Elaine Ingham -- Lecture notes, Work in Beauty workshop, Gallup, NM -- November 7, 2015

Why are all these organisms in your soil? Until recently no idea why they were there or if they were even beneficial. Only in 1981 was the first paper published that showed how important these organisms were to your plants.

Once you have the organisms in the soil, they will work for you -- as long as you don't kill them. Healthy soil, properly maintained, can reduce or eliminate the need for irrigation; the need for hoeing or weeding; the need for tilling; and can decrease water consumption up to 70% in some places, and increase yields significantly, and increase nutrition in those foods. On an average 300 acre farm, we generally reduce costs for growers by $200,000 in the first year.

In grad school, she realized that the methodologies used in the world of microbiology were completely inappropriate for understanding what was going on in the soil. You cannot use plate counts to understand what is going on in the soil. 99.9999% of the organisms that exist in soils cannot and do not grow on plate counts in the laboratory. So we've been very misled by extremely inappropriate technical methodologies that have been used in the past. We have to use something else that tells us about the massive diversity. When you look through a microscope at 400x magnification, you are looking at one billionth of a gram (teaspoon) of soil -- and you can see multitudes of organisms -- bacteria and fungi and nematodes -- and if you were to put that on a plate count, NOTHING would grow. Nothing would come up. And so you would think no life was there, in the soil.

Elaine first started to figure this out when she began to work on the microbiology of the digestive systems of oysters.

While at Oregon State University, where she was a professor for 18 years, she butted heads with the biotech industry. Because her team showed that using GMOs could be EXTREMELY dangerous. If she and her team had not tested one particular genetically engineered organism, there would be no terrestrial plants left on this planet, with the exception of riparian plants. No more carrots or broccoli or onions or wheat.... riparian plants would still be there, because they had the ability to deal with the specific genetic modification. So we would all be eating only rice, for the rest of our lives. So it is extremely important to understand PRECISELY what those changes are in the GMOs. In the work she's done on long-term impacts of GMOs, she believes that NONE OF THEM are safe long-term.

We're talking about biological principles that apply to any living system. You have to understand how nutrients are cycled, how they are retained, how toxic chemicals are decomposed, how do we remediate all of these problems in the world around us. If you understand where all the CO_2 in the atmosphere came from, you would realize that if we all composted properly, if we just took the United States, we could take all of that elevated CO_2 in the atmosphere and put it back into the soil within one year.

Her first paper was published back in 1985, when they were first understanding the good guys and the bad guys -- the fungi and the bacterias, good and bad -- protozoa, arthropods, nematodes, earthworms, mycorrhizal fungi - they are in all soils, over the entire globe. Different species, because of different climates, but still in every soil.

How important are the roots of a plant, to that plant? It depends on the plant! Weeds, for example, don't have much root system. Trees, on the other hand, roots can go down 150 feet. The world of landscaping states that roots of trees and shrubs only go down a few feet and then they go sideways. Balderall. That is a sick plant. That is a plant that has been put into a coffin, and it will die WAY before it should die.

The roots of all our plants should be going down at least as far as they grow above ground. Because of the damage we do to soil -- we come out here and do constant tillage. And every time you take a plow or tillage equipment and you go into that soil and you fluff, where-ever that plow is pushing down on the soil, at the base of the plow, you are causing compaction. And as soon as you no longer have oxygen in that soil, (because of compaction) it is not soil any more, because it is no longer aerobic. Beneficial organisms are selected for an AEROBIC environment. It's the diseases, the pests, the problem organisms, the parasites that grow in reduced oxygen conditions. As soon as you compact your soil, you are setting the stage for the bad guys. And your roots will suffer -- they will not be able to grow down as deep as they ought to grow.

So -- when we compact the soil, what kinds of plants are we selecting for? When we BUILD soil, what kinds of plants are we selecting for? We have to understand that successional process as well.

So -- how are these healthy systems lost in agricultural fields? First is tillage. When we till, a great amount of damage is done, and we lose a HUGE amount of that soil's biology. We now have pests and diseases that start to grow. Next - pesticides -- because we till and because we lose that biology, we no longer have the organisms doing their job, so we have to take over. Weeds - herbicides - because of the damage we've done to the soil, thus selecting for weeds. Then inorganic fertilizers because we don't have nutrients cycling any more. Is there anybody out there in the old growth forests putting down inorganic fertilizers? No... and that is a WAY more productive ecosystem than any agricultural system you want to talk about. In an annual cycle, more nutrients are put away in wood than in any agricultural system -- more nutrients are locked into the organic matter of a tree, in the biomass of the plant, so unavailable for next year's growth, than is ever taken up during farming, and yet no inorganic fertilizers are needed to sustain the old growth forest system. So, how does an old growth forest stay alive, and our agricultural fields aren't?

Please realize: EVERY inorganic fertilizer is a SALT, and it is killing the organisms that would otherwise do that work for you. They kill organisms and plants by keeping H_2O tied up, and unavailable to organisms or plants. Gypsum, lime, calcium sulfate, ammonium nitrate -- are salts, as well, and will produce the same damage to soil life.

When you look at most fungicides, the active ingredient is calcium sulfate. And the stories of the Romans, when they wanted to destroy the fields of their enemies so they could not produce crops -- they did not use calcium chloride, table salt. Table salt was <u>literally</u> worth its weight in gold. The Romans salted the soil with gypsum or lime.

Every single pesticide that we apply -- well, think about the last part of the word: "-icide". It means "to kill." We might as well call it a general soil organism killer. Because it kills way more beneficial organisms than it does pests or diseases or parasites. Pesticides kill organisms by destroying membranes, taking away H_2O, causing lysis (the disintegration of a cell by rupture of the cell wall or membrane). Every time that you use a pesticide you are killing organisms that would otherwise protect your plant against those very diseases! You are setting the stage to start handing over fistfulls of dollars to the chemical companies. You have to go back and understand the natural systems. Sure, you can make compost and put life back into the soil later, but why use these and kill them all again?

