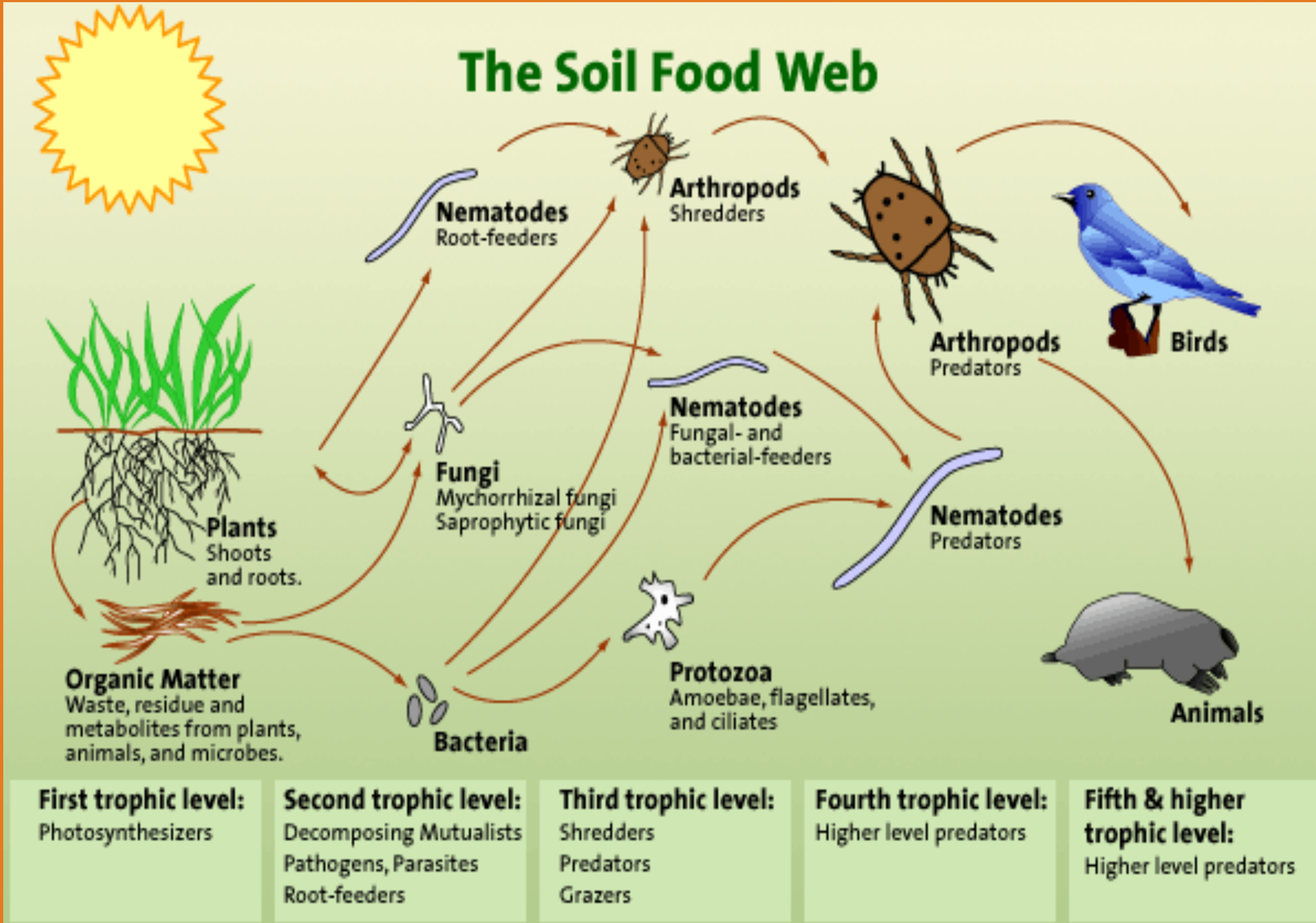
Soil Microbiology

Importance of microbes: Microorganisms (primarily fungi and bacteria) produce enzymes that make biogeochemical cycles run at biologically different rates

