Name: ______________________________

Study Guide – Denizens of the Soil

Field Biology

1. Why does litter decompose so rapidly in oak forests that grow in clay soil as opposed to oak forests that grow in sandy soil?
2. Describe in your own words how soil invertebrates regulate decomposition and nutrient recycling in the soil.
3. What does "BPGT" stand for?
4. Why is the cyanide-producing millipede so important in Northwest forests? What do you suppose would happen if that millipede disappeared?

Denizens of the Soil: Small, but Critical

Adapted from Andy Moldenke, Research Entomologist, OSU, Corvallis

I occasionally teach lectures to forest ecology groups at OSU. The first thing I do when I come in to the board is I write "**BPGT**." By the end of the lecture everybody should be able to tell me what it means. At the end of this reading you should be able to do the same.

Very few people really understand how soils work. I'd like to give three illustrative examples of how soil arthropods, soil microbes and roots work together as a combined system in the real world. The first example is of onion production. Basically, the plant is incapable of taking up any phosphorus from the soil unless it has **mycorrhizae** on its roots. Mycorrhizae, literally meaning fungus roots, are thread like fungal bodies that interact with plant roots that pick up lots of phosphorous and other substances. The growth of the onion plant depends upon the number of arthropods called **springtails** (Figure 1.) living in the soil. Springtails function by eating the tips of the mycorrhizae which stimulates the mycorrhizae to grow, dissolve more nutrients in the soil around it, and feed it to the plant. As the number of springtails in the soil increases, the plant grows faster until there are so many springtails that they eat all the mycorrhizae. Then growth of the onions drops to zero again.

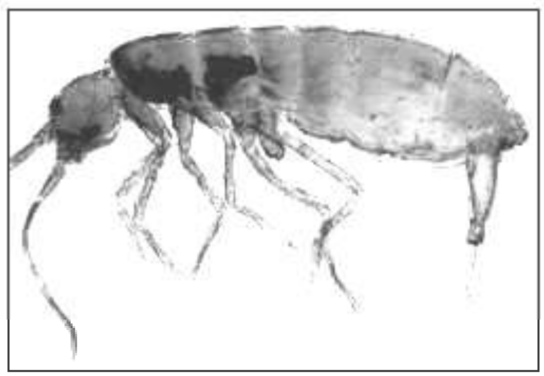

Figure 1. *Tomocerus minori*, also known as a springtail or collemboia. It owes one of its names to the long tail at the right, known as the furcula. Normally, the tail is tucked up close to the insect's body. When the springtail wants to move in a hurry (as it would when a predator approaches), the furcula becomes a powerful spring that propels the insect through the air.

The second example is from oak forests in Europe. When oak trees live on sandy soil they grow very slowly. They don't make many leaves so there's not much **leaf litter** at the end of the year. But the litter that does come down year after year piles up very thick. Most of the nutrients are in the litter layer, unused, not part of the biological growth of that ecosystem. On the other hand, oak trees that grow on clay soil grow very fast and have lots of leaves. But when the leaves hit the ground they decompose very rapidly and make a very thin litter layer. All the nutrients in that ecosystem are bound up into the tree growth itself. An oak tree puts lots of chemicals in its leaves called **phenols** (a mildly acidic toxin) that prevent caterpillars from destroying the trees. When the leaves die and become litter on the ground, the phenols are still in the leaf. When a millipede or an earthworm comes along and starts to eat that leaf, the pH changes and the phenols **polymerize** (combine with each other) forming a plastic rubbery mass that in turn kills the millipedes. In clay soils however, springtails are present and fill their bellies with inorganic clay particles. At night springtails migrate up to the litter layer and feed on fungi and leaf litter. The inorganic clay particles in the gut prevent the polymerization from taking place. As a result, the nutrients in the ecosystem cycle through the environment and leaf litter does not build up. The point of the story is that the productivity of that entire forest ecosystem is basically the result of one little arthropod in that soil.

