KINGDOM FUNGI

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Biology 3a
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Fungi

• Mycology (mykes = mushroom; logia = study)
• Major decomposers of dead organic matter
  – Ecosystem: recycle nutrients
  – Homes: dry rot
  – Clothes: mildew
  – Food: mold spoilage
• Plant diseases
  – Rust, smut, potato blight
• Animal diseases
  – Ringworm, jock itch, athlete's foot, valley fever
• Commercially important
  – Yeast: bread, wine, beer
  – Other fungi: cheeses, soy sauce, antibiotics
Fungi

• Domain Eukarya
• Unicellular or “multicellular”
  – Unicellular: yeast
  – Multicellular: long filaments
    • Filamentous forms or molds
      – Some species exhibit life cycle with both forms
• Heterotrophic
• Cell wall usually chitin
Filamentous Fungal Growth

• **Hyphae** (*hyphe* = web; sing. *hypha*)
  – long, slender filaments grow around and into food source
  – Septa usually divide hyphae into cell-like compartments w/organelles
    • Some species have no septa, many nuclei (coenocytic)
    • Cells with septa have pores that permit cytoplasmic streaming
    • Hyphae form structure of all parts of fungus
Filamentous Fungal Growth

• Hyphae
  – cytoplasmic streaming
    • Cytoplasm w/nutrients & nuclei moves rapidly to growing tip
    • Results in rapid growth
    • Fungus gets larger as hyphae branch and elongate
Filamentous Fungal Growth

• Mycelium ( plur. *mycelia*)
  – Combined mass of hyphae
  – Grows rapidly as hyphae grow (mushrooms form in lawn overnight)

• Fruiting body
  – Sexual reproductive structure
    • Produces spores
  – Mass of hyphae
  – May have sporocarp
  – Conspicuous but small part of organism
  – Rest of hyphae grow into food source and move nutrients to other parts of mycelium
Filamentous Fungal Growth

• Rhizomorphs in some fungi
  – Rootlike structures
    • modified hyphae
  – Anchor fungus to substrate
  – Grow into new food sources
    • Can damage forest root systems
    • Very extensive
      – Largest living organism on earth = Armillaria ostoyae; honey mushroom in Oregon covers almost 4 mile$^2$ (beats out blue whale)
Fungal Nutrition

- Require few raw materials to synthesize their nutrients
  - Water, minerals, vitamins & organic carbon source
- Most species saprophytic (*sapros* = rotten)
  - Feed on dead organic matter
  - Secrete enzymes to break down organic material, then absorb nutrients
    » Enzymes released from secretory vesicles by exocytosis
- Some species parasitic
  - Feed off tissues of living host
    » Plant diseases; Dutch elm disease, wheat rust
      • Specialized hyphae called haustoria
        • Penetrate cell wall and bring nutrients to fungus
          » Athlete’s foot
          » Valley fever
Fungal Associations

• Mycorrhiza (plur. *mycorrhizae*)
  – Mutualistic relationship between fungal hyphae and plant roots
    » 80% of plant species
    » Enhance ability of plant to extract nutrients from soil (Zn, Cu, P, N)
    » Fungus absorbs carbs and other nutrients made by plants
    » Fungus provides large surface area to absorb minerals which are then released to the plant
Fungal Associations

- Mycorrhiza (plural *mycorrhizae*)
  - Endomycorrhizae
    » Hyphae may penetrate plant root cells
  - Ectomycorrhizae
    » Hyphae surround tree/shrub roots (see fig. at right)
- Truffles are reproductive bodies of ectomycorrhizae
Fungal Associations

• Lichens
  – Fungus and algae or cyanobacteria closely associated
    » Fungus = mycobiont
    » Algae (or cyanobacteria) = photobiont
    » Mycobiont comprises most of lichen
      • Photobiont multiplies around fungal hyphae
      • Mycobiont takes up to 80% of photobiont’s food
      • Mycobiont often interferes with algal growth and repro.
      • Mycobiont provides shelter from desiccation and UV light
  – Mutualism or parasitism?
    » At least some of the photobionts could live on their own
Fungal Reproduction

