Soil Biology

The Soil Biology Primer

Chapter 1: THE SOIL FOOD WEB

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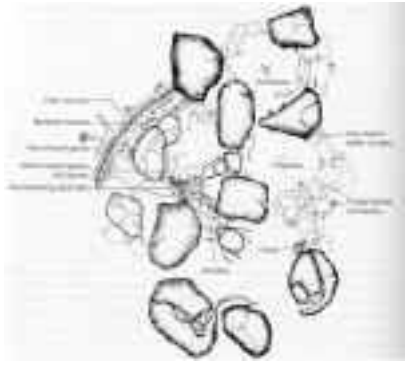
SOIL BIOLOGY AND THE LANDSCAPE

An incredible diversity of organisms make up the soil food web. They range in size from the tiniest one-celled bacteria, algae, fungi, and protozoa, to the more complex nematodes and micro-arthropods, to the visible earthworms, insects, small vertebrates, and plants.

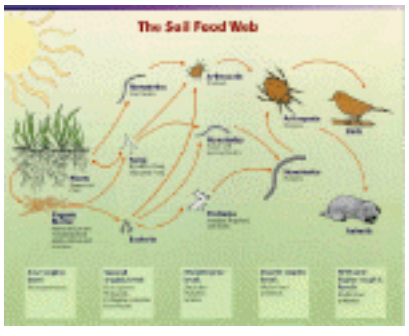
As these organisms eat, grow, and move through the soil, they make it possible to have clean water, clean air, healthy plants, and moderated water flow.

There are many ways that the soil food web is an integral part of landscape processes. Soil organisms decompose organic compounds, including manure, plant residue, and pesticides, preventing them from entering water and becoming pollutants. They sequester nitrogen and other nutrients that might otherwise enter groundwater, and they fix nitrogen from the atmosphere, making it available to plants. Many organisms enhance soil aggregation and porosity, thus increasing infiltration and reducing runoff. Soil organisms prey on crop pests and are food for above-ground animals.



The soil environment. Organisms live in the microscale environments within and between soil particles. Differences over short distances in pH, moisture, pore size, and the types of food available create a broad range of habitats.
***Credit**: S. Rose and E.T. Elliott*

THE FOOD WEB: ORGANISMS AND THEIR INTERACTION



The soil food web is the community of organisms living all or part of their lives in the soil. A food web diagram shows a series of conversions (represented by arrows) of energy and nutrients as one organism eats another (see food web diagram).

All food webs are fueled by the primary producers: the plants, lichens, moss, photosynthetic bacteria, and algae that use the sun's energy to fix carbon dioxide from the atmosphere. Most other soil organisms get energy and carbon by consuming the organic compounds found in plants, other organisms, and waste by-products. A few bacteria, called chemoautotrophs, get energy from nitrogen, sulfur, or iron compounds rather than carbon compounds or the sun.

As organisms decompose complex materials, or consume other organisms, nutrients are converted from one form to another, and are made available to plants and to other soil organisms. All plants – grass, trees, shrubs, agricultural crops – depend on the food web for their nutrition.

WHAT DO SOIL ORGANISMS DO?

Growing and reproducing are the primary activities of all living organisms. As individual plants and soil organisms work to survive, they depend on interactions with each other. By-products from growing roots and plant residue feed soil organisms. In turn, soil organisms support plant health as they decompose organic matter, cycle nutrients, enhance soil structure, and control the populations of soil organisms including crop pests. (See table of functions of soil organisms.)

ORGANIC MATTER FUELS THE FOOD WEB

Soil organic matter is the storehouse for the energy and nutrients used by plants and other organisms. Bacteria, fungi, and other soil dwellers transform and release nutrients from organic matter (see photo).

