Fungi

Chapter 31

- Objectives
  - List the characteristics that distinguish fungi from other multicellular kingdoms
  - Distinguish between ectomycorrhizal and arbuscular mycorrhizal fungi
  - Describe the processes of plasmogamy and karyogamy
  - Describe the evidence that multicellularity evolved independently in fungi and animals
  - Describe the life cycles of Rhizopus stolonifer and Neurospora crassa
  - Distinguish among zygomycetes, ascomycetes, and basidiomycetes

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- Describe some of the roles of fungi in ecosystems, lichens, animal-fungi mutualistic symbioses, food production, and medicine and as pathogens

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Introduction to Fungi

- Fungi are diverse and widespread
  - Essential for the well-being of most terrestrial ecosystems because they break down organic material and recycle vital nutrients
- Despite their diversity fungi share some key traits

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Nutrition and Fungal Lifestyles

- Fungi are heterotrophs but do not ingest their food
- Fungi secrete into their surroundings exoenzymes that break down complex molecules and then absorb the remaining smaller compounds

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- Fungi exhibit diverse lifestyles
  - Decomposers
  - Parasites
  - Mutualistic symbionts

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Body Structure

- The most common body structures are multicellular filaments and single cells (yeasts)
  - Some species grow as either filaments or yeasts; others grow as both

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Morphology

- The morphology of multicellular fungi enhances their ability to absorb nutrients from their surroundings
- Fungi consist of mycelia, networks of branched hyphae adapted for absorption
- Most fungi have cell walls made of chitin

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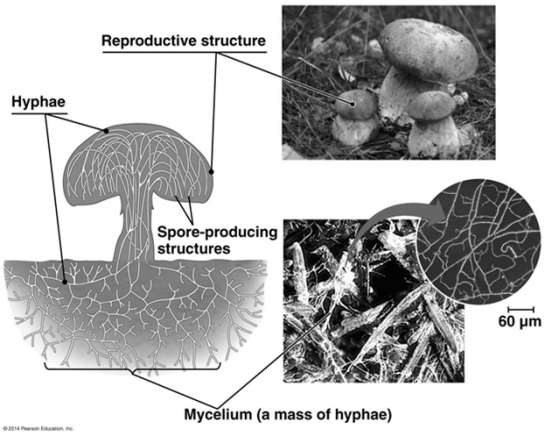

- Some fungi have hyphae divided into cells by septa, with pores allowing cell-to-cell movement of materials
- Coenocytic fungi lack septa

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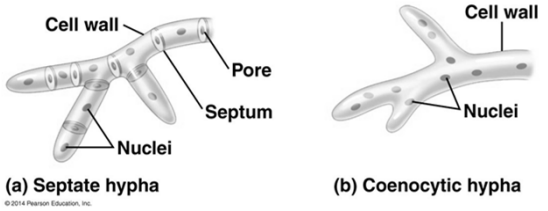

- Some unique fungi have specialized hyphae that allow them to penetrate the tissues of their host

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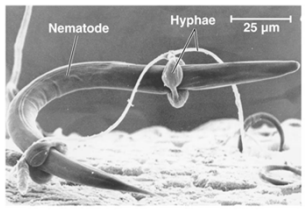
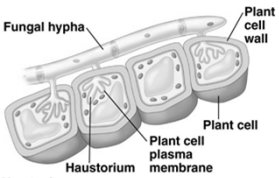


(a) Hyphae adapted for trapping and killing prey



(b) Haustoria

- Mycorrhizae are mutually beneficial relationships between fungi and plant roots
  - Ectomycorrhizal fungi form sheaths of hyphae over the root surface
  - Arbuscular mycorrhizal fungi extend their hyphae through the cell wall forming invaginations in the cell membrane

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Fungal Reproduction

- Fungi propagate themselves by producing vast numbers of spores, either sexually or asexually

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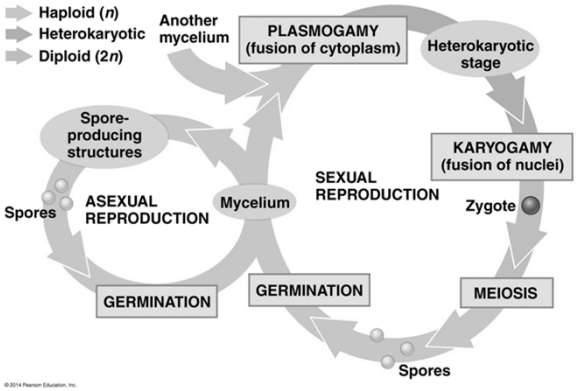