1) *Decomposition* of organic materials (plant, animal, and microbial residues) and mineralization of elements (nutrients) contained within

2) *Transformation* of inorganic elements from one form to another (i.e. biological nitrogen fixation, conversion of N_2 to NH_3

(Pete Stahl Lecture Notes, 2010)



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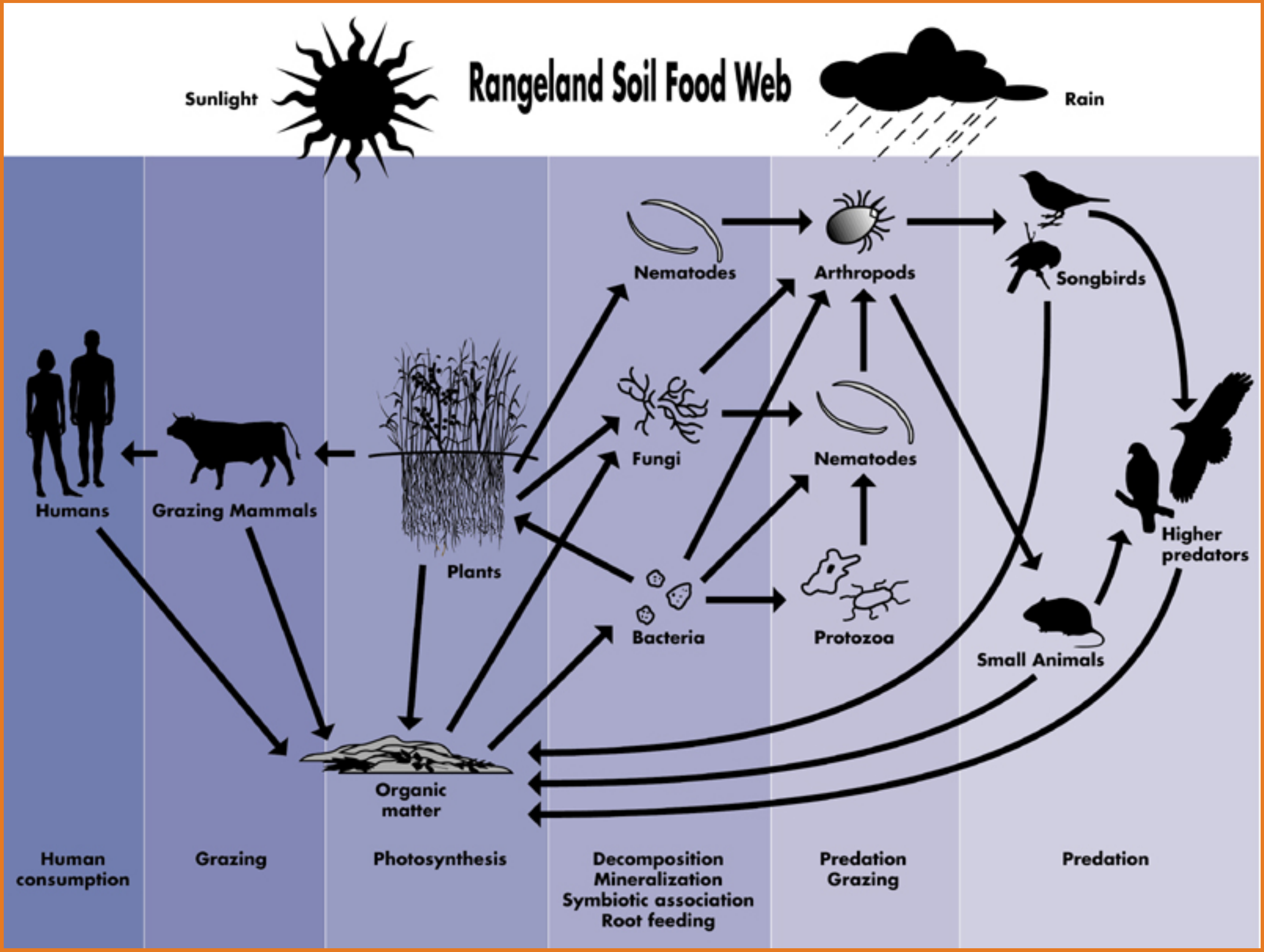

