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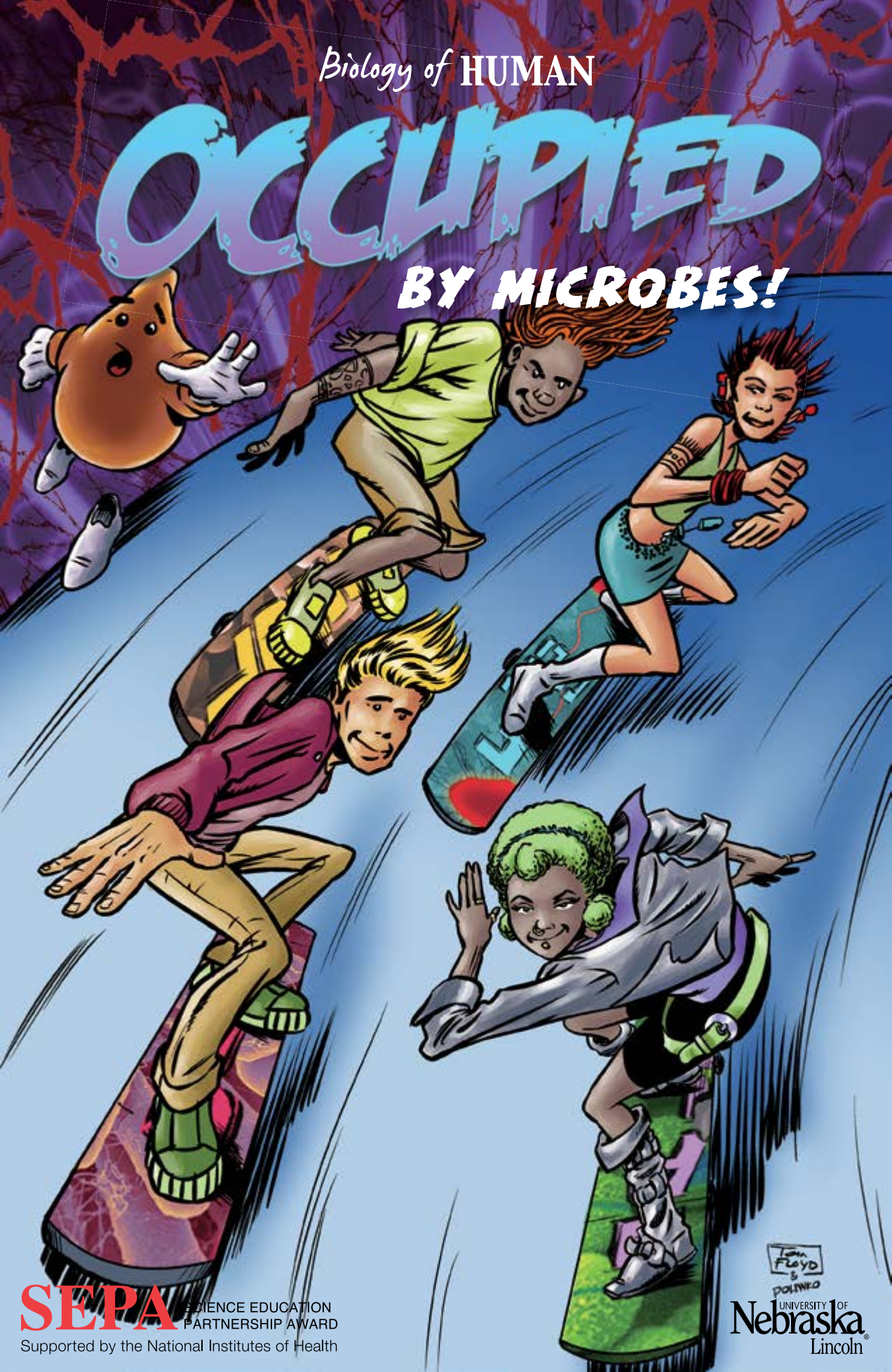
Biology of HUMAN

OCCUPIED BY MICROBES!



Tom Floyd & Polinko

SEPA SCIENCE EDUCATION PARTNERSHIP AWARD
Supported by the National Institutes of Health

University of Nebraska Lincoln

OCCUPIED

by

Judy Diamond, Tom Floyd, Rebecca Smith,
Ann Downer-Hazell, Martin Powell,
Nick Poliwko, Angie Fox, Amy Spiegel,
Trish Wonch Hill, and Julia McQuillan

Our bodies are home to more microbes than human cells. The balance of helpful to harmful microbes in our bodies can make us sick or healthy. The Biology of Human project focuses on helping people understand themselves by exploring scientific principles that underlie modern research in human biology. Biology of Human is an alliance of science educators, artists, science writers, and biomedical researchers working to increase public understanding about viruses and infectious disease.

In this comic, Daniel and Miguel find themselves in the world of the microbes, where they meet the Roid (*Bacteroides*), Longo biffi (*Bifidobacterium longum*), E. coli (*Escherichia coli*), Strep Sally (*Streptococcus salivarius*), and Candi (*Candida albicans*). There are about 100 trillion life forms living inside us. Every human being contains a whole universe of organisms, all living together. To keep our human cells happy, we have to keep our microbes in balance. That's how we stay healthy.

