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The Germs of Life

Our ancestors were bacterial communities

WATCH TV FOR AN HOUR. Flip through a mainstream magazine. Peruse personal hygiene or cleaning products in a store. You'll feel the need to defend yourself with antibacterial soaps and cleaning agents, even antimicrobial pillows and socks. Fear of bacteria has reached a feverish pitch recently, thanks in large part to the work of ever-industrious advertisers.

In our efforts to eliminate these "germs" we have had devastating effects—not on the bacteria, but on ourselves. The bacteria that now pose the greatest threats to humans are products of our own making. The evolution of pests and pathogens resistant to human poisons has a long, well-documented history. Hospitals, where antibacterial drugs, soaps, and cleaners are used in volume, are hotbeds of antibiotic-resistant strains of bacteria. Farmers feed livestock excessive amounts of antibiotics, thereby selecting for bacteria that are resistant to those medicines—versions of which are also used for humans.

But our xenophobia also blinds us to a more fundamental insight: the health of our environment, and our bodies, depends on bacterial communities. Indeed, they are responsible, as ancestors, for our very existence.

If Life had a yearbook, bacteria would win all of the awards, especially "most likely to succeed." A bacterium is an organism made up of one or more small prokaryotic cells, those that have DNA genes but lack nuclei and chromosomes. Bacteria inhabit the farthest reaches of the biosphere. They live in the hottest, coldest, deepest, saltiest, and most acidic environments. They are the most ancient lifeform, having lived on Earth for at least 3.8 billion years, over 80 percent of its history. By contrast, humans have occupied a narrow range of environmental conditions—and for only about 0.003 percent of the Earth's existence. If we even made it into the yearbook, the caption would have read "photo not available."

Earth's environment is in large part the product of bacterial metabolism. Bacterial nitrogen fixation enriches the soil at no cost to us. And the photosynthesis that excretes oxygen and makes food for all life is carried out by the blue-green bacteria called cyanobacteria—both the free-living kind and those that became chloroplasts in the cells of algae and plants. These are just two of bacteria's life-sustaining processes, invented at least 2 billion years ago. We should view them as the wisdom of the ancients.

Even disease-causing bacteria—exceedingly rare despite the fear-mongering of marketers—play a part in ecological health. Anthrax spores, for example, float in the dust of over-eaten and sun-exposed fields, enter the lungs and blood of vulnerable or weak grazers, and kill them. Fields recover their vegetation. The grazers' food supply is spared, the stability of the ecosystem restored.

Bacteria also sustain us on a very local, intimate scale. They produce necessary vitamins inside our guts. Babies rely on milk, food, and finger-sucking to populate their intestines with bacteria essential for healthy digestion. And microbial communities thrive in the external orifices (mouth, ears, anus, vagina) of mammals, in ways that enhance metabolism, block opportunistic infection, ensure stable digestive patterns, maintain healthy immune systems, and accelerate healing after injury. When these communities are depleted, as might occur from the use of antibacterial soap, mouthwash, or douching, certain potentially pathogenic fungi—like Candida or vaginal yeast disorders—can begin to grow profusely on our dead and dying cells. Self-centered antiseptic paranoia, not the bacteria, is our enemy here.

But in our ignorance, we also miss a larger lesson. Bacteria offer us evidence that health depends on community, and independence is an ecological impossibility. Whenever we treat isolated medical symptoms or live socially or physically isolated lives, we ignore warnings from our more successful planetmates.

Bacteria in their natural environments live in well-structured communities based on reciprocity. As one type excretes acid, sugar, or oxygen, its wastes become food

or gas for others. And these communities are ecologically sensitive. Bacteria change form and metabolism in response to environmental cues like dryness or heat. Many multicellular bacteria (such as those made of long filaments of cells) revert to single cells in the laboratory. But in the richness of their normal habitat, from pond water to tongues, they transform back into their long chains.

The bacterial propensity to live in ecological communities has also left its mark in the cells of all larger life. Protoctists (like algae or ciliates) and fungi (like yeasts or molds)—not to mention plants and animals—are all nucleated-cell organisms; their cells contain nuclei that divide by mitosis, a complex dance of chromosomes. As research from our lab and others has proved, nucleated-cell organisms could not have evolved without the multi-million-year-old permanent mergers of specific bacteria. Cellular respiration, for example, the process that releases energy from food, occurs in the cell's mitochondria. Mitochondria were once independent bacteria that attacked, or were engulfed by, an early protist.

More recently, some of us have studied what we think is another historic incorporation of bacteria. This one involves the wily bacteria known as spirochetes, including one that we suspect is an ancestor of all of us nucleated-cell organisms. By new molecular biology techniques we expect to prove that an ancient spirochete fused with another very different bacterium, and that the result was that certain free-swimming spirochetes contributed remnants of their lithe, snaky bodies to become moving components of cells. These parts include the familiar waving hairs called cilia, and the tubules of the mitotic spindle, which moves chromosomes so that cells divide equally.

But an even later consequence of the hypothetical merger evidently extends to sensory tissues. In mammals, the cells of the tongue's taste buds, the inner-ear cells required for hearing, and light-sensitive cells in the retina of the eye all have traceable, peculiar features in common. Even cells of the "semicircular canal" balance organ, the stimulus-receiver that tells us whether we are on our feet or upside down, share the detailed features we interpret as clues to their origin.

The salient feature is that these cells have the hairlike cilia, which sense stimuli like light, touch, or sound. It is widely accepted that these cilia, all composed of skinny tubules arranged in a distinct pattern, evolved from a common ancestor, whose identity remains unknown. Our evidence indicates that it was the ancient spirochete: that in the complex ecology of bacterial communities, the merger happened; and that ultimately out of that merger our sensory apparatus evolved, giving us the basis of our awareness—and by extension our consciousness.

In the symbiotic associations that have persisted, co-habitation ultimately succeeded. Our nucleated-cell ancestors evolved because they could swim, breathe oxygen, eat whole bacteria, and merge. Their success was predicated on an attraction to sugars and each other, struggle, fusion, eventual incorporation, and integration by compromise. Our sensibilities come directly from the world of bacteria. Like all life, we thrive in communities. It's natural that people who have strong social relations prove healthier and longer-lived.

Humans have nonetheless found no shortage of ways to foul communities, cause extinctions, and threaten our own existence in the process. But bacteria wouldn't miss us. They have run the planet for most of its history, and our rush to indiscriminately kill them only reveals our own naïveté. The bacteria, with their complex history and virtuoso performances in energy and food recycling, will easily endure our assault. But our own survival depends on a revolution in human attitudes toward—and ability to learn from—our microbial ancestors.

For more information and reading resources, visit www.orionmagazine.org/bacteria/.

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