Topic 3: Fungi (Kingdom Fungi – Ch. 31)

KINGDOM FUNGI

A. General characteristics

- Fungi are diverse and widespread.
- Ten thousand species of fungi have been described, but it is estimated that there are actually up to 1.5 million species of fungi.
- Fungi play an important role in ecosystems, decomposing dead organisms, fallen leaves, feces, and other organic materials.
  - This decomposition recycles vital chemical elements back to the environment in forms other organisms can assimilate.
- Most plants depend on mutualistic fungi to help their roots absorb minerals and water from the soil.
- Humans have cultivated fungi for centuries for food, to produce antibiotics and other drugs, to make bread rise, and to ferment beer and wine
- Fungi play ecological diverse roles - they are decomposers (saprobes), parasites, and mutualistic symbionts.
  - Saprobic fungi absorb nutrients from nonliving organisms.
  - Parasitic fungi absorb nutrients from the cells of living hosts.
    - Some parasitic fungi, including some that infect humans and plants, are pathogenic.
    - Fungi cause 80% of plant diseases.
  - Mutualistic fungi also absorb nutrients from a host organism, but they reciprocate with functions that benefit their partner in some way.
- Fungi are a **monophyletic** group, and all fungi share certain key characteristics.

B. Morphology of Fungi

1. heterotrophs - digest food with secreted enzymes “exoenzymes” (external digestion)

2. have cell walls made of **chitin**

3. most are multicellular, with slender filamentous units called **hyphae** (Label the diagram below – Use Textbook figure 31.3)

Septate hyphae **Coenocytic hyphae**

hyphae may be divided into cells by crosswalls called **septa**; typically, cytoplasm flows through septa

- hyphae can form specialized structures for things such as feeding, and even for food capture

4. **Mycelium -** interwoven mat-like network of hyphae

   filaments can be packed tightly together (ex: mushroom)

   mycelia can be huge, but they usually escape notice because they are subterranean.

   visible parts usually reproductive structures – mushrooms, morels, etc.

5. **Haustoria** are specialized hyphae that penetrate cells (for feeding or other purposes)

6. Most furngi have **nuclear mitosis** (nuclear membrane remains intact during mitosis)

7. No motile stages for most (no swimming cells – lack cilia and flagella)

C. Fungal Reproduction

1. reproduce by spores

- sexual spores are **meiospores** (formed by meiosis)
- asexual spores are **mitospores** (formed by mitosis)

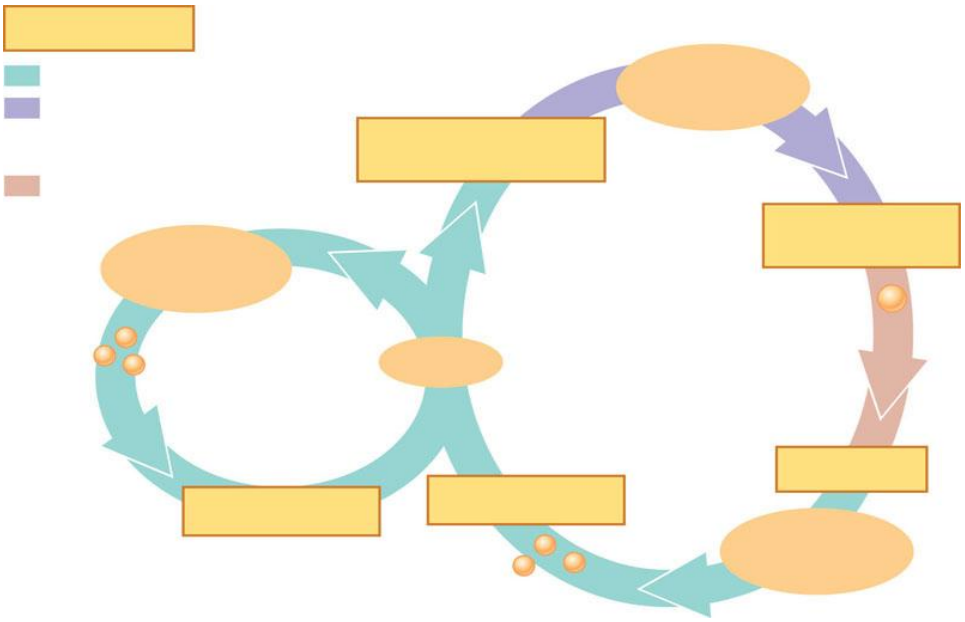
2. sexual reproduction for most by ***zygotic meiosis***, but sometimes in a weird way