Zea Books
Lincoln, Nebraska

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http://worldofviruses.unl.edu

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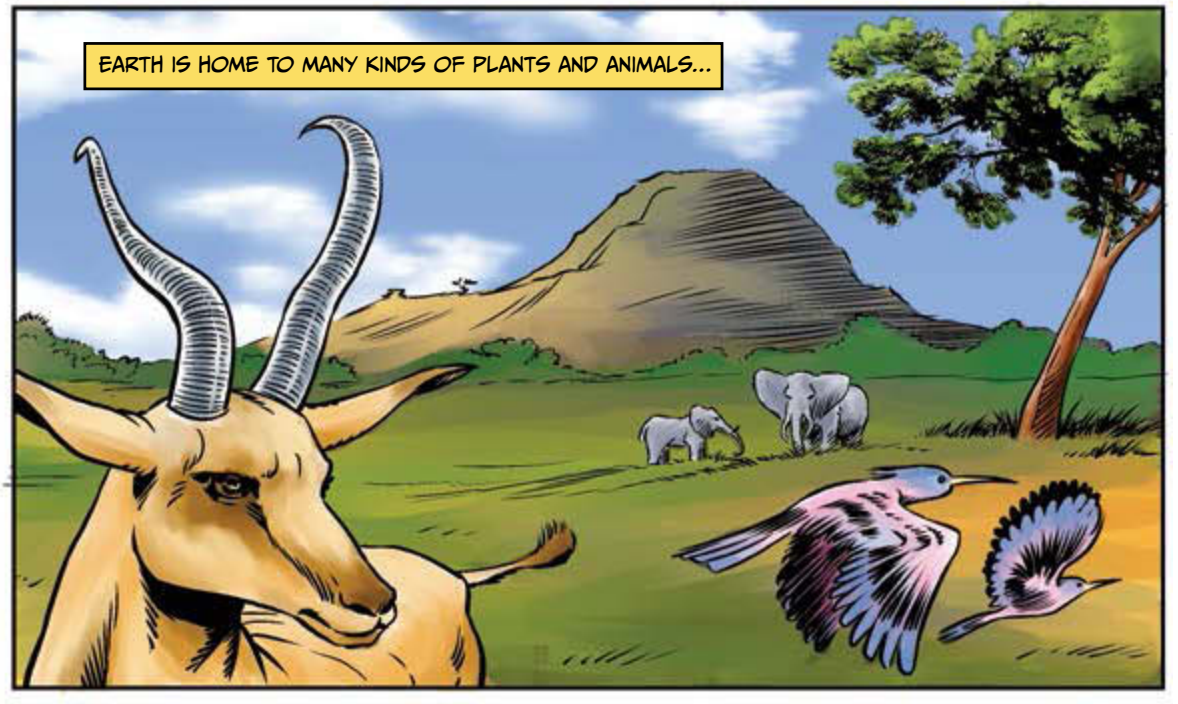
OUR WORLD.


EARTH IS HOME TO MANY KINDS OF PLANTS AND ANIMALS...


