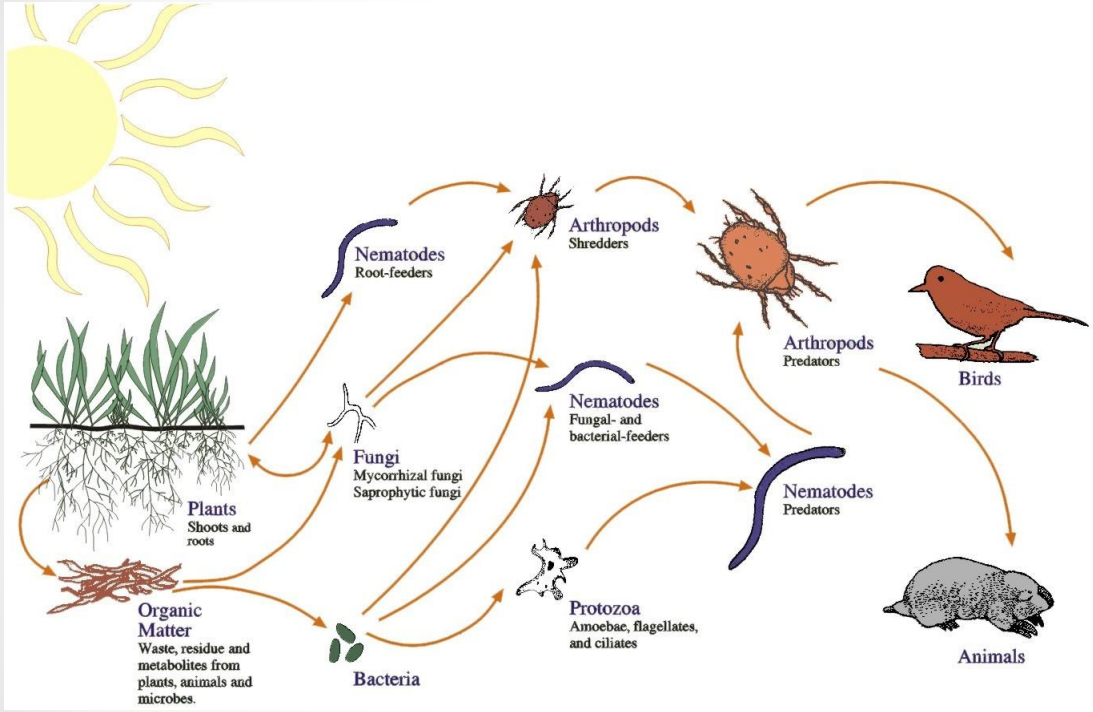
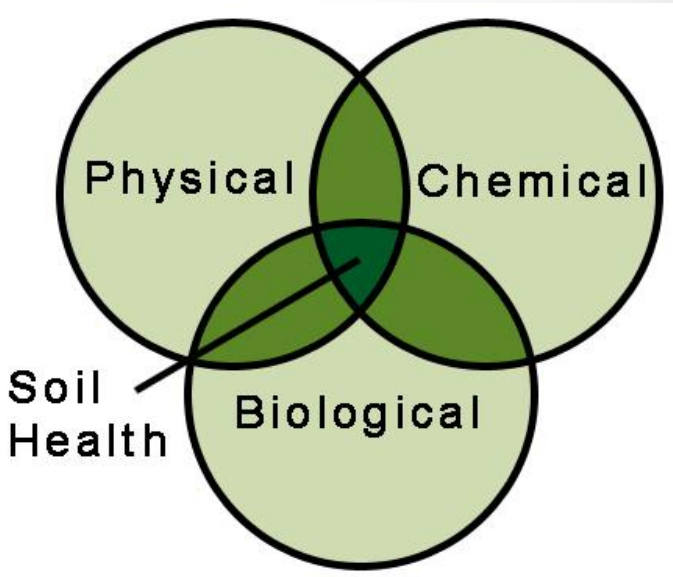
Soil Food Web: Implications to Soil Health





