Chapter 12
The Eukaryotes: Fungi, Algae, Protozoa, and Helminths

The Fungi

- Eukaryotic
- Aerobic or facultatively anaerobic
- Chemoheterotrophic
- Most are decomposers, but a few are parasites
- Mycology is the study of fungi
- Number of serious fungal infections is increasing

List the defining characteristics of fungi.
Differentiate between sexual and asexual reproduction, and describe each of these processes in fungi.

Fungi

<table>
<thead>
<tr>
<th>Kingdom</th>
<th>Fungal</th>
<th>Algal</th>
<th>Protistan</th>
<th>Helminth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nutrition type</td>
<td>Chemo-gram</td>
<td>Chemo-gram</td>
<td>Chemo-gram</td>
<td>Chemo-gram</td>
</tr>
<tr>
<td>Multicellular</td>
<td>All except yeast</td>
<td>Some</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Cellular structure</td>
<td>Fungi</td>
<td>Algae</td>
<td>Protozoa</td>
<td>Helminth</td>
</tr>
<tr>
<td>Spore formation method</td>
<td>Asexual</td>
<td>Sexual and asexual</td>
<td>Sexual and asexual</td>
<td>Sexual and asexual</td>
</tr>
<tr>
<td>Characteristics</td>
<td>Hyphae</td>
<td>Mycelium</td>
<td>Mycelium</td>
<td>Mycelium</td>
</tr>
</tbody>
</table>

Characteristics of fungal hyphae:
- Separated hyphae have cross-walls or septa
- Coenocytic hyphae lack septa
- Hyphae grow by elongating at tips

Mycology: The Study of Fungi

<table>
<thead>
<tr>
<th>Organism</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cell type</td>
<td>Eukaryotic</td>
</tr>
<tr>
<td>Cell wall</td>
<td>Chitin</td>
</tr>
<tr>
<td>Spore</td>
<td>Asexual</td>
</tr>
<tr>
<td>Metabolism</td>
<td>Heterotrophic</td>
</tr>
<tr>
<td>Saccharolytic enzymes</td>
<td>Chitin, cellulose</td>
</tr>
</tbody>
</table>


Molds

- Aerial (with reproductive spores) and vegetative hyphae
- The fungal thallus consists of hyphae; a mass of hyphae is a mycelium.
Yeast – various stages of budding

- Unicellular fungi
- Fission yeasts divide symmetrically
- Budding yeasts divide asymmetrically

Fungal Dimorphism

- Pathogenic dimorphic fungi are yeastlike at 37°C and moldlike at 25°C
- On agar surface, *Mucor rouxii* exhibits yeastlike growth; in agar it is moldlike

Conidiospores: Representative asexual spores

- Fungi classified by type of sexual spore
- Sexual spores usually produced in response to special changes in environment

Conidia arranged in chains on *Aspergillus flavus*

Fungal Life Cycle

Life cycle of *Rhizopus*, a zygomycete: produces asexually usually

Fungal Diseases (mycoses)

- Systemic mycoses: Deep within body
- Subcutaneous mycoses: Beneath the skin
- Cutaneous mycoses: Affect hair, skin, nails
- Superficial mycoses: Localized, e.g., hair shafts
- Opportunistic mycoses: Caused by normal microbiota or fungi that are normally systemic, but can infect any tissue
**Asexual spores**

- Sporangiospore
- Conidiospore
- Arthrospore
- Blastoconidium
- Chlamydospore

**Sexual reproduction**

- Plasmogamy: Haploid donor cell nucleus (+) penetrates cytoplasm of recipient cell (−)
- Karyogamy: + and − nuclei fuse
- Meiosis: Diploid nucleus produces haploid nuclei (sexual spores)

**Sexual spores**

- Zygospor: Fusion of haploid cells produces one zygospore

**Sexual spores**

- Ascospore: Formed in a sac (ascus)

**Sexual spores**

- Basidiospore: Formed externally on a pedestal (basidium)
**Zygomycota**

- Conjugation fungi. Coenocytic. Produce sporangiospores and zygospores.
  - *Rhizopus, Mucor* (Opportunistic, systemic mycoses)

