The Soil Food Web

Jerry Faulring

> "Plants use the sun's energy to convert inorganic compounds into energy-rich, organic compounds, turning carbon dioxide and minerals into plant material by photosynthesis."

It is not uncommon to see plants in a landscape that are sort of 'growing' but really just surviving and more likely dying a very slow death. There are numerous possible causes but most observers will correctly predict "I bet the soil here is really bad". But what do they mean by that observation and do they understand that 'really bad soil' can be brought to life if sterile or restored if depleted? A basic understanding of how healthy soil works makes the solution much easier to implement with confidence. Common knowledge is that good soils need to be 'dark and rich' with lots of good stuff in the mix. What is that good stuff and how does it work to provide a viable home for plants?

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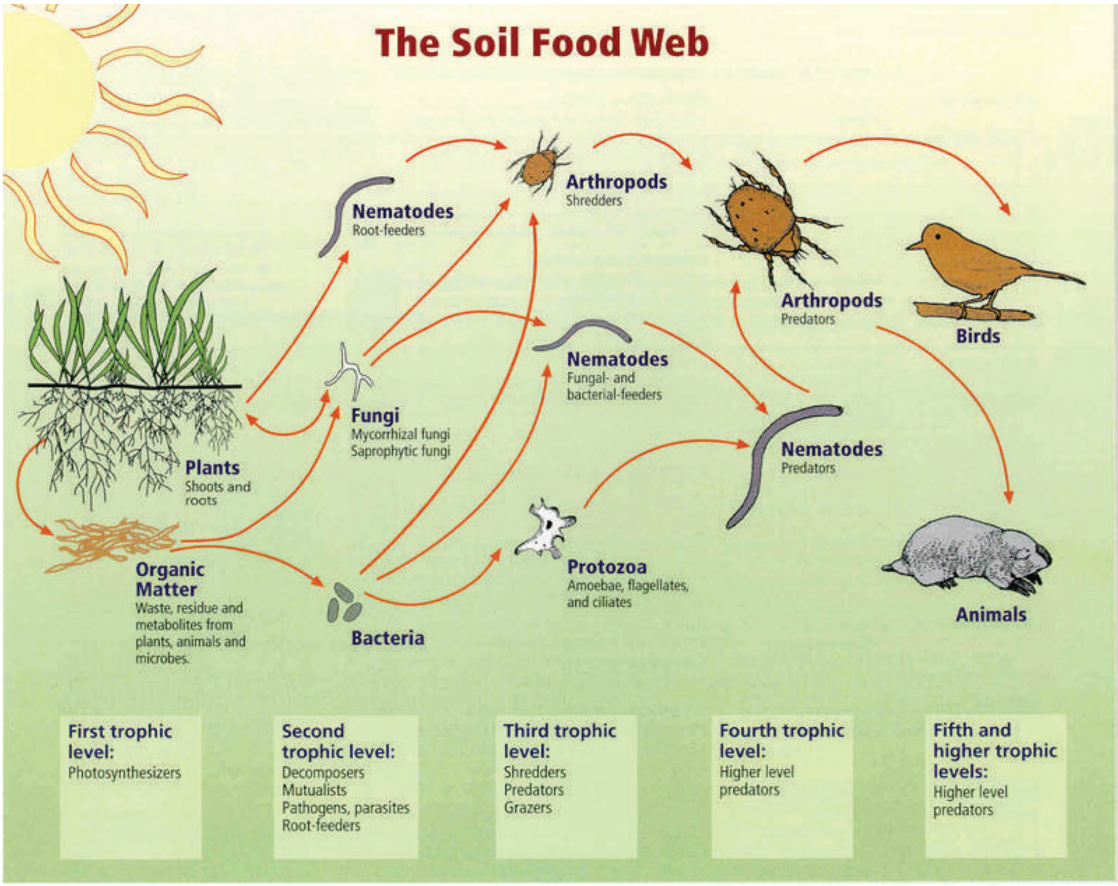


Relationships between soil food web, plants, organic matter, and birds and mammals
Image courtesy of USDA Natural Resources Conservation Service
http://soils.usda.gov/sqi/soil_quality/soil_biology/soil_food_web.html.

