5.3: Fungi

Skills to Develop

- Explain why the study of fungi such as yeast and molds is within the discipline of microbiology
- Describe the unique characteristics of fungi
- Describe examples of asexual and sexual reproduction of fungi
- Compare the major groups of fungi in this chapter, and give examples of each
- Identify examples of the primary causes of infections due to yeasts and molds
- Identify examples of toxin-producing fungi
- Classify fungal organisms according to major groups

The fungi comprise a diverse group of organisms that are heterotrophic and typically saprozoic. In addition to the well-known macroscopic fungi (such as mushrooms and molds), many unicellular yeasts and spores of macroscopic fungi are microscopic. For this reason, fungi are included within the field of microbiology.

Fungi are important to humans in a variety of ways. Both microscopic and macroscopic fungi have medical relevance, with some pathogenic species that can cause mycoses (illnesses caused by fungi). Some pathogenic fungi are opportunistic, meaning that they mainly cause infections when the host’s immune defenses are compromised and do not normally cause illness in healthy individuals. Fungi are important in other ways. They act as decomposers in the environment, and they are critical for the production of certain foods such as cheeses. Fungi are also major sources of antibiotics, such as penicillin from the fungus *Penicillium*.

**Characteristics of Fungi**

Fungi have well-defined characteristics that set them apart from other organisms. Most multicellular fungal bodies, commonly called molds, are made up of filaments called hyphae. Hyphae can form a tangled network called a mycelium.
and form the thallus (body) of fleshy fungi. Hyphae that have walls between the cells are called septate hyphae; hyphae that lack walls and cell membranes between the cells are called nonseptate or coenocytic hyphae). (Figure \(\PageIndex{1}\)).

![Image](https://bio.libretexts.org/Courses/Portland_Community_College/Cascade_Microbiology/05%3A_The_Eukaryotes_of_Microbiol…)

**Figure \(\PageIndex{1}\):** Multicellular fungi (molds) form hyphae, which may be septate or nonseptate. Unicellular fungi (yeasts) cells form pseudohyphae from individual yeast cells.

In contrast to molds, yeasts are unicellular fungi. The budding yeasts reproduce asexually by budding off a smaller daughter cell; the resulting cells may sometimes stick together as a short chain or pseudohypha (Figure \(\PageIndex{1}\)). *Candida albicans* is a common yeast that forms pseudohyphae; it is associated with various infections in humans, including vaginal yeast infections, oral thrush, and candidiasis of the skin.

Some fungi are dimorphic, having more than one appearance during their life cycle. These dimorphic fungi may be able to appear as yeasts or molds, which can be important for infectivity. They are capable of changing their appearance in response to environmental changes such as nutrient availability or fluctuations in temperature, growing as a mold, for example, at 25 °C (77 °F), and as yeast cells at 37 °C (98.6 °F). This ability helps dimorphic fungi to survive in diverse environments. *Histoplasma capsulatum*, the pathogen that causes histoplasmosis, a lung infection, is an example of a dimorphic fungus (Figure \(\PageIndex{2}\)).

![Image](https://bio.libretexts.org/Courses/Portland_Community_College/Cascade_Microbiology/05%3A_The_Eukaryotes_of_Microbiol…)

**Figure \(\PageIndex{2}\):** *Histoplasma capsulatum* is a dimorphic fungus that grows in soil exposed to bird feces or bat feces (guano) (top left). It can change forms to survive at different temperatures. In the outdoors, it typically grows as a mycelium (as shown in the micrograph, bottom left), but when the spores are inhaled (right), it responds to the high internal temperature of the body (37 °C [98.6 °F]) by turning into a yeast that can multiply in the lungs, causing the chronic lung disease histoplasmosis. (credit: modification of work by Centers for Disease Control and Prevention)

There are notable unique features in fungal cell walls and membranes. Fungal cell walls contain chitin, as opposed to the cellulose found in the cell walls of plants and many protists. Additionally, whereas animals have cholesterol in their...
cell membranes, fungal cell membranes have different sterols called ergosterols. Ergosterols are often exploited as targets for antifungal drugs.

