny bits of rock are sand, silt and clay. Sediment covers the seafloor, but can also be found in rivers, lakes and the sides of mountains.

Species: Species are types of living things that have bodies, behaviors and/or habitats that are different from other living things. There are about 1.5 million named species on Earth and there are probably millions more we have not discovered yet. Just to give a few examples, around the world there are over 3000 known species of snakes (like eastern diamondback rattlesnakes, western diamondback rattlesnakes and red diamond rattlesnakes), over 500 known species of sharks (like tiger sharks, sand tiger sharks and sandbar sharks) and over 240 known species of woodpeckers (like red-headed woodpeckers, red-bellied woodpeckers and red-cockaded woodpeckers).

THANK YOU!

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ABOUT THE AUTHOR

Kevin Kurtz is the author of the nonfiction children's books *A Day in the Deep*, *A Day on the Mountain*, and *A Day in the Salt Marsh*, as well as *Uncovering Earth's Secrets*, which was also illustrated by Alice Feagan. He was onboard the *JOIDES Resolution* during a research expedition in which microbiologist Jason Sylvan looked for microbes living in extinct, underwater volcanoes. To learn more about Kevin's books and school visit programs, visit http://kevinkurtz.homestead.com.

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Alice Feagan specializes in traditionaland digital cut paper illustration. She has illustrated picture books, chapter books, children's wall art, and products for clients such as National Geographic Kids Magazine, Kids Can Press, and World Book Encyclopedia. She was onboard the JR for a School of Rock educator workshop as the ship traveled from Curacao to Bermuda. To view Alice's portfolio visit http://alicefeagan.com.

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Water - Energy - Nutrients - Stuff to breathe - Enough space to live - Shelter - The right temperatures

Living things do not all need the exact same things. For example, some living things need fresh water (like humans). Other living things need salt water (like sharks). An environment that has the right combination of the things that a plant, animal, fungus, bacteria, etc. needs to survive is that living thing's habitat.

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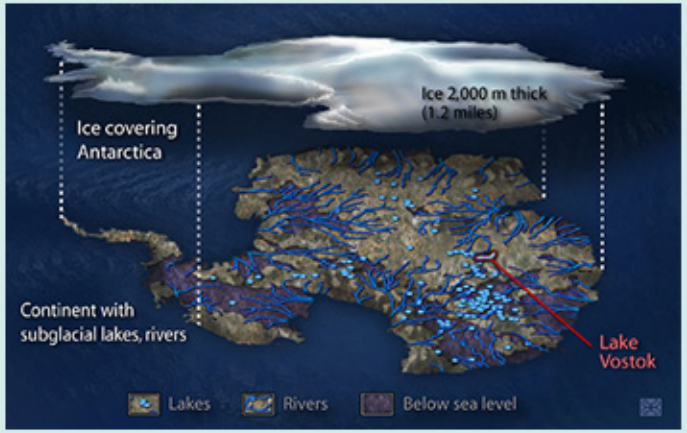
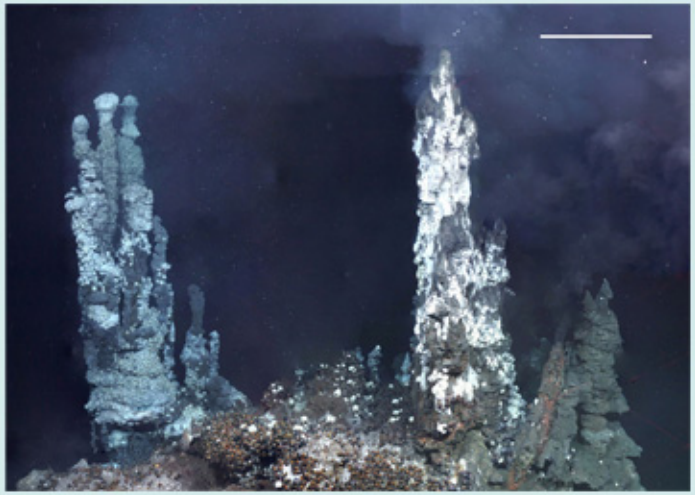
In the 1990's, scientists realized there were freshwater lakes and rivers underneath the mile of ice that covers most of Antarctica. These hidden bodies of water did not seem like good habitats, but some scientists thought there might be living things down there. In 2013, scientists drilled through a thousand feet (300 meters) of ice to reach the water in a place called Lake Whillans. When they brought samples of the water up, they discovered thousands of different kinds of microbes using this subglacial lake as their habitat! Because there is no sunlight, these microbes are chemosynthesizers. They eat chemicals and minerals, such as iron, sulphur, and ammonium. They find these chemicals in both the water and the rocks and sediments at the bottom of the lake.



Yellowstone National Park is famous for its wildlife. It is also famous for its hot springs, where water temperatures can be over 185 degrees Fahrenheit (85 degrees Celsius). Hot springs do not sound like good habitats, but scientists have discovered living things surviving in the scalding water. These microscopic creatures are called microbes. Most of them survive in hot springs by using photosynthesis. They take water, carbon dioxide and sunlight from this habitat and use them to make food energy. Photosynthesizing microbes are found in the green, yellow, orange and red parts of the hot spring (the microbes actually make those colors!). The water in the blue parts of the hot spring is much too hot for photosynthesizing microbes, but some microbes still live there. Those microbes eat chemicals in the water to get the energy they need. They do this through a process called chemosynthesis.