(continued from page 31)

The Soil Food Web is a phrase coined to describe the fact that healthy soil is essentially a vibrant living organism that when acknowledged and leveraged can work with us to provide sustainably, all the food and fiber we need. In the reverse, if we abuse healthy soil we must do stupid things to force cooperation. Below is the story, briefly, of how plant roots, microscopic organisms, and animals synergistically work together to break down organic matter to provide plant nutrients and build soils structurally to enhance drainage, water holding capacity and gaseous exchange. This discussion assumes there is ample organic matter available in the soil.

Food webs describe the transfer of energy between species in an ecosystem. While a food chain examines one, linear, energy pathway through an ecosystem, a food web is more complex and illustrates all of the potential pathways. Much of this transferred energy comes from the sun. Plants use the sun's energy to convert inorganic compounds into energy-rich, organic compounds, turning carbon dioxide and minerals into plant material by photosynthesis. Wikipedia

The Big Picture

A healthy soil is teaming with activity. When all systems are working well together, a vibrant Soil Food Web will exist. Three major 'activity groups' or functional levels work in harmony to support and nurture each other. If one group fails they all suffer. The three groups can be classified into arthropods, bacteria & fungi, and plant roots. I'll organize these in an order of relative importance but keep in mind it is not unlike the question "what came first, the chicken or the egg"?

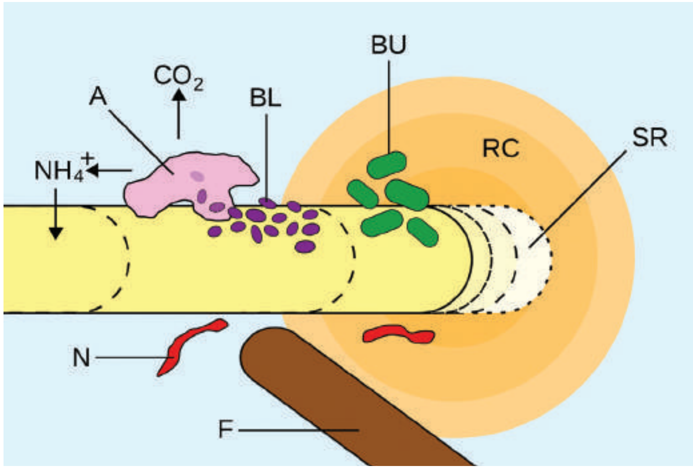
Plant roots feed bacteria and fungi with root exudates. Plants are also the 'thermostat' of the system. Based on seasonal need and climate, exudates increase and decrease in volume to either excite bacteria and fungi activity or cause them to wane.

Protozoa and nematodes feed on bacteria and fungi.

Arthropods feed on protozoa and nematodes.

The Rhizosphere

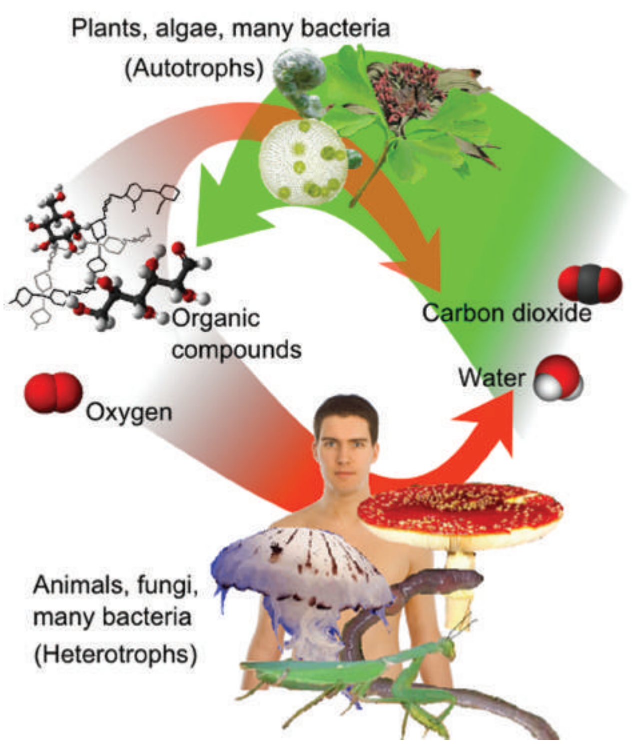
Little known to most of us who grow plants for a living is the knowledge that healthy plant roots live in a 'soup' of extraordinary activity involving bacteria, fungi, protozoa, nematodes and larger animals. The rhizosphere radiates from the roots into a small space only in the range of 1/10th of an inch. Yet this space is teaming with activity that is synergistic for both plants and the microbial life that rely on each other for their existence. The plant roots produce exudates loaded with moisture and minerals. Bacteria and fungi consume the exudates to sustain life. In tern, the bacteria and fungi are consumed by nematodes and protozoa. Whatever they do not absorb for their sustenance is excreted as nutrients to be consumed by plant roots. The protozoa and nematodes consume the bacteria & fungi, and the arthropods feast on the protozoa and nematodes. A healthy soil food web cannot exist with out plants and microbes. Of course, this understates the incredible complexity of the system but is how it works in the simplest explanation.