• Most reproduce both sexually and asexually
  – Sexual reproduction involves genetic contribution from two individuals
  – Asexual reproduction involves genetic contribution from one individual (genetically identical; clone)
Fungal Reproduction

• Single celled yeasts reproduce asexually by binary fission
  – Make copy of DNA in nucleus
  – Bud off new cell
  – Resulting individuals are clones of parent cell

• Some fungi that grow as yeast also have filamentous forms
  – May reproduce only asexually, or have sexual form as well
Fungal Reproduction

• All fungi produce spores
  – Microscopic
    • Form inside parent cell of single-celled fungi
    • Form in hyphae of filamentous fungi
  – Produced in large numbers
  – Most non-motile; lightweight
    • Spread by physical means (wind, water)
  – Haploid (one set of genetic info)
  – May be formed by asexual or sexual means
  – Germinate and grow into hyphae
Fungal Reproduction

• Asexual spore production
  – Haploid hyphae form sporangia
  – Spores formed (genetically identical)
  – Spores germinate and grow into new fungal hyphae, which produce more spores
  – Some filamentous fungi only reproduce asexually
Fungal Reproduction

• Sexual spore production
  – Often triggered by environment (low food, $O_2$)
  – Hyphae from two mating types (+ and -) meet
  – Plasmogamy
    • Cells fuse → one cell with two nuclei (dikaryon; $di=2$, karyo=$nucleus$)
  – Karyogamy
    • Eventually (yrs later?) nuclei fuse (diploid zygote) and then meiosis forms haploid spores genetically different from parent fungi
  – Spores germinate and grow into new fungal hyphae
Spores of one mating type germinate and grow into a new haploid mycelium.

Asexual Reproduction

Haploid mycelium develops spore-producing structure.

Haploid Stage

Sexual Reproduction

Sexual spores

Dikaryon $(n + n)$

Dikaryotic Stage

Karyogamy

Diploid Stage

Meiosis

Generalized Fungal Life Cycle
Fungal Phyla

• Fungal phyla sometimes called divisions
• Taxonomy traditionally based on sexual reproductive structure (if present)
Ph. Zygomycota

• Sexual reproduction via zygospores (no fruiting body)
• Hyphae generally aseptate (coenocytic)

A. Sporangia of *Rhizopus stolonifer*

• Bread mold produces black sporangia; spores blown by air currents
Zygomycete Life Cycle (*Rhizopus*)

1. Gametangia
2. Sexual Reproduction
3. Plasmogamy
4. Diploid Stage
5. Zygospore
6. Meiosis
7. Asexual Reproduction

- **Haploid Stage**
- **Dikaryotic Stage**
- **Karyogamy**
- **Mating Type** +
- **Mating Type** -
- **Asexual Spores**
- **Sporangium**
- **Mycelium**
Ph. Ascomycycota (sac fungi)

- Sexual reproduction produces fruiting body called an *ascocarp* (*askos* = leather bag)
- Hyphae septate
- Dutch elm disease, athlete’s foot, *Candida*, etc.
- Some toxic; some commercially important
- Thousands of species are lichen mycobionts
Ph. Ascomycota

- Ascocarp produces *asci*
- Asci produce sexual *ascospores*
Ph. Ascomycota

- Ascocarp produces *asci*
- Asci produce sexual *ascospores*
Ph. Ascomycota

• A trapping ascomycete
  – Hyphae form rings
  – Stimulation of prey in rings trigger water to move into hypha and rings swell, shrinking the hole
  – Fungus then releases digestive enzymes
Ph. Ascomycota

- *Saccharomyces cerevisiae*
  - Baker’s yeast
  - Facultative anaerobe
  - Fermentation produces ethanol
  - Aerobic respiration produces CO$_2$
    - Leavens bread, causes it to rise
  - Used in genetic experiments
Ph. Ascomycota

- Asexual reproduction
  - Specialized hyphal branches called conidiophores
  - Spores are called conidia (*konis* = dust; sing. *conidium*)
  - Conidia & conidiophores produce white powdery mildew visible on infected roses and grapes
Ascomycota Life Cycle

1. Spores germinate; sexual parts form on hyphae of each mating type. The + and – sexual parts fuse.

2. Dikaryotic mycelium develops with asci at the tips of hyphae.

3. In each ascus, the two nuclei fuse, producing a diploid zygote.

4. Meiosis in the diploid nucleus produces four haploid nuclei.

5. The four nuclei now divide by mitosis; then cell walls form around each of the resulting eight nuclei. These cells are ascospores. Asci develop inside an ascocarp, which began to form soon after sexual reproduction began.