Returning to our plant: how much of the energy from above ground goes down into the root system and stays there? How important are the roots of the plant <u>to</u> the plant? So -- where does the energy come from in your plant? From above ground. From photosynthesis. So all of the energy exists from carbon dioxide and sunlight creating carbon chains through photosynthesis. And those carbon chains (sugars) go down into the root system. And how much of that energy stays in the root system? It depends on the plant. In weeds, only 20% of that energy goes into the roots -- the roots don't go down very far. So, how do we build soil structure -- structure that allows for oxygen and water to penetrate deep into the soil, so we don't have to irrigate, don't have to add water? We have to understand who and what and how that structure is built.

Grasses -- 60% of the energy of our productive grasses will go down into the soil as roots and stay there. When we look at the root systems of the native grasses in this part of the country, the roots can go down 25 feet -- AS LONG AS THE SOILS IS NOT COMPACTED. -- If compaction is above 150 lbs/sq inch, plants cannot grow -- roots cannot penetrate.

The root systems of the PRODUCTIVE plants we want to grow for food and feed stock typically can go down 20, 25 feet. And if plants are allowed to grow deep root systems (no compaction) drought is rarely a concern.

Vegetables put 75% of their energy into root production. And any tree or shrub puts between 80-85% of the photosynthate it makes into the root system and STAYS there. Think of the plants we WANT as icebergs. The majority of the plant is below ground. The majority of the energy is being put into creating structural roots. Why do we need structural roots? So when the wind blows, the plant doesn't fall over. You have a little wind out here in New Mexico, don't you? They need deep structural roots! If you have shallow roots, that plant is going to go right on over in a wind storm. If you have a gully-washer happening, you want your trees, your plants to stay in place so they will slow down the movement of that water. If you don't have deep structural roots how will you stay in place? We have to make sure that we're not compacting the soil so those roots can go down as deep as they possibly can.

Weeds -- 20% of energy produced fixed in the roots
Grasses -- 60% of energy fixed in the roots
Veggies - 75% of energy is fixed in the roots
Shrubs, trees - 80-85% of energy fixed in the roots

Another part of the energy goes into the lateral roots, which are the nutrient-absorbing part of your plant. All of those fine, young roots, maybe one to two years old, so your plants can take up nutrients through the process of simple diffusion. But 50% of the energy that goes down into the root system of the plant is going to be released into the soil as exudates. What is an exudate? Well, an exudate is mostly simple sugar. Straight from photosynthesis - simple sugars. A little bit of protein, and a little bit of carbohydrates. So -- if I sent you into the kitchen and asked you to make something with simple sugars, a little bit of protein, a little bit of carbohydrates, what am I asking you to make? Cakes and cookies! Now, think about all the different kinds of cakes and cookies and pies you can make, based on the different types of simple sugars you have in your kitchen. Similarly, all kinds of different 'cakes and cookies' are coming out of the root system of your plant. Your plants are putting out different exudate compounds based on the stage of its life cycle and/or what the immediate needs of the plants are (nutrition, protection, etc.). So it can attract the right kind of bacteria or fungi to grow around the root system to protect it from diseases and pests, AND so that it can attract the right kind of bacteria that creates enzymes that pull the nutrients it needs out of the soil -- your silt, your clays, your sand, your pebbles, your boulders, gravel, bedrock. So we have to have these micro-organisms to pull the nutrients that are in your soil. NONE of your soils lack nutrients to grow plants. Every time that you are told that these are poor soils -- someone is -- excuse me for being blunt -- they are lying to you. You are being lied to. All of your soils have all of the nutrients you need to grow your plants. They are all present. In the crystalline structures of your rocks, your pebbles, the boulders, the parent material, the sands, the silts, the clays. No matter what composition soils you have, you have the nutrients necessary. Oh, but they are not in a plant-available form.

How does nature get those nutrients out of your sands, silts, clays, pebbles, etc., and move it and turn it into a plant-available form? I will show you the data that shows that your soil has all of the nutrients that your plants require. It's a total lie, when you're told that you have such poor soil that you will have to use inorganic fertilizer. Sorry, not true. You HAVE to have the biology to do the conversion. You must get the proper sets of organisms in the proper balances back into that soil.

So -- cakes and cookies to feed the bacteria and fungi, to do the work of making the enzymes and pulling those nutrients out of that plant-NOT-available form. So, when someone asks you to visualize your plants, you're all going to visualize that root system now, aren't you? And what else should we add to that picture? Ah! The cakes and cookies that your plant is putting out into the soil! (shows a picture of a cross-section of a plant in the ground, both foliar and roots. On each leaf and root section, there is a picture of a different sweet -- a cake, a pumpkin pie, a berry pie, sugar cookies, chocolate chip cookies, etc.) So, right here we have the chocolate chip cookies, because your plant needs more iron. So your plant is going to put out those chocolate chip cookies to feed and attract those bacteria and fungi who utilize chocolate chips to create the enzymes that pull iron right out of the crystalline structure of the mineral components of your soil (in a plant-available form).

[A later note -- Exudates are produced in foliar structures above ground, too; most are totally different from root exudates to select for very different bacteria for above-ground diseases. However, all come from the same inoculant -- from the soil as the seed germinates.]

How many of you live in that part of the area that has the really red rock? That red rock was anaerobic sometime in the past. That's all of the iron in those soils that was turned into completely reduced form of iron, and when oxygen hits it, it oxidizes, but that is a completely unavailable form of iron for your plants. So when you get your soil chemistry tests done, they'll say, "Oh, you've got lots of iron in there!," but none of it is available to your plant, because it's gone through that anaerobic period. When was it anaerobic? Yes - when in was at the bottom of the ocean. Completely waterlogged. And then those rocks uplifted and encountered oxygen and oxidized -- all of those bright reds. Completely unavailable to your plants. You HAVE to get the biology back in there to make the enzymes to pull BACK those nutrients into the biomass of the bacteria and the fungis. So that's why your plant is putting out these cakes and cookies. Over here it needs iron, but over here it needs boron and over here it needs calcium... and you didn't know that that lemon meringue pie was needed to make calcium, did you? And over here it's putting out tea cakes, because in this part of the root system, it's being attacked by mildew, by blight. So your plant is putting out specific cakes and cookies to ensure that your plant will be protected from the diseases and pests that cause problems in your root system.

