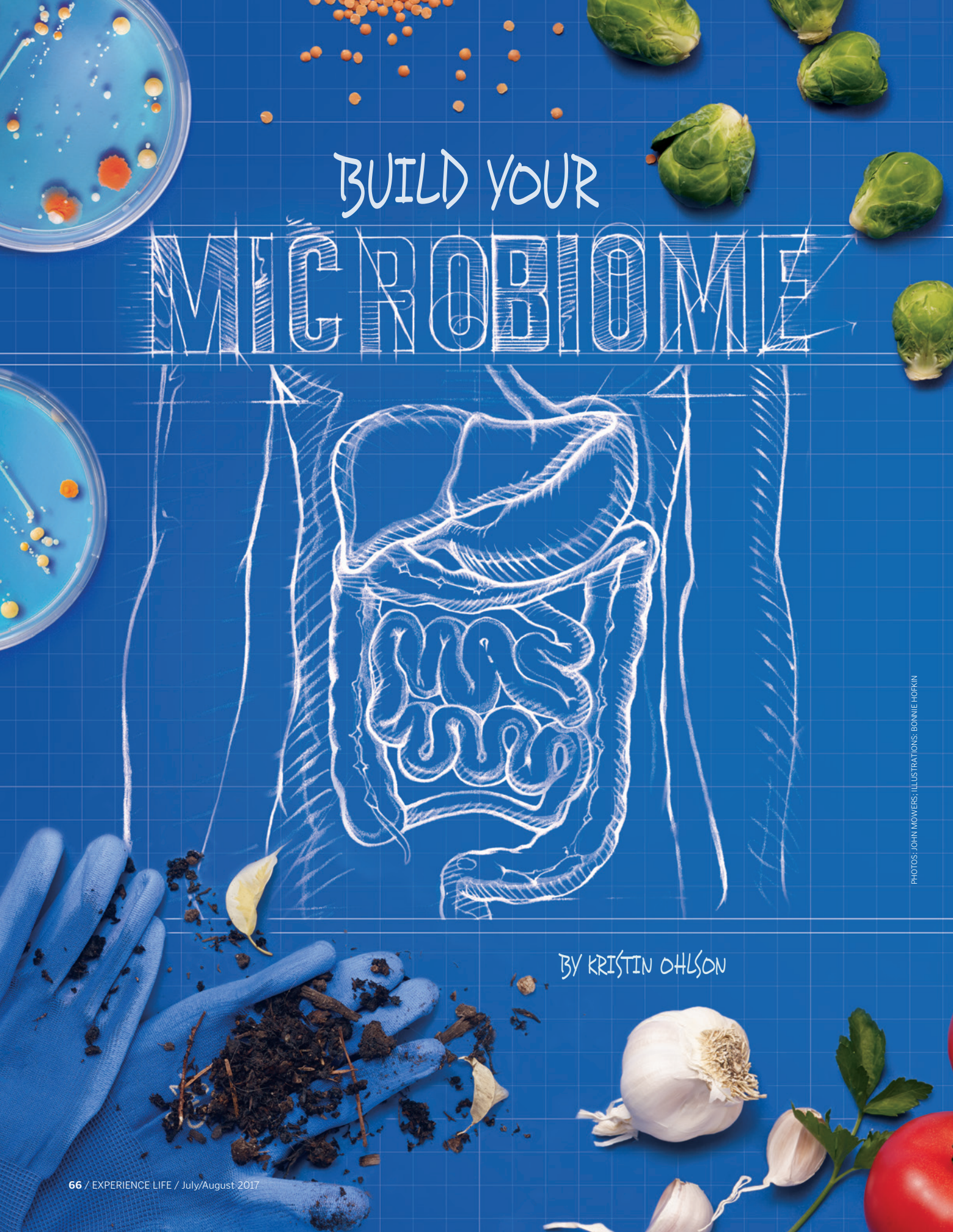
BUILD YOUR MICROBIOME



BY KRISTIN OHLSON

PHOTOS: JOHN MOWERS; ILLUSTRATIONS: BONNIE HOFKIN

MODERN LIFE IS TOUGH FOR THE TRILLIONS OF MICROBES LIVING IN YOUR BODY. LEARN WHAT YOU CAN DO TO PROTECT AND STRENGTHEN THEM.

