Blowing in the Wind

A few thoughts about transgenes and local agriculture

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For the past few weeks, I've been reading books about biofilms. As Betsey Dyer, a biologist at Wheaton College in Massachusetts says, biofilms are organized bacterial communities "hidden in plant sight" (1).

The green slime that one can see just about everywhere that water flows and pools, in street drains, in dripping faucets, on the surfaces of rocks in creeks, indicates an organic community made up mostly of bacteria many of which are blue-green bacteria called cyanobacteria. They were once called algae, but algae are eukaryotes, organisms made up of a fundamentally different kind of cell than bacteria which are called prokaryotes. Many differences distinguish prokaryotic cells from eukaryotic cells. On this earth, the prokaryotes came first. Eukaryotic cells usually have prokaryotes living inside them and also certainly were derived from prokaryotes. Thus animal cells have mitochondria, organelles derived from a specific group of bacteria called proteobacteria. Plant cells have chloroplasts derived from cyanobacteria as well as mitochondria.

The core members of biofilm communities are bacteria with different talents. The blue-green bacteria, cyanobacteria, split water with sunlight giving rise to oxygen and reduced carbon compounds. These compounds feed other bacteria, some of whom fix nitrogen from the air to make amino acids for building proteins and nucleic acids. Teamwork is an integral part of the mixed biofilm communities that have been studied. Some of the bacteria can swim so daily they move to and from the light. Cross feeding intereactions in biofilms are common. The major, essential and ancient contribution to these widespread and routinely overlook biosomes (biological communities) is their bacterial nature. The biofilm communities are found in the cold lakes of Antartica, the hot springs of Yellowstone, the deep ocean vents of the continental plates and in salt brines like those found in the Red Sea and the Great Salt Lake. When conditions are so extreme as to limit or eliminate the snails, rotifers and other microbial grazers, these bacterial communities persist and even flourish.

The bacteria were here before us, by about 3.8 billion years. For several billion of those years, prokaryotes (bacteria) grew and developed as interbreeding communities that shared genetic, biochemical and molecular biological abilities. Thus they survived staying alive during the hot, anoxic (no oxygen), tempestuous (volcanoes, earthquakes, meteor bombardments) conditions that went on during the early eras of this planet. Remnants of these early biological times are stromatolites, fossilized rocks characterized by layers of calcium containing minerals that alternate with bacterial microfossils. These ancient relics were quite obscure until we got interested in biofilms.

Our teeth have a biofilm coating of microbes. These is another biofilm that lines and conforms to the shape of our large intestines. Medical treatments sometimes require insertion of feeding or draining tubes into our bodies and these tubes develop biofilms. Routinely these biofilms contain a *Pseudomonas aeruginosa* bacterium detrimental to our health. Studies of the life cycle of this bacterium uncovered a two phase life system, one in which the microbe lives free in fluid suspension and the other in which it grows attached, sessile, rooted as a biofilm. This has led to a revolution in microbiology. For hundreds of years, microbiologists have been growing bacteria in liquid culture, assuming that this was the primary life style of these organisms. With the interest and study of biofilms, it turns out that the pre-dominant life style of most bacteria is a rooted one, adherent to some surface or another.

Cholera, a disease of polluted water caused by the bacterium *Vibrio cholerae*, has its home at the junction of two major rivers in the Asian Indian subcontinent. The disease occurs during the flooding, monsoon season, a month or two in duration. For the rest of the year, cholera is not a problem. It exists most of the time attached to rocks, logs, streambanks and becomes infectious and free swimming during flooding season. It lives as a biofilm most of the time. In a biofilm, bacteria are much more resistant to antibiotics. They are protected by the polymers of sugars that make up the matrix of the biofilm. The biofilm life style protects the bacteria from drying out, from too much solar radiation, from the "slings and arrows of outrageous fortune".

