Soil Organisms

ESS 210

Chapter 11

p. 449-497

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What You Should Know

- Soil is full of living organisms!
- How many organisms are in soil?
- What types of organisms are in soil?
- Why are they important?

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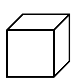
Soil is alive!

- How many?
  - 10^7 to 10^9 bacteria per cm^3
  - 10^3 to 10^6 fungi per cm^3
  - 10 to 1,000 protozoa per cm^3



1.3 g soil = 1 cm^3

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Table 1–2 **Microbial groups with representative size, numbers,† and biomass† found in soil.**

Microbial group	Example	Size (μm)	Numbers (no. g^{-1} of soil)	Biomass (kg wet mass ha^{-1} of soil)
Viruses	Tobacco mosaic	0.02 × 0.3	$10^{10} - 10^{11}$	
Bacteria	*Pseudomonas*	0.5 × 1.5	$10^8 - 10^9$	300 – 3,000
Actinomycetes	*Streptomyces*	0.5 – 2.0‡	$10^7 - 10^8$	300 – 3,000
Fungi	*Mucor*	8.0‡	$10^5 - 10^6$	500 – 5,000
Algae	*Chlorella*	5 × 13	$10^3 - 10^6$	10 – 1,500
Protozoa	*Euglena*	15 × 50	$10^3 - 10^5$	5 – 200
Nematodes	*Pratylenchus*	1,000§	$10^1 - 10^2$	1 – 100
Earthworms	*Lumbricus*	100,000§		10 – 1,000

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General Classification of Organisms

Five Kingdoms:

- Animalia
- Plantae
- Fungi
- Protista
- Monera (bacteria)

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The Tree of Life

- "Phylogeny" = ordering of species into higher taxa based on evolutionary (genetic) relationships
- Based on comparison of ribosomal RNA gene sequences
- Code for ribosomes - protein synthesis
- rRNA genes are "*conserved*" and "*universal*"

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Cell Types

- Eukaryotes: organisms with a membrane-bound nucleus that contains chromosomes (DNA)
  - Includes nearly all organisms, except bacteria
  - May have other organelles
- Prokaryotes: organisms whose DNA are not found within a membrane bound nucleus
  - Sack of chemicals!

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Soil Animals

- Large to near microscopic
- Burrowing animals
  - Moles, mice, prairie dogs, …
- Earthworms
  - Important indicators of soil health
  - Digest plant and animal remains
  - Distribute organic material through soil
  - Improve macro-porosity

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Soil Animals

- Earthworms (continued)
  - Low in agricultural soils (plowing destroys habitat and buries food)
  - Low tolerance for salts, acid pH, sandy soil, dry conditions

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Soil Animals

- Arthropods
  - Ants, termites, mites, centipedes, …
  - Can impact soil structure
- Nematodes
  - Microscopic worms
  - Most are omnivores - eat decaying organic materials
  - Some are important parasites - Soybean Cyst Nematode

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Soil Plants

- Plants derive energy from *photosynthesis*
- Primary producers of organically combined carbon: $CO_2 \rightarrow$ sugars
- Roots exude many different types of compounds
  - Important to soil microbes (food)
  - Area around roots is the *RHIZOSPHERE*

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Soil Plants

- Algae
- Microscopic plants in soil
- Algal blooms - green carpet of growth on warm, moist soils
- Algae can input large amounts of organic carbon

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Soil Protists

- Minor in soil
- Protozoa
  - – Unicellular organisms
  - – No true cell wall
- Protozoa act as grazers
  - – Prey on bacteria, fungi
  - – The *bovines* of the microscopic community
  - – Help maintain active, young populations

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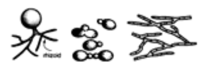
Table 4–2 **Sexual and asexual reproductive structures produced by true fungi in four phyla of the Kingdom Fungi and funguslike organisms in the phylum Oomycota of the Kingdom Stramenopila.**

Phylum	Sexual phase (Teleomorph)	Asexual phase (Anamorph)
Chytridiomycota	Resting chytrid cells	Zoospores (from chytrid cells)
Zygomycota	Zygospores (solitary resting spores)	Chlamydospores (from hyphae), sporangiospores (in sporangia)
Ascomycota	Ascospores (in fruiting bodies)	Conidia (on individual hyphae, aggregates of hyphae, or in fruiting bodies)
Basidiomycota	Basidiospores (on individual hyphae or in fruiting bodies)	Conidia, other specialized asexual spores in complex life cycles
Oomycota	Oospores (solitary resting spores)	Sporangia, zoospores (from sporangia)

