Zygomycetes and fungal lifestyles

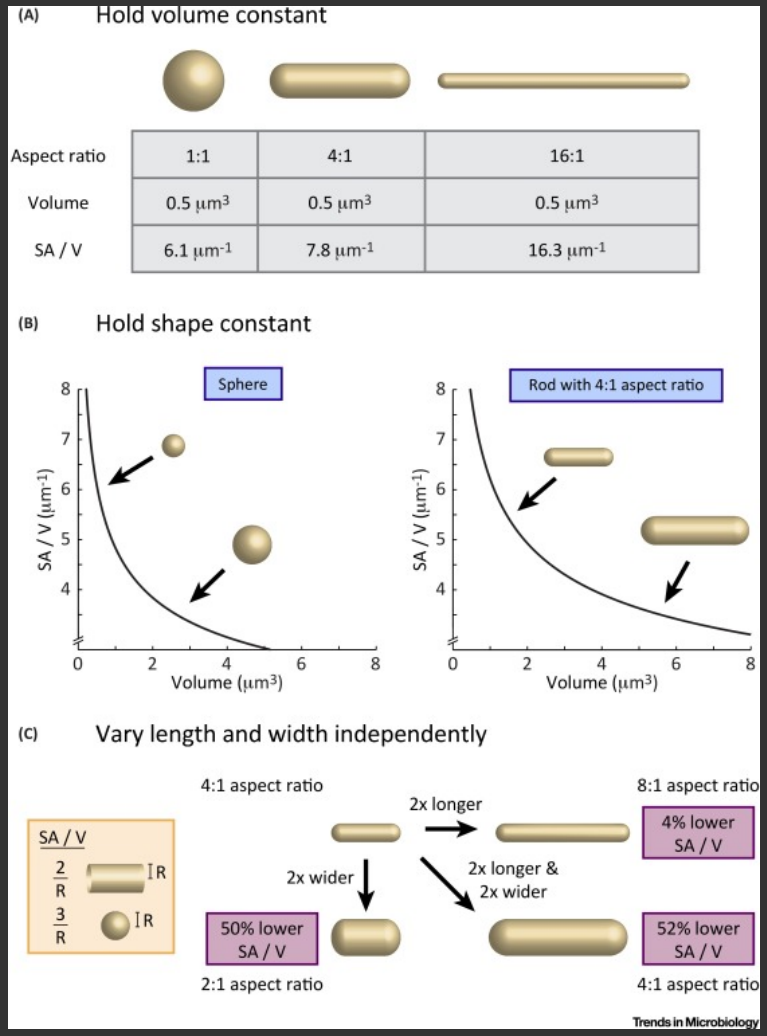
Topics (just the very basics):

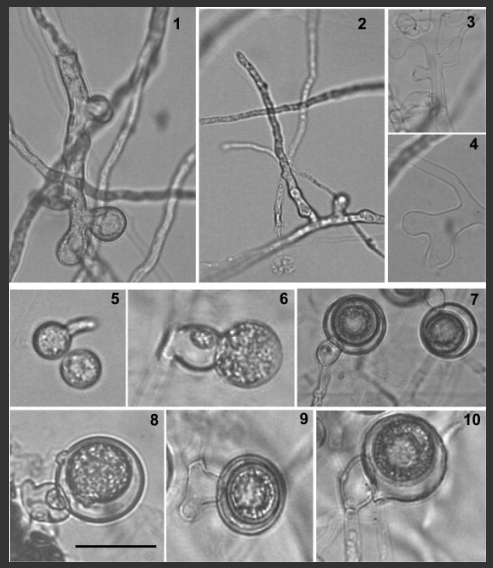
- Hyphal structure and growth
- Mycelium and hyphal aggregates
- Types of spores
- Fruiting body terminology
- Zygomycota
  - Phylogeny and evolution
  - Ecology
  - Closer look at two subgroups:
    - Mucoraceae and Pilobolaceae

Asexual spores Sexual spore

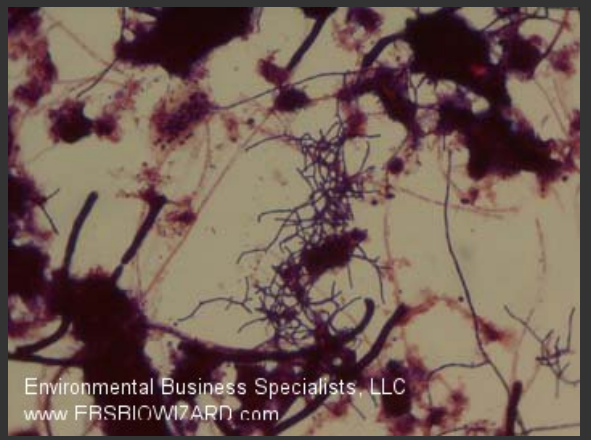
None of these images is of a fungus. Two are actually bacteria!