In 1977, scientists discovered places in the ocean where incredibly hot water pours out of the seafloor. They called these places hydrothermal vents. A hydrothermal vent does not seem like a good habitat. These vents are deep in the ocean, so water pressure there can be incredibly high. You could not see anything because no sunlight reaches that deep. Also, the temperatures there can reach 750 degrees Fahrenheit (400 degrees Celsius). Also, because vents are deep in the ocean, water pressure there can be incredibly high, and you could not see anything because no sunlight reaches that deep. Despite these conditions, many living things make their homes at hydrothermal vents. Some microbes live in the hot water pouring out of hydrothermal vents. They use chemosynthesis to get energy from the minerals and chemicals in the water. Animals such as tubeworms, squat lobsters and rattail fish also make the hydrothermal vents their habitat. These animals use the chemosynthetic microbes as the base of their food chains.



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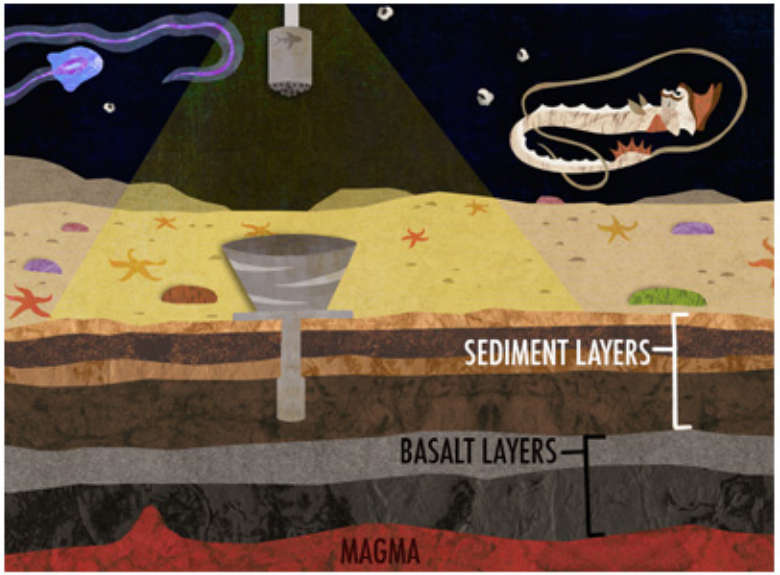
The seafloor is the ground at the bottom of the ocean. It is covered by sediment, which is what scientists call grains of fossils and sand. In most places, the seafloor is covered by a layer of sediment between 150 and 800 feet (45 and 245 meters) thick, though in some places, the seafloor sediment may be over 60,000 feet (18,000 meters) thick! Underneath the sediment is mainly a type of volcanic rock called basalt. This basalt forms as magma inside the Earth rises through the seafloor. When it gets near the cold ocean water, it cools into rock to form new seafloor. This occurs along mid-ocean ridges, where hydrothermal vents are found. Most of the seafloor is less than 6 miles (10 kilometers) thick from the ocean water to the magma.

VIDEO: https://youtu.be/EJP4l6t8Ui4



Scientists have identified and named about 1.5 million different types of living things. Scientists call each unique type of living thing a "species." So far they have found:

About 310,000 plant species
About 100,000 fungus species
About 5,500 mammal species
About 10,000 bird species
About 31,000 fish species
About 85,000 mollusk species
About 1,000,000 insects species
About 7,600 bacteria and archaea species

As well as many other species in other groups of animals and microbes!

We are still discovering new species and most scientists agree there are many other species left to discover. Different scientists have different opinions about how many total species there are on Earth. Most scientists think there are probably around 9 million species total. We won't know for sure exactly how many species are out there until we find them all.

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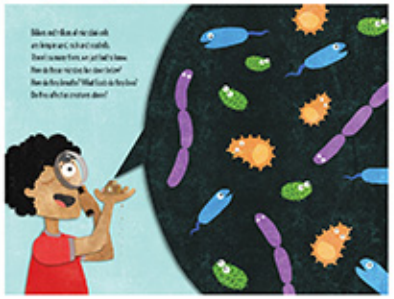
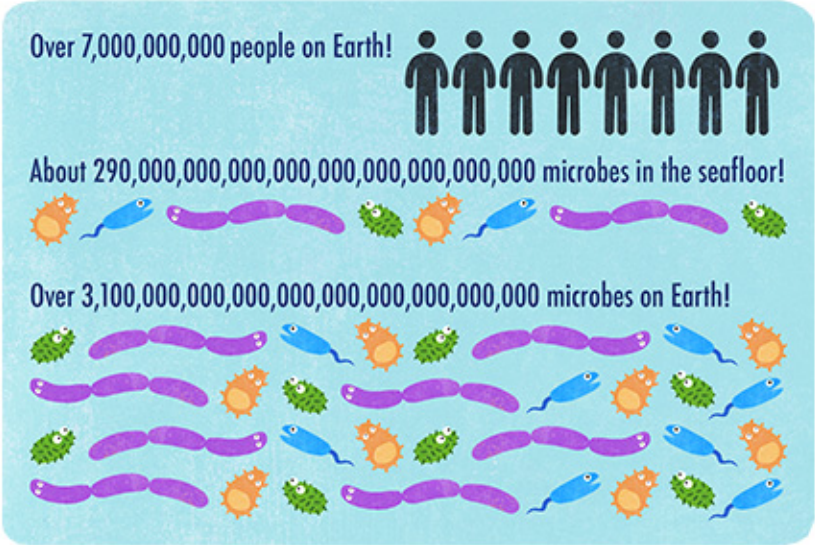
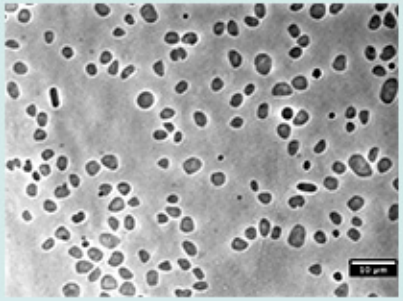


There are over 7,000,000,000 people on Earth (and counting!). That is a big number, but it is not nearly as big as the number of microbes on Earth. It is estimated there may be over three nonillion microbes on Earth. They are by far the most numerous living things on Earth. The seafloor alone may contain 290 octillion microbes!