As we study biofilms, the organisms that comprise them and how these organisms interact to survive and sustain one another, we find several discoveries. Sedimentary rocks arise from biofilms. Rather than coming from the preciptation of minerals in water, the minerals are trapped in biofilms which grow up from the bottom of liquids held by rocks growing bacteria. Bacteria are the primary generators of sedimentary rocks. Those invisible bacteria living organized life in mixed colonies have been cooperating for aeons. Genetic exchange between microbes in biofilms is rapid, common and lively essential for survival.

I began reading about biofilms at the suggestion of a microbial ecologist, Norman Pace Ph.D after I asked him about the kinds of bacteria in soil, particularly organic soil. He said that there were about ten times more regular bacteria (Eubacteria) than extremophilic bacteria (Archaea) in garden soil. Beyond that, there are many, many kinds and what is organic soil, organism rich soil, remains to be revealed.

In particular, having grown yacon, the Andean daisy that makes fructose sugar polymers (inulins, fructo-oligosaccharides FOS) in its edible and health promoting tubers, I observed that cultivation of yacon improves the tilth of the soil. Could there be a relationship between the production of sugar polymers in the roots with improved soil quality? In biofilms, the microbes lay down a marix of extra-cellular polymeric substances (EPS) which are mainly extra-cellular polysaccharide substances (also EPS).

Is what we call organic soil a three dimensional biofilm?

If soil is a three dimensional biofilm and genetic recombination among bacteria is enhanced in biofilms, then soil is an active zone of genetic exchange among organisms. Viruses actively produced by bacteria and archaea are active in promoting genetic events.

Two observations intersect at this point.

Part of the active process of agriculture is tilling the soil and incorporating residues of crops into the soil. Thus corn plants, sugar beet plants, wheat plants, virtually all crop plants and the weeds that grow in the fields are routinely “tilled in”. It is a core process in enhancing agricultural fertility. We rarely notice that bacteria and fungi turn the crop residues into humus or how they do this. Yet part of the process is digestion, breaking down the cellulose, lignin, cell walls, proteins and nucleic acids into sub-structural molecular pieces. Do any of the nucleic acids, the genetic materials of the crop plants end up integrated into the cells of the digesting organisms? Occasional reports indicate that they do. I never thought much about bacteria passing around genes from crop plants, but then again, interest in horizontal gene transfer among microbes has become of interest because of bacterial resistance to antibiotics. This resistance is carried on circular rings of DNA called plasmids and these are easily transferred from one bacterium to another. So if gene exchange is common among bacteria and they transfer genes in a variety of ways, perhaps we should care about what kinds of genes we till into our fields.

This led me to genetically modified organisms. Plants with human made genetic constructs called transgenes are becoming common in commercial agriculture. Genes that poison corn earworms, genes that provide resistance to herbicides like glyphosate are in plants that are widely grown in the USA and are slowly making their way into Oregon. I’ve heard talk of genetically modified Bt corn, herbicide resistance sugar beets and canola crops in the Willamette Valley.

While concern has been raised about the genetic crossing of GMO corn with other corn, with the crossing and pollen dispersal of genetically modified canola with related plants (members of the cabbage-mustard family, the Brassicaceae), I’ve heard little about the transgenes finding their way into the bacteria that live in soil.

Usually during August and September, our local air fills up with the haze of fine dust from ploughed fields. Dust clouds plume up behind tractors and wind blows the clouds everywhere. While a crop maybe confined to a certain field, the dust from its residues and the dust from bacteria interacting with its residues are not so confined. Indeed, given the talents of bacteria in taking in and exchanging genetic information, it seems likely that they can promote the widespread distribution of genes from genetically modified plants.

Perhaps as a species, as communities and as individuals, we need to pay more attention to the continuing release of GMOs into our neighborhoods, towns and agriculture.

1. Fossil and Recent Biofilms, A Natural History of Life on Earth 2003, eds. W.E.Krumbein, D.M. Paterson and G.A. Zavarzin, Kluwer Academic Publishers.