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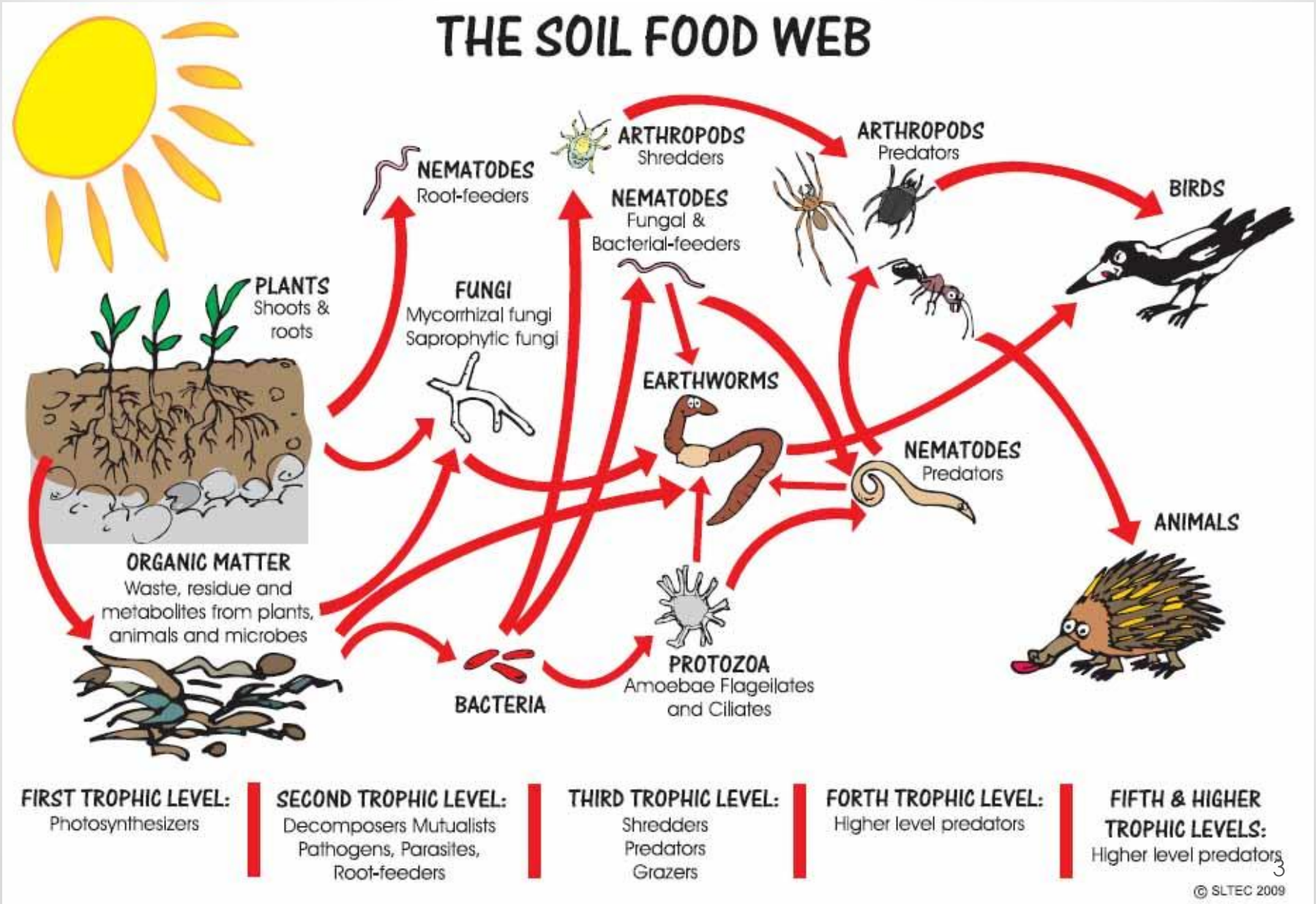
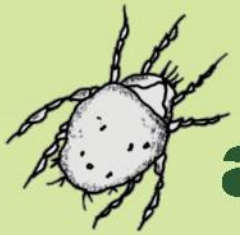
Outline

- Soil organisms and their interactions
- What do soil organisms do?
- Where do soil organisms live?
- Food web structure
- When are soil organisms active?
- How is the food web measured?
- Living soils—Bacteria; Fungi; Earthworms
- Soil Environment

Organisms & Their Interaction





SOIL ORGANISMS and the Soil Food Web

A GOOD SOIL Is A LIVE SOIL

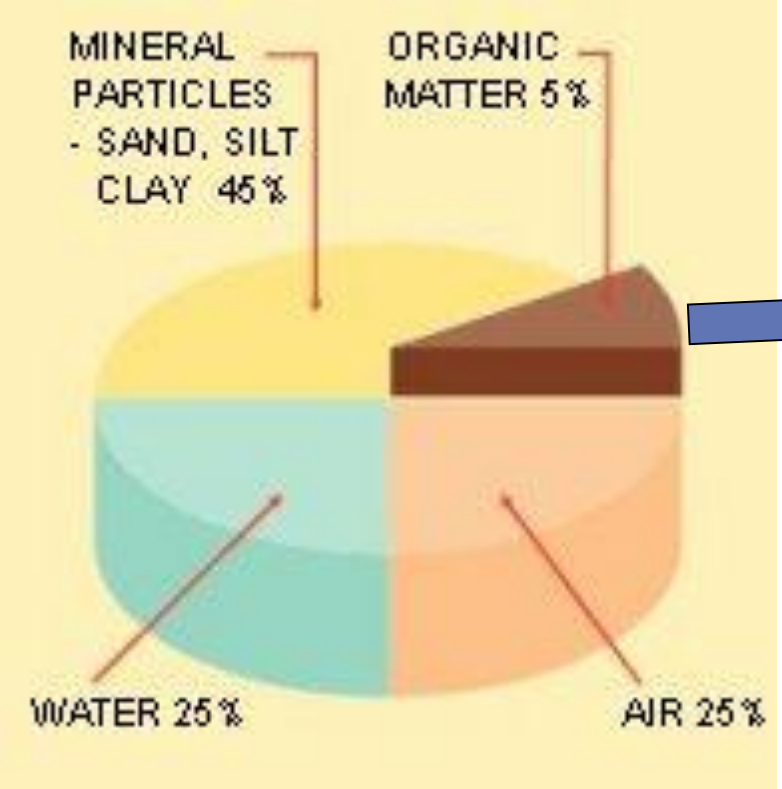
USDA Natural Resources Conservation Service

