There's a Fungus Among Us!
Fungi

Complex Multicellularity

- there are three kingdoms that exhibit complex multicellularity in which individuals are composed of many highly specialized cells
  - plants
  - animals
  - fungi

- two key characteristics of complex multicellular organisms distinguish them from simple multicellular organisms
  - cell specialization
  - intercellular coordination

- cell specialization requires that different cells use different genes
  - different genes are activated during development

- intercellular coordination involves the adjustment of a cell's activity in response to what other cells are doing
  - the cells of all complex multicellular organisms communicate with one another with chemical signals called hormones

A Fungus is Not a Plant

- the fungi are a distinct kingdom of organisms, comprising about 74K species
  - **mycologists** are scientists who study fungi

- there are many significant differences between fungi and plants, including
  - fungi are hetertrophs
  - fungi have filamentous bodies
  - fungi have nonmotile sperm
  - fungi have cell walls made of chitin
  - fungi have nuclear mitosis

- fungi exist mainly in the form of slender filaments called **hyphae** (singular, **hypha**)
  - each hypha is basically a long string of cells
  - different hypha can associate with each other to form much larger structures
  - a mass of hyphae is called a **mycelium**
    - the mycelium is not the conspicuous mushroom but the extensive network of fine hyphae that penetrate the soil, wood, or flesh in which the fungus is growing
    - the mycelium may contain many meters of hyphae

The Body of a Fungus

- fungal cells can intercommunicate because fungal cells are separated by incomplete

septa (singular, **septum**)
- cytoplasm can flow freely among the cells of the hypha
- many nuclei may be connected together by the shared cytoplasm
- proteins synthesized throughout the hyphae can be carried to hyphal tips
- all parts of the fungal body are metabolically active

Septum and pore between cells in a hypha.

Reproduction and Nutrition of Fungi

- fungi reproduce both asexually and sexually
  - all fungal nuclei, except for the zygote, are haploid
  - often in sexual reproduction of fungi, different "mating types" must participate
    - when two hyphae of different mating types come into contact, the hyphae fuse

- in most fungi, the nuclei of two fused hyphae do not fuse immediately but coexist in the cytoplasm
  - **dikaryotic** is a fungal hypha that has two nuclei
  - if the nuclei are from genetically different individuals, it is a called a **heterokaryon**
  - if the nuclei are genetically similar, then the hypha is said to be a **homokaryon**

- when reproductive structures do form in fungi, complete septa separate the reproductive cells from the rest of the fungal body

- there are three kinds of reproductive structures formed
  - **gametangia** form haploid gametes
  - **sporangia** form haploid spores
  - **conidiophores** form asexual spores (**conidia**)

- spores are a common means of reproduction among the fungi
- spores are well suited to the needs of an organism anchored to one place
- spores are small and light and remain suspended in the air for long periods of time and may be carried great distances
- when a spore lands in a suitable environment, it germinates and begins to divide, forming a new fungal hypha

Many fungi produce spores.

- all fungi perform **external digestion**
  - they secrete digestive enzymes into their surroundings and then absorb back into their bodies any organic molecules
  - many fungi are able to break down the cellulose in wood
  - some fungi are carnivores
    - for example, oyster fungus attracts nematode worms and then feeds upon them

The oyster mushroom.

Kinds of Fungi

- there are four fungal phyla that are distinguished from another mainly on the bases of their mode of sexual reproduction
  - Zygomycota
  - Ascomycota
  - Basidiomycota
  - Chytridiomycota

- a fifth group, the imperfect fungi, comprises members not known to reproduce sexually

Fungi

Zygomycetes

- the zygomycetes belong to the phylum Zygomycota
  - these fungi are unique in that the fusion of hyphae does not produce a heterokaryon
  - instead, the two nuclei fuse and form a single diploid nucleus
  - this fusion produces a zygote

- reproduction among the zygomycetes is typically asexual
  - a cell at the hyphal tip becomes isolated by a complete septum
  - an erect stalk tipped by a sporangium forms from this cell and produces haploid spores
  - these spores are shed into the wind and blown to new locations
  - the spores germinate and become new hyphae

- sexual reproduction is unusual in the zygomycetes but may occur in times of stress
  - hyphae from two different mating strains fuse and their nuclei also fuse, producing a diploid zygote

- at the point where the two hyphae fuse, a resistant structure called a **zygosporangium** forms
  - the zygosporangium can remain dormant until conditions become favorable again
  - when favorable, the zygosporangium forms a stalked structure topped with a sporangium
  - meiosis produces haploid spores in the sporangium, which are released to the air

Life cycle of a zygomycete.