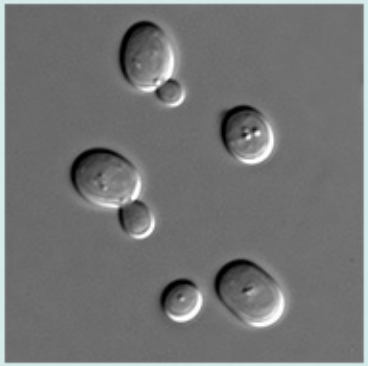


Archaea are microbes that look a lot like bacteria. For a long time scientists thought all archaea were bacteria. In the 1970's, they started realizing that the genes of archaea are very different from the genes of bacteria. Archaeal genes are in some ways more like the genes in our cells than the genes in bacteria. Archaea can live in environments that most living things cannot, such as in the scalding water of hot springs and hydrothermal vents.

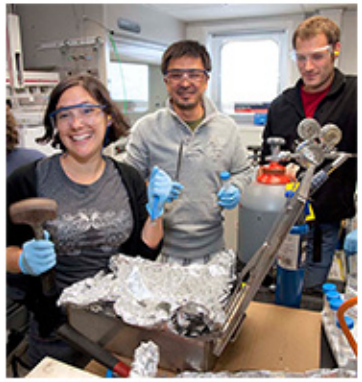
ANIMATION: https://youtu.be/qi1MgmaQM0Q

Bacteria are one of the most common types of microbes, not only in the seafloor, but everywhere. Bacteria tend to come in three basic shapes. Some look like Mike and Ike candies (or Mike and Ike's with tails). Some look like balls without enough airin them. Some look like twisty worms or fusilli pasta. Even though different bacteria species may look mostly the same, there is a lot of diversity among bacteria. There is so much diversity that there can actually be more differences between two different species of bacteria than there are between you and a tomato plant.

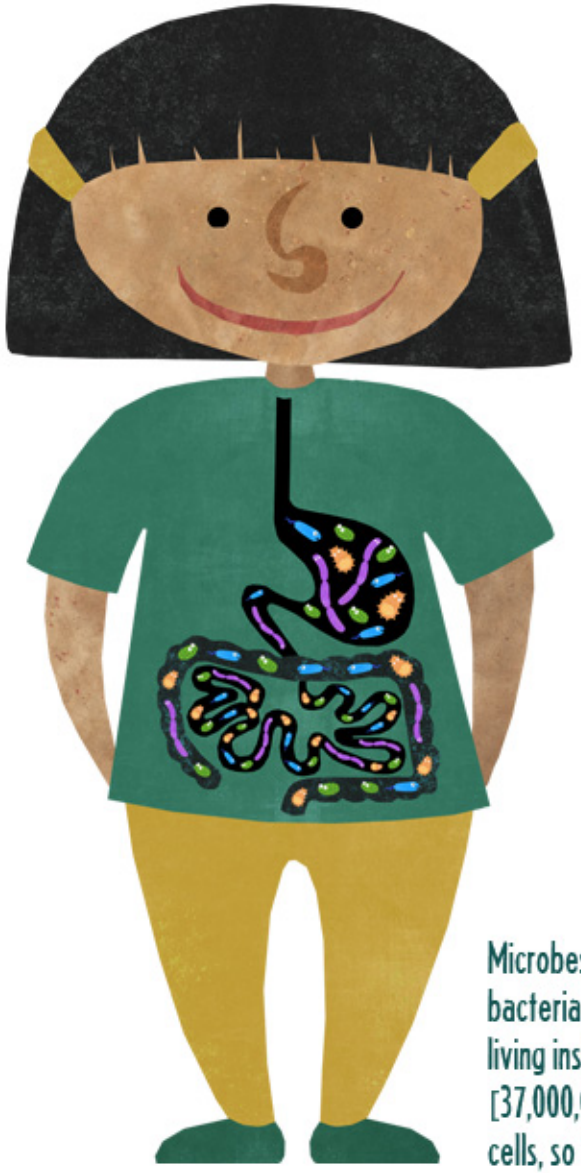
Viruses are usually called microbes, but not all scientists agree they are actually living things. Viruses don't need to eat, drink, or breathe. When they come in contact with a cell from a living thing, though, they can take over the cell and force it to make new viruses. Different kinds of viruses can take over cells from every living thing on the planet, including plants, bacteria and people. The photo shows a bunch of viruses attached to a bacterium.



Though the largest known living thing on Earth is a fungus (the 3.5 mile (5.6 kilometers) wide honey mushroom that lives in Oregon), many fungi are tiny, single-celled microbes, including ones that live in the seafloor. Fungus microbes are decomposers that feed on poop and dead stuff. Seafloor funguses tend to be in the mud and sediment where they can feed on marine snow and other stuff left behind by living things.



Scientists who study microbes are called microbiologists. They specialize in studying living things that cannot be seen with the naked eye, like bacteria, viruses and fungi. They try to understand how microbes live, grow, and survive in their habitats, and how they affect the world around them.