...INCLUDING HUMANS.
THE INCREDIBLE SHRINKING MAN
BOOK

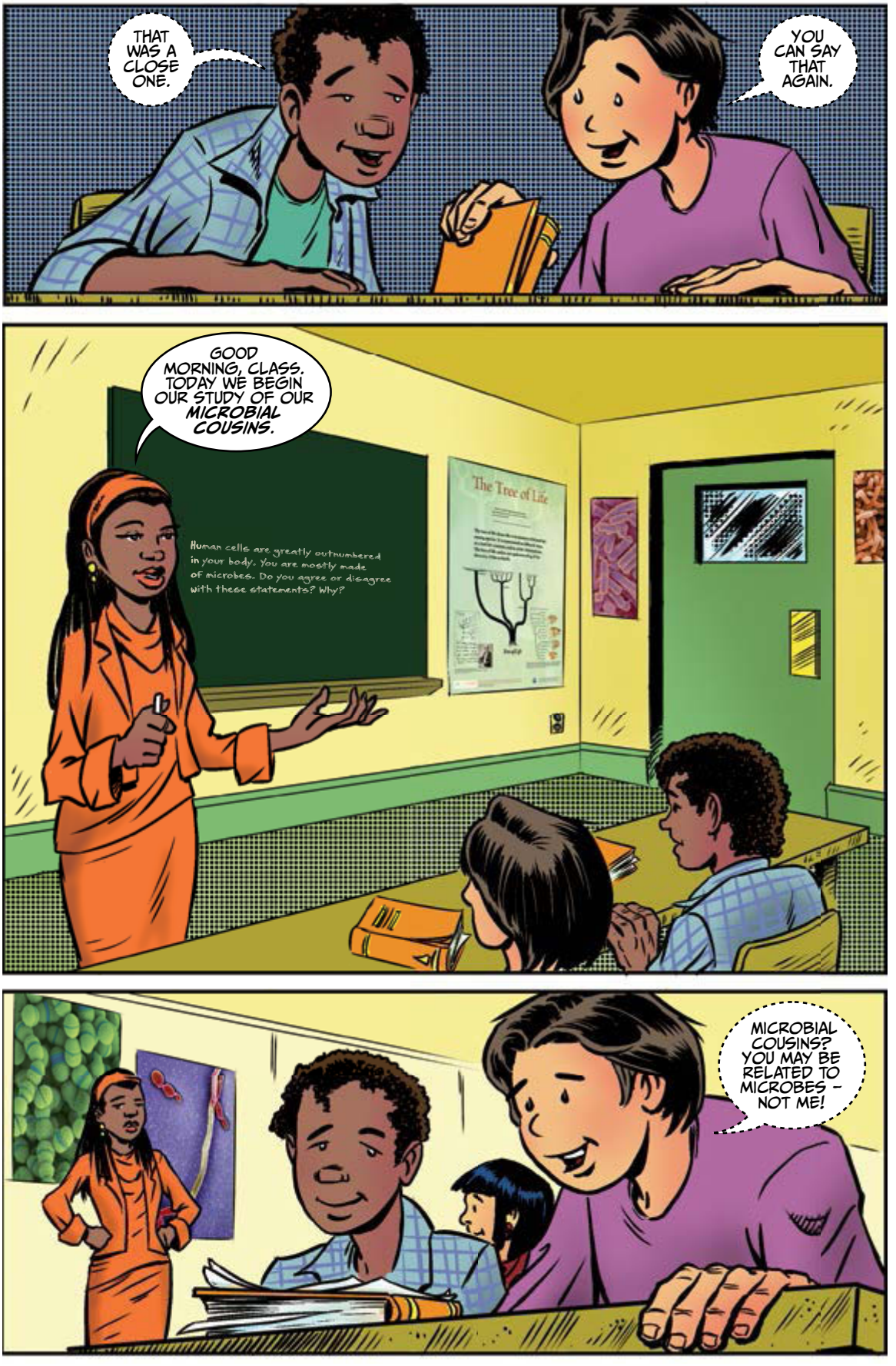

HUMANS THINK THEY ARE NUMBER ONE...
... BUT LOOKS ARE DECEIVING.
THERE ARE *WHOLE UNIVERSES OF INVISIBLE LIFE* WE HUMANS OVERLOOK.
MYRIADS OF *MICROBES* CROWD EVERY NOOK AND CRANNY OF EARTH.


I CAN'T HUNT FOR YOUR LOST SHOE NOW, MARIA. I'M LATE!
BUT I'VE LOOKED *EVERYWHERE*, MIGUEL..!
IF YOU'D REALLY LOOKED EVERYWHERE, THEN YOU WOULD'VE ALREADY FOUND IT.
THAT'S NOT FUNNY. C'MON, HELP ME.
PLEEEEEEEEEASE?


YOU LOOKED EVERYWHERE, HUH? HERE YOU ARE.
YAY!
I'VE GOTTA GET A MOVE ON!
HASTA LUEGO MI MIGUEL!
HEY, MIGUEL! BEEN WAITIN' FOR YA. YOU'RE LATE, MAN!
HEY DANIEL, YEAH, I KNOW!
LET'S GET GOING BEFORE THE BELL RINGS!


UH OH...
SCIENCE PROVES NUTHIN'
C'MON, DANIEL WE'VE GOTTA STOP THIS JERK.
ARE YOU NUTS, MIGUEL? THAT GUY IS BIGGER THAN BOTH OF US!
YEAH, BUT WATCH WHEN WE TEAM UP!
HEY— LEAVE HIM ALONE!!
BACK OFF!!
MIND YER OWN BIZNESS, TWERPS!


THIS IS OUR BUSINESS!
HEY--!
NOT SO TOUGH NOW THAT IT'S THREE AGAINST ONE, ARE YOU?
EHH, GO ON AND GIT OUTTA HERE.
I'M SICK OF LOOKIN' AT YA.
LATER, CLASS HAS BEGUN...
Human cells are greatly outnumbered in your body. You are mostly made of microbes. Do you agree or disagree with these statements? Why?


THAT WAS A CLOSE ONE.
YOU CAN SAY THAT AGAIN.
GOOD MORNING, CLASS. TODAY WE BEGIN OUR STUDY OF OUR MICROBIAL COUSINS.
Human cells are greatly outnumbered in your body. You are mostly made of microbes. Do you agree or disagree with these statements? Why?
The Tree of Life
MICROBIAL COUSINS? YOU MAY BE RELATED TO MICROBES – NOT ME!