The bacteria and fungi grown by the exudates that your plant puts out creates a castle wall around your root system. There is no pest, no disease, no parasite that can make it through that castle wall -- as long as those organisms are there. So, we're killing those organisms, and your plant is putting out its exudates, but there are no organisms there -- no castle wall. No protection. And you'll have disease and pest problems. So you see why agricultural fields have so many pest and disease problems? Because they've killed all of the organisms that the plant is trying to feed, that your plant needs for protection. Our job should be to put those organisms back! So -- how long will it take to put those organisms back? As long as it takes to make really good compost, with all the right organisms.

So we've got to have these food resources coming out of the root system. The plants making them... so, who's in charge of which nutrients are going to be made available? Who's in charge of protecting the root system of that plant? It's the plant! And we have to stop pretending that we know better! How many of you know exactly which nutrient is limiting the growth of your plant, today, right now? Our job is to get that nutrient-cycle re-established in our soils.

So far we have just been talking about plants and bacteria and fungi. The plants feed the bacteria and fungi who create enzymes to pull the nutrients into their bodies. But the plants can't use the nutrients locked in the bodies of the bacteria and fungi. So how has nature figured out how to get the nutrients out of the bacteria and fungi growing right around the root system, and into a plant-available form? Protozoa. Nematodes. Micro-arthropods. Earthworms. That's their function. Bacteria and fungi are taking up massive amount of nutrients into their bodies, all properly balanced, and that's going to attract protozoa, nematodes, micro-arthropods and earthworms right into the root system. Because that's what those guy eat -- the bacteria and fungi. There are more bacteria and fungi growing around your roots than in any other place in your soil. And when the protozoa, etc., eat them, there are more nutrients in the bacteria and fungi than the protozoa, etc., can use, and so their poop has exactly the nutrients your plants need in a plant-available form. All of the nutrients your plants need will be pooped out, right there in the root-zone. Exactly what your plant needs in the proportions it needs it in (example, calcium and magnesium ratio -- your plant is in charge!) How long has this nutrient-cycling system been in place in our soils? About the last 3.5 billion years.

[Discussion of the soil-food-web.]

When Elaine was young, the 'common knowledge' stated that only three essential nutrients -- N-P-K -- were needed for plant growth. Over the years that list has now grown to 42. And yet, arsenic is not on that list -- but arsenic is needed to build structural components. It doesn't need a lot of arsenic, and in fact too much can kill your plants, but it does need some. So -- everything in balance. And that is what the biology is so good at. Releasing all the nutrients in the proper concentrations so nothing is lacking. It's like calling up for a pizza -- the exudates are the telephone, calling up and asking for exactly what it needs, and the bacteria and fungi are the cooks who pull all the right ingredients together, based on what the plant ordered, and the protozoa etc. are the pizza delivery guys, who deposit those nutrients right where the plant needs them, in the root zone. Isn't that cool!? Over the last 3.5 billion years, the plants have figured out what chemical signals to release into the soil to "call up" the types of bacteria or fungi that can produce EXACTLY what the plant needs at that point in its life cycle. And because these bacteria and fungi are now living in vast numbers around the roots of the plant, they create a castle wall that protects the plant from diseases, pests, parasites. Above ground, as well. We HAVE to make sure the right biology is in the soil.

Now -- in our soil food web - do we need to have the 4th trophic level? The 5th and 6th? Yes -- by why? To produce predators that will control the numbers of protozoa etc., thus ensuring all of the protection given by the bacteria and fungi are not totally eaten and destroyed. And thus on up the food chain.

If we get this biology and balance back into the system, we build soil at an incredible rate. In South Africa, on a property she has been consulting on, they have been sequestering a *minimum* of 6 TONS of carbon per acre in the top FOOT of that land every year for the last 25 years she's been working with them. And they are selling those as carbon credit. We need to be doing that here. If you are getting paid to sequester carbon, you don't need to be growing crops any more. They are building soil, to the tune of 2-3 feet of soil, every year.

How deep can soil go? We have this attitude that soil is just this tiny little layer here up on the surface. How far down in the soil do we sequester carbon? How far down to we find active, living, aerobic biology -- bacteria, fungi, protozoa, nematodes, micro-arthropods and sometimes even earthworms? 16 MILES. Conventional farming has come to think of agriculture as a reductive system -- taking things out of the soil. But once we add the biology back into the soil, we can sequester up to 6 tons of carbon per year, in agricultural lands, in the top foot. This is easy to do, but you have got to not be distracted by chemical companies, by pesticide companies, by bio-engineering companies who want to sell you products. You can do this yourself. This is not rocket science.

So -- what is soil? I hammer this in a little more because it is so important. What is soil compared to the four-letter "D" word, "dirt"? Soil is sand, silt and clay and organic matter. You need to have the organic matter to feed your organisms. Water retention comes as a CONSEQUENCE of the organisms doing their job on that organic matter. The organisms also do the work of keeping the soil aerobic. The threshold of going from anaerobic to aerobic is 6ppm (parts per million) of oxygen. (Aerobic soil is greater than 6ppm O_2 --- 6mgO_2/kg soil). Reduced oxygen selects for the bad guys.

Hans Jenny -- the father of soil science -- defined soil as this:

1. Mineral (sand, silt, clay)
2. Organic Matter
3. Aerobic organisms
4. Abiotic factors

When you talk to an agronomist, and they are talking about soil as only sand, silt and clay, that's not soil. That's dirt. American grassland soils -- at the time that the pioneers were making their way through that part of the country, there was 40% organic matter in those soils when farmers first arrived. There was 8% in the dry, arid regions of the country, and in some of the most fertile grasslands, there was up to 75-80% organic matter in the soils. Today, in those regions, where we are conducting agriculture, there is less than 1/2% organic matter in most agricultural soils. Instead, it's up there in the atmosphere, or it's down in the gulf of Mexico; it's in places we don't want it because we have destroyed the biology that would have kept it where we want it. The mineral particles are going to wash away if we don't have the organisms to hold on to them. So, how do we solve climate change? Let's stop worrying about what they are doing in Brazil and let's get the life back into the soil so we can have the fertility and productivity that we want, so we can live here in a healthy fashion. We can reduce water consumption by up to 70%. For example, we grow grapes in the middle of Australia and we don't irrigate, because we have re-established the soils. If we can do it there, we can do it here.