Mary Ruebush settled into her airplane seat and looked on with dismay as a boy in a nearby seat reached into his backpack and began sanitizing his immediate environment with antibacterial wipes: first the seat, then the armrests, then the tray table and the back of the seat in front of him.

"I watched in horror," says Ruebush, PhD, an immunologist and the author of *Why Dirt Is Good*. "I'm worried this kid is going to be sick all the time."

The adults who stuffed this boy's backpack with wipes represent a fear of microorganisms that began not long after humans discovered these tiny life forms. In the 19th century, scientists found a connection between one bacterium and anthrax in cattle. This discovery is linked to what is now known as germ theory, a fundamental tenet of medicine that views microscopic bacterial agents as likely causes of disease.

True, bacteria have always made us sick, and before some key advances in public health, like water chlorination, they often proved fatal. Still, research now shows that bacteria (and other microbes) play far more complex roles than simply that of villain, forcing science to move beyond germ theory.

Today, researchers worldwide are busy investigating the benefits these microorganisms offer to various ecosystems, including those residing in each of us.

The body is an intricate biological package combining the human and the not-human: We each comprise about 30 trillion human cells along with some 40 trillion bacterial cells, as well as fungi, yeasts, viruses, protozoa, and more. That nonhuman cohort is called our microbiota or, more commonly, our microbiome. (The latter actually indicates the genes of our microbiota, but it's come to stand as shorthand for the whole ecosystem.)

The microbiome's assemblage begins in utero, as microbes from the placenta flow into the fetus. It builds as the baby passes through the birth canal and emerges with a life-giving slick of microbes from the mother's vagina and, despite the best efforts of the nurses, often a smudge of fecal matter.

"Most species poo on their babies as they're being born," says Graham Rook, MD, a professor of medical microbiology at University College London. "Koala babies lean out of the pouch and eat a special form of maternal feces. Passing the maternal microbiota to the child is immensely important."

This is because the microbiome plays a critical role in protecting and supporting our overall health throughout our lives. And the more we protect and support our community of tiny organisms in return, the more we'll thrive.

DIVERSITY IS STRENGTH

The densest part of the microbiome is in the gut, where our tiny symbionts range along its 377-square-foot surface area and participate in a variety of vital processes. Researchers believe microbiota affect multiple human traits, and they're currently exploring the connection between the microbiome and a wide variety of diseases, including asthma, allergies, and cognitive issues like dementia and depression. (Learn about other parts of the microbiome in "Beyond the Gut," on the opposite page.)

Studies suggest that diversity is key for optimal-functioning gut microbes. A healthy gut hosts around 1,000 species of bacteria. One critical way these microbes support us is through nutrient assimilation: We may gather and consume our food, but we need these microbiota to digest the countless complex carbohydrates and fibers found in it. Different microbes prefer different carbohydrates and fibers, and they deploy enzymes to break them down into nutrients we can assimilate.

Microbes also manufacture crucial vitamins, and their presence allows us to benefit from a much wider variety of food. Likewise, the more diverse our bacteria, the better we can digest and enjoy what we eat.

Diversity also plays an essential role in immunity. Researchers now understand that our immune system is less an internal army poised for battle against hostile invaders than a nuanced communication system, one whose primary function may be to recognize, tolerate, and glean information from our bacteria.

Rook compares the immune system at birth to a computer with software and hardware but no data. It acquires data by sampling the contents of the small bowel, especially the ileum, as well as our airways, giving a stamp of approval to resident microbes and harmless substances that enter our bodies as we eat and breathe.

"It all makes evolutionary sense," explains Rook. "The sooner a baby's immune system works out what kind of a world it's been dropped into and starts to adapt, the better."

"The sooner a baby's immune system works out what kind of a world it's been dropped into and starts to adapt, the better."

This is the main reason Ruebush was so horrified at the sight of the child sterilizing his environment — without exposure to a variety of harmless bacteria, his immune system is deprived of the chance to build adaptive skills.