These microshredders, immature oribatid mites, skeletonize plant leaves. This starts the nutrient cycling of carbon, nitrogen, and other elements.
Collohmannia *sp.* ***Credit****: Roy A. Norton, College of Environmental Science & Forestry, State University of New York*

Organic matter is many different kinds of compounds – some more useful to organisms than others. In general, soil organic matter is made of roughly equal parts humus and active organic matter. Active organic matter is the portion available to soil organisms. Bacteria tend to use simpler organic compounds, such as root exudates or fresh plant residue. Fungi tend to use more complex compounds, such as fibrous plant residues, wood and soil humus.

Intensive tillage triggers spurts of activity among bacteria and other organisms that consume organic matter (convert it to CO_2), depleting the active fraction first. Practices that build soil organic matter (reduced tillage and regular additions of organic material) will raise the proportion of active organic matter long before increases in total organic matter can be measured. As soil organic matter levels rise, soil organisms play a role in its conversion to humus—a relatively stable form of carbon sequestered in soils for decades or even centuries.

FOOD SOURCES FOR SOIL ORGANISMS

"Soil organic matter" includes all the organic substances in or on the soil. Here are terms used to describe different types of organic matter.

Living organisms: Bacteria, fungi, nematodes, protozoa, earthworms, arthropods, and living roots.

Dead plant material; organic material; detritus; surface residue: All these terms refer to plant, animal, or other organic substances that have recently been added to the soil and have only begun to show signs of decay. Detritivores are organisms that feed on such material.

Active fraction organic matter: Organic compounds that can be used as food by microorganisms. The active fraction changes more quickly than total organic matter in response to management changes.

Labile organic matter: Organic matter that is easily decomposed.

Root exudates: Soluble sugars, amino acids and other compounds secreted by roots.

Particulate organic matter (POM) or Light fraction (LF) organic matter: POM and LF have precise size and weight definitions. They are thought to represent the active fraction of organic matter which is more difficult to define. Because POM or LF is larger and lighter than other types of soil organic matter, they can be separated from soil by size (using a

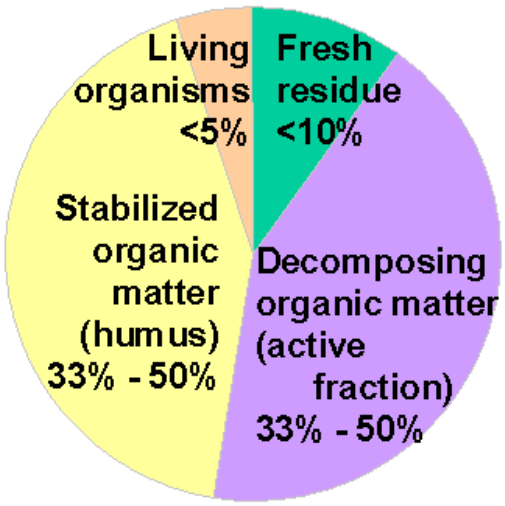
sieve) or by weight (using a centrifuge).

Lignin: A hard-to-degrade compound that is part of the fibers of older plants. Fungi can use the carbon ring structures in lignin as food.

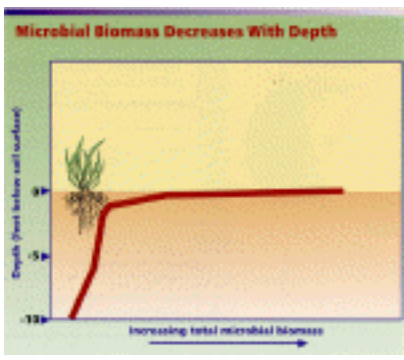
Recalcitrant organic matter: Organic matter such as humus or lignin-containing material that few soil organisms can decompose.

Humus or humified organic matter: Complex organic compounds that remain after many organisms have used and transformed the original material. Humus is not readily decomposed because it is either physically protected inside of aggregates or chemically too complex to be used by most organisms. Humus is important in binding tiny soil aggregates, and improves water and nutrient holding capacity.

Components of Soil Organic Matter



WHERE DO SOIL ORGANISMS LIVE?



