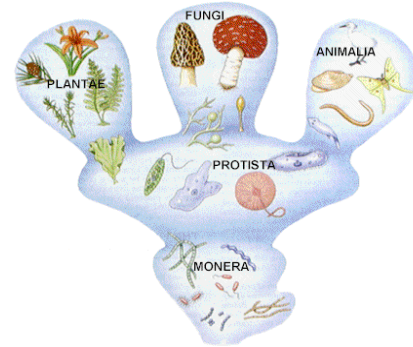


## Chapter 12

### Fungi

## Five-Kingdom classification



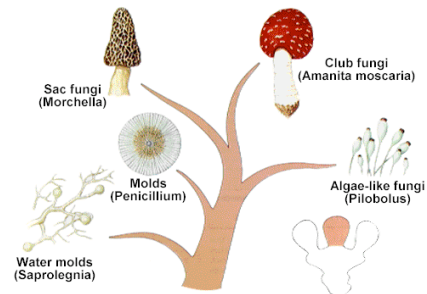
## Fungi

yeasts, molds, mushrooms

- ✓ Eukaryotic
- ✓ Uni- or multicellular
- ✓ Nutrition by absorption
- ✓ Asexual and sexual reproduction; complex life cycle
  - Spores - dormant for years to days
  - Germination into hyphae - branched hyphae is mycelium
  - Coenocytic (non septate) or non-coenocytic (septate)
- ✓ Asexual reproduction - hyphal or mycelial fragments



## Fungi

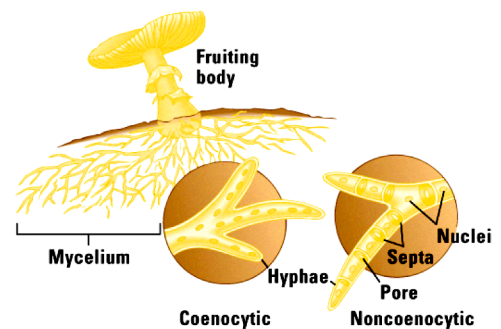


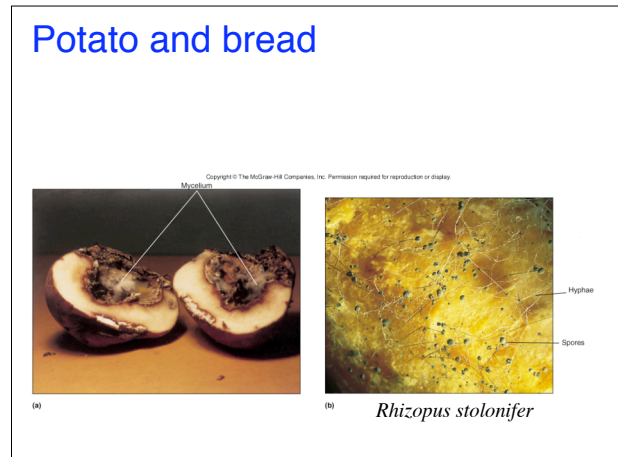
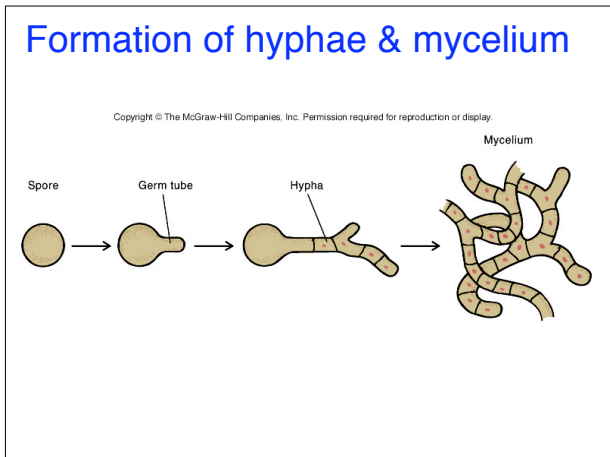
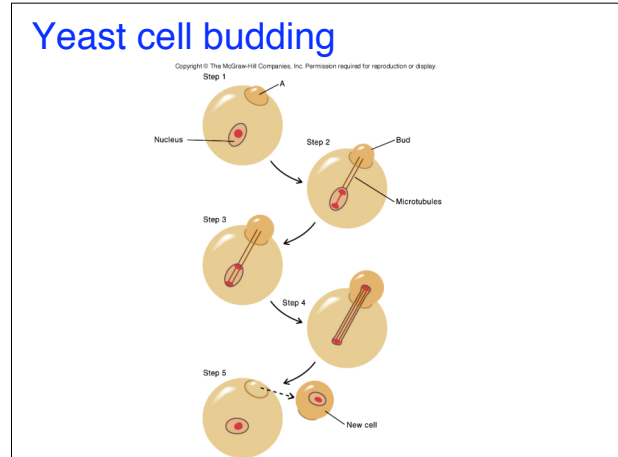
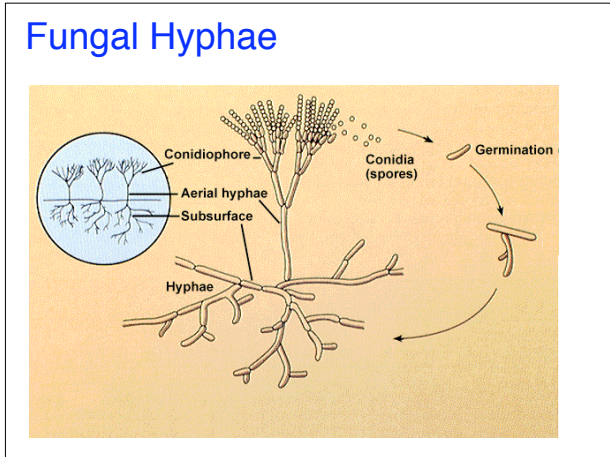
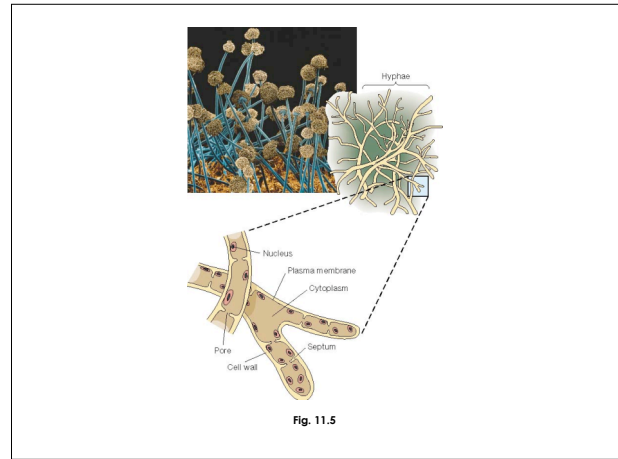
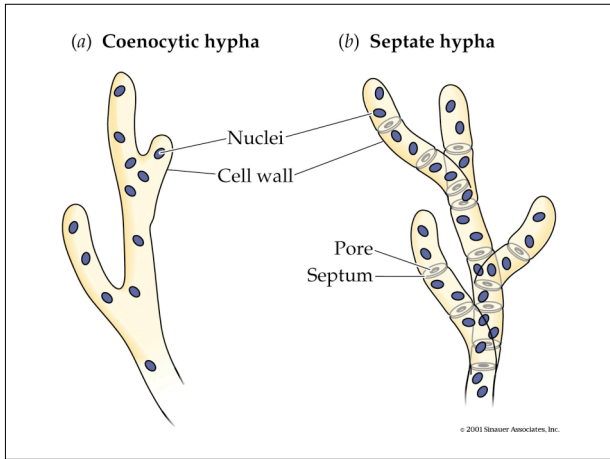
## Fungi