An illustration of the rhizosphere.
A=Amoeba consuming bacteria
BL=Energy limited bacteria
BU=Non-energy limited bacteria
RC=Root derived carbon
SR=Sloughed root hair cells
F=Fungal hyphae
N=Nematode worm   Wikipedia

Plants are called autotrophs because they make their own energy; they are also called producers because they produce energy available for other organisms to eat.

Heterotrophs are consumers that cannot make their own food. In order to obtain energy they eat plants or other heterotrophs.



Autotrophs and Heterotrophs - Wikipedia

Arthropods

By definition an arthropod is an animal with segmented bodies, jointed appendages and a hard outer skeleton or exoskeleton. Examples living in the soil food web are hundreds of different insects and spiders. They impact the soil food web by eating nematodes and protozoa. While routing around in the soil for food they aerate it, incorporate organic matter and mix the profile. Ants are particularly adept at this function.

Beyond arthropods but equally important are worms, slugs, insect larvae, and snails who also digest and mix organic matter.

Bacteria

Soil bacteria are the engines of organic matter decay. Without them organic matter would just collect and provide little benefit. There are good bacteria requiring oxygen to survive and bad bacteria that do not require oxygen (anaerobic) causing putrefaction or the rotting smell common to water logged, oxygen deprived soil. How many times have we heard that plant roots need oxygen? It is true that roots need atmospheric oxygen but it is also true bacteria need oxygen to produce organic matter decay releasing nutrients needed by the plant roots. Plants also obtain oxygen from water.

Three types of soil bacteria perform roles in the development of healthy soils; a fourth works against the process.

Nitrification. This is the process of transforming ammonia nitrogen, not usable by plants, to the useful form of nitrates which plants convert back to proteins.

Nitrogen fixation. This process converts atmospheric nitrogen into the ammonia form making it available for nitrification. Some nitrogen fixing bacteria live in close proximity to legumes and fix nitrogen into organic bearing nodules.

Actinobacteria. These good fellows are responsible for converting organic matter into humus; more about humus later.

Denitrification. This is not a good thing. These bacteria, mostly anaerobic, convert stabilized organic nitrogen back into the gaseous form releasing back to the atmosphere. This occurs when soils are deprived of oxygen and the putrefaction process takes over.