[Example of how she, and other people, have taken documented sand-only material and created productive soils in one year by adding only compost.] Adding one ton of compost per acre, making sure they are adding it as a liquid compost form, several times during the growing season, and by the middle of the growing season they have a soil that behaves like loam. They have the structure of a loamy soil. It is the micro-organisms that take all the tiny little particles and glue them together. Micro-organisms - bacteria and fungi - create types of "glues" that allows them to stay where they want to be, near the feeding-zones of roots. They will glue themselves to the root system, to the neighboring organic material, to the adjacent sand particles. The pH of these glues are between 7-12, depending on if they are aerobic or anaerobic bacteria. Aerobic bacteria always make glues that are on the alkaline side, because we need to make the right conditions in an aerobic soil to be able to pull out those micro-nutrients. The bacteria will use that glue and start to build an aggregate of soil materials right around the root system of your plant. It's going to start growing lots and lots of bacteria as well, and is going to start adjusting the pH as well. And who is in control of all of this? Your plant - they produce exudates to select for the best bacteria to mediate your soil conditions. If your water is disgustingly alkaline -- if it has lots of salts in it, there's the problem - you are going to need a micro-organism that is going to pull those salts out of your soil. Out of your water. And put it back into the structure of the organic matter. You've going to want to have healthy micro-organisms in your soil in order to do that. So those glues are going to do a lot to push your soils in an alkaline direction. If your plants need more acidic soils, it's going to put out exudates to attract the fungi. Most fungi have an acidic structure. And the fungi grows long strands that grow as threads. And they are going to take the micro-aggregates that the bacteria are making and start binding and pulling them together and make macro-aggregates, creating more acidic structures, and now oxygen and water will go deeper and deeper along with your roots.

Looking at the mineral component of your soil: EVERY soil contains magnitudes more nutrients in every teaspoon of soil than your plant requires. Some of it is currently in plant-unavailable form. Soil tests only tell you what is plant-available AT THE TIME of the soil test. They tell you nothing about the plant biology that is <u>constantly</u> and <u>continually</u> cycling the plant-unavailable nutrients into available forms at the right times at the direction of the plants (through the types of exudates created). You do not WANT excesses of nutrients floating around, unbound in your soil because they can leech out during watering. It is not true that your soils are poor for any nutrient. None of them are poor -- even the ones that are on the far sides of the spectrum for any nutrient. None of them are poor. You might have to deal with the salts out there, but how do you manage salts? With compost. And with the organisms that will put it back into the carbon chain. When you put an inorganic fertilizer on your soil and the plant grows better, what does that tell you? That you do not have the biology in your soil.

> [A note from the lecture given by Christine Jones at the Quivira Conference, Nov. 11, 2015: Christine provided lots of data about the falling nutritional value in our food plants. The official explanation -- "dilution effect" -- 'as yield increases, nutrition declines." This explanation does not hold up, when compared to soils farmed without inorganic fertilizers.
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> Her research shows that an over-abundance of available nutrients, like provided by inorganic fertilizer applications, leads to "lazy" plants -- that is, they no longer produce exudates in the amount and varieties produced by plants in unfertilized healthy soils. Because of this, plants do not attract and maintain the right levels of bacterial and fungal companions, making the plant more susceptible to diseases, but more importantly -- the supporting soil biology does not produce the OTHER nutrients and micro-nutrients the plant needs to be healthy, thus creating plant parts -- our food -- that are SIGNIFICANTLY depleted of nutritional value. She has documented 70-80% depletion in plant (vegetable) nutritional values, as well as similar depletion of the protein content in grains, as compared to foods grown without fertilizers in biologically healthy soils. 80-95% of plant nutrition is microbially mediated. The nutrients are there in the soils, but the plant-exudate-bacteria-protozoa cycle has been critically disrupted. In working with grain farmers in Australia, she has seem Brix levels in grain increase by 200-300% by restoring - and taking steps to protect -- the biology in the soil. (more on this at the end of the Elaine notes.)]

When we started doing this work back in the 1970s, we believed that the breaking down of parent material only happened by weathering -- sun, wind, rain. Is wasn't until recently that we've been able to understand the role of bacteria and fungi in this process. Bacteria and fungi are responsible for the MAJORITY of soil break-down, much more than weathering.

When you send a soil chemistry test into a soil chemistry lab, what do they tell you about? They will report back on ONLY the soluble, inorganic forms of the nutrients. Where do you get more? You have to have the organisms that will pull those nutrients out. There is no soil test anywhere that will tell you about the total pool. You could go the NRCS and they can tell you about the total pool, and I guarantee if you do, you will never buy inorganic fertilizers ever again.

So - who told you that you have to have a soil chemistry test? The same people who want you to buy fertilizers.

So - let's go over what having the proper biology in the soil does:

-- Suppress disease (castle wall, selecting for aerobic bacteria, etc.)
-- Retain nutrients right in the root zone
-- attract bacteria & fungi predators that poop out the right nutrients every second of every day
-- Those nutrients become available at the levels and rates that plants require
-- Replenish!! We don't want excess, because they leech out of the soil!
-- Prevents water contamination (tied up in the bacteria and fungi which are glued to the root zone)
-- Decompose toxins (aerobic biology does this work)
-- Build soil structure
-- Roots go deeper
-- Water holding capacity is increased

Elaine made a brief reference to her belief that crop rotation predicated by a desire to avoid crop-killing pathogens isn't necessary when you have the proper biology in the soil. That if the soil biology is correct, you can plant the same crop in the same soil year-on-year without fear of wide-spread plant disease issues. Ditto the concern that you will take up all the mineral nutrients for a given plant.

Now, getting back to organic matter. Where does it come from? Initially, from photosynthesis. And then chains of carbon. And then the dead plant material falls back to the surface of the soil. The most rapid rates of decomposition ever recorded on this planet were in systems like we have here: in arid systems, under a layer of snow. Once you have snow covering the dead material, it will decompose faster than it disappears in a tropical rain forest. The fastest rates of decomposition have been recorded over and over again in the Rocky Mountains and in this part of the world. If, come spring, you see you still have a lot of undecomposed plant material on the ground, it means you don't have a healthy food web.