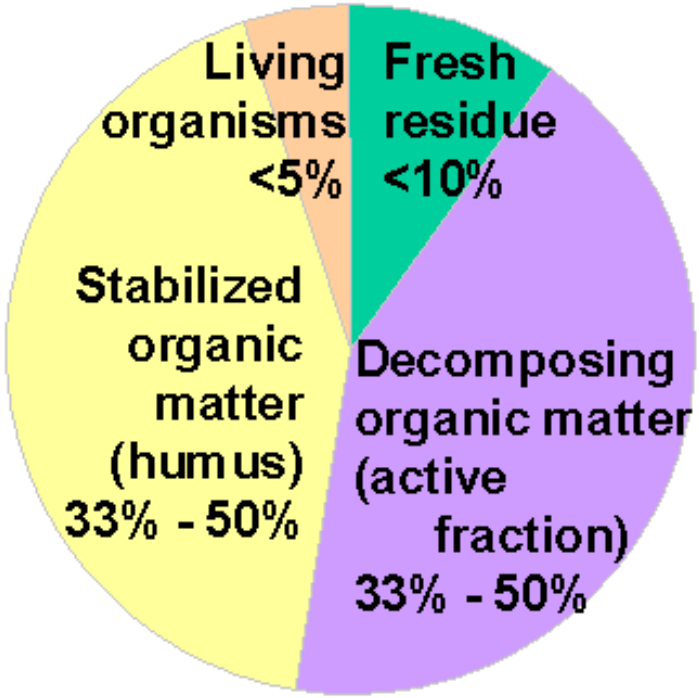
What do soil organisms do?

Soil organisms support plant health as

- decompose organic matter,
- cycle nutrients,
- enhance soil structure,
- control the populations of soil organisms including crop pests.