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Main Players in Soil Microbiology

A. **Bacteria**: most numerous and diverse of all organisms in soil; up to 1 billion bacterial cells per gram of soil; generally decompose more simple molecular substrates

B. **Fungi**: in most soils represent largest portion of soil microbial biomass: hyphal length up to 0.62 mile per gram of soil; less diverse than bacteria; generally decompose more complex molecular substrates

C. **Protists** (Protozoans): diverse group of unicellular organisms active only is soil water include flagellates, amoebae, ciliates, and euglenoids

D. **Soil Metazoa**: soil animals include nematodes, enchytraeid worms, and microarthropods

E. **Earthworms**: 30- 300 per square meter of soil, 200 species worldwide

(Pete Stahl Lecture Notes, 2010).

Why is soil such a good habitat for organisms?

1) Reliable source of energy and nutrition

2) Good source of water

3) High diversity of microhabitats and environments

4) Less drastic fluctuations in climatic influences as above-ground

Cepheidae (top right), Anachipteria (bottom right) and Liochthonius (top left) mites are found in Great Plains soil. They eat bacteria, fungi, nematodes and other soil animals, chew litter into small pieces and distribute bacteria and fungi throughout the soil. Galumna (bottom left), a mite found in pastures, eats plants, litter and other organic matter. The images have been enhanced by computer colorization.

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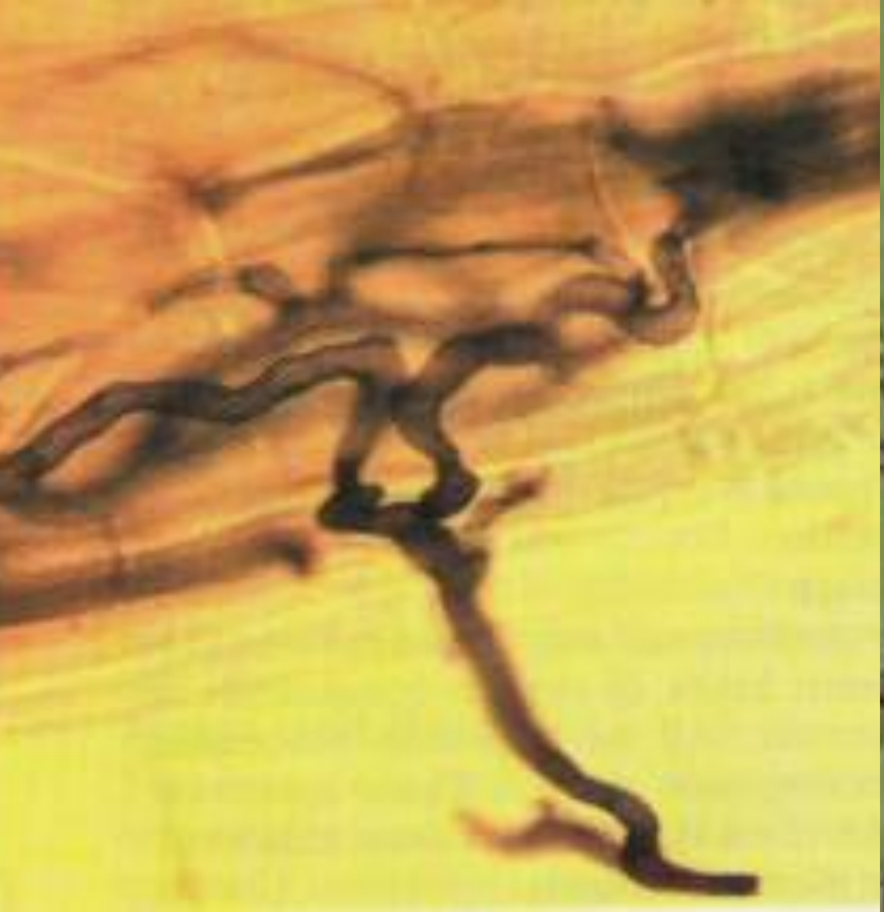