The decomposition process begins with certain species of bacteria and fungi, which then are consumed by other bacteria and fungi and then on up the trophic levels, creating more complex sugar chains over time -- sugars then amino acids, and proteins and lipo-polysaccarides and hormones, then your olmic, fulvic and humic acids. The humic acids appear in your microscope (under 400x magnification) as dark brown blobs. The fulvic acids appear as honey-colored blobs. These are your savings accounts in your soil. Where all the nutrients are stored. Your most important specie require those fulvic acids and the humic acids, so you want to make sure your soil is getting darker and darker brown.

Pay attention to the color of your soil, and of your compost! Notice that this is NOT black -- it is a very rich brown! If your soil has become anaerobic, the pests and the bacteria and diseases that live in anaerobic environments will produce BLACK soil. (Think of soil at the bottom of a pond or lake). All of your nitrogen will be gone. All of your sulfur. All of your phosphorus. All will be gone into the environment as a gas. Only under anaerobic conditions are these lost into the environment as a gas. You can usually tell by the smell. Your will be producing some pretty toxic chemicals -- preservatives, in some cases, like formaldehyde.

So - soil should not be black. It should be a rich, dark brown color. There is a color chart that you can go buy, so I invite you to go to the grocery store, and buy a color chart for your soils, for your compost. That color chart can be found in the chocolate bar section. You want to buy a 70% cocoa chocolate bar. That is the color of humic acid. That's what we're aiming for, in your compost. Or, you might also want to buy a milk chocolate bar. If your compost is this color, that humus isn't far enough along yet. You don't have the right biology -- you don't have the fungi you need. This color chart works for your soil, it works for your compost. It works when you're trying to make your own humic acid.

Where do you get your humic acid? DO NOT BUY LEONARDITE EXTRACTED HUMIC ACID! It will not feed your soil! It's denatured! What does denatured mean? It means that no living organism can use it. Instead, make your own humic acid. Begin by making good, dark rich brown (70% cocoa dark) compost, take a little bit of that compost and put it in a strainer. Put a little cheesecloth around it so you don't get a lot of particulates in it, and dribble water over the top of it. Very passively. Just dribble water through the compost and collect what comes out the bottom and it should be the same 70% cocoa color as the compost itself. That's liquid humic acid. Use it to feed your fungi. Use it to spray on your plants. It does a great job of suppressing a lot of the disease-causing organisms that we have, and it does a lot to grow the beneficial fungi.

If you look at the molecular structure of humic acid, it has a lot of carbon molecules in it. So as we are creating humus, we are sequestering lots of carbon and holding it in our soils.

[For the next half-hour, Elaine walked us through identification of different types of micro-organisms found in the soil. The notes for this are not extremely useful without the slides to reference.]

We are looking at these soil samples at a total 400x magnification. Many microbiologists will tell you that you cannot see bacteria at anything less than oil immersion. 1000x or more. OK. They are following the classical microbiological methods, and they are not thinking about what they are doing. You have to realize that in the world of microbiology, the way they have been taught to prepare their bacterial samples, is to take that microscope slide, put a drop of water on it, and pick a colony of bacteria off of a petri dish, and mix those bacteria into that drop of water. And then they're going to spread that drop across that slide so that they have a very thin film of that water and all that bacteria across that microscope slide and then they are going to allow this to air-dry.

What happens to you if we air-dry you? You shrink! It gets harder to see you! So then, they're going to take that microscope slide that they let air-dry and they're going to pass it through a flame, like a bunsen burner. OK, so now we're going to turn you into charcoal. Now, what happens when we heat your body up to high temperature? You shrink even more. You go from somebody who's 150 pounds to somebody who's only 3 pounds. Do you think we're going to need a microscope to see that person? Especially if we started out with a bacteria that's only one micron in size? You've now shrunk them down by over 10,000 times. You have to use oil immersion to even see them. But we don't need to do that, because we are not producing a sample to be stained with all kinds of stains and mordants and dehydrating materials. We want to be looking through a microscope so what can see these organisms doing what they normally do in the soil! We want to see our protozoa chasing our bacteria so we can see them when they're getting eaten! We want to see our nematodes moving around because they're way easier to see when they're moving! We want our fungi to be in nice, long strands and not some piece of crystallized material, near impossible to see. So, we are looking at our samples with a total 400x magnification. These are not very expensive microscopes.

[In a discussion of plant root / endo-mycorrhizal fungus relationship] -- 40% of the plant roots need to be colonized to get the fungal benefits. Once arbuscules are formed, the extramatrical hyphae of the fungi will grow up to 10 inches in every direction from the roots to seek out the nutrients requested by the plant.

Ecto-mycorrhizal fungi have a symbiotic relationship with pines and conifers. What kind of tree are you trying to grow? Make sure you have the right kind of organism in your compost!

So, there's another really important concept that I've just touched on -- why it is that we see certain plants in certain places, and why that changes over time. This process of succession. If a massive disturbance comes along and destroys all of the plant material, and we now have bare soil, then pretty soon weeds start coming in. We're going to be in a weed system for a while. But given enough time, those weeds secede to early-successional grass species -- the Brassicas, typically. And then given more time, the plants convert into something else. That's going to be a nice meadow, with mid-successional grasses and herbs. And given even more time, we are going to process to highly productive grasses that will allow our elk, our cow, our deer, our ruminants to grow very healthy and very well. But then around the edges of that meadow, now we start seeing shrubs sneaking in there. And pretty soon, if we don't do anything to disturb our meadow, pretty soon it will become a shrubland, and then pretty soon deciduous trees will show up, and pretty soon it's a deciduous forest and pretty soon it will be a conifer forest. In most parts of the world, the conifer, ecto-mycorrhizal plants are going to be the peak of this cycle. What causes that succession? What causes the plants to change? As we go through succession, we are going from the LEAST productive eco-systems - when you're looking at total plant production - up through more and more productive eco-systems, you are looking at greater and greater fungi-to-bacteria ratios in the soil. And we see this in depleted and over-tilled lands -- there is SO much bacteria in the soil that you often can't find any fungi. And there were almost no protozoa or nematodes. Mother Nature pushes soil productivity by ever-increasing the fungal biomass in these soils. As we see an increase in the fungal biomass, we see a change in the species of plants. So, how do we push our soils to more fungally-dominated? Through compost.