**Ascomycota**

- Sac fungi. Septate. Produce ascospores and frequently conidiospores.
  - *Aspergillus* (opportunistic, systemic mycosis)
  - *Blastomyces dermatitidis, Histoplasma capsulatum* (systemic mycoses)
  - *Microsporum, Trichophyton* (cutaneous mycoses)

**Basidiomycota**

- Club fungi. Septate. Produce basidiospores and sometimes conidiospores.
  - *Cryptococcus neoformans* (systemic mycosis)
Anamorphs

- **Teleomorphic fungi:**
  - Produce sexual and asexual spores.
- **Anamorphic fungi:**
  - Produce asexual spores only.
  - rRNA sequencing places most in Ascomycota, a few are Basidiomycota
  - **Penicillium**
  - **Sporothrix** (subcutaneous mycosis)
  - **Stachybotrys, Coccidioides, Pneumocystis** (systemic mycoses)
  - **Candida albicans** (Cutaneous mycoses)

**Identify two beneficial and two harmful effects of fungi.**

<table>
<thead>
<tr>
<th>Fungi</th>
<th>Positive Effects</th>
<th>Negative Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saccharomyces</td>
<td>Bread, wine, beer</td>
<td>Food spoilage</td>
</tr>
<tr>
<td>Trichoderma</td>
<td>Cellulose used for juices and fabric</td>
<td></td>
</tr>
<tr>
<td>Taxomyces</td>
<td>Taxol production</td>
<td>Carbohydrate production (chestnut brown)</td>
</tr>
<tr>
<td>Entomophaga</td>
<td>Gypsy moth control</td>
<td></td>
</tr>
</tbody>
</table>

**Economic Effects of Fungi**

<table>
<thead>
<tr>
<th>Fungi</th>
<th>Type of Mycetoma</th>
<th>Clinical Notes</th>
<th>Page Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lichinates</td>
<td>Systemic</td>
<td>Opportunistic pathogen</td>
<td>688</td>
</tr>
<tr>
<td>Mucorales</td>
<td>Systemic</td>
<td>Opportunistic pathogen</td>
<td>678</td>
</tr>
<tr>
<td>Ureals</td>
<td>Systemic</td>
<td>Opportunistic pathogen</td>
<td>687</td>
</tr>
<tr>
<td>Sclerotinia</td>
<td>Systemic</td>
<td>Infection</td>
<td>687</td>
</tr>
<tr>
<td>Soil</td>
<td>Systemic</td>
<td>Infection</td>
<td>634</td>
</tr>
<tr>
<td>Soil, animals</td>
<td>Cutaneous</td>
<td>Tissue damage</td>
<td>606</td>
</tr>
<tr>
<td>Soil, animals</td>
<td>Cutaneous</td>
<td>Tissue necrosis</td>
<td>605</td>
</tr>
<tr>
<td>Soil, animals</td>
<td>Cutaneous</td>
<td>Tissue growth</td>
<td>605</td>
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<td>Soil</td>
<td>Systemic</td>
<td>Infection</td>
<td>634</td>
</tr>
<tr>
<td>Human normal</td>
<td>Cutaneous, systemic, opportunistic, opportunistic</td>
<td>605, 752</td>
<td></td>
</tr>
<tr>
<td>Mycobacterium</td>
<td>Systemic</td>
<td>Opportunistic pathogen</td>
<td>695</td>
</tr>
<tr>
<td>Brittigenes</td>
<td>Systemic</td>
<td>Infection</td>
<td>691</td>
</tr>
<tr>
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<td>Infection</td>
<td>691</td>
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**Lichens**

Describe the roles of the fungus and the alga in a lichen.

- Mutualistic combination of an alga (or cyanobacterium) & fungus
- Alga produces and secretes carbohydrates, fungus provides holdfast
- Lichens colonize habitats unsuitable for alga or fungus alone
- Lichens classified by morphology: crustose, foliote, or fruticose

**Economic Effects of Fungi**

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<td>Gypsy moth control</td>
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Lichens

- List the distinguishing characteristics of lichens, and describe their nutritional needs.

The Algae
- Eukaryotic
- Unicellular, filamentous, or multicellular (thallic)
- Most are photautotrophs and aquatic
- Produce 30 – 50 % of world’s oxygen
- Reproduce asexually by cell division and fragmentation
- Classified according to structures and pigments
- Primary producers in the aquatic food chain

The Algae

- Eukaryotic
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Algae

- List the defining characteristics of algae.
- List the outstanding characteristics of the five divisions of algae discussed in this chapter.

