Fungi

Chapter 31 + parts of chapter 28

2

5 major Eukaryote Clades

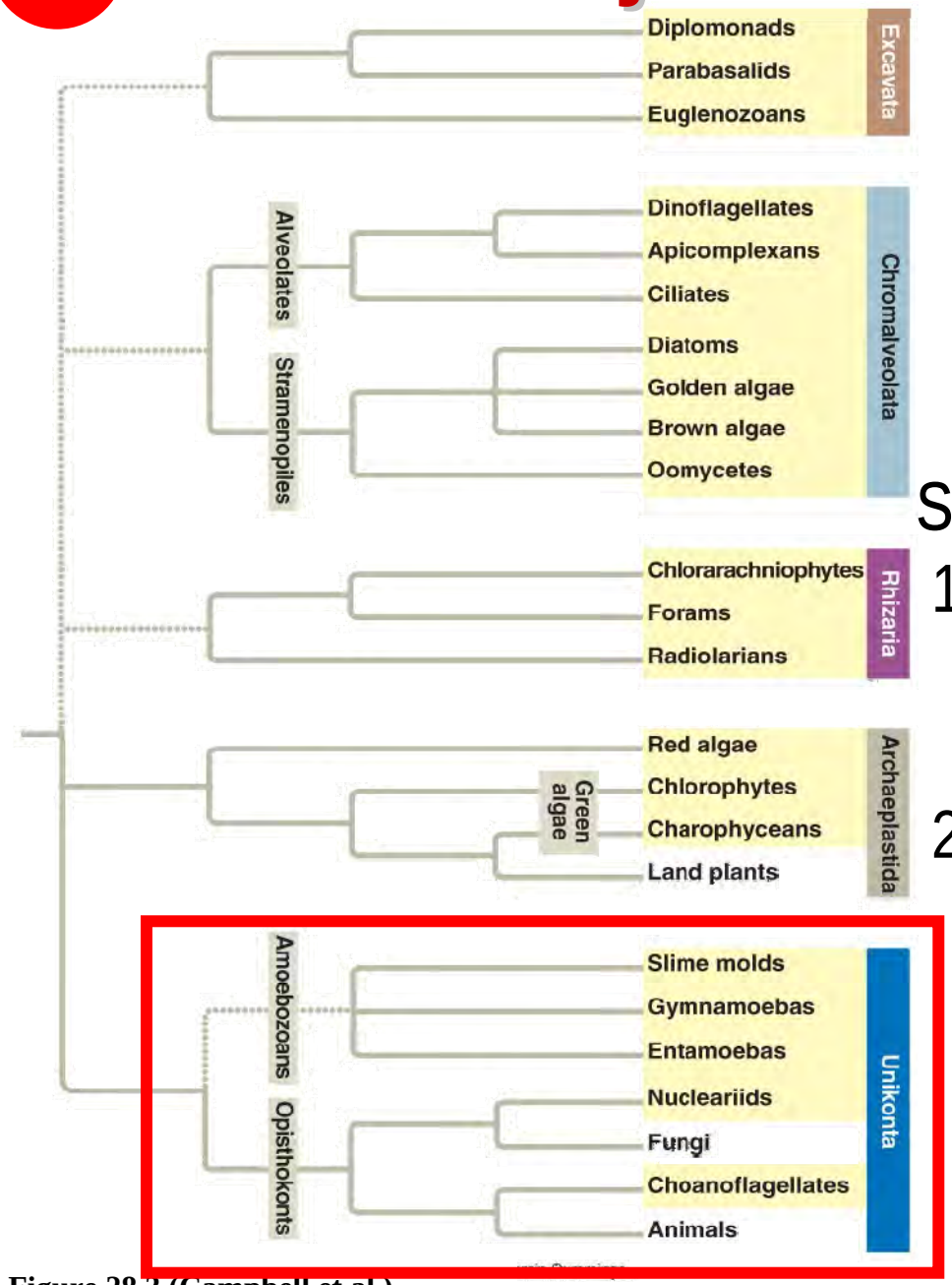


Figure 28.3 (Campbell et al.)

Unikonts

2 major subclades

1. Amoebozoans
2. Opisthokonts

Synapomorphies:

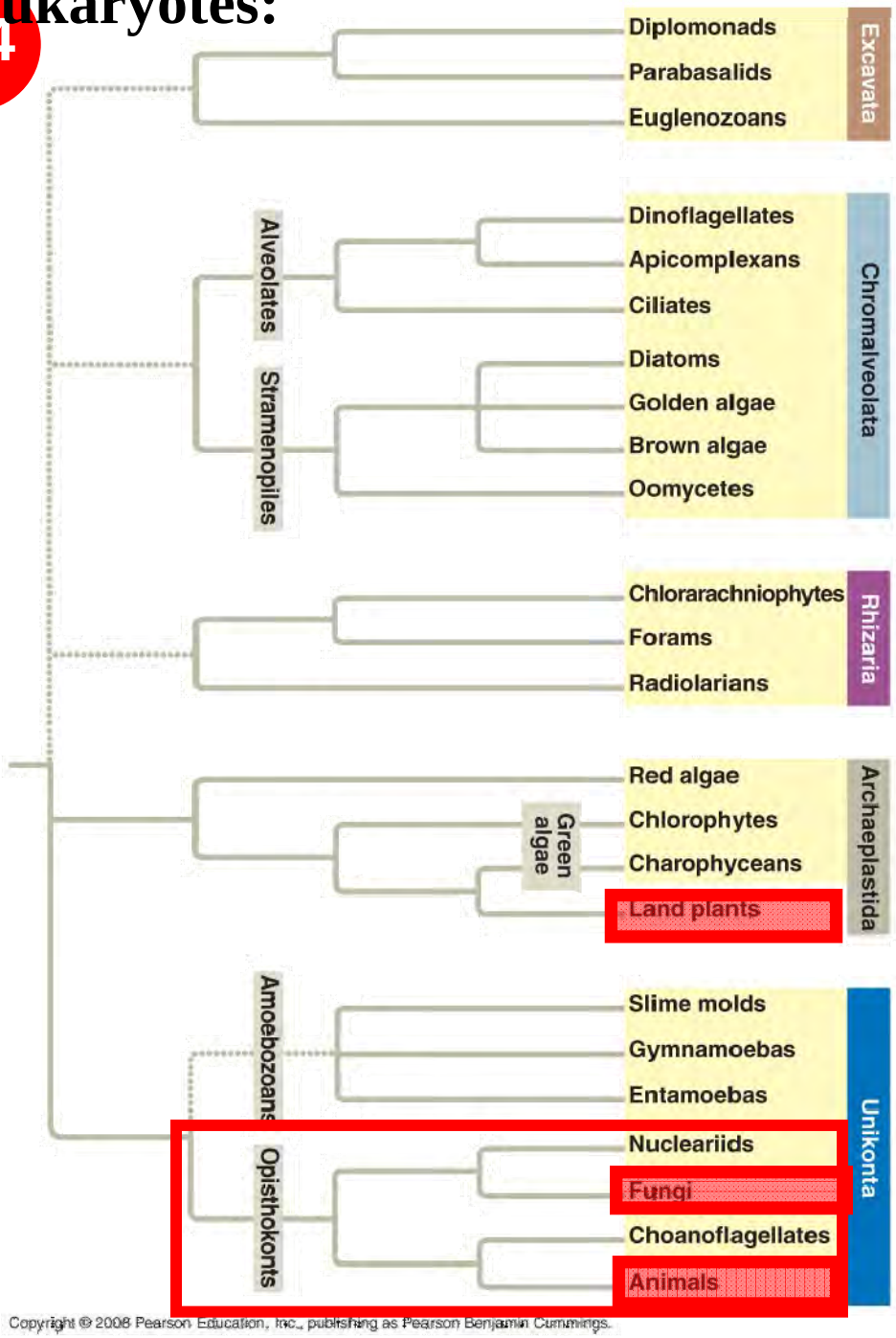
1. A single flagellum or are an "amoebae" with no flagellum

2. Similar proteins and DNA???

Fungi vs. Plants

- Often mistakenly associated with Plant Kingdom
  - Look more like a plant than animal
  - Sessile
- But…
  - heterotrophic
  - no chlorophyll
  - no roots or leaves
  - cell walls of chitin

Eukaryotes: 4



Opisthokonta

Fungi are much closer related to Animalia than Plantae

Molecular homologies:
- rRNA sequences,
- amino acid sequences

Morphological homologies:
- single posterior flagellum
  (in fungi only in chytrid fungi)
- similar mitochondria w/ flat cristae

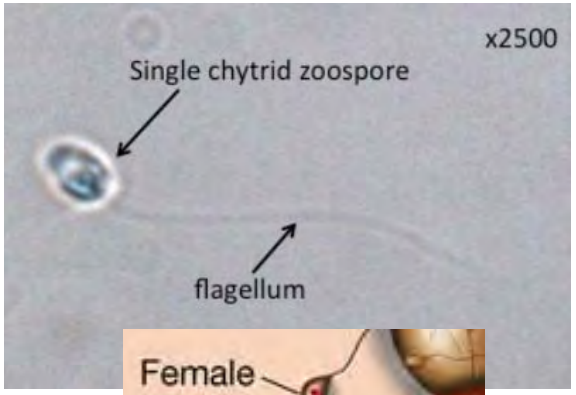
Fungi

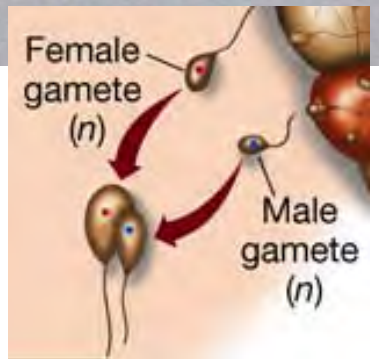
Animals

5

Posterior flagellated gametes

Rat Seastar Rhino Snow leopard Sea urchin Rhea Human

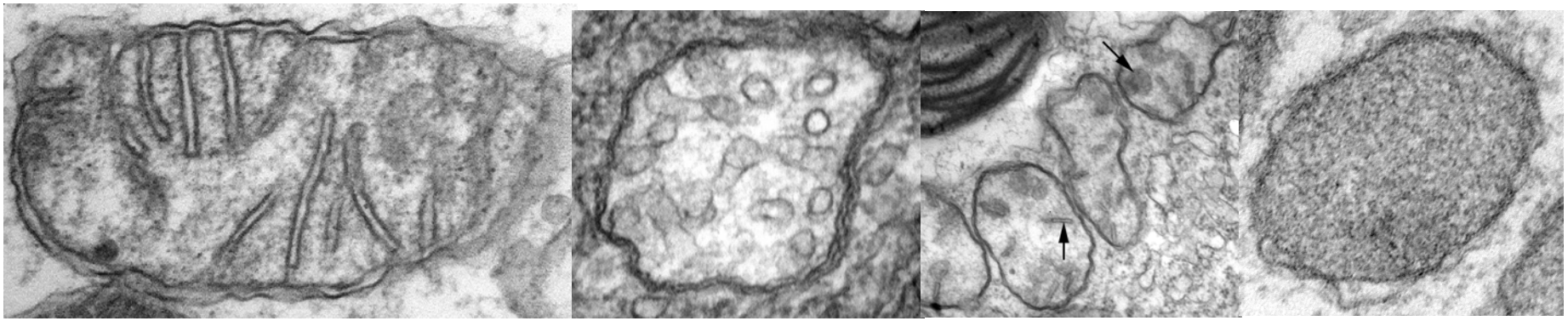




Chytrid fungus

3 main types of mitochondral cristae (infoldings of membrane)

flat tubular discoidal none



e.g. opithsokonts e.g. diatoms e.g. euglenids e.g. parabasalids

6

Enormous species diversity:

- 100,000 species described. Probably more like 1.5 million.

7

ENORMOUS BIOMASS

Armillaria ostoyae

Armillaria:

Honey fungus.

Single organism:
Giant subterranean network of hyphae

~ 1,000 hectares (3.8 mile^2)

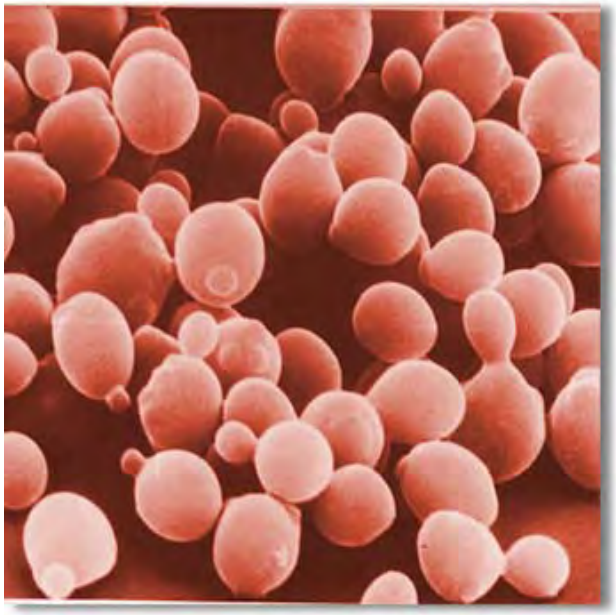
- Hundreds of tons

~ 2000 years old

Above-ground fruiting bodies only a small fraction of the biomass of the underground network.

Morphology of Fungi

- Most spp multicellular
- Some spp single cellular
  - "yeasts" = those in Ascomycota and Basidiomycota
- Some spp w/ both single and multicellular stages



Yeast

see Figure 31.7 (Campbell et al.)

Morphology of Multicellular fungi

- Fungi are made of thread-like structures called <u>hyphae</u> (sing. hypha)
- A diffuse network of *feeding* hyphae are collectively called a <u>mycelium</u>
  - Can be beneath surface (i.e. ground or material on which it feeds), on the surface, or both
  - High surface area to volume ratio increases feeding efficiency
- A group of woven *reproductive* hyphae is a <u>fruiting body</u>
  - A spore producing structure
  - Some are above ground (aka mushrooms) so can dispense spores they produce into air

1 cm^3 of soil:
- 1 km of hyphae
- 300 cm^2 surface area

http://www.shutterstock.com/pic-34273630/stock-photo-mold-strawberry.html

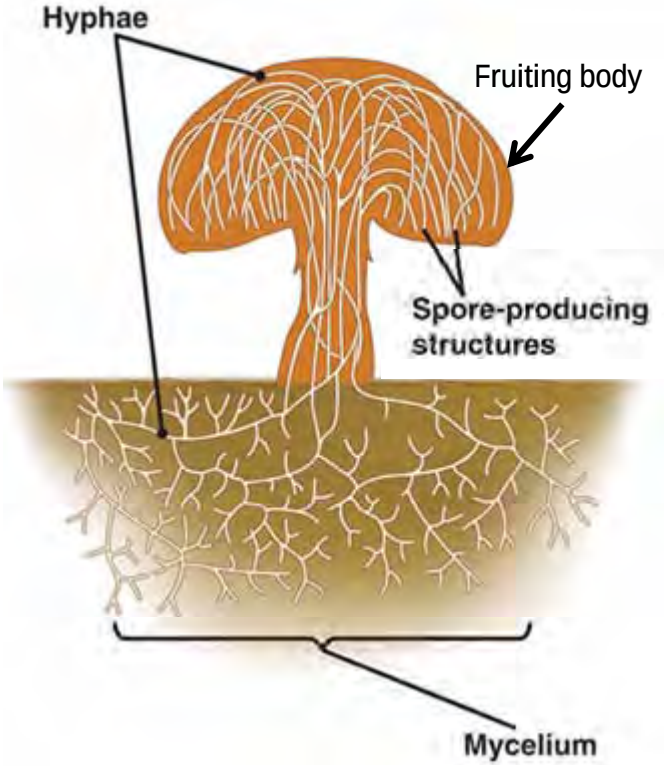
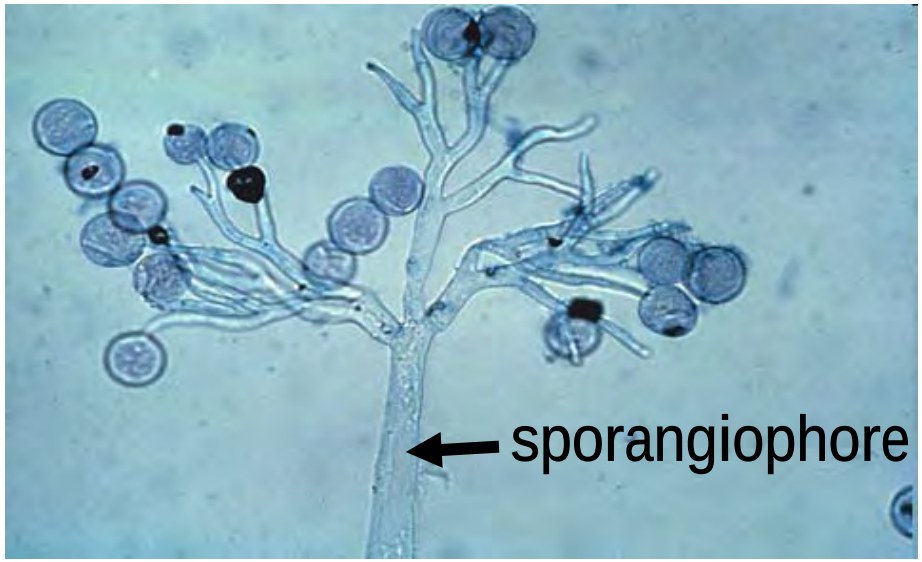


Figure 31.2 (Campbell et al.)

