Chapter 31: Fungi

I. Introduction: What are Fungi?
   a. 80,000 identified species so far
   b. Eukaryotes
   c. Single or multi-celled (branching networks of multicellular filaments)
   d. Terrestrial
   e. Heterotrophs, Decomposers
      i. without fungi, the Earth would be piled high with dead trees
      ii. only fungi and a few bacteria are capable of digesting both cellulose (in plant cell wall) and lignin (in wood)
   f. Parasites (athlete's foot, yeast infection), mutualists

II. Why Do Biologists Study Fungi?
   a. Fungi Provide Nutrients to Land Plants
      i. Fungi + plant root = mycorrhizal association
   b. Fungi Speed up the Carbon Cycle on Land
      i. Decomposers and recyclers
      ii. Saprophytes (eat dead plant material)
      iii. During Carboniferous Period
         1. few fungal fossils (high acid environment)
         2. An increase in peat and coal production because plants were not broken down.
      iv. at the end of the Permian Period (250 mya)
         1. greatest mass extinction of all time
         2. brief increase in fungal fossils
         3. thought that massive die-off of trees provided rotting wood and a favorable environment for fungi.
      v. Fungi complete carbon cycle by breaking down dead/rotting organisms
   c. Fungi Have Important Economic Impacts
      i. Some (a very few) are pathogenic
      ii. Some produce antibiotics
      iii. Impact on crop production and storage
      iv. Impact on food industry
         1. mushrooms are eaten
         2. food production using fungi: bread, soy sauce, tofu, cheese, beer, wine, whiskey
      v. Impact on environment
         1. pathogen to certain trees (chestnut blight) Dutch elm disease
   d. Fungi are key model organisms in Eukaryotic genetics
      i. Neurospora (one gene, one enzyme)
      ii. Saccharomyces – model for eukaryotic cells (easy to grow in lab)

III. How Do Biologists Study Fungi?
   a. Direct sequencing
   b. Analyzing morphological traits (only 2 growth forms)
      i. Single-celled = yeasts
      ii. Multi-celled, filamentous = mycelia
         1. dynamic: grow out and die back with changes in food supply
         2. can become very large (1310 acre organism in Oregon)
         3. hyphae (individual filaments of mycelium)
            a. haploid (some are heterokaryotic (2 haploid nuclei)
            b. hyphae are very thin tubes. This thinness increases surface area to volume ratio and increases the absorption potential, while

unfortunately increases the risk of drying out as well. (must live in moist environment)

c. most contain septa (cross walls) with gaps to allow for the flow of nutrients, organelles, even nuclei (due to this flow, fungi are sometimes thought of as an intermediate between a multicelled organism and a large unicellular organism)

d. those without septa (coenocytic = common celled), and act like an enormous single-celled organism

4. Reproductive structures (define 4 major groups) **Fig 31.7**

a. Thick fleshy structures

i. Exposed to air

ii. Do not absorb food (though they arise from mycelia and have hyphae)

b. Mycota = fungus

Group	Aka	Reproduction	Special trait	Fruiting bodies
Chytridiomycota	Chytrids	Asexual = flagellated spores Sexual = gametes with flagella	Motile cells	
Zygomycota	Yoked fungi	Haploid hyphae combine (if genetically distinct enough)	Chemical signals released by hyphae indicate mating type	Zygosporangium
Basidiomycota	Club fungi (mushrooms)	Spores form in basidia at the ends of hyphae	Basidia	Mushroom, puffball, etc
Ascomycota	Sac fungi	Tips of hyphae for asci, which produce spores	Asci	asci

c. Evaluating molecular phylogenies

i. DNA sequencing

ii. Morphological traits (underscore relatedness to animals)

1. chitin in cell walls
2. similarities in flagella
3. energy stored as glycogen

iii. How are the four major groups of fungi related?

