WONDERS OF LIFE—FUZZ

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References: "Unseen Allies" by Lance Frazer in Rotarian Magazine, Nov. 2001 and Science News, April 3, 99; May 1, 99; and July 14, 2001 among others.

Wonders of life. Beauty that surrounds us. Bay. Swans. And Beauty that we travel to visit. Tropical Islands. Snow covered peaks. The wonders of our world.

There is a certain fascination in how they got that way. Peacocks. Tropic birds with their long white tails soaring over the sailboat. Colorful fish beneath the keel on the reefs, chasms, and canyons of the deep. Each a fascinating subject in itself. A joy of discovery. An appreciation of their magic and mysteries. Some call it evidence of a god.

And then there are the smaller creatures, frequently harder to find and harder to see. We think of smaller as simpler and, one would think, easier to comprehend, easier to understand …maybe a little less wonder. Not so much the focus of our awe. Not needing a god to fill in the blanks.

Awhile back we talked about …….and mentioned that one of the smaller creatures of the earth is really the most massive. Even though they collectively outweigh all other living organisms on earth and despite their contributions to environmental health, the lowly bacteria remain largely unseen, ignored – and certainly underappreciated.

Not a typical target of claims of beauty and awe. In fact, just the opposite in the minds of many. Bacteria … they're bugs, right? Not an uncommon response.

Let's see if we can move bacteria up your list of wonders of life and, thus, elevate your wonder at the world around us. Something to accompany your next magnificent sunrise.

While trying for a National Bacteria Week might be a stretch, maybe we can settle for your next conscious encounter with the little guys, a response of …

H-mmm-m-m, amazing little creatures. And thus give you one more reason to celebrate the intricacies of the world we share.

Now isn't this really UUism? Stepping up to bat for the little guy?

First of all, they're virtually everywhere. In the ground, in the water, in plants, animals and birds. Bacteria that are sulfur, rather than oxygen, based seem to be the foundation of life around the recently discovered deep sea volcanic vents – the basis of a whole new world of tube worms and other such creatures that we never knew existed. Amazing! And we thought all life depended on oxygen. Bacteria are an active presence deep within the earth and there is a growing belief that they, not dinosaurs and prehistoric ferns, are the source of so-called fossil fuels. That would explain why oil, gas, and coal are now being found among geological structures never have thought to have ever seen the light of day. It also would explain why some oil and gas wells are seeming to replenish themselves, albeit very slowly. Wouldn't that be a shocker – fossil fuels not fossil based at all, but renewing themselves? And some scientist believe they have evidence of bacteria in meteors from Mars – although the jury seems to be still out on that one. We are discovering more and more ways bacteria help us live and make a better life. Prepare yourself for a presumptuous statement. Ready? Bacteria, of course, don't know they're being helpful to humans as they go about their business. It's just something they do as they ingest food. And when they excrete waste, it's surprising how many times that waste product is something useful.

For example, one bacterium currently toils as part of a miniature highway construction crew. Australia's Road Technologies International produces a microbe-based product call Road Tech 2000, which helps form a weather- and traffic-durable surface when applied during the road-building process. It was developed after geologist noticed that gravel and clay roads that had been built in recent years had already begun to break down, while others, built 20 years earlier, looked almost new. What actually was happening was that a type of microbe was digesting certain minerals in the soil and producing a polymer (yes, a plastic) that helped to bind the clay particles in the soil, thus protecting and strengthening the roadway. One might be tempted to make a connection on one hand between asphalt coated roads, called tarvy in some regions, made from tar, a so-called fossil fuel extract, and, on the other hand, plastics which are derived primarily from so-called fossil fuels, and, on the third hand, this newly discovered little polymer excreting road worker. Is this little bacteria making "fossil fuel" right under our noses?

Environmentalists over the last 20 years or so focused on the presence of toluene as evidence of human pollution. Toluene is one of the Volatile Organic Compounds (VOC's) in the atmosphere that react with other chemicals to form smog. Toluene (also known as methyl benzene) is a suspected carcinogen found in gasoline, adhesives, and household solvents. Toluene ascribed to these sources has been discovered in the soil and groundwater. Until recently, about the only method of dealing with toluene-contaminated soil was to dig it up, then either incinerate it, or mix it with a sealing material, such as cement.