BUILDING A PROTECTIVE WALL AGAINST INFLAMMATION

Among our trillions of microorganisms are many that can make us sick or even kill us, like *E. coli* and *Clostridium difficile*. Still, it appears that a diverse, well-populated microbiome keeps these resident threats in check and defends us against dangerous outside invaders, either by attacking them or by not giving them the opportunity to infect.

"If all the seats on the bus are filled with friends, it's really hard for a bad player to muscle in and grab a seat," explains functional physician Gregory Plotnikoff, MD, coauthor of *Trust Your Gut*.

Beneficial gut microbes feed the cells that line the colon and maintain the integrity of the gut wall, he explains. That wall not only keeps inner microbes from invading parts of the body where they don't play a positive role, but it also keeps food where it belongs. Chronic inflammation, meanwhile, can make intestinal walls more permeable, allowing undigested food particles to enter the bloodstream — a troublesome condition called leaky gut.

"When we talk about a leaky gut, we're really talking about breakdowns in that fence between us and them," says Plotnikoff. "In this case, a good fence really does make for good neighbors." (For more on this, see ELmag.com/leakygut.)

CHALLENGES OF EVERYDAY LIFE

Unfortunately, just about every aspect of our modern lifestyles disrupts our microbiome, with effects beginning in utero. If a pregnant mother is given antibiotics, for instance, the drugs decrease the woman's suite of microbes as well as the ones the fetus encounters through the placenta.

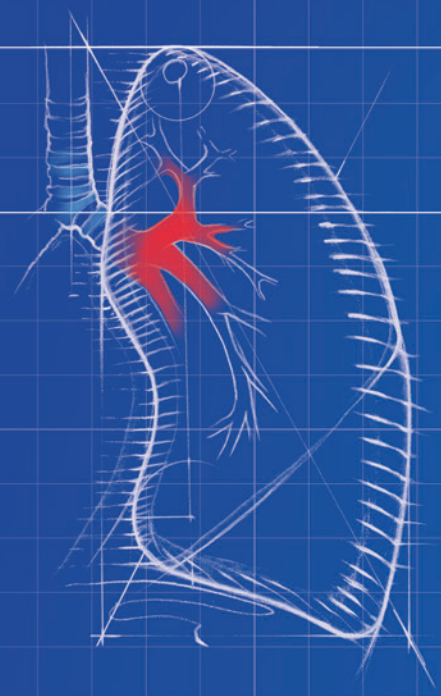
Throughout pregnancy, the microbial composition of the vagina tends to change, a process scientists believe helps provide newborns with beneficial microbes. But if a baby is delivered by cesarean section — as one in every three U.S. children is — he or she misses out on being exposed to this special microbial assemblage, which may have a long-term impact on immune function. Some studies indicate that C-section babies have higher rates of obesity, asthma, and other conditions. (For details on these studies, see ELmag.com/babybiomes.)

The assaults continue after birth. The gut microbiome is largely shaped by what we eat and drink, and breast milk is loaded with hundreds of carbohydrates called oligosaccharides that are digestible only by a baby's microbes — indicating that breast milk nourishes a baby as well as her biotic diversity. Still, many women are physically unable to breastfeed, choose not to, or are prevented from doing so by workplace demands, stress, childhood trauma, and other obstacles.

After infancy, many children eat a Western diet — with its heavily processed foods, simple sugars and carbohydrates, and meats from animals dosed with antibiotics — and their microbiota continue to starve.

One study comparing the microbiomes of urban Italians with that of Tanzanian hunter-gatherers who live on wild foods — mostly meat, honey, tubers, berries, and baobab fruit — showed that the hunter-gatherers have significantly greater microbial richness and biodiversity. They also don't experience the autoimmune and inflammatory diseases that ravage their urban counterparts, like Crohn's disease and ulcerative colitis, which studies have found often correspond to low microbial diversity.

BEYOND THE GUT: THE BODY'S MICROBIAL LANDSCAPE

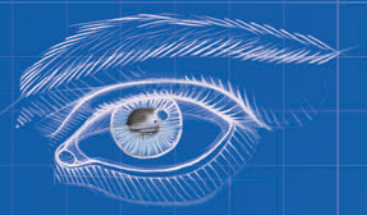


The microbiome is not just located in the gut — our bodies actually host dozens of microbial communities. "Think of the body as a world with all these different habitats where microbes live," says Athena Aktipis, PhD, an evolutionary biologist at Arizona State University. These are a few of the other habitats in your body.

