Lecture Outline: The Colonization Of Land By Plants And Fungi

I. **Introduction to Plants and Fungi**
   A. Fungi and Plants are non-protist Eukaryotes
      1. A protist is a Eukaryote that is not an animal, plant, or fungus
      2. Fungi and plants are not highly related phylogenetically
         a. Fungi are more related to animals than they are to plants
         b. Plants have algae (specifically Charophyte algae) as their sister taxon
   B. Trophic Interactions
      1. Plants are **autotrophs** (specifically photoautotrophs/producers)
      2. Fungi, like animals, are **heterotrophs** (cannot make their own food)
   C. Shared Lifestyle: Digestion and Absorption
      1. Both fungi and animals acquire nutrition by digesting food outside their main body
         a. Enzymes (catalyst proteins) are secreted to break down complex molecules into small subunits (e.g., amino acids, monosaccharides)
         b. Absorption occurs when small molecules penetrate the cell membrane and enter the body
      2. Digestion in Animals
         a. Food is put into the alimentary canal (a continuous tube from mouth to anus)
         b. The entire contents of the alimentary canal are outside the body
         c. Enzymes are secreted into the canal for digestion before absorption into body cells
      3. Digestion in Fungi
         a. Fungi live directly on their food source
         b. Enzymes are secreted outside the body onto the food
         c. Smaller molecules are then absorbed into the fungus's body
   D. Rationale for Studying Plants and Fungi Together
      1. They **co-evolved**, appearing on land about the same time (roughly half a billion years ago)
      2. Their co-evolution continues to affect each other's evolutionary trajectories

II. **Plant Origins and Characteristics**
   A. Evidence Linking Plants and Charophyte Algae
      1. Shared cell walls made largely of cellulose (a structural polysaccharide)
         a. Cellulose is built by hooking together glucose monosaccharides

2. Unique circular arrangements of proteins in the plasma membrane
    a. These molecular machines build and string out cellulose polymers for the cell wall
    b. Other organisms using cellulose have similar devices, but they are not ringed like this

B. Life Cycles: Alternation of Generations (AOG)
1. All sexual species must alternate between fertilization and meiosis
    a. Fertilization (gamete fusion) **doubles ploidy** (e.g., N to 2N)
    b. Meiosis **halves ploidy** (e.g., 2N to N)
2. Ploidy definition: How many of each type of chromosome a cell has
    a. N represents the number of different kinds of chromosomes (haploid)
    b. 2N represents diploid (two of each type)
3. Animal Life Cycle
    a. Only the diploid (2N) stage is multicellular
    b. The haploid (N) stage (gametes) remains unicellular
4. Fungi Life Cycle
    a. The haploid (N) stage is multicellular (mycelium)
    b. They produce gametes by mitosis (since they are already N)
    c. The diploid (2N) stage (zygote) is unicellular, immediately undergoing meiosis
5. AOG in Plants
    a. Plants have multicellularity in **both** the haploid (N) and diploid (2N) phases
    b. The multicellular haploid phase is the **gametophyte** (gamete-producing plant)
        (1) Produces gametes by mitosis
    c. The multicellular diploid phase is the **sporophyte** (spore-producing plant)
        (1) Produces haploid spores by meiosis
6. Plants produce **multicellular dependent embryos** that develop inside the body of the previous generation

C. Plant Colonization of Land
1. Ancestors were aquatic algae
2. Land is a desiccating environment (drying out)
3. Evolutionary breakthrough: The polymer **sporopollenin** provides desiccation resistance to spores and pollen grains
4. The earliest plants appeared around 475 million years ago

D. Major Plant Groups and Innovations
1. Plants are a monophyletic taxon
2. **Nonvascular Plants (Bryophytes)**
    a. The basal group (most primitive/ancestral)

b. Includes mosses, liverworts, and hornworts
c. Lack vascular tissues (vessels) and are size-constrained (cannot be big in all three dimensions)
d. Have rhizoids (root-like structures) only for anchoring, not transport
e. AOG status: Gametophyte (N) is the dominant generation; sporophyte (2N) is dependent on it

