Workshop on Kingdom Fungi
by Dana Krempels

Introduction
Kingdom Fungi is an ostensibly monophyletic assemblage of ecologically important organisms that not only perform the vital function of decomposition, but also engage in a wide variety of symbiotic relationships with other species. Although once thought to be related to plants, fungi are now known to share a more recent common ancestor with animals than with plants. Several characteristics set fungi apart from all other organisms, as you have learned in lecture.

In today's workshop, your goals will be to
1. Understand the general terminology associated with fungi, their structure and function.
2. Understand the general life cycle of the fungi, and how this life cycle is similar and different in each of the major fungal taxa.
3. Consider the important ecological roles various fungi play as decomposers and as symbionts in a wide array of symbiotic relationships.

I. Structure and Function of Fungi: Terminology
Discuss the precise meanings of the following terms as they relate to fungi.

A. Anatomy
1. mycelium - the body of the fungus, usually composed of haploid hyphae
2. thallus - the body of the fungus, including fruiting bodies, etc.
3. hypha (pl. hyphae) - threadlike structures of which the mycelium is composed
4. haustoria - specialized hyphae used by parasitic fungi to invade host cells.
5. coenocytic - literally "shared cell": a single mass of cytoplasm with multiple nuclei not separated by plasma membranes
6. septum (pl. septa) - a wall within the hyphae, separating the cytoplasm into compartments.
7. chitin - a structural polysaccharide providing the primary structural support in fungal cell walls.
8. mold - rapidly growing, hyphal form of a fungus that is reproducing via asexual spores.
9. yeast - single-celled form of a fungus, usually found in a moist medium, and reproducing asexually by budding.
2. saprobe - organism that digests nutrients extracellularly, and then absorbs the digestive breakdown products through the cell membrane.

B. Life Cycle
1. sporangium - structure within which spores are produced (via mitosis for asexual spores; via meiosis for sexual spores)
2. conidium (pl. conidia) - asexual spores produced by the Ascomycota (and the "Fungi Imperfecti") via mitosis and budding from a conidiophore.
3. "+" and "-" mating types - complementary mating types of fungal hyphae (analogous to male and female, though neither + nor - is male nor female)
3. plasmogamy - the union of cytoplasm without fusion of cell nuclei.
4. karyogamy - the fusion of two haploid nuclei (equivalent to fertilization)
5. dikaryotic - cytoplasm containing multiple, haploid nuclei from two different mating types
6. fruiting body - the "mushroom" formed by dikaryotic hyphae
C. Taxonomy

1. CHYTRIDIOMYCOTA
   a. What characteristics to the Chytridiomycota share with more derived fungi?
      Nucleic acids and proteins sequences of chytrids indicate monophyly with fungi.
      Metabolic and enzymatic pathways similar to those in other fungi.

   b. What characteristics do Chytrids exhibit that are NOT FOUND in other fungi?
      Flagellated zoospores (gametes) (Flagella not found in any other fungi)
      Cellulose in the cell walls (not found in any other fungi)

   c. Besides the other fungi, with what other major group are the chytrids believed to share an
      evolutionary affinity?
      Possibly the Chromista (a.k.a. Stramenopila), with which they share some
      primitive characters.

2. ZYGOMYCOTA
   a. What is the common name of Phylum Zygomycota? Can you think of a familiar example?
      Black Bread Molds
      example: uhhhhhh....black bread mold? (Rhizopus)
   b. In the Zygomycota, describe each of the following, and list its ploidy (haploid, diploid
      or dikaryotic):
      i. mycelium: haploid; consists of multiple, branching hyphae growing through
         substrate
      ii. zygosporangium: dikaryotic; appears as a tough, spiny ball that is
         environmentally resistant and long-lasting.
      iii. zygote: diploid cell formed by the karyogamy of nuclei from + and - hyphae.
      iv. zygospore: haploid; formed via meiosis of the zygote. Each has the capacity to
         germinate and develop into a new haploid mycelium.