- ✓ Mycology - study of fungi
- ✓ Thallus - body of the fungus
- ✓ Mycelium - a mass of hyphae
- ✓ Hyphae - threadlike structures composed of cells
- ✓ Cell walls - made of chitin (a polysaccharide also found in insects)
- ✓ Septa - a division in hyphae
- ✓ Dimorphic - two different forms; yeast or mold

## Hyphae of fungi

Two types of fungal hyphae

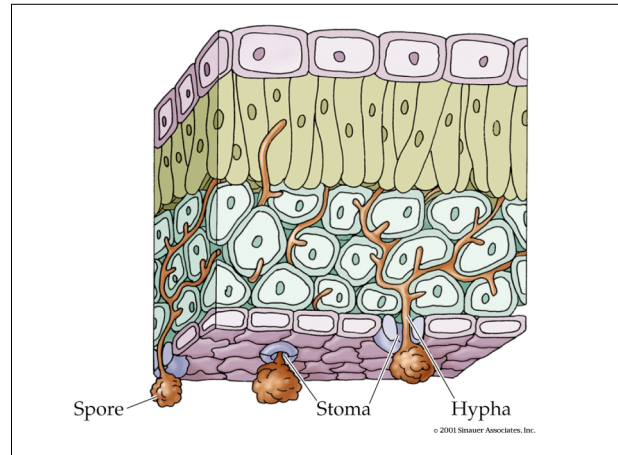




## Fungi

### ✓ Haustorium

- Hyphae penetration into plant
- Usually through stomates



## Fungi reproduce both asexually and sexually

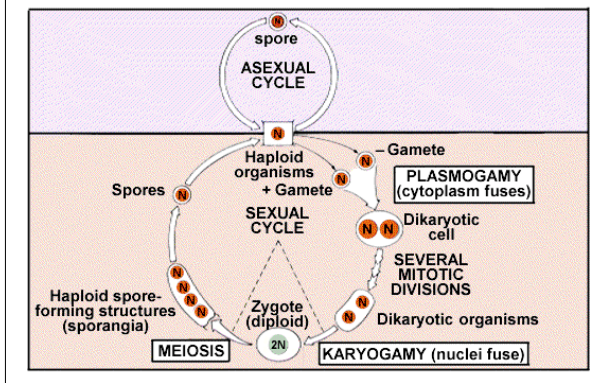


Table 12.3 Characteristics of Major Groups of Fungi

Group and Representative Member	Usual Habitat	Some Distinguishing Characteristics	Asexual Reproduction	Sexual Reproduction
Zygomycetes <i>Rhizopus stolonifer</i> (black bread mold)	Terrestrial	Multicellular, coenocytic mycelia (with many haploid nuclei)	Asexual spores develop in sporangia on the tips of aerial hyphae	Sexual spores known as zygospores can remain dormant in adverse environment
Basidiomycetes <i>Agaricus campestris</i> (meadow mushroom) <i>Cryptococcus neoformans</i>	Terrestrial	Multicellular, unbranched mycelia. Group includes mushrooms, smuts, rusts that affect the food supply	Commonly absent	Produce basidiospores that are borne on club-shaped structures at the tips of the hyphae
Ascomycetes <i>Neurospora</i> , <i>Saccharomyces cerevisiae</i> (baker's yeast)	Terrestrial, on fruit and other organic materials	Unicellular and multicellular with septated mycelia	Is common by budding; conidiospores	Involves the formation of an ascus (asc) on specialized hyphae
Deuteromycetes (Fungi Imperfecti) <i>Penicillium</i> , <i>Aspergillus</i>	Terrestrial	A number of these are human pathogens	Budding	Absent or unknown

## Fungi

### ✓ Zygomycota

- Bread molds, conjugation fungi (Zygosporangium) - *Rhizopus*

### ✓ Ascomycota

- Sac fungi (sac-like structure called ascus - ascospores)
- Yeast, morels, *Saccharomyces*, *Neurospora*, *Trichophyton*, *Aspergillus*

## Fungi

### ✓ Basidiomycota

- Club fungi (clubbed shaped sexual structures called basidia-basidiospores)
- Mushrooms such as *Amanita*, Rust; Ergot (*Claviceps purpurea*), *Cryptococcus neoformans*

### ✓ Deuteromycota

- Fungi imperfecti - most human pathogens
- *Coccidioides immitis*, *Penicillium*,

## Fungi

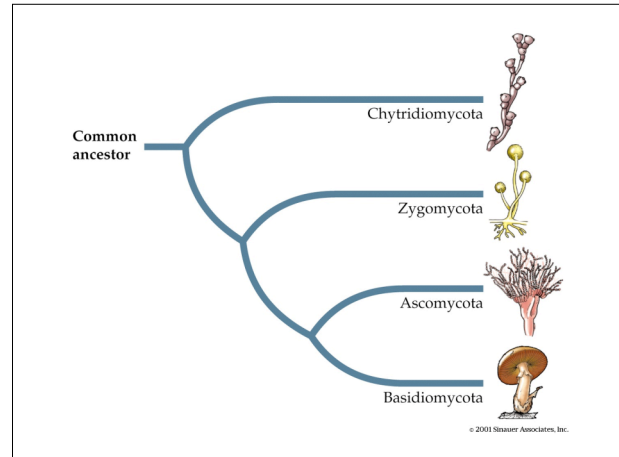
Phylum Typical Examples

**Ascomycota** Yeasts, truffles, morels

**Imperfect fungi** *Aspergillus*, *Penicillium*

**Basidiomycota** Mushrooms, toadstools, rusts

**Zygomycota** *Rhizopus* (black bread mold)



## Fungi

✓ Protists (Kingdom Chromista)

➤ Chytridiomycota

- ☐ Zygotic, sporic (gametic) and asexual reproduction
- ☐ Motile gametes and zoospores
- ☐ Centrioles present
- ☐ Aquatic

## True fungi -

- Haploid, dikaryotic, unicellular to filamentous hyphae
- Zygotic meiosis
- Spindle pole apparatus is distinct
- Asexual reproduction
  - ☐ Sporangia - zygomycetes
  - ☐ Spores (Conidia) - ascomycetes and basidiomycetes
- Food by absorption
- Mostly terrestrial