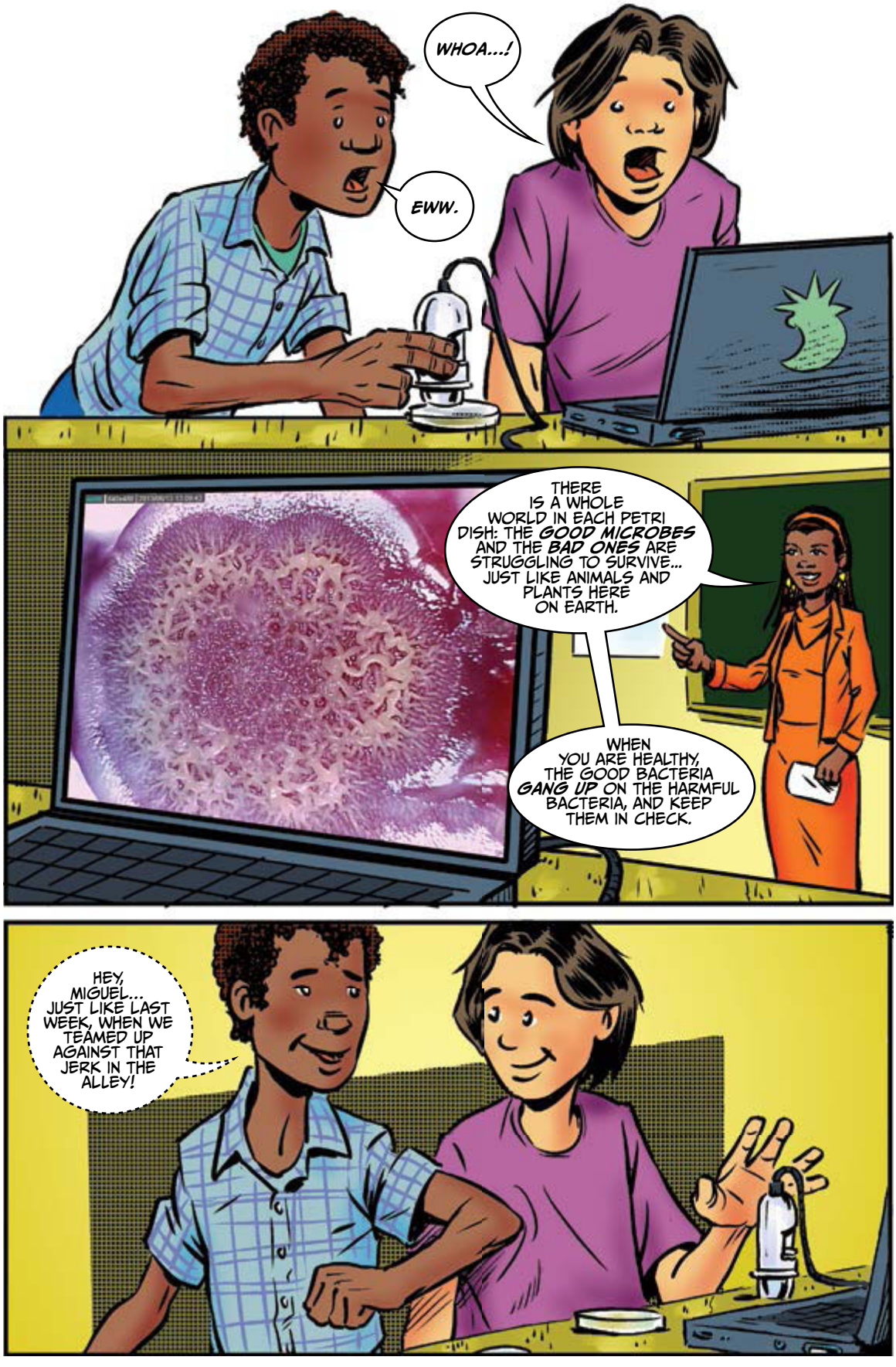

OH YES, YOU ARE, MIGUEL. ALL LIVING THINGS ON EARTH EVOLVED FROM A COMMON ANCESTOR.
SO WE ARE ALL RELATED ON THE TREE OF LIFE.
JUST LIKE COUSINS ON A FAMILY TREE


LISTEN CLOSELY, CLASS. HANDLE THESE PETRI DISHES VERY CAREFULLY.
USE YOUR MARKERS TO DRAW A LINE DOWN THE MIDDLE, SEPARATING IT INTO TWO HALVES.


NOW UNWRAP YOUR COTTON SWABS...


...AND RUB ONE END ON YOUR CHEEK INSIDE YOUR MOUTH.

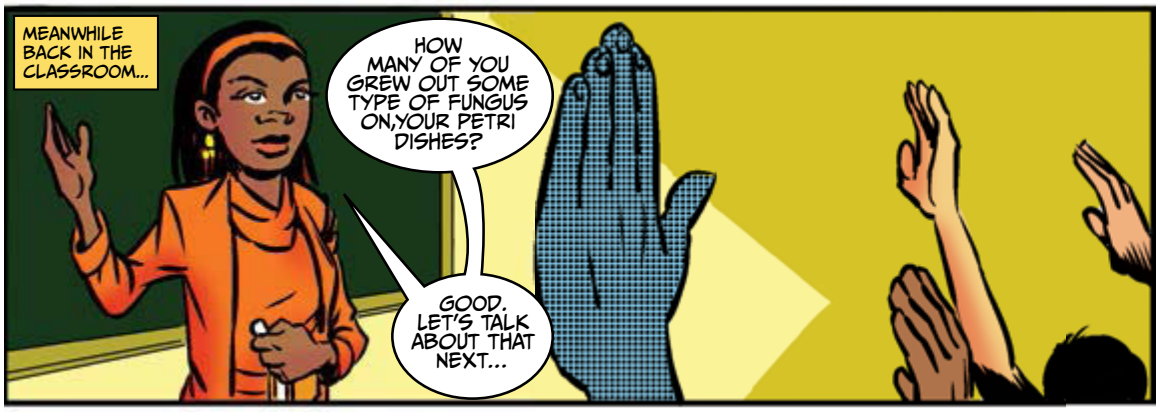

ALL RIGHT... NOW RUB THE OTHER END OF THE SWAB ACROSS THE SKIN OUTSIDE YOUR MOUTH.
AFTER YOU'VE DONE THAT, RUB EACH SIDE OF THE YOUR PETRI DISH WITH A DIFFERENT END OF THE SWAB.
THAT WAY, HALF OF THE DISH HAS MICROBES FROM INSIDE YOUR MOUTH AND THE OTHER HALF CONTAINS MICROBES FROM OUTSIDE ON YOUR SKIN.
OKAY, WE'RE PUTTING THESE AWAY IN THE CABINET FOR A WEEK TO SEE WHAT GROWS.
THE NEXT WEEK...
ALL RIGHT, CLASS. LET'S TAKE A LOOK AT YOUR PETRI DISHES NOW.
BE PREPARED FOR A BIT OF A SHOCK.