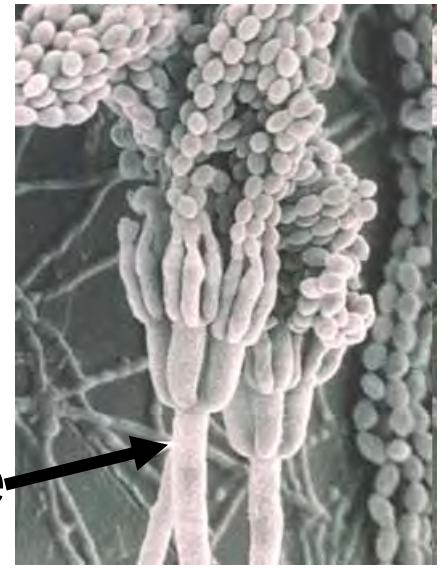
10

Fruiting Bodies are variable among groups

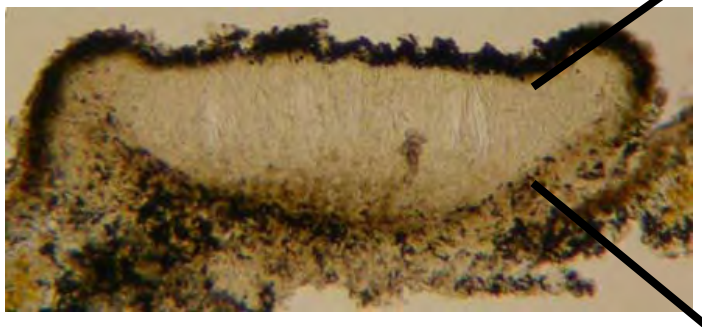
Zygomycota



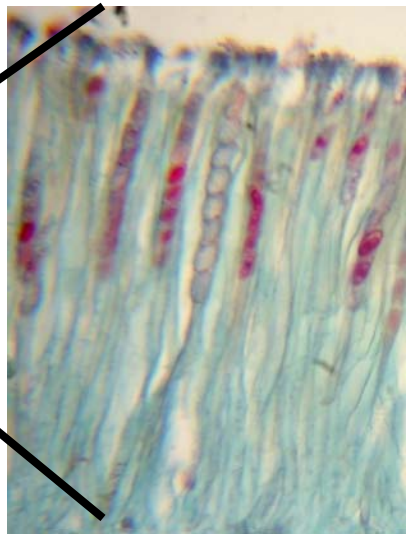
Ascomycota



Ascomycota

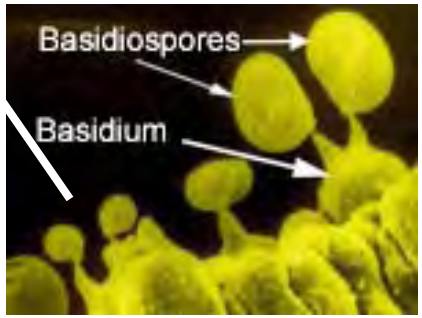


Ascocarp w/ Asci



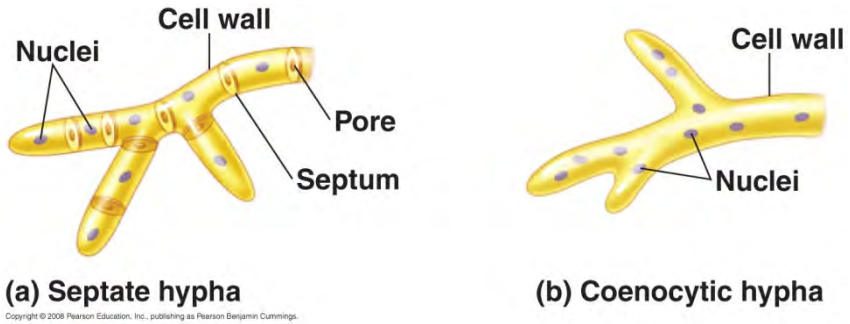
Asci w/ ascospores

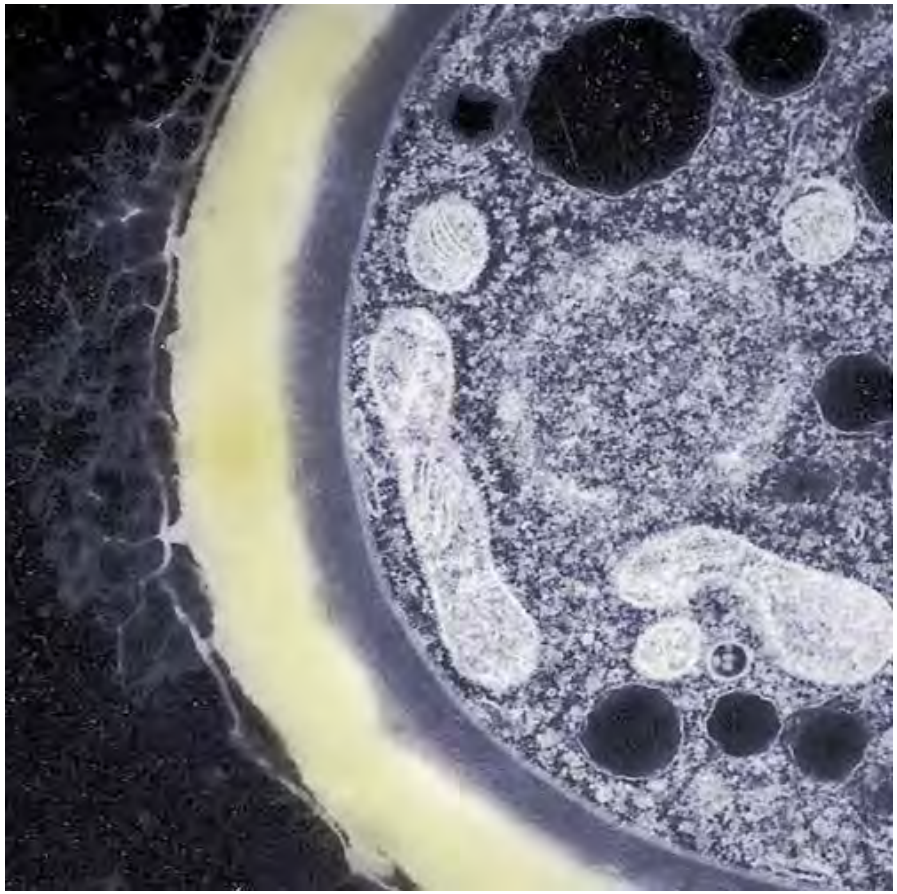
Basidiomycota



Morphology of Multicellular fungi

- **Cell walls = mostly *chitin***
  - Chitin is a nitrogen containing polysaccharide derived from glucose
  - Very strong for support
  - Found where else?





http://www.flickr.com/photos/ajc1/3420421465/

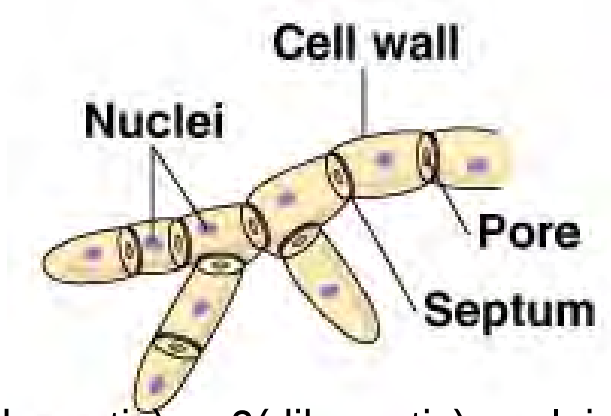
Figure 31.3 (Campbell et al.)

Morphology of Multicellular fungi

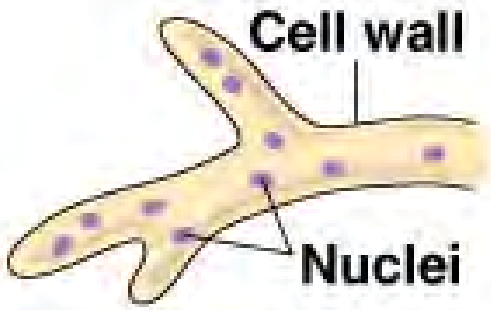
- Septate spp - hyphae divided into cells by septa
- Aseptate spp - cells are undivided

Septate hyphae

Aseptate hyphae



1 (monokaryotic) or 2(dikaryotic) nuclei / cell



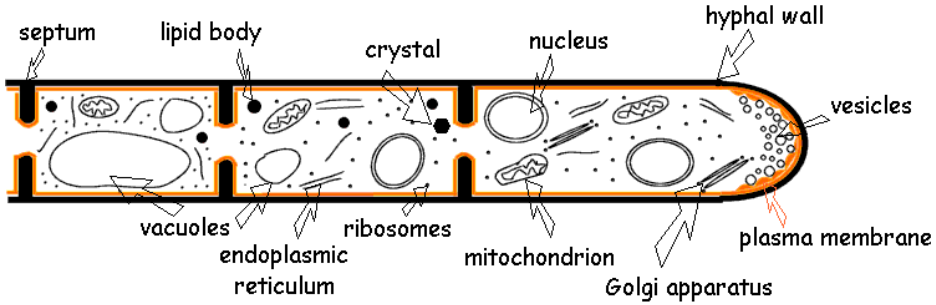
Multiple nuclei (>2) / cell (Coenocytic)

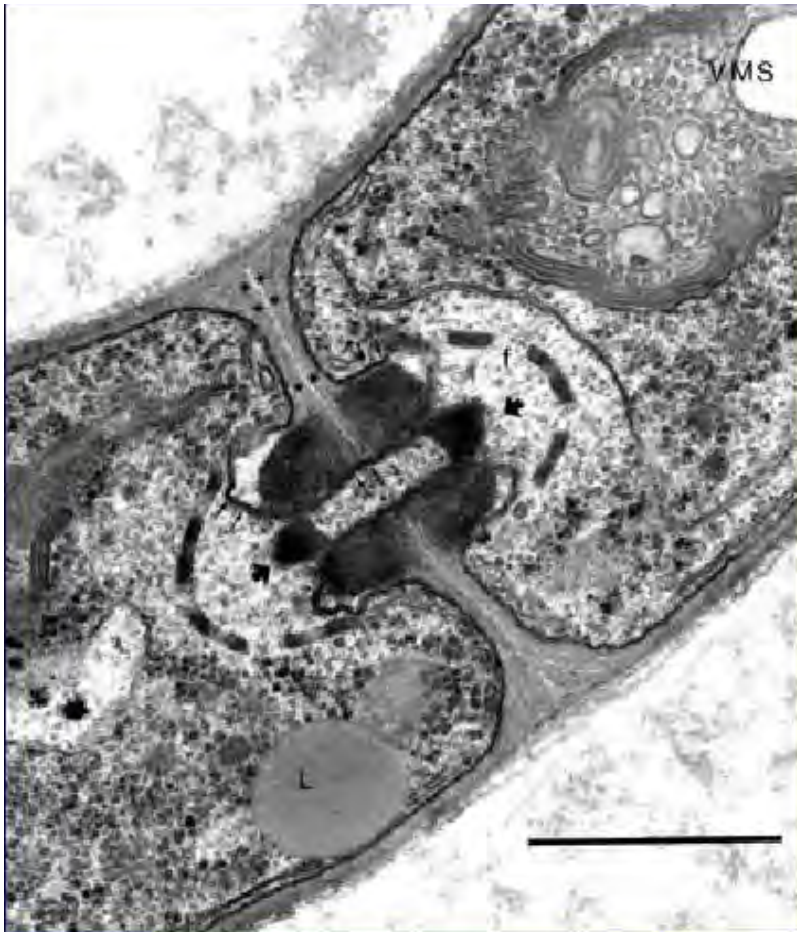
Figure 31.3 (Campbell et al.)

Morphology of Multicellular fungi

In septate hypha, pores in septa may allow flow of:

- cytoplasm,
- mitochondria
- ribosomes
- even nuclei!





http://www.bsu.edu/classes/ruch/msa/blackwell/9-33.jpg

Are fungi really multicellular???

Pore closure separating cells allows cells to perform different functions

e.g. develop into a reproductive structure

http://www.fungionline.org.uk/3hyphae/1hypha_ultra.html

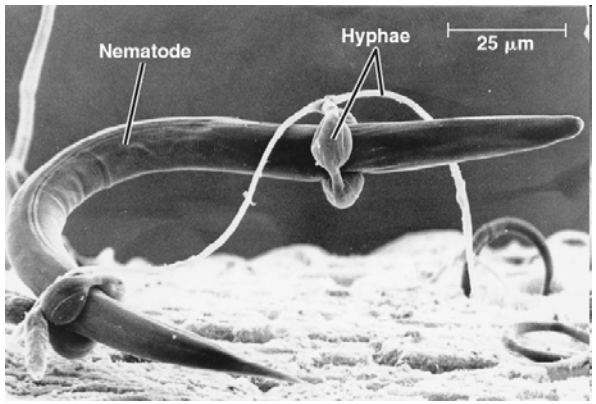
Nutrition

All fungi are <u>absorptive</u> <u>heterotrophs</u>

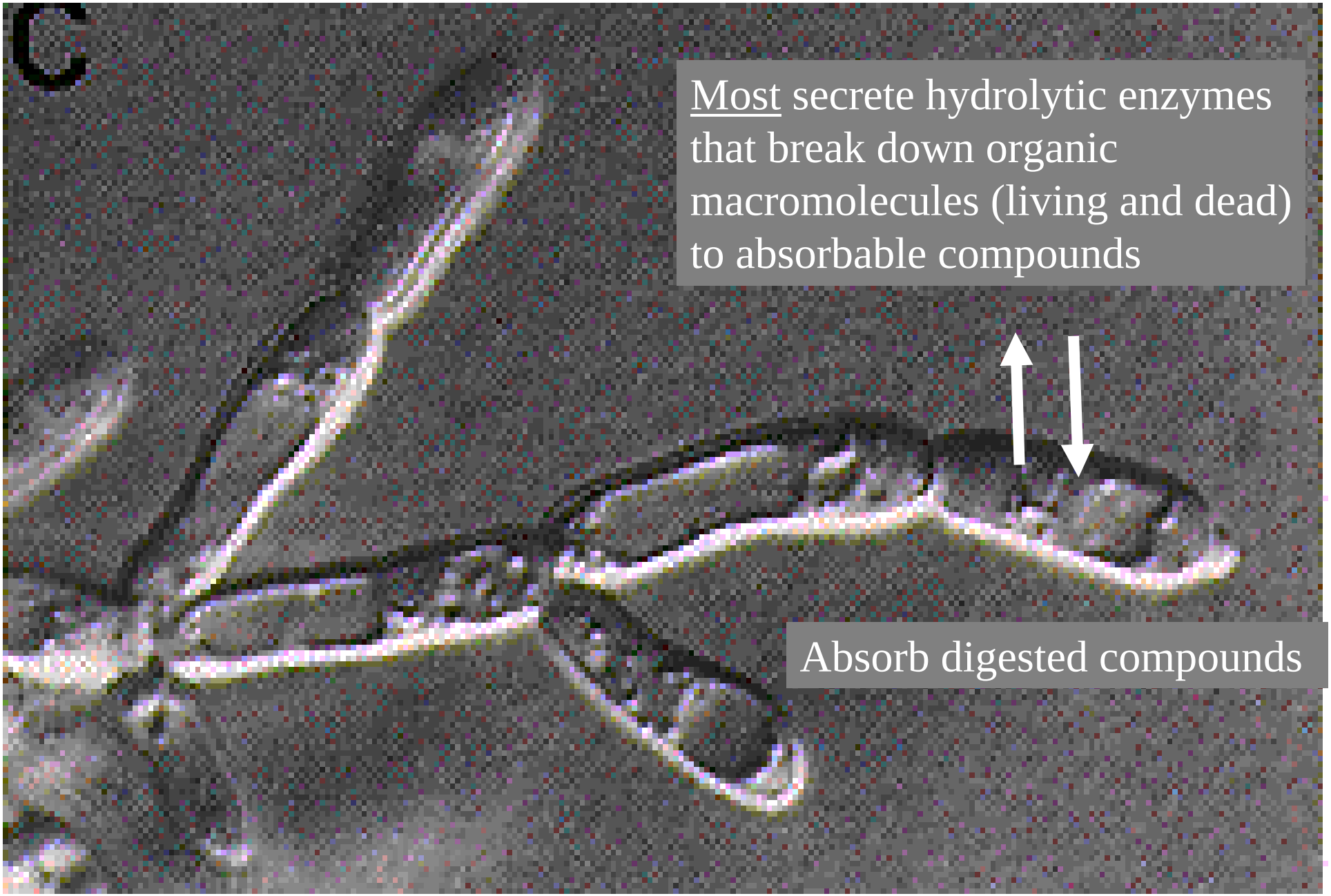
- NO chlorophyll
- NO fixing of carbon from CO_2
- Enzymes digest food outside body

3 ways which fungi obtain nourishment:

1. Saprobic
   - from nonliving or decaying organic matter
2. Parasitic
   - from living hosts in or on which they live
3. Predatory
   - by capturing live animals



Saprobic Fungi



Nutrition

Some use specialized hyphae (haustorium) to extract absorbable nutrients directly from cells w/o using enzymes

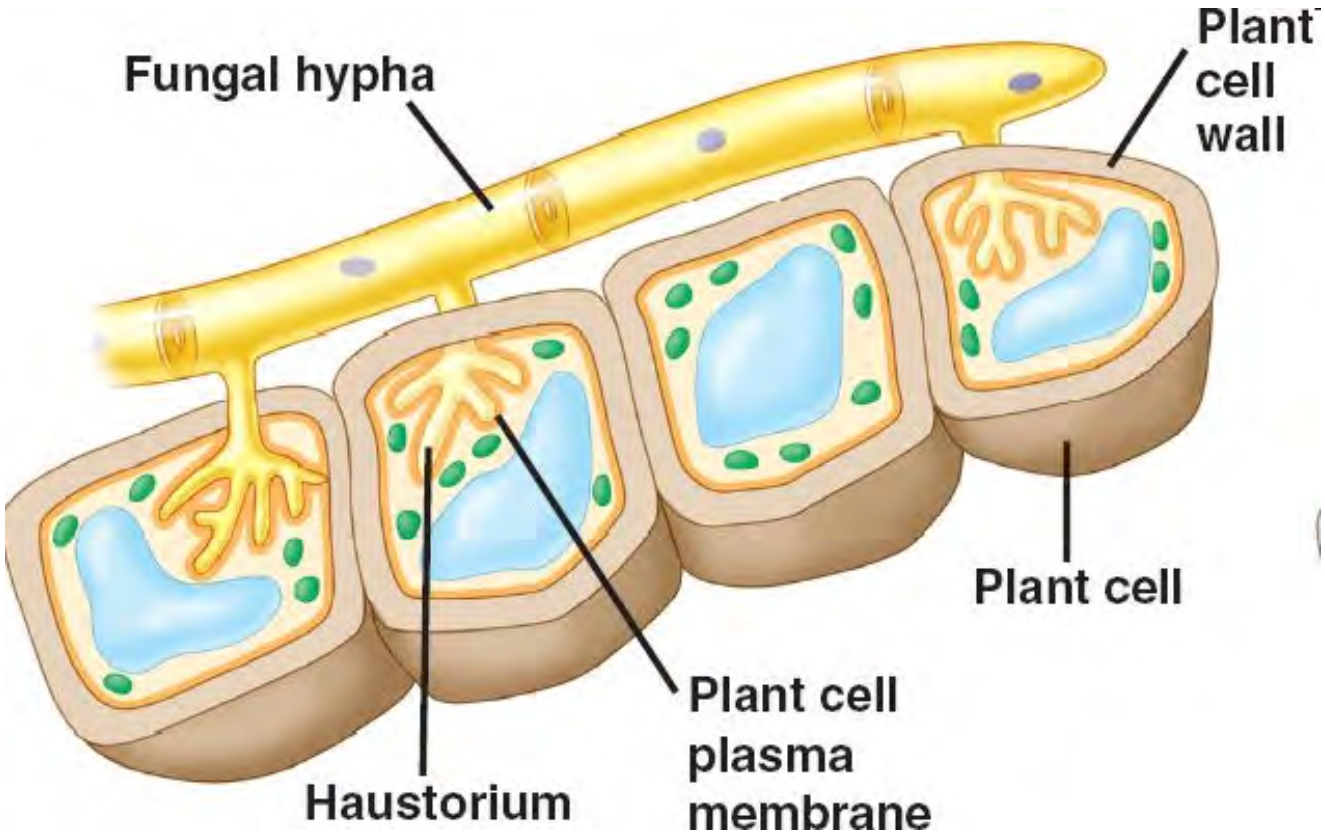


Figure 31.4 (Campbell et al.)

