The Washington Post
Democracy Dies in Darkness

Uncovering how microbes in the soil influence our health and our food

By Daphne Miller
September 29, 2019 at 8:00 a.m. EDT

When Bill Robertson, a soil scientist at the University of Arkansas, wants to check whether a field is healthy, he doesn't reach for some high-tech gadget. He grabs a pair of men's 100 percent cotton underwear.

"I call it the 'Soil Your Undies' test," he said, describing how he buries the underwear two to four inches deep, leaving the waistband showing so he can find them and dig them up five weeks later.

"Soil creatures — bacteria, fungi and nematodes — eat cellulose, and those briefs are basically cellulose," Robertson explained. "If that soil is alive then, after five weeks, [the underwear] should fall apart like a wet newspaper." If, on the other hand, the soil isn't thriving, then what is left is a dirty, but intact, set of briefs.

Until recently, Robertson said, most agricultural experts thought of soil as nothing more than a matrix to hold plants and minerals. But the same technologies that have allowed us to better understand the bacteria and fungi that make up our microbiome have led to breakthroughs in soil science.

And what they are showing is that those underwear-munching microbes play key roles in preventing soil erosion, conserving water and breaking down environmental pollutants. They also capture and store atmospheric carbon — which might help fight climate change.

If this were all soil microbes did, they would clearly be central to our well-being and survival on this planet. But emerging research suggests that the soil microbiome might have an even more direct effect on our health by communicating directly with our own cells and by boosting the nutrient content of our food.

“For a long time, [scientists] have been obsessed with the idea is that there are things in the soil that are trying to kill us,” said Rob Knight, a microbiologist at University of California at San Diego who studies communities of microbes, including those that typically live in soil and those that inhabit our bodies. He mentioned several disease-causing soil dwellers, including tetanus, that are often held up as proof that soil is a dangerous place.

But recently, Knight said, scientists have begun to abandon their “war metaphor.” Instead, they are exploring ways that microbes in the soil might protect us.

He gave the example of *Mycobacterium vaccae*, a benign soil-dwelling bacteria that was first identified on the shores of Lake Kyoga in Uganda in the 1970s. Researchers at the University of Colorado Boulder have observed that heat-killed M. vaccae has immune-modulating and mood altering properties when it is injected into experimental mice. While the studies have yet to be replicated in humans, the thinking is that M. vaccae, along with a host of other microbes that live in soil and the natural environment, co-evolved with us and have the power to communicate with our own cells.

Hunt for the 'right microbes'

Donata Vercelli, professor of cellular and molecular medicine at the University of Arizona, also studies how these ancient microbes affect our health.

Her interest was sparked about a decade ago when she learned that farm children in Germany had lower rates of allergy and asthma than their counterparts raised in urban areas. She joined a multinational research team to understand what was behind this phenomenon.

“What we are discovering is that living in these traditional farming environments means living in a place that is extremely rich in microbes — the right microbes that our immune system has evolved to live with and learn from,” Vercelli said.

She explained that the constellation of organisms found in soil and on farm animals programs how a child responds to allergens throughout her lifetime. This programming probably starts in utero and continues to shape the immune system during the first few years of life.

Soil microbes help regulate our emotions and immune response. And they also play a key role in determining the nutrient content of our food.

“For centuries, people have had this idea of the ‘good earth,’ ” Cornell plant scientist Jenny Kao-Kniffin said. She studies the underground interactions that take place between soil microbes and the roots of plants, a zone she refers to as the phytobiome.

“This could be the next frontier in nutrition science,” said Kao-Kniffin, explaining how plants secrete compounds to feed nearby microbes and, in exchange, the microbes enable plants to capture essential nutrients (such as nitrogen) and manufacture a series of chemicals called phytonutrients or antioxidants.

These chemicals protect plants from pests and other stressors; they also give fruits and vegetables their color, smell and distinctive flavor. Research shows that these same chemicals directly benefit us by stimulating our immune system, regulating our hormones and slowing the growth of human cancer cells.

Kao-Kniffin’s most recent finding is that soil with a diverse microbial community promotes plant growth while soil with more homogeneous microbial makeup suppresses growth.

Throughout most of his career, Robert Beelman has focused his research on quantifying the antioxidant content of plants and describing how these nutrients affect our own cells. But recently, Beelman, an emeritus professor of food science at Pennsylvania State University, took an unorthodox step for a nutrition researcher by expanding his investigation to include soil.