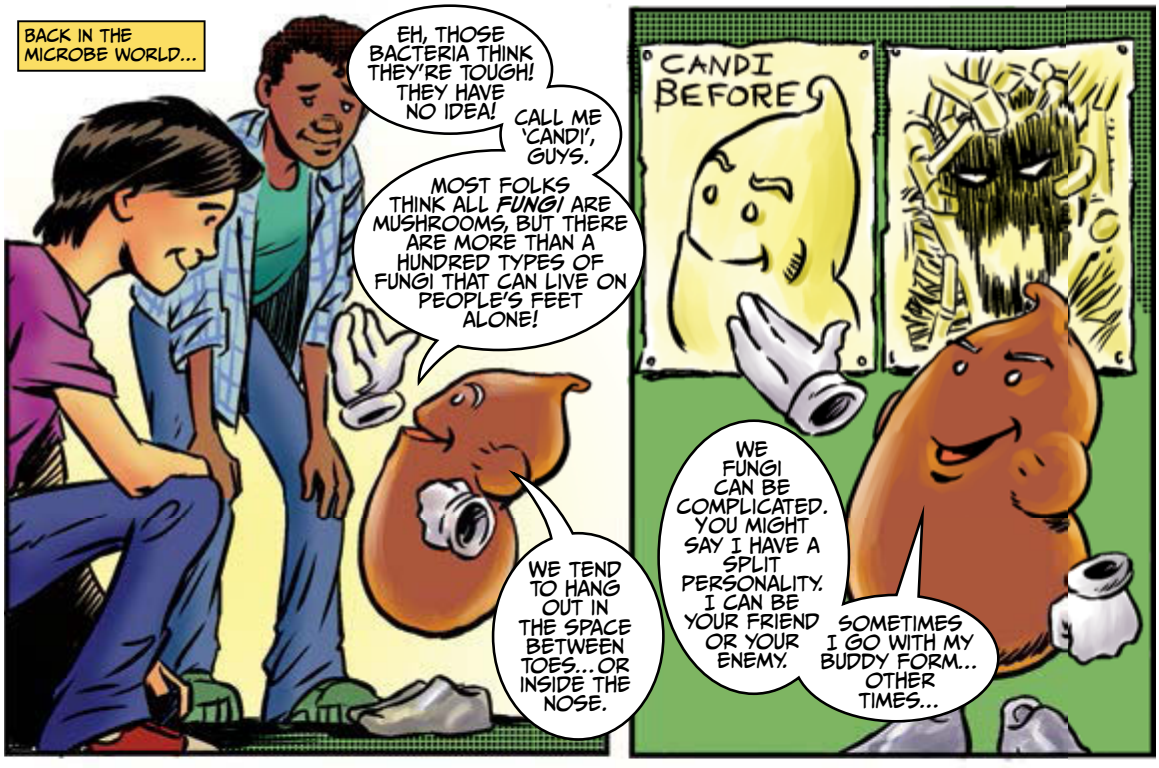

WHOA...!
EWW.
THERE IS A WHOLE WORLD IN EACH PETRI DISH: THE GOOD MICROBES AND THE BAD ONES ARE STRUGGLING TO SURVIVE... JUST LIKE ANIMALS AND PLANTS HERE ON EARTH.
WHEN YOU ARE HEALTHY, THE GOOD BACTERIA GANG UP ON THE HARMFUL BACTERIA, AND KEEP THEM IN CHECK.
HEY, MIGUEL... JUST LIKE LAST WEEK, WHEN WE TEAMED UP AGAINST THAT JERK IN THE ALLEY!


YEE-OOWWW--!!
WHAT THE HECK –
-- IS GOING ON?!
WH-WHERE ARE WE??
SOMEHOW WE'VE SHRUNK DOWN INSIDE THE PETRI DISH...!

