CHAPTER 1

The Zoo Inside You

Our microbes are intimately involved in every aspect of our health—from ensuring our digestive well-being to influencing our likelihood of being obese and our risk of developing cancer or diabetes. They even play a role in our brain chemistry and mental health, affecting our moods, our emotions, and our personalities. We are, it seems, single individuals comprised of multiple living, breathing, moving parts. The more we learn about this fascinating microscopic community, the clearer it becomes that our fate is inextricably tied to theirs, making it essential that we learn more about where our microbes come from, what they do, and why we literally can't live without them.

Meet Your Microbiome

The microbiome refers to all of the organisms that live in or on your body: all of the bacteria, viruses, fungi, protozoa, and helminths (worms, for those of us who have them), as well as all of their genes. A staggering hundred trillion microbes that include thousands of different species inhabit your nooks and crannies—with more than a billion bacteria in *just one drop* of fluid in your colon alone.

Your unique microbial footprint develops over your lifetime, and it reflects everything about you: your parents' health, how and where you were born, what you've eaten (including whether your first sips were breast milk or formula), where you've lived, your occupation, personal hygiene, past infections, exposure to chemicals and toxins, medications, hormone levels, and even your emotions (stress can have a profound effect on the microbiome). The end result is a microbial mix so distinctive from person to person that yours is a more accurate identifier of you than your own DNA.

We've known about the microbiome since the 1600s, when Antoni van Leeuwenhoek first looked at his own dental plaque under the microscope and described "little living animalcules, very prettily a-moving." But it's taken us a few centuries to figure out that these fellow travelers might actually be helping rather than hindering us, with a specific purpose that's very much aligned with our own survival. The overwhelming majority of our microbes aren't germs that cause disease. Quite the contrary—they're an essential part of our ecosystem and play a vital role in keeping us healthy.

How do we get from germ-free fetus to living, breathing petri dish, colonized with trillions of bacteria? Let's start at the cradle and work our way toward the grave, to find out exactly how our microbiome evolves and the crucial role it plays at every stage in our development.

Pregnancy

Long before we enter the world, our mother's microbiome starts to prepare for our arrival. One of the most dramatic changes happens in her vagina. During pregnancy, cells in the vaginal lining ramp up production of a carbohydrate called glycogen, sending glycogen-loving *Lactobacillus* bacteria into a feeding frenzy and increasing their numbers. *Lactobacilli* convert lactose and other sugars to lactic acid, creating an acidic, unfriendly environment that helps to protect the growing fetus from potential invaders.

Bacteria don't just protect us from undesirable germs that can enter via the vagina; they also nurture us. In the third trimester of pregnancy, *Proteobacteria* and *Actinobacteria* species increase in number and cause a corresponding rise in the mother's blood sugar and weight gain in her breasts, with the specific goal of ensuring adequate growth and breast milk for the baby. Transplanting gut bacteria from late-trimester pregnant women into nonpregnant mice produces identical changes in the mice—confirming that the transformation is indeed mediated by gut bacteria, not hormones.

In addition to our founding species of bacteria, we also receive protective antibodies from our mother through the placenta. Armed with these antibodies and our own few but plucky microbial soldiers, we're ready to make our entrance into the world. But exactly how we enter isn't just a matter of convenience; it has significant microbial repercussions that continue to affect our health well into adulthood.

Birth

During a normal delivery, the baby's head turns to face the mother's rectum as it crowns and exits the birth canal. This turning brings the baby's nose and mouth into direct contact with her vaginal and rectal contents. What better way to get inoculated with a good dose of bacteria than to come face-to-tush with the source? A study published in *Proceedings of the National Academy of Sciences* showed that babies born vaginally are colonized with *Lactobacillus* species and other "good bacteria," while babies born by C-section tend to have more common hospital "bad bacteria" like *Staphylococcus* that are associated with illness and infection.

