BIOL 1010 Introduction to Biology: The Evolution and Diversity of Life. Spring 2011 Sections A & B

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Fungi – more than just 'shrooms

We are used to the mushrooms we buy in the grocery store to eat, and even the wild ones in our yards, many of which are poisonous or totally inedible, but fungi are all around us doing all sorts of important jobs. And there’s even ones doing some nasty things to us as well.

As usual Wikipedia has a great article: http://en.wikipedia.org/wiki/Fungus
Remember – they’re a sister group to the animals . . .

All molecular analyses place them way closer to the animals than the plants, even though mycology (the science of fungi) is often taught in botany courses and texts. So, if they are more of an animal than a plant . . .

Just how much of a vegetarian are you while munching on your Portabella burger sandwich?

http://tolweb.org/Eukaryotes/3
There are ten groups within the fungi. We’ll visit many of these today. ToL has a great introductory article on them. There’s more than 70,000 species, and could be as many as 1.5 million! http://tolweb.org/Fungi/2377
Fungal diversity

- They live nearly everywhere, and...
- Range in size from microscopic to 2,200 acres (a single 605 ton, 2,400 year old, mushroom clone in Oregon State!)
  http://en.wikipedia.org/wiki/Armillaria_ostoyae
- They include mushrooms, rusts, smuts, puffballs, truffles, morels, molds, yeasts and a bunch of less well known critters.
- Some benefit humans, some hurt humans, many hurt other organisms; however, many are vitally...
- Important in nearly all ecosystems, being molecular garbage disposals (along with Bacteria, Archaea, and protists).
- http://www.botany.hawaii.edu/faculty/wong/BOT135/Lect03_a.htm and http://www.emc.maricopa.edu/faculty/farabee/BIOBK/BioBookDiversity_4.html have great reviews of fungal diversity.
Here's a tiny one.

Powdery mildew and its reproductive structures.
And here's a huge one . . .

At least the part we can see. The underground part of this guy (Amillaria gallica) extends for almost 40 acres in Michigan.
And they even come unicellular – this is the common baker’s yeast \textit{(Saccharomyces cerevisiae)} in the process of reproducing by budding.
Here's a bunch of 'em, mainly 'shrooms, set to the theme from the 2008 Beijing Olympics.

http://www.youtube.com/watch?v=06fMNvwmZUY
Animals are similar in many ways, even though fungi don’t generally move about . . .

- Both are heterotrophs.
- Both manufacture hydrolytic enzymes that can break down biopolymers, which can be absorbed for nutrition, except animals do it in digestive organs like stomachs, whereas fungi do it extracellularly.
- Fungal cell walls are composed of chitin, like the exoskeleton of some animals (not cellulose, like plants).
- Both store carbohydrates as glycogen.
However, fungal sex is a bit weird.

* For one thing it only occurs when conditions are just right (wait, isn’t that just like in humans)! However, . . .

* Some fungi can have sex with themselves, others with others, and in many, the zygote is the only diploid cell.

* Meiosis occurs in the zygote to yield haploid nuclei, which subsequently divide mitotically as the fungus grows larger and larger.

* Some fungi remain in this haploid state most of their life. Prior to mating all fungi release pheromones.

* In others, two individuals fuse to form a dikaryotic stage in which each cell retains two separate nuclei. This doesn’t occur in any other kingdom of life.
Fungal body forms

- Most fungi are multicellular, but the...
- Yeasts are unicellular.
- Some species can even switch between the two body forms.
- Hyphae – microscopic filaments that make up the bulk of a multicellular fungus. These are often underground.
- Mycelium – a mass of aggregated hyphae that may form visible strands. These surround and impregnate the food source.
- Spores – microscopic reproductive cells produced by the (usually) visible reproductive structure. Spores are released and germinate in suitable habitats creating new feeding hyphae and mycelium.
- Conidia – asexual spores formed by hyphae in many species.
- Fruiting body – specialized sexual spore-producing organ in other species, e.g. mushrooms, puffballs, and truffles.
Here’s a bunch of conidia being produced by a mold.
And here's the more complex body form of a typical mushroom.
We’ll concentrate on four of those ten ToL clades.
Classification . . .

These four traditional phyla were originally based on sexual structures, but DNA supports them as well:

- **Chytridiomycetes** – the simplest, flagellated asexual and sexual spores.
- **Zygomycetes** – thick-walled sexual zygospores.
- **Ascomycetes** – sexual spores in sacs.
- **Basidiomycetes** – sexual spores from ‘clubs.’