Ascomycetes

- the phylum Ascomycota contains the ascomycetes and is the largest of the four fungal phyla

- reproduction among the ascomycotes is usually asexual

  - the tips of the hyphae become isolated by the formation of a complete septum and

form asexual spores called conidia

- each conidia often contains several nuclei but the spores are haploid

- the conidia are dispersed by wind to another place, where it germinates to form a new hypha

- the ascomycetes are named for their sexual reproductive structure, the **ascus** (plural, **asci**)
  - the ascus differentiates into a larger structure, called the **ascocarp**
  - each ascus is a microscopic cell that forms on the tips of the hyphae within the ascocarp
  - the ascus is where the zygote forms

Ascomycetes

- in ascomycetes, the zygote is the only diploid nucleus of the entire life cycle

- when a mature ascus bursts, individual spores (called **ascospores**) are thrown great distances

Life cycle of an ascomycete.

Basidiomycetes

- the basidiomycetes comprise the phylum Basidiomycota
  - the life cycle begins with the production of a hypha from a germinating spore
  - when the hyphae of two different mating types fuse, they form cells in which the nuclei remain separate
  - asexual reproduction is infrequent among members of this group

- sexual reproduction occurs when the two nuclei fuse to form zygotes
  - the site for fusion occurs within a club-shaped reproductive structure, called the **basidium** (plural, **basidia**)
  - around the many thousands of basidia, the mycelium forms a complex called the **basidiocarp** or mushroom
  - meiosis occurs in each basidium to produce spores called **basidiospores**

Life cycle of a basidiomycete.

Chytridiomycetes, Imperfect Fungi, and Yeasts

- members of the phylum Chytridiomycota, the chytrids, are the most primitive fungi in that they retain flagellated gametes

- several species are plant pathogens and one is thought to be a potential pathogen of frogs

The pathogenic chytrid, *Batrachochytrium dendrobatidis*, has infected this frog.

- there are more than 17K described species of fungi in who sexual reproduction has not been observed

- these are the so-called imperfect fungi and appear to have lost the ability to reproduce sexually

- many skin diseases are caused by imperfect fungi

Imperfect fungi.

- yeast is the generic name given to any unicellular fungus

- most of yeast production is asexual and takes place by cell fission or budding

- sexual reproduction takes place when two yeast cells fuse

- the new cell containing two nuclei functions as an ascus

Budding in *Saccharomyces*.

Ecological Roles of Fungi

- fungi, together with bacteria, are the principal decomposers in the biosphere
- fungi are virtually the only organisms capable of breaking down lignin in wood
- fungi, by breaking down substances release critical building blocks from the bodies of dead organisms and make them available to other organisms
- fungi often act as disease-causing organisms for both plants and animals
- fungi have many important commercial uses
  - the manufacture of bread, beer, wine, and soy sauce all depend on fungi
  - many antibiotics are derived from fungi
  - some fungi can be used to clean up toxic substances from the environment

- fungi are also involved in a variety of intimate symbiotic associations with algae and plants
  - the fungus contributes the ability to absorb minerals and other nutrients from the environment
  - the photosynthesizer contributes the ability to use sunlight to power the building of organic molecules
- two kinds of mutualistic associations between fungi and autotrophic organisms are ecologically important
  - **mycorrhizae** are symbiotic associations between fungi and the roots of plants
  - **lichens** are symbiotic associations between fungi and either green algae or cyanobacteria

- mycorrhizae occur in about 80% of all kinds of plants
  - they greatly increase the surface area of the root
  - filaments of the fungus act as superefficient root hairs and aid in the direct transfer

of phosphorous and other minerals from the soil into the roots of the plant
  - the plant supplies organic carbon to the fungus

Mycorrhizae on the roots of pines.

- in almost all mycorrhizae, the fungal hyphae actually penetrate the outer cells of the plant root and extend far out into the soil
  - these are called **endomycorrhizae**
- in only some mycorrhizae, the fungal cells grow between but do not penetrate the roots
  - these are called **ectomycorrhizae**

Endomycorrhizae and ectomycorrhizae.

- a lichen is a symbiotic association between a fungus and a photosynthetic partner
  - most of the visible body of the lichen consists of its fungus but interwoven between hyphal layers are cyanobacteria, green algae, or both
  - lichens can invade harsh habitats but are sensitive to pollutants

Lichens growing on a rock.