- haploid phase predominates
- BUT, syngamy (fertilization) has 2 steps
  - **plasmogamy**: union of gamete cells
  - **karyogamy**: union of gamete nuclei

- some fungi do plasmogamy but delay karyogamy, forming cells that each have two separate haploid nuclei; these hyphae are called **dikaryotic**

- example of fungal life cycle with dikaryotic hyphae: mushroom
  - dikaryotic mycelium is major phase
  - only when mushroom is formed does karyogamy occur, followed by meiosis

Complete the life cycle to explain the generalized life cycle of fungi (use textbook Figure 31.5):



D. Fungal phylogeny

- Five phyla plus "imperfect fungi"
- phyla separated mainly by how meiospores are formed (how sexual reproduction done)

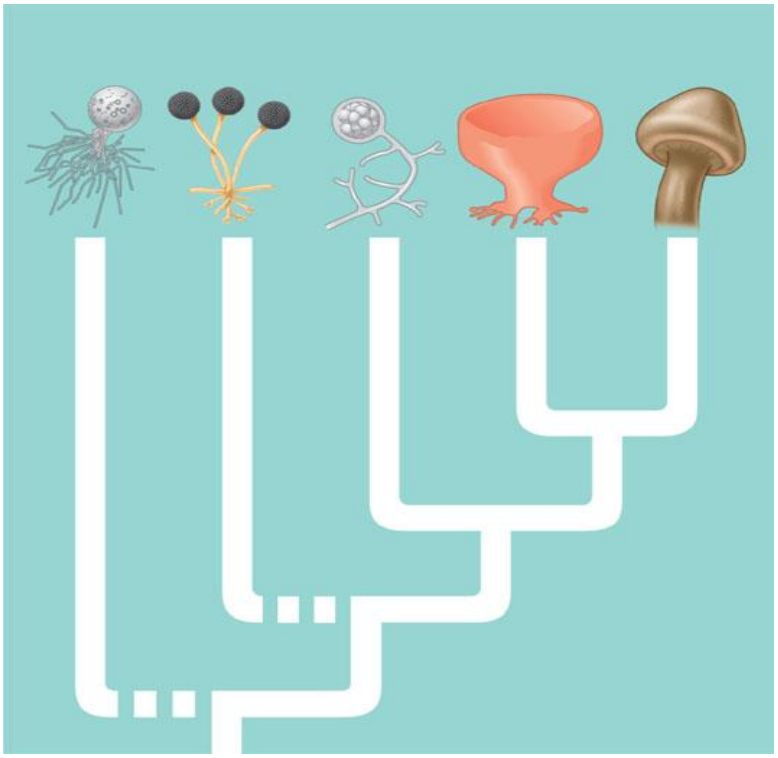
1. Phylum **Chytridiomycota** – chytrids
2. Phylum **Zygomycota** – zygomycetes

3. Phylum **Glomeromycota** – glomeromycetes
4. Phylum **Ascomycota** – ascomycetes; sac fungi
5. Phylum **Basidiomycota** – basidiomycetes; club fungi
6. imperfect fungi (also known as deuteromycetes)

- Kingdom Fungi forms a clade with Kingdom Animalia, choanoflagellates, and perhaps others
  - ***What Kingdom is Fungi a sister kingdom to ?***

- last common ancestor between Fungi and Animalia apparently about 670 million years ago (MYA)
- basal fungal group for Fungi appears to be Chytridiomycota, which is likely paraphyletic
- phylogeny of Zygomycota uncertain; likely paraphyletic, perhaps polyphyletic
- Glomeromycota is monophyletic, and also forms a clade with Ascomycota and Basidiomycota
- Ascomycota and Basidiomycota form a clade, and each is monophyletic itself
- Aside – for modern cladograms see the Tree of Life online: http://tolweb.org

Fill in the phyla names (Textbook Fig. 31.9)