Plus . . . **Deuteromycetes** – the “imperfect fungi” with no known sexual phase, includes many molds.

Even molecular data has a hard time sorting out the exact relationships, but clearly the Ascomycetes and Basidiomycetes are sister clades.
### Table 21.1 Four Groups of Fungi

<table>
<thead>
<tr>
<th>Group</th>
<th>Sexual Spore Type</th>
<th>Feeding Hyphae</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chytridiomycetes</td>
<td>Flagellated zoospore</td>
<td>Variable. Some species do not have true hyphae; others produce haploid or diploid hyphae.</td>
</tr>
<tr>
<td>Zygomycetes</td>
<td>Diploid zygospore formed from union of two cells</td>
<td>Haploid, without cross walls separating nuclei</td>
</tr>
<tr>
<td>Ascomycetes</td>
<td>Haploid ascospore formed in ascus after meiosis</td>
<td>Usually haploid, with cross walls separating nuclei</td>
</tr>
<tr>
<td>Basidiomycetes</td>
<td>Haploid basidiospore formed on basidium after meiosis</td>
<td>Usually dikaryotic, with cross walls separating pairs of nuclei</td>
</tr>
</tbody>
</table>
In turn, the Chytrids . . .

- Are ‘primitive,’ perhaps protist, fungi. And they . . .
- May provide a glimpse of what the earliest fungi were like. Their . . .
- Body form varies from single cells to slender hyphae. They . . .
- Differ from other fungi in producing zoospores — motile spores — each with an individual flagellum.
- They are powerful decomposers. And along with Bacteria and Archaea digest cellulose in ruminant digestive tracts. But they also . . .
- Contribute to the ongoing worldwide amphibian decline by causing a lethal skin infection.
Here are some pic’s of chytrids.

* The top panel is the hyphae and sporangia of *Allomyces*.

* The lower panel are the zoospores from *Blastocladeilla*.

http://en.wikipedia.org/wiki/Chytridiomycota
And here’s chytrid that kills frogs.
Next, the Zygomycetes...

- 900 or so species, but this is only about 1% of all identified fungi, and they all grow really fast.
- Yet they include many familiar critters.
- Such as the black bread mold (*Rhizopus stolonifer*).
- They are also all over decaying stuff in the soil.
- And many are insect parasites, others even colonize cow patties! Plus, the very important...
- Mycorrhizae that symbiotically live in and on plant roots, greatly increasing surface area for absorption. Now classified as Glomeromycota.

Here’s one parasitizing a fly. Entomophthora muscae invades a fly killing it within days, then bursts forth with a shower of spores.
This is the cow poop one.

No, not Psilocybin, that’s a Basidiomycota. This one, Pilobous, explodes spores that need to go through a cow before they’ll germinate!
Zygomycetes have a distinctive sex life.

* Two hyphae fuse in a ‘yoke’ (from the Greek zygon).
* Their haploid nuclei merge to form a diploid zygospore with a spiny, dark wall.
* Diploid zygospore nuclei undergo meiosis . . .
* To form haploid hyphae, which emerge.
* The hyphae immediately produce a spore sac.
* Which bursts releasing haploid spores.
* Each spore gives rise to new haploid mycelium.
* But asexual spores (conidia) are much more common than the sexual zygospores.
Here's the diagram.
And next the Ascomycetes . . .

- This is the largest group of fungi with more than 30,000 known species.
- Many decompose plant matter, and others form symbiotic relationships with plants. A few are even carnivores!
- Many are our foes, e.g. those that cause Dutch elm disease, chestnut blight, athlete’s foot, and vaginal Candidiasis.
- But others have been very useful, e.g. Penicillium – source of our first antibiotic, and the source of the robust flavor of many cheeses like Roquefort. And . . .
- Saccaromyces – used in baking and beer and wine making.
- And Aspergillus oryzae ferments soy to make soy sauce.
- And Neurospora crassa, which has been an invaluable laboratory model organism. Plus some are really yummy . . .
Here's a carnivorous one.

Arthrobotrys anchonia attacking a nematode worm. It releases a sweet odor that the worm can't resist, only to be eaten from within.
And a really yummy one – a morel.

Each ‘pit’ in the cap produces thousands of asci, each containing eight ascospores.
And the great lab ‘rat’ *Neurospora crassa*. 

Prof. Dr. Peter Ruoff, University of Stavanger
Here's another you may not know about.

This is a *Coccidiodes immitis* spherule bursting out hundreds of spores, and it causes Valley Fever.
Claviceps purpurea, ergot, infecting wheat

In the Middle ages this caused “St. Anthony's Fire” and in 1938 Albert Hofmann synthesized LSD (lysergic acid diethylamide) from ergot alkaloids.
Ascomycetes sex (and asexuality) is incredibly effective.