MOUTH: The mouth is a microcosm of distinct microbial communities. A few hundred types of bacteria live on the tongue, the roof, and the insides of the cheeks. A 2009 Swedish study found some of these microbiota have a nitrate-regulating effect, which may help protect against ulcers and lower systemic blood pressure.

LUNGS: Scientists used to think the lungs were sterile, but they have recently discovered that a small population of microbes lives there, including migrants from the mouth and airborne travelers. Researchers have found associations between changes in the lung microbiota and diseases like chronic obstructive pulmonary disease (COPD), asthma, and rheumatoid arthritis, but studies have not proven causality.

SKIN: Some 1 trillion bacteria reside in our three major skin terrains: oily, moist, and dry. Microorganisms show environmental preferences. Fungi, for instance, like to cluster near our ears and forehead and not strictly near the feet, as you might think. Overall, skin microbes protect us against pathogens and parasites and assist in wound healing. Disruptions to the skin microbiota are associated with skin disorders, such as psoriasis, atopic dermatitis, and acne.



EYES: Blinking and tears make the eyes a tough environment for microbes, but a small number of bacteria and other microbes manage to live there and are thought to protect against infection. The diversity of the eye microbiota is changed by contact use, which can lead to an infection called keratitis. Studies suggest that the condition known as dry eye is associated with alterations in the eye microbiota.

VAGINA: The microbiome of the vagina varies among women, and even within one individual there is enough day-by-day fluctuation to make researchers dizzy. What they know so far: These organisms protect women from potentially pathogenic organisms, including those that cause vaginosis, yeast infections, sexually transmitted infections, and urinary-tract infections.

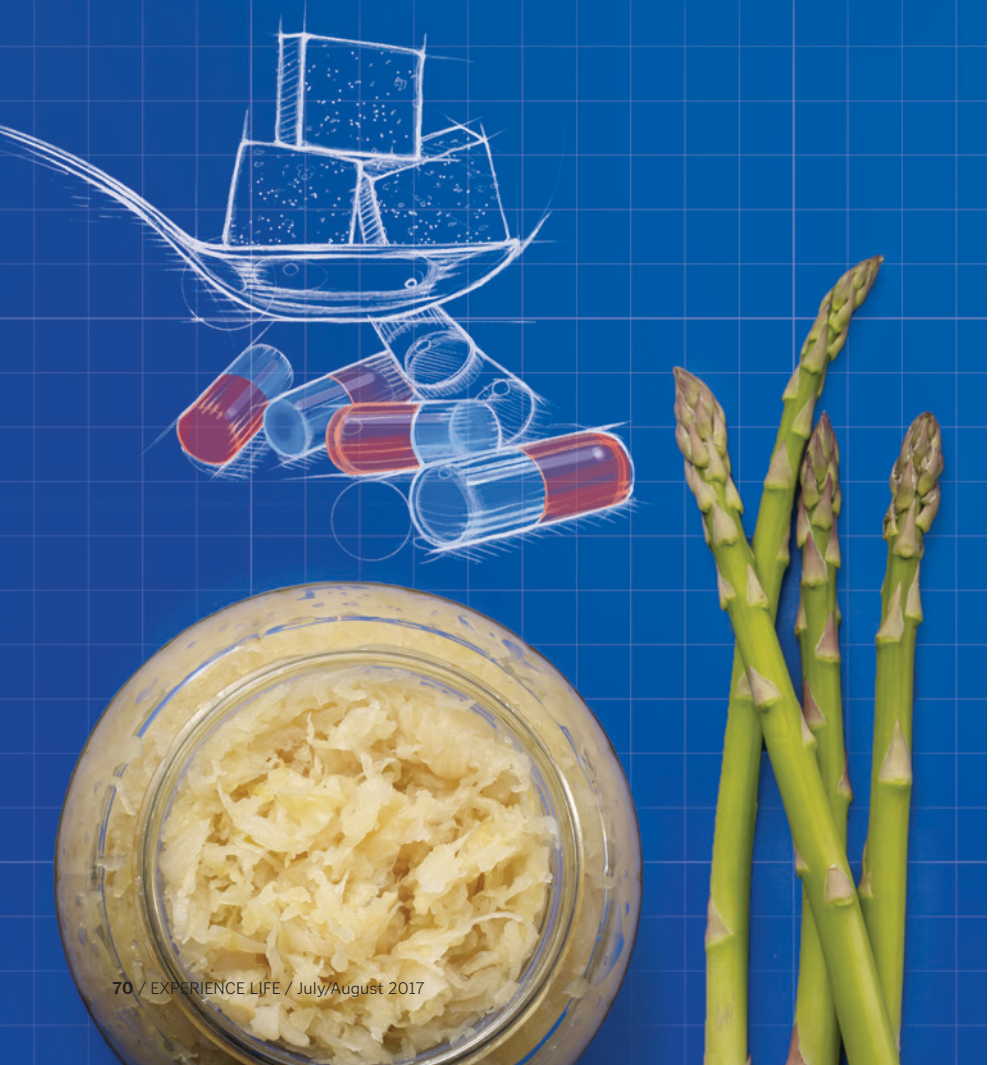
DID YOU KNOW? A 2015 study at the University of Oregon found that our bodies emit millions of bacteria into the air around us. This "microbial cloud" contains a unique, identifiable signature that lingers in the places we've been, so we literally leave our mark wherever we go.