Organic Matter

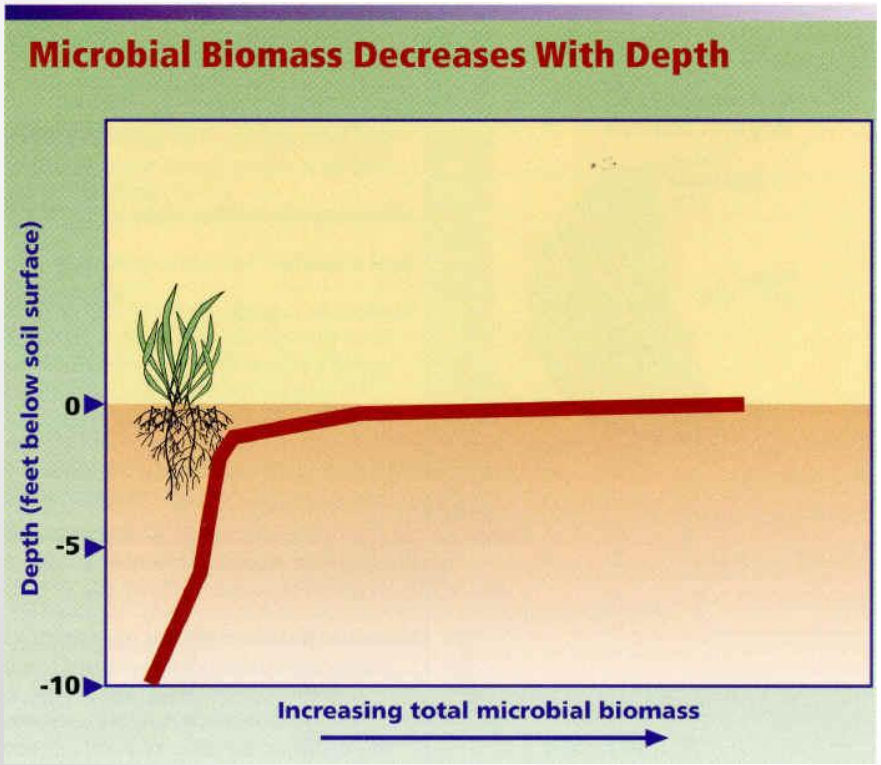


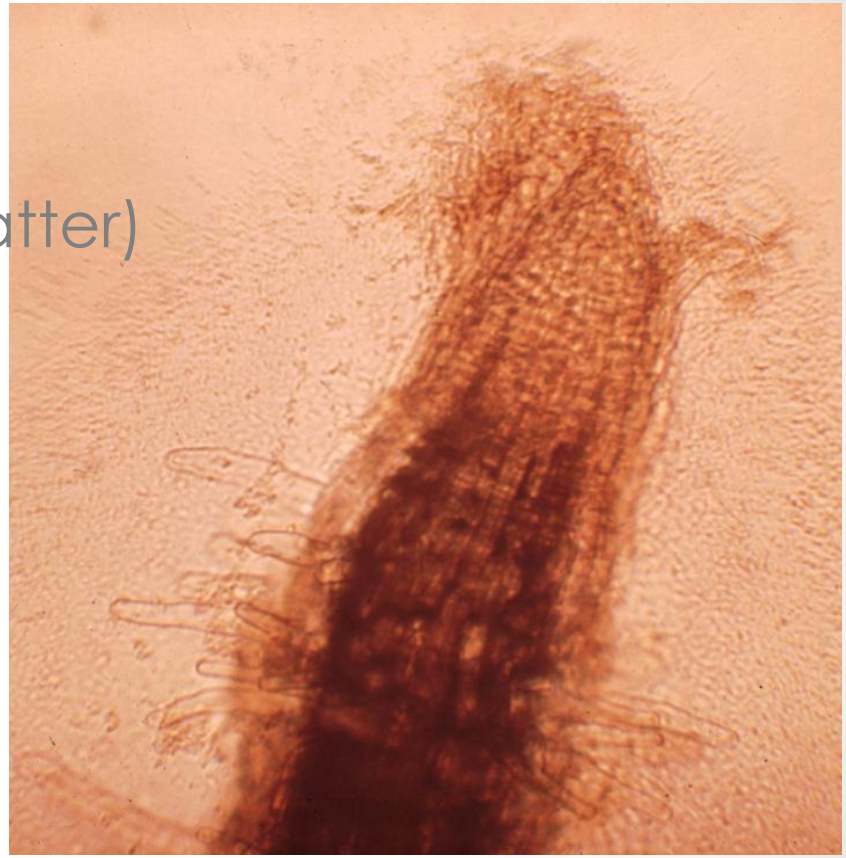


- Food sources for soil organisms
- Agricultural top soil ~1-6% (In CA, ~1-3% SOM)

Where do soil organisms live?

- Around roots(rhizosphere)
- Plant litter (C sources)
- Humus (stabilized organic matter)
- Surface of soil aggregates





Typical Food Web Structure

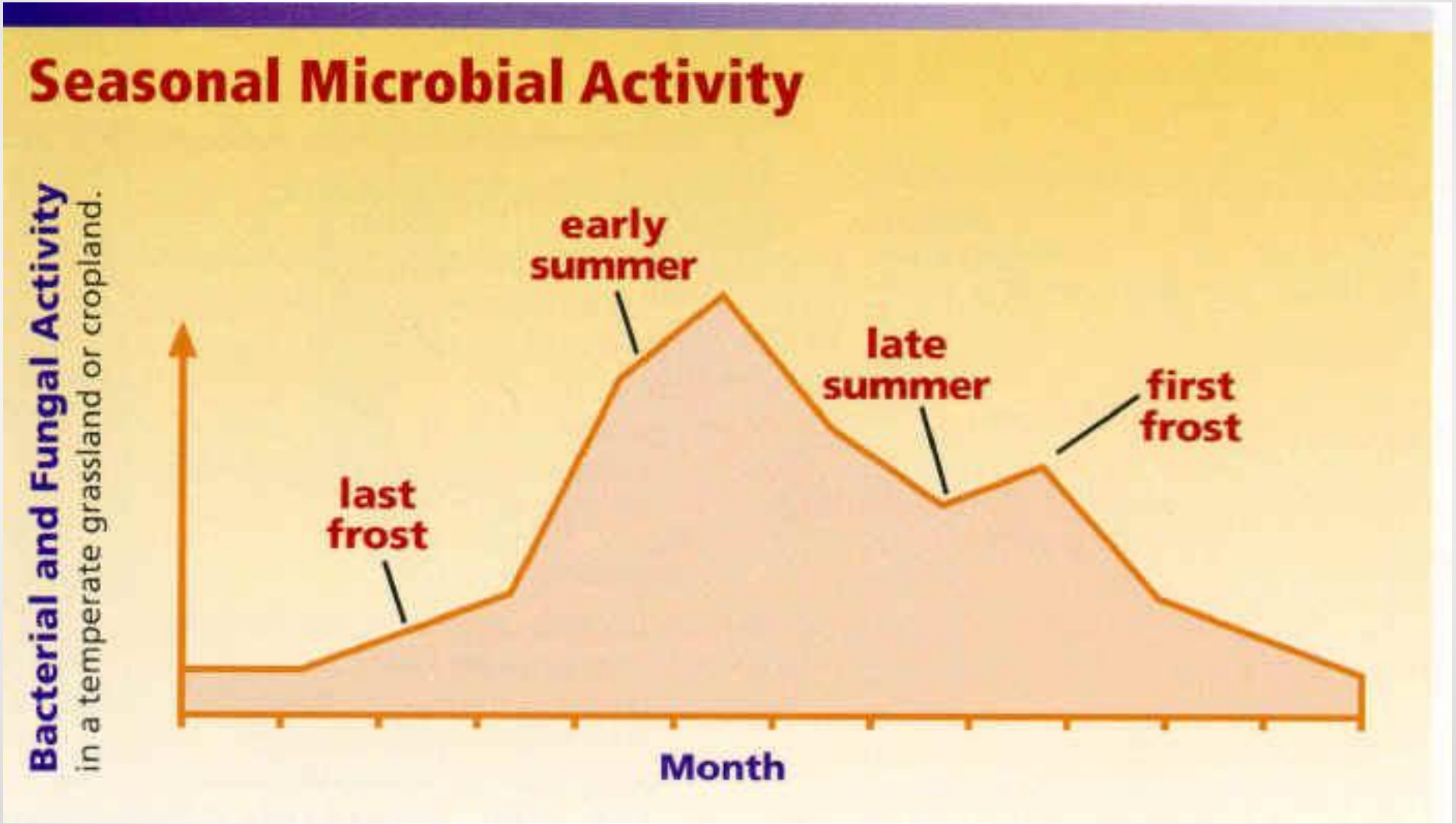
- bacterial-dominated food webs
  - Grassland & Agri Soils
  - Ratio of fungi to bacteria, ~1:1 for productive agri. soils

- fungal-dominated food webs
  - Ratio of fungal to bacterial, ~5:1 to 10:1 in a deciduous forest and 100:1 to 1000:1 in a coniferous forest

