CHAPTER 23 EVOLUTION OF FUNGI

Chapter Outline

23.1 Characteristics of Fungi

A. Fungi Are Multicellular Eukaryotes
   1. Fungi are mostly multicellular eukaryotes that share a common mode of nutrition.
   2. Similar to animals, they are heterotrophic and consume preformed organic matter.
   3. However, animals are heterotrophic by ingestion while fungi are heterotrophic by absorption.
   4. Fungal cells secrete digestive enzymes; following breakdown of molecules, the nutrients are absorbed.
   5. Most fungi are saprotrophic decomposers, breaking down wastes or remains of plants and animals.
   6. Some are parasitic, living off tissues of living plants and animals.
      a. Fungi enter leaves through stomates; plants are especially subject to fungal diseases.
      b. Fungal diseases account for millions of dollars in crop losses each year; fungal diseases also have decimated some tree species.
      c. Fungi also cause human diseases including ringworm, athlete's foot, and yeast infections.
   7. Several types of fungi are adapted to mutualistic relationships with other organisms.
      a. As symbionts of roots, they acquire inorganic nutrients for plants and receive organic nutrients.
      b. Others form an association with a green alga or cyanobacterium to form a **lichen**.

B. Structure of Fungi
   1. Fungi can be unicellular (e.g., yeasts).
   2. Most fungi are multicellular in structure.
      a. The **thallus** (body) of most fungi is a **mycelium**.
      b. A **mycelium** is a network of **hyphae** comprising the vegetative body of a fungus.
      c. **Hyphae** are filaments that provide a large surface area and aid absorption of nutrients.
      d. When a fungus reproduces, a portion of the mycelium becomes reproductive structures.
   3. Fungal cells lack chloroplasts and have a cell wall made of **chitin,** not cellulose.
      a. **Chitin,** like cellulose, is a polymer of glucose molecules organized into microfibrils.
      b. In chitin, unlike cellulose, each glucose has an attached nitrogen containing amino group.
   4. The energy reserve of fungi is glycogen as in animals, and not starch.
   5. Fungi are nonmotile; their cells lack basal bodies and do not have flagella at any stage in their life.
   6. Fungi move to a food source by growing toward it; hyphae can grow up to a kilometer a day!
   7. **Nonseptate** hyphae lack **septa** or cross walls; hyphae are multinucleated.
   8. **Septate fungi** have cross walls in their hyphae; pores allow cytoplasm and organelles to pass freely.
   9. The septa that separate reproductive cells, however, are complete in all fungal groups.

C. Reproduction of Fungi
   1. In general, fungal sexual reproduction involves the following:
      haploid hyphae → dikaryotic stage → diploid zygote
      ↑---------- meiosis----------↓
   2. During sexual reproduction, haploid hyphae from two different mating types fuse.
   3. If nuclei do not fuse immediately, the resulting hypha is **dikaryotic** (contains paired haploid nuclei, n + n).
      a. In some species, nuclei pair but do not fuse for days, months or even years.
      b. The nuclei continue to divide in such a way that every cell has at least one of each type of nucleus.
   4. When the nuclei fuse, the resulting zygote undergoes meiotic cell division leading to spore formation.
   5. Fungal **spores** germinate directly into haploid hyphae without embryological development.
   6. Fungal Spore Formation
      a. Spores are an adaptation to life on land and ensure that the species will be dispersed to new locations.
      b. A **spore** is a reproductive cell that can grow directly into a new organism.
      c. Fungi produce spores both during sexual and asexual reproduction.
      d. Although nonmotile, the spores are readily dispersed by wind.
   7. Asexual reproduction can occur by three mechanisms:
      a. Production of spores by a single mycelium is the most common mechanism.

b. **Fragmentation** is when a portion of a mycelium becomes separated and begins a life of its own.
c. **Budding** is typical of yeasts; a small cell forms and gets pinched off as it grows to full size.

23.2 Evolution of Fungi

A. Evolution of Fungi
1. Evolutionary origin of fungi is not known; they had evolved by about 570 million years ago.
2. Fungi may not share a common ancestor but may have evolved separately from protist ancestors.
3. Some biologists propose that fungi evolved from red algae; both lack flagella in all stages of the life cycle.
4. R. H. Whittaker argued for their own kingdom based on their multicellular nature and mode of nutrition.
5. Fungi share similarities and have differences with other groups of protists.
6. Not knowing phylogeny, fungal groups are classified according to differences in life cycles and types of **sporangia.**
7. New comparative DNA research has not yet changed the classification of fungi.

