Soil Organisms

Soil is home to many different organisms. These represent different kingdoms and range in size from sequoia roots to bacteria. Some produce their own organic structure from inorganic substrates. Others are consumers.

Terms

Energy source
Autotroph
Heterotroph

Size
Macro
Meso
Micro

Kingdom (older terminology)
Fauna
Flora

Producer / consumer
Primary producers
Primary consumers
Secondary consumer

Measures of Biologic Activity

Numbers per unit mass of soil
Biomass per unit volume or area of soil
CO_2 evolution

Organisms	log (# / g)	kg / ha
Microflora		
Bacteria	8 - 9	400 - 5000
Actinomycetes	7 - 8	400 - 5000
Fungi	5 - 6	1000 - 20000
Algae	4 - 5	10 - 500

Organisms	log (# / g)	kg / ha
Fauna		
Protozoa	4 – 5	20 - 200
Nematodes	1 - 2	10 - 100
Earthworms		100 - 2000
Others		20 - 400

Earthworms

Lumbricus terrestris	nightcrawler
Allolobophora caliginosa	redworm

Predominant species in US

Benefits derived from healthy earthworm populations

Increase availability of certain nutrients
Aid decomposition of plant residues
Churn the soil and increase porosity
Better aeration and drainage

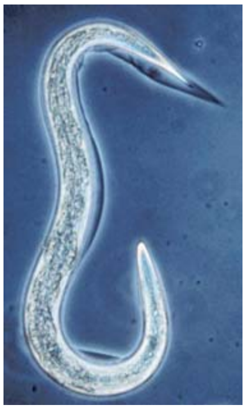
Burrows continuous with the soil surface increase water infiltration but these may be channels for preferential flow and rapid transport of contaminants. Soil conditions affect earthworm activity including moisture, aeration, pH, Ca and management practices. Earthworms need a moist environment but not excessive wet environment. They also need good aeration, intermediate range pH (5.5 - 8.5) and good supply of Ca for mucus production. Ammonia fertilizer, insecticides and tillage reduce earthworm populations.

Termites

Most common in tropical and subtropical areas. Termites generally do not consume living plants but strip the soil of plant residues. Unlike earthworms, they do not aid nutrient availability since plant residues are exhaustively decomposed. Physical effects on soil properties are localized to the mound. Its existence and longevity is a mostly a nuisance to production.

Nematodes

Tiny roundworms. Most are detritivores or predatory of soil microflora or other nematodes, however, some attack plant roots. Wounds are invaded by pathogens leading to stunted root and shoot growth.

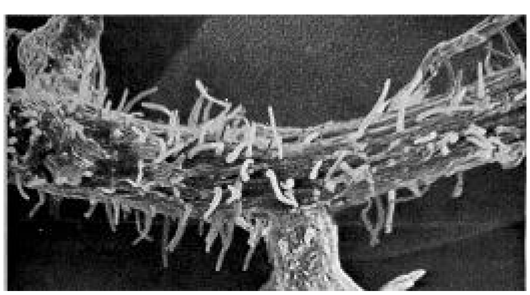


Protozoa

Soil protozoa include flagellates, pseudopoda and ciliata. They thrive in moist but aerated soil at or near the surface. Protozoa are a minor component to overall biological activity in soil.

Plant Roots

Vary in size down to 10 - 50 µm for root hairs. These extensions of epidermal cells help anchor the root and increase surface area for nutrient and water absorption. Root hairs are more common where nutrient concentration is low. Larger (100 - 500 µm) feeder roots are common where nutrient concentrations are higher.



Root hairs.

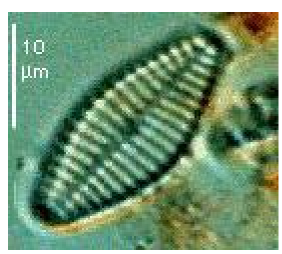
Root residues constitute a major source of organic matter addition to soil. The living root system also adds organic substances to the *rhizosphere*, which is a zone within 1 - 2 mm of root surface. It is biologically and chemically different from the bulk soil due to *rhizodeposition*. Substances and materials lost from the root include low MW organic acids, sugars and phenolics, some of which are *allelopathic;* high MW mucilage (mucigel) that mixes with microbial cells and clay, lubricating the growing root, improving contact with soil and stimulating microbial growth; cells lost from the root cap and epidermis.