Humans are so tiny that sixteen sextillion adult humans could fit in the Earth

16,000,000,000,000,000,000,000 humans = 1 Earth

Fleas are so tiny that thirty-three thousand of them could fit in an adult human

33,000 fleas = 1 human

Bacteria are so tiny that one trillion of them could fit in a flea

1,000,000,000,000 bacteria = 1 flea

Viruses are so tiny that ten thousand of them could fit in a bacteria

10,000 viruses = 1 bacteria

Microbes are very tiny compared to us. An adult human can be over 33 million billion (33,000,000,000,000,000) times bigger than a bacteria. We are so much bigger that our bodies are habitats for microbes. You have about 100 trillion (100,000,000,000,000) microbes living inside of you right now. This is about three times as many human cells as you have in your body (you have only about 37 trillion [37,000,000,000,000] of those). Even though we have so many microbes in our body, microbe cells are very tiny compared to human cells, so they only make-up a couple pounds of your weight.

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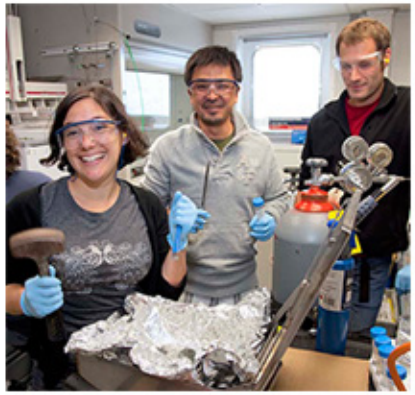

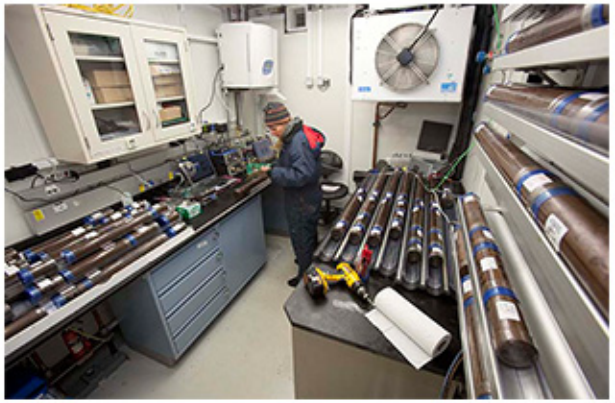

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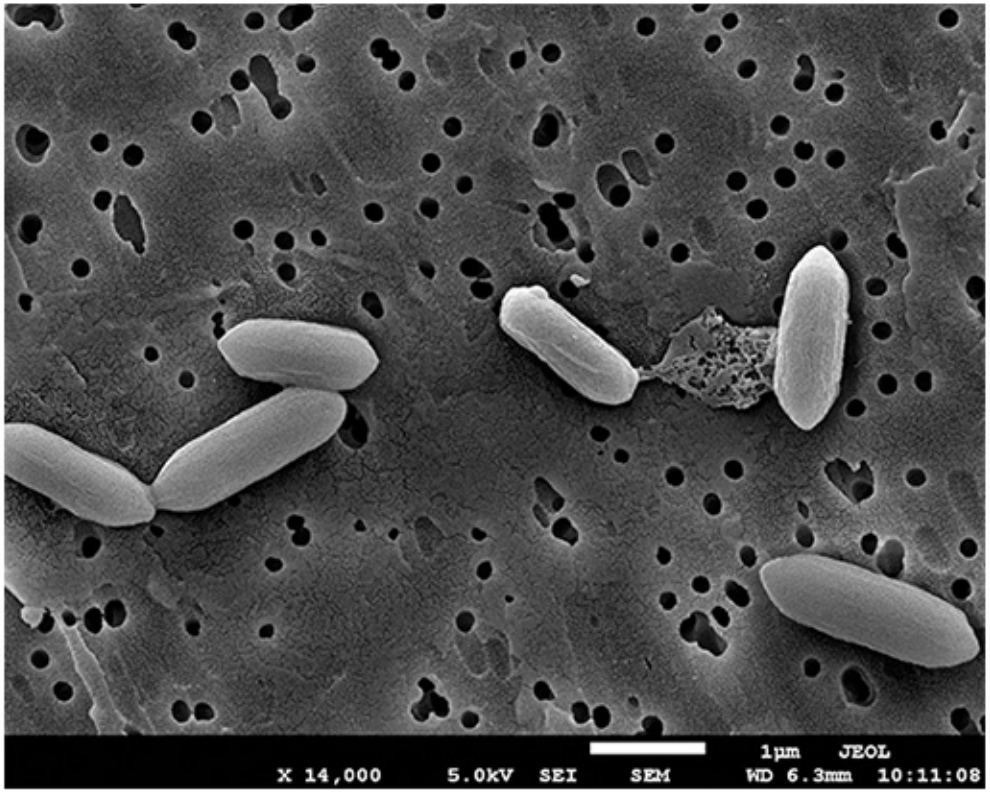
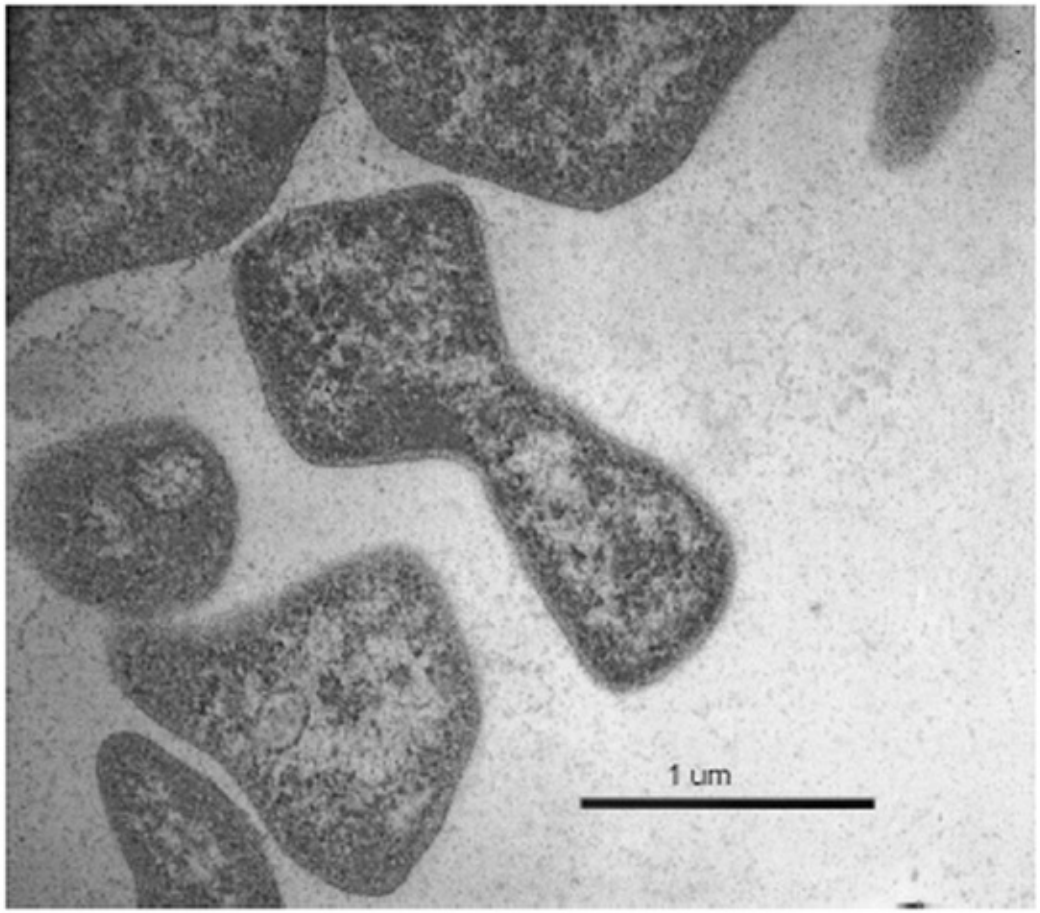
This microscope photograph was taken of bacteria that were collected 1,118 feet (341 meters) below the seafloor. These bacteria were found northeast of New Zealand in an extinct underwater volcano that was part of the Louisville Seamount Trail. Their species name is *Bacillus rigiliprofundi.*