Algae and their habitats

Green Algae

- Brown algae (kelp)
- Cellulose + alginic acid cell walls
- Multicellular
- Chlorophyll a and c, xanthophylls
- Store carbohydrates
- Harvested for alginate

Phaeophyta

- Brown algae (kelp)
- Cellulose + alginic acid cell walls
- Multicellular
- Chlorophyll a and c, xanthophylls
- Store carbohydrates
- Harvested for alginate
**Rhodophyta**
- Red algae
- Cellulose cell walls
- Most multicellular
- Chlorophyll $a$ and $d$, phycobiliproteins
- Store glucose polymer
- Harvested for agar and carrageenan

**Chlorophyta**
- Green algae
- Cellulose cell walls
- Unicellular or multicellular
- Chlorophyll $a$ and $b$
- Store glucose polymer
- Gave rise to plants

**Bacillariophyta**
- Diatoms
- Pectin and silica cell walls
- Unicellular
- Chlorophyll $a$ and $c$, carotene, xanthophylls
- Store oil
- Fossilized diatoms formed oil
- Produce domoic acid

**Dinoflagellata**
- Dinoflagellates
- Cellulose in plasma membrane
- Unicellular
- Chlorophyll $a$ and $c$, carotene, xanthins
- Store starch
- Some are symbionts in marine animals
- Neurotoxins cause paralytic shellfish poisoning

**Oomycota**
- Water molds
- Cellulose cell walls
- Multicellular
- Chemoheterotrophic
- Produce zoospores
- Decomposers and plant parasites
  - *Phytophthora infestans* responsible for Irish potato blight
  - *P. cinnamomi* infects *Eucalyptus*
  - *P. ramorum* causes sudden oak death
The Protozoa

Protozoa: Conjugation in ciliate Paramecium

- Eukaryotic – soil, water, microbiota in animals
- Unicellular
- Chemoheterotrophs
- Vegetative form is a trophozoite
- Asexual reproduction by fission, budding, or schizogony
- Sexual reproduction by conjugation
- Some produce cysts for survival

Archaezoa

- No mitochondria
- Multiple flagella
- Giardia lamblia
- Trichomonas vaginalis (no cyst stage)

Microspora

- No mitochondria or microtubules
- Cause diarrhea in AIDS patients
- Non-motile
- Intracellular parasites
- Nosema

Rhizopoda (amoebas)

- Move by pseudopods
- Entamoeba
- Acanthamoeba

Entamoeba histolytica – ingested red blood cells diagnostic for this
Apicomplexa

- Apical organelles for penetrating host tissue
- Nonmotile
- Intracellular parasites
- Complex life cycles
- *Plasmodium* (in two slides)
- *Babesia*
- *Cryptosporidium* (next slide)
- *Cyclospora*

Cryptosporidium

Ciliophora (ciliates)

- Move by cilia
- Complex cells
- *Paramecium* has specialized structures (mouth for ingestion, anal pore, contractile vacuoles)
- *Balantidium coli* is the only human parasite
- *Vorticella* attaches by base of its stalk

Euglenozoa

- Move by flagella
- Photoautotrophs
  - Euglenoids
- Chemoheterotrophs
  - *Naegleria*
    - Flagellated and amoeboid forms, meningoencephalitis
  - *Trypanosoma*
    - Undulating membrane, transmitted by vectors
  - *Leishmania*
    - Flagellated form in sand fly vector, ovoid form in vertebrate host
Cellular Slime Molds

- Cellular slime molds
  - Resemble amoebas, ingest bacteria by phagocytosis
  - Cells aggregate into stalked fruiting body.
  - Some cells become spores

- Plasmodial slime molds
  - Multinucleated large cells
  - Cytoplasm separates into stalked sporangia
  - Nuclei undergo meiosis and form uninucleate haploid spores
Helminths (parasitic worms)
- Eukaryotic
- Multicellular animals
- Chemoheterotrophic
- Kingdom: Animalia
  - Phylum: Platyhelminthes (flatworms)
    - Class: Trematodes (flukes)
    - Class: Cestodes (tapeworms)
  - Phylum: Nematodes (roundworms)
- Adult stage parasitic helminth found in definitive host
- Larval stage found in intermediate host

Trematodes: Flukes
Heavy infestations may block bile ducts from the liver

Humans as Definitive Host (Lung Fluke)
Differentiate between an intermediate host and a definitive host.