6. Asci release their ascospores through an opening in the ascocarp.

7. When an ascospore germinates, it gives rise to a new mycelium.

Haploid conidia (spores) develop on conidiophores by mitosis.

KEY
- Haploid
- Diploid
- Meiosis
- Dikaryotic

Figure 30-11, p. 660
Ph. Ascomycota

- *Coccidioides immitis*
  - Cause of valley fever when conidia inhaled
    - Infection may spread to skin, bones, nervous system, lymph nodes, adrenal glands
  - Sporangia form round spherules in infected tissues
  - Sexual stage unknown
In the environment, *Coccidioides* spp. exist as a mold (1) with septate hyphae. The hyphae fragment into arthroconidia (2), which measure only 2–4 μm in diameter and are easily aerosolized when disturbed (3). Arthroconidia are inhaled by a susceptible host (4) and settle into the lungs. The new environment signals a morphologic change, and the arthroconidia become spherules (5). Spherules divide internally until they are filled with endospores (6). When a spherule ruptures (7) the endospores are released and disseminate within surrounding tissue. Endospores are then able to develop into new spherules (6) and repeat the cycle.
Conidial (Imperfect) Fungi

- No sexual phase known
- Only conidial (asexual) spores known
- As sexual phases discovered, species are moved into correct phylum
- Most have been ascomycetes
Ph. Basidiomycota (Club Fungi)

- Sexual reproduction produces variety of fruiting bodies

A. Coral fungus
B. Shelf fungus
C. White-egg bird’s nest fungus
D. Fly agaric mushroom
E. Scarlet hood
Ph. Basidiomycota

- Includes edible mushrooms
- Some species have enzymes to digest cellulose and lignin
  - Decompose woody plants
- Many trap and consume bacteria or microscopic animals
- Many form mutualistic relationships with tree roots (ectomycorrhizae)
- Many are toxic
  - *Amanita muscaria* -- euphoria, extreme nausea
  - *Amanita phalloides* – stops protein synthesis; kidney, liver degeneration; death
Ph. Basidiomycota

- Fruiting body called *basidocarp* (*basidio* = base, foundation)
  - Spore producing cells (*basidia*) club-shaped
  - Sexual spores called *basidiospores*
Ph. Basidiomycota

- Basidia located on “gills” on underside of basidiocarp cap
Ph. Basidiomycota

• A few reproduce only asexually

• Sexual reproduction is most common
  – Dikaryotic hyphae comprise feeding mycelium
    • Grows for years
    • Produces many fruiting bodies
    • Responsible for large mycelia producing many basidiocarps (*Armillaria*) and extensive root rot in forests
Figure 30-13, p. 662

**Basidiomycota Life Cycle**

1. Basidiospores from two compatible fungi germinate and form haploid mycelia.
2. Plasmogamy occurs. The tips of the two hyphae fuse.
3. Plasmogamy produces a dikaryotic cell that contains two genetically different nuclei.
4. The dikaryotic cell grows into a mycelium.
5. Hyphae form a basidiocarp. Spore-producing cells are under the cap, on flaplike gills.
6. Eventually karyogamy takes place as nuclei of different mating types fuse.
7. In the zygote, meiosis produces four haploid nuclei.
8. Four basidiospores form and are released.

**KEY**
- Haploid
- Diploid
- Dikaryotic

**PLASMOGAMY**
- Dikaryotic cell
- Haploid mycelia
- Mycelium

**HAPLOID STAGE (1n)**
- Basidiospores
- Basidium

**DIPLOID STAGE (2n)**
- Meiosis
- Basidia on gills
- Spore-producing cell

**DIKARYOTIC STAGE (n + n)**
- Basidium
- Basidiospores

**SEXUAL REPRODUCTION**
- Karyogamy
- Zygote formed when nuclei fuse