VIDEO: https://youtu.be/akXrwDR4FkU



This microscope photo was taken of archaea that were collected 810 feet (247 meters) below sea level. They were found just off the eastern coast of Japan in the sediments that fill the Nankai Trough. Their species name is *Methanocelleus submarinus.*

Mikucki JA, Liu YT, Delwiche M, Colwell FS, Boone DR. 2003. Isolation of a methanogen from deep marine sediments that contain methane hydrates, and description of Methanoculleus submarinus sp nov. Applied and Environmental Microbiology 69: 3311-3316

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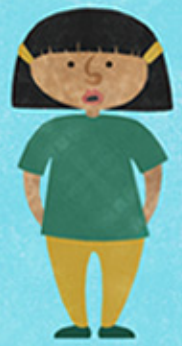
AIR



People need oxygen to breathe. We breathe oxygen from the atmosphere using our lungs. The oxygen in our **atmosphere** comes from plants, algae and microbes that do **photosynthesis**.

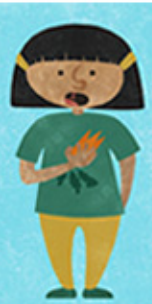
Microbes near the top of the seafloor breathe oxygen. They absorb it from the ocean water flowing through the seafloor. Microbes deeper in the seafloor live in places without oxygen. They have to breathe other things, such as iron and sulphur.

TEMPERATURE

People can survive in temperatures between 40 and 94 degrees Fahrenheit (4 and 35 degrees Celsius). Because of technology we have created, such as clothing, insulated buildings, heaters, and air conditioners, we can live year round in some places that get much warmer or colder than that.

Seafloor microbes live in temperatures that are just slightly above freezing.

FOOD



People get energy and nutrients from the food we eat. We eat animals, like chickens, goats, fish and crabs, and also plants, like carrots, lettuce, mangoes, rice, walnuts, chili peppers and sunflower seeds. Just about all the food you eat was grown on a farm.

Most microbes in the seafloor sediment eat poop and dead stuff to get the energy and nutrients they need. Some microbes there eat other microbes instead. Microbes deeper down in the seafloor eat minerals, chemicals and metals to meet their energy and nutrient needs. They get these by eating rocks or by eating minerals and chemicals in the seawater that flows between the cracks in the rocks.

SPACE

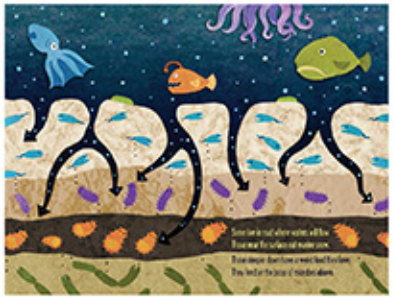
Living things need space to survive ("space" meaning room to move and live, not "space" meaning what you travel through to get to Mars). We need space for a home to shelter us from weather, predators and thieves. We also need space for our food to grow. Though most people don't grow their own food, the average person needs at least 1.2 acres of farmland to grow enough food each year to allow that one person to survive.

Microbes are tiny, so they don't need nearly as much space as a person, but they still need space to live on, as well as enough space to provide the food, water and stuff to breathe that they need to survive.