Habitats of Fungi

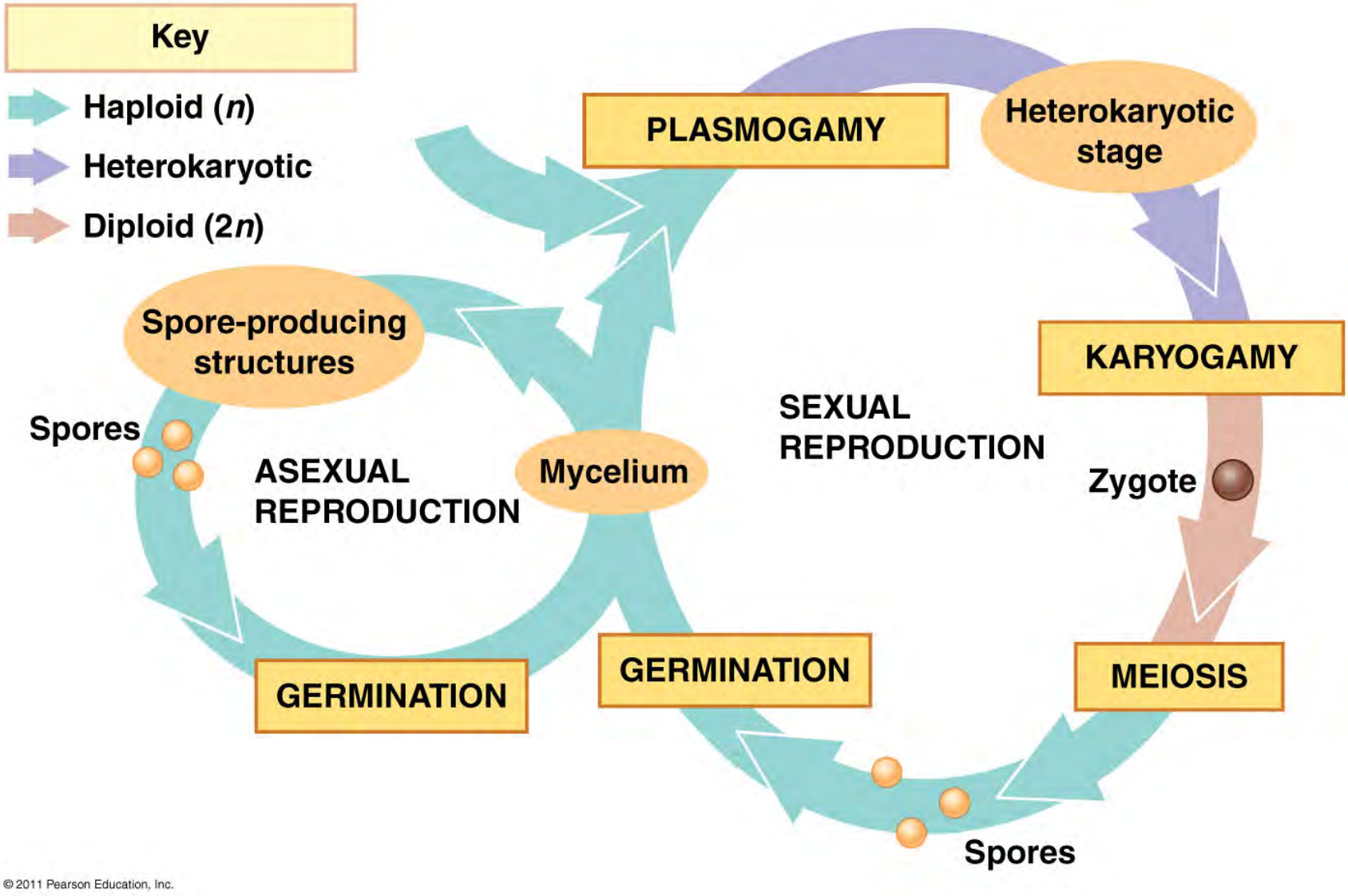
1. Mostly terrestrial
   - moist, o_2 rich

2. Many live in or on other organisms (i.e. parasitic)
   - e.g. rusts, ringworm, athletes foot, yeast…

3. Some aquatic…
   - including the “chytrids” that are implicated in many frog deformities and population declines

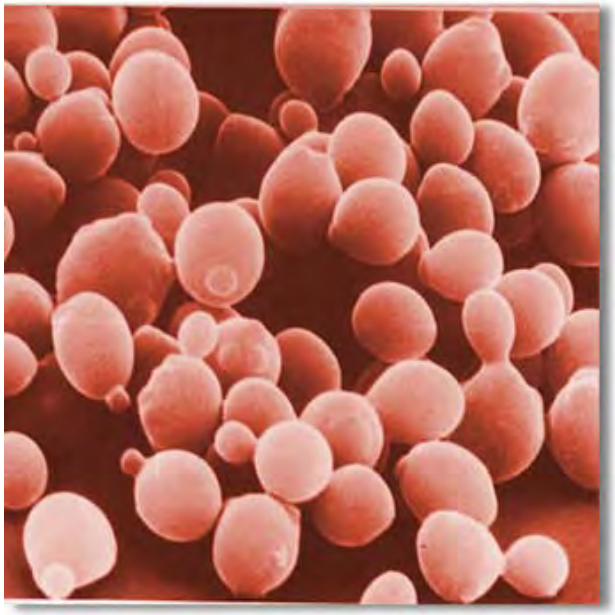
Life history and reproduction

Different spp reproduce sexually, asexually, or both



Unicellular fungi usually reproduce asexully via budding

Outgrowths of parent pinch off to form separate individual



Asexual Budding

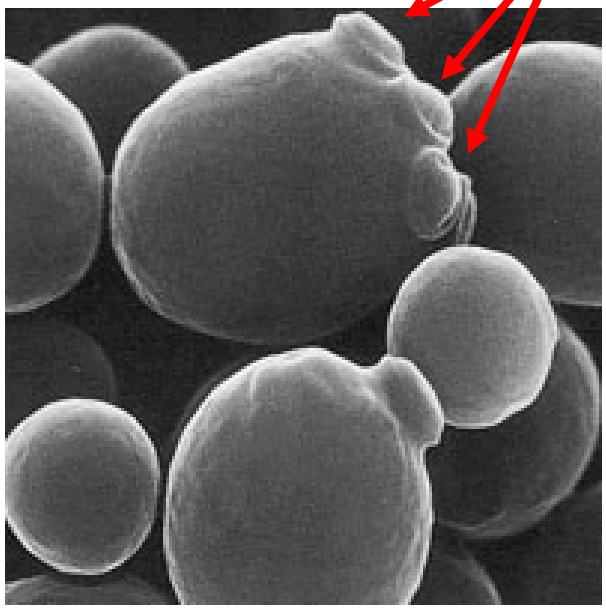


Figure 31.7 (Campbell et al.)

3 types of multicellular sexual reproduction in different Eukaryotes

- Haploid Dominant
- Diploid Dominant
- Alternation of Generations

REVIEW: Sexual life cycles (Ch 13)

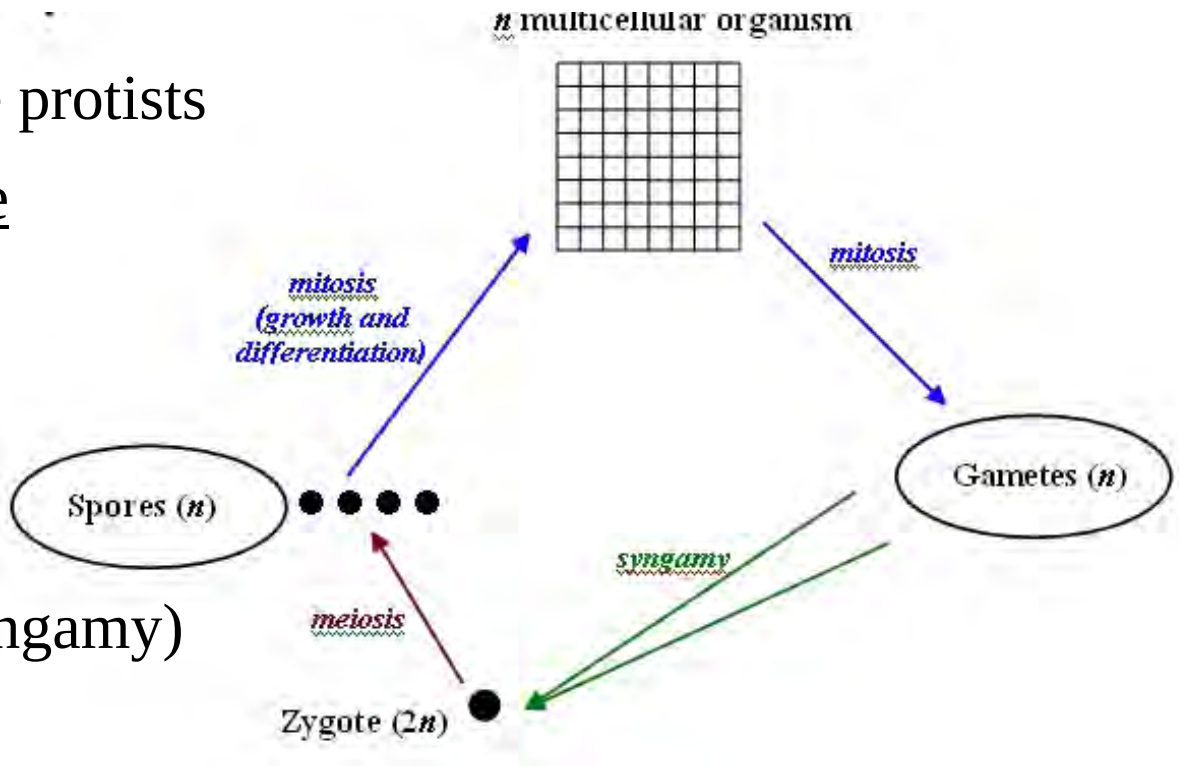
Haploid Dominant Sexual Life Cycle

REVIEW:
Sexual life cycles (Ch 13)

Fungi are primarily haploid organisms
w/ a brief diploid phase during sexual reproduction

Haploid Dominant

- Occurs in fungi & some protists
- ONE multicellular stage
  w/ all HAPLOID cells
- Gametes produced
  via mitosis
- Zygote produced
  via fertilization (aka syngamy)
  - only diploid stage
- Spores produced via meiosis
  - Single cell w/ protective coating
- Spores germinate & grow into haploid multicellular mycelium

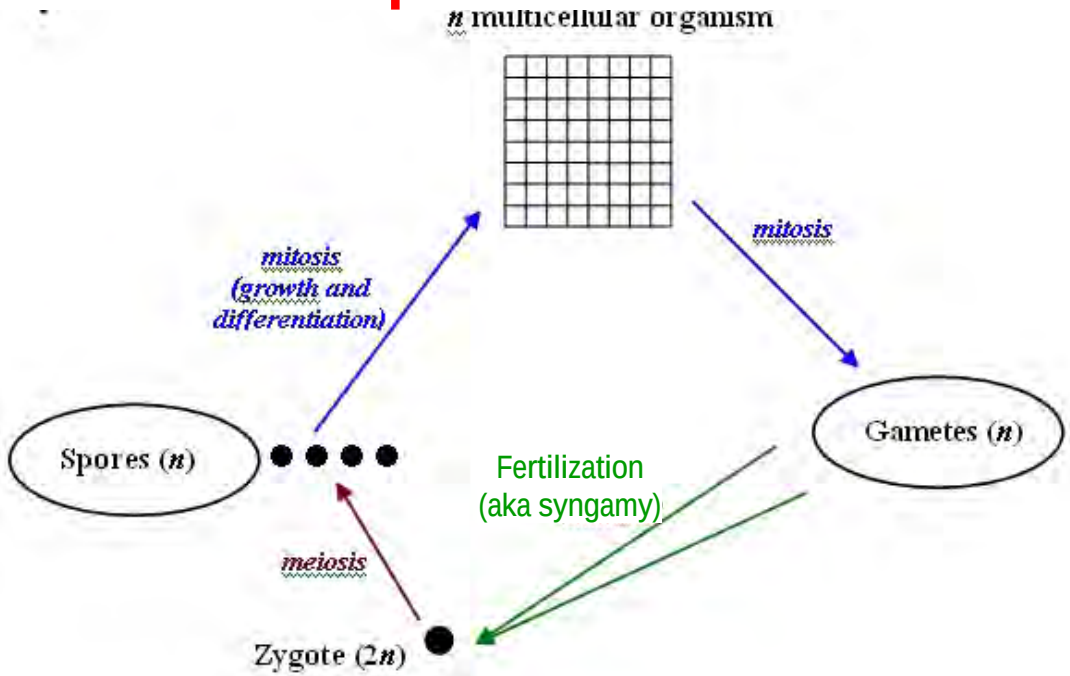


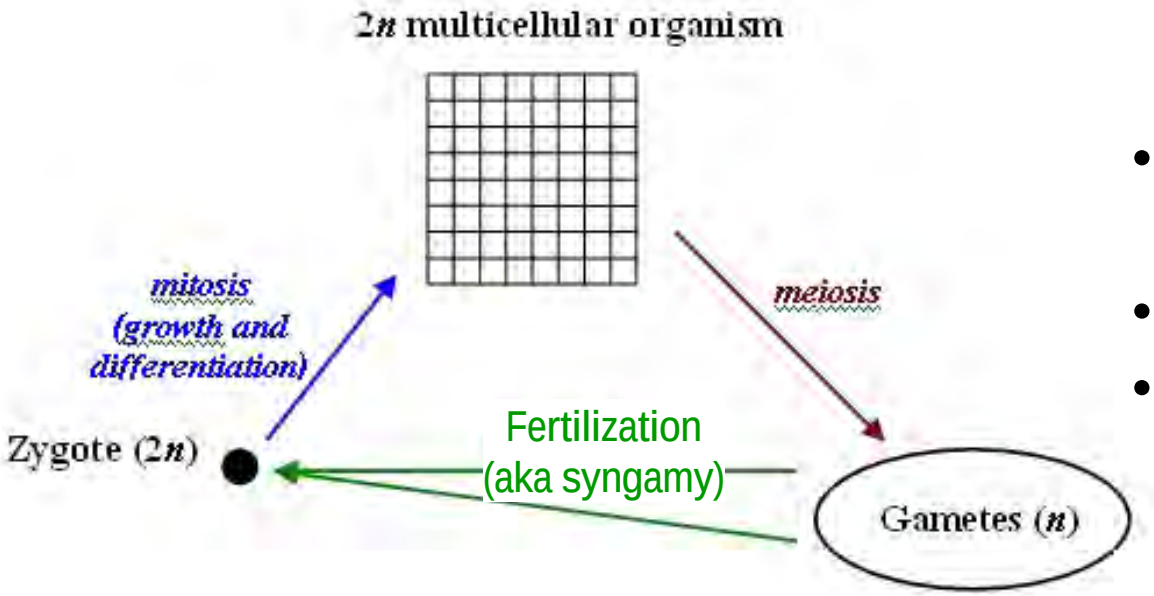
See Fig. 13.6 (Campbell et al.)

Haploid Dominant vs Diploid Dominant

Haploid Dominant

One multicellular stage w/ all HAPLOID cells





Diploid Dominant

- One multicellular stage w/ all DIPLOID cells
- No spore stage
- Occurs in animals and some protists

See Fig. 13.6 (Campbell et al.)

Generalized reproduction in multicellular fungi

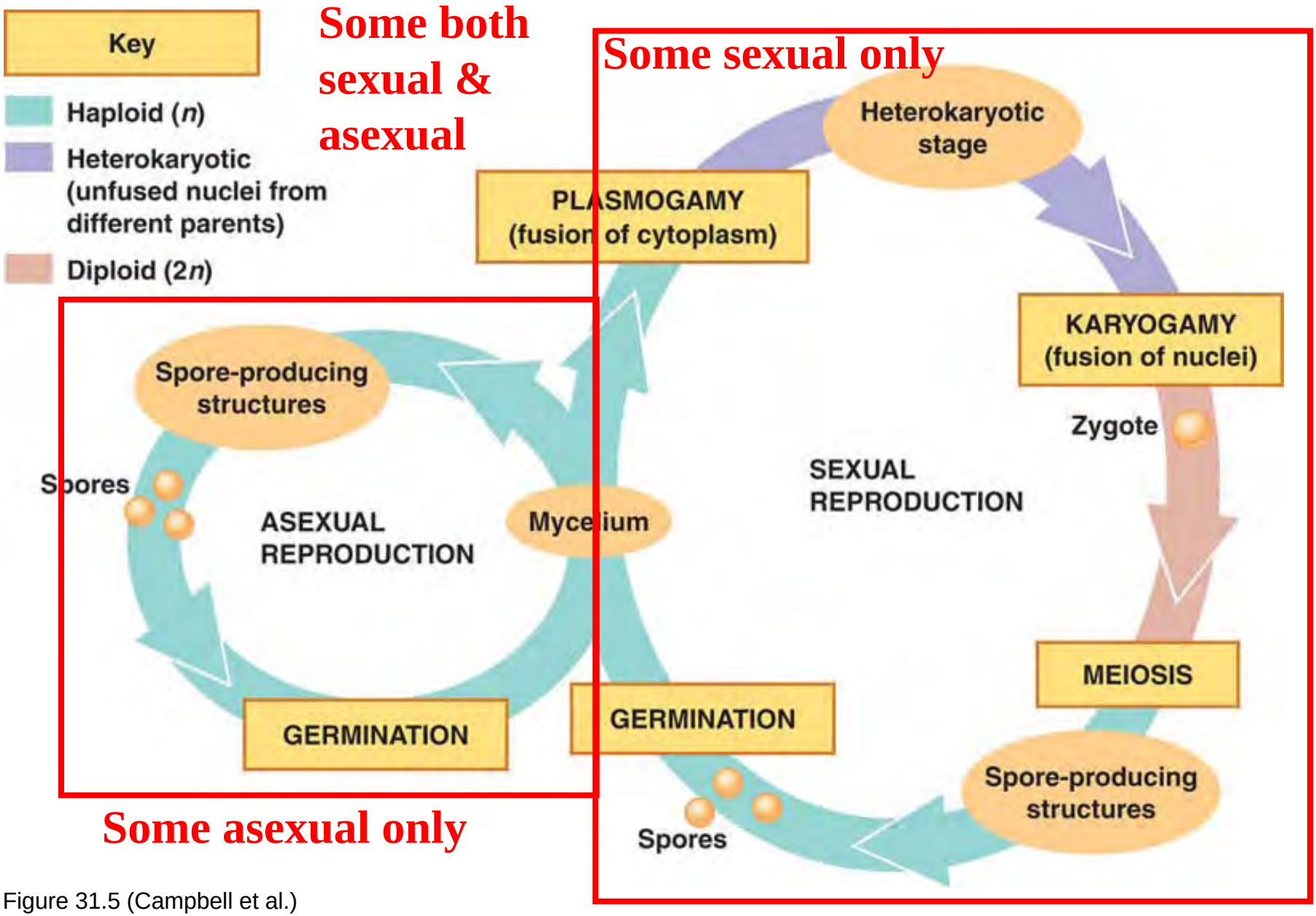
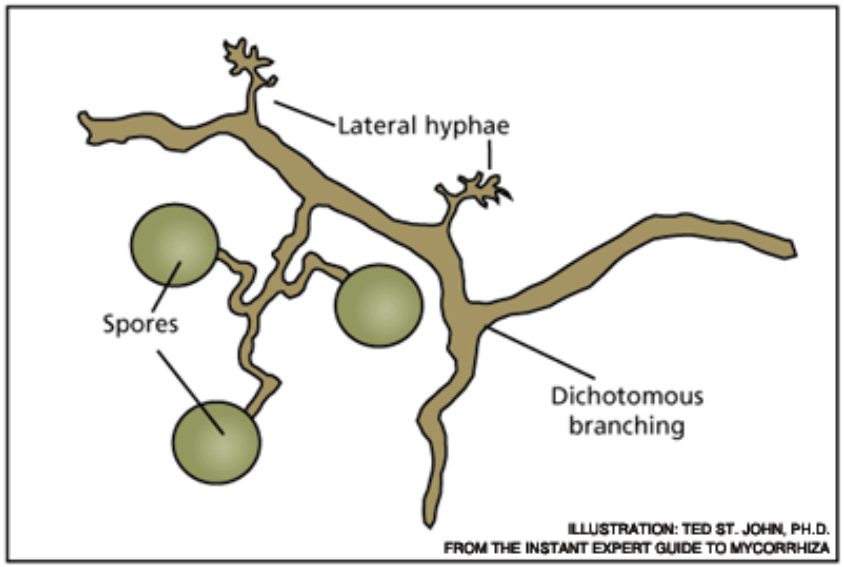


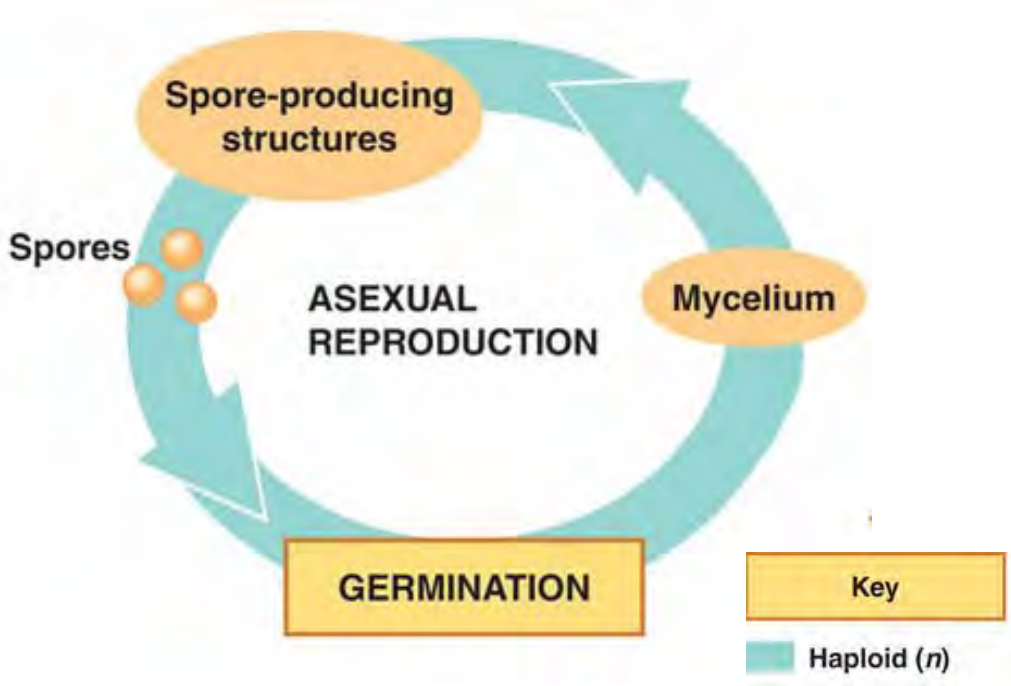
Figure 31.5 (Campbell et al.)