Some bacteria feast on certain chemicals classified as toxins, including toluene, breaking them down into harmless substances, such as water and carbon dioxide. However, most bacteria require oxygen to perform their digestive wonders, which presents a problem in the case of contaminated waste sites, where toxic substances often percolate deep into airless soils. But Dr. Peter Coschigano, an assistant professor of environmental microbiology at Ohio University, has discovered a bacterium that can consume toluene in the absence of oxygen. Likewise, Southern Illinois University's Dr. John Coates has discovered a bacterium that can break down certain other petroleum compounds under similar conditions.

Joost A. de Gouw, an atmospheric chemist at the University of Utrecht in the Netherlands discovered a burst of these VOC pollutants from cut grass. Scientists began looking elsewhere for sources of these so-called man-made pollutants and discovered that Sunflowers and Scotch pine, in particular, expel large bursts of toluene under stress from draught, wind damage, bug attack, or disease. Alex Guenther of the National Center for Atmospheric Research in Boulder, CO now says "Globally, plants emit about 90 percent of the VOC concentration in the air.…the more interesting impact (is) an undermining of measurements that use toluene as a tracer for air pollution generated by people. Biochemist Ray Fall of the University of Colorado elaborates "When you start to crop millions of acres of alfalfa and it's drying, that makes us quite a source. Environmentalists have measured some elements of smog over Indiana farmland during summer, a finding that puzzled researchers. Where did all this natural toluene go before mankind was encouraged to dig up the dirt and incinerate it? Well, apparently the bacteria ate it.

Bacteria have survived on earth for billions of years, while much larger organisms have become extinct. One reason that bacteria have fared so well is their extreme hardiness, and it's difficult to imagine any bacterium tougher than Deinococcus radiodurans. Able to withstand 3,000 times the lethal radiation dose for humans, Deinococcus is able to consume the toxic mercury compounds associated with nuclear weapons production. Maybe other strains have developed a taste for other radioactive wastes. Maybe a little genetic engineering would help. More promise for the future.

Awesome, isn't it, about how we go out on a limb over toluene or radioactivity, and these little tiny guys make us look small. I wonder about their view of God – if they bother.

Yes, bacteria are everywhere, and are a part of many of our amazing earth systems… including a very important part of you. Smile at the person seated next to you and show them your bacteria. Animals without bacteria, raised that way for research purposes, have to be fed many more nutrients for them to survive since they are digesting on their own – no bacteria helpers. A typical human digestive system has about a quarter pound of these helpers. And there's more in your lungs and elsewhere in your body.

Until recent decades, all knowledge about bacteria came from studies of individual, free-floating cells. Although microscopy pioneer Anton van Leeuwenhoek included colonies among his first observations in the late 1600's, scientists weren't aware of the complexity and prevalence of bacteria community lifestyles until the 1970's.

We tend to think of bacteria as primitive, single-celled creatures, but in gatherings, they differentiate, communicate, cooperate, and even deploy collective defenses against antibiotics. Individual microorganisms in a connected group act together like one multi-cellular organism.

Bacteria in most environments opt for such communal living at least some of the time. They form colonies called biofilms, which have implications far beyond dental hygiene.

The little guys don't just stop at building neighborhoods, but they also build villages, towns, cities, and beyond, but they also form slimes that cover river rocks and other wet surfaces and occasionally foul industrial equipment. The colorful scum around the geysers of Yellowstone National Park consists of biofilms that can be hundreds of years old. Microbial mats in marshes are also long-lasting communities that extend inches into the sand.

Karen Sauer of Montana's Center for Biofilm Engineering at the University of Montana in Bozeman tracks the biofilm process from start to finish in an unaltered bacteria by monitoring the proteins they produce.

Her bundle of joy is a soil bacterium called Pseudomonas putida, which uses a long whiplike tail to propel itself through water. This tail, or flagellum, also helps the bacterium to stick to a surface when it first settles down.

In one experiment, Sauer provided her bacteria with hair-thin silicon tubing in which they could make a home. She found that within the first 6 hours, the bacterium turns off genes that make the tail.

Sauer's assays indicate that her little friends don't produce much during the first several hours. However, it begins synthesizing proteins to make pilli, which are multipurpose appendages that look like stiff hairs protruding from a cell's surface. The bacteria "are suddenly in a new environment, and it's as if they need all new equipment," she explains.

The pilli can act like Velcro to anchor the bacteria securely to a surface. They can also beat rapidly, enabling the bacteria to swarm over the surface with a twitching movement. Like thousands of tiny tongues or noses, the pili can detect whiffs of chemicals, which may help the bacteria sniff out food or find each other.