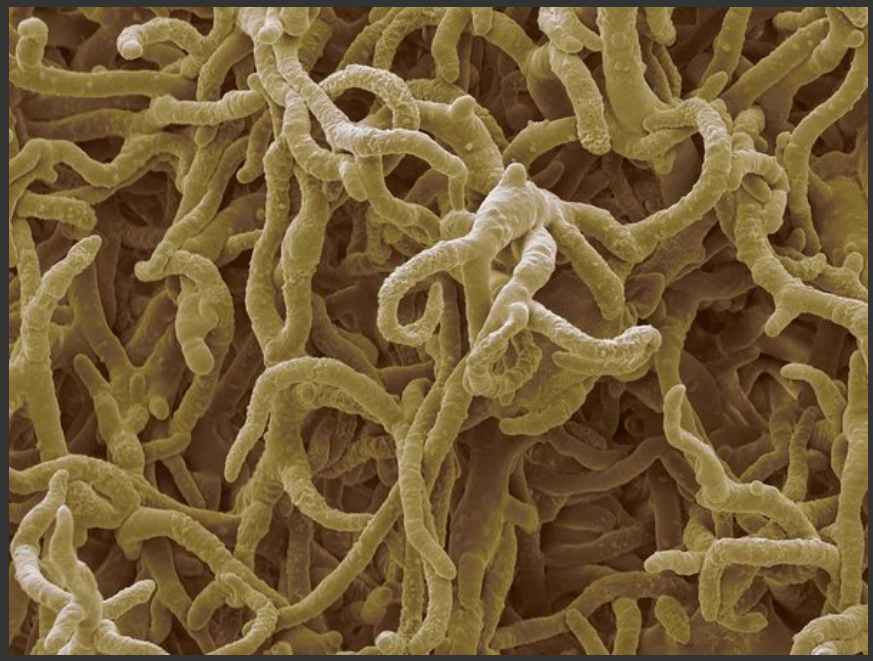
...but they all have filamentous growth





Filamentous growth has arisen independently many times because of physical constraints on lysotrophy

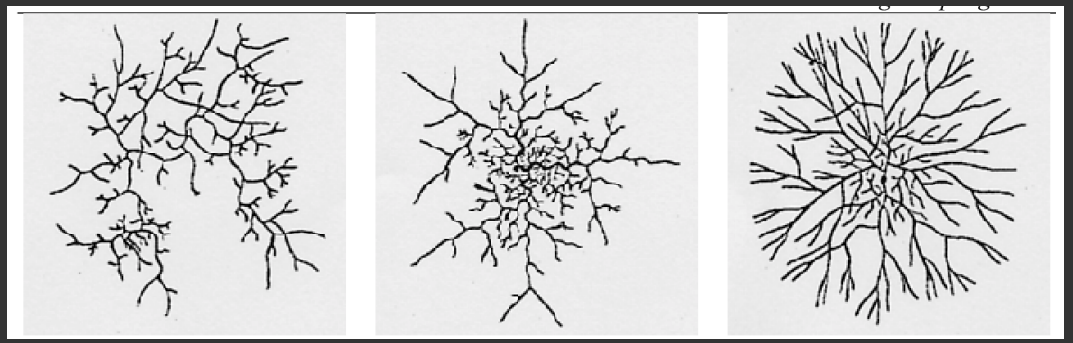




SEM - Credit: Steve Gschmeissner

Hyphae can aggregate into myriad forms. These aggregates take on lots of different functions. Sclerotia (dormant), rhizomorphs (aboveground competitive structures), ectomycorrhizae (surround plant roots), fruiting bodies (like mushrooms).

See website "resources" for a good web page on this.



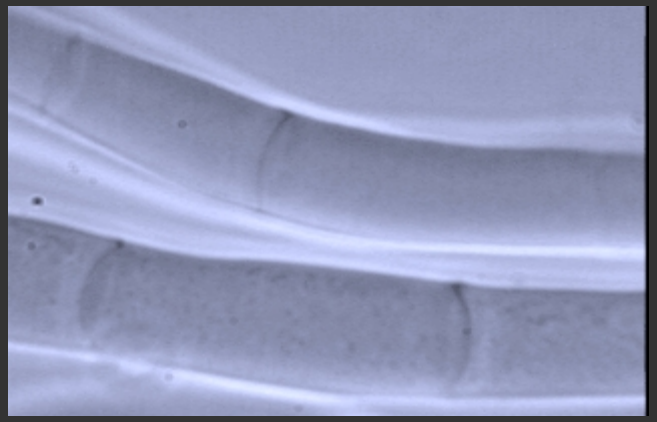
Hyphal colony morphogenesis types

Rhizopus (Mucormycotina) hyphal mass

Hyphal divisions?