Sexual Reproduction

- Fungal nuclei are normally haploid, with the exception of transient diploid stages formed during the sexual life cycles
- Sexual reproduction requires the fusion of hyphae from different mating types
  - Fungi use sexual signaling molecules called pheromones to communicate their mating type

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- Plasmogamy is the union of two parent mycelia
  - In most fungi, the haploid nuclei from each parent do not fuse right away; they coexist in the mycelium, called a heterokaryon
  - In some fungi, the haploid nuclei pair off two to a cell; such a mycelium is said to be dikaryotic

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- Hours, days, or even centuries may pass before the occurrence of karyogamy, nuclear fusion
  - During karyogamy, the haploid nuclei fuse, producing diploid cells
  - The diploid phase is short-lived and undergoes meiosis, producing haploid spores

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Asexual Reproduction

- Many fungi can reproduce asexually
  - Many fungi that can reproduce asexually grow as mold, sometimes on fruit, bread, and other foods
  - Other asexual fungi are yeasts that inhabit moist environments which reproduce by simple cell division
- Many molds and yeasts have no known sexual stage
  - Mycologists have traditionally called these deuteromycetes, or imperfect fungi

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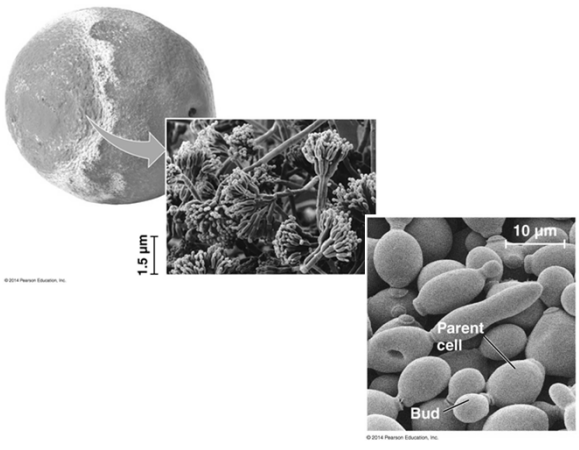

Fungal Origin

- Fungi and animals are more closely related to each other than they are to plants or other eukaryotes
  - Fungi, animals, and their protistan relatives form the opisthokonts clade
  - DNA evidence suggests that fungi are most closely related to unicellular nucleariids while animals are most closely related to unicellular choanoflagellates

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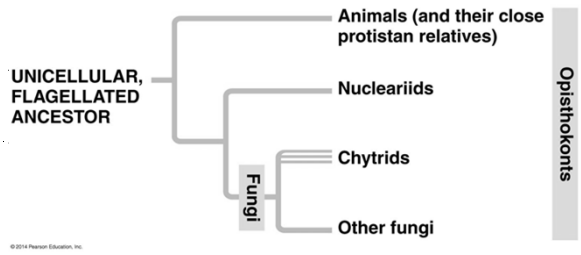

- This suggests that fungi and animals evolved from a common flagellated unicellular ancestor and multicellularity arose separately in the two groups
- The oldest undisputed fossils of fungi are only about 460 million years old

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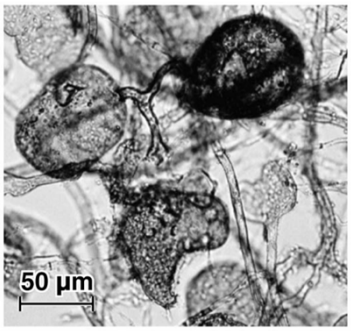

Are Microsporidia Closely Related to Fungi?

- Microsporidia are unicellular parasites of animals and protists
- They have tiny organelles derived from mitochondria but not conventional mitochondria
- Molecular comparisons indicate they may be closely related to fungi

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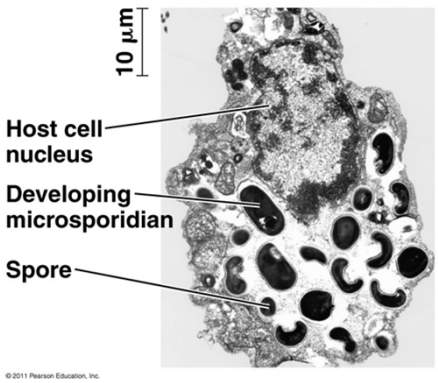

The Move to Land

- Fungi were among the earliest colonizers of land, probably as symbionts with early land plants

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Fungal Phylogeny

- The phylogeny of fungi is currently the subject of much research
- Molecular analysis has helped clarify the evolutionary relationships between fungal groups, although there are still areas of uncertainty