3. **Vascular Plants** (Vascularity evolved around 425 million years ago)
   a. Vascularity allows for larger size by transporting materials internally (e.g., xylem and phloem)
   b. Almost all extant plant species are vascular
   c. AOG status: Sporophyte (2N) is the dominant generation
4. Seedless Vascular Plants
   a. Examples include ferns and lycophytes
   b. AOG status: Sporophyte is dominant, gametophyte is microscopically small (with free-living, swimming gametes)
5. **Seeded Plants** (Seeds evolved around 300 million years ago)
   a. The seed is a protective, desiccation-resistant package containing a growing embryo and a food supply
   b. A seed develops from a fertilized ovule; the embryo is the sporophyte of the next generation
   c. AOG status: Sporophyte is dominant; the gametophyte is barely multicellular (2-3 cells) and lives entirely inside the sporophyte
6. Gymnosperms (Naked seed)
   a. Gymno means naked; seeds are exposed to the surroundings (e.g., on cones)
   b. Examples: Conifers (pine trees, fir trees)
7. Angiosperms (Chamber seed)
   a. Angio means chamber; seeds develop inside a chamber (the ovary)
   b. Also known as **flowering plants** (the most successful group)
   c. The "Three Fs" of Angiosperms:
      (1) Flowers (advertisements for pollinators)
      (2) Fruit (a seed-bearing structure developed from the ovary)
      (3) Double Fertilization

E. Flower Structure (Angiosperms)
1. A flower is the reproductive structure
2. Complete flowers have four major parts called whorls:

a. Sepals and Petals: **Sterile parts** (do not directly produce gametes)
b. Stamens (Male parts): **Fertile parts**
    (1) Anther produces pollen grains (containing sperm cells)
c. Carpels (Female parts): **Fertile parts**
    (1) Ovary (bulbous base) contains ovules (which become seeds)
    (2) Style (slender stalk)
    (3) Stigma (sticky surface) receives pollen grains

III. **Fungi Morphology, Life Cycle, and Phylogeny**

A. Fungal Structure
1. Most fungi are multicellular; unicellular fungi are called **yeasts**
2. The body consists of highly branched, slender filaments called **hyphae** (singular: hypha)
3. The overall network of hyphae is the **mycelium**
    a. The mycelium is the interface for efficient digestion and absorption
    b. Slender and branched hyphae maximize surface area for contact with food
4. The mushroom structure is primarily for reproduction

B. Fungal Sexual Life Cycle
1. Fertilization is often drawn out into two separate steps:
    a. **Plasmogamy**: Fusion of the cytoplasm of two gametes
    b. Heterokaryotic stage: A single cell containing two distinct nuclei
    c. **Karyogamy**: Fusion of the two nuclei, forming a diploid (2N) zygote
2. The diploid zygote immediately undergoes meiosis to produce haploid (N) spores
3. Spores undergo mitosis (germination) to become the multicellular haploid (N) adult (mycelium)
4. Asexual reproduction involves making genetically identical spores via mitosis

C. Major Groups of Fungi
1. Fungi are a monophyletic taxon (a true clade)
2. The degree of speciation (adaptive radiation) varies greatly among groups
3. The five major groups:
    a. Chytrids (approx. 1,000 species): Often unicellular, mostly aquatic
    b. Zygomycetes (approx. 1,000 species): E.g., common bread molds
    c. Glomeromycetes (approx. 160 species): Least successful in speciation
        (1) Ecologically vital as primary formers of mycorrhizae
    d. Ascomycetes (approx. 65,000 species): The largest group, called "sac fungi"
    e. Basidiomycetes (approx. 30,000 species): Called "club fungi," includes most familiar mushrooms

IV. **Ecological Interactions Between Fungi and Plants**

A. Mycorrhizae (Fungus roots)

1. A **mutualistic symbiosis** between plant roots and fungi
2. Fungal hyphae grow close to the plant cells in the root, maximizing surface area for exchange
3. Hyphae branch into finger-like projections but do not pierce the plant's plasma membrane

B. Endophytes (Within a plant)

1. Fungi that live **inside** plant parts, such as leaves
2. Also a mutualistic symbiosis; the plant feeds the fungus, and the fungus protects the plant from pathogens

C. Other Roles

1. Lichens: A symbiotic relationship between a fungus and a unicellular photosynthetic organism (alga or cyanobacterium)
    a. Ecologically important for breaking down bare rock (weathering) and initiating soil formation
2. Pathogenic fungi cause significant loss of agricultural crops

V. **Co-evolution and Speciation in Flowering Plants**

A. Co-evolution with pollinators (animals that carry gametes) drives plant evolution

B. Flower Symmetry and Pollinator Entry

1. Radially symmetrical flowers: Have multiple entry points for pollinators
2. Bilaterally symmetrical flowers: Have limited (typically one) entry point for pollinators

C. Symmetry and Speciation

1. Bilaterally symmetrical flowers restrict how pollinators enter, ensuring consistent pollen placement and delivery
2. This restriction leads to **less gene flow** between populations
3. Less gene flow results in **more speciation** (adaptive radiation) compared to radially symmetrical flowers