Types of Soil Microbes and their Function in Ecosystems

Table 1 summarizes the ecosystem functions carried out by soil microbes, and Table 2 indicates the relative density of the major groups of soil microbes in grassland ecosystems. Besides plant roots, soil microbes are by far the most abundant biotic component of soil. Although the values in Table 2 change from ecosystem to ecosystem (e.g., forests have a higher fungi:bacteria ratio due to their tendency to have moist, more acidic soil and the abundance of tough, woody material that fungi are better adapted to break down) this is a useful starting point.

Table 1. Essential ecosystem functions performed by different members of the soil biota.

Ecosystem Function	**Organisms Involved**
Regulation of soil water permeability	Burrowing invertebrates and plant roots
Gas exchanges and carbon sequestration	Mostly microorganisms and plant roots, some C protected in large compact invertebrate aggregates
Soil detoxification (e.g., biological breakdown of soil pollutants)	Mostly microorganisms
Nutrient cycling	Mostly microorganisms and plant roots, some soil and litter feeding invertebrates
Decomposition of organic matter	Invertebrates and microorganisms

Table 2. Approximate range of biomass of each major component of the microbial biota in a typical grassland soil. Earthworms and "other" (e.g., burrowing mammals) included for comparison.

Component of Soil Biota	**Biomass (tons per hectare)**
Plant roots	Up to 90 but usually ~20
Fungi	2-5
Bacteria	1-2
Actinomycetes	0-2
Protozoa	0-0.5
Nematodes	0-0.2
Earthworms	0-2.5
Other	0-0.5

Fungi

By weight, fungi are the dominant soil microbe biota. Their cells contain nuclei and are therefore eukaryotic, although some are unicellular with multiple nuclei. They reproduce both asexually and sexually by producing spores (Table 3) which are capable of surviving prolonged periods of nutrient deprivation. Because of their larger size, they are found in larger spaces between clumps of soil particles.

Their appearance is similar to that of the actinomycete bacteria, but they are much larger, with a diameter of 2-10 μm and a length up to 50-100 μm. In one extreme exception, researchers in northern Michigan (Smith et al., 1992) discovered a fungus estimated to be 21,000 pounds, 30 acres wide, and 1500 years old; other similarly large soil fungi have since been discovered. Though not as large as giant redwoods, these discoveries make fungi among the largest and oldest living things on earth.

Fungi are obligate aerobes, unable to survive in anoxic conditions. They have a variety of life history strategies, but their most important ecological role is that of decomposer. They are able to break down very tough molecules such as lignin and soil humic acids. They are able to tolerate acidic conditions better than bacteria, and in extremely acidic forest soils (such as in coniferous forests) they perform a task usually restricted to bacteria, that of fixing nitrogen

Bacteria

Soil bacteria are the most numerous (though not the largest by mass- see Table 1) component of the soil microbe community. They are typically 3 μm in size. Bacteria are often found adhering to soil particles via chemical bonds, and many are aquatic in that they survive in thin films of water adhering to soil particles. Some are capable of movement using one or more flagella that extend from their cell membrane (see Figure 2). They reproduce asexually by budding or, less commonly, binary fission. Some bacteria only survive in aerobic conditions (obligate aerobes), some prefer aerobic conditions but can tolerate anaerobic ones (facultative anaerobes), and some can only survive in anaerobic conditions (obligate anaerobes).

There is a wide variety of bacteria in the soil. When compared to bacteria grown in a lab culture, soil bacteria in their natural habitat are enveloped by a thick mucilaginous shell that is thought to protect them from changes in moisture, pH, and other conditions. Bacteria must be able to adapt to periods of severe lack of food or water by shifts in metabolic activity and structures such as the mucilaginous shell. Some species form spores under extremely dry conditions and will return to their normal shape when moisture returns.

The type of bacteria in the soil depends on the conditions of the soil. Oxygen-deprived soils, for example, are likely to be dominated by members of the genus Clostridium. Bacteria are also more common in smaller soil pore spaces where they are protected from predation by protozoa and nematodes.