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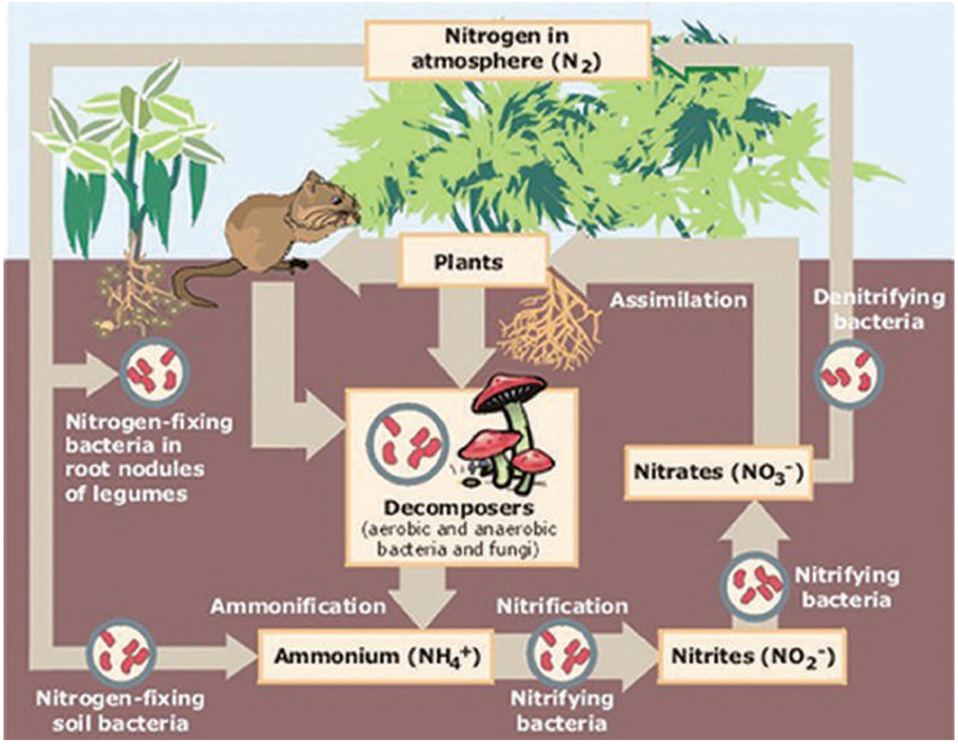


The chart above generally shows all these processes in action. Many will remember this from school as The Nitrogen Cycle. Wikipedia

Mycelial cord made up of a collection of hyphae; a key part in the process of saphrotrophic nutrition, it is used for the intake of organic matter through its cell wall. The network of hyphae is referred to as a mycelium, which is fundamental to fungal nutrition. Wikipedia

Fungi

Soil fungi are usually yeasts and moulds. Fungi cannot produce their own food and rely on a chemical source of energy rather than sunlight as well as organic substrates as a source of carbon for growth. Parasitic fungi such as pythium and rhizoctonia are damaging to plants while other fungi are antagonistic toward damaging fungi and have beneficial plant relationships. Saprotrophic fungi which live on dead or decaying organic matter are responsible for humus creation.

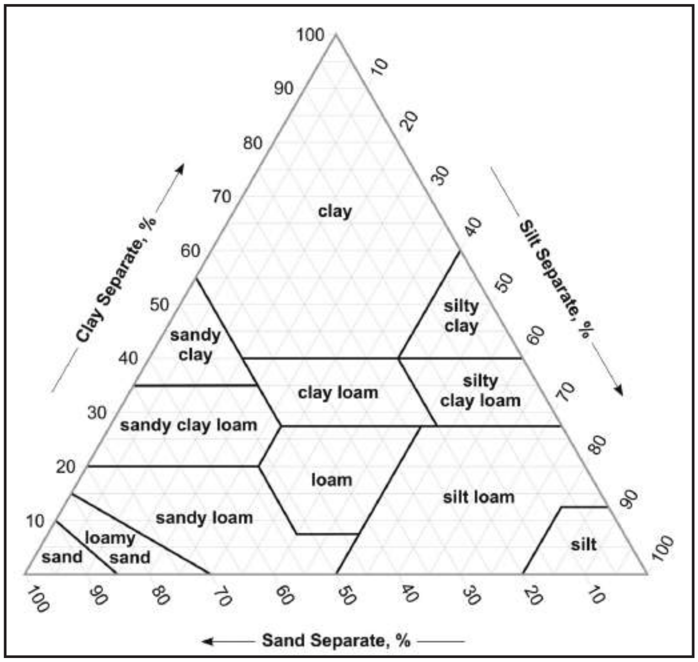
Humus is the end product of organic matter decomposition. Whereas organic matter must be replenished either naturally such as leaf litter in the forest or from soil amendment by us, humus is thought to remain in the soil indefinitely due to its insolubility.