3. ASCOMYCOTA
   a. What is the common name of Phylum Ascomycota? Can you think of a familiar example?
      The Sac Fungi
      examples: Edible Morel, Baker's yeast, truffles (not the chocolate kind)
   b. In the Ascomycota, describe each of the following, and list its ploidy (haploid, diploid
      or dikaryotic):
      i. mycelium: haploid; consists of multiple, branching hyphae growing through
         substrate
      ii. ascocarp: solid mass of dikaryotic hyphae that forms the typical ascomycete
         "mushroom"-like structure above ground (or sometimes below, as in the case of
         truffles.
      iii. ascus: specialized dikaryotic cells that will undergo karyogamy to become
         diploid, and then undergo meiosis to produce...
      iv. ascospore: the product of meiosis in the ascus. Ascospores actually undergo a
         second mitotic division after meiosis, to produce eight ascospores per ascus. These are
         arranged in the order in which the mitotic spindle was facing, and are useful in genetic
         studies of mitosis and meiosis.

4. BASIDIOMYCOTA
   a. What is the common name of Phylum Basidiomycota? Can you think of a familiar
      example? The Club Fungi. examples: just about all the most common
      "mushrooms" you know!
b. In the Basidiomycota, describe each of the following, and *list its ploidy* (haploid, diploid or dikaryotic):

i. mycelium: haploid; consists of multiple, branching hyphae growing through substrate
ii. basidiocarp: the fruiting body, consisting of dikaryotic hyphae.

iii. basidium: specialized dikaryotic cells that will undergo karyogamy to become diploid, and then undergo meiosis to produce...

iv. basidiospore: the haploid spore, a product of meiosis in the basidium.

II. Fungal Life Cycles

The diagram below shows a generalized fungus life cycle. Study this overview, and note the ploidy of each life cycle stage. Next, use the three template life cycle on the following pages to fill in the names and ploidies of every similar life cycle stage in the (1) Zygomycota, (2) Ascomycota and (3) Basidiomycota.

1. Is the life cycle diagrammed above sexual or asexual? How can you tell?
   Sexual. There is genetic recombination in the step between diploid cell and new, haploid spores.

2. If the generalized fungus above were to engage in asexual reproduction, where on the life cycle diagram would this occur? Draw it into the diagram, indicating the ploidy of all relevant structures. (Draw a circle from haploid hyphae to "sporangium" inside which mitosis occurs to produce genetically identical, asexual spores. These are released and grow into hyphae identical to the original parent hyphae.)
3. Which of the major fungal taxa do reproduce via asexual spores? Which do not?
Below is a diagram similar to the one on the previous page, but with three major life cycle stages replaced by "A", "B" and "C".

**Zygomycota, Ascomycota:** yes. **Basidiomycota:** no

4. In the **Zygomycota**:
   - What is the name of A? - **zygosporangium**
   - What is its ploidy? - **dikaryotic, then diploid**
   - What is the name of B? - **zygosporangium**
   - What is its ploidy? - **dikaryotic**
   - What is the name of C? - **zygote**
   - What is its ploidy? - **diploid**
   - What are the spores called? **zygospores**
   - What are their ploidy? **haploid**

5. In the **Ascomycota**:
   - What is the name of A? - **ascocarp**
   - What is its ploidy? - **dikaryotic**
   - What is the name of B? - **ascus**
   - What is its ploidy? - **dikaryotic**
   - What is the name of C? - **ascus**
   - What is its ploidy? - **diploid**
   - What are the spores called? **ascospores**
   - What are their ploidy? **haploid**

6. In the **Basidiomycota**:
   - What is the name of A? - **basidiocarp**
   - What is its ploidy? - **dikaryotic**
What is the name of B? - **basidium**
What is its ploidy? - **dikaryotic**
What is the name of C? - **basidium**
What is its ploidy? - **diploid**
What are the spores called? - **basidiospores**
What are their ploidy? - **haploid**

7. What do you think is the evolutionary significance of the similarity of life cycles across the three fungal taxa?

*Strong indication of common ancestry and monophyly of these taxa.*

### III. Fungi in Symbiotic Relationships

Symbiosis (literally "living together") occurs when two species maintain a close ecological association. There are many different types of symbiosis, each defined by the effect of the relationship on each of the participating populations. Using standard symbiosis shorthand, we will assign a population a "+" if it benefits from a particular relationship, a "-" if it is harmed by the relationship, and a "0" if it is not affected by the relationship. In so doing, we can construct a grid of possible symbiotic relationships, as shown below.