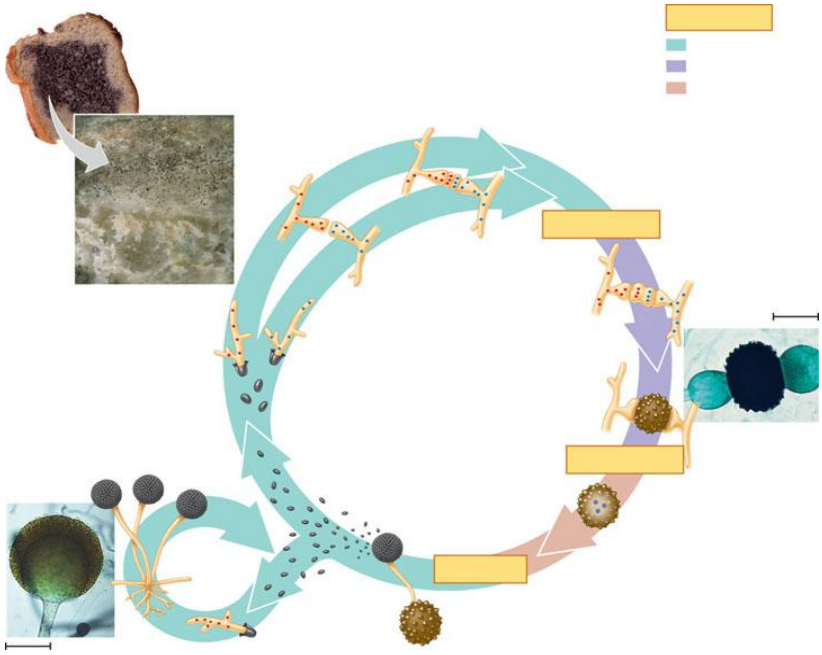
D.1. Phylum Chytridiomycota – chytrids

- apparently paraphyletic

- motile **zoospores** – only fungi with flagella (thus only fungi with true motility)
- primarily aquatic (rest of fungi are primarily terrestrial)
- likely either a **sister group** to other fungi or a **paraphyletic basal assemblage**
  - fossils resembling modern chytrids date back as far as about 400 MYA
  - chytrids may give us a good picture of what the ancestors of all fungi were like
- reproduction
  - both sexual and asexual
  - some have alternation of generations

D.2. Phylum Zygomycota – zygomycetes

- apparently paraphyletic
- hyphae lack septa, except in reproductive structures
- hyphae typically multinucleate
- no dikaryotic hyphae: plasmogamy and karyogamy together, followed by **zygosporangium** formation, then followed by meiosis when conditions are right
- sexual reproduction: meiospores made in **zygosporangia**
  - specialized, thick-coated microscopic structures that protect the diploid (zygotic) cells inside
  - contain one or more zygotic cells
  - considered "resting structures" because they are essentially dormant until an environmental signal of some sort sparks the zygotic cells to undergo meiosis, forming meiospores and breaking open the zygosporangium
- asexual reproduction
  - more commonly seen than sexual reproduction for this group
  - mitospore-forming **sporangia** on **sporangiophore** stalks
- ~1000 species known
- importance: includes many bread molds