Where does the plant you want to grow fall on this fungal succession? Carrot? What kind of eco-system did carrots originate in? Meadows. Mid-successional vegetable systems. For best nutrition, strongest plants, least water use, you want your soils to be slightly bacterial (F:B => 0.75 : 1) Strawberries? Where do they grow naturally? They are understory in forests. Needs to be fungal-dominated, anywhere from F:B of 5:1 to 100:1 .

Typically, we see fungi concentration up at 70,000,000 micrograms per gram of soil. USDA says -- I'm sure we've all seen the little pie-charts, the USDA says that micro-organisms only occupy 5% of the soil volume, as if that's true for all soils everywhere -- only for very sick soils. When we get up into that old growth forest soil, 75% of the volume of the soil is fungus. The bacteria take another slice, the protozoa and nematodes another, so when we look at life in the most highly-productive eco-systems on this planet, micro-organisms comprise 95% of the volume of that soil. Don't tell me micro-organisms aren't important. So -- what do you want to grow? Then work to get the right biology in the soil that best suits the plants you want to grow. Get the biology right, and you will have to do way less work.

So -- how does this play out in a real-world situation? First, you need to decide what you are going to grow. What you grow will determine the type of micro-organisms you want in your compost, more fungal, more bacterial, or something in between. If you want more fungal materials, you want to add more woody materials, more lignin. And why compost? What if you had diseases in your plants? Composting destroys the pathogens that could infect your new crops. Worm composting destroys pathogens. As that material passes through the worm, the bacteria in the worm gut destroys all pathogens, but you HAVE to makes sure that all the organic material passes through the worm's digestive system.

And what if you don't like worms? Do hot composting. You'll need to get a lot of nitrogen into that compost pile so you can raise that temperature to about 131 degrees F. for at least 15 full days. Those are the regulations. That temperature does NOT kill the beneficial organisms. They go to sleep or go dormant or find a cooler place in the pile to hang out. You don't want your pile to go above 160 degrees F., and you will want to turn that pile 5 times, to move the hot inner parts to the outside of the pile, and the cooler stuff to the middle. The rapid growth of the bacteria and the fungi cause the heat in your compost pile. Thing about yourselves -- if you do a lot of reproductive activities, is there going to be a little heat involved? Yeah! Bacteria and fungi are the same! And like us - they're going to need a lot of wine and chocolate to fuel those reproductive activities. That's the nitrogen. You can find a lot of nitrogen in legumes, and there are a lot of high-nitrogen (nitrogen-fixing) trees in this area -- alder, poplar, locusts; as well as in manure. If you don't like using manure, use legumes. Anything that's high in nitrogen. So just get the temperature high enough long enough and you destroy the problem organisms. So we want to compost so that we don't have those pathogens being re-introduced into our living systems.

[Elaine presented an example of a project they did in Texas for the George W. Bush center in Dallas, where they turned a packed-earth parking lot into native Texan grasslands. The following notes are taken from some of the questions asked during the conversation.]

If your soil is compacted to 150 lb / sq. inch, the roots of the plants you want to grow will NOT be able to grow through there. A simple test -- can you push a metal rod into the soil? If you can't, then the soil is compacted beyond 150 lbs / sq. inch. And there is no plant on this earth that can push through 300 lbs / sq inch of compaction.

Micro-organisms will decompose all toxic materials (diesel, gasoline, pesticides) if you give them good organic matter. Aerobic decomposition is critical here. The question was asked -- will composting take care of genetically modified organisms - the GMOs? Yes. As long as you do it aerobically. The work that we're doing, we are showing that if we are composting AEROBICALLY, we could not detect the genetically engineered sequences in the final product at all. (Later comments suggest she means specifically HOT aerobic composting). If we composted anaerobically, we could still detect those GMO sequences at the end of the composting process. And the question about Roundup -- Roundup is a bacterial food -- and if you have the proper biology, it breaks down quite rapidly in the soil <u>if</u> the life is there. And that's the problem -- there is no biology left in the soil, so if builds up in the soil. And eventually, nothing can grow there if the concentration gets so high. Question: so, would you compost GMO alfalfa if you had no choice? Elaine: That's the ONLY thing I'd do with GMO alfalfa.

Same goes with antibiotics -- all antibiotics are proteins, and in a composting situation, bacteria eat and break them down very quickly.

So -- how do you take soil and turn it into a parking lot? So that even when you get heavy rains, it doesn't turn into mud, and can still support the semis, tractor-trailers, big haulers? What do you do to turn soil into a concrete-like surface? You take gypsum and anhydrous ammonia and you treat the surface. Usually it takes about 4 weeks for that surface to turn into total concrete. This is what we do when we want to turn a stretch of earth into a landing pad for an airplane. Now, in the corn world, what are the two treatments they're told to use at the beginning of the growing season? Anhydrous ammonia and gypsum, and sometimes lime. And then they wonder why at the end of the growing season their soil is just like concrete.

In this case study, the compaction was at 6,000 lb/sq. in. They dug down 10-15 feet, grinding the dirt and mixing it with compost, to re-establish the natural hydrology of the system. "You cannot do this work by biology alone if the treatment of the land has been so extreme. You MUST re-establish the hydrology of the system -- the biology will not do this work for you alone."

Planting trees -- they removed the wrapping around the rootball and soaked it in compost tea before planting, and put pure compost around the tree when planted, to make sure the tree had the proper inoculation.

The land had been laser-leveled. One of her team did the archival work on the piece of property to see where the natural streams and ponds were prior to being turned into a parking lot, so they used earth contouring to re-establish that the natural hydrology. Used swales to direct water away from the building: "permaculture at its best."

The starts for the grasslands -- they started them in 100% pure compost, because that brings with it all the proper biology for those riparian plants.

The dirt-to-compost ratio depended on the amount of biology in the soil found in the different parts of the base material. Where they were dealing with the really bad dirt, lots of toxic materials, lots of diesel and chemicals and pesticides, they were using 50% compost, 50% site soil. In less damaged areas, they used about one ton on compost per acre. The percentage varied based on what was the base biology and what was the toxic load of that soil.

Applied a top-layer of ground kelp over the grass starts -- a food that both bacteria and fungi can readily consume.