- They can produce an enormous numbers of asexual spores.
- Plus, they can use sexual reproduction, which involves the fusion of two compatible mating types' hyphae.
- However, the individual nuclei of the two parents do not immediately merge – they form a dikaryotic cell.
- The two nuclei undergo mitosis separately.
- A fruiting body contains a fertile layer of dikaryotic cells.
- Eventually the two nuclei in each cell fuse forming a diploid zygote.
- The zygote immediately undergoes meiosis to form four haploid nuclei. Each of which usually . . .
- Undergoes mitosis once to form eight haploid ascospores (from the Ancient Greek askos for sac).
- Ascospores disperse and germinate to form new haploid individuals.
That's a lot; how about a diagram?
And finally the Basidiomycetes.

* One third of all described fungi are Basidiomycetes. These are the familiar ‘club’ fungi. The 30,000 some species include . . .

* Mushrooms, toadstools, puffballs, stinkhorns, shelf fungi, bird’s nest fungi, wood brackets . . .

* Many are edible, but . . .

* Others are deadly, and . . .

* Some are hallucinogenic (here’s those Psilocybins)!

* Others are plant pathogens, the smuts and rusts.

* Many are decomposers of wood.

* http://en.wikipedia.org/wiki/Basidiomycetes
Here’s some examples.

a. Puffballs (Lycoperdon)

b. Stinkhorns (Phallus) and, yes, they have that name because they look like one.

c. Turkey tail brackets (Trametes).

d. Bird’s nests (Order Nidulariales)
And here’s a nice pictorial video of many of the Basidomycetes (plus some morels and truffles), especially the edible ones: http://www.youtube.com/watch?v=W-bMjNWdulo
Basidiomycetes prefer sex (who doesn’t).

- They can reproduce asexually. However, the...
- Sexual phase is usually far more prominent. The...
- Fusion of two haploid hyphae create a dikaryotic mycelium.
- The mycelium grows in its food source and then eventually produces mushrooms when the conditions are right.
- Basidia – dikaryotic club-shaped cells – line mushroom gills.
- Inside each basidium, the haploid nuclei fuse to form a diploid zygote. The...
- Zygote undergoes meiosis to yield four haploid nuclei.
- Each nucleus migrates into a basidiopsore.
- After dispersal, germination will form new haploid hypha.

Thursday, March 17, 2011
Here's the diagram.
Fungi interact with other organisms in many symbiotic relationships.

- For instance the mycorrhizae already mentioned ...
- Form a very tight association between the fungal hyphae and the plants' roots.
- Plants and fungi have evolved together for around 450 million years, from when plants first moved onto land.
- Over 80% of all land plants have mycorrhizae.
- The relationship benefits both partners.
- The plant obtains water and minerals from hyphae.
- And the fungi gains carbohydrates from the plant's photosynthetic capabilities.
- Some types of mycorrhizae hyphae wrap around cells while other types pierce cells. Either way, it's a good thing.
Here's some pic's of mycorrhizae.

a. Roots of a lodgepole pine seedling with fruiting body.
b. Photomicrograph of hyphae around a root tip.
c. The type of mycorrhizae that go inside the root cells.
Another cool example of a fungal mutualism is the...

* Leaf-cutter ants of Central and South America and the southern U.S.A. cultivate *Lepiota* in special underground chambers.

* The ants eat the hyphae. And the...

* Fungi have a home with plenty of food in the form of a saliva/leaf paste provided by the ants. Furthermore, the...

* Ants have symbiotic *Streptomyces* bacteria that makes an antibiotic that kills off competing fungi. Isn’t that cool!
Lichens are another example of a symbiosis.

* They are a dual organism, consisting of . . .
* A fungus that harbors green algae (and/or much less often Cyanobacteria) inside it. The . . .
* Photosynthetic partner contributes food.
* The fungus absorbs essential minerals. Both benefit.
* Lichens are very important ecologically as they break rock down into soil, plus many also harbor nitrogen-fixing Cyanobacteria.
* They can survive extreme environmental conditions.
* Lichens are used to monitor air quality because they won't grow in polluted areas — they can't excrete toxins, which eventually derails photosynthesis.
Here's some lichen pic's . . .

That show their anatomy and form. The hyphae tightly wrap around their companion algal cells.
That’s enough about Fungi for now.

Next time we’ll begin a survey of their sister clade, the Animal kingdom, with the Invertebrates.