Soon after the bacteria start gathering together, they pull out a special set of weapons. They turn on genes to make proteins that help them resist attack. If the quantity or type of bacteria are detrimental, nature attempts to keep all this in balance. If the interests of the bacteria conflict with the interests of its host, this is when bacteria infecting a person can become nasty.

Some of the bacterium's resistance genes produce proteins that essentially build a barbed-wire fence around it, says Sauer. Most of these are enzymes that break down antibiotics, be those antibiotics naturally produced or induced. Other genes set an internal pump in motion that pushes the hazardous chemicals out of the bacterium as fast as they rush in.

As the bacteria make a simple layer, one cell deep, they begin to produce slim. It protects them from being washed away or drying out and also slows down those antibiotics and other toxins that might seep in.

After the first 6 hours, the bacteria start to communicate. They make protein messages and release them, Sauer reports. At first, this appears to be nothing more than chemical chatter. Then, the chemical messages become so concentrated that whispers turn into shouts. When the messages are loud enough, the bacteria start to pile onto each other, making three-dimensional structures.

After establishing the highly structured biofilm, some of the bacteria turn on their flagella-making genes again. Small groups then leave the community to start the biofilm-making process over again in another location.

The planktonic and biofilm life stages of P. putida are so different that Sauer compares them to a pair of separate species. It's "like the difference between a tree and a mushroom." She says. As many as one-third to one-half of the organism's genes are used in only one lifestyle or the other, she reports.

"What is common to all of these (biofilm infections) is that you can't easily get rid of the bacteria once they enter the body," says Michael Givskov of the Technical University of Denmark in Lyngby. The immune system, which can mop up free-floating bacteria in the blood, has difficulty reaching bacteria in biofilms. In most cases, patients' only defense has been antibiotics, but bacteria in biofilms clearly react differently than lone bacterial cells do to even these assaults.

New research indicates that a biofilm's exceptional resistance stems from several characteristics. As they activate specialized resistance genes, bacteria in biofilms seem to benefit from pooling their efforts. Bacteria can produce an enzyme that inactivates the antiseptic hydrogen peroxide, for example, but a lone cell can't produce enough of the substance to save itself. A community of bacterial cells, however, can generate a large enough shield of the enzyme to surround and protect the biofilm.

Dormant cells don’t participate in the activity, so they aren’t usually vulnerable to any of these drugs. Although these bacteria don’t actively contribute to the growing colony, they can weather the catastrophe of antibiotic treatment and quickly renew the biofilm afterward.

The interior of the biofilm also offers a shelter from the antibiotics. It harbors little oxygen, which some antibiotics need to work.

Givskov, Holby, their colleagues in Denmark, and a group in Australia have pioneered the medical use of chemical compounds that target the bacteria’s ability to communicate. Like a military attack on command and control centers isolate the troops. Without a call to organize, the researchers reason, the bacteria will remain as loners and be much less likely to cause disease and other problems.

The international team has enlisted the help of a marine alga called Delisea pulchra. It grows off the Australian coast near Sydney in underwater groves full of broad, red-tinged leaves. Films of bacteria coat rocks, dock pilings, and boat bottoms there but not the surfaces of these leaves. The leaves remain free of bacteria, which would block the sun and clog their pores.

Furanones isolated from D. pulchra leaves prevent bacteria from forming biofilms in the lab, too

Someday, they might keep the bottoms of boats free of damaging bacterial slime. Boaters now use highly toxic metal-based paints for this purpose.

When bacteria in a biofilm aggregate on surfaces, they produce copious amounts of a sugary, mucous coating. Within this slime, they can form complex communities with intricate architecture featuring columns, water channels, and mushroom-like towers all on a very small scale, of course. These structural details may improve nutrient uptake and waste elimination, as blood vessels do in an animal’s body. From our size perspective, it’s just fuzz.

In the case of what goes on inside your mouth at night, teeming bacteria can in just a few hours erect the microscopic equivalent of a coral reef on your teeth. So as the sun rises and spreads its beautiful colors across the sky and you run your tongue over that fuzzy reef on your teeth, think of this additional wonder of life – how those little guys overnight, shed their tails, raised a cacophony of chemical signals and built that structure while you slept. Don't be surprised if you exclaim "Hey, neat – god at work between my teeth", but do so with your face turned away from your loved one until after you brush.

Isn't this world absolutely amazing? And as life resurrects itself from winter's dormancy, it is indeed great to be spiritually alive and a part of it. Now, I am counting on our resident microbiologist, Dr. Larry Graves, to help with questions and comments -- without him I would truly feel abandoned in the Garden.