“We all say that healthy soil equals healthy people,” said Beelman, “but the truth is that we are still blowing smoke and we need to do more research to investigate this idea.”

“I got to wondering,” he added. “Have our modern agricultural practices been screwing up the fungal and bacterial populations in the soil to the point where the amount of [nutrients] in our diet has been compromised?”

To pursue this question, Beelman decided to focus on one antioxidant, l-ergothioneine — which he refers to as “Ergo.”

This is an interesting nutrient because it is only made by soil fungi and certain soil-borne bacteria, while several lines of evidence suggest that Ergo is an important nutrient for humans: Ergo deficiency might predispose us to inflammation and premature aging. Mushrooms, the fruits of fungi, are by far our best dietary source of Ergo, but it is also found in many plants, including oats.

The trouble with tillage

Beelman teamed up with the nearby Rodale Institute, an agricultural research center in Kutztown, Pa., to trace Ergo from field to plate. First, they planted oats in the different farm plots, each plot under a different kind of experimental farm management. Then they harvested the grains and sent them to Beelman’s lab to measure the Ergo levels.

“Tillage made the biggest difference,” said Beelman, jumping to the punchline. Tillage is essentially plowing without turning the soil over. For centuries, farmers have tilled to eliminate weeds, bury the remnants of old crops and prepare the ground for planting — but newer research suggests that disturbing the top layer of soil destroys microbial populations and contributes to soil erosion.

Indeed, oats grown in the “no-till” fields had 25 percent more Ergo than their counterparts in tilled soil, and the soil in the no-till field also had more Ergo. Beelman said he believes this is because tillage disrupts networks of bacteria and fungi.

Andrew Smith, lead scientist at Rodale, said the Ergo study aligns with other results showing that farming practices that protect topsoil also produce a greater diversity and density of soil microbes and plants with a higher concentration of antioxidants.

“This makes sense,” he added, echoing Kao-Kniffin’s finding that plants manufacture these compounds in consort with microbes.

Predictably, in response to promising research linking “health” and soil microbes, soil-inspired probiotics are flooding the market. These products claim to contain earthy organisms that will protect us from disease and enhance growth and development.

Vercelli said she believes that it is far too early to be touting products for human health — we are just beginning to understand how these invertebrates work together and how they interact with their environment. Plus, she wonders if the symphony is more important than any lone player.

“There is a tendency to try and identify individual microbes that are responsible for this and for that,” she said. “I do not think that is a realistic way of going about this. Microbes operate in communities and they work together.”

In the realm of plant health, Kao-Kniffin also thinks that group dynamics are more important than the effects of specific microbes. “The current industry focus on examining single microbial isolate effects on plant traits will be replaced with more emphasis on complex interactions involving multiple players.”

Accordingly, Knight is involved in an effort to bank ancient soils — just as we are banking ancient seeds — so that these combinations of microbes are on hand to protect us at some future date when we are better equipped to understand how they work.

Meanwhile, he said, “let’s stop practices that are bad for the soil and start doing all those things that we know preserve topsoil and preserve invertebrate biodiversity.”

Knight listed the same soil-conserving practices that Smith is studying at Rodale, practices labeled “organic,” but more accurately described as “regenerative” or “beyond organic” because they adhere to the Agriculture Department’s definition of organic farming (no antibiotics, synthetic pesticides and herbicides), and also include rotating crops and grazing animals, feeding the soil with cover crops — plants grown to keep the soil covered offseason — and compost, conserving water, and minimizing tillage.

Robertson sums it up nicely: “Soil health is public health.”

He wants consumers and policymakers to support soil conserving practices and farmers to adopt these practices. He sees the soil health movement gaining ground nationwide but says there is still a lot of room for improvement. (In my home state of California, for example, less than 4 percent of the cropland is managed with cover crops.)

“When it comes to making change, most of us are from Missouri, you gotta ‘show me,’ ” Robertson said.

And this is where the “Soil Your Undies” test comes in.

Once we see that invisible underground creatures can disassemble a pair of underwear in a matter of weeks, perhaps we are more inspired to protect them.

Daphne Miller is a family physician, clinical professor at University of California at San Francisco, and author of “Farmacology: Total Health From the Ground Up.”