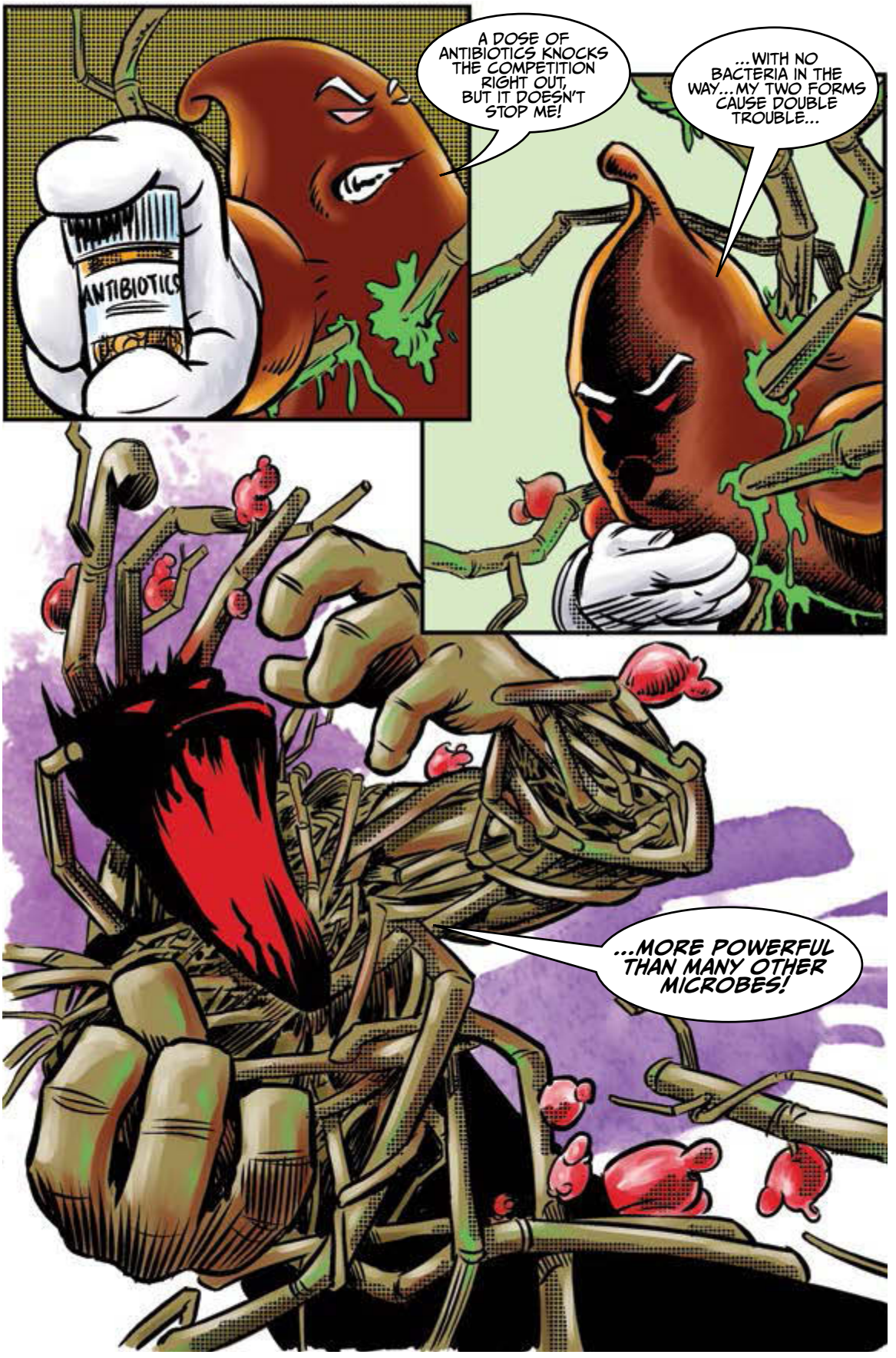

WE'RE IN THE WORLD OF THE MICROBES!
HI THERE. COME ON OVER.
I'M 'THE ROID.'
ROID


UH, HEY. UM, WHAT'S UP?
WHO ARE YOU?
MEET THE GANG!
LONGO BIFFI...
E. COLI...
AND STREP SALLY!
WE KEEP THINGS RUNNING SMOOTH AROUND HERE.
YUMM-MMY! I HAVE THE BEST JOB, I GET TO BREAK DOWN SUGARS IN THE HUMAN GUT.
IF YOU ARE HEALTHY, YOUR GUT HAS ENOUGH OF MY BUDDIES TO KEEP BAD MICROBES OUT.
THE ROID
I TRAVEL TO HUMAN BABIES' INTESTINES THROUGH MOM'S MILK. I MAKE AN ACID THAT KEEPS OUT BAD BACTERIA!
THAT'S RIGHT, TOGETHER, BUGS LIKE US KEEP MICROBE BULLIES AWAY!
LONGO BIFFI
JUST CALL ME 'E. COLI.' MOST OF MY FAMILY MEMBERS ARE HELPFUL (BUT SOME OF MY SIBLINGS GIVE US A BAD REP).
I MAKE VITAMIN K – A VITAMIN YOU HUMANS NEED BUT CAN'T MAKE YOURSELVES – FROM FOOD IN HUMAN GUTS!
I USUALLY LIVE IN THE MOUTHS OF HUMANS....AND I MAKE A TOXIN THAT POISONS DANGEROUS MICROBES!
E. COLI
STREP SALLY


MEANWHILE BACK IN THE CLASSROOM...
HOW MANY OF YOU GREW OUT SOME TYPE OF FUNGUS ON,YOUR PETRI DISHES?
GOOD. LET'S TALK ABOUT THAT NEXT...


BACK IN THE MICROBE WORLD...
EH, THOSE BACTERIA THINK THEY'RE TOUGH! THEY HAVE NO IDEA!
CALL ME 'CANDI', GUYS.
MOST FOLKS THINK ALL *FUNGI* ARE MUSHROOMS, BUT THERE ARE MORE THAN A HUNDRED TYPES OF FUNGI THAT CAN LIVE ON PEOPLE'S FEET ALONE!
WE TEND TO HANG OUT IN THE SPACE BETWEEN TOES...OR INSIDE THE NOSE.
CANDI BEFORE
WE FUNGI CAN BE COMPLICATED. YOU MIGHT SAY I HAVE A SPLIT PERSONALITY. I CAN BE YOUR FRIEND OR YOUR ENEMY.
SOMETIMES I GO WITH MY BUDDY FORM... OTHER TIMES...