Typical Numbers of Soil Organisms in Healthy Ecosystems

		Agricultural Soils	Prairie Soils	Forest Soils
Bacteria	Per teaspoon of soil (one gram dry)	100 million to 1 billion.	100 million to 1 billion.	100 million to 1 billion.
Fungi		Several yards. (Dominated by vesicular-arbuscular mycorrhizal (VAM) fungi).	Tens to hundreds of yards. (Dominated by vesicular-arbuscular mycorrhizal (VAM) fungi).	Several hundred yards in deciduous forests. One to forty miles in coniferous forests (dominated by ectomycorrhizal fungi).
Protozoa		Several thousand flagellates and amoebae, one hundred to several hundred ciliates.	Several thousand flagellates and amoebae, one hundred to several hundred ciliates.	Several hundred thousand amoebae, fewer flagellates.
Nematodes		Ten to twenty bacterial-feeders. A few fungal-feeders. Few predatory nematodes.	Tens to several hundred.	Several hundred bacterial- and fungal-feeders. Many predatory nematodes.
Arthropods	Per square foot	Up to one hundred.	Five hundred to two thousand.	Ten to twenty-five thousand. Many more species than in agricultural soils.
Earthworms		Five to thirty. More in soils with high organic matter.	Ten to fifty. Arid or semi-arid areas may have none.	Ten to fifty in deciduous woodlands. Very few in coniferous forests.

When are soil organisms active?



How is the food web measured?

- **Counting.** Organism groups (bacteria, protozoa, arthropods, etc.); or subgroups (bacterial-feeding, fungal-feeding, and predatory nematodes), are counted and through calculations, can be converted to biomass.

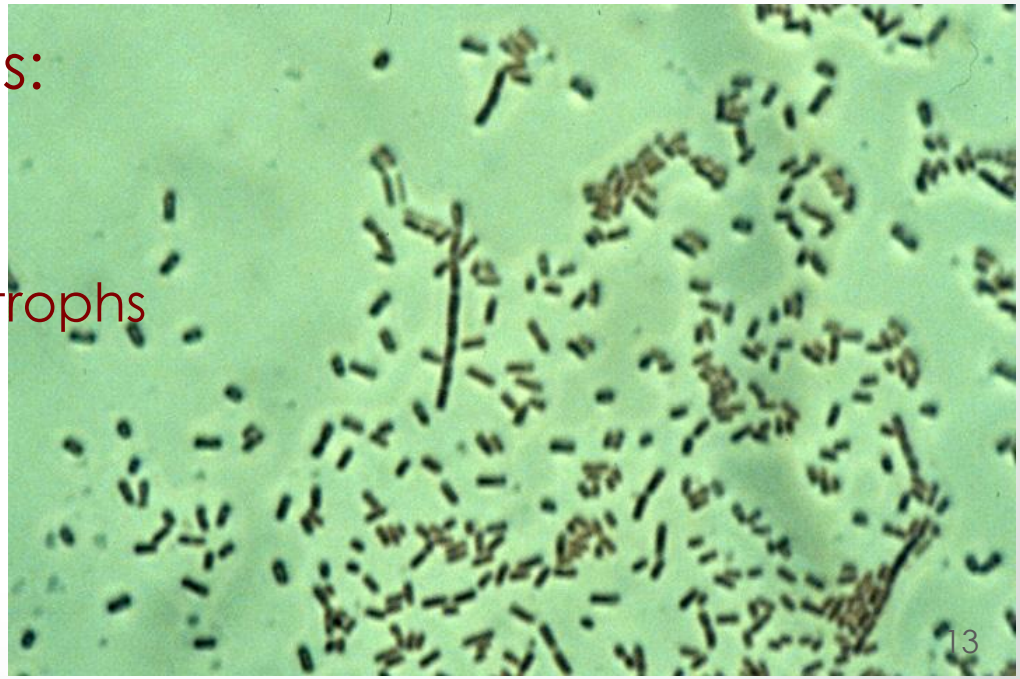
- **Measuring activity levels.** The amount of by-products, i.e., respiration (CO_2); nitrification and decomposition rates

- **Measuring cellular constituents.** Biomass carbon, nitrogen, or phosphorus; Enzymes; Phospholipids and other lipids; DNA and RNA

Rats, we've caught a dung beetle:
They taste horrible...