The organisms of the food web are not uniformly distributed through the soil. Each species and group exists where they can find appropriate space, nutrients, and moisture. They occur wherever organic matter occurs – mostly in the top few inches of soil (see figure), although microbes have been found as deep as 10 miles (16 km) in oil wells.

Soil organisms are concentrated:

Around roots. The rhizosphere is the narrow region of soil directly around roots (see photo). It is teeming with bacteria that feed on sloughed-off plant cells and the proteins and sugars released by roots. The protozoa and nematodes that graze on bacteria are also concentrated near roots. Thus, much of the nutrient cycling and disease suppression needed by plants occurs immediately adjacent to roots.

Bacteria are abundant around this root tip (the rhizosphere) where they decompose the plentiful simple organic substances. ***Credit:*** *No. 53 from* Soil Microbiology and Biochemistry Slide Set*. 1976 J.P. Martin, et al., eds. SSSA, Madison WI.*

In litter. Fungi are common decomposers of plant litter because litter has large amounts of complex, hard-to-decompose carbon. Fungal hyphae (fine filaments) can "pipe" nitrogen from the underlying soil to the litter layer. Bacteria cannot transport nitrogen over distances, giving fungi an advantage in litter decomposition, particularly when litter is not mixed into the soil profile. However, bacteria are abundant in the green litter of younger plants which is

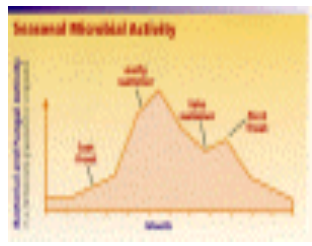
higher in nitrogen and simpler carbon compounds than the litter of older plants. Bacteria and fungi are able to access a larger surface area of plant residue after shredder organisms such as earthworms, leaf-eating insects, millipedes, and other arthropods break up the litter into smaller chunks.

On humus. Fungi are common here. Much organic matter in the soil has already been decomposed many times by bacteria and fungi, and/or passed through the guts of earthworms or arthropods. The resulting humic compounds are complex and have little available nitrogen. Only fungi make some of the enzymes needed to degrade the complex compounds in humus.

On the surface of soil aggregates. Biological activity, in particular that of aerobic bacteria and fungi, is greater near the surfaces of soil aggregates than within aggregates. Within large aggregates, processes that do not require oxygen, such as denitrification, can occur. Many aggregates are actually the fecal pellets of earthworms and other invertebrates.

In spaces between soil aggregates. Those arthropods and nematodes that cannot burrow through soil move in the pores between soil aggregates. Organisms that are sensitive to desiccation, such as protozoa and many nematodes, live in water-filled pores. (See Figure page 1.)

WHEN ARE THEY ACTIVE?



The activity of soil organisms follows seasonal patterns, as well as daily patterns. In temperate systems, the greatest activity occurs in late spring when temperature and moisture conditions are optimal for growth (see graph). However, certain species are most active in the winter, others during dry periods, and still others in flooded conditions.

Not all organisms are active at a particular time. Even during periods of high activity, only a fraction of the organisms are busily eating, respiring, and altering their environment. The remaining portion are barely active or even dormant.

Many different organisms are active at different times, and interact with one another, with plants, and with the soil. The combined result is a number of beneficial functions including nutrient cycling, moderated water flow, and pest control.

THE IMPORTANCE OF THE SOIL FOOD WEB

The living component of soil, the food web, is complex and has different compositions in different ecosystems. Management of croplands, rangelands, forestlands, and gardens benefits from and affects the food web. The next unit of the Soil Biology Primer, “The Food Web & Soil Health,” introduces the relationship of soil biology to agricultural productivity, biodiversity, carbon sequestration and to air and water quality. The remaining six units of the Soil Biology Primer describe the major groups of soil organisms: bacteria, fungi, protozoa, nematodes, arthropods, and earthworms. For more information about the diversity within each organism group, see the list of readings at the end of “The Food Web & Soil Health” unit.