Mycorrhizal fungi (left) live within the roots of most crop plants. Soil fungi (right) help decompose organic matter and form soil aggregates. Most soil fungi are beneficial, rather then pathogenic.

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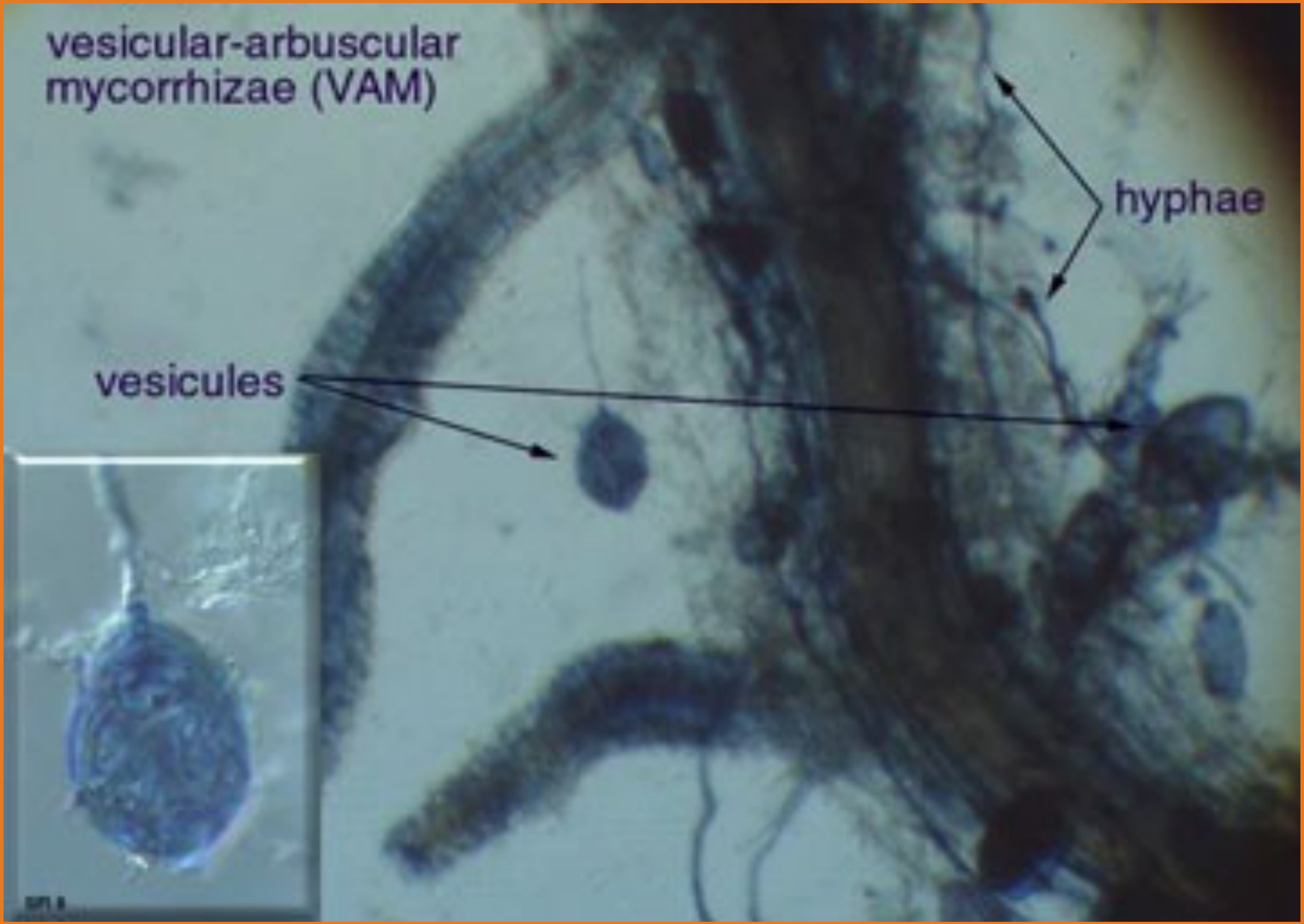
A section of plant feeder root that is heavily colonized by a desirable fungus called "**endomycorrhizae**".
The structures within the root where nutrient-absorbing "arbuscules" that have converted to "vesicles" or spores.
Another name for endomycorrhizae is "vesicular-arbuscular mycorrhizae ", or VAM. Where VAM is colonizing a root,that portion will be protected from root rot fungi and parasitic nematodes. VAM are symbiotic with plant roots. They take some nutrients from the sap that the plant can afford and reach out into the soil for phosphorus, other minerals and water