## Zygomycota

➤ Bread molds, mold on fruits and vegetables

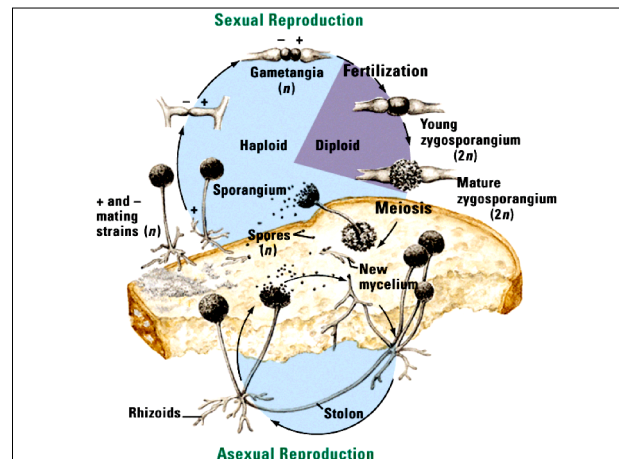
Zygosporangium, conjugation fungi

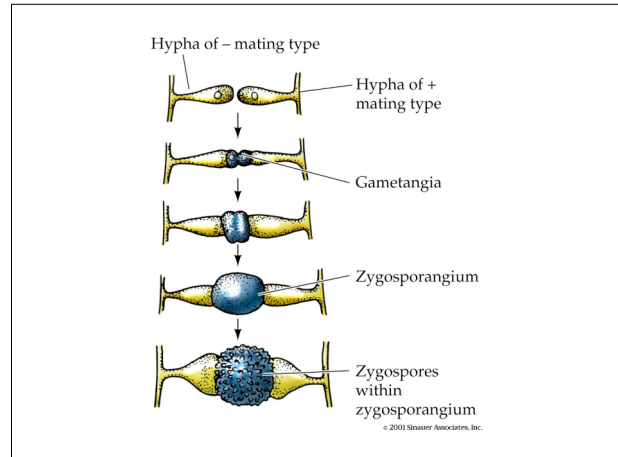
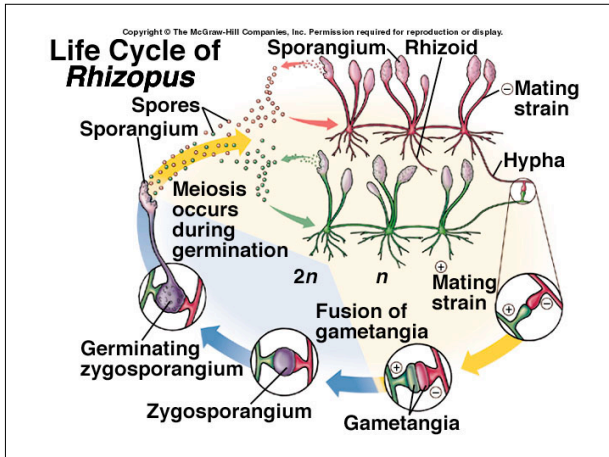
☐ Class Zygomycetes

- Sporangia - conidia
- *Rhizopus* (Tempeh), *Mucor* (tofu)
- *Pilobolus* (dung mold)

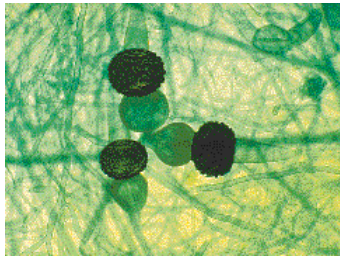
☐ Class Trichomycetes

- Short hyphae
- No mycelium
- Symbiotic - insect gut
- Need a host

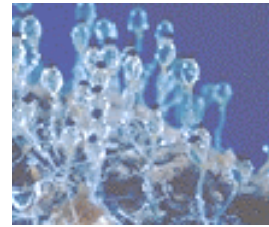




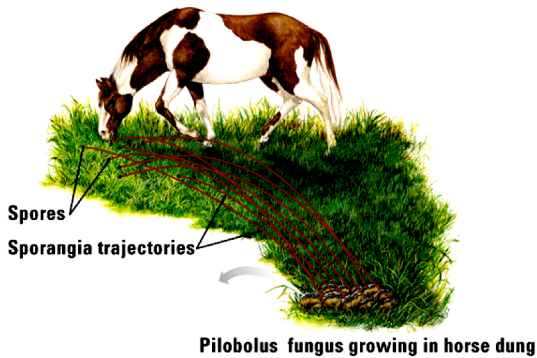
### Conjugation to form Zygospores in *Rhizopus*



### Pilobolus



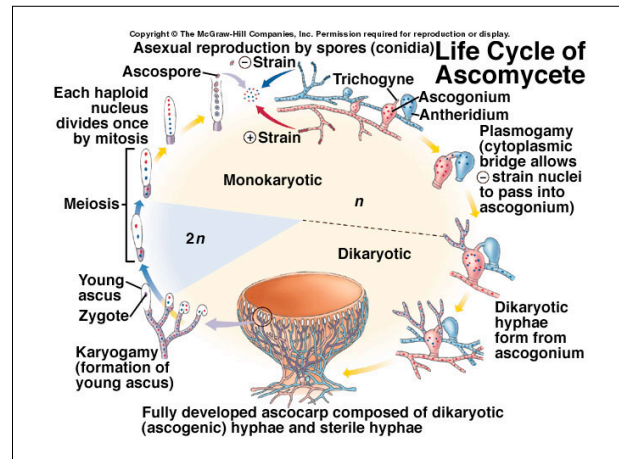
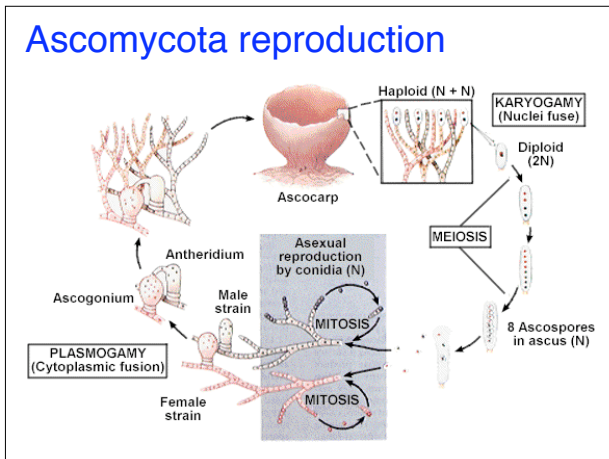
### Fungi disperse their spores effectively



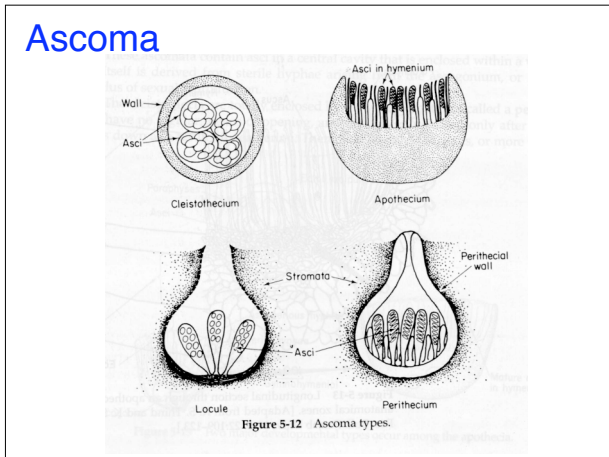
### Ascomycota

- Sac fungi (sac-like structure called ascus - ascospores)
- Class Hemiascomycotina
  - Order Saccharomycetales
    - ☞ Yeast, *Saccharomyces cerevisiae*, Bakers yeast
    - ☞ Single cells make four naked ascospores
    - ☞ *Schizosaccharomyces* - fission yeasts
- Class Euascomycotina