1. biologists hypothesized that each of the groups defined by reproductive strategy would be a monophyletic group
2. tested this by sequencing a series of genes from each group
3. Results in **Fig 31.9**

a. Chytrids: most basal of all groups. Backs up idea that fungi evolved from aquatic ancestors. (Many chitrids are aquatic)

b. Chytridiomycota and Zygomycota are paraphyletic (neither group is represented by all of the descendents of a single common ancestor). The traits of flagellated reproductive cells and yoked reproductive cells either evolved more than once, or were present in a common ancestor, but lost in certain lineages.

c. Microsporidia are in fact fungi (and not their closest relative, as had been previously thought).

d. Glomeromcota (reproductive strategy yet unknown)is a monophyletic group
e. Basidiomycota and ascomycota are both monophyletic and highly derived groups.

d. Experimental Studies of Mutualism
i. Estimate 90% of plants live in close physical association with fungi
ii. Symbiotic relationship
1. Mutualism + / + (both benefit)
2. Parasitism + / - (one benefits, the other is harmed)
3. Commensal + / 0 (one is benefited, the other is unaffected)

iii. presence-absence experiments
1. show that plants grow larger with normal symbiotic fungi present
2. fungi unable to grow without their plant host

iv. Isotope studies reinforce
1. plants pass along labeled CO2 (in form of sugar) to fungi
2. fungi pass along Potassium or Nitrogen they get from soil to plants.

IV. What Themes Occur in the Diversification of Fungi?
a. Fungi participate in several types of mutualism
i. Ectomycorrhizal Fungi (EMF)
1. Found in tree species in temperate climates and northern coniferous forests
2. Hyphae cover root tip and extend inward between cells as well as outward into soil
3. Basidiomycetes and Ascomycetes
4. How do they help?
a. Aid in quicker breakdown of needles
b. Release peptidases (enzymes that break down proteins) that free up amino acids
c. Makes Nitrogen and phosphorus available for trees in the forest

ii. Arbscular Mycorrhizal Fungi (AMF)
1. found it the grasslands and in the tropics
2. hyphae grow *into* root cells
3. transfer phosphorus from soil to plant root cells

iii. Endophytic fungi
1. fungi that live in above-ground parts of plants
2. May produce compounds tat deter or even kill herbivores

V. What Adaptations Make Fungi Such Effective Decomposers?
i. Structure of hyphae (see above)
ii. Extracellular digestion
1. fungi secrete enzymes and perform digestion outside of the organism (extracellular digestion)
2. especially helpful when food particles are too large to absorb directly
a. lignin
i. lignin = strong polymers that give wood its woody texture
ii. only basidiomycetes can break down lignin to CO2
iii. fungi use lignin peroxidase
iv. removes electrons from lignin ring, destabilizing it and allowing it to be broken down more easily
v. enzymatic combustion – unpredictable
vi. most fungi cannot use lignin alone as a food source, but break it down to reveal the cellulose behind it.

vii. Commercial application? Remediation in lumber mills?

b. Cellulose

i. Fungi use cellulases (enzymes that break down cellulose)

ii. Highly specific enzymes

VI. Variation in Life Cycles

a. Basic aspects of fungal life cycles

i. The Spore is the fundamental reproductive cell in fungi

ii. Produced in both asexual and sexual phases

iii. Demonstrated in figure 31.13 a

1. asexual: remains haploid. Spores are haploid.
    a. Some organisms only reproduce asexually
    b. Organism is haploid
    c. Spores (produced by mitosis) are haploid
2. sexual: note steps:
    a. plasmogamy- fusion of cytoplasm \
    b. karyogamy –fusion of nuclei /
        i. note: plasmogamy and karyogamy are 2 steps of fertilization. The time between the steps varies greatly
        ii. in-between time is called 'heterokaryotic stage', when cells contain 2 independently functioning nuclei, (dominant stage in many fungi)
    c. meiosis - production of haploid spores