- **Chytrid cells:** solitary globose cells with or without specialized rootlike filaments called **rhizoids** (Fig. 4–2a). They are unique to organisms of the phylum Chytridiomycota in the Kingdom Fungi and the phylum Hyphochytridiomycota in the Kingdom Stramenopila. The latter group is discussed in more detail by Alexopoulos et al. (1996).
- **Yeast cells:** spherical to ovoid cells are formed by fungi in the phyla Ascomycota and Basidiomycota. They divide by budding or fission (Fig. 4–2b). Some fungi are dimorphic and can change from a mycelium to a yeast form under conditions where penetration of a substrate is not needed to obtain nutrients, such as in aqueous environments or insect cavities.
- **Mycelia:** a filamentous network of hyphae (Fig. 4–2c) that branch and grow only by apical (tip) extension (Fig. 4–3a). This vegetative growth form is the most common of organisms in the Kingdom Fungi, and in soil fungi especially.

A mycelium is incredibly resilient because growth is open-ended for as long as a nutrient source is available. The result is that size is highly variable, ranging from a pinpoint to a mass covering hectares of land. On an **agar** medium in Petri



a b c

Figure 4–2 Types of cells that make up the vegetative body (thallus) of fungal organisms: (a) chytrid cells, (b) yeast cells, and (c) a mycelium containing compartments separated by crosswalls (septa).

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Soil Fungi

- Plant-like Eucaryotic cells with cell walls
- No photosynthesis
- Live off of dead or living plant, animal, microbial remains
- Yeasts - single-celled, anaerobic conditions
- Filamentous fungi
  - – Hyphae: individual fungal filaments
  - – Mycelium: mass of hyphae

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Soil Fungi

- Mushrooms
  - – Sexual fruiting bodies of certain fungi
  - – Releases sexually developed spores
  - – Many form symbiosis with roots: mycorrhizae
- Molds - asexual fungi
  - – Often dominate soil fungi
  - – Well adapted to acid soil pH
  - – Very important in organic residue decomposition

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Importance of Fungi

- Organic residue decompostion
  - – Dominant in forest soils
  - – Primary degraders of cellulose and lignin
  - – As a group, most versatile degraders
- Humus formation
- Nutrient recycling
- Aggregate stabilization
- Predators on nematodes

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Importance of Fungi

- Mycorrhizal relations
- Source of important chemicals
  - – Beneficial: penicillin, alcohols, organic acids
  - – Toxic: aflatoxin - carcinogen (*Aspergillus flavus)*
- Plant pathogens
  - – Wilts, e.g., *Verticillium*
  - – Root rots, e.g., *Rhizoctonia*

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Mycorrhizae - “Fungus Root”

- Symbiotic (mutually beneficial) relationship
  - Plant provides carbon source for fungus
  - Fungus provides enhanced water, P, nutrient uptake
  - Nearly all plants are mycorrhizal
- May reduce other pathogens
- Enhances N_2 fixation
- Better stress tolerance

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Ectomycorrhizae (ecto = outside)

- Fungus forms sheath around root
- Doesn’t penetrate root cells, hyphae between cells
- Changes root morphology
- Common on many types of trees, especially conifers, some hardwoods

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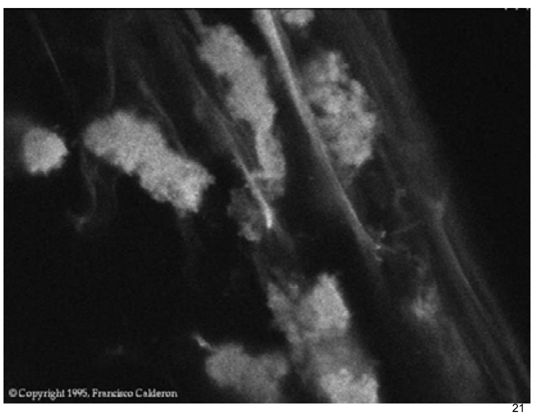

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Endomycorrhizae (endo = inside)

- No obvious sheath
- Hyphae penetrate into plant cells
- Often called VAM
  - Vesicular Arbuscular Mycorrhizae
  - Vesicles are sac structures
  - Arbuscles are tree-like fungal structures inside plant cells
- Most common, most plants
- Very important in P uptake