Fungal life cycles are unique and complex. Fungi reproduce sexually either through cross- or self-fertilization. Haploid fungi form hyphae that have gametes at the tips. Two different mating types (represented as “+ type” and “– type”) are involved. The cytoplasms of the + and – type gametes fuse (in an event called plasmogamy), producing a cell with two distinct nuclei (a dikaryotic cell). Later, the nuclei fuse (in an event called karyogamy) to create a diploid zygote. The zygote undergoes meiosis to form spores that germinate to start the haploid stage, which eventually creates more haploid mycelia (Figure 3). Depending on the taxonomic group, these sexually produced spores are known as zygospores (in Zygomycota), ascospores (in Ascomycota), or basidiospores (in Basidiomycota) (Figure 4).

Fungi may also exhibit asexual reproduction by mitosis, mitosis with budding, fragmentation of hyphae, and formation of asexual spores by mitosis. These spores are specialized cells that, depending on the organism, may have unique characteristics for survival, reproduction, and dispersal. Fungi exhibit several types of asexual spores and these can be important in classification.

Figure 3: Zygomycetes have sexual and asexual life cycles. In the sexual life cycle, + and – mating types conjugate to form a zygosporangium.
Figure \(\PageIndex{4}\): These images show asexually produced spores. (a) This brightfield micrograph shows the release of spores from a sporangium at the end of a hypha called a sporangiophore. The organism is a Mucor sp. fungus, a mold often found indoors. (b) Sporangia grow at the ends of stalks, which appear as the white fuzz seen on this bread mold, Rhizopus stolonifer. The tips of bread mold are the dark, spore-containing sporangia. (credit a: modification of work by Centers for Disease Control and Prevention; credit b right: modification of work by “Andrew”/Flickr)

Exercise \(\PageIndex{1}\))

Is a dimorphic fungus a yeast or a mold? Explain.

**Fungal Diversity**

The fungi are very diverse, comprising seven major groups. Not all of the seven groups contain pathogens. Some of these groups are generally associated with plants and include plant pathogens. For example, Urediniomycetes and Ustilagomycetes include the plant rusts and smuts, respectively. These form reddish or dark masses, respectively, on plants as rusts (red) or smuts (dark). Some species have substantial economic impact because of their ability to reduce crop yields. Glomeromycota includes the mycorrhizal fungi, important symbionts with plant roots that can promote plant growth by acting like an extended root system. The Glomeromycota are obligate symbionts, meaning that they can only survive when associated with plant roots; the fungi receive carbohydrates from the plant and the plant benefits from the increased ability to take up nutrients and minerals from the soil. The Chytridiomycetes (chytrids) are small fungi, but are extremely ecologically important. Chytrids are generally aquatic and have flagellated, motile gametes; specific types are implicated in amphibian declines around the world. Because of their medical importance, we will focus on Zygomycota, Ascomycota, Basidiomycota, and Microsporidia. Figure \(\PageIndex{9}\)) summarizes the characteristics of these medically important groups of fungi.

The Zygomycota (zygomycetes) are mainly saprophytes with coenocytic hyphae and haploid nuclei. They use sporangiospores for asexual reproduction. The group name comes from the zygospores that they use for sexual reproduction (Figure \(\PageIndex{3}\)), which have hard walls formed from the fusion of reproductive cells from two individuals. Zygomycetes are important for food science and as crop pathogens. One example is *Rhizopus stolonifer* (Figure \(\PageIndex{4}\)), an important bread mold that also causes rice seedling blight. *Mucor* is a genus of fungi that can potentially cause necrotizing infections in humans, although most species are intolerant of temperatures found in mammalian bodies (Figure \(\PageIndex{4}\)).