B. Zygospore Fungi
1. Phylum **Zygomycota** contains about 665 species of **zygospore fungi.**
2. Most are saprotrophs living off plant and animal remains in the soil or bakery goods in a pantry.
3. Some are parasites of small soil protists, worms, or insects.
4. The black bread mold, *Rhizopus stolonifer,* is a common example.
   a. With little cellular differentiation among fungi, hyphae specialize for various functions.
   b. **Stolons** are horizontal hyphae that exist on the surface of the bread.
   c. **Rhizoids** are hyphae that grow into the bread, anchor the mycelium, and carry out digestion.
   d. **Sporangiophores** are stalks that bear sporangia.
   e. A **sporangium** is a capsule that produces spores called sporangiospores.
   f. During asexual reproduction, all structures are haploid.
5. The division name refers to the zygospore seen during sexual reproduction.
   a. Hyphae of different mating types (+ and –) are chemically attracted and grow toward each other.
   b. Ends of hyphae swell as nuclei enter; cross walls develop behind each end, forming **gametangia.**
   c. Gametangia merge into a large multinucleate cell in which nuclei of two mating types pair and fuse.
   d. A thick wall develops around the cell, forming a **zygospore.**
   e. The zygospore undergoes a period of dormancy before meiosis and germination takes place.
   f. Germination involves the development of one or more **sporangiophores,** with sporangia at their tips.
   g. The spores are dispersed by air currents and give rise to new haploid mycelia.

C. Sac Fungi
1. Phylum **Ascomycota** contains about 30,000 species of **sac fungi.**
2. Most are saprotrophs with an essential role digesting cellulose, lignin, collagen and other resistant materials.
3. Red bread molds, cup fungi, morels, and truffles are also sac fungi.
4. Many ascomycetes are plant parasites and include the powdery mildews that grow on leaves, leaf curl fungi, chestnut blight, and Dutch elm disease.
5. Ergot is a parasitic fungus on rye; it produces a toxin that can cause hysteria and death.
6. Yeasts are unicellular, but most ascomycetes are composed of septate hyphae.
7. Sexual reproduction involves production of eight **ascospores** within **ascus** contained within saclike **ascocarp**.
   a. Ascus-producing hyphae remain dikaryotic except in walled-off portion that becomes ascus.
   b. **Asci** are the fingerlike sacs in which nuclear fusion, meiotic cell division, and **ascospore** formation occur during sexual reproduction of sac fungi; usually surrounded by an **ascocarp.**
   c. Each ascus contains eight haploid nuclei and produces eight ascospores.
   d. In most ascomycetes, the asci become swollen and burst, expelling the ascospores.
   e. If released into the air, the spores are windblown.
8. Asexual reproduction, which is the norm, involves the production of **conidiospores**.
   a. There are no sporangia in ascomycetes.
   b. **Conidiospores** (**conidia**) develop directly on tips of **conidiophores**, modified aerial hyphae, and are windblown when released.

D. Yeasts
    1. Yeasts are unicellular and reproduce asexually by budding.
    2. *Saccharomyces cerevisiae* is brewer's yeast; a small cell forms and is pinched off as it grows.
    3. Sexual reproduction in yeasts occurs when food runs out, and produces asci and ascospores.
        a. Ascospores from two different mating types fuse, resulting in a diploid cell.
        b. A diploid cell reproduces asexually, then undergoes meiotic cell division forming ascospores.
        c. The haploid ascospores function directly as new yeast cells.
    4. Yeasts produce ATP through fermentation—ethanol and CO_2 are waste products.
    5. Yeasts are added to prepared grains to make beer.
    6. Because of its ability to produce alcohol, yeast fermentation is important in the production of wine; special strains are added to essentially sterile grape juice and the CO_2 is kept for sparkling wines.
    7. Because it produces CO_2, yeast fermentation is important in the production of bread.
    8. Yeasts are also used in genetic engineering experiments requiring a eukaryote.