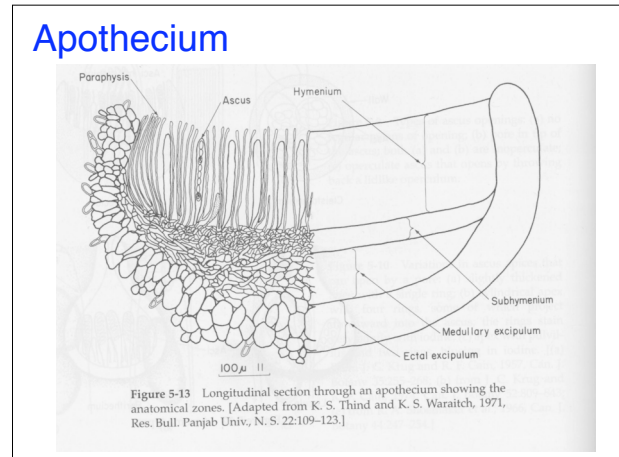
## Ascomycota reproduction



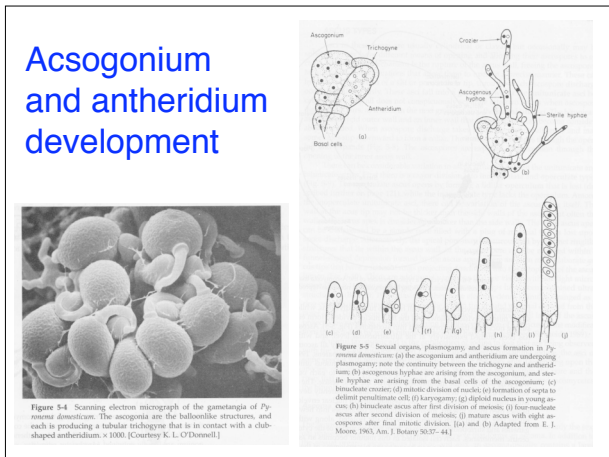
## Ascoma



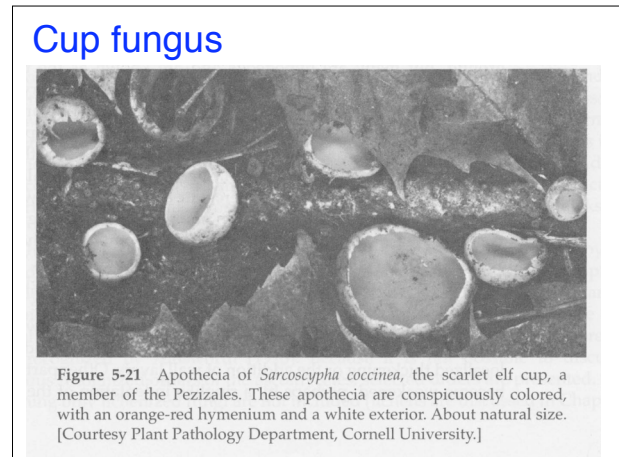
## Apothecium



## Ascogonium and antheridium development



## Cup fungus



## Order Pezizales

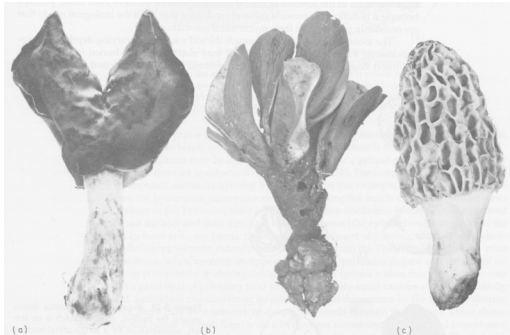


Figure 5-22 Noncupulate, relatively large members of the Pezizales: (a) *Helvella infula*; (b) *Wynnema americana*; (c) *Morchella esculenta*, an edible morel. [(a) Courtesy U.S. Department of Agriculture; (b)-(c) courtesy Plant Pathology Department, Cornell University.]

## Truffles

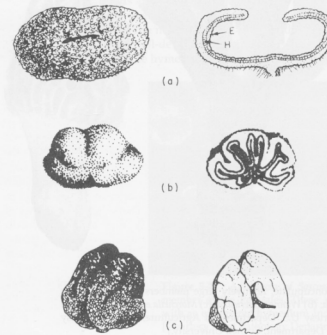


Figure 5-23 Representative ascoma forms among the truffles. A habit sketch is on the left, accompanied by a longitudinal section on the right: E, epithelium; H, hymenium. (a)  $\times 4.6$ ; (b) and (c)  $\times 1.5$ . [From L. E. Hawker, Phil. Trans. Roy. Soc. London, Ser. B 237:429-546.]

## Morels



## Ascomycetes



Figure 25.10 Division Ascomycota. (a) The common morel, *Morchella esculenta*, is one of the choicest edible fungi. It fruits in the spring. (b) Scarlet cups, *Sarcoscypha coccinea*, with open ascocarps (apothecia). (c) The black truffle, *Tuber brumale*, is highly prized for its flavor by gourmet cooks. Technically truffles are mycorrhizal associations on oak trees.

## Peziza (pigs ears)



## Powdery mildews

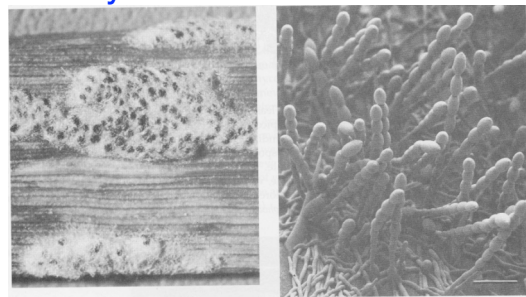


Figure 5-30 Powdery mildew fungus, *Erysiphe graminis* on a leaf. (a) The dark cleistothecia are immersed within the light mycelium and conidia. Approximately  $\times 10$ . (b) Scanning electron micrograph of conidia. Scale bar = 50  $\mu\text{m}$ . [(a) Courtesy Plant Pathology Department, Cornell University; (b) courtesy Richard J. Howard.]

## Claviceps purpurea

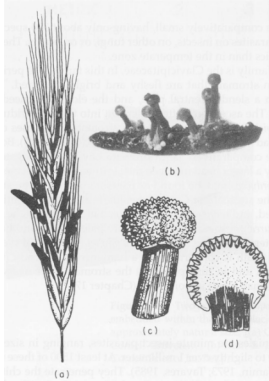


Figure 5-40 *Claviceps purpurea* (Hypocreales): (a) sclerotia (ergots) produced among rye grains; (b) sclerotia producing fleshy stromata; (c) detail of fertile head of stroma; (d) longitudinal section through stromatic head showing embedded flask-shaped perithecia. (a), (b) approximately 3/4 natural size. [(a) From A. Engler and K. Prantl, 1897, Die natürlichen Pflanzenflora; (b) after Tulasne, in: A. Engler and K. Prantl, 1897, Die natürlichen Pflanzenflora.]

## Saccharomyces cerevisiae

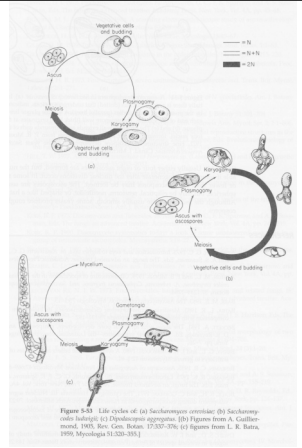


Figure 5-33 Life cycle of (a) *Saccharomyces cerevisiae*; (b) *Saccharomyces uvarum*. (a) *Saccharomyces cerevisiae*; (b) *Saccharomyces uvarum*. Figures from A. Gullermond, 1950, *Rev. Can. Bot.* 27:227-270; (a) Figure from L. R. Batra, 1959, *Mycologia* 51:329-351.

## Fungi

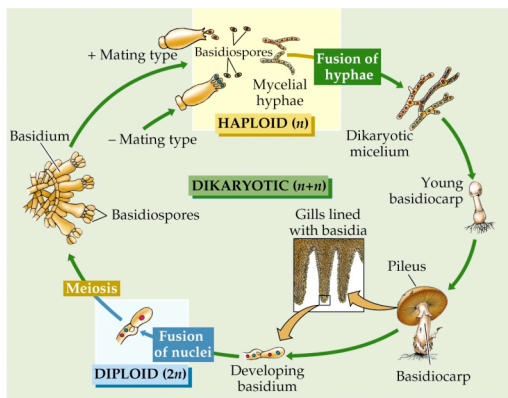
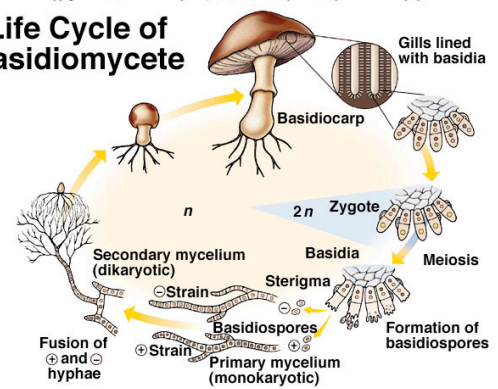
### ✓ Basidiomycota