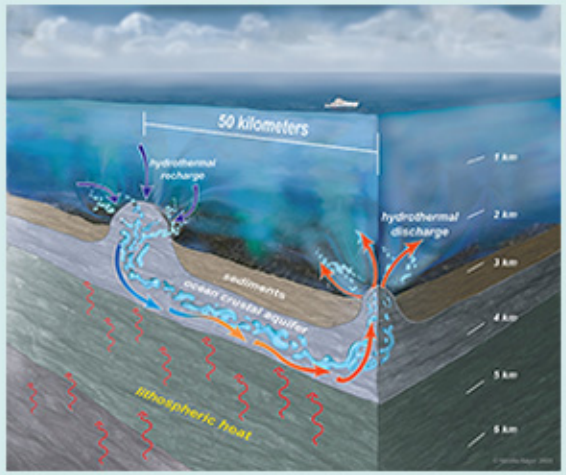
WATER

Humans need to drink fresh water. All of the water we drink came originally from the rainwater that collects in rivers, lakes and in the ground. Thanks to the technology we have created, we are able to move freshwater from these places to our kitchen sinks.

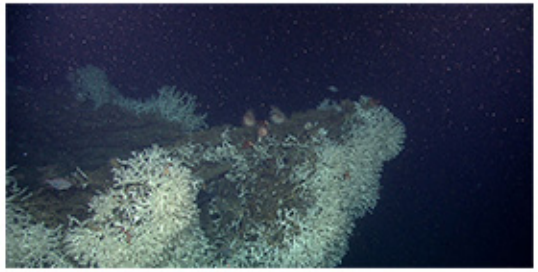
Seafloor microbes drink the salty seawater that flows between the cracks and empty spaces in the seafloor. Microbes absorb the water they need through their skin (called **cell membranes**).



Each layer in the seafloor sediment can be a different habitat, each with a different community of microbes. This is part of a core that was drilled in the South Pacific Gyre by the *JOIDES Resolution*. If you look closely, you can see different bands of red, beige and brown. Each colored band may be the home to different species of microbes.

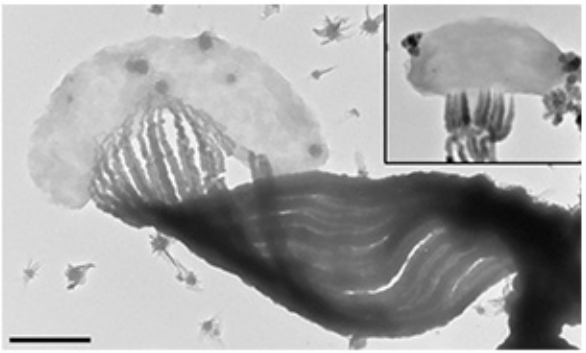


Microbes would not be able to survive in the seafloor if the seafloor was not full of water. About 2% of all the water in the ocean is in the seafloor. (That's about 7,000,000,000,000,000,000 (7 quintillion) gallons in the seafloor, which is more than twice as much freshwater as is found in all the rivers, streams, lakes and groundwater on land around the word!)



Marine snow is the stuff that falls down through the ocean from all the animals and other living things that live there. It falls in such large amounts that deep in the ocean it looks like it is snowing. The flakes are mainly made of poop and the remains of dead fish, algae, plankton and other ocean creatures. Marine snow eventually reaches the seafloor, where decomposing microbes can eat it to get the energy and nutrients they need.

As gross as it may seem, many microbes love poop. People are grossed out by poop because poop can contain the type of microbes that we call "germs" (the ones that can makes us sick). This is because animal poop contains many microbes from inside the animal's gut. For example, about 30% of the stuff in your poops is made of your body's microbes. We avoid poop, but for decomposing microbes, poop does not make them sick and it is an easy way to get the energy and nutrients they need.



Microbes that live deep in the seafloor cannot eat marine snow, because it does not seep that far down into the seafloor. Instead, many of these microbes eat the poop of other microbes. The seafloor sediment is made of layers of different species of microbes, each eating the poop of the microbes above them. Microbe poop isn't like ours, though. Depending on what they eat and breathe, ty tmicrobes can poop out chemicals, minerals and even metals.