The Ascomycota include fungi that are used as food (edible mushrooms, morels, and truffles), others that are common causes of food spoilage (bread molds and plant pathogens), and still others that are human pathogens. Ascomycota may have septate hyphae and cup-shaped fruiting bodies called asccocarps. Some genera of Ascomycota use sexually produced ascospores as well as asexual spores called conidia, but sexual phases have not been discovered or described for others. Some produce an ascus containing ascospores within an asccocarp (Figure \(\PageIndex{5}\)).

Examples of the Ascomycota include several bread molds and minor pathogens, as well as species capable of causing more serious mycoses. Species in the genus *Aspergillus* are important causes of allergy and infection, and are useful in research and in the production of certain fermented alcoholic beverages such as Japanese *sake*. The fungus *Aspergillus flavus*, a contaminant of nuts and stored grains, produces an aflatoxin that is both a toxin and the most potent known
natural carcinogen. *Neurospora crassa* is of particular use in genetics research because the spores produced by meiosis are kept inside the ascus in a row that reflects the cell divisions that produced them, giving a direct view of segregation and assortment of genes (Figure \(\PageIndex{6}\)). *Penicillium* produces the antibiotic penicillin (Figure \(\PageIndex{5}\)).

Many species of ascomycetes are medically important. A large number of species in the genera *Trichophyton*, *Microsporum*, and *Epidermophyton* are dermatophytes, pathogenic fungi capable of causing skin infections such as athlete’s foot, jock itch, and ringworm. *Blastomyces dermatitidis* is a dimorphic fungus that can cause blastomycosis, a respiratory infection that, if left untreated, can become disseminated to other body sites, sometimes leading to death. Another important respiratory pathogen is the dimorphic fungus *Histoplasma capsulatum* (Figure \(\PageIndex{2}\)), which is associated with birds and bats in the Ohio and Mississippi river valleys. *Coccidioides immitis* causes the serious lung disease Valley fever. *Candida albicans*, the most common cause of vaginal and other yeast infections, is also an ascomycete fungus; it is a part of the normal microbiota of the skin, intestine, genital tract, and ear (Figure \(\PageIndex{5}\)). Ascomycetes also cause plant diseases, including ergot infections, Dutch elm disease, and powdery mildews.

*Saccharomyces* yeasts, including the baker’s yeast *S. cerevisiae*, are unicellular ascomycetes with haploid and diploid stages (Figure \(\PageIndex{7}\)). This and other *Saccharomyces* species are used for brewing beer.

*Figure \(\PageIndex{5}\):* (a) This brightfield micrograph shows ascospores being released from asci in the fungus *Talaromyces flavus* var. *flavus*. (b) This electron micrograph shows the conidia (spores) borne on the conidiophore of *Aspergillus*, a type of toxic fungus found mostly in soil and plants. (c) This brightfield micrograph shows the yeast *Candida albicans*, the causative agent of candidiasis and thrush. (credit a, b, c: modification of work by Centers for Disease Control and Prevention)
Figure \(\PageIndex{6}\): These ascospores, lined up within an ascus, are produced sexually. (credit: Peter G. Werner)

Figure \(\PageIndex{7}\): The life cycle of an ascomycete is characterized by the production of asci during the sexual phase. The haploid phase is the predominant phase of the life cycle.

The Basidiomycota (basidiomycetes) are fungi that have basidia (club-shaped structures) that produce basidiospores (spores produced through budding) within fruiting bodies called basidiocarps (Figure \(\PageIndex{8}\)). They are important as decomposers and as food. This group includes rusts, stinkhorns, puffballs, and mushrooms. Several species are of particular importance. Cryptococcus neoformans, a fungus commonly found as a yeast in the environment, can cause serious lung infections when inhaled by individuals with weakened immune systems. The edible meadow mushroom, *Agricus campestris*, is a basidiomycete, as is the poisonous mushroom *Amanita phalloides*, known
as the death cap. The deadly toxins produced by *A. phalloides* have been used to study transcription.

