Characteristics of Fungi
Diversity approx. 80,000 described; 1.6 million estimated

Phylogenetic depth - (tree figure) - a kingdom equal in age to Plants and Animals

Filamentous thallus (with exceptions)
  **Hypha** (pl. hyphae) in mass **Mycelium**
  high surface to mass ratio
  Absorptive nutrition - extracellular enzymes
  easily modified for infection structures **haustoria**
  or bundled together into conductive structures: **Rhizomorphs or mycelial cords**

Cell wall - carbohydrate polymers (Chitin, Cellulose, other B-glucans)

Nuclei and chromosomes typically small - DNA content varies from about 2-10X that of E. coli, largest genome of fungi = smallest of plants. **Genomes tend to be very plastic in size and arrangement.**

Bizarre nuclear condition - Uninucleate diploids rare - coenocytic diploids (Oomycetes), haploids, dikaryotes, heterokaryotes

Recent *Evolution* paper by James et al. (2008) on behavior of *Heterobasidion parviporum* shows that nuclear ratio in heterokaryons can be highly variable.

**Mitotic propagules** common - spores (Conidia) and resting structures (Sclerotia)

Advantages of clonal propagation?

Components of sex (i.e., Syngamy=fusion of cells, karyogamy=fusion of haploid nuclei, and meiosis=reduction division to produce haploid nuclei from diploids) frequently separated in the life cycle

**Fungi are territorial** - Vegetative (= somatic, or heterokaryon) compatibility

Post fusion reaction
Genetics behind it: compatible reaction requires identity at all Het loci.
Why do fungi fuse or not?

**Major groups of fungi** - all named for their meiotic organs.

**Oomycetes** - the watermolds
  **Unrelated to higher fungi** - more closely related to brown algae
Fuscosterol (when sterols synthesized), DAP lysine pathway, biflagellate zoospores, Mitochondria with tubular cristae, Nuclear division with intact membrane

Typical life cycle
- Coenocytic diploid life cycle, **Oogamy** - a resting structure in many species
- other resting structures - chlamydomspores (**Phytophthora cinnamomea**)

**Importance in Forests**
- SOD - **Phytophthora ramorum** **Sudden oak death**
- Seedling diseases (damping off) - **Pythium, Phytophthora**
- Root diseases - **Phytophthora** (little leaf disease, root rot of Port Orford cedar)
- Declines - Pythium?, **Phytophthora** (oak decline in Europe)

**True fungi**

**Glomeromycota** - important in **Arbuscular mycorrhizae** (Redwoods, incense cedar, maples and most herbs), no ergosterol! apparently cholesterol in membranes

**Ascomycetes** (sac fungi)
- coenocytic haploids, with a transient dikaryotic state
- site of karyogamy and meiosis - **ascus** (pl. **asci**)  
- Production of macroscopic **sexual fruitbodies** (ascocarps, ascomata)
- Three basic forms: balls, flasks, and cups or Cleistothecia, Perithecia, Apothecia

Sometimes fruitbodies are within sterile tissue called a **Stoma**

Often many morphologically distinct asexual spore states - sometimes dispersed in different ways
- **Conidia** - an asexual spore produced externally
- **Asexual fruitbodies**: Pycnidia, Acervuli, sporodochia, synnemata

Many fungi are known only from their asexual state: **fungi imperfect or Deuteromycetes** (e.g. **Blackstain Leptographium wageneri**)

**Dual naming system**

Importance in forest ecosystems
- many pathogens - wilts, blue stains, cankers, root diseases, foliar diseases
- mycorrhizal symbionts - truffles!
- some wood decay fungi (**Xylaria, Daldinia**)  
- endophytes
- Mycoparasites (**Trichoderma**)  
- saprobes

**Basidiomycetes**
- Dikaryotic dominate life cycle, many have **clamp connections**
- Site of karyogamy and meiosis - **Basidium** (pl. Basidia)
Often produce macroscopic fruitbodies (Basidiocarps, basidiomes) resupinates, conks, mushrooms, and others

Multiple spore states less common (except in rusts), and often have a sexual function

**Types of fungal associations found in forest ecosystems**

- **Biotrophic symbionts of plants**
  - Obligate parasites - (e.g. rusts, powdery mildews)
  - mycorrhizae - many mushroom-forming basidiomycetes, some ascomycetes
  - Endophytes - mostly ascomycetes
- Necrotrophic and hemibiotrophic parasites of plants - most pathogens
- Primary saprobes - wood decay fungi
- Secondary saprobes - fermentation fungi
- Predators and parasites of microinvertebrates and insects.