Humans as Intermediate Host
Tapeworm Echinococcus granulosus, in intestines of canines

Cestodes: Adult Tapeworm
Humans serve as definitive host for beef tapeworm, and cattle are the intermediate host
Humans serve a definitive host and can be intermediate host for pork tapeworm
Humans serve as intermediate host for Echinococcus granulosus, definitive hosts are canines spp.

Nematodes: Eggs Infective for Humans
- Roundworms have a complete digestive system.
- Pinworm Enterobius vermicularis, eggs deposited by female on perianal skin at night.
**Hookworm**

- *Necator americanus* – free-living larvae inhabit soil and infect definitive human host by penetrating skin

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**Nematodes: Larvae Infective for Humans**

- *Necator americanus* – free-living larvae inhabit soil and infect definitive human host by penetrating skin

---

**Table 12.6: Representative Parasitic Helminths**

<table>
<thead>
<tr>
<th>Phylum</th>
<th>Class</th>
<th>Human Parasite</th>
<th>Intermediate Host</th>
<th>Definitive Host Site</th>
<th>Disease</th>
<th>Location in Humans</th>
<th>Figure Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nematoda</td>
<td>Ascarina</td>
<td>Ascaris lumbricoides</td>
<td>Adult - small intestine</td>
<td>Eggs ingested</td>
<td>Ascaroids</td>
<td>Small intestine</td>
<td>21.23</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Adult - large intestine</td>
<td>Eggs ingested</td>
<td>Ascaroids</td>
<td>Large intestine</td>
<td>12.29</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Adult - small intestine</td>
<td>Eggs ingested</td>
<td>Ascaroids</td>
<td>Small intestine</td>
<td>12.30</td>
</tr>
<tr>
<td></td>
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<td></td>
<td>Adult - large intestine</td>
<td>Eggs ingested</td>
<td>Ascaroids</td>
<td>Large intestine</td>
<td>12.31</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Adult - small intestine</td>
<td>Eggs ingested</td>
<td>Ascaroids</td>
<td>Small intestine</td>
<td>12.32</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Adult - large intestine</td>
<td>Eggs ingested</td>
<td>Ascaroids</td>
<td>Large intestine</td>
<td>12.33</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Adult - small intestine</td>
<td>Eggs ingested</td>
<td>Ascaroids</td>
<td>Small intestine</td>
<td>12.34</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Adult - large intestine</td>
<td>Eggs ingested</td>
<td>Ascaroids</td>
<td>Large intestine</td>
<td>12.35</td>
</tr>
</tbody>
</table>

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**Defend arthropod vector.**

- **Table 12.7: Important Arthropod Vectors of Human Diseases**

<table>
<thead>
<tr>
<th>Arthropod</th>
<th>Order</th>
<th>Vector</th>
<th>Disease</th>
<th>Figure Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insects</td>
<td>Lepidoptera</td>
<td>Mosquitoes</td>
<td>Dengue fever</td>
<td>12.92</td>
</tr>
<tr>
<td></td>
<td>Diptera</td>
<td>Ticks</td>
<td>Lyme disease</td>
<td>12.32</td>
</tr>
<tr>
<td></td>
<td>Arachnida</td>
<td>Flies</td>
<td>Rabies</td>
<td>12.53</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mosquitoes</td>
<td>Malaria</td>
<td>12.54</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fleas</td>
<td>Relapsing fever</td>
<td>12.55</td>
</tr>
</tbody>
</table>

---

**Arthropods as Vectors**

- Define arthropod vector.

- List the characteristics of the three groups of parasitic helminths, and give an example of each.

  - Kingdom: Animalia
  - Phylum: Arthropoda (exoskeleton, jointed legs)
    - Class: Insecta (6 legs)
    - Lice, fleas, mosquitos
    - Class: Arachnida (8 legs)
    - Mites and ticks
    - May transmit diseases called vectors