E. Club Fungi
    1. Club fungi are in phylum **Basidiomycota** and include about 16,000 species.
    2. They have septate hyphae and include mushrooms, bracket fungi, puffballs, bird's nest fungi, and stinkhorns.
    3. Sexual reproduction involves production of **basidiospores** within clublike **basidia** contained within a **basidiocarp**; asexual reproduction is rare and involves the production of **conidiospores.**
        a. Sexual reproduction begins when monokaryotic hyphae of two different mating types meet and fuse to form a dikaryotic (n + n) mycelium.
        b. The dikaryotic mycelium continues its existence for years (perhaps even hundreds of years) and occasionally produces one or more **basidiocarps.**
        c. **Basidiocarps** are fruiting bodies (e.g., mushrooms and puffballs) composed of tightly packed dikaryotic hyphae whose walled-off ends become the club-shaped **basidia.**
        d. **Basidia** are club-shaped structures, formed within a basidiocarp from the walled-off ends of dikaryotic hyphae, where nuclear fusion, meiotic cell division, and basidiospore production occur.
        e. Basidium contains four projections; cytoplasm and a haploid nucleus enters to form four **basidiospores.**
        f. Released basidiospores are windblown; when they germinate, a new haploid mycelium forms.
    4. In a puffball, spores inside parchmentlike membranes are released through a pore or when the parchment breaks down.
    5. In bird's nest fungi, raindrops splatter basidiospore-containing "eggs" through the air.
    6. Stinkhorns have a slimy cap and attract flies by their bad odor to pick up and distribute spores.
    7. Smuts and Rusts
        a. **Rusts** and **smuts** are club fungi that parasitize cereal crops (e.g., corn, wheat, oats, and rye) and cause great economic crop losses every year.
        b. Rusts and smuts do not form basidiocarps; their spores are small and numerous, resembling soot.
        c. Some smuts enter seeds and exist inside the plant, becoming visible only at maturity.
        d. Corn smut mycelia grow between the corn kernels and secrete substances to cause tumors on ears.
        e. They have a complex life cycle that may involve more than one host; thus, control measures may center on eradicating the alternate hosts.

F. Imperfect Fungi
    1. About 25,000 species are imperfect fungi in the phylum **Deuteromycota.**
    2. They reproduce asexually by forming conidiospores; these are produced at the tips of aerial hyphae and not in sporangia.
    3. They are "imperfect" because no sexual stage is known and may not exist; thus it cannot be easily classified.
    4. Cell morphology and biochemistry indicate some are sac fungi that lost ability to reproduce sexually.
    5. Several species of imperfect fungi are of great economic importance.
        a. Some species of *Penicillium* mold provide antibiotic penicillin; others give a characteristic aroma and flavor to certain cheeses (e.g., Roquefort and Camembert).
        b. Cyclosporine suppresses the immune system and is from an imperfect fungus found in soil.
        c. *Aspergillus* is used in the production of soy sauce, citric acid, and gallic acids.
    6. Some imperfect fungi cause human diseases.
        a. Aspergillosis is a respiratory infection caused by inhaling spores.

b. An aspergillus that grows on moist seeds secretes aflatoxin, a potent natural carcinogen.
b. Athlete's foot and ringworm are skin infections caused by direct contact.
c. *Candida albicans* is a yeastlike fungus causing infections of the vagina, diaper rash, and thrush.

31.3 Symbiotic Relationships of Fungi

A. Lichens
1. **Lichens** are a symbiotic association between fungus and cyanobacterium or green alga.
2. The body of a lichen is composed of three layers.
   a. a thin, tough upper layer, and
   b. a loosely packed lower layer
   c. that shields the photosynthetic cells in the middle layer.
3. Special fungal hyphae penetrate or envelope the photosynthetic cells and transfer nutrients directly to the rest of the fungus.
4. Lichens can reproduce asexually by releasing fragments that contain hyphae and an algal cell.
5. This association was considered mutualistic, but experimentation suggests a controlled parasitism by fungus of the alga.
   a. The algae grow faster when they are alone rather than when they are part of a lichen.
   b. On the other hand, it is difficult to cultivate the fungus, which does not grow naturally alone.
   c. Different lichen species are identified based on the fungal partner.
6. Three types of lichens are recognized.
   a. Compact **crustose lichens** are often seen on bare rocks or tree bark.
   b. **Foliose lichens** are leaflike.
   c. **Fruticose lichens** are shrublike.
7. Lichens are efficient at acquiring nutrients; they survive with low moisture, temperature, or poor soil.
8. Lichens may live in extreme environments and on bare rocks; they help form soil.
9. Lichens also take up pollutants and cannot survive where the air is polluted.

B. Mycorrhizae
1. **Mycorrhizae** are mutualistic relationships between soil fungi and roots of most plants.
2. Fungus enters the cortex of roots but does not enter the cytoplasm of plant cells.
3. Ectomycorrhizae form a mantle that is exterior to the root, growing between cell walls.
4. It helps the roots absorb more minerals; in turn, the plant passes on carbohydrates to the fungus.
5. The truffle lives in association with oak and beech tree roots; it can be inoculated with the fungus.
6. The fossil record indicates that the earliest plants had mycorrhizae associated with them; mycorrhizae helped plants adapt to and flourish on land.