REJUVENATE YOUR MICROBIOME

We can take steps to protect and revitalize our microbial communities, beginning with shifting how we describe ourselves. We are actually what scientists call a superorganism, meaning a creature comprising many organisms, so it's helpful to think of our body as a team.

"I tell my children that it's kind of like being a superhero," says Athena Aktipis, PhD, an evolutionary biologist at Arizona State University. "We have this diverse microbiota that allows us to do things we otherwise could not. It's kind of like having superpowers."

The following tips can help you protect your microbial superpowers.



BE CONSERVATIVE ABOUT ANTIBIOTIC USE. While antibiotics are invaluable for treating life-threatening infections, using them for routine problems can deplete the microbiota in ways that allow bad players to take over.

"Considering what we now know about the role of gut bacteria in keeping us healthy, it should be considered malpractice for dermatologists to prescribe oral antibiotics for acne," says Robynne Chutkan, MD, author of *The Microbiome Solution*, who attributes her struggles with rosacea to antibiotics she was prescribed as a teenager. "Even if they work, they can create other diseases that are arguably worse." Antibiotic resistance, for example, is an extremely serious consequence of overprescribing antibiotics for non-life-threatening conditions.

Many experts recommend avoiding antibiotics except in cases of serious infection. When they're necessary, protect your microbiota by taking probiotics or a form of yeast called *Saccharomyces boulardii* (available in capsules).

Another source of unnecessary antibiotics is feedlot meat. Livestock raised in feedlots are fed antibiotics, including those designed for human use, both to prevent the spread of disease in their crowded conditions and to help them put on weight. When we eat these animals, we're eating antibiotic residue, as well as possibly dangerous microorganisms that evolved resistance to the antibiotics. You can avoid this problem — and support farmers who use more humane methods — by choosing meat from animals raised on pasture. (For more on this, see ELmag.com/conscientiouscarnivore.)

CONSUME PREBIOTICS. Research has shown that the molecular structure of some plant fibers makes them superfoods for microbes; these are sometimes called prebiotics. Among these are Jerusalem artichokes, asparagus, under-ripe bananas, Brussels sprouts, chicory root, dandelion greens, raw garlic, jicama, leeks, legumes, onions, and peas. Try to consume a few of these whole foods each day.

STEER CLEAR OF SUGAR. Eating a lot of sugar — especially in the absence of fiber — strengthens *E. coli* and other pathogens that feed on it. It also triggers a battle between bad microbes and our own cells, which fight for this quick source of energy.

"These harmful microbes proliferate, then your immune system is activated to fight them, and you get a lot of inflammation," explains Aktipis, who researched this process for a study published in the *Annals of the New York Academy of Sciences*. "The microbes can actually increase their virulence and try even harder to monopolize the resources."

When we fill up on prebiotic fiber to feed our good bacteria and avoid sugar, we effectively starve harmful microbes and win the battle against their influence.

