Fungi & Animals: You and the humble mushroom aren’t so different

Growth structures
Reproductive structures
Dispersal
Where do Fungi belong?

- DNA synapomorphies unite Animals & Fungi
- Some morphological synapomorphies
  - Both synthesize **chitin**
  - Both have gametes with a **single, posterior flagella** - Opisthokonts
  - Use **same** energy storage molecule: **glycogen**
History & Diversity

• ~ 1.65 million species
  – Only 80,000 have been described.
  – Have yet to identify reproductive structures in most!
  – ~ 1000 new species each year

• Probably diverged from Animals ~ 700 Mya (1060 – 760)

• Oldest fossil 460 Mya
(b) Top view of lichens on a rock
Phylogeny & Ecology

- **Chytrids**: disease
- **Zygomycetes**: “Yoked hyphae” form tough zygosporangium; molds & some animal parasites
- **Glomeromycetes**: Mutualistic mycorrhizal association with plants
- **Ascomycetes**: Yeasts -> elaborate forest fungi (cups, morels); plant pathogens; lichens
- **Basidiomycetes**: Yummy; psychotropic; deadly
Adaptations of Fungi

• They can decompose both cellulose & lignin
• Cells walls are perforated, which allow flow of nuclei, nutrients, organelles
• Feeding/absorptive structures (mycelium) can add up to 1 km of hyphae per day
• Tremendous S.A., so digestion & absorption can occur rapidly
Fungi have special ecological roles

- They decompose live & dead organic matter
  - The ONLY group that can digest both cellulose & lignin
- Mutualisms with Cyanobacteria: Form lichens - make inorganic components of soil
- Mutualisms with Animals: Leafcutter ants
- Mutualisms with Land Plants (Embryophytes): EMF/AMF
- Mutualisms with us: Bread, Cheese, Beer!!
- Parasites and saprophytes on our beloved angiosperms (cereals) & gymnosperms
  - Corn smut
  - Rye ergot
  - Dutch elm disease
Amazing external digestion

• They’ve given up on ingestion
• Instead, they secrete digestive enzymes outside their bodies & into their food (extracellular digestion)
  – Lignin peroxidase: enzymatic combustion
    • Releases energy that cannot be harnessed
  – Cellulase: cuts cellulose into glucose - an awesome source of food
    • This energy is useful
Growth forms

- Single celled: yeasts
- Multicellular: mycelia
  - **Hyphae**: finger-like cellular projections that invade live & dead organic matter
  - **Mycelium**: Entire branching network of hyphae; specialized for absorption (huge S.A.)
- Mycelium continuously grows & dies off
Mutualisms: Mycorrhizal Fungi

• **Observations:**
  – Plants grow faster & larger due to associations with fungi
  – The range of conditions that *permit* growth is larger if fungi are around

• Perhaps the fungi are benefiting the plant
Mycorrhizal Fungi

- **Observations:**
  - **EMF:** found on temperate forest tree species
  - **AMF:** found in 80% of all land plant species.
    - Common in grasslands & warm tropical forests
  - In all cases, *mycorrhiza touch root cells*
Hypothesis on mutualisms

• Are these associations **mutually** beneficial?

• $H_1$: Plant provides *organic* nutrients (C) to fungus. Fungi provides *inorganic* (N & P) to plant.

• Exp: Follow **labeled** nutrients

**Experiment**

**Experimental setup:**

- **Labeled carbon treatment:** Plant leaves are exposed to radioactive CO$_2$. Mycorrhizal fungi present.
- **Labeled carbon control:** Plant leaves are exposed to radioactive CO$_2$. Mycorrhizal fungi absent.
- **Labeled P or N treatment:** Plant roots are exposed to radioactive P or heavy isotope of N. Mycorrhizal fungi present.
- **Labeled P or N control:** Plant roots are exposed to radioactive P or heavy isotope of N. Mycorrhizal fungi absent.
Do nutrients flow both ways?

- Where do you expect to find labeled **Carbon** if plants are sharing with fungi?
- Where do you expect to find labeled **N & P**, if fungi are sharing with plants?

**Experiment**

**Results:**

- **Labeled carbon treatment:** Up to 20% of labeled carbon taken up by plant is transferred to mycorrhizal fungus.
- **Labeled carbon control:** Little to no labeled carbon is found in soil surrounding plant roots.
- **Labeled P or N treatment:** Large amount of labeled P or N is found in host plant.
- **Labeled P or N control:** Little labeled P or N is found in host plant.

**Conclusion:** The relationship between plants and mycorrhizal fungi is mutualistic. Plants provide mycorrhizal fungi with carbohydrates. Mycorrhizal fungi supply host plants with nutrients.
Lichens - Ascomycetes

- A mutualism: Did you hear about Alice Algae and Freddie Fungus?
  - Cyanobacteria or Green alga makes sugars; fungus absorbs $H_2O$ & inorganic nutrients
- Then they share!
Increase rates of **Carbon cycling**

- Recall **lignin peroxidase**. Without fungi, we would suffocate beneath mountains of undigested plant tissue.
- Fungi devour the corpses of the world.
Parasitism on plants: Corn Smut

- Basidiomycete hyphae infection
  - Sounds terrible: decreases crop yields
  - Tastes *delicious*: Huitlacoche “Raven’s excrement” is made of the spore filled reproductive structures
Mutualisms with Animals

• Leafcutter ants grow fungal gardens
• Ants win
  – Feed the fungus to their young, ravenous brood
• Fungus wins
  – In return, fungal spores are dispersed & propagated by the ants
Bread, cheese, beer!!
Clicker Q

• How would you classify Fungi’s method of acquiring Carbon compounds & making ATP?
  1. Chemoautotrophs
  2. Photoautotrophs
  3. Organoheterotrophs (organic)
  4. Lithoheterotrophs (inorganic)
Clicker Q

• With what other Eukaryote group do they share this mode of metabolism?

1. Green Algae
2. Animals
3. Angiosperms
General life cycle

- **Heterokaryotic (dikaryotic) stage**: unfused nuclei \((n + n)\); growth without fertilization

The same sequence of events is common to most fungal life cycles.
General life cycle

• Haploid spores are **dispersal** structures
• Hyphae of unrelated fungi happily *attract* each other
• *Cells fuse* (*plasmogamy*), &
• *Grow in heterokaryotic stage* (for minutes, weeks, years, centuries) until environmental cues cause *nuclei* to fuse (*karyogamy*).
• **Meiosis** and spore production follows.
Reproductive Structures

- **Chytrids**: swimming spores and gametes
- **Zygomycetes**: Spores in tough, **zygosporangium**
- **Basidiomycetes**: Spores in **basidia** ("little pedestals") - synapomorphy defines the group
- **Ascomycetes**: Spores in **asci** ("sacs") - synapomorphy defines the group
Basidiomycete life cycle

(d) Basidiomycota have reproductive structures with many spore-producing basidia.
Zygomycete life cycle

(c) Zygomycota form yoked hyphae that produce a spore-forming structure (zygosporangium).
Ascomycete life cycle

(e) Ascomycota have reproductive structures with many spore-producing asci.
Do DNA phylogenies match?

- Chytrids are basal
- Chytridiomycota & Zygomycota (one EMF) are paraphyletic
- Glomeromycota (AMF) is monophyletic; sexual repro. Unknown
- Asco & Basidiomycota are monophyletic (EMF)
Clicker Q

• When considering all species of Fungi, what type of trait is “spores produced in basidia”?  
  1. Synapomorphy  
  2. Symplesiomorphy  
  3. Homoplasy