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Example of **Ectomycorrhizae** on tree roots. This is a highly desirable colonization of tree and shrub roots that causes the very shape of the root branching pattern to change. Roots in this condition are very efficient at absorbing phosphorus, other nutrients and water. Also where this symbiotic colonization is present the roots are protected from root rot fungi and parsitic nematodes. Trees and landscape shrubs are often planted into a site where the symbiotic fungus is lacking, causing the plants to lack vigor and often eventually die

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Spores of Pythium spp. root rot fungus in a plant root. An example of disease that can occur where the soil foodweb is degraded or lacks diversity that would otherwise suppress root rot.

Fungal Strands in Compost

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Methods of Measuring Microbial Activity

- Culture based techniques
- Phosopholipid fatty acid analysis (PLFA): differences in communities
- CO_2 respiration : total biomass
- Nucleic acid : functional gene targeting

Many Organisms = Many Survival Strategies

Different organisms respond to present conditions & substrates with different mechanisms:

Substrate:

1) Autochthonous: organisms that grow slowly in soil containing no readily oxidizable substates; probably use humic substances, lignin, or inorganic substrates
2) Zymogenous: organisms that exhibit bursts of activity when fresh residues are added to the soil; probably use readily decomposable substrates such as sugars, starches, and proteins

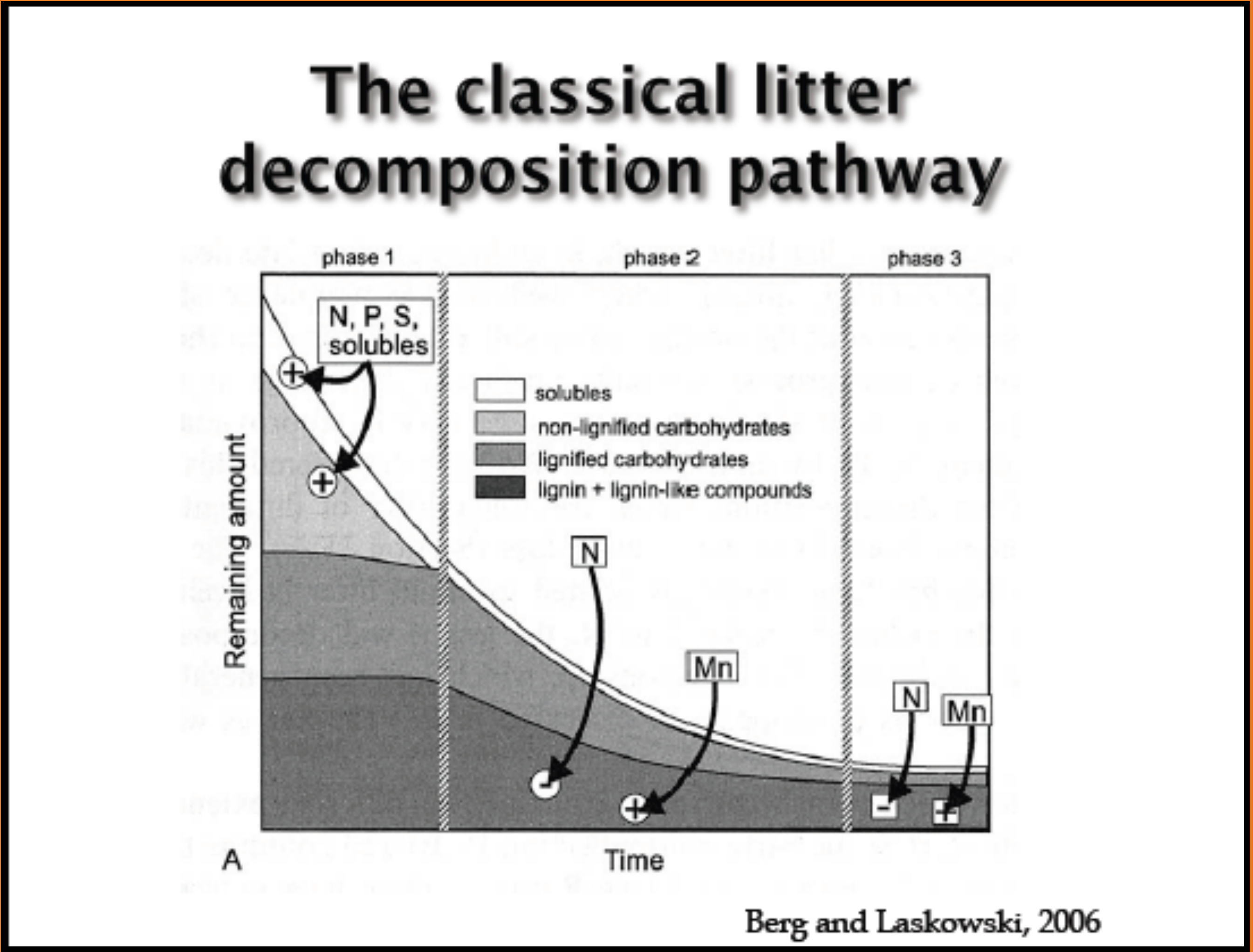
Oxygen:

1) Aerobes: organisms which only grow when oxygen is present
2) Anaerobes: organisms which are inhibited or killed when exposed to oxygen
3) Microaerophiles: obligate aerobes, but grow best at low oxygen tension
4) Facultative Anaerobes: active under aerobic or anaerobic conditions

(Pete Stahl Lecture Notes, 2010)

Overview of Decomposition As An Oxidation Processes

$R—(C,4H) + 2O_2 \rightarrow CO_2 + 2H_2O + \text{energy}$ (Brady and Weil, 1996)



Phase 1 (leaching): fast growing microbes that eat solubles- already present on fallen litter.

