Small, Small World

They're invisible. They're everywhere. And they rule.

By Nathan Wolfe

1 Breathe in. Feel the air pass through your nostrils and move into your nose. Your diaphragm contracts, pulling the air deep into your chest. Oxygen floods into tiny cavities in your lungs and travels into your capillaries, ready to fuel every cell in your body. <u>You're alive.</u>

2 So is that breath you just took. When we inhale, our nostrils capture millions of invisible particles: dust, pollen, sea spray, volcanic ash, plant spores. These specks in turn host a **teeming** community of bacteria and viruses. A few types may trigger allergies or asthma. Far more rare are inhaled pathogens that are themselves the **agents** of diseases, such as SARS, tuberculosis, and influenza.

3 We have known about bacteria, which make up much of the mass of life on Earth, only since Antoni van Leeuwenhoek began training his microscopes on samples of pond water and saliva some 350 years ago. Viruses—much smaller than bacteria but far more **numerous** than all other life-forms combined—were discovered not much more than a century ago, when people were already driving around in automobiles. And it is only in the past few decades that we have come to realize how **ubiquitous** microbes are, **flourishing** from the tops of clouds to miles below the Earth's surface. We've just begun to understand how **vital** they are to our health and to the health of the Earth. We pride ourselves on having explored nearly every corner of this planet, but behind our world is a shadow world of microbes—and they are often calling the shots.

4 Our past ignorance of the microbial **abundance** on the planet stemmed in large part from our inability to grow most microorganisms in the laboratory. Lately DNA sequencing techniques have allowed us to study whole populations in a given environment without the need to **culture** any of them in a petri dish. In 2006, for instance, scientists at Lawrence Berkeley National Laboratory announced that air samples collected from San Antonio and Austin, Texas, **harbored** at least 1,800 distinct species of airborne bacteria, putting the richness of air in the same **league** as that of soil. Among them were bacteria from hayfields, sewage plants, hot springs, and human gums, as well as the oddly common bacteria found in **deteriorating** paint.

Question 1

Paragraph 3 uses the words "ubiquitous" and "flourishing" to describe microbes. ***Explain*** how these terms apply to microbes ***using evidence from the text.***

5 Many airborne microbes haven't come from very far away, but some have traveled enormous distances. Dust from deserts in China moves across the Pacific to North America and east to Europe, eventually circling the globe. Such dust clouds **harbor** bacteria and viruses from the soils where they originated, as well as other microbes they pick up from the smoke of garbage fires or from the mist above the oceans they cross. Take a breath, and you sample the world. **6** Above the air we breathe, the upper atmosphere also contains microbes, floating as high as 22 miles above Earth's surface. I believe they could go even higher, though it's hard to imagine they could live long so far from water and nutrients. Lower down, they appear to survive and even thrive. There is evidence that despite high levels of ultraviolet radiation that would kill most bacteria, some metabolize and perhaps even reproduce inside clouds. In fact they may play a part in the formation of snowflakes that require a **nucleator,** or small particle, to crystallize around. In 2008 Brent Christner of Louisiana State University and his colleagues showed that microorganisms were the most efficient ice nucleators present in snow. That's right—snow is literally alive. **7** Microbes don't just **inhabit** the air—they created it, or at least the part we most depend upon. When life began on Earth, the atmosphere had no **significant** oxygen. Oxygen is a waste product of photosynthesis, and we owe the invention of that process, about two and a half billion years ago, to cyanobacteria. These bacteria are directly responsible for as much as half of the oxygen made on Earth each year and indirectly for most of the rest. Hundreds of millions of years ago ancient forms of cyanobacteria made their way into cells that would evolve to become plants. Once **embedded** in those ancestor plants, they evolved into chloroplasts, the photosynthetic, oxygen-producing engines of plant cells. Together, free-living cyanobacteria and their long-lost chloroplast cousins in plants carry out the vast majority of photosynthesis on our planet.	Question 2 Describe the roles bacteria play in our atmosphere ***using evidence from the text.***

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8 But let's get back to your nose. Those airborne microbes you unwittingly inhaled? They're just passing through. Your nasal passages also host a rich and complicated population of full-time residents. Three **genera**—*Corynebacterium, Propionibacterium,* and *Staphylococcus*—account for most of the bacteria in your nostrils. They form one community among the many that make up the human microbiome: the full genetic complement of bacteria and other organisms at home on your skin, gums, and teeth, in your genital tract, and especially in your gut.