Generalized ASEXUAL reproduction in multicellular fungi

- Mycelium (n) forms spore-producing structures

- Cells in spore-producing structures undergo *mitosis* → *asexual* spores (n)
- Spores germinate and undergo *mitosis* to form new mycelium





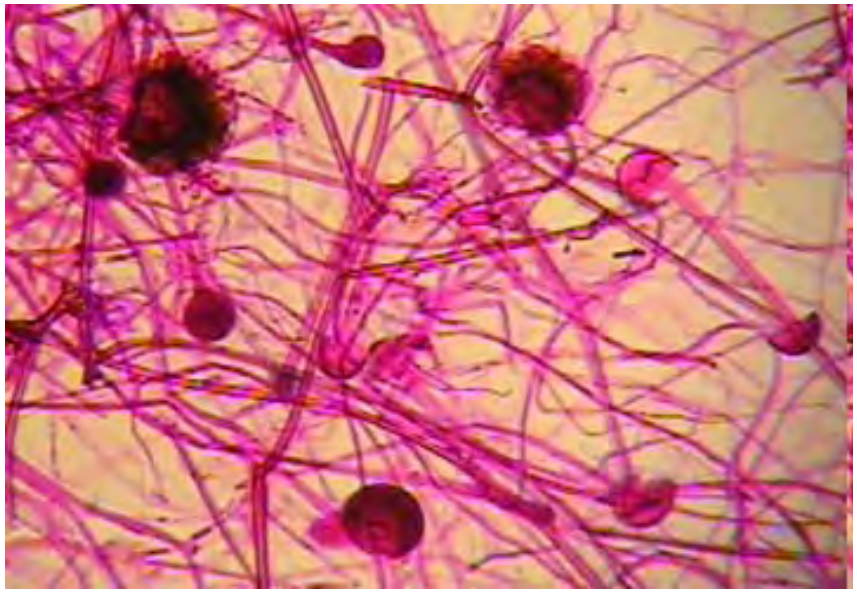


Figure 31.5 (Campbell et al.)

Generalized SEXUAL reproduction in multicellular fungi

- Different mating strains' hyphae brought together by pheromones and fuse (plasmogamy)
  - Plasmogamy = fusion of cytoplasm but not the nuclei
- Results in heterokaryotic (n+n) hypha (i.e. cells contain multiple haploid nuclei from different individuals)
- Hours, days, decades or centuries later the nuclei (n) fuse (Karyogamy) forming the zygote (2n)
- Zygote undergoes *meiosis* forming structures that produce sexual spores (n)
- Spores are dispersed, germinate, & grow via *mitosis* into new mycelium

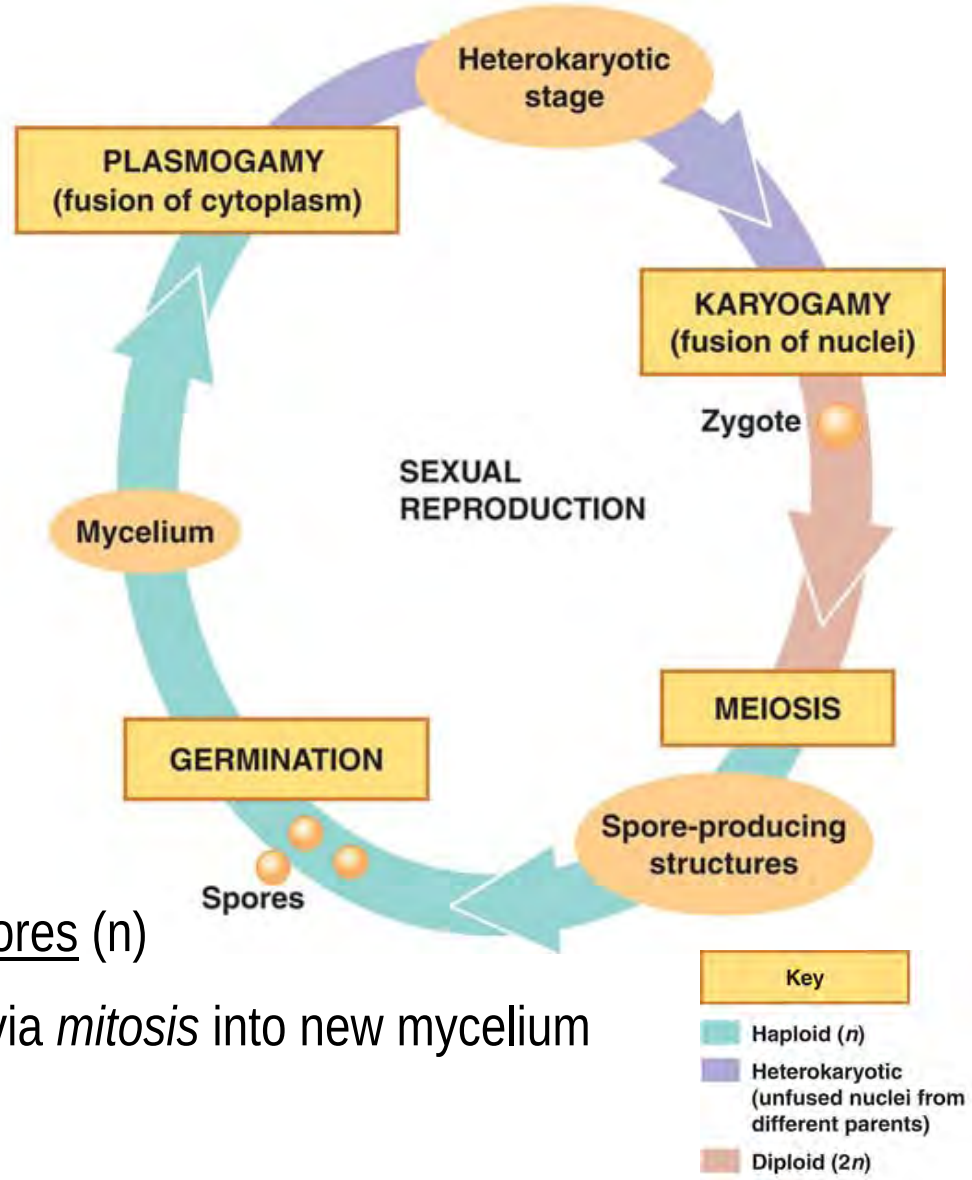
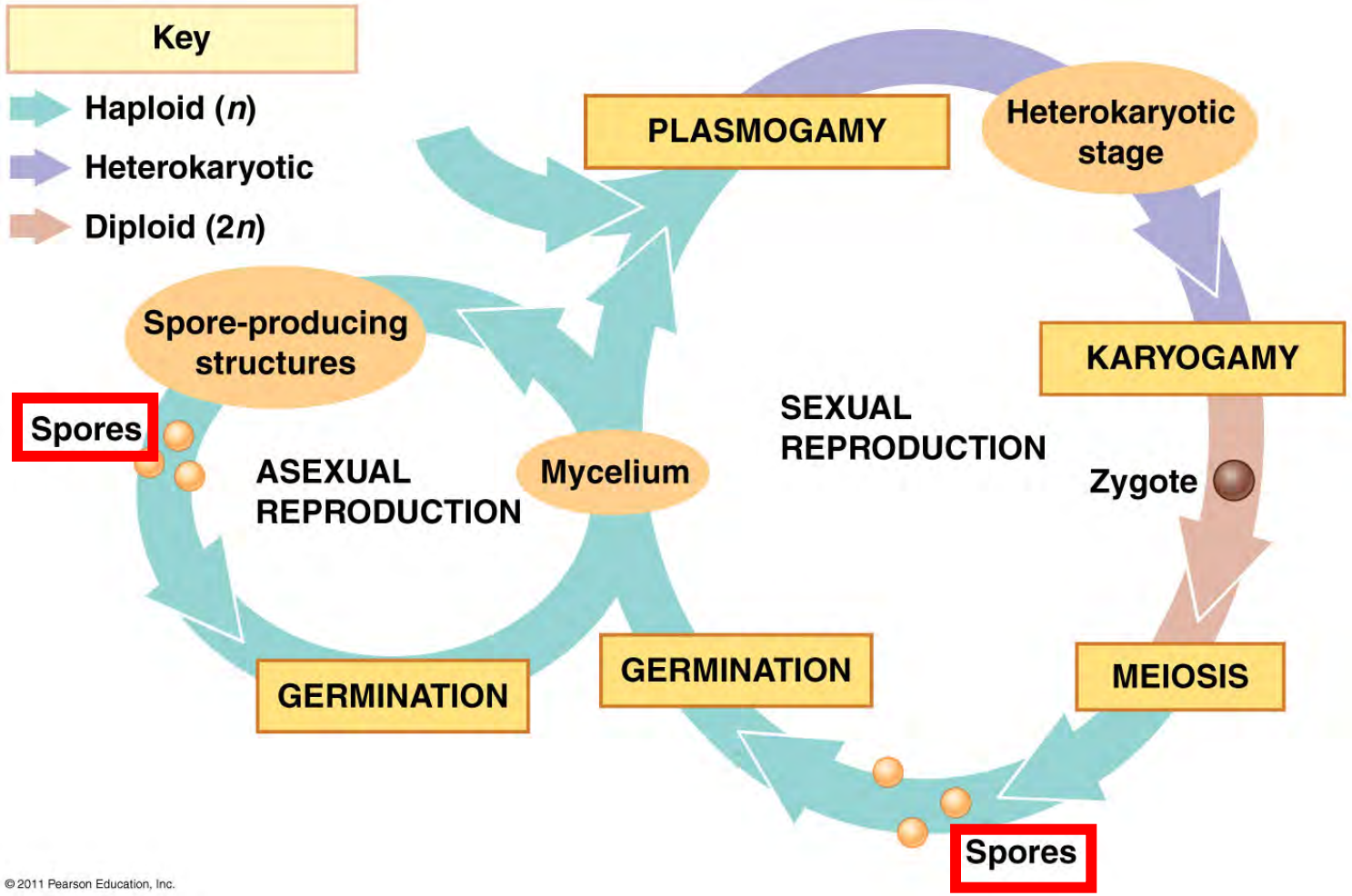
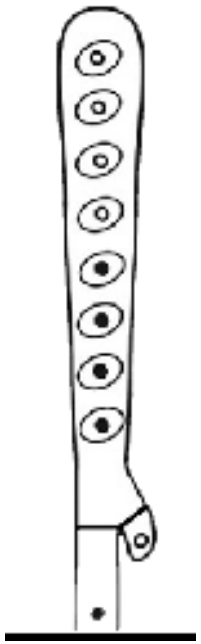


Figure 31.5 (Campbell et al.)

Disperse primarily w/ airborne spores

- generated by mitosis (asexual) or meiosis (sexual)





Disperse primarily w/ airborne spores

Giant puffball: *Calvatia gigantea*

- Up to 1.5 m diameter and 20 kg.
- Up to 5 trillion spores!

http://www.youtube.com/watch?v=iPO4Rry4m4U

29

Diversity

5 clades recognized

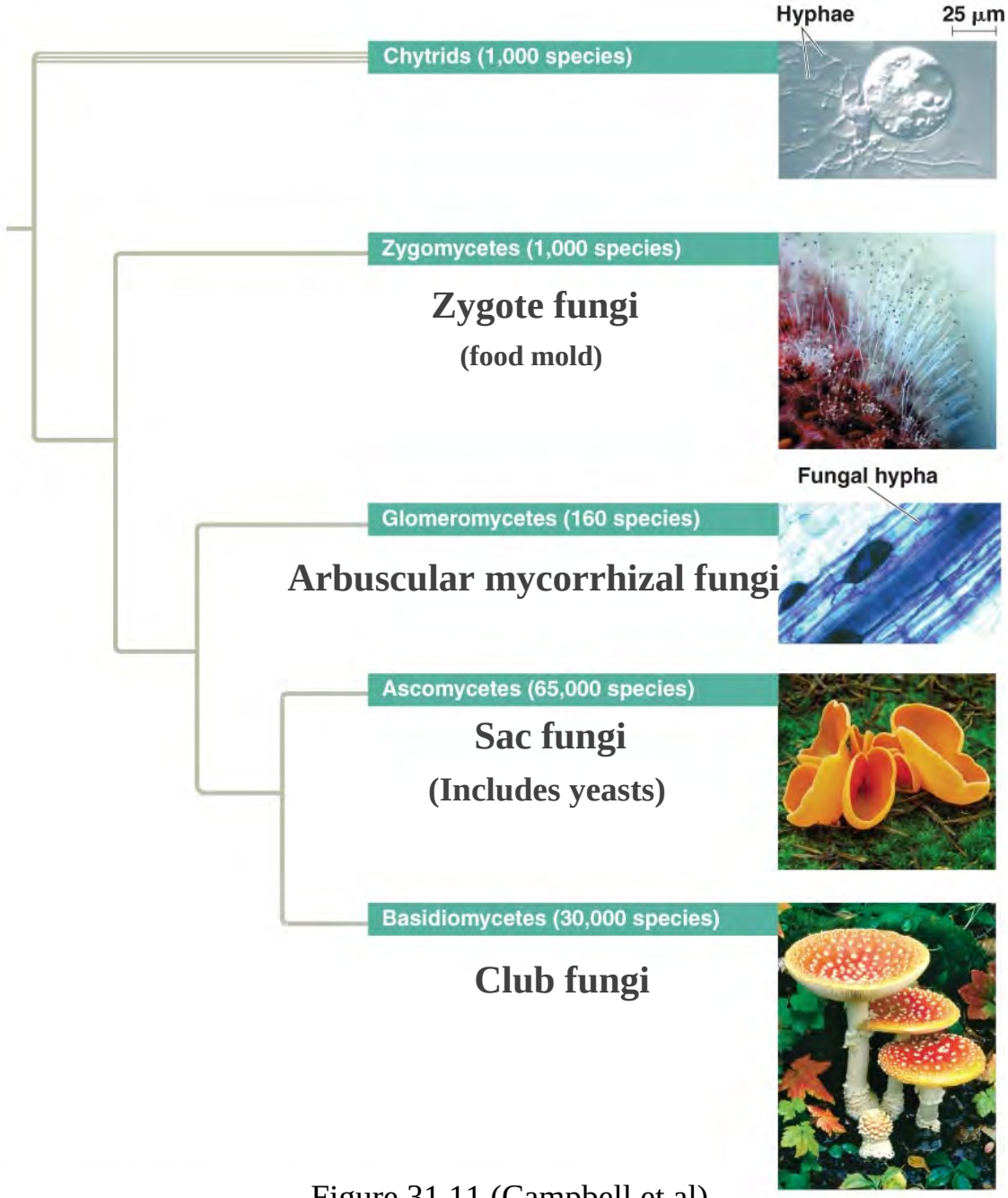


Figure 31.11 (Campbell et al)

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1. Chytrids

~1000 species

- Oldest lineage of fungi
- Some single- & others multi-cellular
- Usually asexual but sometimes sexual
- Alternation of generations not haploid domi
- Motile gametes (♀ and ♂) and spores (zoospores) all w/ a posterior flagellum
- Occur in almost all H_2O & soil
- Some decomposers, parasites, & mutualists
  - Help cattle breakdown plants in their stomach
  - Responsible for some amphibian declines

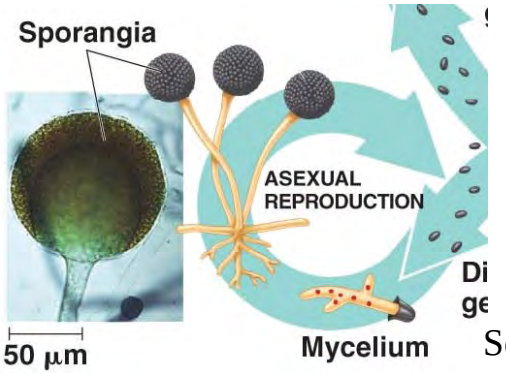
Figure 31.11 (Campbell et al)

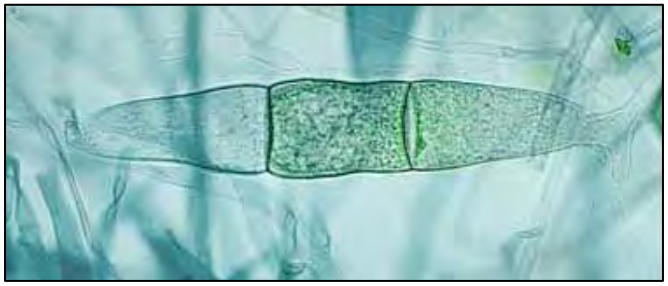
2. Zygomycetes

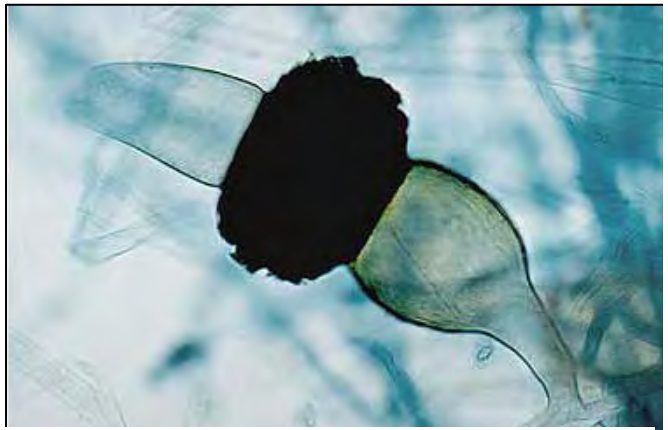
~1000 species known

- Many fruit & bread molds

- Aseptate hyphae
  (thus many nuclei in same "cell" (coenocytic)
- Asexual reproduction during good times
  (i.e. produce *asexual* spores)
- Sexual reproduction when conditions bad (e.g. food runs out)
  - Different strains' hyphae fuse (i.e. plasmogamy)
  - Form a thick-walled structure (Zygosporangium) btwn hyphae which produces *sexual* spores when conditions improve