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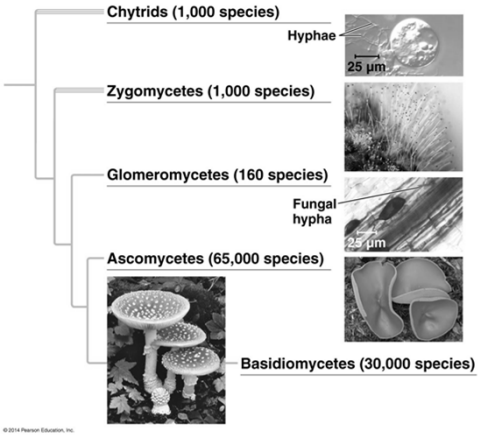

Chytrids

- Fungi classified in the phylum Chytridiomycota, or chytrids are found in freshwater and terrestrial habitats
  - They can be decomposers, parasites, or mutualists
- Molecular evidence supports the hypothesis that chytrids diverged early in fungal evolution
- Chytrids are unique among fungi in having flagellated spores, called zoospores

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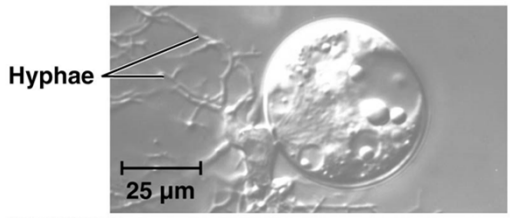
Chytrids (1,000 species)



- Until recently, systematists thought that fungi lost flagella only once in their history
  - Molecular data indicate that some "chytrids" are actually more closely related to another fungal group, the zygomycetes

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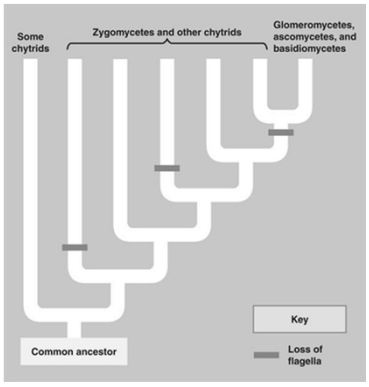

Zygomycetes

- Fungi in the phylum Zygomycota, the zygomycetes exhibit a considerable diversity of life histories
  - Include fast-growing molds, parasites, and commensal symbionts
- They are named for their sexually produced zygosporangia
- The life cycle of Rhizopus stolonifer is fairly typical of zygomycetes

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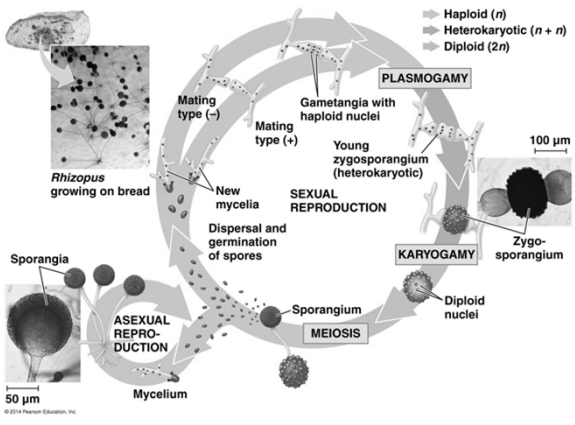

- Some zygomycetes, such as Pilobolus can actually “aim” their sporangia toward conditions associated with good food sources
- Zygosporangia, which are resistant to freezing and drying are capable of persisting through unfavorable conditions
  - Can undergo meiosis when conditions improve

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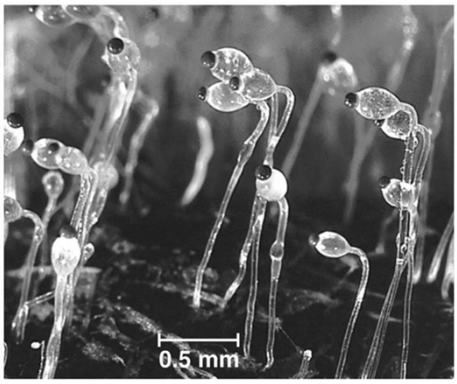

Glomeromycetes

- Fungi assigned to the phylum Glomeromycota were once considered zygomycetes
  - Are now classified in a separate clade
- All glomeromycetes form a distinct type of endomycorrhizae called arbuscular mycorrhizae