Young roots may lose up to 30 % of the translocated C in rhizodeposition. Total losses from the root system may exceed total mature root biomass.

The sheath of soil adhering to root system of uprooted plant approximates the rhizosphere.

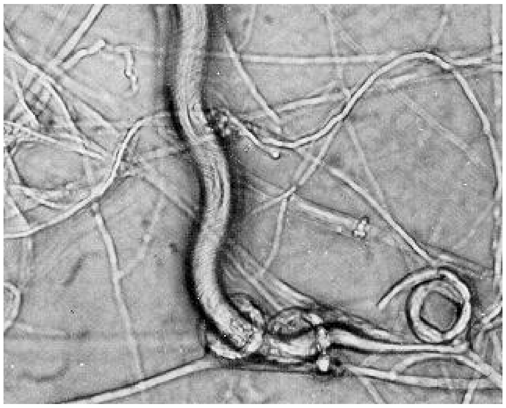
Algae

Green, yellow green and diatoms occur in soil. These are eucaryotic cells that contain chlorophyll and carry out photosynthesis. Accordingly they live at or near the soil surface.



Fungi

Eukaryotic, aerobic and nonphotosynthetic. These include yeasts and filamentous fungi (molds and mushrooms). Filaments are long, threadlike structures called hyphae. A mass of hyphae is called a mycelium. Filamentous fungi reproduce via spores of fruiting bodies that may be microscopic as with the mold or macroscopic as with mushrooms.



Nematode trapped by fungal hyphae.

Puffball.

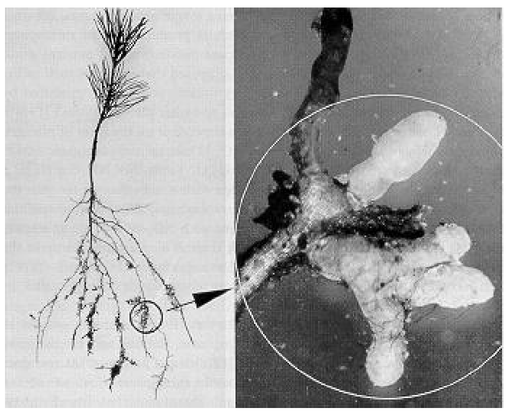
Mushroom fungi are important in forest and grassland ecosystems, however, molds are responsible for greater amount of organic matter decomposition. Molds tolerate a wide range of soil pH.

Fungi are more efficient decomposers than bacteria or actinomycetes and are very important in decomposition of resistant organic substrates and synthesis of humus. Some produce antibiotics and toxins including *aflatoxin* (carcinogen from *Aspergillus flavus*). Others responsible for plant disease such as wilts and root rots.

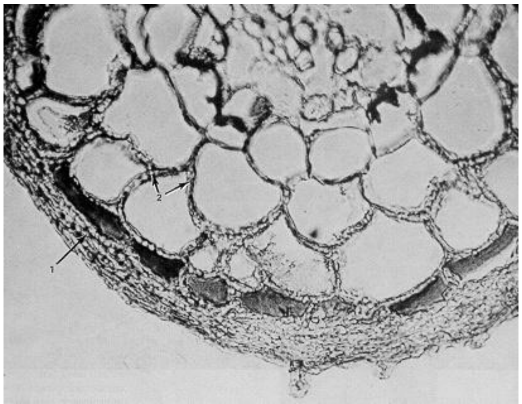
Mycorrhizae

Symbiotic association between certain fungi and plant roots (fungus root). The fungus utilizes photosynthates from plant but increases availability of soil nutrients for plant use, especially P. The two major types are *ectomycorrhizae* and *endomycorrhizae*.