Discuss each type of symbiosis, and then try to name a fungal association that fits into that category. Be sure to note whether the fungal symbiont is population A or population B, and whether it is parasite, host, pathogen, prey item, predator, or other appropriate term. There may be more than one fungal association in any given category, and there may be none in some of the categories. It's up to you to recall them!

<table>
<thead>
<tr>
<th>type of interaction</th>
<th>pop'n A</th>
<th>pop'n B</th>
<th>nature of effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>mutualism</td>
<td>+</td>
<td>+</td>
<td>obligatory; both populations benefit</td>
</tr>
<tr>
<td>EXAMPLES:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>protocooperation</td>
<td>+</td>
<td>+</td>
<td>NOT obligatory; both pop'ns benefit</td>
</tr>
<tr>
<td>EXAMPLES:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>competition</td>
<td>-</td>
<td>-</td>
<td>populations inhibit one another</td>
</tr>
<tr>
<td>EXAMPLES:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>neutralism</td>
<td>0</td>
<td>0</td>
<td>populations don't affect one another</td>
</tr>
<tr>
<td>EXAMPLES:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>predation</td>
<td>+</td>
<td>-</td>
<td>predator (A) kills &amp; consumes prey (B)</td>
</tr>
<tr>
<td>EXAMPLES:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>parasitism</td>
<td>+</td>
<td>-</td>
<td>parasite (A) exploits the host (B), but does not kill it outright</td>
</tr>
<tr>
<td>EXAMPLES:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>parasitoidism</td>
<td>+</td>
<td>-</td>
<td>parasitoid (A) eventually kills host (B)</td>
</tr>
</tbody>
</table>


IV. Discussion Questions

1. In what ways might a broad-spectrum fungicide (i.e., one that kills all fungi) applied to an agricultural plant crop be harmful to the crop?
   - Mycorrhizae will be killed, and plants thus robbed of their essential symbionts.
   - Predatory and competitive fungi that keep plant pathogens in check will be removed.
   - Decomposition of organic matter in the soil will be reduced.

2. Humans have been able to obtain many different medicines (such as antibiotics) from fungi. Of what possible use to the fungi are these compounds?
   - They deter fungivores!

3. Just about everyone knows that certain species of mushrooms can be hallucinogenic. Of what possible utility to the fungus is such a property?
   - It's POISON. Duh. Those fungi are trying to tell you something. While you're tripping, your liver is melting. Again, this is a fungivore-deterrent. At least it deters the smarter fungivores...

4. The American Chestnut Tree, which once made up more than 25% of North American hardwood forests, were killed off by a deadly fungal blight that does not affect the closely related Asian Chestnut Tree. It is believed that the fungus was accidentally imported with Asian Chestnut trees imported as ornamentals. Why do you suppose the fungus affects only the North American trees?
   - The Asian trees have co-evolved with the fungus for perhaps millions of years, and have been selected for resistance. The North American trees have not undergone such selection, and their genome didn't contain anything that conferred resistance when the pathogen arrived.

   What does this tell you about the importance of careful control of imported species?
   - They can be extremely dangerous to ecosystems which have not had exposure to them, and whose inhabitants might not have any form of genetic resistance to them.

   Do you think that such accidental importation of pathogens (of plants, animals, etc.) will become more frequent or more rare in the future? Why?
   - Probably more common with global economy becoming a realized goal. It is likely that importation restrictions will be capricious at best, with economic gain being more important than ecological safety.

5. If fungi were to suffer a massive, global, multi-species extinction, what do you think the effect on various ecosystems would be? Explain in some detail, using specific examples.
   - Use examples of decomposition, mycorrhizae, etc.