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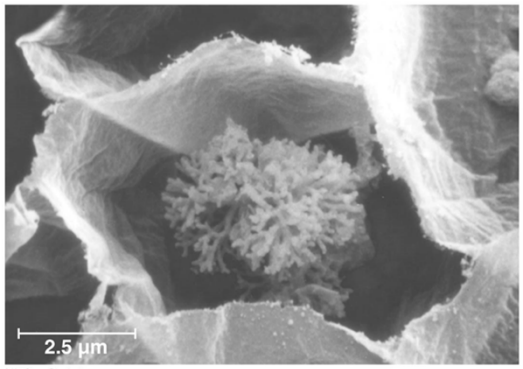

Ascomycetes

- Fungi in the phylum Ascomycota are found in a variety of marine, freshwater, and terrestrial habitats
  - The phyllum is defined by the production of sexual spores in saclike asci, which are usually contained in fruiting bodies called ascocarps
    - ascomycetes are commonly called sac fungi
- Ascomycetes vary in size and complexity from unicellular yeasts to elaborate cup fungi and morels

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Morchella esculenta

Tuber melanosporum

- Ascomycetes include plant pathogens, decomposers, and symbionts
- Ascomycetes reproduce asexually by enormous numbers of asexual spores called conidia
  - Conidia are not formed inside sporangia; they are produced asexually at the tips of specialized hyphae called conidiophores
  - Neurospora is a model organism with a well-studied genome

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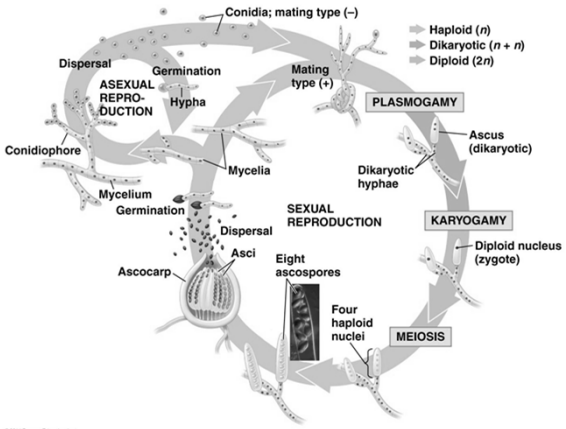

Basidiomycetes

- Fungi in the phylum Basidiomycota include mushrooms and shelf fungi
  - The phyllum is defined by a clublike structure called a basidium, a transient diploid stage in the life cycle
- The basidiomycetes are also called club fungi

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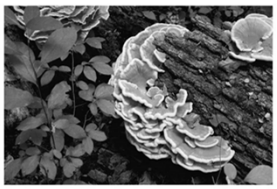
Puffballs



Shelf fungi

Maiden veil fungus

- The life cycle of a basidiomycete usually includes a long-lived dikaryotic mycelium
  - In response to environmental stimuli, the mycelium reproduces sexually by producing elaborate fruiting bodies call basidiocarps
- Mushrooms are examples of basidiocarps
- The numerous basidia in a basidiocarp are sources of sexual spores called basidiospores

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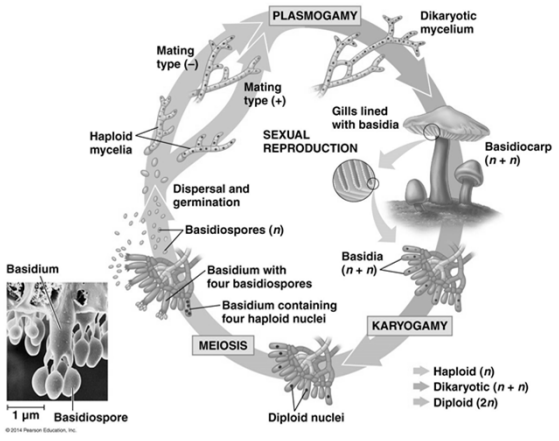

Fungal Roles in Ecosystems

- Fungi have a powerful impact on ecosystems and human welfare

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Decomposers

- Fungi are well adapted as decomposers of organic material performing essential recycling of chemical elements between the living and nonliving world

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Symbionts

- Fungi form mutualistic relationships with plants, algae, cyanobacteria, and animals
  - All of these relationships have profound ecological effects

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Fungal-Plant Symbiosis

- Mycorrhizae are enormously important in natural ecosystems and agriculture
- Plants harbor harmless symbiotic endophytes that live inside leaves or other plant parts
  - Endophytes make toxins that deter herbivores and defend against pathogens