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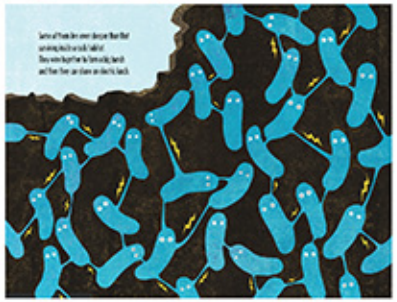
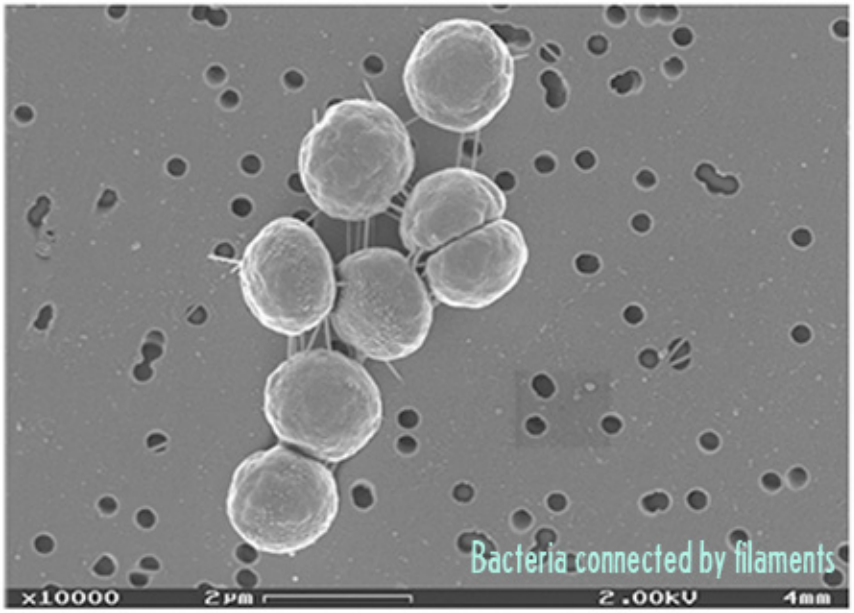
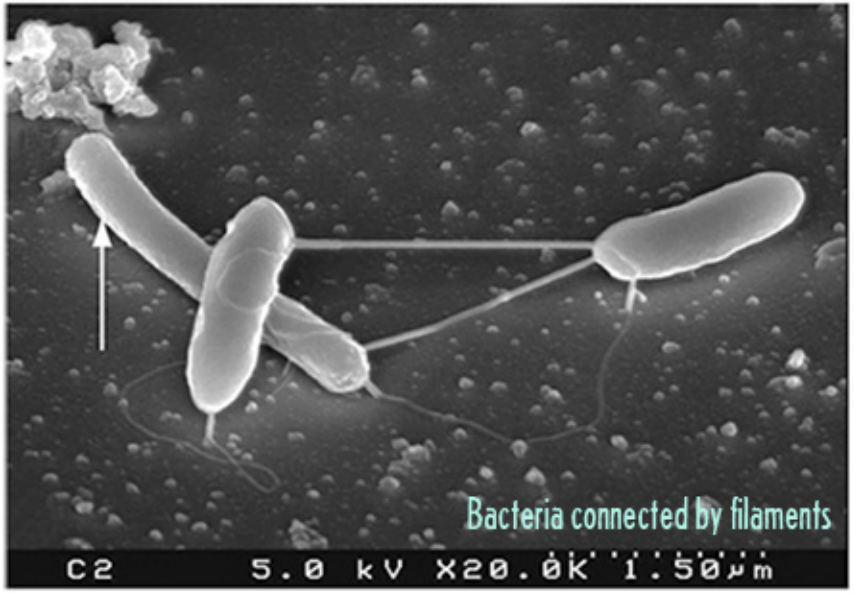


Bacteria that live inside seafloor rocks live in a place without oxygen. Some of these microbes have a unique way of getting the energy they need to survive. They can pull electrons out of the rocks to make electricity and then share the electricity with other bacteria. Filaments grow between the bacteria to connect them. The electricity flows through the filaments, just like electricity flows through the wires in your house.

VIDEOS: http://www.pnas.org/content/suppl/2014/08/19/1410551111.DCSupplemental



Bacteria connected by filaments



Bacteria connected by filaments

So far, the deepest microbes have been found in the ocean is 2,500 meters below the seafloor. That equals about 8,200 feet or over 1.5 miles!

Electricity happens when electrons flow. Electrons are non-living particles that are so tiny, we have not yet invented a microscope that can see one. All around your home, electrons flow through wires to provide energy to lights, refrigerators, phone chargers, and everything else that runs on electricity. All around your body, electrons are flowing too. When the oxygen you breathe reaches sugars from the food you ate, the oxygen pulls electrons from the sugars, which creates electrical current. The cells in your body use this felectrical current to make ATP, which is the fuel our cells use to power our body. All living things that breathe oxygen use the oxygen to turn sugar into energy.

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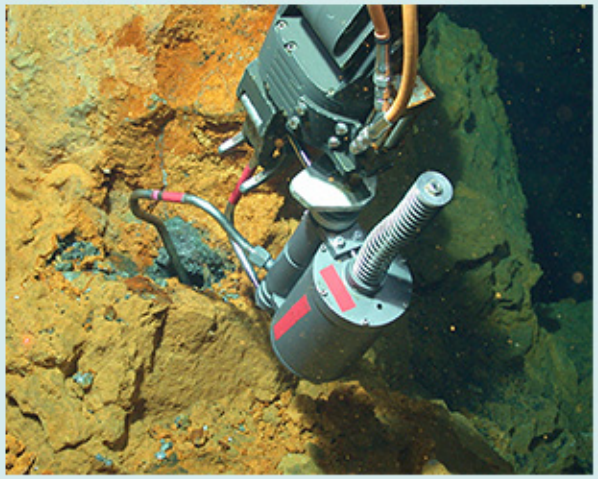
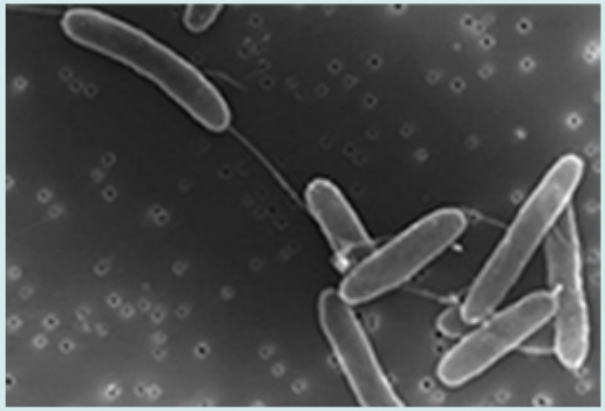
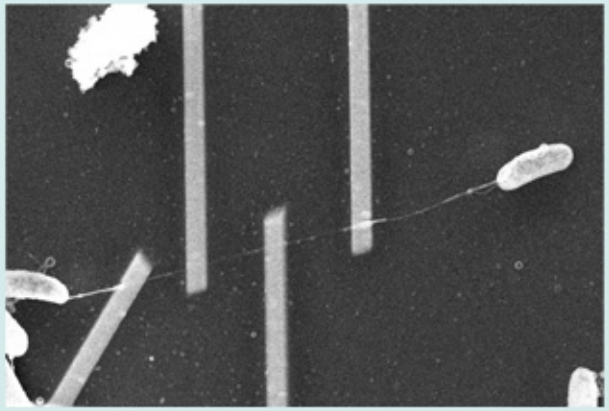
The rusty layer on these rocks was put there by microbes that eat iron and poop out rust. Some microbes eat and breathe metals and minerals and then poop them out as different kinds of metals and minerals. The minerals and metals they poop out can be ones that are useful to people, but hard to find. Some microbiologists are looking at seafloor microbes to see if any of them poop out rare metals and minerals that people need. These microbes could potentially work for us by making metals for us, without us having to mine the metals from the ground.

