Intro to Mycology
Summer HSSP 2020
Week 3, 4 Notes – 7/25/2020, 8/1/2020
Fungal Types and Classifications

Basidiomycota contains about 30,000 described species of fungi. They are found in virtually all terrestrial ecosystems, as well as freshwater and marine habitats. They include many "traditional" examples of fungi, such as: mushrooms, puffballs, stinkhorns, bracket fungi, jelly fungi, boletes, smuts, bunts, rusts, chanterelles, and earth stars. Symbiotic lifestyles (associations with other living organisms) are well developed in the Basidiomycota. These include parasitic fungi such as rusts (Uredinales) and smuts (Ustilaginales) that affect many crops of economic importance.

Fungi in the group basidiomycota are so variable that it is impossible to identify morphological characteristics that are both unique to the group and constant in the group. The fungi can be unicellular or multicellular, sexual or asexual, and terrestrial or aquatic. The most diagnostic feature in identifying a basidiomycete is the production of **basidia**, cells on which sexual spores are produced, and from which the group takes its name. Nuclear fusion and meiosis occur on a basidium cell. Another characteristic feature is the **clamp connections**, which are hyphal outgrowths that form when cells in hyphae divide. Clamp connections are unique to basidiomycota but not present in all basidiomycota. Another unique characteristic is forcibly discharged **ballistospores** that are propelled into the air. This type of spore discharge must have evolved very early in the evolutionary history of the basidiomycota because it is found in members of the earliest diverging lineages within the group. Not all basidiomycota have ballistospory: aquatic Basidiomycota and forms that produce spores inside the fruiting body, such as puffballs, have lost ballistospory. Currently, ballistospory is only associated with the fungi that directly discharge spores into the air. Mating in Basidiomycota involves fusion of haploid cells, but fusion of the nuclei is usually delayed until the basidia are formed.

Ascomycota are also sometimes called sac fungi. Ascomycota are the largest phylum of fungi with over 64,000 species and include fungi of culinary importance. Some members are unicellular (e.g. yeasts). Ascomycetes have certain morphological traits. Multicellular members of this family often have vivid, eye-catching fruiting bodies (called **ascomata** or **ascocarps**) and relatively large spores. The production of fruiting bodies depends on external environmental factors, including nutrient availability, temperature, pH, aeration/oxygen content, and light available. There are four types of fruiting bodies: cleitothecia, perithecia, apothecia, pseudothecia. The **ascus** (plural asci) is a sac-like structure that contains haploid **ascospores** for meiosis. During sexual reproduction, thousands of asci fill the fruiting body. The asci produce sexual **ascospores**.

Ascomycetes are divided into two main groups, or **subphyla**. **Pezizomycotina** have fruiting bodies similar to mushrooms and include morels, truffles, ergot, and cup fungi. **Truffles** are one of the most expensive foods on the planet. They are impossible to grow on a large scale and a rare in the wild. Pigs or dogs with especially sensitive noses are used to locate the fruiting bodies. White truffles can cost up to $5 per gram ($2,000 per pound). **Saccharomycotina** comprises most of the yeast. This includes **baker's yeast** and ***Saccharomyces cerevisiae***, one of the most commonly used eukaryotic model organisms in scientific studies. **White bloom** on the surfaces of grapes is a mixture of wild yeasts and molds. In the past, natural yeasts present on grapes were used to ferment grape juice and produce wine, but now winemakers inject grape juice with a high dose of a specific strain of *S. cerevisiae*. The yeasts consume sugar without oxygen and produce alcohol and carbon dioxide through fermentation.

Ascomycetes are a large and diverse phylum. As such, different species have different methods of **obtaining nutrients**. Some exclusively obtain their nutrition from dead and decaying matter (saprotrophs). Some form symbiotic relationships with other organisms such as cyanobacteria in **lichens** and obtain nutrients from this relationship. Some act as parasites on insects and then revert to saprotrophic nutrition. This allows them to survive in different environments.