...I GROW *WILD*...AND TURN INTO A HYPHA!
CANDI


A DOSE OF ANTIBIOTICS KNOCKS THE COMPETITION RIGHT OUT, BUT IT DOESN'T STOP ME!
ANTIBIOTICS
...WITH NO BACTERIA IN THE WAY...MY TWO FORMS CAUSE DOUBLE TROUBLE...
...MORE POWERFUL THAN MANY OTHER MICROBES!


IN THE SICKEST PEOPLE, I CAN TURN INTO A DEADLY KILLER...
...CAPABLE OF INVADING NEARLY ALL BODY SYSTEMS AND ORGANS!!!


H-HOW CAN CANDI BE STOPPED BEFORE IT GETS OUT OF CONTROL?!
HERE'S ONE WAY.
C'MON!
WE'VE GOT TO GET THE GOOD BACTERIA BACK!!
NO...NO!!
NOT THAT! STAY BACK!
KEEP AWAY FROM MEEEEEE EEEEEEE!!


REMEMBER CLASS, THERE ARE ABOUT 100 TRILLION LIFE FORMS LIVING INSIDE US HUMANS.


EVERY SINGLE ONE OF YOU ARE A WHOLE UNIVERSE OF ORGANISMS...
...ALL LIVING TOGETHER.


TO KEEP OUR HUMAN CELLS HAPPY, WE HAVE TO KEEP OUR MICROBES IN BALANCE.
THAT'S HOW WE STAY HEALTHY.
NOPE, I'M NOT GONE, GUYS.
I'M JUST WAITING FOR MY CHANCE TO GET THE UPPER HAND... AND TRANSFORM INTO MY OTHER SELF!
THE END

Cast of Characters

Bacteroides – "the Roid"

You are what you eat. Most of the microbes in your gut belong to this group, especially if you eat lots of protein and animal fat. The Roid is one of the most common bacteria in your intestines, which is good news for you. A lot of the food you eat is made of complex sugars that are difficult for your body to break down for energy. Without the Roid, those foods might pass through your intestines untouched. The Roid has the tools to break those big sugars down, releasing energy that keeps you going every day. Helping you get the energy you need from food is just one of the ways the Roid helps you out. There are millions of Roids in your intestines and together they keep other microbes out. With so many Roids around, harmful invading microbes have no place to settle, so most of the time they pass through your gut unnoticed, without making you sick.

Cast of Characters

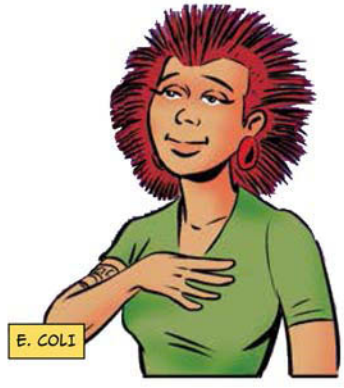
Bifidobacterium longum – "Longo Bifi"

Mom's milk encourages the growth of these friendly bacteria, thereby crowding out the harmful ones. Longo bifi convert sugars in mother's milk into chemicals your body can use for energy. You probably don't remember, but Longo Bifi were likely the first bacteria you met. There are more of these bacteria in babies than any other type. Longo Bifi are passed from mom to baby through the mother's milk. They travel to the intestine and begin producing acid that prevents harmful bacteria from moving in. Some baby formula manufacturers even add Longo Bifi to the mix. That's good for babies. When you get older, your diet changes. Your new diet includes all kinds of bacteria that begin to grow in your gut. Even with all the other new bacteria moving in, Longo Bifi sticks around. You still find it in your food – especially in fermented foods, like yogurt, kimchi, and sauerkraut. It lives inside you until you're an adult.

Cast of Characters

Escherichia coli – "E. coli"

These bacteria live in your gut and in the intestines of many other animals as well. Some strains help you by producing Vitamin K – an important vitamin that your body cannot make without its bacterial helpers. Other strains of E. coli produce toxins that can make you sick. E. coli is a famous gut microbe. It shows up in the news every few months because some strains can cause food poisoning. Even though it gets a bad rap in the news, the E. coli that live in you are actually helpful. They live peacefully in your large intestine, helping you digest your food and producing vitamin K. How does E. coli end up in the news as a microbial terror? Some strains of E. coli are just a little different, and these can produce dangerous toxins that cause diarrhea and fever. The illness can be serious, sometimes even deadly. Although E. coli isn't usually a bad guy, the members of this family that make toxins can be really nasty.



Cast of Characters

Streptococcus salivarius – "Strep Sally"

When these bacteria settle on your teeth, they build a sticky landing pad for other microbes, which we call plaque. You probably picked up Strep Sally from your environment just after you were born. Strep Sally continues to live in your mouth for the rest of your life. The hot, humid interior of your mouth is an ideal home. Strep Sallies grow where they don't need to compete with other microbes for food and space. They even produce a toxin that keeps competing microbes from being able to grow nearby. Strep Sally gloms onto your teeth with long threads. If it grows alone on teeth, Strep Sally doesn't seem to cause much harm. However, it doesn't take long for sticky Strep Sally to be joined by millions more microbes. Brushing and flossing helps dislodge these teeming millions from your teeth.