- Club fungi (clubbed shaped sexual structures called basidia-basidiospores)
- Mushrooms such as *Amanita*, Rust; *Cryptococcus neoformans*

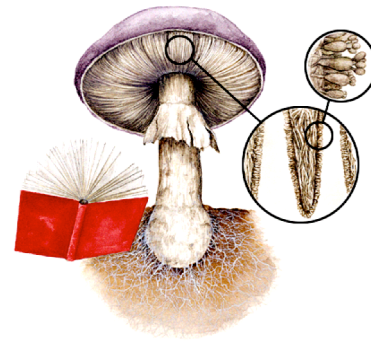
### ✓ Deuteromycota

- Fungi imperfecti - most human pathogens
- *Coccidioides immitis*, *Aspergillus*, *Penicillium*,

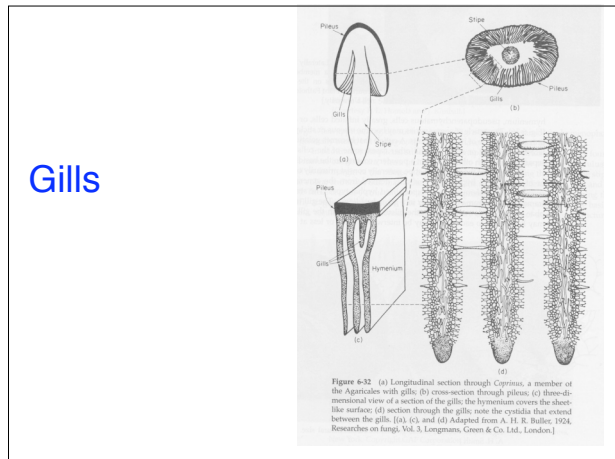
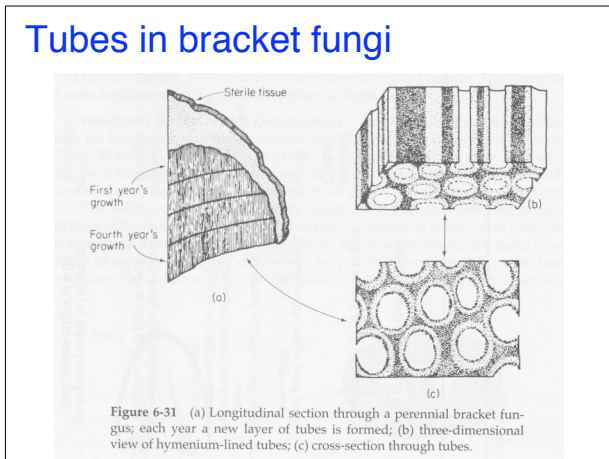
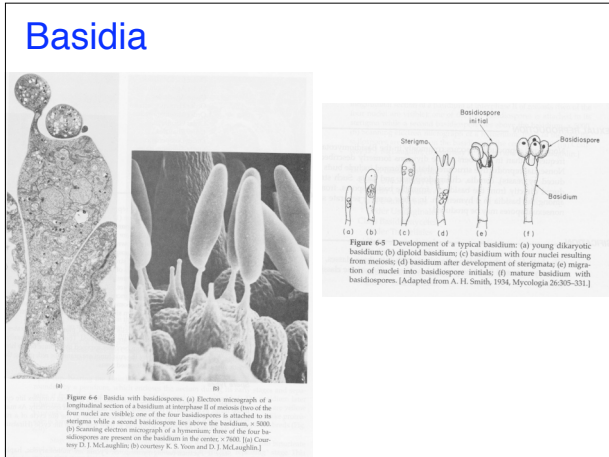
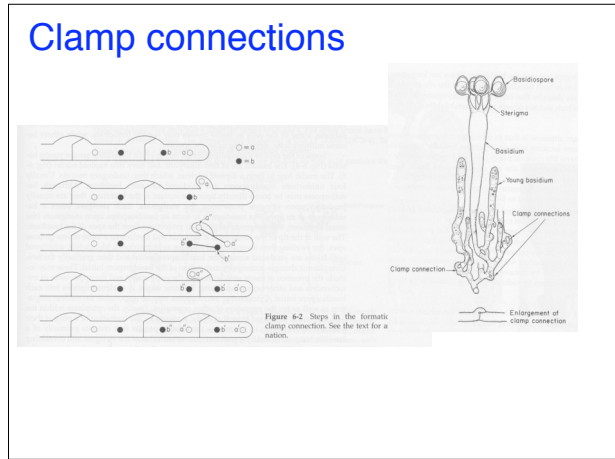
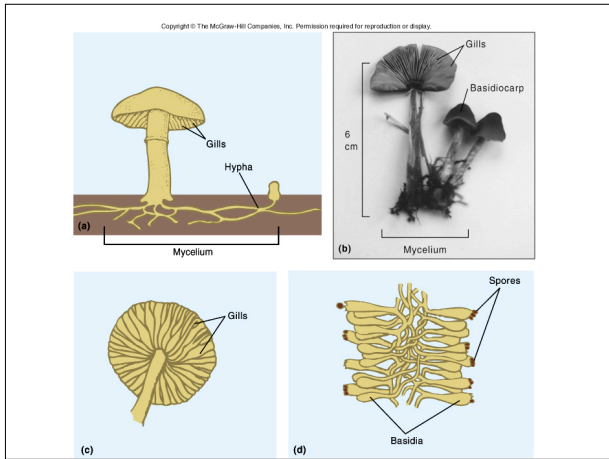
## Life Cycle of Basidiomycete



## The gills of a basidiomycete are like the pages of a book



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# Coral Fungus

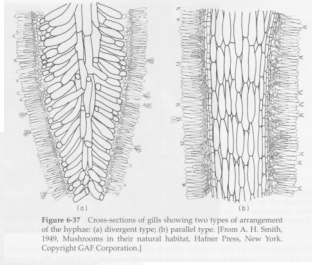
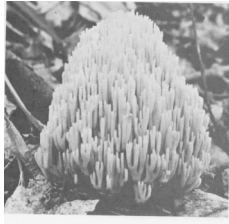


Figure 6-37 Cross-sections of gills showing two types of arrangement of the hyphae: (a) divergent type; (b) parallel type. [From A. H. Smith, 1949, Mushrooms in their natural habitat, Hafner Press, New York. Copyright G&F Corporation.]

Figure 6-25 Basidioma of a coral fungus. The smooth hymenophore covers the upright branches. The basidioma is about 10 centimeters tall. [From E. J. Moore and V. N. Rockcastle, Fungi, Cornell Science Leaflet.]

# Pileus development

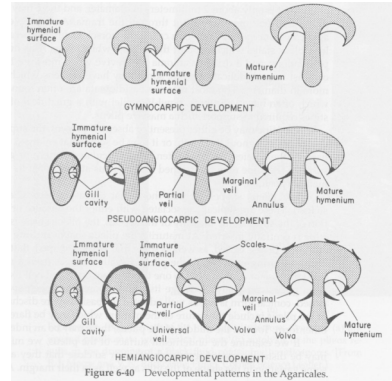


Figure 6-40 Developmental patterns in the Agaricales.

# Inky cap mushrooms



Figure 6-41 Basidiomata of the inky cap mushroom, *Coprinus*: (a) unopened basidiomata with conical pileus; (b) autolysis of the pileus results in the dripping of a black fluid containing basidiospores. [From E. J. Moore and V. N. Rockcastle, Fungi, Cornell Science Leaflet.]