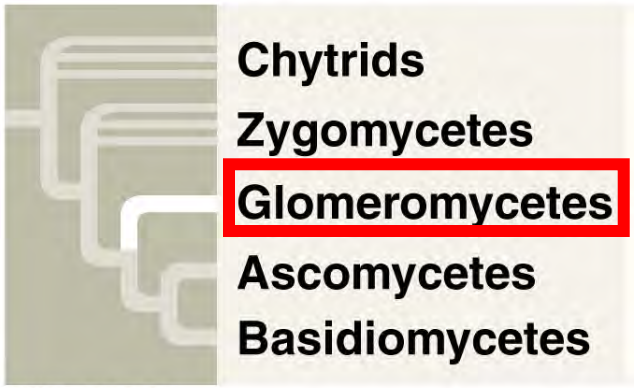






See Figure 31.13 (Campbell et al) but DO NOT need to remember all details of this lifecycle

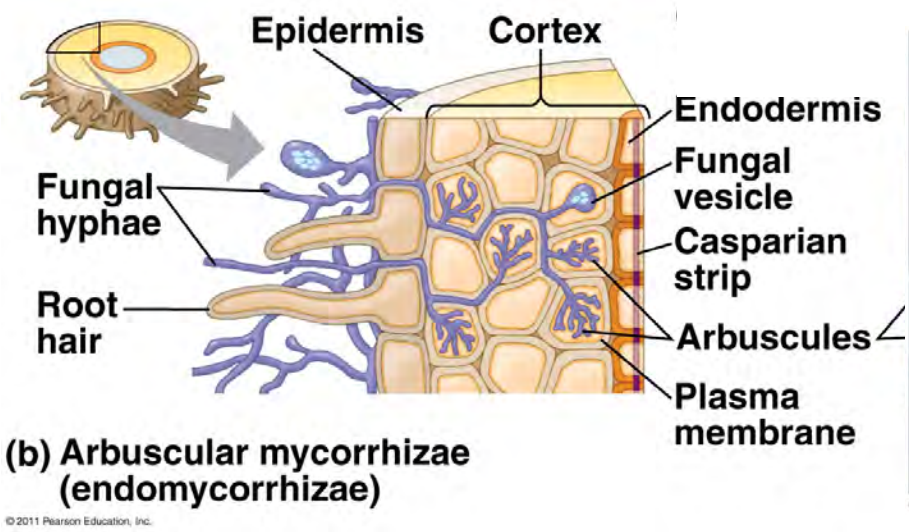
33

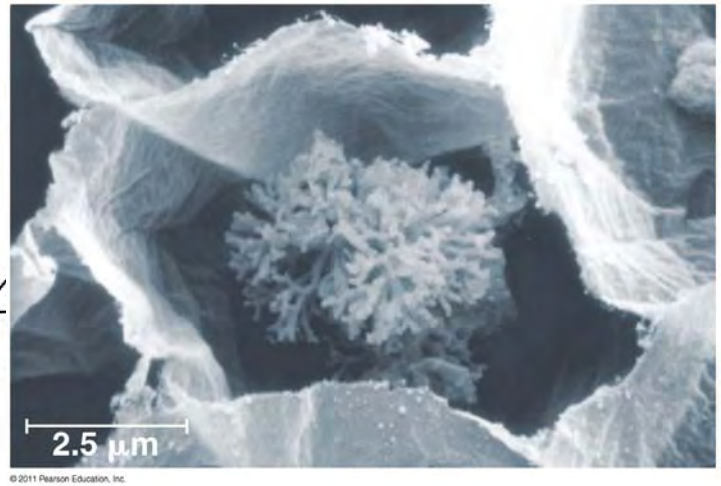


3. Glomeromycetes

~160 species known

- Usually aseptate (coenocytic)
- Most form Endomychorrhizae (arbuscular)
  - Associated w/ ~90% of all plant spp!



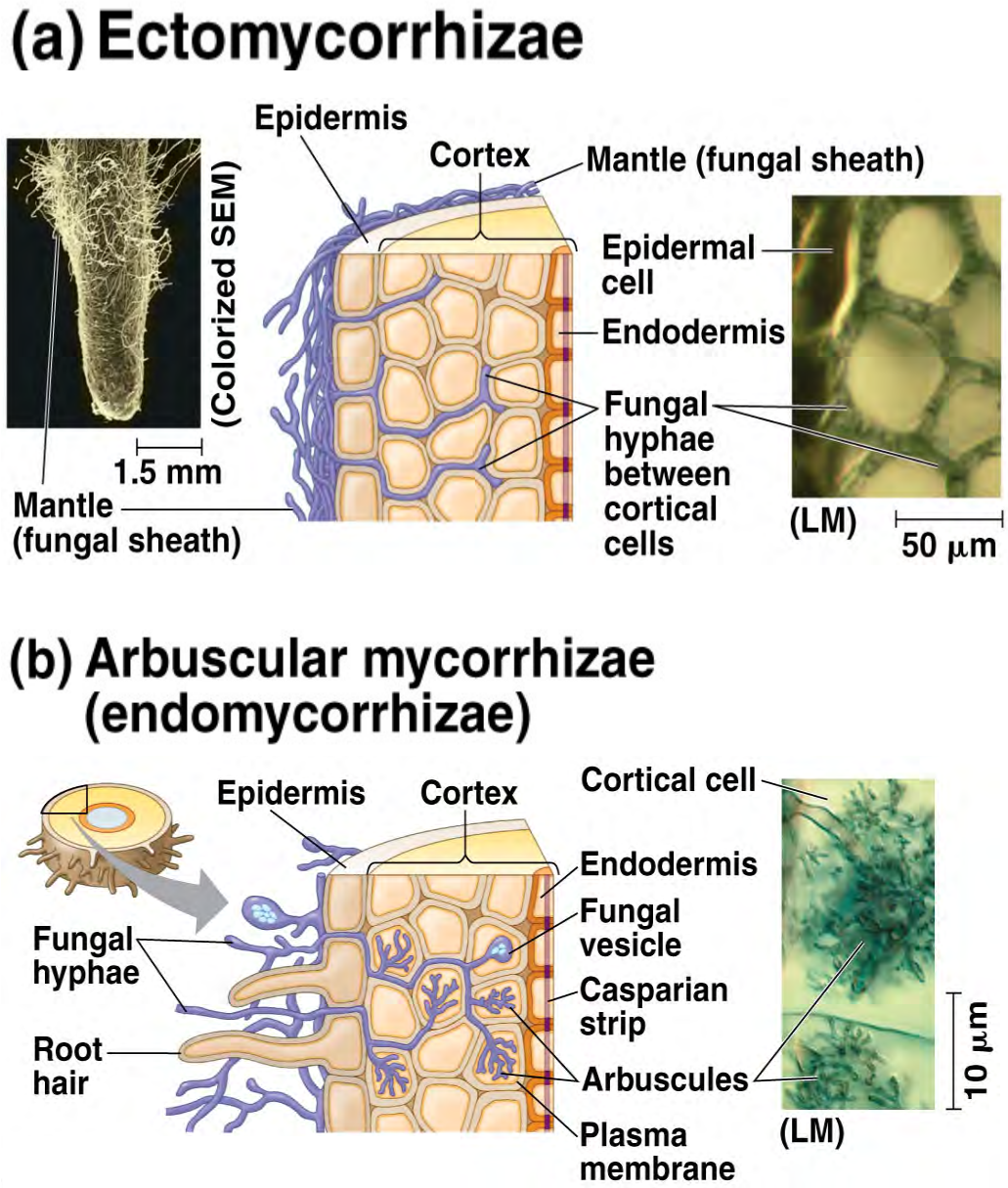


- Branched hyphae tips (*arbuscules*) penetrate root cell walls
  - Take some glucose
  - Give some water & minerals

Figure 37.13 (Campbellet al.)

Figure 31.15 (Campbellet al.)

Ecto- vs. Endomycorrhizae

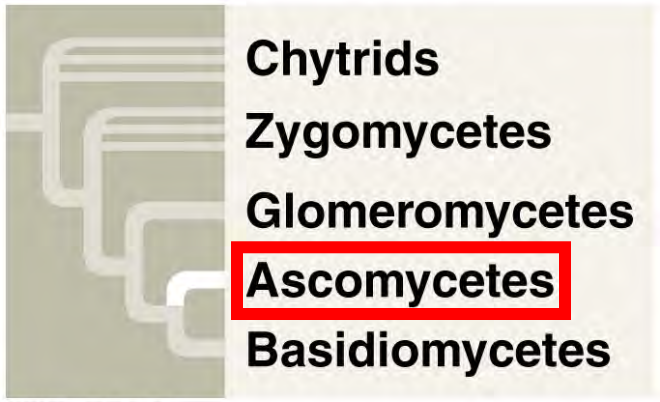


Ectomycorrhizae

- Cover root in dense mat
- Hyphae go btwn cells (haustoria) but do not penetrate cell wall
- Formed by several clades (mostly Basidiomycota and Ascomycota, but a few are Zygomycota) vs. endo- only in Glomeromycetes

Figure 37.13 (Campbellet al.)

35



4. Ascomycetes (Sac Fungi)

- > 65K species known
- Includes unicellular yeasts and many multicellular species (e.g. penicillium, morels, truffles)
- Septate hyphae
- Sexual spores produced in sac-shaped fruiting body (ascocarp)

(a) "Orange peel fungus"

Morel

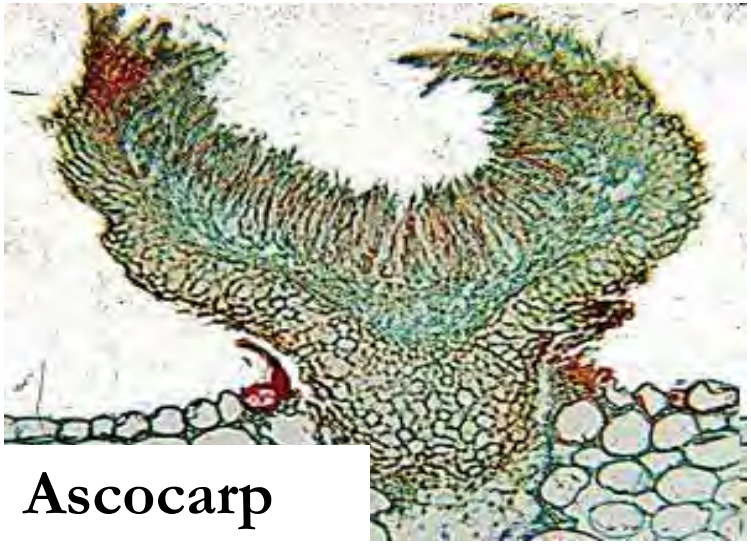
Truffle

Penicillium

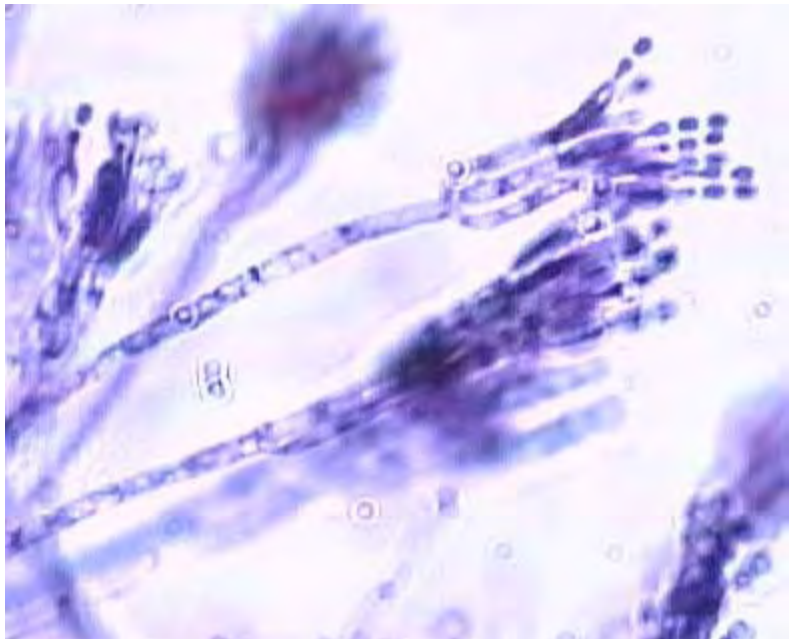
Figure 31.16(Campbell et al)

See Figure 31.17 (Campbell et al) but DO NOT need to remember all details of this lifecycle

4. Ascomycetes (Sac Fungi)

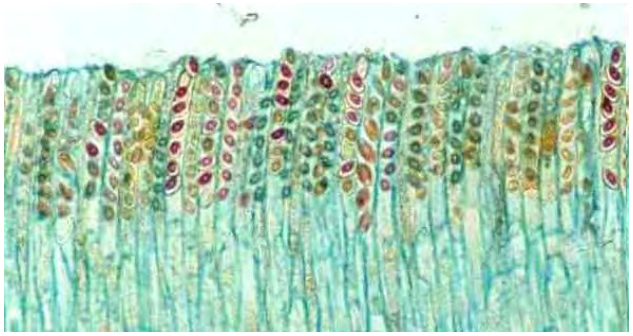


Ascocarp

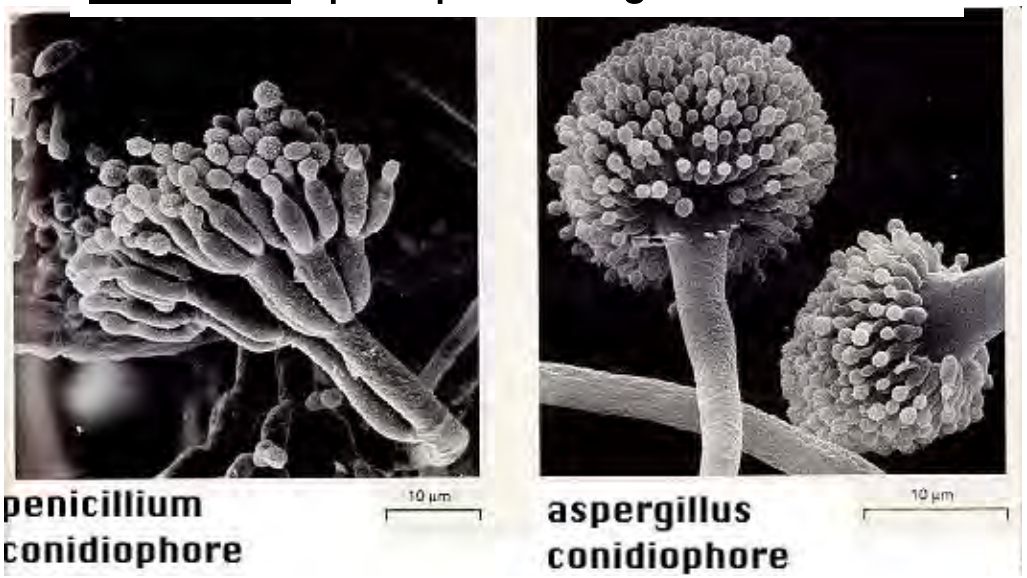


Asexual spore producing structures

Sexual spore producing structures



Ascocarps have cells called asci that produce sexual spores called ascospores



Conidiophores produce *asexual* spores called conidia

37

Chytrids
Zygomycetes
Glomeromycetes
Ascomycetes
Basidiomycetes

5. Basidiomycetes (Club Fungi)

- ~30K species known
- Includes shelf fungi & typical white mushrooms
- Septate hyphae
- Sexual spores produced in fruiting body (basidiocarp) in club-shaped basidia

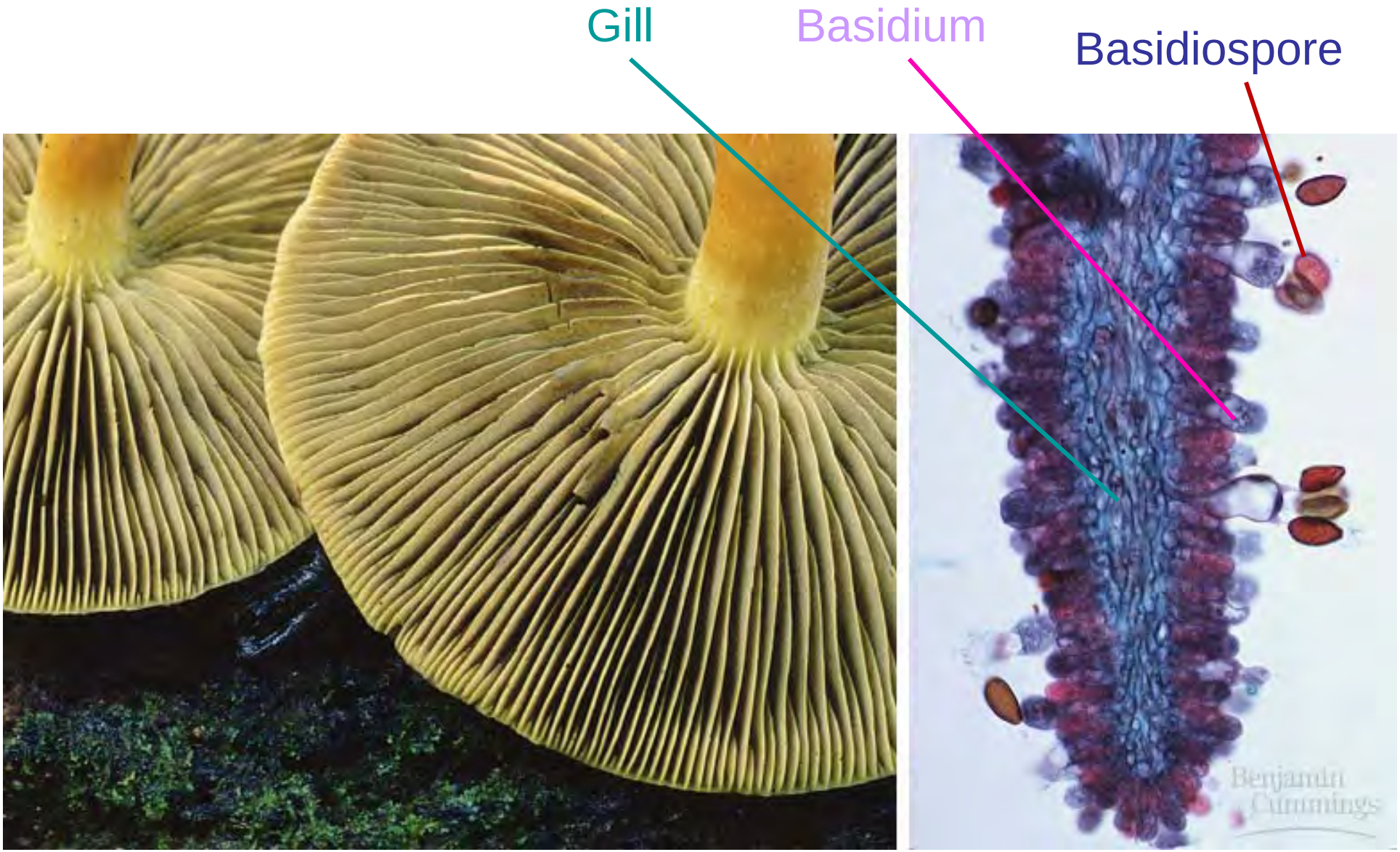
(a) Fly agaric

(b) Maiden veil fungus

(d) Puffball

(c) Shelf fungus

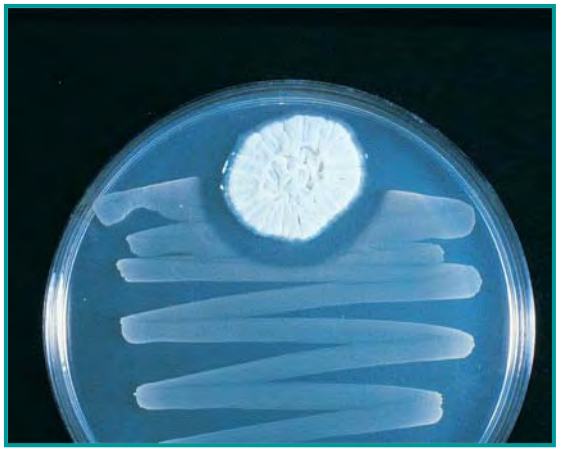
5. Basidiomycetes



See Figure 31.19 (Campbell et al) but DO NOT need to remember all details of this lifecycle

