

An Introduction to Fungi

Fungi (singular fungus) are **nucleated** (therefore eukaryotic), **achlorophyllous** (lack green chlorophyll pigments, so are not plants), **osmotrophic** (digest food materials outside and take in only small molecules), and typically **spore-bearing** (reproduce by means of spores).

The science or study of fungi is called **Mycology** (mykes = mushroom), and dealt initially with macroscopic organisms rather than microscopic forms.

Fungi are members of the **domain Eukarya** and the **kingdom Fungi** (Myceteae), although some references place some types of fungi in the kingdoms Chromista and Eumycotina. They are **not plants** because they lack green chlorophyll pigments and cannot function as photoautotrophs (cannot use light energy, and cannot fix carbon). Fungi are **chemoheterotrophs**, and often use dead organic materials as food, so are **saprotrophs** (sapro = rotten). Most fungi are free living in soil and rotting vegetation, but some are parasites and some are potential pathogens.

Fungi can be divided into three morphological categories; **yeasts** (single-celled organisms), **molds** (filamentous and microscopic forms), and **fleshy fungi** (filamentous and macroscopic forms). Yeast grown on agar plates form colonies that resemble those of bacteria, while molds typically form larger, fuzzy-looking colonies. Fleshy fungi are more familiar to most people as they are easy to see growing in their natural settings.



The body of a mold-type or fleshy fungus (body = soma or thallus), is called a **mycelium** and is often visible to the naked eye. The mycelium is composed of many microscopic thread-like filaments called **hyphae** (singular = hypha). The portion of the mycelium that extends into the air (often above the ground) is called the **aerial mycelium** and is involved in reproduction, while the portion within the substrate is called the **vegetative mycelium** and is involved in food getting.

Hyphae may be **septate** (with crosswalls) or **aseptate** (without crosswalls), but in either case the protoplasm is interconnected because the crosswalls are incomplete. Thus the cells of a fungus form a true **syncytium** (multinucleated mass of protoplasm), and nutrients are readily passed from cell to cell. Though most fungus cells contain a single nucleus, those called dikaryons have two (dikaryon = two nuclei), and both are haploid.

Fungus cells have walls made of polysaccharides (cellulose, chitin, glucan, etc.), so are resistant to damage caused by exposure to hypotonic environments.

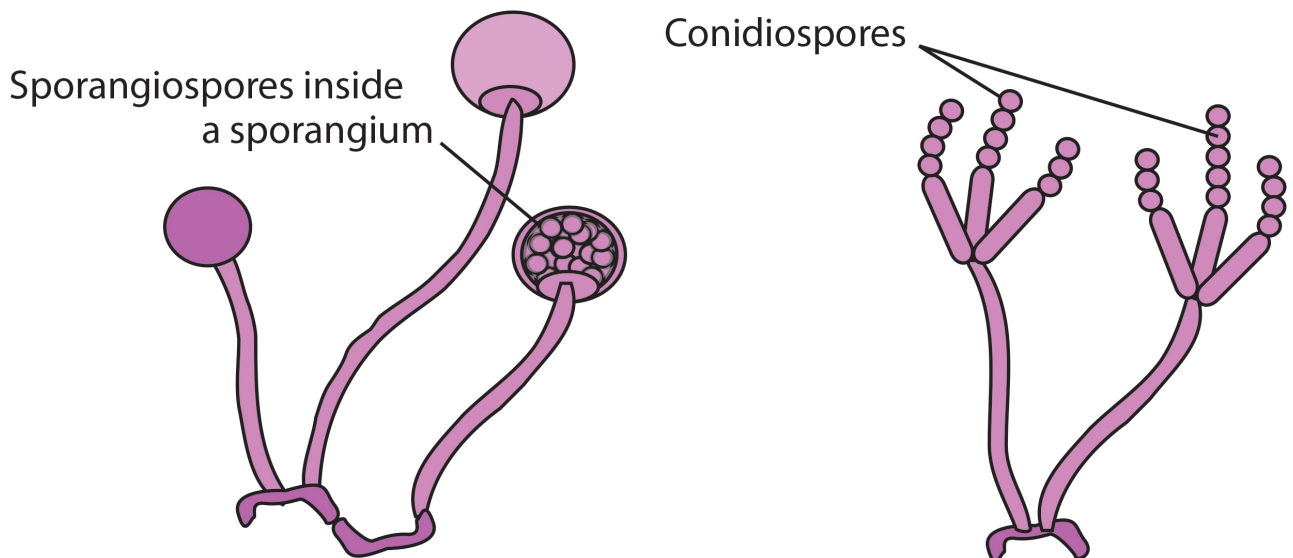
Hyphae produced by various types of fungi are sometimes specialized and have been given specific names as follows:

1. Hyphae supporting asexual spores are called **sporangiophores** or **conidiophores** (as shown in the laboratory) depending on the type of spores they support.
2. Hyphae made by parasitic fungi that penetrate host cells and absorb nutrients are called **haustoria** (haust = to suck).
3. Hyphae of fungi that form mutualistic relationships with plant roots are called **mycorrhizae**, and help plants absorb water and minerals (especially phosphorous) from soil.

