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 heterotrophs
  ▪ 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 hyphae 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 ascomycetes 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.**