Impact of Fungi

- Recycle nutrients
- Plant & animal pathogens
- Commercial/medical uses
- Symbiosis w/other organisms

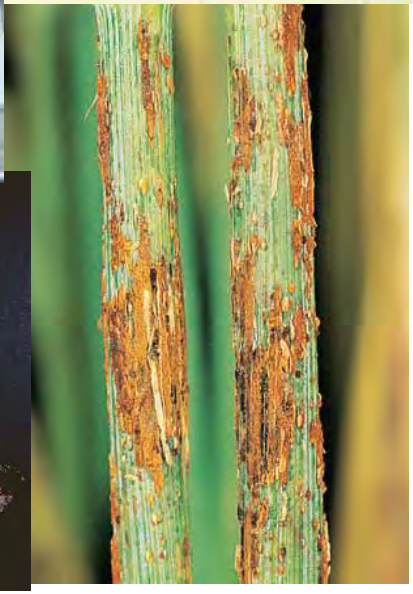


Decomposers

- Recycle carbon, nitrogen etc. to soil and air
  - – break down cellulose, lignin, and keratin
    - Fungi, bacteria and a few protists breakdown cellulose
    - Only fungi breakdown lignin (plants) and keratin (animals)

Plant pathogens

(About 30% of fungal species)



- **Corn leaf blight**
- **Chestnut blight**
- **Barley powdery mildew**
- **Rice blast**
- **Wheat leaf blotch**
- **Dutch elm disease**
- **Wheat rust**
- **Barley blotch**
- **Canola stem rot**

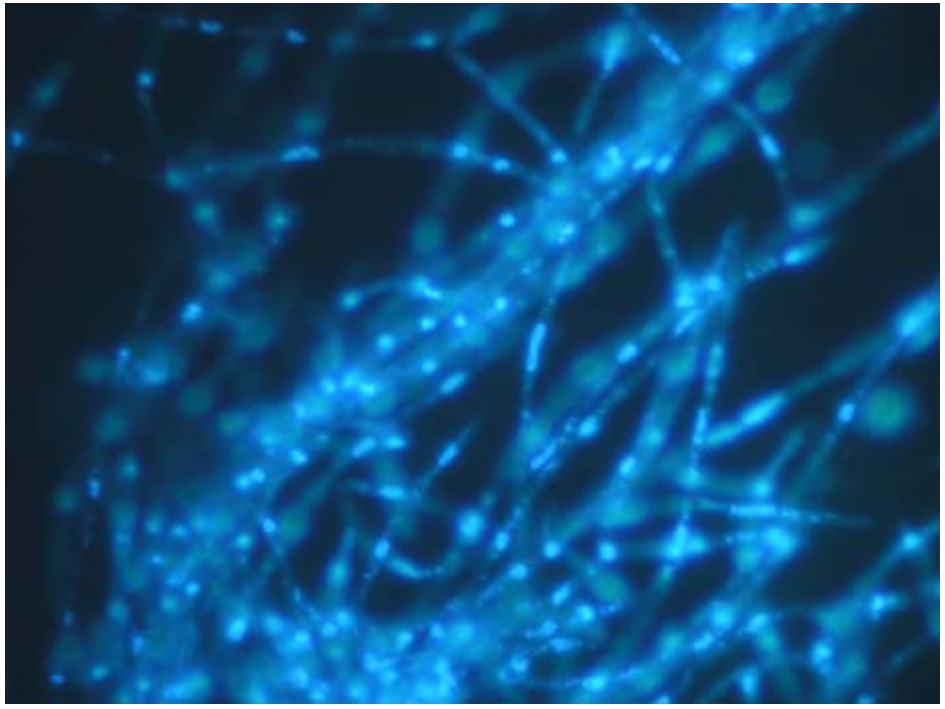
and <u>many</u> more

Dutch elm disease: killed ~200 million trees in N. America & U.K.

Animal Pathogens

Mycosis = fungal infection

~50 known diseases in humans



Mycelium of *Trichophyton*, a human pathogenic fungus

Athlete's foot (aka tinea pedis)

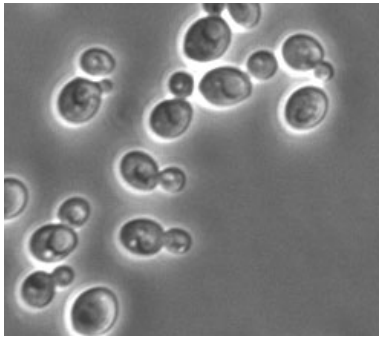
Ringworm (aka tinea corporis)

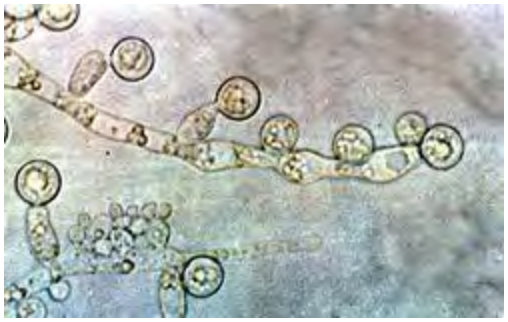
Animal Pathogens

Oral “thrush”

•Common in AIDS patients.
•Can become systemic.

***Candida albicans*:**

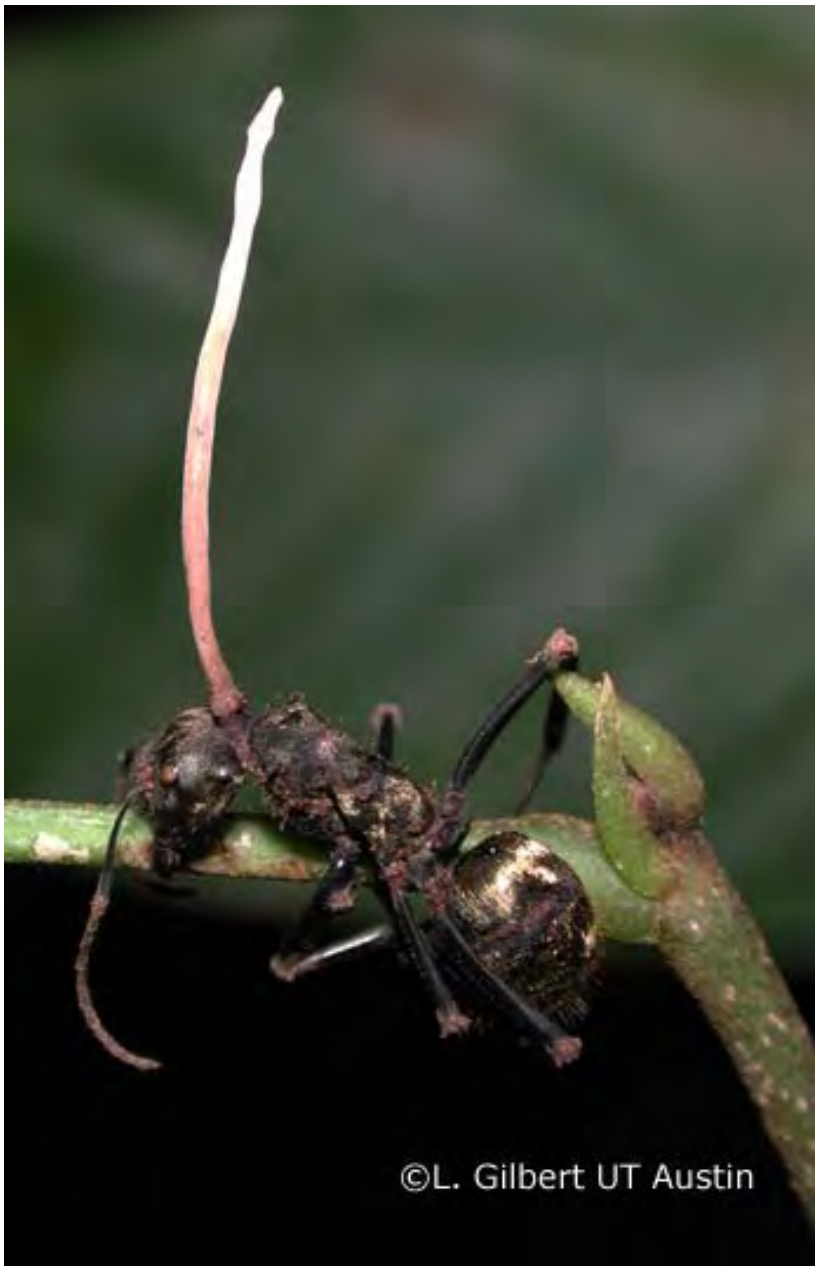




•Can grow as yeast or filaments (hyphae)
• In 80% of people’s guts w/o causing harm

•Diaper rash, vaginal infections, etc…

Animal Pathogens



Cordyceps unilateralis

Fungal parasites of ants and other rainforest insects

Ascomycete fungi (sac fungi) that includes about 400 described species

http://www.youtube.com/watch?v=XuKjBIBBAL8

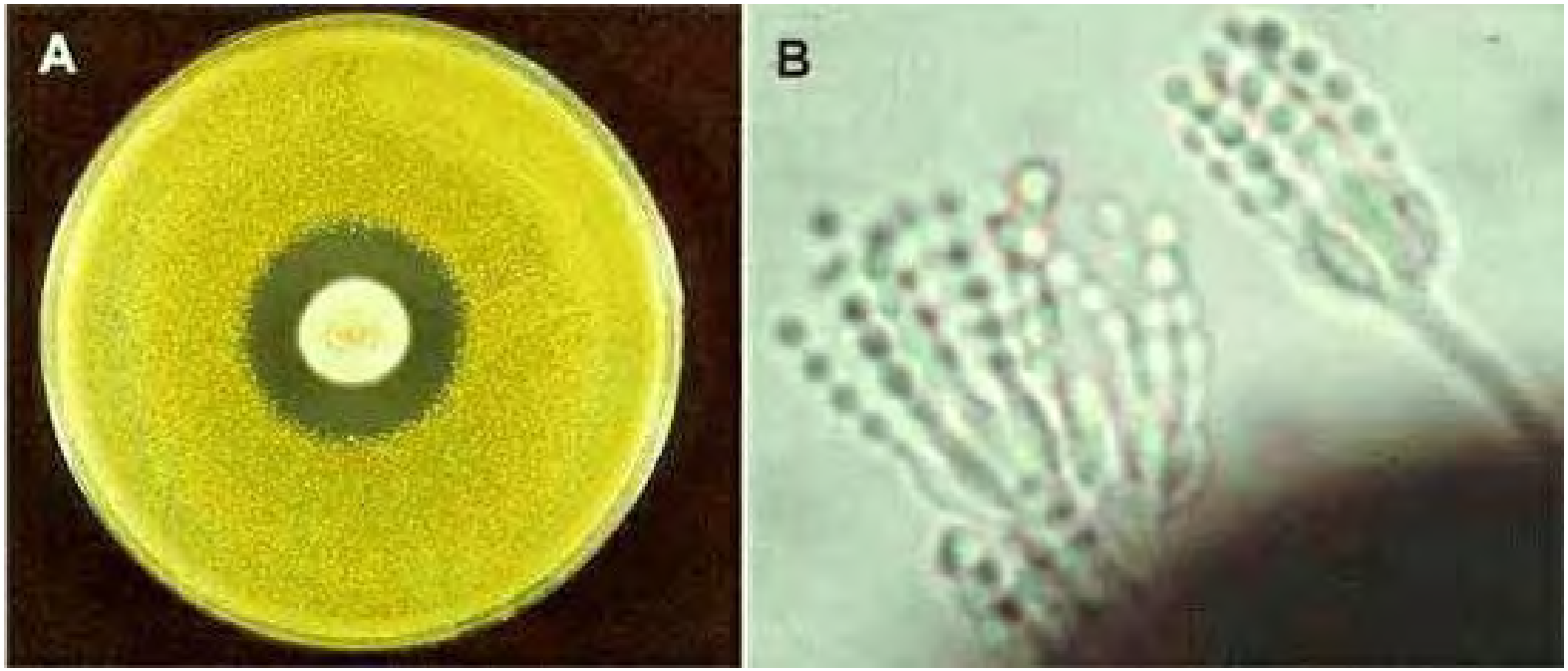
Commercial uses

Roquefort & blue cheeses

baking & brewing

citric acid for colas

Medical uses



Penicillium

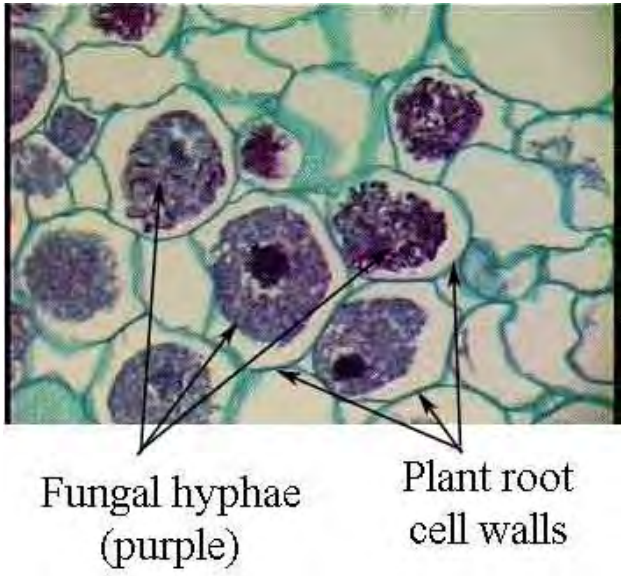
Symbiosis: Mycorrhizae

Fungus

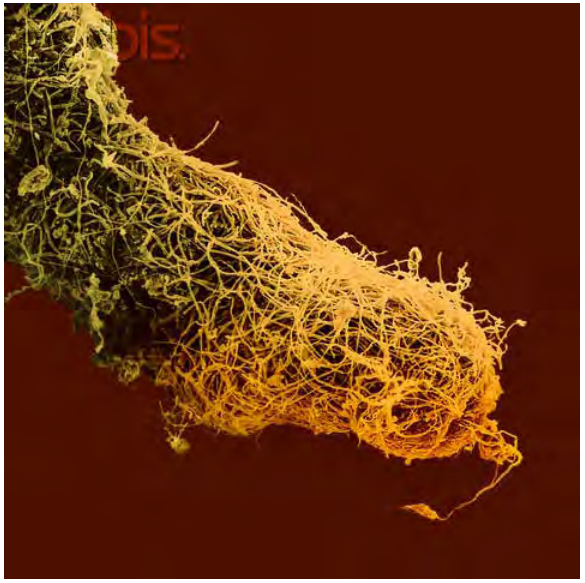
- supplies water and minerals

Plant

- Supplies sugar



Endomycorrhiza (aka arbuscular)



Ectomycorrhiza

See Figure 37.13 (Campbellet al.)

Symbiosis: Lichens

Fungus (usually ascomycota)
- supplies H_2O & shelter

& autotroph (<u>green algae</u> OR <u>cyanobacteria</u>)
- supplies sugars

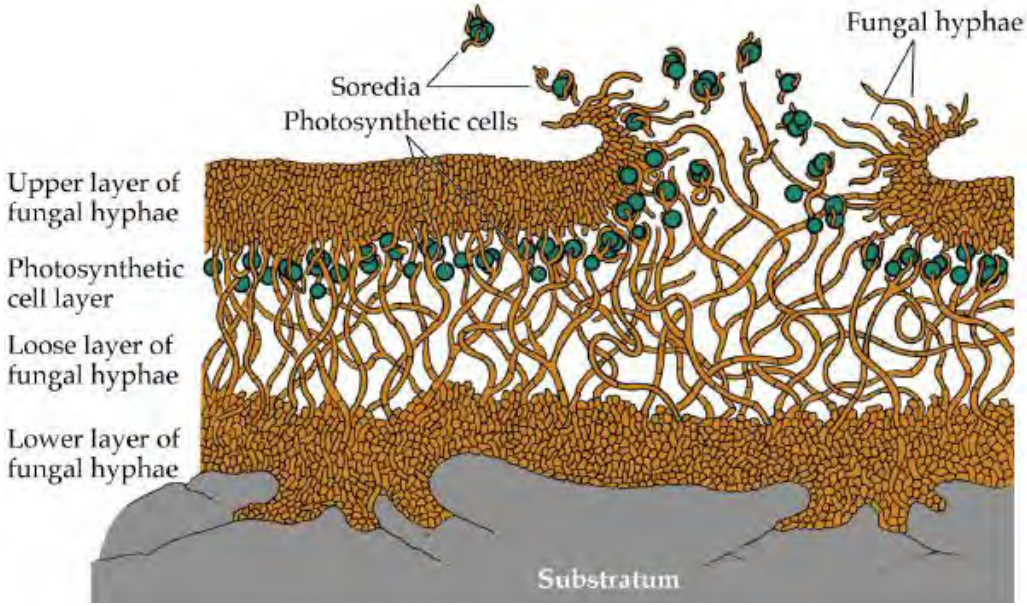
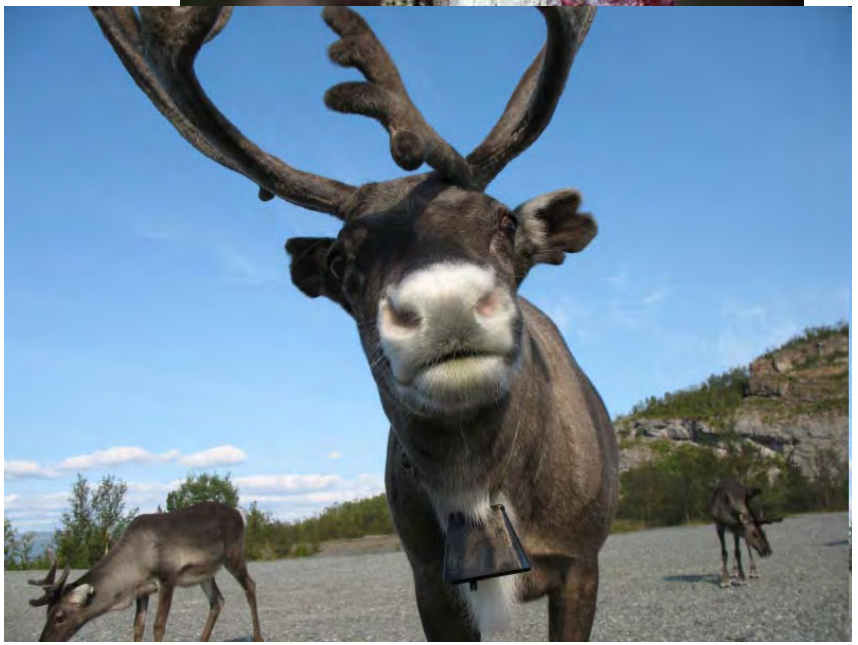


Figure 31.24 (Campbell et al.)