Fungi grow into long thin threads (mycelia) reaching well into surrounding soils of living plants. A symbiotic relationship beneficial to both the plants and the fungi can result; these fungi are known as mycorrhizae. The mycelia become entwined with plant root hairs and the soil. These mycelial growths can either form a sheath around the root hairs or become concentrated at the root tip. Mycorrhizae draw carbohydrates from the root and provide nutrients to the plant. Mycorrhizae have evolved to the extent that some are mated to a specific plant genus. Fungi often produce above ground fruiting bodies, (collectively called mushrooms) that animals feed on and can subsequently disseminate spores. And you thought deer in the nursery or landscape were a bad thing.

Friable Soil Wanted!

Friable soil refers to the aggregation of sand, silt, and clay particles into larger, visible aggregates. Sand sized particles are visible to the eye but silt and clay particles are microscopic.

The soil textural chart shows the desirable percent of each particle size to form a good soil of the clay loam to medium loam characteristics; this favorable ratio does not necessarily indicate soil quality. Friable soil is easily crumbled and that is the easiest way to begin the analytical process of determining soil quality in the field. The larger, aggregated particles are the essence of good soil. They form as a result of all the activity in the soil food web.



Soil textural triangle; medium loam is the goal.

Bacteria will simply 'wash' away if they do not bind to something. To affect this ability to bind to individual soil particles they exude a slime that acts as glue. Fungi produce hyphae as seen above and these structures stick to the soil particles. Working together, bacteria and fungi 'glue' the soil particle types into aggregates.

Worms and insect larvae make a significant contribution to aggregation by borrowing through the soil in search of food. They increase the air space and their fecal discharge contributes to the soil soup.

This is all significant for several reasons keeping in mind that aggregation will not occur in the absence of organic matter. First, as stated above, the larger soil particles represent a home for the microorganisms. Second, the particles create air space reducing the soil bulk density allowing for greater gaseous exchange and drainage. Third, the particles act as sponges to hold to retain water that will be released when plants need it.

Nutrition

Here is the magic. If the soil food web is healthy with all the participants working well together, they provide all the nutrition needed for plants to thrive without added fertilizers. It is known that for every one percent organic matter contained in a soil, the soup of microscopic life can produce 20 pounds of nitrogen per acre per year. An ideal soil would contain 8% organic matter producing 160 pounds of nitrogen per acre per year. Most of us think in terms of N per 1,000 square feet so we can see that this equals about 4 pounds per 1,000 square feet – every year! Equally important, phosphorus and potassium as well as many micronutrients are produced. Even better, all this nutrition is derived from organically bound or immobilized sources. Synthetic fertilizers are soluble and will move through the root zone if unused finding a new home in the ground water. Organically bound nutrients stay bound in the soil particles until the nutrient equilibrium gets out of balance. Thinking this through it is easily understood how the great grasslands, prairies and forests succeeded so vigorously before man arrived.

Summary

Research has shown that up to 80% of synthetic nitrogen is never used by plants; it either volatizes or leaches into the ground water. Of course 80% is probably an extreme but knowing that possibly 50% of the nitrogen budget is wasted is not very encouraging from both a financial and environmental perspective.

Ideal soils high in organic matter do not just happen in the landscape as they will in woodlands, grasslands and forest. We need to give these soils a boost by adding organic matter.

Synthetic fertilizers are salts. Salts in solution can damage a healthy soil food web. Therefore, an optimal soil solution should not be fertilized except when using organic sources.

ONE gram of a **healthy** soil contains the following – something to really ponder:
-600 million bacterial individuals
-15,000 to 20,000 bacterial species
-150 to 300 meters of fungal biomass
-5,000 to 10,000 fungal species
-10,000 protozoa
-20–30 beneficial nematodes
AND
-200,000 arthropods per square meter
Source: Dr. Elaine Ingham and Soil Food Web, Inc.

Previously I mentioned that in the absence of naturally sourced nutrition we have to do stupid things to make soil perform. The stupid thing is to spend our fossil fuel resources to manufacture nitrogen as well as mine the other nutrients required to sustain plant life. ❦

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