When doing this type of work Elaine says to continue to monitor the biology in your soil periodically to make sure that the right types of organisms have established themselves: more bacterial or more fungal, depending on the plant in that area. If it does not have the right biology, re-apply compost with the correct F:B organisms, and test again later. If the right biology has established, then there is nothing else to do. While the biology is out of balance, you will want to go back out during the growing season with a compost tea (with the right biology) to do a foliar application to help protect the plant.

As we go up those chains from simple sugars to proteins to humic acid, we are going from a carbon: nitrogen ratio of 5:1 up to a carbon: nitrogen ratio of 500:1. So we are sequestering tons of carbon. The turn-over time (how long it will take for those carbon chains to break down) of plant-forms is about 5 years. The turn-over time of humic acid is about 500 years. That stuff is deeply sequestered. Only when you go back and disturb that soil, till it and turn it, will humus decompose in a shorter period of time. So once you start sequestering this carbon, you really need the biology there to hold it in place.

So, how are you going to seed your crops without tilling the soil? You have to keep the biology so you just put a narrow blade where you just cut a slit where you drop your seeds, and that closes up because of the structure of the soil, so the only disturbance is that tiny slit where you drop your seed. And make sure you have mulch on that soil to protect the biology.

On her new research farm, she is covering the soil with very low-growing perennial plants -- a living 'mulch', protecting that soil surface. The work being done at Washington State University clearly shows that if you have the right kinds of plants on your soil surface, the plants prevent evaporation from the soil surface. The healthier the soil (the really dark brown soils), the greater the evaporation. So you must do something to protect that soil surface. A perennial understory. The research shows that we greatly reduce soil evaporation if we have perennial plant covers that are resistant to evapo-transpiration. This is especially critical for this part of the world. Currently, Elaine is trialing a whole series of cover crops to be able to make recommendations for this. Hopes to have recommendations by fall of next year. But wants to point out right now -- hairy vetch -- DON'T. It is very heavy on evapo-transpiration. It blows off a LOT of water. You want to look for things that have very waxy leaves, that are very low to the ground, and very prostrate, so it won't interfere with crops. A list of all the plants she is currently trialing is on the soilfoodweb.com website.

The best way to treat city water is with compost. Take one cup REALLY good compost, dribble 12 cups of water through it, and that compost extract should have that same dark, rich color. There's your humic acid. One drop of humic acid in one gallon of water will neutralize the chlorine and chloramine that is in your city water. Lots of water in this part of the country is very salty, so if you have high electro-conductivity in your water, you will need to add two or three drops of humic acid. Feel free to err on the side of 'lots.' Make your own humic acid! Do not buy it!

If you allow the water to PASSIVELY pass through the compost, you are not disturbing the organisms -- they stay glued in place -- you are simply diluting the fluvic and humic acids accumulated in the compost. Since you are not shaking or mixing the compost in this process, you will not dislodge the organisms. When you are done, just throw that wet compost back into your compost bin, they will start working again for you.

So -- tap water and city water have two components in it that we have to worry about: chlorine and chloramine. Chlorine is a gas, so if you shake your water, it will leave the system. The problem is today most water systems throughout the world are adding chloramine in order to prevent the growth of disease-causing organisms on the pipes between the water treatment plant and your house. At this point, a lot of our human pathogens (including the truly pathogenic version of e. coli) are resistant to chlorine.

Chloramine is NOT a gas. You CANNOT shake your water and get rid of it. You have to add something that is going to complex this material so that it's not going to be killing your organisms. The easiest thing to do is to add an organic acid. It could be any one of the organic acids -- you could put in orange juice, you could put in vitamin C, ascorbic acid. But the problem is when you are putting in an organic acid that is colorless, you don't know when you've added enough. When you use humic acid, when that humic acid has completely neutralized the chloramine, you're going to see a color change in your water. It turns a light tan color, and then you know you've put enough in. Use a test gallon to see how much you'll need to use to treat your particular water, and then just use that much going forward. If it is more than two drops, you may want to contact your city water plant.

She gave an example of a water treatment plant she encountered in Australia that was inadvertently adding three times as much chlorine and chloramine to their water because of poor procedural documentation. Best to go by the color change -- and feel free to contact your water treatment facility if you think the levels might be too high.

A humic acid treatment will also neutralize a salt / alkalinity problem with your water. For this purpose you will probably want to use an EC meter or pH meter to determine the correct amount.

Fungal-rich soils are not good for your brassicas and early-season vegetables.

How do you maintain good soil health in closed systems like greenhouses? Compost, again, with the proper ratio of fungus to bacteria. When you need to, use a compost extract or compost tea application.

Elaine highly recommends replacing peat moss -- and in fact all of your potting mix -- with compost. This does not burn your seedlings. PhD work by a student has shown the healthiest seedlings were grown in 100% compost.

Compost extract -- massage bag, do not scrub! Massage, like you would on a person. Compost extract is appropriate for soil applications. If you need a foliar application make compost tea.

Making different types of compost for different types of plants is a lot of work, so she usually makes one compost with equal amount bacterial and fungal biomass -- 10% high nitrogen (manure or legumes), 30% green plant material (bacterial food), 60% woody material - leafs, conifer needles, wood chips, paper from your house. This makes a compost that's about equal parts bacterial and fungi biomass.

So -- what kinds of species are going to be growing in our compost? It depends on the types of organisms that are living on the surface of your composted plant materials. You want to put lots and lots of different types of things in your compost pile. You cannot make good compost out of just straw and manure. It's just not possible -- there's just not enough diversity going into the pile. You want DIVERSITY. But please don't use salad greens you get in little packages from the grocery store. The greens don't decompose in those little bags because it's in a nitrous oxide atmosphere. Nothing's decomposing. The nitrous oxide kills all of the organisms on the greens in that package.

You will need a good inoculant with a vast diversity of life. Go into the forest, below the litter layer, and look for that good dark rich brown layer with lots of strands of fungi that you can see very clearly. Remember fungi can be almost any color. Be sure to get some of those strands of fungi. You only need one pinch! No need to take a lot!

Be cautious when using sawdust! The lasagna method does not apply when you are using sawdust! Be SURE to mix it in! Because it easily compacts, and you can quickly create anaerobic conditions below the sawdust level.