Fungus Reproduction

Most fungi reproduce both sexually and asexually, though asexual reproduction is more common. Different types of fungi display **asexual reproductive methods** that are essentially variations on a common theme; **fission** (one cell divides into two cells). These are as follows:

1. **Binary fission** – One cell divides across its long axis to form two daughter cells of approximately equal size.
2. **Budding** – Budding involves an uneven division of the cytoplasm, such that one cell is large, and one (the bud) is very small. Both receive a complete set of chromosomes, but if conditions are poor, and the bud is unable to develop properly, the “mother” cell hasn’t lost much. Asexual spores called **blastospores** are essentially buds (as are microconidia).
3. **Fragmentation** – Fragmentation occurs after fission has allowed multiple cells to form an extensive network of hyphae. Then the hyphae break apart into multiple fragments. Fungi that form **arthrospores** and **chlamydoconidia** do so by means of fragmentation.
4. Spore formation (sporulation) – **Sporangiospores** (contained within sac-like structures called sporangia) and **conidiospores** (formed at the ends of hyphae, like beads on strings) are the two types of asexual spores most commonly observed.



Sexual reproduction requires the participation of two genetically dissimilar fungi (of the same species), and typically involves three stages or steps as follows:

1. **Plasmogamy** – Plasmogamy (plasma = protoplasm, gamous = union or marriage) involves the union or joining of protoplasm from two separate individuals.
2. **Karyogamy** – Karyogamy (karyon = nucleus) involves the union of two haploid nuclei and results in the formation of a diploid zygote (a cell with two sets of chromosomes).

3. **Meiosis** – Meiosis (reduction division) involves the separation of chromosomes (along with the formation of new chromosome combinations due to independent assortment and crossing over), and results in the formation of four haploid daughter cells each with unique genetic characteristics. These give rise to the sexual spore types observed in lab, i.e., **oospores**, **zygospores**, **ascospores** and **basidiospores**.

Significance (importance) of fungi

1. Fungi are **saprotrophs** or decomposers that break down dead materials and release nutrients into soils. Imagine what the world would be like if this did not happen.
2. Many fungi form **mycorrhizae** essential for the survival of forest trees and other plants.
3. Many fungi are edible, so serve as **food material** for other organisms.
4. Humans use fungi in the **production of cheese, bread, wine, beer**, and other food products.
5. Certain fungi are sources of **antibiotics**, e.g., Penicillins and Cephalosporins.
6. The **enzymes** produced by various fungi are used in industrial processes.
7. Certain fungi are used in the commercial production of **organic acids and solvents** (some even form a metabolic end product similar in composition to jet fuel).
8. Fungi can be **genetically engineered** to produce a variety of proteins for human use.
9. Some fungi are **pathogens** (infecting both animals and plants) and some produce toxins that can cause severe liver damage or cause hallucinations.

Medical Mycology

Many fungi can cause diseases in plants (apple scab, Dutch elm disease, peach leaf curl, smut, rust, etc.), but only about 100 of the thousands of fungi known cause disease in healthy humans and other animals. Fungal induced diseases are called **mycoses** (singular = mycosis), and are grouped for convenience into three categories, **superficial**, **subcutaneous**, and deep or **systemic**. In general the superficial mycoses (involving hair, skin, and nails), are limited in severity. Although they tend to be chronic (long term), they rarely affect the general health of the individual. Deep or systemic mycoses on the other hand occasionally lead to fatality. The primary factor determining if or not fungi will infect and cause disease symptoms within an animal is the **condition of the animal's immune system** (host resistance). Human susceptibility to fungal infection can be increased by prolonged exposure to antibiotics, chemotherapy used in the treatment of cancer or administered to transplant patients, and infection with HIV. All of these decrease host resistance.

1. Superficial Mycoses

Superficial mycoses are caused by fungi that infect keratinized regions of the body surface (skin, hair, nails), and do not usually invade deeper tissues. Three genera of importance are *Epidermophyton*, *Trichophyton* and *Microsporum*, a group sometimes referred to as **dermatophytes**. These organisms enjoy worldwide distribution and some can live as saprotrophs when not associated with host organisms, others are obligate parasites. Diagnosis involves microscopic examination of skin scrapings, hair or nails and the culturing of causative organisms.