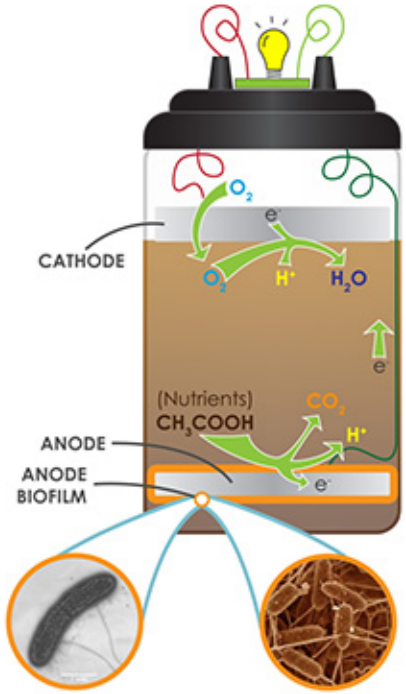


The seafloor microbes we are now discovering may help us find living things on other planets. We now know some living things can be far from the sunlight and can get the energy they need from rocks and minerals. That means there may be microbes on other planets, like Mars, that also live underground and eat and breathe rocks.





Some microbes make filaments that are very strong and are also great at conducting electricity. These filaments act just like tiny living wires. Some microbiologists are looking at how microbes make these filaments. They may find ways these microbe wires can help us make new sustainable technology that can improve our lives.



Bacteria that conduct electricity are already being used to make electricity in small batteries. These microbe-powered batteries make renewable energy without making any pollution. Some microbiologists are looking for ways these microbes may one day produce large amounts of pollution-free electricity for us.

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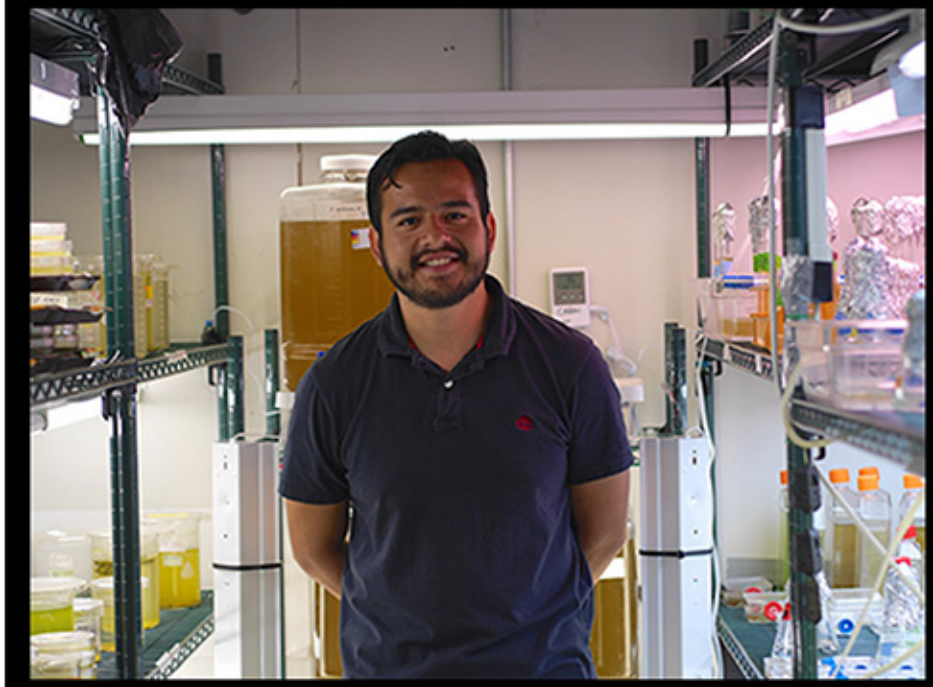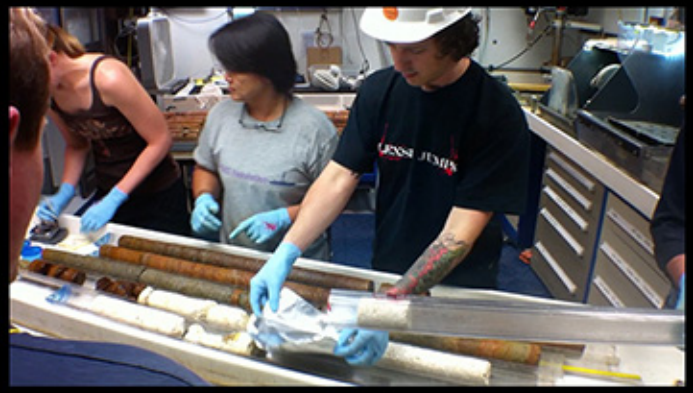
Science isn't just a bunch of facts we already know. It is a way to learn new things so we can better understand the world we live in. Scientists are basically explorers who observe the biggest and smallest things in the universe (and everything in between). They use their creativity to solve problems and learn new things. The seafloor microbiologists are helping us understand how these microbes affect our ocean, atmosphere and other parts of the world. The microbiologists also study what these microbes do and then think of ways that microbes can possibly help us. Like all scientists, they are helping us to better understand the world, so we can make better decisions and lead better lives.