Besides their important role in decomposition, bacteria are also key to nitrogen cycling, as they are the most important soil microbe involved in fixing atmospheric nitrogen into an organic form and also, in some groups such as those in the genus Nitrosomonas, mineralizing it to an inorganic form.

Actinomycetes are a type of bacteria that are often discussed separately because of their unique shape. Rather than being rod or sphere shaped as other bacteria are, actinomycetes form long stringy, hair-like networks called hypha (collectively called mycelium) that reproduce asexually via spores. Their growth is similar to that of fungi described below, but their hypha are considerably smaller (10-15 μm long by 0.5-2 μm wide). Actinomycetes decompose a wide variety of substances, many of which are difficult to break down and include chitin (the outer covering of fungi and many invertebrates) and cellulose. They are far more common in high pH soils and tend to be replaced by bacteria and fungi in lower pH soils. They are also more common in soils located in drier and hotter regions.

These microbes also have life history traits of wide interest to people. They are responsible for secreting many antibiotics now used in medicinal applications - such as streptomycin - which were discovered in the 1950s to be able to combat bacterial infections in humans such as strep throat. In their natural habitat, it is thought that these compounds play a role in protecting actinomycetes from predation by other soil microbes. A second interesting fact is that actinomycetes secrete an organic compound, geosmins, that contribute to the earthy smell of soil most easily noticed after a rainfall.

Protozoa

Amoeba, Ciliates, and Flagellates belong to a group of organisms known as protozoa – single celled but with a nucleus. They reproduce asexually and sexually. They are typically 10 μm in diameter and live in soil pore spaces of that size or larger. Flagellates have 1 to 4 whip-like projections called flagella that aid in locomotion; ciliates have many small hair-like projections (these can number in the thousands) that help them move. Amoeba move by use of pseudopods – extensions of their flexible membrane pushed forward by internal body fluids. They therefore continuously change shape as they move about the soil environment. Amoeba require relatively moist soil to be active, and research suggests that amoeba spend much of their life as cysts since soil conditions are often too dry.

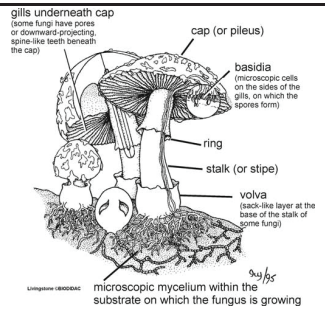
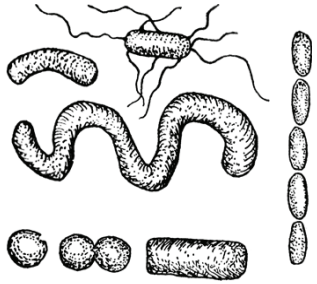
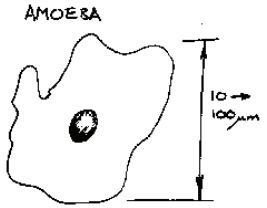
They are mainly predators, feeding on bacteria and some fungi, but they also process fine organic particles, either as free-living organisms or inside the gut of a host organism such as termites. Bacteria are able to protect themselves from some protozoan predation due to their ability to inhabit soil pores too small for amoeba to reach.

Nematodes

Nematodes are typically 1mm in length and 0.05 mm in diameter. They reproduce sexually. Nematodes are mostly parasites (of plants and other soil microbes) and predators; their role in causing diseases of agricultural crops makes them a frequent pest for farmers, but they also play an important role in the decomposition process. Nematodes are large and therefore inhabit films of water surrounding large soil pores. They are capable of forming cysts to survive drought periods.

Name_____ Date_____ Hour_____

Description of Soil Microbe Community

	How they look	Abundance (tons/hectare)	Habitat characteristics	Potential role in food chain and ecosystem
Fungi				
Bacteria				
Protozoans				
Nematodes				

adapted from Killham 1999