# Jelly fungus

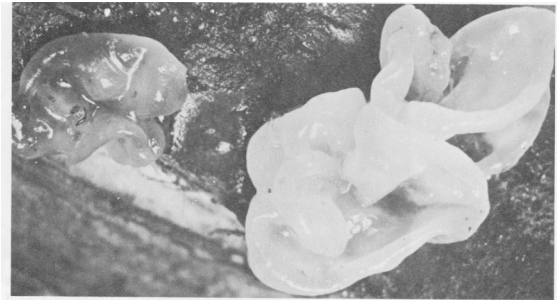


Figure 6-19 Basidiomata of *Tremella fibulifera*, a jelly fungus. The larger basidioma is about 4 centimeters in diameter. [Courtesy J. S. Furtado.]

# Mushrooms & rusts

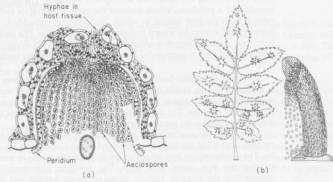


Figure 6-9 Aecia in the Uredinales: (a) acecium of *Puccinia graminis* showing typical cupulate form,  $\times 510$ ; an enlarged aceciospore is also shown; (b) a hornlike acecium of *Gymnosporangium juniperi-reginae* ( $\times 80$ ) and its appearance on the host plant. [From P. Sappin-Trouilly, 1896, Botaniste 5:29-244.]



Figure 6-38 Agaric that forms a universal veil. Left: a young basidioma is just beginning to rupture the universal veil; right: the universal veil is left as a volva at the base of an older basidioma. Note that a cortina and an annulus are lacking. [Courtesy Plant Pathology Department, Cornell University.]

# Rust life cycle

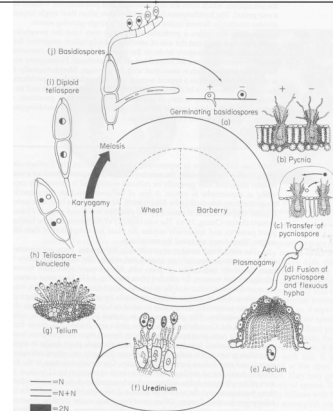
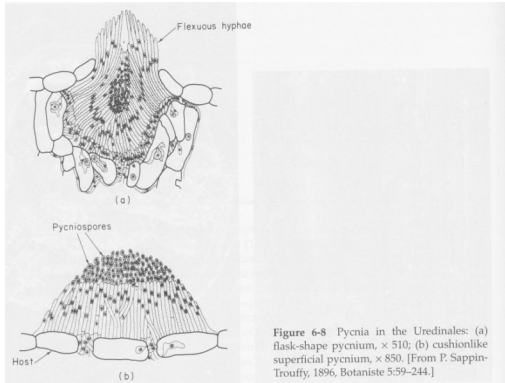
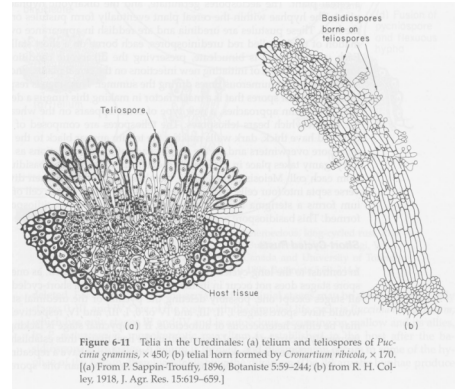


Figure 6-12 Life cycle of a typical heteroecious, long-cycled rust, *Puccinia graminis*. [B]-[d] From A. H. R. Buller, *Researches on Fungi*, Vol. 7, by permission of Royal Society of Canada and University of Toronto Press; [e]-[g] from P. Sappin-Trouilly, 1896, *Botaniste* 5:29-244.]

## Pycnia (Rusts)



## Teliospores



## Puffball



## Giant Puffballs



Figure 6-53 Basidiomata of the giant puffball, *Calvatia gigantea*. Compare their size with the 36-inch ruler. [Courtesy Plant Pathology Department, Cornell University.]

## Earthstars



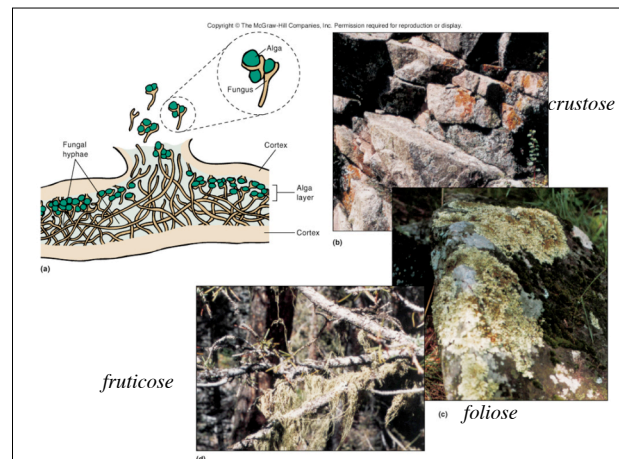
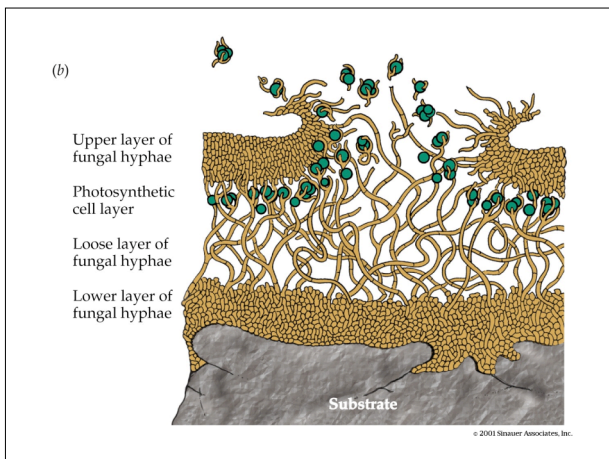
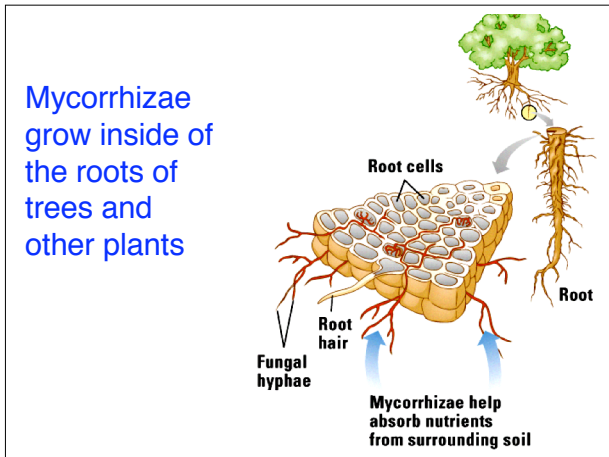
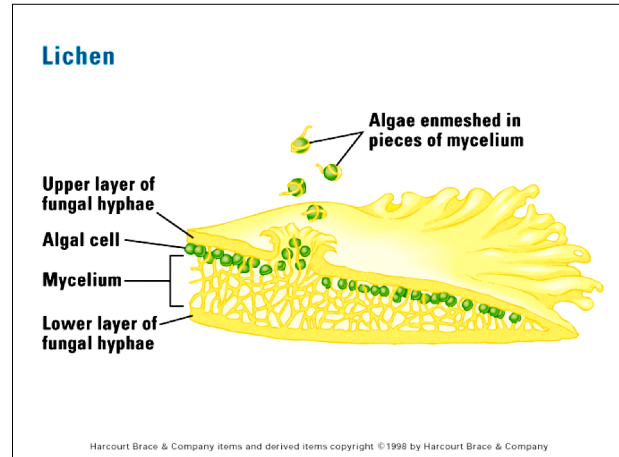
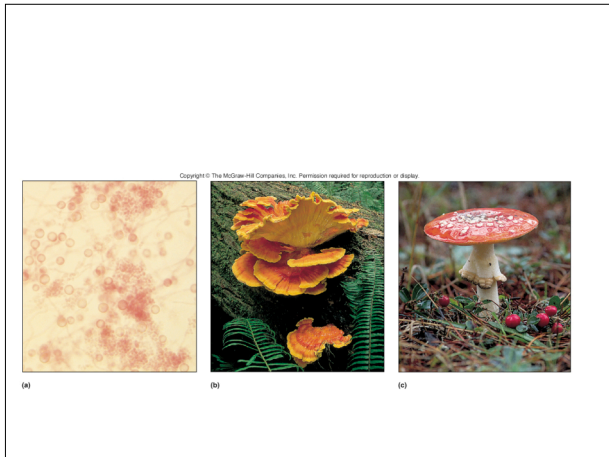
Figure 6-54 Earthstar, *Geastrum*. Note that the peridium of the basidioma at the left has not ruptured and also note the outside in the thin inner peridium of the central basidioma. The peridium of the basidioma at the right has collapsed after discharge of the capillitium and basidiospores. Approximately  $\times 1$ . [From E. J. Moore and V. N. Rockcastle, *Fungi*, Cornell Science Leaflet.]