A. Tinea pedis (Athletes foot)

This is usually caused by fungi in the genera *Trichophyton* and *Epidermophyton*, and is the most prevalent of the superficial mycoses. Symptoms include vesicles that rupture and weep, cracked skin and severe itching. When nails are involved they become brittle, thickened and sometimes crumbly. Secondary bacterial infection is not uncommon.

B. Tinea corporis (ringworm of the body)

Ringworm typically occurs on relatively hairless regions of the body and appears as itchy circular lesions with dry scaly centers and advancing red borders. The fungi live on dead skin, but produce metabolic by-products that cause irritation.

C. Tinea capitis (ringworm of the scalp)

Scalp ringworm is usually caused by fungi in the genera *Trichophyton* and *Microsporum*, forms that tend to invade hair follicles. The fungi cause hairs to break off, resulting in bald patches, with areas of redness, scaling, and itchy vesicle formation.

2. Subcutaneous Mycoses

Subcutaneous mycoses are caused by fungi common in soil and decayed vegetation. These fungi do not infect skin surfaces, but must be introduced into the subcutaneous tissues in order to cause disease. Symptoms include lesions that may spread slowly from the area of implantation.

A. Sporotrichosis

Sporotrichosis is caused by soil fungi identified as *Sporothrix schenckii* that are often introduced during injuries caused by thorns; hence the name “rose thorn disease”. Infection is characterized by subcutaneous nodules and ulcers that are usually self-limiting.

B. Chromomycosis

Chromomycosis is characterized by slowly progressing granulomas of the skin and may be caused by several different types of fungi known as “black molds”. The fungi typically enter during trauma (usually to the feet or legs) and produce wart-like growths along the lymphatics in the infected area.

3. Deep or Systemic Mycoses

Deep (systemic) mycoses are caused by fungi that normally live in soil and in decaying vegetation; and are often restricted to specific geographic regions. The fungi typically enter the body through the respiratory system (inhalation), and the majority of people exposed develop only minor symptoms if any. In those individuals that develop significant disease symptoms, the fungi may spread to any part of the body, often with fatal results.

Pathogenic fungi do not produce toxins, but regularly induce hypersensitivity (allergic) reactions resulting in the formation of granulomas (inflamed tumor-like masses), with varying degrees of necrosis (cell death) and abscess formation (localized collections of puss).

A. Coccidioidomycosis – Caused by *Coccidioides immitis*

Fungi identified as *Coccidioides immitis* are soil dwelling organisms that form hyphal fragments called **arthrospores**. These are very lightweight and are readily picked up and carried by wind. Most individuals exposed to the fungi are asymptomatic, but a few develop influenza-like symptoms (fever, malaise, cough and body ache). About 5-10% of those who develop significant symptoms develop hypersensitivity reactions that appear as erythema (red patches on the skin surface). The symptom complex is commonly called “San Joaquin Valley Fever” or “Desert Rheumatism” and is self-limiting in most instances. In about 1% of these cases the fungi become widely disseminated with lesions developing in various organs of the body. These cases are highly fatal. Endemic areas include the San Joaquin and southern regions of the

Sacramento Valleys, where infection is most common during dry summers when dust is prevalent. During drought years cases occur much farther north.

B. Histoplasmosis – Caused by *Histoplasma capsulatum*

The fungi that cause histoplasmosis are commonly found in soils rich in nitrogen due to the presence of bird or bat feces. The *Histoplasma* conidia enter the body through the respiratory tract and are consumed by macrophages, but not killed. The macrophages carry the fungi throughout the body, and they sometimes form granulomas (usually in the lungs or spleen). Heavy exposure sometimes results in pneumonia. Severe infection usually occurs only in infants, aged persons and the immunosuppressed, but these can result in damage to the spleen, liver and lymphatic system. Such infections have a high fatality rate.

4. Some Fungi Recognized as Opportunistic Pathogens

Fungi that are not usually associated with disease, but can under certain circumstances infect individuals and cause disease symptoms are considered opportunistic pathogens. Almost any type of fungus can cause infection in individuals that are severely immunocompromised, but the following examples are more likely to do so.

