Intro to Mycology
Summer HSSP 2020
Week 5 Notes – 8/8/2020
Fungi in the Environment

Fungi have many different relationships with their surrounding environment. Many are **symbionts**, organisms that live in relationships with others. Fungi and insects have complex relationships. **Leafcutter (attine) ants** eat a significant amount of vegetation - typically 12 - 15% of all leaves produced in South American forests. Some scientists estimate this diet has held for up to 50 million years; during that time, the ants may have co-evolved with fungal partners. The ants collect leaves which are specifically used to grow fungi in their underground nests. Because ants cannot digest the leaves directly, they feed on the fungi that grows on the leaves. The ants benefit when fungi break down the indigestible cellulose of plants and convert it into edible materials that ants can harvest. The ants, in turn, provide food for the fungus and even secrete antibiotics to prevent bacteria competing on the leaves that the fungus eats. The ants also carry the fungus in their mouths to new locations when starting new nests. **Ambrosia beetles and fungi** also have a mutualistic relationship. Beetles chew up wood and provide nitrogen in their excrement that promotes fungus growth. In turn, the fungi provide enzymes to breakdown the wood and provide food for beetles and larvae. They also seem to promote beetle reproduction. Fungi are collected and dispersed from structures called mycangia within the beetle.

Fungal endophytes are fungi that infect plant tissues, mainly leaves. They are common to all plants. One particular leaf may have many fungi depending on plant species, environment, and climate. Fungal endophytes are either generalists (found widely in the environment) or specific. They are common in grasses; the types of fungal endophytes in grasses are usually specific. They secrete toxic substances that protect the plant against herbivores. In some cases, endophytes can confer esistance to abiotic (heat/drought, salt) stress or biotic stress (pathogenic fungi, herbivores). Some types of endophytes can also be harmful (pathogenic, increased water use). Most of the effects are unknown. Some scientists think they are dormant and "camp out" while waiting for the leaf to die, sort of like a lysogenic virus.

Fungus and bacteria also have unique relationships in crops of economic importance. The bacterium Burkholderia was found to live in the cytoplasm of Rhizopus microsporus, a fungal plant pathogen used in traditional soy fermentation methods, such as those used to prepare tempeh (fermented soybean product) and sufu (fermented bean curd). The bacterium produces a toxin (rhizoxin) that is shown to breakdown young rice plants and other plants such as sunflower, thus allowing the Rhizopus to develop (only in the presence of the rhizotoxin that the bacterium produces). The bacteria are necessary for the fungus to produce sporangiospores, which is a method that the fungus uses to reproduce and spread to other plants.

Mycorrhizae are symbiotic associations between certain fungi and plant roots. The plant gets increased surface area on the root to explore and intake more nutrients from increased soil volume. The plant also is exposed to new biochemical reactions in the fungus to convert inaccessible nutrients to accessible forms. Fungi that are present in the plant roots also prevent pathogenic fungi from growing there (by competition). The fungus gets a supply of sugars from plant photosynthesis. There are different types of mycorrhizae depending on whether the fungus surrounds or penetrates the root cells. Ectomycorrhizae surrounds the root cells and endomycorrhizae (also called vesicular -arbuscular mycorrhizae or VAM) penetrates the root cells. Neither type penetrates the epidermis of plant root cells.

Ectomycorrhizae are the oldest mycorrhizae association. It can be traced to fossils in at least the Triassic period (maybe even older). This group is monophyletic. The fungus cannot grow without the plant host. The fungal-plant interactions are typically non-specific, meaning many different types of fungus can interact with many different plants. The membrane that separates the plant from the fungus is of plant origin. A transporter within this membrane is responsible for a lot of the fungal interactions with the plant. If this transporter doesn't work, the plant will die. Phosphorus (immobile) is the key nutrient gained by the plant in exchange for carbon. Some studies have shown that a connection to a pre-existing mature ectomycorrhizal network can help some seedlings survive. Ectomycorrhizae contribute to the dominance and grove-formation of host species. Once a network is established, it is hard for other species of fungi/plant hosts to compete.

Endomycorrhizae evolved from wood rotting fungi in the Cretaceous period. This group is polyphyletic. Interestingly enough, they are closely related to some saprophytic (obtaining food from decaying organic matter) lineages. Because endomycorrhizae penetrate plant cell walls, they have enzymes that can digest such walls. They are more host-specific than ectomycorrhizae. They develop extensive, spreading hyphal networks that extend into the soil. They are common in cool climates with high organic matter soils. They can access organic nitrogen (useful for creating amino acids). Roots with endomycorrhizae are altered: they are shorter, thicker, and more branched.

Another type of mycorrhizae is **orchid mycorrhizae**. This type is essential for seed establishment in some types of orchids. The seeds are mycoheterotrophic, meaning they metabolize via a fungal partner that provides a source of carbon and mineral nutrients. Mycoheterotrophic orchids that do not produce chlorophyll of their own associate with trees or are saprophytic/parasitic. There are 20 different evolutions of mycoheterotrophy in orchids. It is not clear that fungi ever benefit from associating with an orchid; instead of mutualism, this could be an example of commensalism.

Mycorrhizae and bacteria also have complex relationships. The rhizosphere is soil region directly influenced by root secretions and associated soil microorganisms collectively known as the root microbiome. The rhizosphere structure and impact is top down: the plant community composition drives mycorrhizal community which then drives the rhizosphere bacterial community. Interactions between each layer are not well characterized yet.

Mycoremediation consists of using fungi or its derivatives for breaking down environmental pollutants into less toxic substances. After devastating fires in California, more than 40 miles of wattles (straw-filled, snake-like tubes that prevent erosion) containing oyster mushrooms were placed around parking lots, along roads, and across hillsides. The tubes would provide makeshift channels to divert runoff from affected waterways. The mushrooms would be able to break down harmful compounds as the water passed through. This method has been mainly used on a local scale. It’s not as widespread on a federal scale yet because federal regulations require the removal of all targeted contaminants within a short time frame. Current mycoremediation solutions are too slow to keep up with this time constraint.