**References**

see chapter 10 in Forest Health

This paper is way beyond anything you need to know for this class, but for anyone interested in Basidiomycota this is the most awesome paper I've seen in ages:


**Terms you will hear again and should know (especially terms in bold)**

- **Hypha(e):** a microscopic filamentous string of cells - the common cell type for most fungi.
- **mycelium** - all of the hyphae of an individual.
- **rhizomorph or cord** - a string-like macroscopic differentiated assemblage of hyphae; these are used for conducting of water and nutrients over long distances. (ex: Armillaria, and many other fungi, especially basidiomycetes)
- **sclerotium (pl: sclerotia)** - a harden, often darkly pigmented, aggregation of hyphae used to wait out adverse times. (ex: Rhizoctonia, Macrophomina)
- **conidium, (pl: conidia)** - an externally produced mitotically produced spore. The spore-forming cell is called a **conidiophore**.
**ascus** (pl. asci)- microscopic cell which is the site of meiosis in Ascomycetes, **ascospores** (typically 8 or 4) are produced internally within it. Fungi that produce these are in the phylum **Ascomycota**, and are often referred to by the former class name **ascomycetes**, which is now treated like a common name. Fruitbodies that produce asci can be called **ascocarps**.

**basidium** (pl. basidia)- microscopic cell which is the site of meiosis in Basidiomycetes. **Basidiospores** (typically 4) are produced externally on the basidium. Fungi that produce these are in the phylum **Basidiomycota**, and are often referred to by the former class name **basidiomycetes**, which is now treated like a common name. Fruitbodies that produce basidia can be called **basidiocarps**.

**fruitbody**, fruiting body, or sporocarp: a common name for any type of macroscopic structure that produces spores. The spores may be either mitotic or meiotically produced. Types of fruitbodies we will see include:

- **agarics**: fancy name for mushrooms produced by a basidiomycete in which the sporulating surface is on gills (or lamellae, if you want another technical term)

- **polypores**: a hard or at least leathery basidiocarp in which the spores are produced inside small tubes or pores. If the fruitbody is soft and mushroom-like it is then called a bolete, instead of a polypore.

- **conks**: common name for a harden polypore.

- **resupinate fruitbody**: a fruitbody, usually a basidiocarp, that is a thin, essentially two-dimensional crust-like structure; the sporulating surface is a exposed. (ex: *Phellinus weirii*)

- **gastromycete** - basidiocarps in which the spore are enclosed within the fruitbody. Examples include puff balls, false-truffles, and bird’s nest fungi.

- **tooth fungi** - basidiocarps in which the spores are produced on hanging tooth-like structures. Fungi that do this are sometimes put in the artificial family hydnaceae.

**Apothecia**: cup-like ascocarps. The ascomycetes that make apothecia are called **cup fungi**, or discomycetes. A **hysterothecium** is a special linear-shaped cup formed on needles of confers (e.g. *Lirula*, and other needle cast fungi).

**Perithecia** - an enclosed, typically flask-shaped ascocarp in which spores are released through an apical pore in the flask. Ascomycetes that make these are called **pyrenomycetes**. (ex: *Ophiostoma* - blue stains, dutch elm disease & *Cryphonectria* - chestnut blight).
Telomorph - The spore stage at which meiosis occurs (ex: basidiocarps, ascocarps)

Anamorph - The spore state which is produced mitotically (ex: all conidial stages). Fungi which are only known from their anamorphs are call Imperfect fungi or Deuteromycetes, this is not a monophyletic grouping.
### Generalizations about behavior of Basidiomycota, Ascomycota and Oomycota in Forest systems