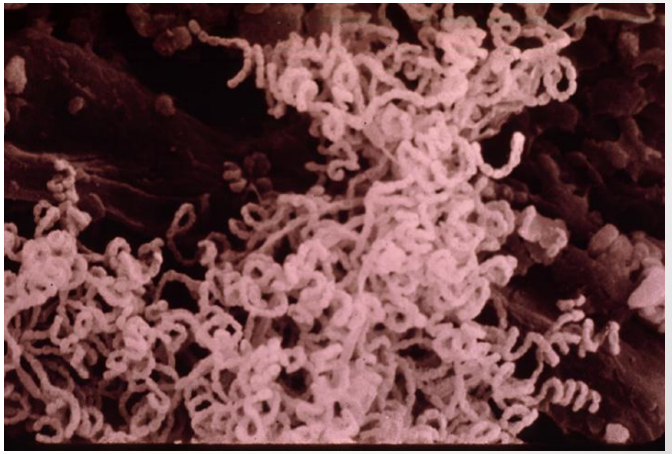
Soil Bacteria

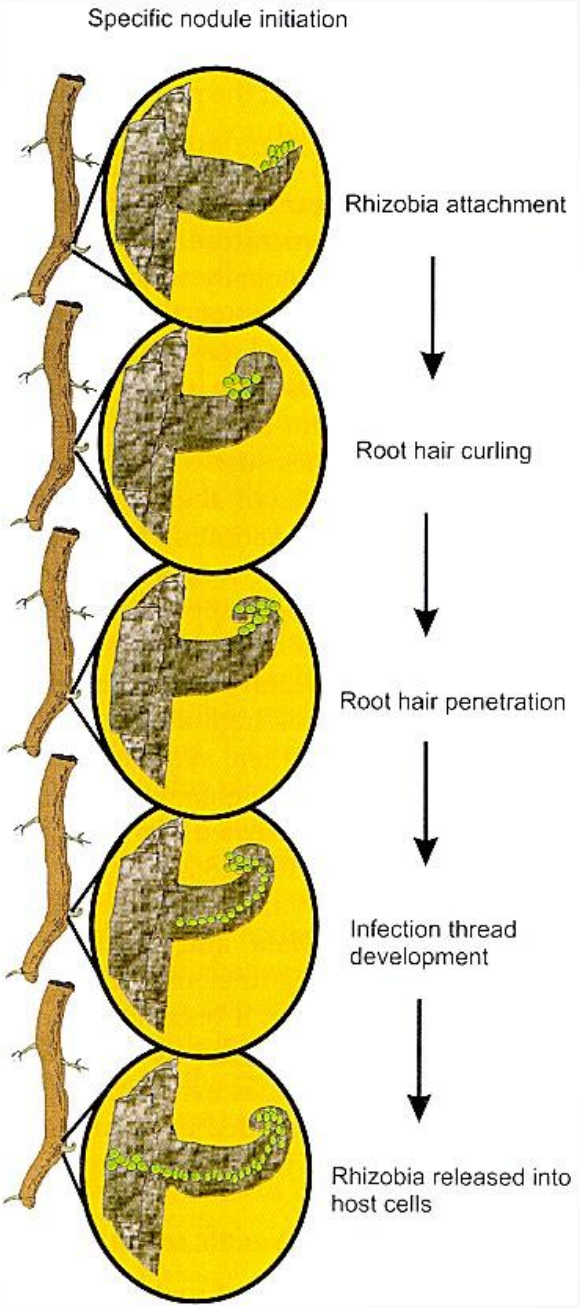
- One-celled organisms – generally 4/100,000 of an inch wide (1 μm)
- A teaspoon of productive soil generally contains between 100 million and 1 billion bacteria (~two cows per acre).
- 4 major functional groups:
  1. decomposers
  2. mutualists
  3. lithotrophs or chemoautotrophs
  4. pathogens



A Few Important Bacteria

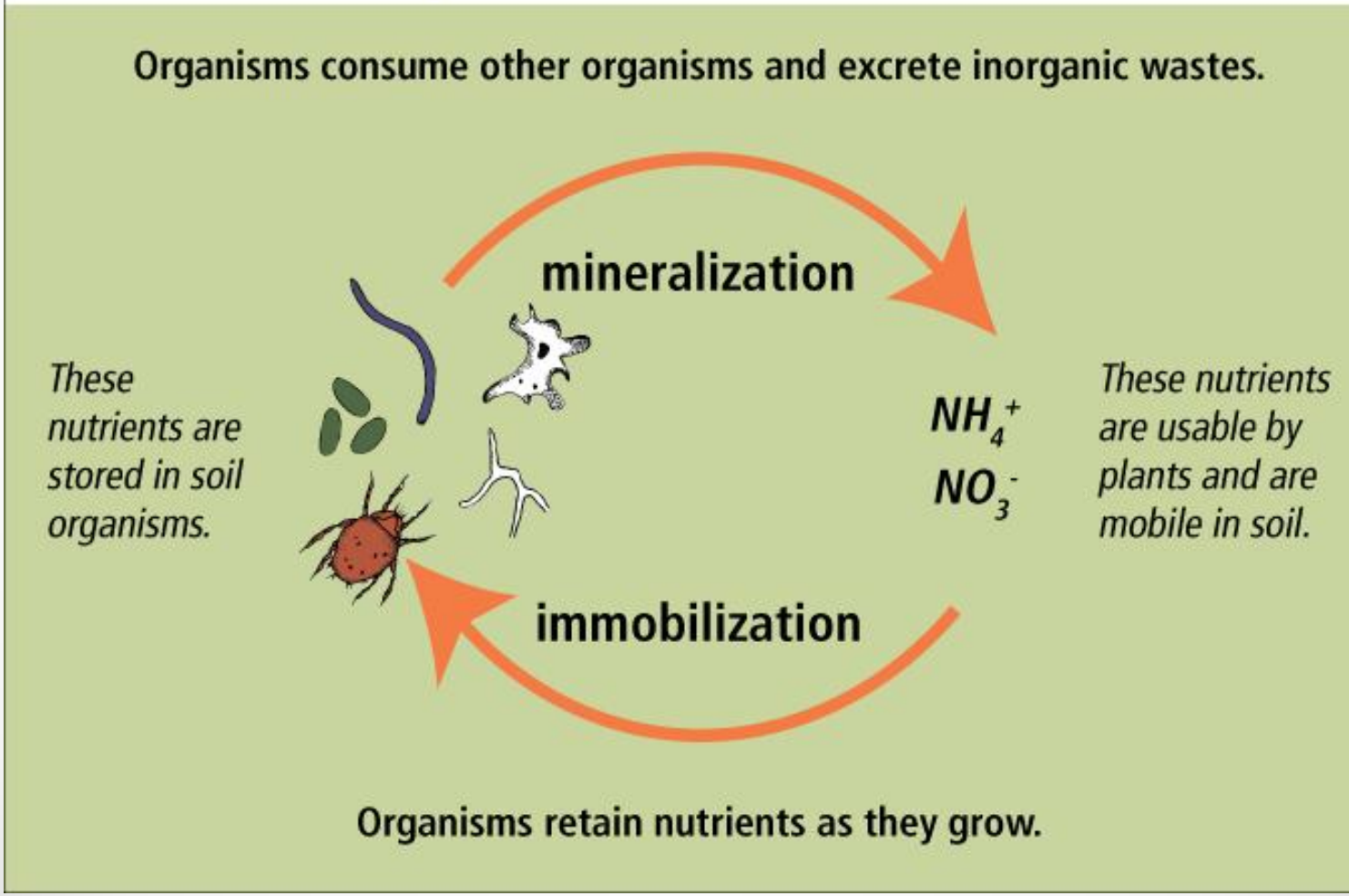
- N-fixing bacteria (legumes)
- Nitrifying bacteria change ammonium (NH_4+) to nitrite (NO_2-) then to nitrate (NO_3-)
- Denitrifying bacteria convert NO_3- to nitrogen (N_2) or nitrous oxide (N_2O) gas
- Actinomycetes (earthy smell)