**Figure\PageIndex{8}**: The life cycle of a basidiomycete alternates a haploid generation with a prolonged stage in which two nuclei (dikaryon) are present in the hyphae.

Finally, the Microsporidia are unicellular fungi that are obligate intracellular parasites. They lack mitochondria, peroxisomes, and centrioles, but their spores release a unique polar tubule that pierces the host cell membrane to allow the fungus to gain entry into the cell. A number of microsporidia are human pathogens, and infections with microsporidia are called microsporidiosis. One pathogenic species is *Enterocystozoa bieneusi*, which can cause symptoms such as diarrhea, cholecystitis (inflammation of the gall bladder), and in rare cases, respiratory illness.
### Select Groups of Fungi

<table>
<thead>
<tr>
<th>Group</th>
<th>Characteristics</th>
<th>Examples</th>
<th>Medically Important Species</th>
<th>Image</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ascomycota</td>
<td>Septate hyphae&lt;br&gt;Ascus with asci and ascospores&lt;br&gt;Conidia&lt;br&gt;Spores</td>
<td>Cup fungi&lt;br&gt;Edible mushrooms&lt;br&gt;Morels&lt;br&gt;Truffles&lt;br&gt;Neurospora&lt;br&gt;Penicillium</td>
<td>Aspergillus spp.&lt;br&gt;Trichophyton spp.&lt;br&gt;Micromonospora spp.&lt;br&gt;Epidermophyton spp.&lt;br&gt;Blastomyces dermatitidis&lt;br&gt;Histoplasma capsulatum</td>
<td><img src="image" alt="Aspergillus niger" /></td>
</tr>
<tr>
<td>Basidiomycota</td>
<td>Basidia produce basidiospores in a basidiolep&lt;br&gt;Club fungi&lt;br&gt;Rusts&lt;br&gt;Stinkhorns&lt;br&gt;Puffballs&lt;br&gt;Mushrooms&lt;br&gt;Cryptococcus neoformans&lt;br&gt;Amanita phalloides</td>
<td></td>
<td>Cryptococcus neoformans</td>
<td><img src="image" alt="Amanita phalloides" /></td>
</tr>
<tr>
<td>Microsporidia</td>
<td>Lack mitochondria, peroxisomes, and plastids&lt;br&gt;Spores produce a polar tube</td>
<td>Enterocytozoon bieneusi</td>
<td>Enteroctozae bieneusi</td>
<td><img src="image" alt="Microsporidia (unidentified)" /></td>
</tr>
<tr>
<td>Zygomycota</td>
<td>Mainly saprophytes&lt;br&gt;Coenocytic hyphae&lt;br&gt;Haptid nuclei&lt;br&gt;Zygospores</td>
<td>Rhizopus stolonifera</td>
<td>Macrococcus spp.</td>
<td><img src="image" alt="Rhizopus sp." /></td>
</tr>
</tbody>
</table>

**Figure \(\PageIndex{9}\):** (credit “Ascomycota”: modification of work by Dr. Lucille Georg, Centers for Disease Control and Prevention; credit “Microsporidia”: modification of work by Centers for Disease Control and Prevention)

**Exercise \(\PageIndex{2}\)**

Which group of fungi appears to be associated with the greatest number of human diseases?

**EUKARYOTIC PATHOGENS IN EUKARYOTIC HOSTS**

When we think about antimicrobial medications, antibiotics such as penicillin often come to mind. Penicillin and related antibiotics interfere with the synthesis of peptidoglycan cell walls, which effectively targets bacterial cells. These antibiotics are useful because humans (like all eukaryotes) do not have peptidoglycan cell walls.