Be cautious with wood ash -- it's a salt.

Ozone generators - avoid. That ozone contains a free radical that destroys just about any membrane. Protozoa cannot deal with it.

(Should compost treatments be surface-only?) It depends on the state of your soil. Use your metal rod to find out if you have a compaction layer. If you have a compaction layer, mix compost in down below that compaction layer. If there is no compaction problems, then top treatment is fine -- the organisms will move on down through the soil.

Compost -- if you use compost extract or compost tea to water a new compost pile, you can have finished compost in 21 days. This is how Elaine has been doing it -- hot composting with moisture provided in the form of compost tea, turned three times :: 21 days. Turn when the temp hits around 165 degrees. So, if you use a compost tea as an inoculant, you will probably have to turn at 48 hours, then again 24 hours later, then the third time 24-48 hours later, if it's still coming up to temperature then you'll turn maybe another one or two times, but then the temperature drops very quickly back down to ambient, and you're finished in 21 days. If you want to hit Federal regs, you'll want to make sure you get 5 turns in.

Elaine heats her greenhouse with two compost piles, one on either end, alternating.

Elaine does NOT recommend using grey water directly on food plants. As a microbiologist, she feels strongly about ensuring any potential pathogens have been considered. Run in through your compost process.

[A discussion of the toxic chemicals produced under anaerobic conditions.] If your pile goes anaerobic, spread it out, wet it down, let it dry to get rid of all the anaerobic components, then use it as "woody" material in your next pile.

Notes, Christine Jones, Quivera conference, November 11, 2015

[Note: Elaine Ingham was in attendance in the audience at Christine's lecture.]

95% of terrestrial life exist only in the soil. 99% of those refuse to be cultured and grown in the laboratory.

Plant cycle is a regenerative biogeochemical process.

Christine covered many of the same points as Elaine -- the importance of roots. The importance of creating the capacity in your soil for root DEPTH. Data on the amount of carbon that can be sequestered in root formation, as well as the vast amounts of carbon that is sequestered in humic acid / humus. (78% of the newly sequestered carbon was in the humic (non-labile) fraction. Soil can now hold 18,000 gal. H_2O per acre.)

85-90% of plant nutrition is microbially mediated.

<u>Increases</u> in soil nutrients:
-- Calcium -- 177%
-- Magnesium -- 38%
-- Potassium -- 46%
-- Sulfur -- 57%
-- Selenium -- 17%

Aerobic soil is a net-sink for methane. Methanatrobes

Christine says to think of yourself as a "light farmer":
-- Build photosynthetic <u>capacity</u>
-- Enhance photosynthetic <u>rate</u>

Leaves are <u>COOL</u> -- photosynthesis is an <u>endothermic</u> reaction. Plants cool the air and ground below; also, dew collects and forms on leaves and is directed back into the ground.

Look to create <u>100%</u> ground cover, through all four seasons: photosynthesis supports the life-cycle of microbes and ergo soil.

NO BARE GROUND. If your ground is bare, your soil is dying. Most soil microbes are PLANT DEPENDENT.

Photosynthesis supports the life-cycle of microbes and ergo soil.

Ground cover should be <u>tiered</u> -- many levels. (Her examples were with cash grain fields; obviously, tiered becomes a different issue when you are growing lower-profile crops).

-- How much light is being captured? Leaf size, width, height, compactness.
-- Grow a DIVERSITY of plants in your soil, in your ground cover. You want the diversity of micro-organisms that a diversity of plants attracts and maintains.

Recommends finding both an appropriate C-3 (cool weather) and C-4 (warm weather, very water efficient) grasses for ground cover, to cover all seasons.

> The perennial grasses can be classified as either C3 or C4 plants. These terms refer to the different pathways that plants use to capture carbon dioxide during photosynthesis. All species have the more primitive C3 pathway, but the additional C4 pathway evolved in species in the wet and dry tropics. The first product of carbon fixation in C3 plants involves a 3-carbon molecule, whilst C4 plants initially produce a 4-carbon molecule that then enters the C3 cycle. Why are these differences important?

> These differences are important because the two pathways are also associated with different growth requirements. C3 plants are adapted to cool season establishment and growth in either wet or dry environments. On the other hand, C4 plants are more adapted to warm or hot seasonal conditions under moist or dry environments. A feature of C3 grasses is their greater tolerance of frost compared to C4 grasses.

"It's a matter of finding the thing in nature that already does the thing we want."

Grasslands are being discovered to be fungally-dominant. Of all the fungi, mycorrhizal fungi are KING.

While some plants are known for being 'nitrogen-fixers', in reality, EVERY green plant is a Nitrogen-fixer, provided they have the supporting biology. Carbon cannot be stable in the soil unless it is linked with nitrogen. Likewise, nitrogen can only be stable in the soil if it is in an organic compound, i.e., linked to carbon.

Nitrogen is needed to make proteins. Chlorophyll is a protein. Nitrogen provided by mycorrhizae is transported into the plants as amino acids -- the plant then links those amino acids together to make proteins.

If provided nitrogen in the form of an inorganic fertilizer, the plant has to add carbohydrates to break down the inorganic form, and we get a build-up of nitrates and nitrites, which are toxic. We consume these.

[Note: many of the following notes were given while speaking about grain crops. She highly recommends adding livestock grazing to any grain-crop production cycle. There are multiple benefits to adding 'pulse grazing' of your cash crop to the production cycle.]

"Pasture cropping" -- Do NOT allow grazing (or cutting) to go below 50% of the height of the matured plant. Up to 50% of above-ground plant being cut does NOT significantly affect root development (only causes 2-4% root growth retardation.) There is a direct relation between leaf area removed and impact on roots. More than that significantly affects root growth. (Note: I would assume this applies to pruning, as well.)

Graze 2-3 times a year. Graze at the height of stage 2 (right before reproductive cycle of the plant).
**The healthier the soil, the longer the vegetative cycle will linger. **

Principles of Soil Health
-- We need something growing
-- We need diversity of what's growing
-- We need some form of animal impact (some form of small disturbance and recovery -- that is what natural systems do)

Christine recommended the "Climate, Water, Soil & Hope Project" -- Soil Carbon Coalition -- Peter Donovan -- http://www.soilcarboncoalition.org/