Specific nodule initiation
Rhizobia attachment
Root hair curling
Root hair penetration
Infection thread development
Rhizobia released into host cells

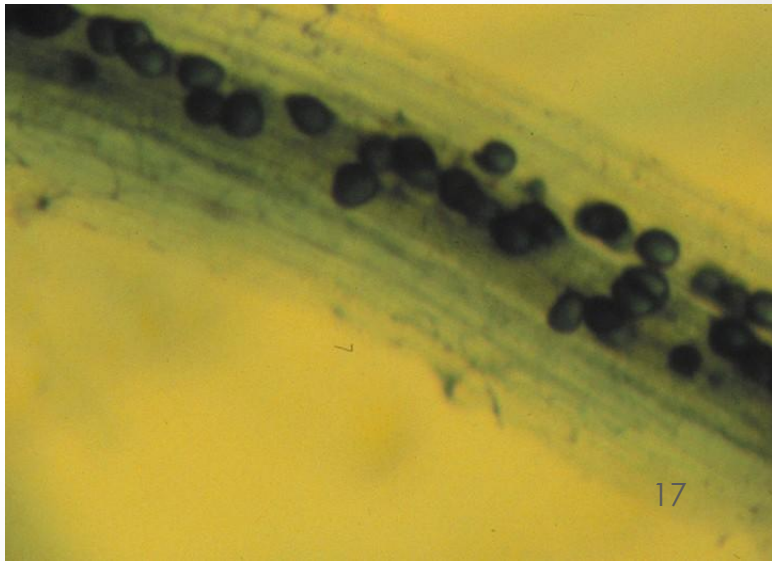
What Are Mineralization and Immobilization?

Soil nutrients generally occur in two forms: inorganic compounds dissolved in water or attached to minerals, and organic compounds part of living organisms and dead organic matter. Bacteria, fungi, nematodes, protozoa, and arthropods are always transforming nutrients between these two forms. When they consume inorganic compounds to construct cells, enzymes, and other organic compounds needed to grow, they are said to be "immobilizing" nutrients. When organisms excrete inorganic waste compounds, they are said to be "mineralizing" nutrients.



Soil Fungi

- Fungi are microscopic cells that usually grow as long threads or strands called hyphae, which push their way between soil particles, roots, and rocks.
- A single hyphae can span in length from a few cells to many yards. A few fungi, such as yeast, are single cells.
- Decomposers--Convert hard-to-digest organic material into forms that other organisms can use
- Fungal hyphae physically bind soil particles together, creating stable aggregates that help increase water infiltration and soil water holding capacity.



Mycorrhizal fungi in agriculture

- Symbiotic association between fungi and plant roots
- Exceptions are many members of the Cruciferae family (e.g., broccoli, mustard), and the Chenopodiaceae family (e.g. lambsquarters, spinach, beets)
- Land management practices caused declining…
  - fallowed fields
  - planted to crops that do not form mycorrhizae
  - Frequent tillage may reduce mycorrhizal associations
  - Broad spectrum fungicides application
  - Very high levels of nitrogen or phosphorus fertilizer may reduce inoculation of roots.
- Some inoculums of mycorrhizal fungi are commercially available and can be added to the soil at planting time.

As you can see for yourself,
this property has a very rich soil...

Earthworms

- Major decomposers of dead and decomposing organic matter, and derive their nutrition from the bacteria and fungi that grow upon these materials
- Occur in most temperate soils and many tropical soils.
- Divided into 23 families, more than 700 genera, and more than 7,000 species. Ranging from an inch to two yards in length and are found seasonally at all depths in the soil.