9 All told, the microbes in your body outnumber your own cells by ten to one and can weigh as much as or more than your brain—about three pounds in an average adult. Each of us is thus both an organism and a densely populated ecosystem, with habitats harboring species as different from one another as the animals in a jungle and a desert. Even the resident microbes in the gum pockets around your teeth can vary greatly, suggesting, as David Relman of Stanford University puts it, that "each of our teeth is essentially an island, rocks in an intertidal pool."

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Question 3

Paragraph 9 uses the phrase "Each of us is thus both an organism and a densely populated ecosystem." ***Using evidence from the text, explain*** what is meant by this phrase.

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10 For the most part, the microbes inhabiting our bodies are either beneficial ones or **unobtrusive** freeloaders. They help us digest our food and absorb nutrients. They manufacture vital vitamins and anti-inflammatory proteins that our own genes cannot produce, and they train our immune systems to combat infectious intruders. Resident bacteria on our skin secrete a sort of natural moisturizer, preventing cracks that could allow pathogens to penetrate.

11 Our bodies also host some pretty shifty characters. At any one time about a third of us harbor in our nostrils *Staphylococcus aureus,* a normally **benign** bacterium that can turn **virulent.** Usually competition from other members of the nostril microbe community appears to keep this bacterium under control. But *S. aureus* can get nasty, especially when it ventures into other environments. In the skin it can cause everything from an occasional pimple to a life-threatening infection. Under certain conditions, the individual bacteria **coalesce** into a filmy mass that acts as a united front, invading new tissues and even infecting intravenous catheters and other hospital equipment. Superbug strains of *S. aureus* can cause lethal infections such as toxic shock syndrome or necrotizing fasciitis—flesh-eating disease.

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Question 4

Compare and contrast the different roles bacteria play in our bodies using evidence from the text. What conclusion(s) about our relationship with can be drawn through this comparison? ***Reference text in your answer.***

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12 What makes these strains so dangerous is their **resistance** to antibiotics, those miracles of modern medicine that since the middle of the past century have saved millions of lives. The more we learn about our microbiota, however, the more we realize how easy it is for helpful microbes to get caught in the line of fire between an antibiotic and its intended target. Some 10 to 40 percent of children who are given a broad-**spectrum** antibiotic develop antibiotic-associated diarrhea, because their gut microbiota have been disturbed. **13** The widespread use of antibiotics early in life may have more profound effects over time. The stomach microbe *Helicobacter pylori* has long been known to provoke ulcers in some people but in most serves the useful function of regulating immune cells in the stomach. Martin Blaser, a microbiologist at New York University who has studied *H. pylori* for decades, notes that an ever shrinking share of adults is populated with the microbe, partly because of repeated high doses of antibiotics during childhood. Blaser believes the **diminished** presence of the bacteria and the rise in asthma in American youth might be related. **14** So should we treat our wheezing children with a healthy dose of *H. pylori*? It's often more complicated than that. As we learn more about the relationships between ourselves and our microbes—and their own complex relationships with one another—scientists are coming to see the microbiome the way ecologists have long viewed an ecosystem: not as a collection of species but as a **dynamic** environment, defined by the multitude of interactions among its **constituents.** This should mean greater care in the use of antibiotics and, increasingly, targeted probiotic treatments that don't just temporarily boost the numbers of one microbe or another but that shore up the whole population so that our health is improved. "We know how to disturb a community," says Katherine Lemon, a microbiome researcher at the Forsyth Institute in Cambridge, Massachusetts, and a clinician at Boston Children's Hospital. "What we need to learn is how to coax it back into a healthy state."	Question 5 Paragraph 12 discusses the "line of fire." ***Using evidence from the text, explain*** what is meant by this term. Question 6 Paragraph 14 uses the phrase "dynamic environment." ***Using evidence from the text, explain*** what is meant by the term and why it is appropriate when describing microbes. Question 7 Select three bolded terms from the article that best summarize the main idea of the article. Explain your reason for including each term using evidence from the text.