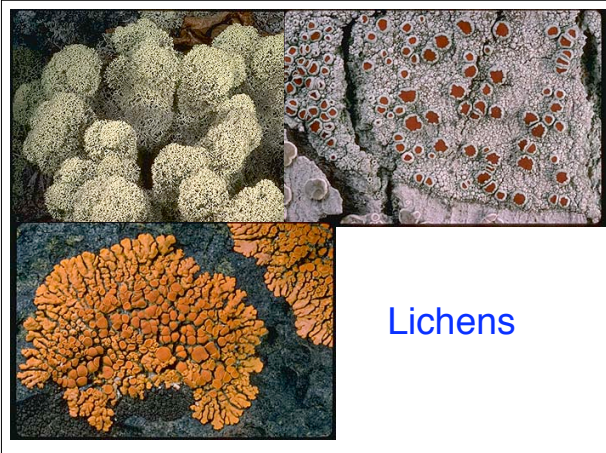
## Mushrooms



## Mushrooms







Lichens

- ✓ Fred Fungus and Alice Algae took a "lichen" to each other.
- ✓ They got married, but unfortunately their marriage has been on the rocks ever since.

*Candida albicans* budding

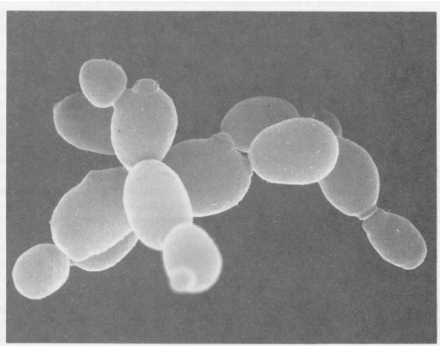
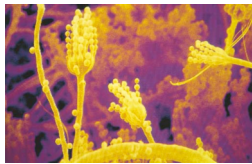


Figure 7-1 Budding cells of a yeast, *Candida albicans*.  $\times 11,130$ . [Copyright by David M. Phillips/Visuals Unlimited.]

Aspergillus



Figure 25.11 Asexual Reproduction in Ascomycetes. Characteristic conidiospores of *Aspergillus* as viewed with the electron microscope ( $\times 1,200$ ).



(a)



(b)

Fig. 11.8

Conidia development

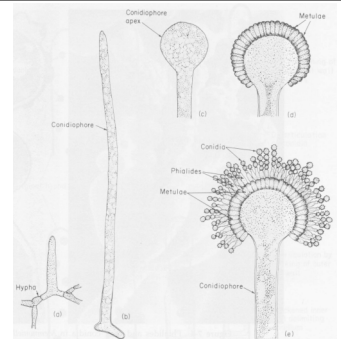


Figure 7-3 Development of the conidial apparatus in *Aspergillus niger*: (a) foot cell originating from hypha and bearing young conidiophore as a vertical branch; (b) developing conidiophore; (c) swelling of the terminal portion of the conidiophore; (d) development of metulae from the conidiophore apex; (e) young sporulating apex showing phialides bearing chains of conidia. (a) and (b)  $\times 172$ , (c)-(e)  $\times 265$ . [From C. Thom and K. B. Raper, 1945, A manual of the Aspergilli, Williams & Wilkins Company, Baltimore.]

## Phialides and conidia

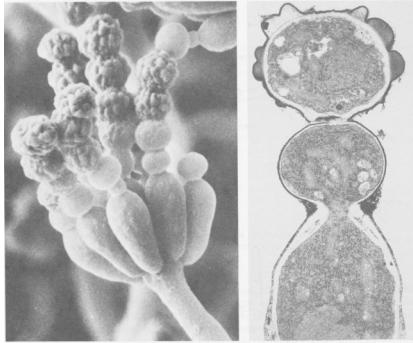


Figure 7-4 Phialides and their conidia in *Monilia echinata*. Left: scanning electron micrograph showing a surface view of a cluster of phialides and their chains of conidia; note that the basal conidia are still incompletely developed and have not yet formed their rough markings. Right: transmission electron micrograph showing a section through the phialide tip and two conidia. [Courtesy R. Campbell, Bristol University; from 1975, *Mycologia* 67:760-769.]

## Conidia development

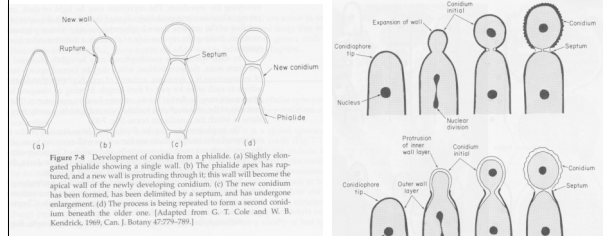


Figure 7-4 Development of conidia from a phialide. (a) Slightly elongated phialide showing a single wall. (b) The phialide apex has ruptured, and a new wall is protruding through it; this wall will become the apical wall of the newly developing conidium. (c) The new conidium has been formed, has been delimited by a septum, and has undergone enlargement. (d) The process is being repeated to form a second conidium beneath the older one. [Adapted from G. T. Cole and W. B. Kendrick, 1969, *Can. J. Botany* 47:779-789.]

Figure 7-6 Top: holoblastic conidium development; bottom: enterothallic conidium development. Successive stages are shown in each series.

## Chlamydospores

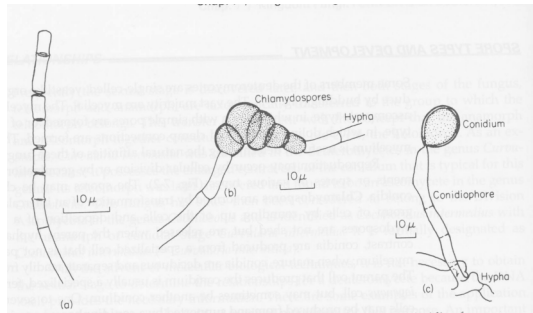


Figure 7-2 Types of spores formed by the Deuteromycota: (a) oidia of *Geotrichum*; (b) chlamydospores of *Peyronella*; (c) conidium of *Acromoniella*. [From drawings by H. H. Swart.]

## Conidia

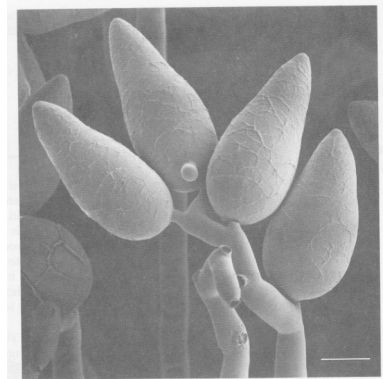


Figure 7-7 Holoblastic development of conidia by *Magnaporthe grisea*. Note the extrusion of the bud. Scale bar = 5.0 μm. [Courtesy Richard J. Howard.]