b. Unique aspects of Fungal life cycles

i. Chytridiomycota

1. the only fungus that produce gametes (not called sperm and ova)
2. show alteration of generation
    a. gametophytic mycelium (n)
    b. sporophytic mycelium (2n)
3. Look for P-K-M
    a. Plasmogamy and karyogamy occur simultaneously to form the zygote
    b. Zygote grows into a 2n stage that produces a fruiting body (sporangium)
    c. Cells in sporangium undergo meiosis, producing haploid spores
    d. Spores are released, forming haploid mycelia

ii. Zygomycota

1. form yoked hyphae to for zygosporangium
2. look for P-K-M
    a. Plasmogamy occurs when dissimilar hyphae make and encounter; zygospore forms
    b. Karyogamy occurs a little later, forming a true zygote
        i. This zygote is surrounded by a tough outer covering that can persist until conditions are favorable to make spores
    c. Meiosis occurs to for haploid spores
    d. Spores are released, forming haploid mycelia

iii. Basidiomycota

1. form the familiar mushroom fruiting body
2. Look for P-K-M
    a. Plasmogamy occurs when hyphae of different mating types fuse

i. Growth occurs and eventually, a fruiting body (still heterokaryotic) forms from the mycelia.
ii. Pedestal structures (basidia) line the external surface

b. Karyogamy occurs in basidia, followed by
c. Meiosis, which forms haploid spores
d. Spores are released, forming haploid mycelia

iv. Ascomycota

1. cup fungi
2. Look for P-K-M
    a. Plasmogamy occurs when haploid (n) hyphae of two different mating types make contact and fuse
        i. Resulting dikaryotic (n+n) mycelia grow
        ii. Ascocarp (mature, spore-producing body) is formed (n+n)
    b. Karyogamy occurs in the asci of the mature ascocarp (now 2n)
    c. Meiosis occurs in each ascus, forming 4 haploid spores. Then, mitosis follows, resulting in a total of 8 cells. (4, original, genetically unique spores, and an exact copy of each)
    d. Spores are released, forming haploid mycelia

VII. Key Lineages of Fungi

a. In order to be considered a phylum, a group must be monophyletic. We know that Chytridiomycota and Zygomycota are not, so understand that this classification will soon be changed. But for the time being…

i. Chytridiomycota

1. aquatic
2. motile cells
3. important decomposers in aquatic habitats
4. may be parasitic or live in mutualistic arrangement in the guts of large, plant-eating mammals.
5. may be responsible for recent decline in global frog populations.

ii. Microsporidia

1. all known species are single-celled and parasitic
2. have a polar tube at one end that allows for penetration of host cells
3. common parasites of insects and fish (intracellular parasites, because they enter the cells of their hosts)
4. some are marketed as biological control organisms

iii. Zygomycota (the yoked fungi)

1. soil dwellers
2. saprophytes, predatory or parasites
3. commonly found on rotting fruit; bread mold
4. some are used to produce alcohol and fermented foods

iv. Glomeromycota

1. important in supplying grassland and tropical species with phosphorus
2. Arbuscular mycorrhizal fungi (AMF)
3. No known sexual stage

v. Basidiomycota

1. saprophytes
2. one of few organisms capable of completely digesting wood.
3. Ectomycorrhizal fungi (EMF) form mutualistic associations in temperate and northern forest
4. Important to timber industry
5. Some used for food, though others are toxic

vi. Ascomycota

1. the most common of all fungi
2. cup fungi and lichen formers
3. lichens
    a. symbiotic relationships between fungus and aalgae or cyanobacterium
    b. common in boreal foress
    c. major food of caribou
    d. colonizers of bare rock (vital to succession)
    e. used in perfume products… either as fragrance or base to stabilize the fragrance
4. cup fungi
    a. cup fungi and single-celled yeast
    b. some form ectomycorrhizal fungi, and many are endophytic fungi on above-ground tissues
    c. some form penicillin
    d. aspergillus makes citric acid used to flavor soft drinks and candy
    e. truffles, morels, bakers and brewers yeast