<table>
<thead>
<tr>
<th></th>
<th>Basidiomycota (except rusts)</th>
<th>Rust fungi (also Basidiomycota)</th>
<th>Ascomycota</th>
<th>Oomycota</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meiotic stage (sexual,</td>
<td>Fruiting bodies often large and conspicuous, basidiospores often the main dispersal stage;</td>
<td>Fruiting body usually small, basidiospores often used to infect a different host, dispersal relatively local</td>
<td>Fruiting body usually small, in many species it may be rare or absent.</td>
<td>No fruiting bodies. Oospores small and inconspicuous; a resting stage that disperses primarily through time not space.</td>
</tr>
<tr>
<td>teleomorphic)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mitotic spores (asexual,</td>
<td>rare, usually used for genetic exchange, not dispersal</td>
<td>Usually abundant, often used for long-range dispersal</td>
<td>Usually abundant, and often the primary inoculum for dispersal and colonization.</td>
<td>abundant. The most important stage for infection. (zoospores, chlamydospores, whole sporangia)</td>
</tr>
<tr>
<td>anamorphic)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Size of individual mycelia/ presence of rhizomorphs or mycelia cords</td>
<td>small to very large (&gt; sq mile) - Rhizomorphs and cords common</td>
<td>small always localized in a single host - But single genotypes can be dispersed over continents by mitotic spores; Rhizomorphs and cords absent</td>
<td>small to moderate - localized in a single host or unit resource (like a log). Rhizomorphs and cords present rare</td>
<td>basically small, but can cause large root disease centers probably by locally dispersed spores rather than mycelial growth, Rhizomorphs and cords absent</td>
</tr>
<tr>
<td>Wood decay</td>
<td>Causal agent for most decay</td>
<td>None</td>
<td>few important decays - Hypoxylon and Xylaria are the main exceptions</td>
<td>Phytophthora cinnamomi apparently decays small to moderate small to moderate roots, but otherwise this behavior is rare.</td>
</tr>
<tr>
<td>Ectomycorrhizal</td>
<td>Most EM fungi are basidiomycetes</td>
<td>None</td>
<td>Some important EM fungi (e.g. truffles)</td>
<td>None</td>
</tr>
<tr>
<td>interactions</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Root diseases</td>
<td>Most root diseases, virtually all that involve decay are basidiomycetes</td>
<td>None</td>
<td>A few important root diseases (e.g. Blackstain), these usually behave as wilts and do not cause decay.</td>
<td>Phytophthora cinnamomi and others cause serious root diseases; Phytophthora species cause damping off and many cryptic sublethal root disease.</td>
</tr>
<tr>
<td>Foliage diseases</td>
<td>almost none</td>
<td>very common</td>
<td>Common - all needle cast and needle</td>
<td>Many in tropical setting, Phytophthora</td>
</tr>
</tbody>
</table>

### Size of individual mycelia:
- Basidiomycota: small to very large (> sq mile), Rhizomorphs and cords common.
- Rust fungi: small always localized in a single host.
- Ascomycota: small to moderate, localized in a single host or unit resource.
- Oomycota: basically small, but can cause large root disease centers probably by locally dispersed spores rather than mycelial growth.

### Wood decay:
- Basidiomycota: Causal agent for most decay.
- Rust fungi: None.
- Ascomycota: few important decays (Hypoxylon and Xylaria).
- Oomycota: Phytophthora cinnamomi apparently decays small to moderate roots, but otherwise this behavior is rare.

### Ectomycorrhizal interactions:
- Basidiomycota: Most EM fungi are basidiomycetes.
- Oomycota: None.

### Root diseases:
- Basidiomycota: Most root diseases, virtually all that involve decay are basidiomycetes.
- Ascomycota: A few important root diseases (e.g. Blackstain).
- Oomycota: Phytophthora cinnamomi and others cause serious root diseases; Phytophthora species cause damping off and many cryptic sublethal root disease.

### Foliage diseases:
- Almost none for Basidiomycota.
- Very common for Ascomycota.
- Common - all needle cast and needle for Oomycota.
<table>
<thead>
<tr>
<th>Canker diseases</th>
<th>Some canker rots</th>
<th>Many important cankers of pines</th>
<th><strong>Most cankers</strong> diseases</th>
<th><strong>Phytophthora ramorum</strong> and others can cause cankers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insect vectoring</td>
<td>Rare, but some are vectored by bark beetles (e.g. <em>Peniophora</em>, and Western and Southern pine beetles) or wood wasps (e.g. <em>Amylostereum</em>)</td>
<td>Used for genetic exchange by most rusts (i.e., the spermatial stage)</td>
<td><strong>Most of the fungi vectored by bark beetles and ambrosial beetles</strong> are members of the Ascomycota (e.g. blues stains, black stain, ambrosia fungi)</td>
<td>None</td>
</tr>
</tbody>
</table>

Blight are ascomycetes.

Ramorum is a temperate example.