Developing medications that are effective against eukaryotic cells but not harmful to human cells is more difficult. Despite huge morphological differences, the cells of humans, fungi, and protists are similar in terms of their ribosomes, cytoskeletons, and cell membranes. As a result, it is more challenging to develop medications that target protozoans and fungi in the same way that antibiotics...
Fungicides have relatively limited modes of action. Because fungi have ergosterols (instead of cholesterol) in their cell membranes, the different enzymes involved in sterol production can be a target of some medications. The azole and morpholine fungicides interfere with the synthesis of membrane sterols. These are used widely in agriculture (fenpropimorph) and clinically (e.g., miconazole). Some antifungal medications target the chitin cell walls of fungi. Despite the success of these compounds in targeting fungi, antifungal medications for systemic infections still tend to have more toxic side effects than antibiotics for bacteria.

Sarah is relieved the ringworm is not an actual worm, but wants to know what it really is. The physician explains that ringworm is a fungus. He tells her that she will not see mushrooms popping out of her skin, because this fungus is more like the invisible part of a mushroom that hides in the soil. He reassures her that they are going to get the fungus out of her too.

The doctor cleans and then carefully scrapes the lesion to place a specimen on a slide. By looking at it under a microscope, the physician is able to confirm that a fungal infection is responsible for Sarah’s lesion. In Figure 10, it is possible to see macro- and microconidia in Trichophyton rubrum. Cell walls are also visible. Even if the pathogen resembled a helminth under the microscope, the presence of cell walls would rule out the possibility because animal cells lack cell walls.

The doctor prescribes an antifungal cream for Sarah’s mother to apply to the ringworm. Sarah’s mother asks, “What should we do if it doesn’t go away?”

Exercise

Can all forms of ringworm be treated with the same antifungal medication?
**Figure\PageIndex{10}**: This micrograph shows hyphae (macroconidium) and microconidia of Trichophyton rubrum, a dermatophyte responsible for fungal infections of the skin. (credit: modification of work by Centers for Disease Control and Prevention)

**Key Concepts and Summary**

- The fungi include diverse saprotrophic eukaryotic organisms with chitin cell walls
- Fungi can be unicellular or multicellular; some (like yeast) and fungal spores are microscopic, whereas some are large and conspicuous
- Reproductive types are important in distinguishing fungal groups
- Medically important species exist in the four fungal groups Zygomycota, Ascomycota, Basidiomycota, and Microsporidia
- Members of Zygomycota, Ascomycota, and Basidiomycota produce deadly toxins
- Important differences in fungal cells, such as ergosterols in fungal membranes, can be targets for antifungal medications, but similarities between human and fungal cells make it difficult to find targets for medications and these medications often have toxic adverse effects

**Multiple Choice**

Mushrooms are a type of which of the following?

- A. conidia
- B. ascus
- C. polar tubule
- D. basidiocarp

- D

Which of the following is the most common cause of human yeast infections?

- A. Candida albicans
- B. Blastomyces dermatitidis
- C. Cryptococcus neoformans
- D. Aspergillus fumigatus

- A

Which of the following is an ascomycete fungus associated with bat droppings that can cause a respiratory infection if inhaled?

- A. Candida albicans
B. Histoplasma capsulatum  
C. Rhizopus stolonifera  
D. Trichophyton rubrum

Fill in the Blank

Nonseptate hyphae are also called _________.  

coenocytic

Unicellular fungi are called _________.  

yeasts

Some fungi have proven medically useful because they can be used to produce _________.  

antibiotics

Short Answer

Which genera of fungi are common dermatophytes (fungi that cause skin infections)?

What is a dikaryotic cell?

Critical Thinking

Which of the drawings shows septate hyphae?

A  
B
Explain the benefit of research into the pathways involved in the synthesis of chitin in fungi.

**Contributor**

- [Template:ContribOpenSTAXMicrobiology](https://bio.libretexts.org/Courses/Portland_Community_College/Cascade_Microbiology/05%3A_The_Eukaryotes_of_Microbiology)