EAT "COOPERATIVE" FOOD. Simple sugars cause conflict between our microbes and our cells, but eating a wide variety of vegetables, legumes, grains, and fruits encourages cooperation between them. These foods contain complex molecular structures that require many steps to break down, thus recruiting more kinds of microbes.

Different microbes preferentially consume different complex carbohydrates and fibers, strengthening the community of the gut microbiota by prompting a range of services from them. As they busily metabolize various foods, they release a range of short-chain fatty acids and chemicals. Some support our health directly, while others build up their fellow microbes in the gut community.

Plotnikoff suggests adhering to the old Japanese admonition to eat at least 30 different whole-food ingredients every day.

EAT THE RAINBOW. We are drawn to bright-red tomatoes, deep-green spinach, and the bluest blueberries for a reason. Just as plant fibers help the microbiota thrive, so do the flavonoids and other phytonutrients found in brightly colored vegetables, fruits, herbs, and spices. These seem to encourage diversity in the gut microbiota that helps control inflammation, says Leo Galland, MD, author of *The Allergy Solution*.

FEAST ON FERMENTED FOODS. Kefir, yogurt, kimchi, sauerkraut, and other cultured foods are loaded with living microorganisms, and though researchers no longer expect them to simply repopulate our guts, they do support gut function in other ways.

"Probiotics are beneficial, but not in the ways we thought," says Robert Rountree, MD, a Boulder, Colo.–based functional-medicine physician, who sometimes prescribes high-dose probiotic capsules to patients and checks their fecal bacteria to see how it's changed.

"You don't necessarily find the kinds of bacteria that were in the dose, but you see improvement in overall diversity and growth in the numbers of bacteria that ferment carbohydrates to make short-chain fatty acids," he explains. "It seems that the probiotic's main effect is to help other bacteria. They come and help their friends."

GET A LITTLE DIRTY. Babies put everything in their mouths — toes, toys, random objects in the backyard. This appears to be part of an evolutionary strategy to "feed data" to the immune system. Even as adults, our immune systems need ongoing challenges to stay in shape.

This is why antimicrobial products may make us more, not less, susceptible to disease-causing organisms, warns Ruebush: They kill off most of the bacteria on our hands and on surfaces but leave behind the more robust organisms, which can mutate and become superbugs. A common-sense approach to cleanliness is to rely on soap and water and avoid excessive use of antibacterial cleansers.

TAKE A DEEP BREATH OF FRESH AIR. We might be able to repopulate certain kinds of bacteria in our guts just by getting some fresh air. About a third of gut microbiota is made up of spore-forming bacteria that slough off and persist in the soil for hundreds of years. When we breathe and swallow air containing these ancient bacterial spores, they can repopulate our guts.

"If we go to places where humans have been, there will be spores of these gut microbes," says Rook. "I'm sure I have organisms in my gut derived from Julius Caesar, because he would have passed through London, where I now live."

Some beneficial microbes we encounter in nature aren't derived from human microbiota, but they still affect it. One experiment found that immunizing mice with an inert bacterium called *Mycobacterium vaccae*, which is typically found in soil where cattle have grazed, prevented stress-induced colitis despite microbiota changes characteristic of the inflammatory bowel disease. It also seems to protect against anxiety and depressive behaviors.

BE AFFECTIONATE. Back in the days when microbes were universally shunned, scientists couldn't understand why hugging, kissing, hand-holding, and other physical intimacies persisted in so many cultures. Didn't these behaviors spread germs and make people sick?

"Now that we know that most microorganisms are commensal or even beneficial, it seems reasonable to think that this transfer of microbes is in many cases beneficial," says evolutionary biologist Andrew Moeller, PhD, a Miller Research Fellow at the University of California, Berkeley. In 2016 he published a paper in *Science Advances* showing that chimpanzees who engaged in lots of these intimate social behaviors had a more diverse microbiota.

So go ahead, shake some hands. Pat a few friends on the back. Embrace the vast microbial life that's in us and wafts around us like a cloud, and know that you are never alone. ◕

Kristin Ohlson is the author of *The Soil Will Save Us.* She lives in Portland, Ore.