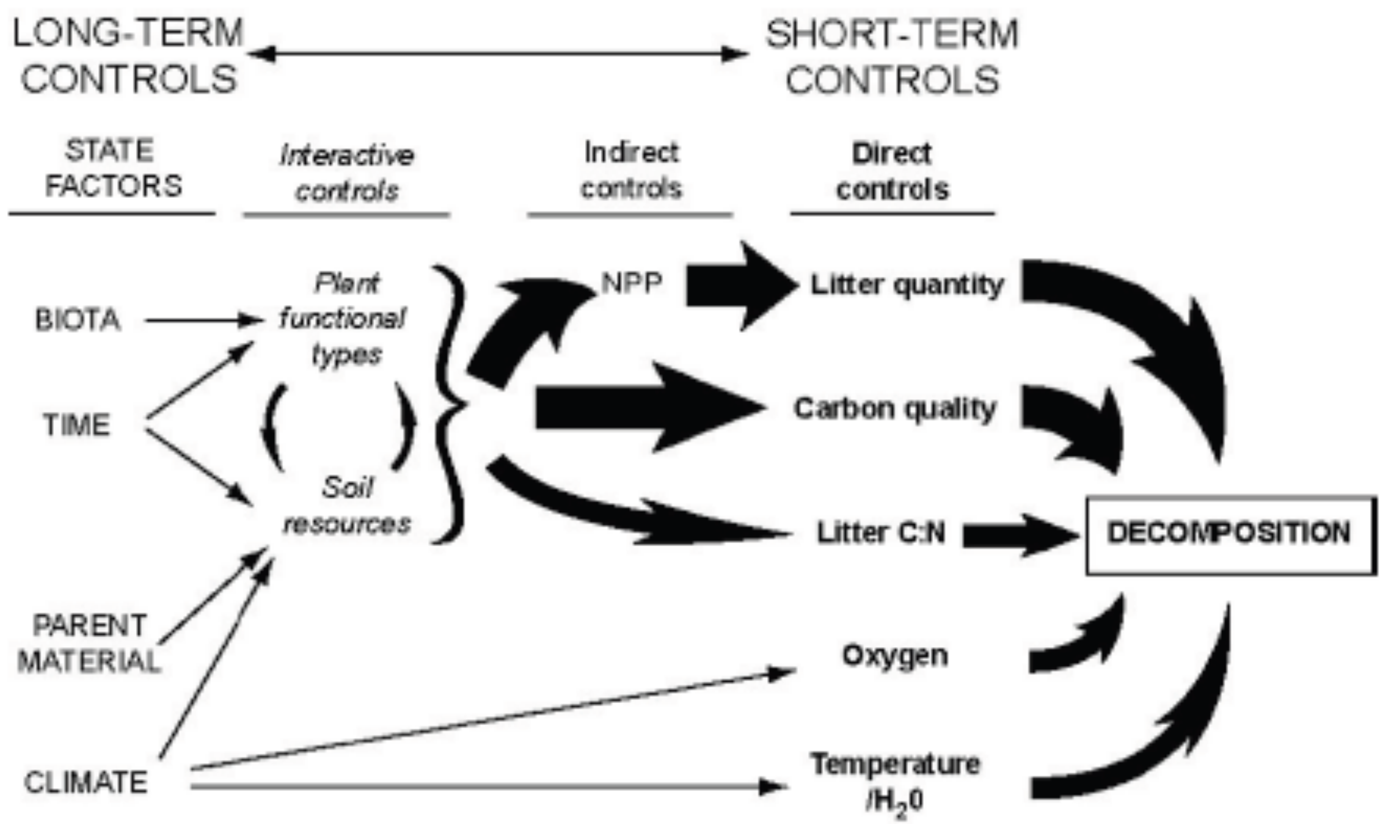
Phase 2: medium fast growers that degrade starches and sugars.

Phase 3: slow growers that degrade lignin. Includes fungi whose hyphae extend into the soil.

Controls over decomposition range from long-to-short term

- Long-term: State factors
- Intermediate: Interactive controls
- Short-term: Indirect and direct physiological controls