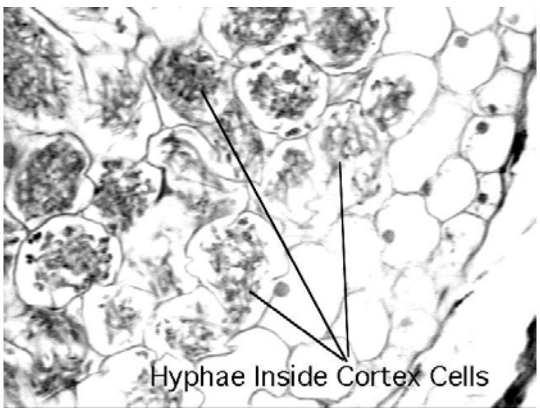
Ectomycorrhizae are associated with trees. These form a mantle around plant roots. Infected roots are short, stubby and often have a Y shape. The hyphae invade the intracellular space of roots but do not invade cortical cells. In contrast, endomycorrhiza hyphae invade root cells. There they form highly branched arbuscules inside cells which function to transfer of nutrients between hyphae and plant. Some endomycorrhizae may also produce storage structures called vesicles. These are called vesicular arbuscular (VA) mycorrhizae. Endomycorrhizae are common with agronomic and horticultural crops. The benefit of this symbiotic relationship is greatest in infertile soil.



Ectomycorrhizae infected root and close-up of mantle.



Hyphae of ectomycorrhizae do not invade root cells.

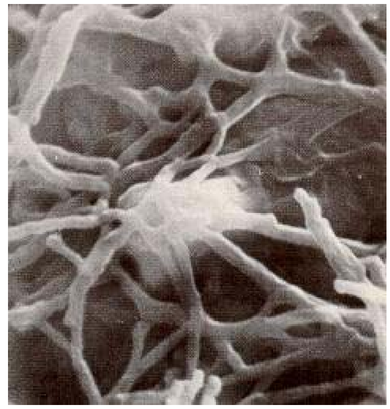


Cross section of root infected with endo-mycorrhizae.

Mutual infection of N-fixing legume and non-legume provides a channel for the transfer of N from the legume to the nonlegume, enhancing growth of the non-legume.

Actinomycetes

Filamentous but unlike fungi are prokaryotic. Also, unlike the fungi, these are sensitive to low soil pH. Highest numbers of actinomycetes are found in moist and aerated soil. Some are capable of fixing atmospheric N.



Bacteria

These single-celled prokaryotes are small (0.5 - 5.0 μm). Bacteria include coccus (spherical), bacillus (rod) and spirilla (spiral) organisms. Many are motile. Some are autotrophic and derive energy from oxidation of NH_4 and S but most are heterotrophic. Along with fungi and actinomycetes are responsible for general decomposition of organic matter and release of nutrients.

Special transformations due to bacteria include

Nitrogen fixation

$N_2 + 6H^+ + 6e \rightarrow 2NH_3$

Symbiotic fixation (legumes and non-legumes) and fixation by free-living bacteria.

Nitrification

$NH_4^+ + 2O_2 \rightarrow NO_3^- + H_2O + 2H^+$

Two step process by chemautotrophs, *Nitrosomonas* and *Nitrobacter*.

Denitrification

$NO_3^- \rightarrow NO_2^- \rightarrow NO \rightarrow N_2O \rightarrow N_2$

Reduction of NO_3^- to gaseous forms leads to loss of N from soil.

Sulfur oxidation

$2S + 3O_2 + H_2O$ 6 $2H_2SO_4$

Carried out by *Thiobacillus*.

Factors Affecting Soil Bacteria

O_2 status dictates the activity of aerobes, anaerobes and facultative anaerobes. Bacteria generally do best at warm temperatures (20 - 40 C optimum). Heterotrophic bacteria need organic substrates and are stimulated by root exudates in the rhizosphere. Growth is generally best at intermediate pHs though some survive at more extreme values. Growth is also favored by an adequate supply of Ca.

Effects of Agricultural Management on Soil Organisms

Numbers and diversity

Favored	Reduced
Native vegetation	Cropping
Fertilization and lime	Tillage
Good drainage / aeration	Pesticides

Beneficial Effects of Soil Organisms

These encourage organic matter decomposition which releases nutrients bound in organic combinations (*mineralization*); formation of humus, the stable end product of microbial decomposition and synthesis; carry out various transformations including the oxidation of N and S and N-fixation; and are responsible for various detoxification reactions.

Adverse Effects on Plant Growth

Some are pests and cause diseases including wilts and root rots. Microflora may compete with plants for nutrient, immobilizing nutrients into microbial biomass. They accelerate the depletion of O_2 under wet conditions. Under anaerobic conditions nitrate is chemically reduced and lost by denitrification. Toxicity due to increased Fe^{2+} or Mn^{2+} concentrations is also possible.