Earthworm Functions

- **Stimulate microbial activity.** As organic matter passes through their intestines, it is fragmented and inoculated with microorganisms. Increased microbial activity facilitates the cycling of nutrients from organic matter and their conversion into forms readily taken up by plants.

- **Mix and aggregate soil.** As they consume organic matter and mineral particles, earthworms excrete wastes in the form of casts, a type of soil aggregate. A large proportion of soil passes through the guts of earthworms, and they can turn over the top six inches (15 cm) of soil in ten to twenty years.

- **Increase infiltration.** Enhance porosity as they move through the soil. Some species make permanent burrows deep into the soil, and can be a major conduit for soil drainage, particularly under heavy rainfall. Also, the burrows minimize surface water erosion.

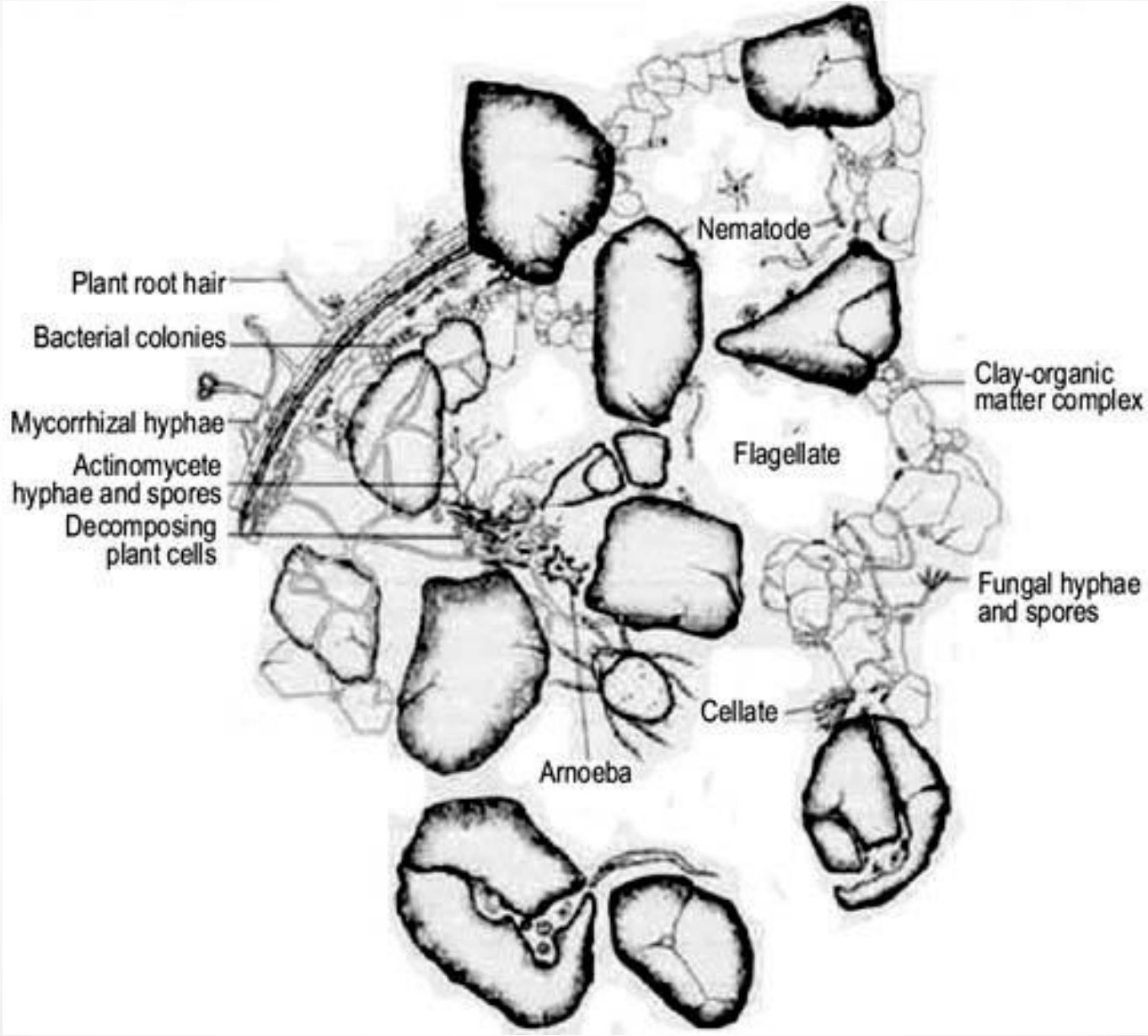
Earthworm Functions

- **Improve water-holding capacity.** By fragmenting organic matter, and increasing soil porosity and aggregation
- **Provide channels for root growth.** Made by deep-burrowing and make it easier for roots to penetrate deep into the soil.
- **Bury and shred plant residue.** Plant and crop residue are gradually buried by cast material deposited on the surface and as earthworms pull surface residue into their burrows.

Management practices change food webs, for example, …

- Reduced tillage agricultural systems, the ratio of fungi to bacteria increases over time, and earthworms and arthropods become more plentiful.
- Frequent tillage, which slices, dices and crushes the organisms, especially beneficial fungi
- Applications of pesticides, herbicides and fungicides which kill far more than just the target organism species
- High levels of inorganic fertilizers which are salts that kill organisms through osmotic removal of water and rapid changes in soil pH
- Compaction, which reduces oxygen content in the soil, and selects for anaerobic species.

Soil Environment



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