Direct controls: Environment and substrate quality



Chemical alteration

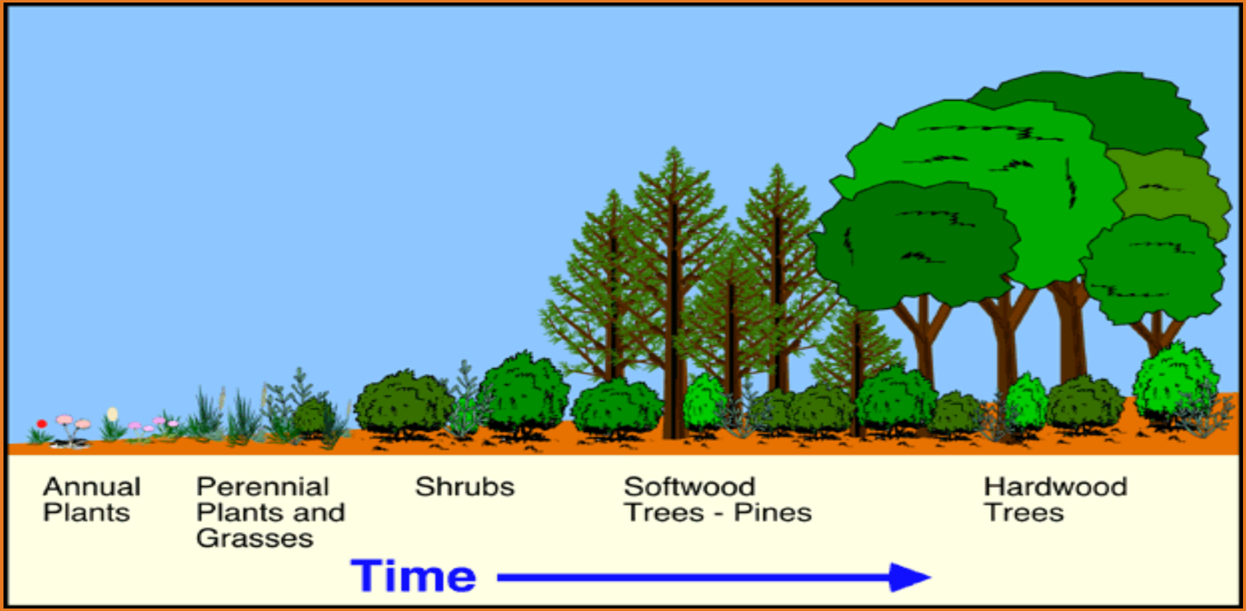
- Most organic compounds are polymers and cannot be directly assimilated (eaten) by microbes
- Microbes produce extracellular enzymes to depolymerize these compounds so they can assimilate them
  - Enzymes are proteins, which contain C and N
    - Thus, the production of enzymes is constrained by N availability
    - Proteins are also 'food' for microbes, and are broken down by protease enzymes

What Does Decomposition of OM Do for Your Soil?

- Enhanced microbial functions
- Increased water holding capacity
- Increased aggregation
- Increased mineralization
- Decreased erosion
- More nutrient retention
- Increased insulation
- Warmer average soil temps
- More stable pH
- Better aeration
- Lower fertilizer needs
- Increased gas exchange
- Adsorption of pollutants

Implications for Land Management

- higher microbial biomass and diversity is related to productivity of soil
- protect soils and microbes for erosion, and disturbance
- reduce erosion from wind and water by vegetating bare soil and controlling water flow that cuts soil
- use no-till or conservation tillage practices
- plant diverse plant communities when possible
- use pasture rotation and use available organic inputs such as manure and compost



Bacteria dominated	balanced F: B	Fungi dominated
Alkaline	balanced pH	Acidic
Nitrates		Ammonium

http://www.physicalgeography.net/fundamentals/images/succession.gif

Seeing Is Believing

A yield trial of two corn fields was conducted during the summer of 2009, when Mexico was experiencing its worst drought in 68 years. During this time, dryland-farmed corn failed all over the country. The difference between microbiological treated organic corn and a field of non-treated organic corn is an eye-opener. The benefits of microbiological farming is clear.

Control non-treated organic corn: Sept. 18/09

Microbiological treated organic corn: Sept. 18/09

Control corn on left--Biological on right

Compost Teas are being used to try
to inoculate soils and jump start or manipulate the soil microbial populations and compositions.

This process has proved difficult, especially with fungi, some of whom cannot be grown outside their host or native soil.

http://www.soilfoodweb.com/sfi_approach3.html#Whyuse