This brief act of swallowing a mouthful of our mother's microbes as we enter the world confers unbelievably important benefits. It turns out that exposure to bacteria is a critical early step in the development of our immune system. C-sections bypass this crucial event and are associated with higher rates of asthma, allergies, obesity, type 1 diabetes, and other autoimmune conditions. I'll explain the importance of early microbial exposure in detail in Chapter 3, and the modern plagues that are a result of not having enough of it.

Breast-feeding

Human milk oligosaccharides (HMOs) are the third-most common ingredient in breast milk, despite the fact that they're completely indigestible by infants. HMOs are indigestible because they're not there to feed the baby. They're there to feed the baby's bacteria—specifically, *Bifidobacterium*, present in high numbers in breast-fed infants. *Bifidobacterium* repels *Staphylococcus* and other harmful microbes on the mother's nipple, so it's an essential part of the baby's microbial arsenal. While *Bifidobacterium* gorges on HMOs, *Lactobacillus* in the newborn's gut breaks down sugars and the other digestible components of breast milk—an incredibly well-designed example of the symbiotic relationship between humans and microbes.

Breast-fed babies in the United States have an astounding 20 percent higher survival rate than their formula-fed peers. I'll discuss the worrisome trend of formula over breast milk in Chapter 7, where we examine the microbial implications of some of our modern practices.

Infancy

When we are babies, everything eventually ends up in our mouth. It's one of the ways we interact with our environment. It's also one of the ways our environment interacts with our microbiome, allowing bacteria from our home, our siblings, and even our pets to gain access to our gut and help train our immune system to distinguish friend from foe. Factors like family size, early nutrition, and the quality of our water supply have a profound effect on our blossoming microbiome.

Not surprisingly, as infants our microbiome most closely resembles that of other household members, especially our mothers. But it's a constantly changing and evolving mix, with lots of species diversity, and events like a fever, a dietary change, or a course of antibiotics can have a major ripple effect. Within a few weeks after birth, bacteria in various parts of our body start to branch out and specialize, and within a few months, the number of species starts to rise, increasing from about a hundred in infancy to a thousand or more by adulthood.

Childhood to Adulthood

By age three our microbiome is almost fully formed and is very similar to that of an adult, although major changes like puberty, the onset of menstruation, pregnancy, and menopause are associated with huge microbial shifts. Some of the physical changes associated with puberty, such as increased oil production that can lead to acne, or more pungent body odor under the arms and in the groin, are actually the result of changes in bacteria, as different species become more or less dominant.

By the time we become senior citizens, we've lost much of our bacterial diversity, and our microbiome starts to resemble that of others in our peer group. Shifts within various microbial populations continue to occur, but as we get older, our microbiome becomes more stable, tending to revert to its previously established baseline after events like an infection or a course of antibiotics.

Renewal

We start out in the womb with no microbes at all, and we eventually acquire trillions. What happens to all of those microbes when we die? Interestingly, the microbes aren't recycled. They die with us, and each subsequent generation goes through its own cycle of microbial rebirth, starting from scratch and working its way up to an incredibly well-stocked microbial kingdom, well adapted (let's hope) to the requirements of that generation.

Diversity of species is a vital part of maintaining a balanced ecosystem in the outside world, and it's also crucial in the microscopic world inside us. Unfortunately, modern life has made microbial depletion part of our legacy, with decreased diversity in each successive generation as a result of medications, our overprocessed diet, and our supersanitized lifestyle. Americans today have only about two-thirds as many bacterial species as native tribesmen in the Amazon who haven't been exposed to antibiotics. As we'll learn in the second part of this book, restoring those lost microbes takes real commitment.

While there is no perfect microbiome, some are clearly healthier than others, notwithstanding the incredible variation from one to the other. The Human Microbiome Project and other research efforts like it seek to establish what the "normal" human microbiome looks like today—an important endeavor, considering the rate at which our microbial landscape is changing. Companies like uBiome allow the citizen scientist to catalogue his or her own microscopic habitat, compare it to others, and reassess it as diet and habits change.

The human microbiome may well be the next big frontier in medicine, providing answers to why we get sick and novel solutions for how to heal ourselves. In the next chapter we'll learn more about what our gut bacteria actually do—besides make gas—and why they're so essential to our health and well-being.