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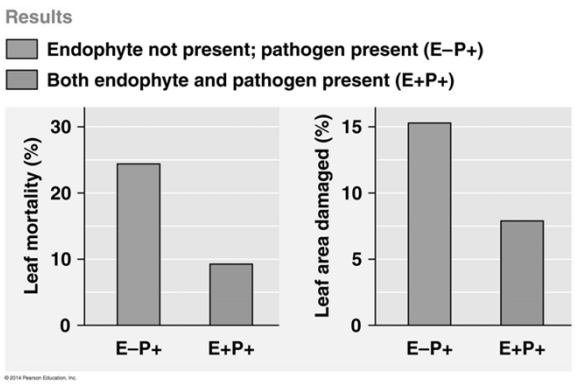

Fungus-Animal Symbiosis

- Some fungi share their digestive services with animals helping break down plant material in the guts of cows and other grazing mammals
- Many species of ants and termites take advantage of the digestive power of fungi by raising them in “farms”

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Lichens

- Lichens are a symbiotic association of millions of photosynthetic microorganisms held in a mass of fungal hyphae
  - The hyphal mass constitutes the bulk of the lichen mass
  - Lichens are named for their fungal component
    - foliose (leafy)
    - fruticose (shrubby)
    - crustose (crusty)

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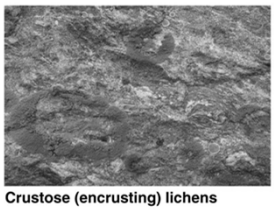
A fruticose (shrublike) lichen

A foliose (leaflike) lichen



Crustose (encrusting) lichens

- The fungal component of a lichen is most often an ascomycete
- Algae or cyanobacteria occupy an inner layer below the lichen surface
- The algae provide carbon compounds, cyanobacteria provide organic nitrogen, and fungi provide the environment for growth

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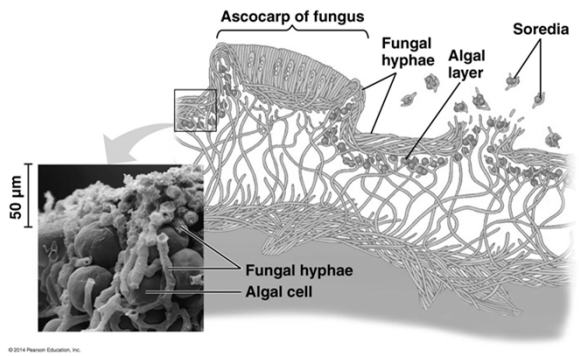

- The fungi of lichens can reproduce sexually and asexually
  - Asexual reproduction is by fragmentation or the formation of soredia, small clusters of hyphae with embedded algae
- Lichens are important pioneers on new rock and soil surfaces
- Lichens are sensitive to pollution, and their death can be a warning that air quality is deteriorating

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Pathogens

- About 30% of known fungal species are parasites or pathogens, mostly on or in plants
  - Some fungi that attack food crops are toxic to humans
- Animals are much less susceptible to parasitic fungi than are plants
  - The general term for a fungal infection in animals is mycosis

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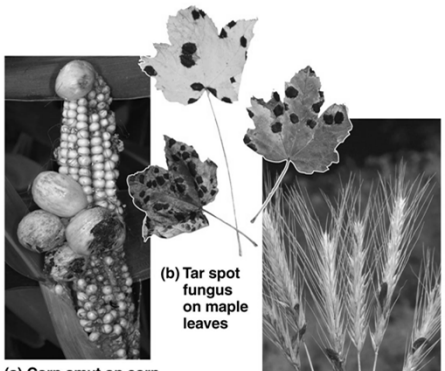
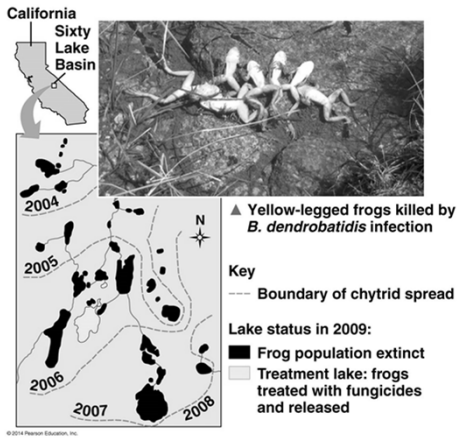


(a) Corn smut on corn

(b) Tar spot fungus on maple leaves

(c) Ergots on rye



Practical Uses of Fungi

- Humans eat many fungi and use others to make cheeses, alcoholic beverages, and bread
- Some fungi are used to produce antibiotics for the treatment of bacterial infections, for example the ascomycete *Penicillium*
- Genetic research on fungi is leading to applications in biotechnology
  - For example, insulin-like growth factor can be produced in the fungus *Saccharomyces cerevisiae*

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