Symbiosis: Lichens

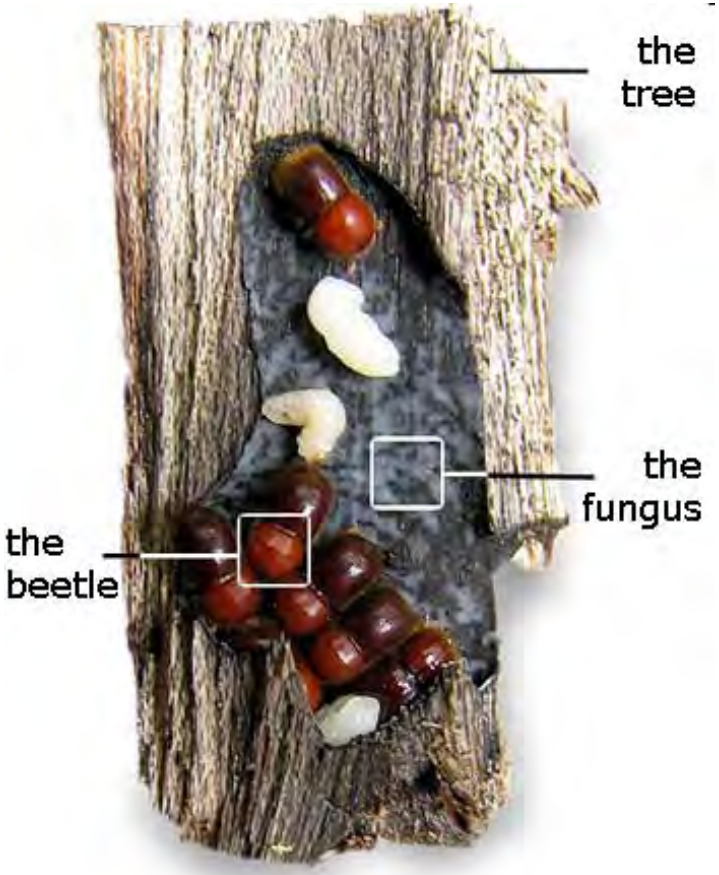
- Ecological importance?
  - Food
  - Rock / trunk colonizers
  - Soil formation



Symbiosis: Ambrosia fungus/ Ambrosia beetle

Species: ~50+??

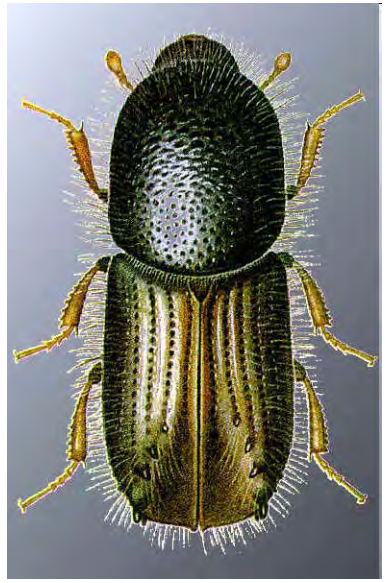
Supplies: food to beetle



All spp are reliant on ambrosia beetles for dispersal (in mycangia) and sometimes nutrition

Symbiosis: Ambrosia fungus/ Ambrosia beetle

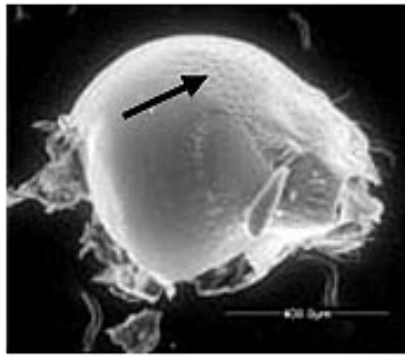
Species:	~50+??	~1400-3000
Supplies:	food to beetle	habitat, dispersal, nutrition

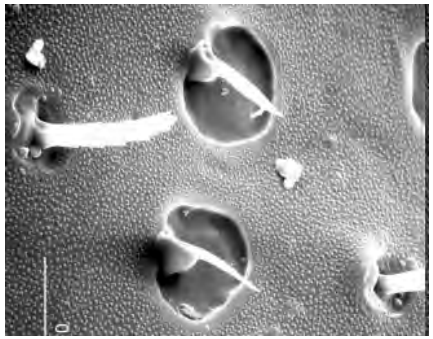


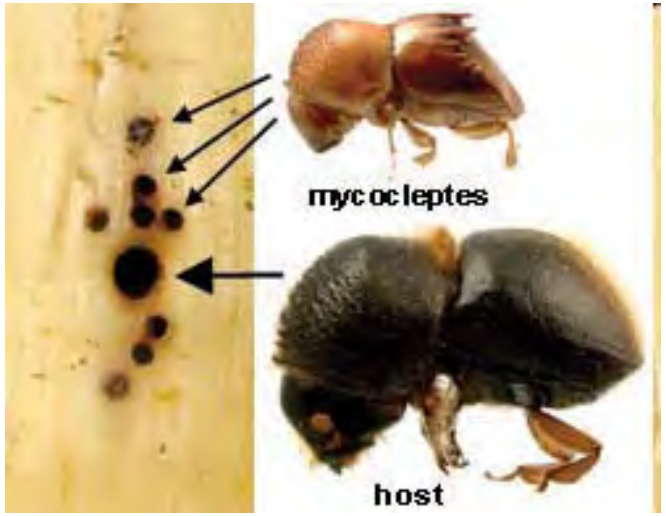
- larvae reliant on fungus
- some adult spp reliant on fungal mycelia
- store and feed spores in mycangia

Symbiosis: Ambrosia fungus/ Ambrosia beetle

Mycangia for storing and transporting fungus







1. Transport fungi in mycangia
2. Some mycangia have glands to supply nutrition to fungi
3. Some spp don't have mycangia and transport spores in gut
4. Some spp "steal" fungus by boring holes next to others so the fungus grows in these holes (Small steals fungus from large beetle).

Symbiosis:

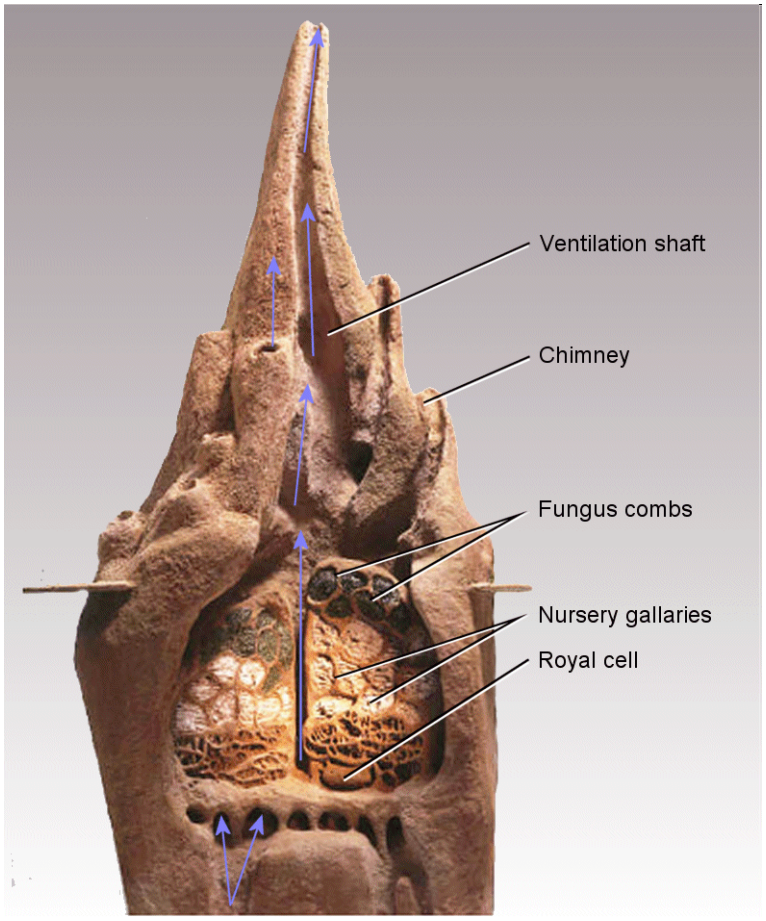
Basidiomycota fungus & Termites

- Forager worker termite chews up wood & inoculates w/ fungal spores from gut
- Pass slurry to nest workers who form fungus comb.

Symbiosis:

Basidiomycota fungus & Termites

- Receives: proper habitat and protection Composting

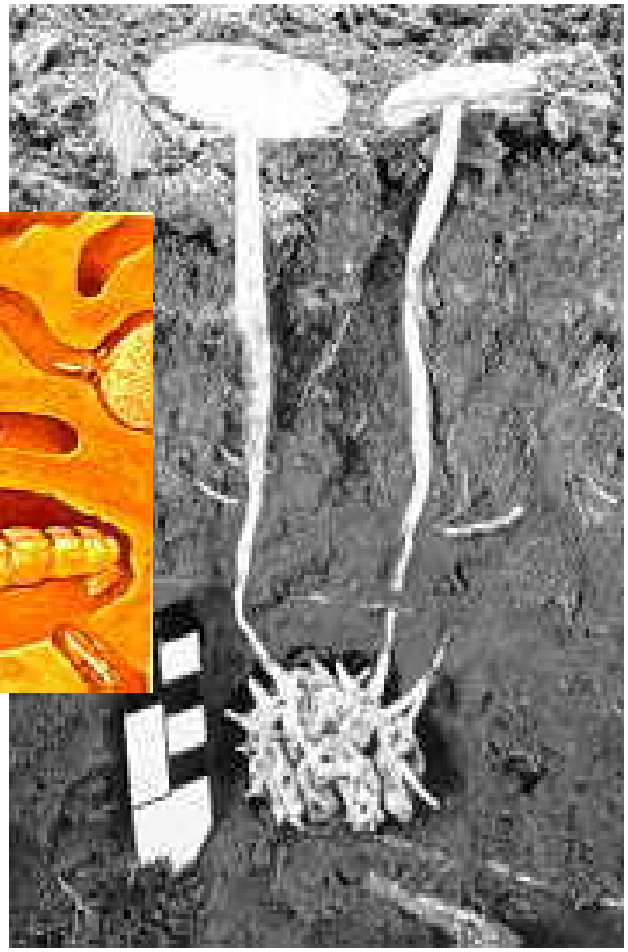


- As fungus grows it breaks down cellulose & lignin
- Termites can now eat this compost
- Fungus benefits by proper habitat (likes acidic high CO_2 environment) and protection
- Termites benefit by composting of wood to make edible food (They do NOT digest wood!).

Symbiosis:

Basidiomycota fungus & Termites

People benefit because mushroom will grow which is a prized delicacy



Symbiosis:

Basidiomycota fungus & Termites

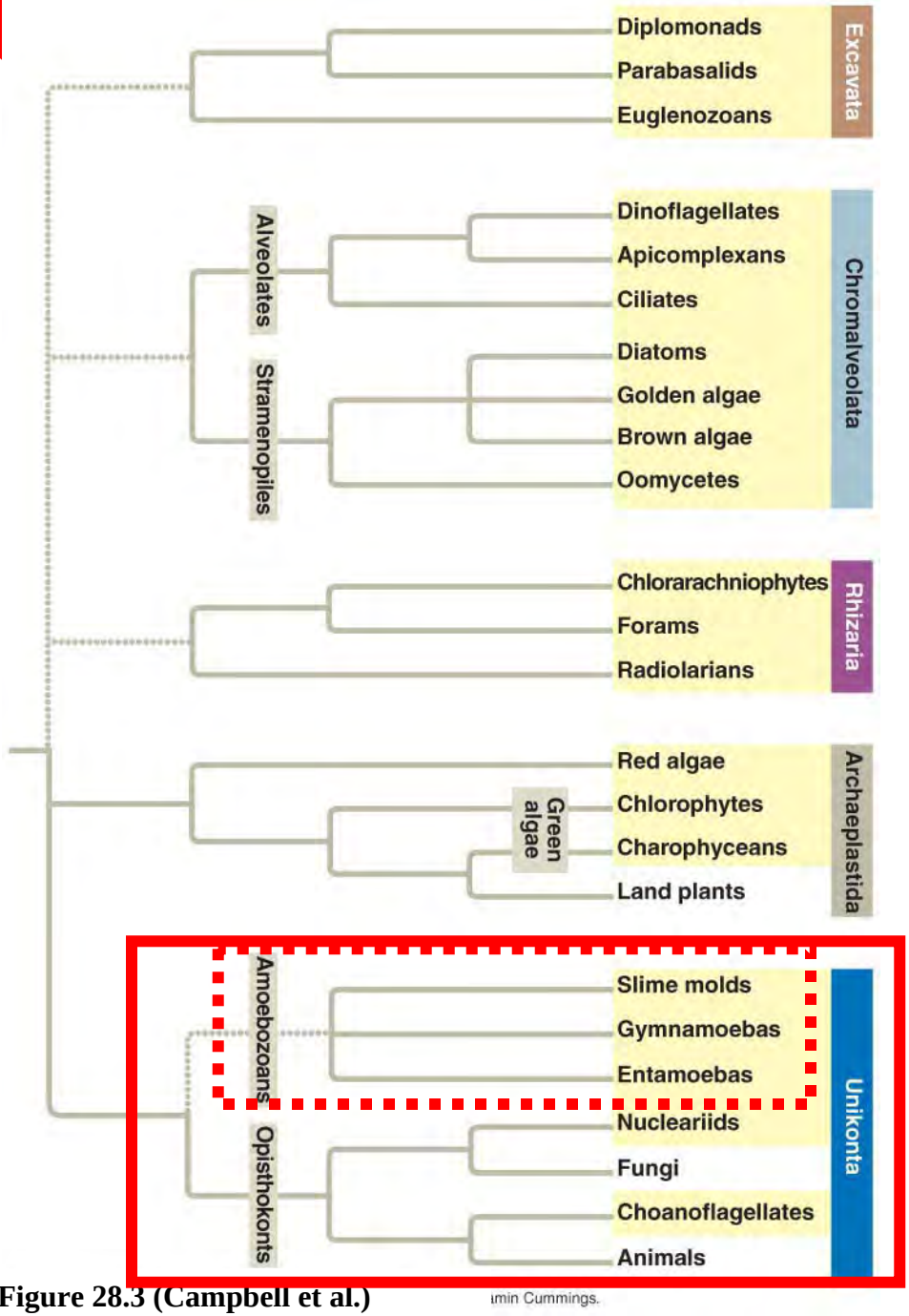


Figure 28.3 (Campbell et al.)

imin Cummings.

Unikonts

Synapomorphy:
All unikonts have a single flagellum or are an amoebae with no flagella

2 major subclades

1. Amoebozoans
2. Opisthokonts

See Chapter 28 Section 28.6

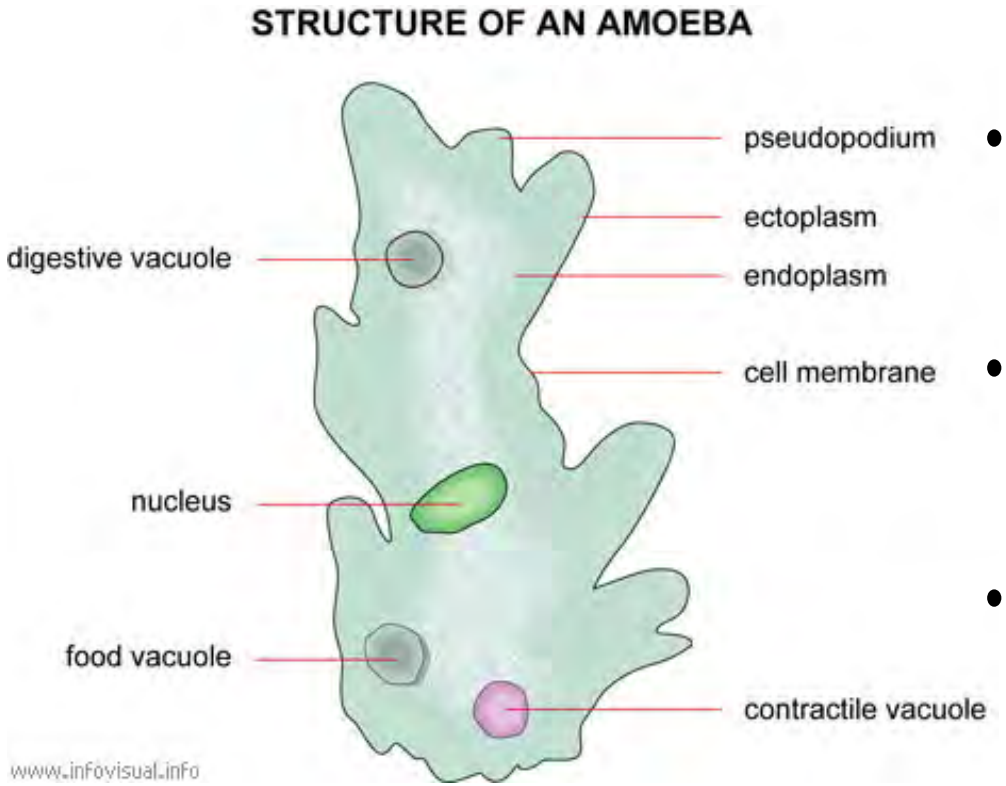
2 clades of Amoebozoa

Gymnamoebas

- Free-living (terrestrial, aquatic & fossorial)
~200 spp

Entamoebas

- parasites of vertebrates & inverts
~10 spp



- Move via cytoplasmic streaming creating/extending pseudopodia
Video1
- Also use pseudopodia to surround and eat food.
Video 2
- Freshwater spp w/ contractile vacuole for expelling excess water

Amoebozoa

Gymnamoebas

Entamoebas

- parasites of vertebrates & inverts

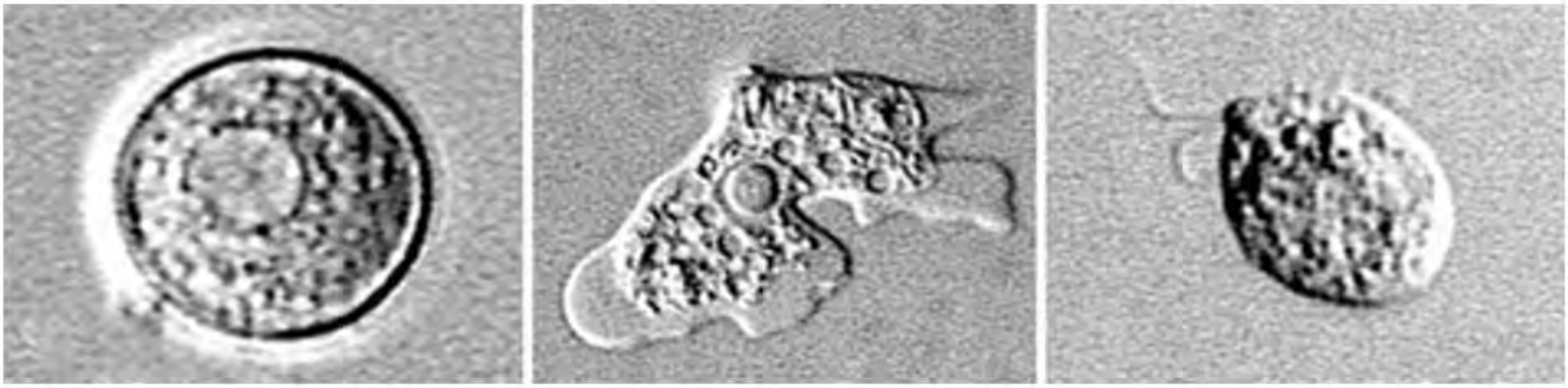
~10 spp

***Entamoeba histolytica* – causes amoebic dysentery. 100,000 deaths per year (globally)**

Deadly brain amoeba infects US tap water for the first time

Maggie Fox , NBC News

Sep. 16, 2013 at 4:35 PM ET



Centers for Disease Control and Prevention

The CDC says it's found Naegleria fowleri, an almost always deadly amoeba, in a U.S. drinking water supply for the first time.

A deadly brain amoeba that's killed two boys this year has been found in a U.S. drinking water supply system for the first time, officials said Monday -- in a New Orleans-area system.