D.3. Phylum Glomeromycota – glomeromycetes

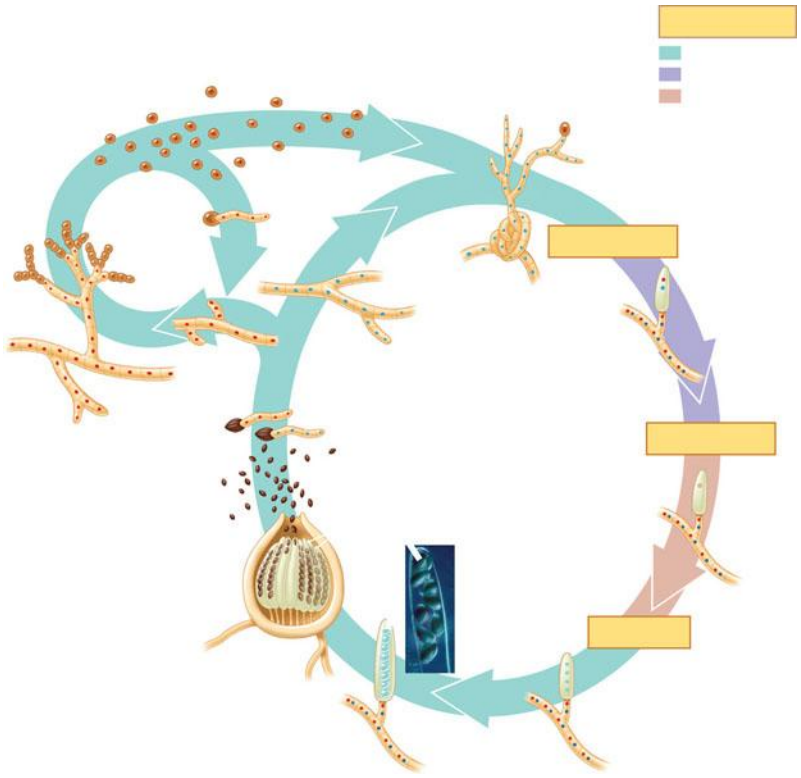
- monophyletic
- newly defined, previously thought to be zygomycetes
- ~160 known species
- important for mycorrhizal relationships with many plants
- **mycorrhizae**: association of fungus with plant root
    - a type of **mutualism** (relationship between 2 species where both benefit)
    - fungus extends into soil and aids in uptake of nutrients (P, Zn, Cu in particular) for plant
    - fungus obtains sugars from plant
    - very common, found with most plant roots – ~90% of plants have a mycorrhizal relationship with glomeromycetes
    - important in revegetation/reclamation of disturbed areas: if fungi not present, plants don't do well!
    - two types:
    - **endomycorrhizae**: (the kind that glomeromycetes make; sometimes called arbuscular mycorrhizae)
        - fungus penetrates into root cells
        - most common type of mycorrhizal relationship
        - only formed by glomeromycetes, but over 200,000 plant species involved
        - very general and probably have a long evolutionary history
    - **ectomycorrhizae**:
        - fungus surrounds but does not penetrate root cells
        - far fewer plants involved, usually a very specific relationship of one kind of fungus with one kind of plant
        - plants involved are often trees
        - fungi involved are mostly basidiomycetes, but some are ascomycetes

D.4. Phylum Ascomycota – ascomycetes; sac fungi

- monophyletic
- septate hyphae
- both dikaryotic hyphae and monokaryotic hyphae (in fact, some are polykaryotic)
- sexual reproduction:
    3. **ascus** – sac where meiospores are formed (plural: asci)
    4. asci are containing in fruiting body called an **ascoma** (plural ascomata) or ascocarp
    5. ascoma is made of dikaryotic hyphae and monokaryotic hyphae
- asexual reproduction
    6. very common in ascomycetes
    7. **conidiophores**: modified hyphae for making mitospores
    8. **conidia**: mitospores made by cells pinching off from cells at tips of conidiophores
- ~45,000 species known
- importance: includes morels, truffles, yeasts, fungal part of lichens, and many animal and plant pathogens
    - some ascomata are edible and highly prized by gourmets

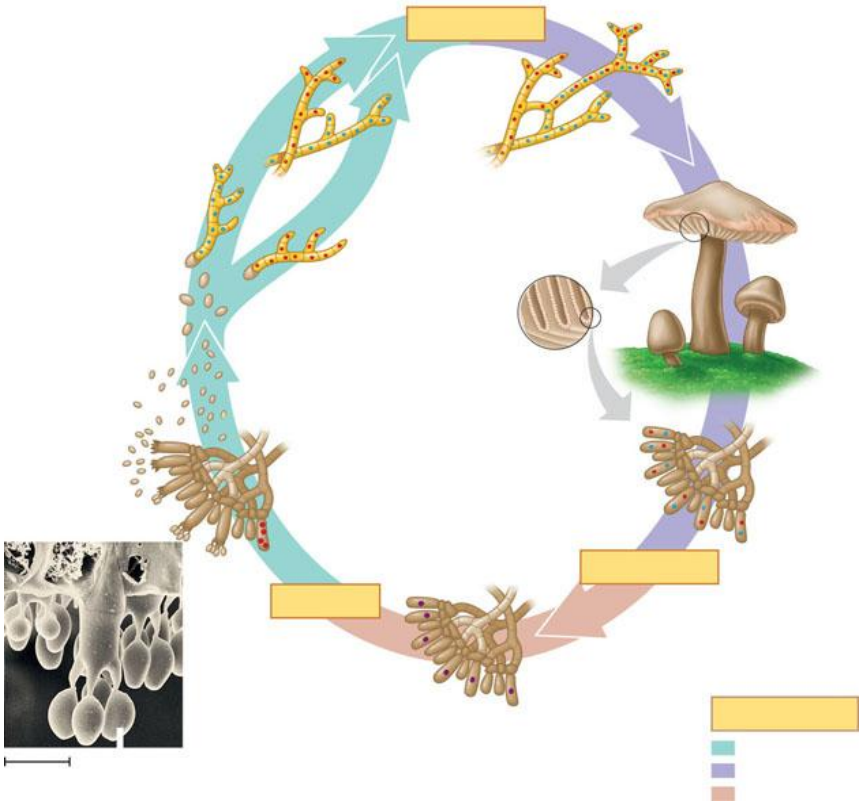
- truffles (worth up to $320/pound)
- morels