A. *Candida albicans* – Causative agent of Candidiasis (thrush, vaginal infection, etc.)

Candida is a common inhabitant of mucous membranes associated with the upper respiratory, gastrointestinal and genital tracts, and is therefore considered part of the “normal microbiota” or “human microbiome”. Although usually non-virulent, *Candida* can gain dominance in various regions of the body and can then invade the bloodstream causing septicemia or endocarditis. It can also infect the eyes and other organs. Other species of *Candida* can also be opportunistic pathogens.

B. *Cryptococcus neoformans* – Causative agent of cryptococcosis or cryptococcal meningitis

Cryptococcus is a yeast-like fungus widely distributed in nature, but often associated with the droppings of pigeons and other birds. Spores are taken in via inhalation and pneumonia-like symptoms can develop. From the lungs, the fungi can enter the circulation and are attracted to nervous tissue; circulatory infections with *Cryptococcus* commonly lead to meningitis. In some hospitals, *Cryptococcus neoformans* is the leading cause of death among immunocompromised patients.

Cryptococcus gattii is a related species formerly restricted to tropical regions, but recently found to infect people in the United States (Washington and Oregon). Though the symptoms caused by this fungus are similar, infection has not been restricted to individuals with compromised immune function.

C. *Aspergillus fumigatus*, *niger* and others – Causative agents of aspergillosis

Fungi in the genus *Aspergillus* are ubiquitous molds commonly associated with decaying vegetation. The conidiospores of these fungi can enter burn wounds, lesions, or the external ear and they sometimes invade the respiratory tract causing tuberculosis-like symptoms. Infection occurs only in weakened hosts, but some species produce toxins that can cause intoxication when ingested (see below).

D. *Rhizopus stolonifer* – Causative agent of Zygomycosis

Fungi in the genus *Rhizopus* are common in the environment, but can invade and proliferate in the walls of blood vessels causing thrombosis (clots), infect the paranasal sinuses, lungs or

gastrointestinal tract. In the lungs they often colonize regions of damaged tissue forming “fungus balls”. Patients must be compromised for infection to occur.

5. Fungi Associated with Intoxication

Many non-pathogenic fungi produce poisonous substances called **mycotoxins** that can cause acute or chronic intoxication resulting in tissue damage and sometimes death. Disease caused by the ingestion of fungus toxins is called **mycotoxicosis**.

A. *Amanita phalloides* – Commonly known as the “Death Cap”

Amanita phalloides forms ectomycorrhizae with various types of broadleaved trees, and is widely distributed in forest regions. It resembles several types of edible mushrooms commonly harvested by humans and is involved in the majority of human deaths due to “mushroom poisoning”. The primary toxin is α -amanitin, which causes often-fatal damage to kidney and liver tissue leading eventually to renal failure and hepatitis.

B. *Aspergillus flavus* – Producer of Aflatoxin

Aspergillus flavus is a mold-type fungus commonly associated with soil and decaying vegetation. Because of this, the toxin produced (called *Aflatoxin* from the genus name initial *A*, followed by the first three letters of the specific epithet, *fla*), is commonly associated with grain and peanuts. Aflatoxins are among the most carcinogenic substances known, and so are often associated with liver cancer. Aflatoxins can be present in the milk of animals fed moldy hay or grain.

C. *Claviceps purpurea* – Causes ergot on grain and ergotism in animals

Claviceps purpurea infects the flowering portion of grain plants causing ergot, a plant disease characterized by grains that are swollen, dark colored and filled with fungus spores containing high concentrations of the alkaloid ergotamine. When ergot contaminated grain is eaten by humans and other animals, it causes ergotism (St. Anthony’s Fire), characterized by a severe burning sensation in the limbs. Vasoconstriction can lead to gangrene and loss of extremities; other symptoms include uterine contractions, nausea, seizures and unconsciousness. Ergot alkaloids may cause hallucinations and irrational behavior (thus the potential link to the Salem witch trials). Ergotamine is used in the synthesis of lysergic acid diethylamide (LSD).

D. *Stachybotrys chartarum* or *S. atra* – Black Molds

Fungi in the genus *Stachybotrys* are soil organisms that can become associated with the cellulose of wood and the paper coatings of wallboard when these materials become wet (as during episodes of flooding or leaky roofs). These “toxic black molds” are frequently associated with poor indoor air quality. Inhalation or ingestion of spores can cause a variety of symptoms including chronic fatigue, headaches, fever, irritation in the eyes and mucous membranes of the mouth, nose and throat, chronic cough, sneezing and sometimes rashes.

Note – The spores produce by many different types of fungi are frequently the cause of allergic (hypersensitivity) reactions characterized by itchy, watery eyes, a runny nose and sneezing. Many individuals suffer chronic symptoms during periods when spores are abundant in the air.