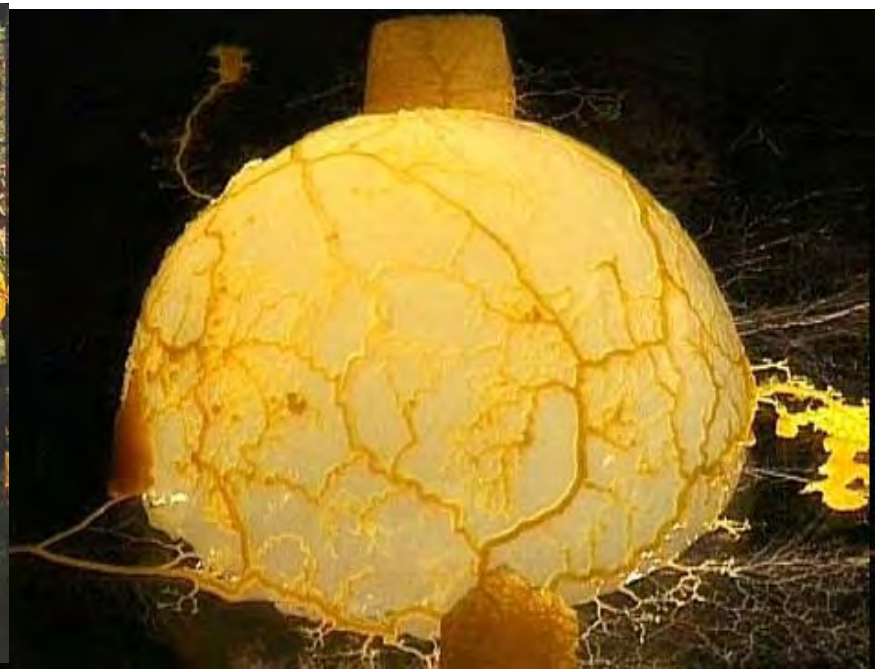
The Naegleria fowleri parasite killed a 4-year-old Mississippi boy who likely got it playing on a back yard Slip 'N Slide, Centers for Disease Control and Prevention officials say. Tests show it's present throughout the water supply system in St. Bernard Parish, directly southeast of New Orleans.

132 people known to have been infected from 1962 to 2014, but only three survived,

Clade: Amoebozoa
Slime Molds

Characteristic features:

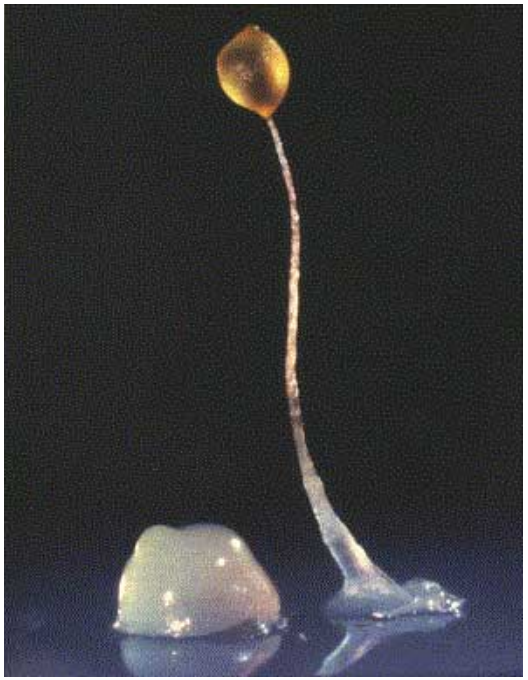
- **Motile**
- **Ingest food by phagocytosis**
- **Produce fruiting bodies**



Slime Molds vs. Fungi

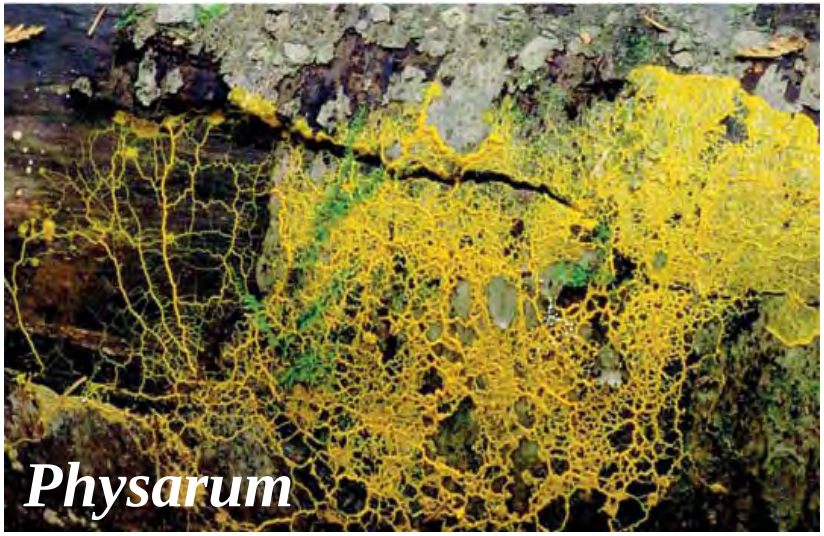
Look similar but not closely related

- No hyphae
- No cell wall
- Motile (vs. nonmotile)
- Ingestive feeding
  (vs. absorptive feeding)
- Predators
  (vs. saprobes (i.e. feed on
  decaying vegetation))



Clade: Amoebozoa
Subclade: Plasmodial Slime Molds

- 500 spp
- Plasmodium most of life
  - Feeding stage
  - 1 large cell w/ many diploid nuclei (coenocytic)
- Haploid spores created to wait out adverse conditions.
- Reproduction always sexual never asexual


Physarum

Fuligo septica

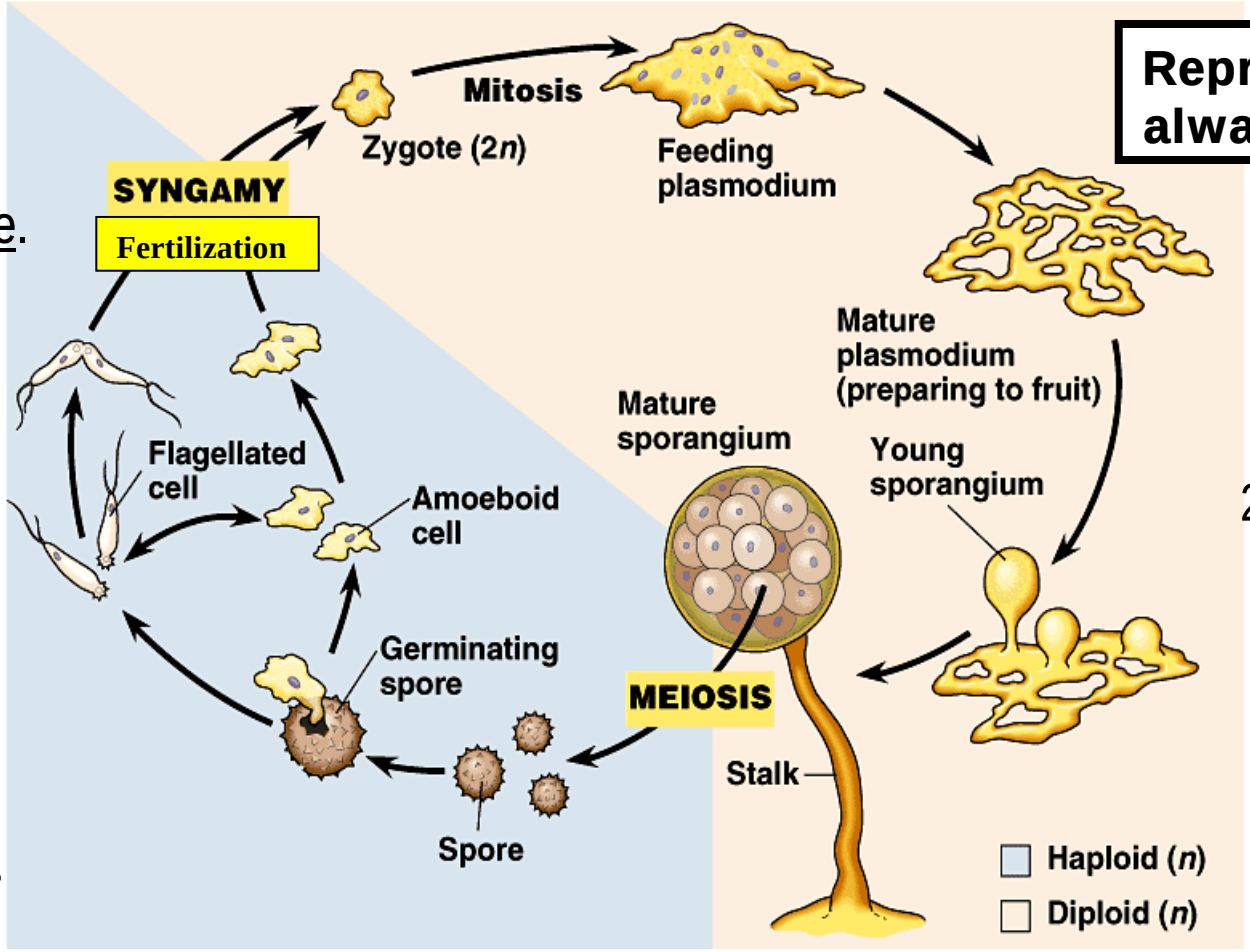
Plasmodial Slime Mold Life Cycle

6. Zygote nucleus divides multiple times via mitosis w/o cytokinesis

1. Diploid multinucleate plasmodium

Reproduction is always sexual

5. Like cells fuse forming diploid zygote.



4. Spores germinate in favorable conditions producing motile **amoeboid or flagellated cells**

2. Under harsh conditions makes **fruiting body** which produces haploid spores via *meiosis*

3. Spores w/ tough coat disperse through air

Figure 28.24 (Campbell et al.)

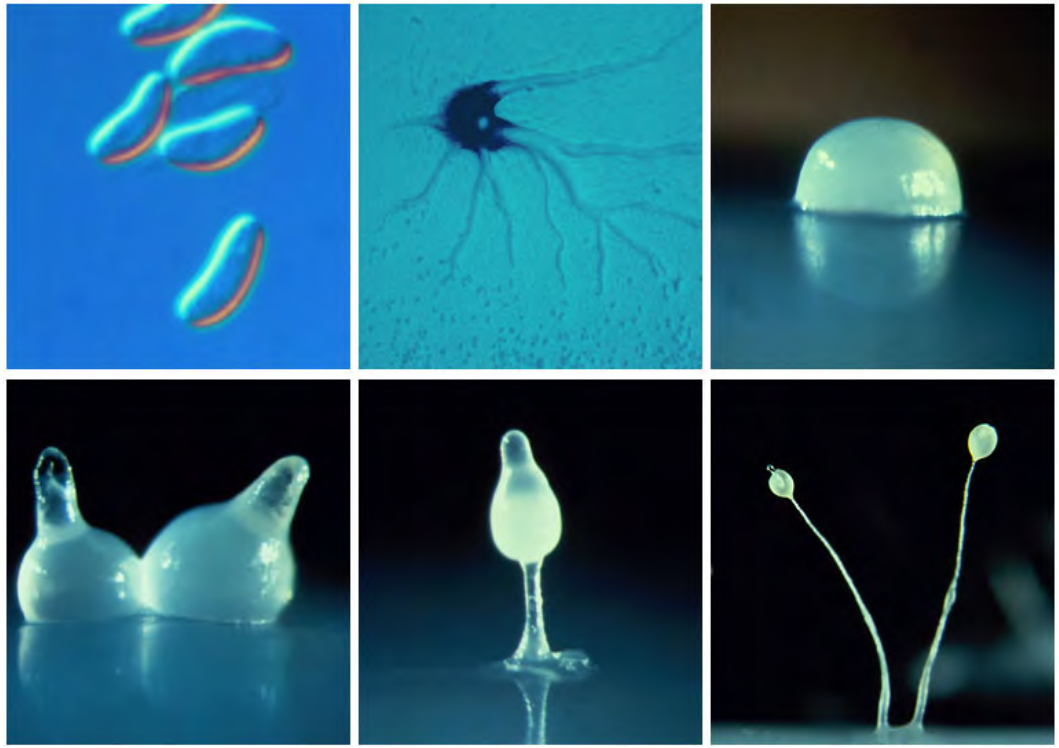
Clade: Amoebozoa
Subclade: Cellular Slime Molds

- 35 spp

- Most of life cycle:
  solitary "amoebas"
  (a single cell w/
  1 haploid nucleus)

- Reproduces sexually
  (i.e. join to form diploid zygote)

- When food depleted amoebas aggregate (slug) and reproduce asexually

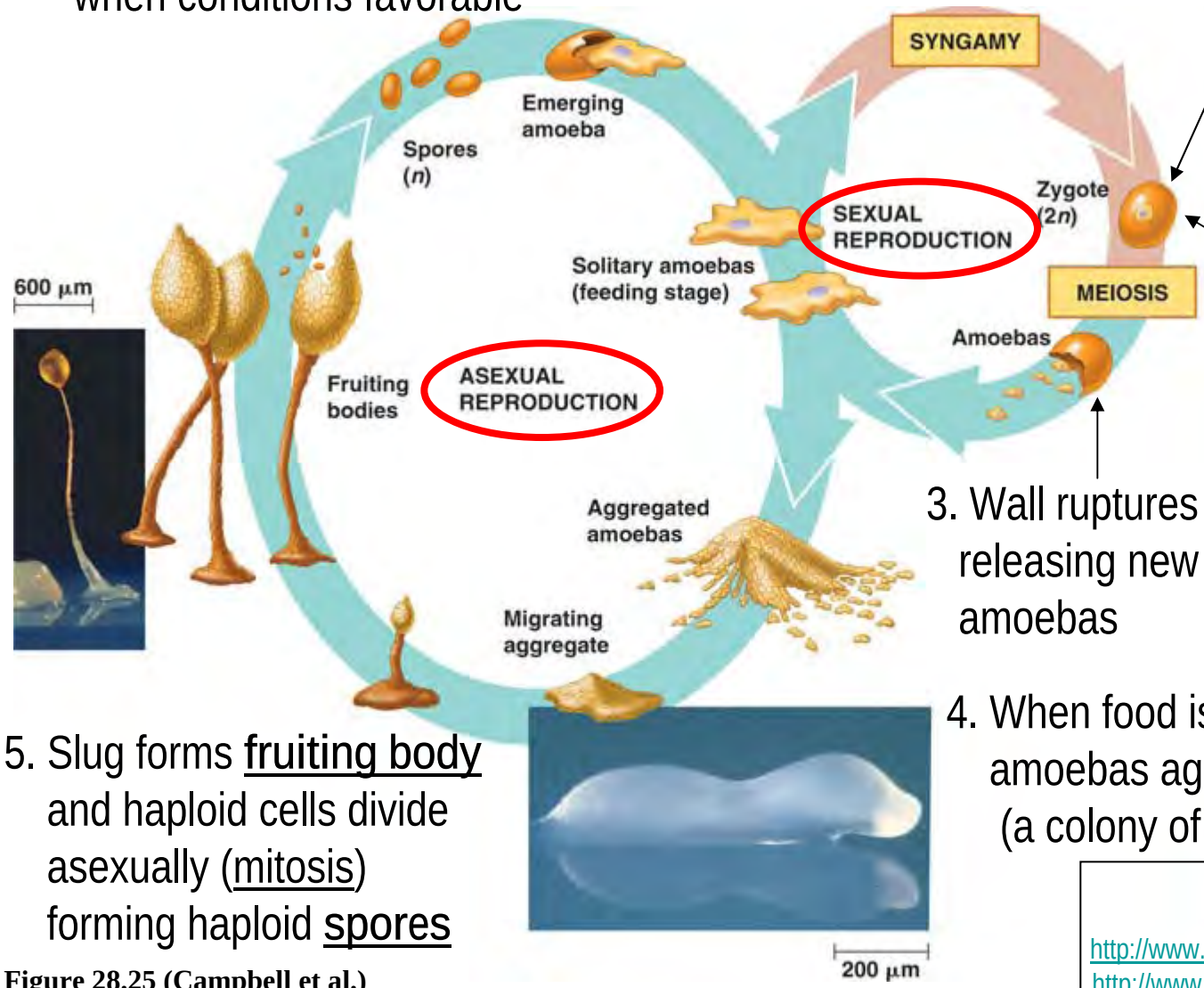


77 Cellular Slime Mold Reproduction

Have Sexual and Asexual stages

6. Amoebas emerge from spore coat when conditions favorable

1. Two haploid amoebas fuse forming a diploid zygote (only diploid stage) which eats all other amoebas then forms outer wall.



2. Zygote divides via meiosis to 2 haploid inds. Each divides several times via mitosis to make multiple haploid inds.

3. Wall ruptures releasing new amoebas

Key
Haploid (n)
Diploid (2n)

4. When food is gone amoebas aggregate forming a "slug" (a colony of multiple inds.)

5. Slug forms fruiting body and haploid cells divide asexually (mitosis) forming haploid spores

Figure 28.25 (Campbell et al.)

MOVIES:
http://www.youtube.com/watch?v=bkVhLJLG7ug
http://www.youtube.com/watch?v=HKZ2LtfDrmg

http://acbailey88.blogspot.com/2010_04_01_archive.html

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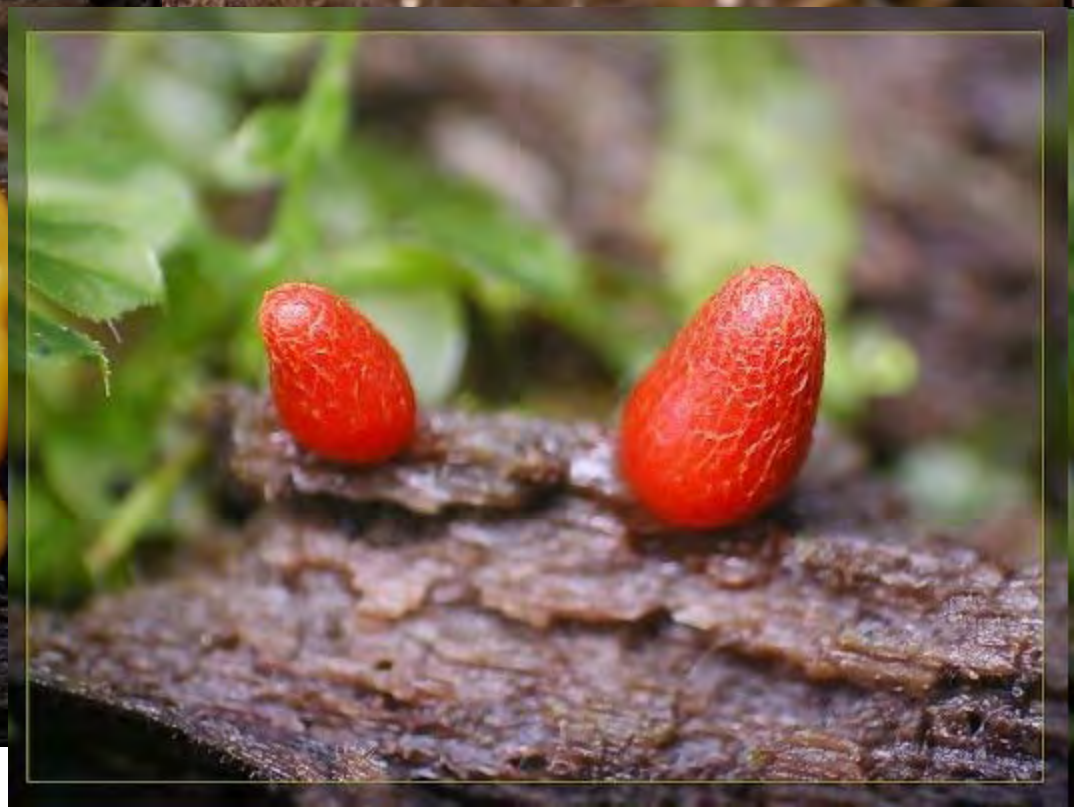

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http://acbailey88.blogspot.com/2010_04_01_archive.html

http://acbailey88.blogspot.com/2010_04_01_archive.html

Readings on which you will NOT be tested

- Figure 31.13
- Figure 31.17
- Figure 31.19
- Figure 31.21 (Inquiry)

- In general:
  - You are NOT responsible for definitions of terms or sections included in the text but which were not discussed in lecture
  - You are not responsible for the details of examples used in the text but not discussed in lecture. HOWEVER, these additional examples will help your understanding of concepts discussed and may be used on exams to test if you understand the general concepts.
  - You ARE responsible for material covered in lecture but not included in the readings

Next Chapter

Chapter 29 – Plant Diversity I