Cast of Characters

Candida albicans – "Candi"

This tough little yeast helps break down carbohydrates in your gut. When your immune system gets out of balance, Candi can overgrow and cause disease. Candi is a two-faced fungus that lives in your body. Most of the time, it lives in a peaceful form as a common resident of your gut. But sometimes Candi shows its dark side, causing serious disease. Antibiotics can be good medicine for fighting bacterial disease. However, antibiotics can't tell the difference between good and bad microbes. They sometimes wipe out all the helpful bacteria in your intestines. With room to spread and grow, Candi's forms take over – the hyphal form is particularly nasty, capable of invading tissues and organs. Candi can even invade your bloodstream and make you seriously sick.

Bacteria Wanted Dead not Alive

Yersinia pestis – "Y-Pest"

Y-Pest usually lives out in the country, deep in animal burrows. But when it makes a trip into the city, it can bring disease and death to people. In the United States, Y-Pest is at home out West on the range, living in prairie dog towns. Occasionally, it hitchhikes on a flea to infect people. When a flea sucks the blood of an infected animal, it swallows some Y-Pests, too. The bacteria travel to the top of the flea's stomach. There they reproduce, forming a plug. Now no food can reach the flea's stomach. Eventually the flea starves. But before it does, it may spread Y-Pest by biting a new host: a rat, a prairie dog, or a person. When an infected flea bites a person, most of the Y-Pests are swallowed up by immune cells that patrol the body. But a few survive. These bacteria make chemicals to outwit the body's immune system, like a burglar turning off a security system. Once the body's defenses are shut down, Y-Pests get into the bloodstream. Doctors have to give infected people antibiotics quickly, or Y-Pest can kill them.

Bacteria Wanted Dead not Alive

Clostridium tetani – "King Tet"

If you step on a rusty nail, will you get lockjaw? Maybe. This soil-dweller is a sneaky shape-shifter. These bacteria live in the soil where farm animals live. King Tets don't tolerate heat or oxygen, and they form tough little packets called spores. Spores are tiny hitchhikers. They grab onto things and catch a ride to places where it's dark and airless, like the inside of a wound. Then they shape-shift back into their regular form and start making a toxin. When people get sick from King Tet, it's called tetanus. Tetanus short-circuits the signals between muscles and the brain. Often the first symptom that King Tets are inside you is "lockjaw," painful spasms of the muscles in your jaw. Is it dangerous to step on a rusty nail? Yes and no. It's not the rust that gives you King Tet, but the dirt, which contains spores. The tetanus vaccine can protect you against King Tet by introducing your immune system to a weak form of the King Tet toxin. The vaccine works like a wanted poster for King Tet. It allows your immune system to recognize an invader that might do your body harm. When actual King Tets show up, your immune system remembers the toxin from before, and fends off the bacteria.

Bacteria Wanted Dead not Alive

Bacillus anthracis – "Thrax"

Most of the time this soil-dweller infects cows and other grass-munchers, but rarely, a farmworker may be infected. In World War II, it was recognized that Thrax could be used to attack people – as a bioweapon. Thrax can hang out in the soil for years as a spore—a tiny, tough capsule that contains just the bacterium's genetic code and some parts of the cell. Flies that feed on dead cows or bite living ones for their blood can spread Thrax, too. When a cow dies, scavengers open the carcass, and spores escape to infect other cattle. People can catch Thrax from infected livestock. Because most ranchers now vaccinate their cattle, Thrax doesn't often infect people in the United States. Still, people can come down with Thrax through contact with dust or dirt that contains spores. Thrax can cause two different kinds of disease. One kind is an annoying skin disease. But, if you breath Thrax spores into your lungs, you can get a lung infection that can make you very sick and even die. Both kinds of anthrax are treated with antibiotics. Big cities worry they could be attacked with biological weapons made from Thrax spores. They have drills so their fire fighters, police, and doctors can practice how to respond.

Microbes on the Tree of Life

Life on Earth arose billions of years ago. The first life was small and simple. But every mouse, elephant, blade of grass, and human being on the planet can trace its ancestry back to that first life form. Today, living things with many cells, like animals and plants, are vastly outnumbered by tiny microbes that we can only see with a microscope. We have trillions of microbes inside us. They include bacteria, archaea, fungi, and other very small living things. Inside our bodies, we have microbes that span the entire tree of life.

The Tree of Life is like a family history for life on this planet. From simple origins, all life evolved into the many species we know today. But surprisingly, there are only three general branches of living things. The branch with the largest organisms—Eucarya—includes plants, animals, and fungi. They have cells with a nucleus that contains their DNA. Candi (*Candida albicans*) is a kind of fungi that belongs to this group of organisms, making it more closely related to people than other kinds of microbes.

The branch with the most abundant group of living things—Eubacteria—are single-celled bacteria like the Roid (*Bacteroides*), Longo biffi (*Bifidobacterium longum)*, E. coli (*Escherichia coli)*, and Strep Sally (*Streptococcus salivarius)*. The branch that lives in the strangest places—Archaea— are single-celled life forms like Mr. Smith (*Methanobrevibacter smithii*). These microbes often live where other life can't in places like hot springs, salt lakes, deep-sea vents, and sometimes in your body.

Nearly every living thing on this planet can be sorted into one of these three groups. These great branches on the tree of life show how all life on Earth today arose from a common ancestor long ago. Everywhere scientists look, they find more microbe relatives to add to the tree.

http://worldofviruses.unl.edu

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