- yeasts – unicellular, ferment carbohydrates (actually yeasts in each fungal phylum, but most yeast are ascomycetes)
  - fermentation by yeasts useful for making alcoholic beverages and in baking; worth billions of dollars a year to industry
  - released CO_2 raises bread, carbonates beer and wine
  - released ethanol is the alcohol for beer and wine
  - *Saccharomyces cerevisiae* is an important lab organism
- **lichens** – mutualistic partnership between fungi and unicellular photosynthesizer (green alga or cyanobacteria)
  - fungus forms body and protects and directs photosynthesizer, obtains materials from partner
  - together, can colonize harsh environments (**pioneer organisms** – typically first organisms in an environment)
    - primary producers in harsh environments (base of food chains)
    - example, reindeer in arctic eat large amounts of lichens
  - some are pollution sensitive: used as bioindicators of air quality
  - about 40% of ascomycetes species are part of lichens
- pathogenic ascomycetes: examples
  - human yeast infections
  - Dutch elm disease
  - chestnut blight



D.5. Phylum Basidiomycota – basidiomycetes; club fungi

- monophyletic, and in a clade with Ascomycota
- septate hyphae
- both monokaryotic and dikaryotic hyphae; dikaryotic hyphae predominate in life of organism
- sexual reproduction:
  9. main form of reproduction for basidiomycetes is sexual reproduction
  10. **basidium** – club-shaped reproductive structure that produces meiospores (plural: basidia)
  11. basidia are contained in fruiting body called a **basidioma** (plural basidiomata) or basidiocarp
  12. basidioma is made of only dikaryotic hyphae
- asexual reproduction: usually do not make mitospores, but mycelium can become fragmented to form separate individuals
- ~22,000 species known
- importance: include mushrooms, puffballs, shelf fungi, etc., as well as many rusts and smuts
  - some basidioma are edible, some deadly poisonous, some hallucinogenic
  - sometimes form circle as fungus grows from initial point: “fairy ring”
  - pathogens of plants (smuts and rusts cause billions of dollars in damage to grain crops).
  - important decomposers (as are most fungi)



D. 6. imperfect fungi (also known as **deuteromycetes**)

- fungi that don't make meiospores (to our knowledge)
- reproduce only asexually (conidiophores, with conidia)
- not a true phylum but a temporary holding group
- group likely includes members of each fungal phylum, probably mostly ascomycetes
- ~17,000 species
- famous examples: *Penicillium* and the organism that causes of athlete's foot
- importance
    13. decomposers
    14. food rotters (can make toxins: aflatoxins in peanuts)
    15. food production (flavor cheeses: Roquefort, Bleu cheese)
    16. produce antibiotics (ex, penicillin from *Penicillium*) and other drugs (cyclosporin)
    17. plant and animal diseases (human examples: athlete's foot and ringworm)

E. Fungal ecology

- together with bacteria, fungi are the principle decomposers
- fungi are virtually the only organisms able to break down lignin in wood
- many cause diseases of plants and animals – blights, athlete's foot, yeast infections, etc.
- fungal diseases can be hard to treat (cells are much like human cells)
- many fungi are important in food production – yeast (bread, beer), cheeses, etc.
- other uses in drugs (antibiotics – penicillin, etc.), biochemical manufacturing, toxin remediation
- important mutualistic symbiotic relationships (lichens, mycorrhizae)

Fill in the following table and draw or explain the mode of reproduction in the different phyla of Fungi

Phylum	Features	Reproduction
Chytridiomycota		
Zygomycota		
Glomeromycota		

Ascomycota		
Basidiomycota		
Imperfect fungi		