## Holothallic & enterothallic conidia development

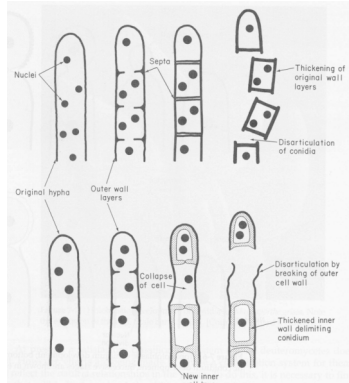


Figure 7-5 Top: holothallic conidium development; bottom: enterothallic conidium development. Successive stages are shown. In each type, a random number of nuclei are included in each conidium.

## Pycnidia

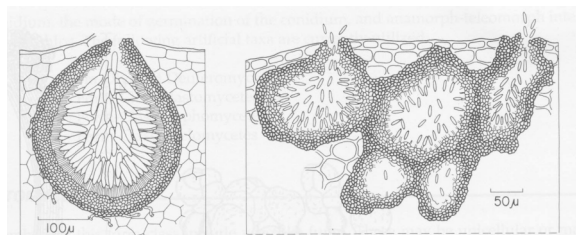
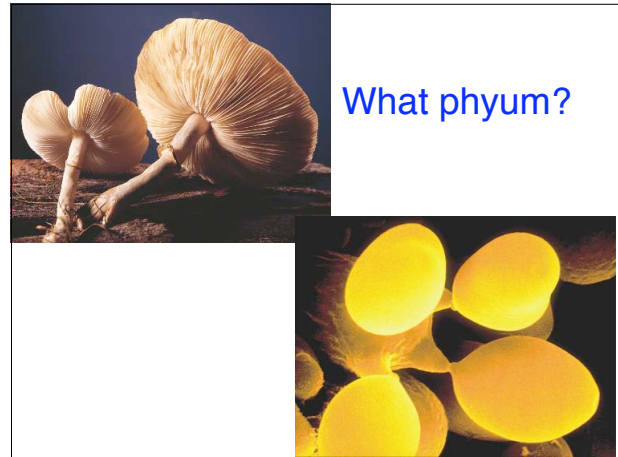
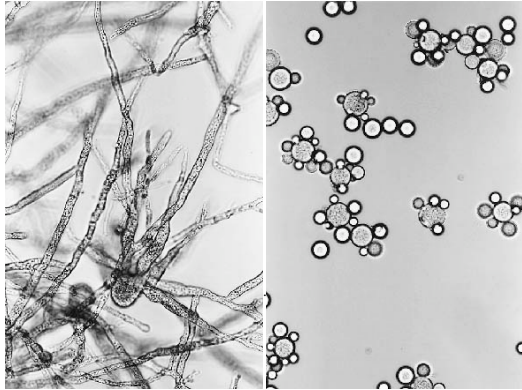


Figure 7-10 Longitudinal sections through pycnidia of two species of *Macrophoma*. [From G. Morgan-Jones, 1971, *Can. J. Botany* 49:1921-1929.]

## Mucor (Dimorphism)

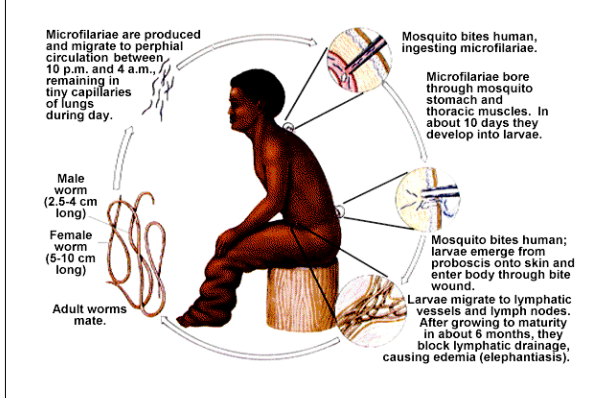


## Helminths

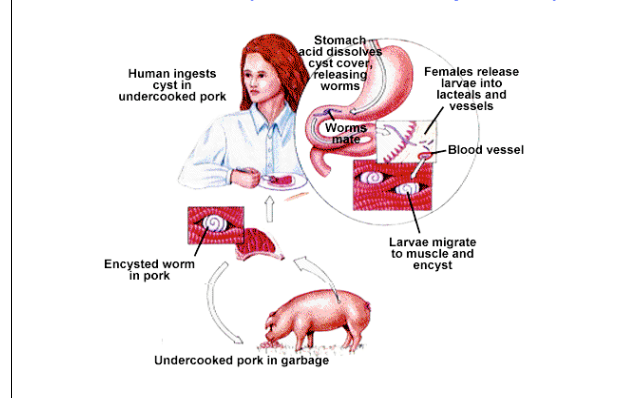
Flatworms	Parasites live in or on hosts	Taenia and other tapeworms are internal parasites; flukes can be internal or external parasites.
Nematodes	Most parasites live in the intestine or blood of hosts	Hookworms, pinworms, and several other nematodes live in intestines or lymph.

Arachnids	Have eight legs	Spiders, scorpions, ticks, mites
Insects	Have six legs	Lice, fleas, flies, mosquitoes, some bugs
Crustaceae	A pair of appendages on each body segment	Crabs, crayfish, copepods

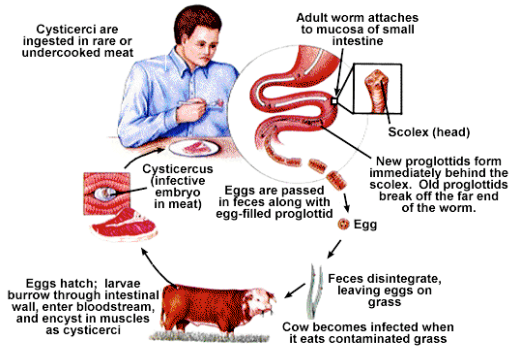
## Roundworm (*Wuchereria bancrofti*)



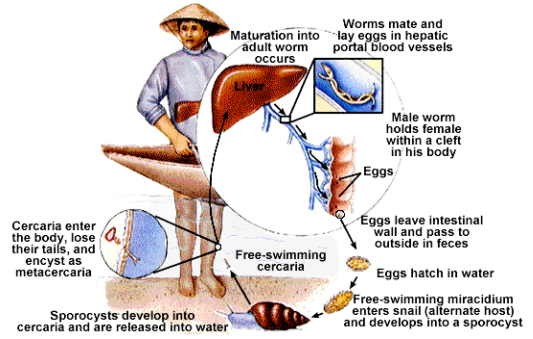
## Roundworm (*Trichinella spiralis*)



## Tapeworm (*Taenia saginata*)

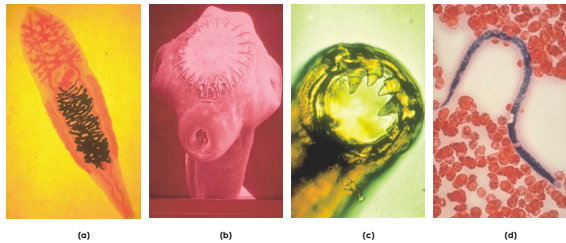


## Blood fluke (*Schistosoma japonicum*)



## Helminths

- ✓ A. Liver fluke
- ✓ B. Scolex of a tapeworm
- ✓ C. Mouth of a hookworm
- ✓ D. Fililaria of a heartworm



## Arthropods-vectors or disease