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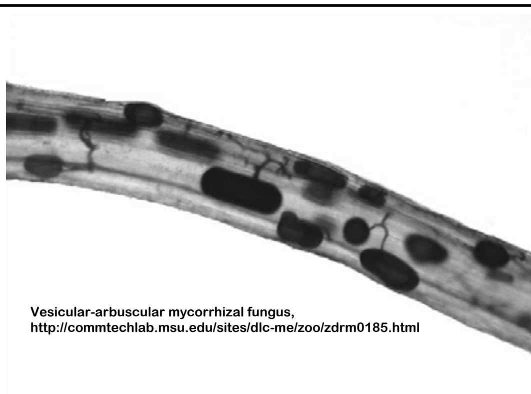

Vesicular-arbuscular mycorrhizal fungus, http://commtechlab.msu.edu/sites/dlc-me/zoo/zdrm0185.html

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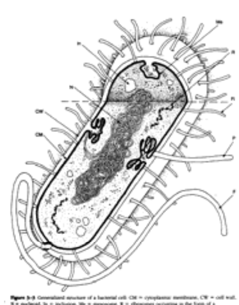
Soil Bacteria



- Unicellular, prokaryotic
  - No organized nucleus
- Most numerous of soil organisms: 10^6 to 10^9 per gram
- 1 µm or less
  - Still larger than most clay particles
- Classified by:
  - Nutritional class
  - Oxygen needs

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Nutrition Classes of Bacteria

- Autotrophs - derive C from CO_2
- Heterotrophs - derive C from preformed organic C compounds
- Phototrophs - energy from light (photosynthesis)
- Chemotrophs - energy from reduced inorganic compounds

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Nutrition Classes of Bacteria

- Photoautotrophic
  - Photosynthesis
  - C from CO_2
  - Energy from light
  - Cyanobacteria (blue-green algae)

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Nutrition Classes of Bacteria

- Chemoautotrophic
  - C from CO_2
  - Energy from oxidation of reduced, inorganic compounds
- Nitrification

$NH_4^+ + 1.5O_2 \rightarrow NO_2^- + H_2O + 2H^+ + \text{energy}$

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Nutrition Classes of Bacteria

- Chemoheterotrophic
  - C from organic C compounds
  - Energy from oxidation of organic C compounds
- All fungi, protists, animals, *MOST* bacteria

$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{energy}$

(reduced C^0) (oxidized C^{IV})

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Oxygen Requirements

- Organisms require a terminal electron acceptor to generate energy
- Aerobic
  - *REQUIRE* free oxygen - O_2
- Anaerobic:
  - Function in the absence of O_2
- Facultative anaerobes
  - O_2 or other oxidized compound (e.g., NO_3^-)

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Actinomycetes

- Special class of bacteria
- Look more like fungi
- Procaryotic
- Source of antibiotics
- “Earthy” smell of fresh soil - geosmin
- Dominant in alkaline soils

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Importance of Bacteria

- Decomposition of organic compounds
- Nutrient cycling
- Humus production
- Soil aggregation
- Nitrogen fixation
- Plant growth promotion
- Plant pathogens

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N-fixation

- Certain bacteria can transform unavailable N_2 into available NH_4^+
- Catalyzed by an enzyme: *nitrogenase*
- Symbiotic, associative, and non-symbiotic

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

NH_3 + organic acids → amino acids → proteins

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Symbiotic N-fixation

- *Rhizobium*-legume symbiosis
  - *Rhizobium* bacteria form **nodules** on roots of legumes
  - Plant provides organic carbon for bacteria
  - Bacteria provide fixed N for plants
- Actinomycetes form nodules on many non-legumes
- Cyanobacteria with various plants
  - *Azolla-Anabaena* important in rice

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Symbiotic N-fixation

- Very high N-fixation rates
- *Rhizobium &* legume
  - Soybeans - 50 to 150 kg N ha^{-1} y^{-1}
  - Alfalfa - 150 to 250 kg N ha^{-1} y^{-1}
  - Leucena - 100 to 500 kg N ha^{-1} y^{-1}
- Actinomycetes & alder trees
  - 50 to 150 kg N ha^{-1} y^{-1}
- *Azolla-Anabaena* - 150 to 230 kg N ha^{-1} y^{-1}

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Associative N-fixation

- Bacteria associated with plant roots
- Use organic C exuded by root as energy source to drive N-fixation
- Low amounts: 5 to 15 kg N ha^{-1} y^{-1}
- *Azospirillum*

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Non-symbiotic

- Free-living bacteria
- Low amounts
  - < 5 kg N ha^{-1} y^{-1}
- *Azotobacter, Clostridium*

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Other Symbioses

- Lichens
- Algae and fungi
- Colonize harsh environments
- First stages of soil formation

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