Neocallimastigomycota fungi live in the digestive tracts of plant-eating animals like sheep. They represent the earliest diverging lineage of the zoosporic fungi. The enzymes that they produce break down polysaccharides like **cellulose**, the tough material that gives plants their strength. Once these fungi do their work, the simpler carbohydrates that are produced can be used by sheep as food. They are notable in that they have **hydrogenosomes** rather than mitochondria. Hydrogenosomes are symbiotic bacteria or organelles that generate hydrogen as a kind of anaerobic mitochondrion. After examining the hydrogenosomes of *Neocallimastix particiarum*, it was shown that hydrogenosomes were reduced mitochondria that were adapted to an anoxic environment. The hydrogenosomes make them distinct from other "chrytrid" fungi. Neocallimastigomycota has so far been found in the gut contents of mammals, but they likely will be found in other anoxic environments such as wetland soils. They are motile, using a **flagellum** to move around.

The **blastocladiomycota** family consists mostly of soil dwellers that digest detritus of all kinds. They can also be parasites in freshwater. This phylum has zoospores with a distinct ribosome-filled cap around the nucleus. They were traditionally classified into the chytridiomycota group, but they have been transferred to new phylum because of phylogenetically distinctness. Most of the true chytrids (Chytridiomycota) produce a limited mycelium while the blastocladiomycetes usually make extensive mycelia. They are motile, using a **flagellum** to move around.

An example of a blastocladiomycete is **Allomyces**. Allomyces is anisogamous, meaning it has gametes of different sizes. Female gametes are colorless and sluggish, male gametes are orange (they contain α-carotene) and very active, swimming in arcs interspersed with movement. This allows male gametes to find female gametes because female gametes produce a chemical attractant called **sirenin.** To create this molecule, the female gamete converts acetyl-CoA to farnesyl pyrophosphate, which in turn is converted to sirenin. So much acetyl-CoA is diverted to form sirenin that there is less ATP available in the mitochondrion for flagella motion, which is why the female gametes are not active. The male gamete has membrane receptors that respond to sirenin concentration. Sirenin stimulates the influx of calcium ions (Ca^{2+}) into the sperm cytoplasm and the physiological response is to reduce the length of the arc in the swimming of the male gametes. So, the pheromone influences the frequency of directional changes and the duration of the chemotactic run, the end-product being movement towards the source of the pheromone (the female).

The phylum **Glomeromycota** has 150 described species distributed among ten genera. Most are defined primarily by spore morphology, but more recently, DNA sequences have been used to assign classifications. Glomeromycotan fungi have relatively large (40-800 µm) spores that contain several hundreds to thousands of nuclei and are surrounded by layered walls. The hyphae of glomeromycotan fungi lack regular cross walls called **septae** that is a hallmark of Basidiomycota and Ascomycota. Members of this group are obligate symbionts; they form mycorrhizal associations intracellularly within the roots of the vast majority of herbaceous plants and tropical trees. This is an example of **mutualism** because the fungus and host plant both benefit. The fungal symbiont receives carbohydrates from the plant in exchange for functioning as an extended root system and improving mineral uptake by plant roots. They are obligate symbionts (need to be in a relationship with a plan) because no one has been successful in growing glomeromycotan fungi separately from their symbiotic plant host (as of 2012).

The oldest fossil fungi so far known are **chytridiomycota** that were found in northern Russia and belonged to the Vendian period. Because they are so ancient, these chytrid fungi may paint a good picture of what the ancestors of fungi were like. Most are found in freshwater or wet soils. In fact, they are dependent on the presence of some source of water to survive. Most are parasites of algae and animals or live on organic debris as saprobes, organisms that digest decaying organic matter. A few species cause plant disease. One species, *Batrachochytrium dendrobatidis*, has been shown to cause disease in frogs and amphibians.

Microsporidia were re-classified from protozoa. They are widely distributed in nature with over 1200 species characterized. All are obligate, spore-forming, intracellular parasites (meaning they have to be parasitic to survive) and they invade vertebrates and invertebrates. A characteristic feature is the **polar tube** or **polar filament** found in the spore used to infiltrate host cells. At least 15 species of microsporidia have been reported to infect humans. Microsporidia infection in humans, microsporidiosis, is normally found in patients with compromised immune systems, especially those who have HIV or have undergone organ transplants.