Soil invertebrates are system **catalysts**. They regulate the rate of decomposition and the rate of nutrient cycling by breaking down litter and small organisms (like chewing) but don't chemically process nutrients in the soil. This is important because every chemical and physical property of soil is basically driven by the surface area to volume ratio of the particles that make it up. In essence soil invertebrates make nutrients and organic components usable for other organisms. Additionally, soil invertebrates mix organic and the inorganic components changing the microstructure of the soil, which in turn drives the complex processes of microbial **succession** (the process by which a plant or animal communities change over time). Invertebrates feed on the current microbial crop and their own feces provide for a new and different type of microbial community to develop. In fact, most organisms eat the manure or feces of the other things. As a result, the total nutrient content of a soil, whether tied up in organic matter or immobilized in inorganic phases in the mineral soil, are of secondary importance. The critical parameter is how dynamic soil-converting processes are. In other words, how many dung beetles do you have in the system, and how many species do you have in that system?

So what does "**BPGT**" mean? "Bug Poop Grows Trees."

Oregon State University is actually the first place in the U.S. where researchers have made slides of soil and looked at them. We found that even deep down in the soil all of it is made up of invertebrate feces.

Soil Bio-diversity

The upper layers of soil, which are the only ones that are important for plant life, are alive. Litter and topsoil are biologically the most diverse part of any terrestrial ecosystem. They are also the most chemically diverse part of an ecosystem. Studies have shown that forest soils in the Blue Mountains are composed of hundreds of species of arthropods in every square meter of soil, AND HUNDREDS OF THOUSANDS of individuals per square meter of soil. These are all things you can see walking around in your hand; they've got eyes they've got legs, they get hungry, they get tired, they lust after their mates, they do little mating dances, they have behavior.

You can find a variety of these critters any time you go out and take a shovelful of dirt. The most common things in the soil are oribatid mites. The variation among mites is amazing. The biggest one is the size of a period on a printed page; the smallest is 1/250th of an inch in length. There are long-legged oribatid mites, flat-backed, aircraft-carrier, and mites that have scales that resemble ostrich plumes all over their bodies.

The other major group of soil dwellers is springtails, which we talked about earlier. There are about 100,000 per square meter in the forest. When attacked, they have a little clamp that releases their fercula (tail), which is under very high blood pressure, and catapults the springtail into the air. Springtails about 1/12th of an inch long are able to jump a yard away. A very effective evasion strategy. Another springtail is all covered with scales like the wings of a butterfly.

Another critical soil organism is the cyanide-producing millipede that is very common in western Oregon. All the nutrient transfers take place in the soil itself, from one fecal particle to another fecal particle and pass it down that chain of succession. But how do you get from a dead leaf on the ground to a fecal particle? Well, that's the role of the cyanide-feeding millipede in our forest. There's really only one common millipede in the whole forest system from southern Alaska all the way to northern California. Basically every single leaf, both deciduous and coniferous, that falls on the ground, actually goes through the gut of that one species of millipede before it even enters the soil ecosystem. So there you have one species that does something that can't really be substituted for by anything else. It is an excellent example of a **keystone species** (a species that is the center, or supports, an ecosystem).

The point that I want to make is that all the upper layers of the soil are biogenic.

Soil organisms are so important that they are used in biological control in many parts of the world. In Oregon we use them heavily in the pear industry down in Ashland and Medford. There are pseudoscorpions, skunk spiders, centipedes, and snail-feeding beetle.

Aside from animals bacteria are present also. Nitrogen-fixing bacteria for example, do something unique, something that can't be substituted for. They transform atmospheric nitrogen into nitrates that are required for plant growth. Without these, ecosystems would rely on decomposing animals and plants for nitrogen but would eventually collapse without nitrogen-fixing bacteria.

Key Point

First, soils are alive. They are biogenic. All the upper layers are in fact nothing but living critters or the feces of living critters.

Second, soil arthropods are the regulators in most soil processes. They are the system catalysts that drive the microbial processes of chemical excitement. All of those processes would stop if we didn't have the critters here feeding upon them.

Third, soils are by far the most biologically diverse part of any terrestrial ecosystem.

Fourth, by monitoring the types of diversity that are there you can learn how an ecosystem is functioning. We can generate useful information on different time and spatial scales that is different from what you can learn by looking at soil cores or tree rings.

Last, we need to start to use our eyes and examine the world we live in. We will see what a really neat world we live in and just maybe we will stop treating soil as if it were dirt.