Dikarya

Septate hyphae



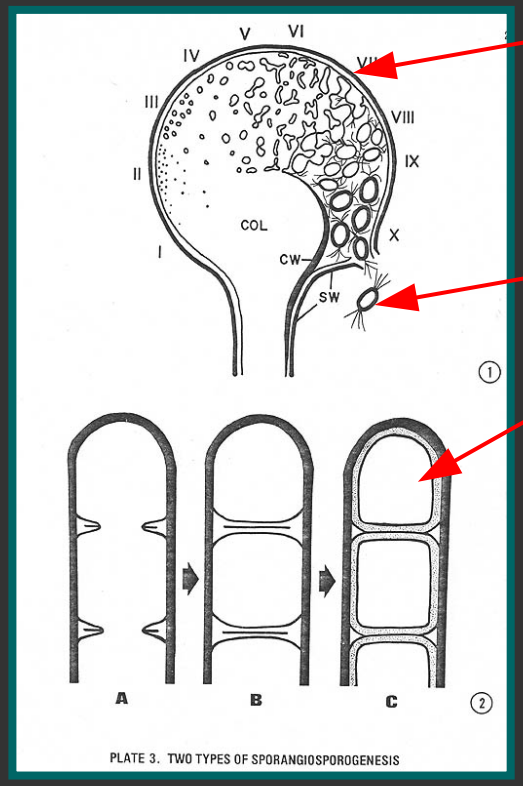
Zygos and Chytrids

Aseptate (coenocytic) hyphae

Fungi can produce spores in a lot of different ways.
Seems like every source of spores gets its own special name:

Sporangiospores: spores produced by a sporangium in many fungi such as zygomycetes.
Zygospores: spores produced by a zygosporangium, characteristic of zygomycetes.
Conidiospores: spores produced by an asexual conidium, typical of ascomycetes and zygomycetes.

.... and so on. You get the idea.

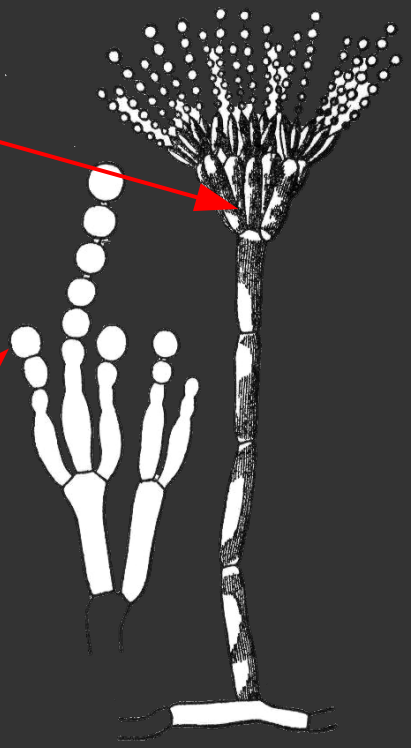


Credit: O'Donnell, 1979

Sporangium

Sporangiospores

Conidium



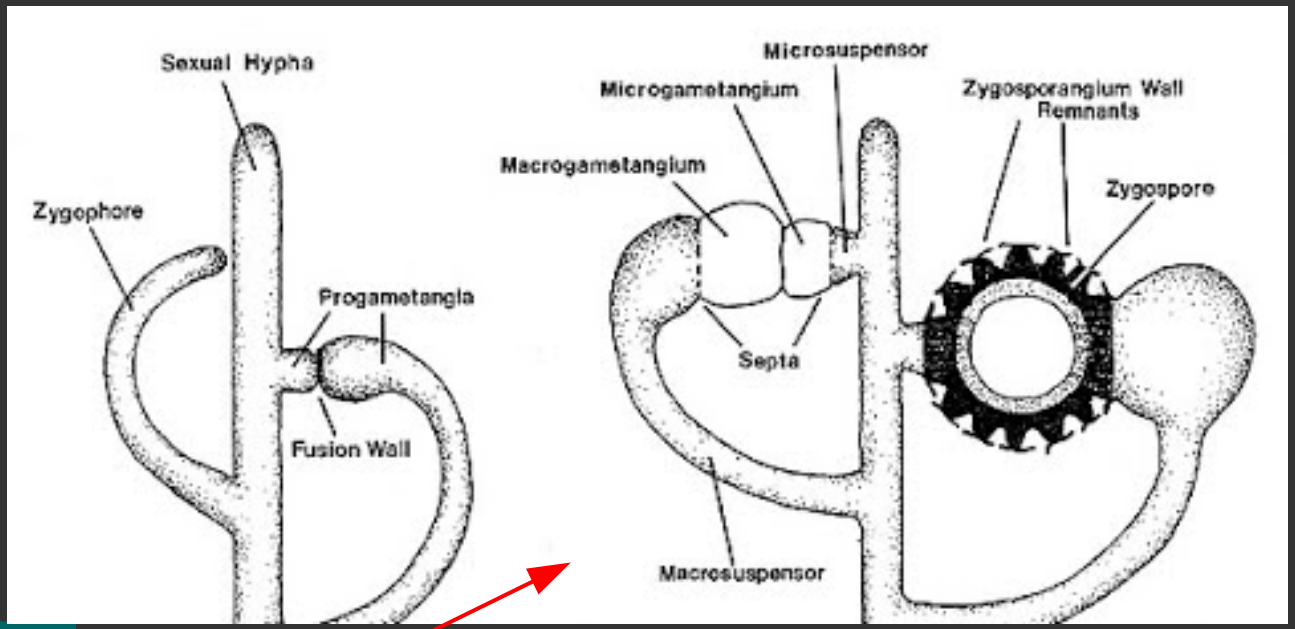
Conidiospores

Zygomycota

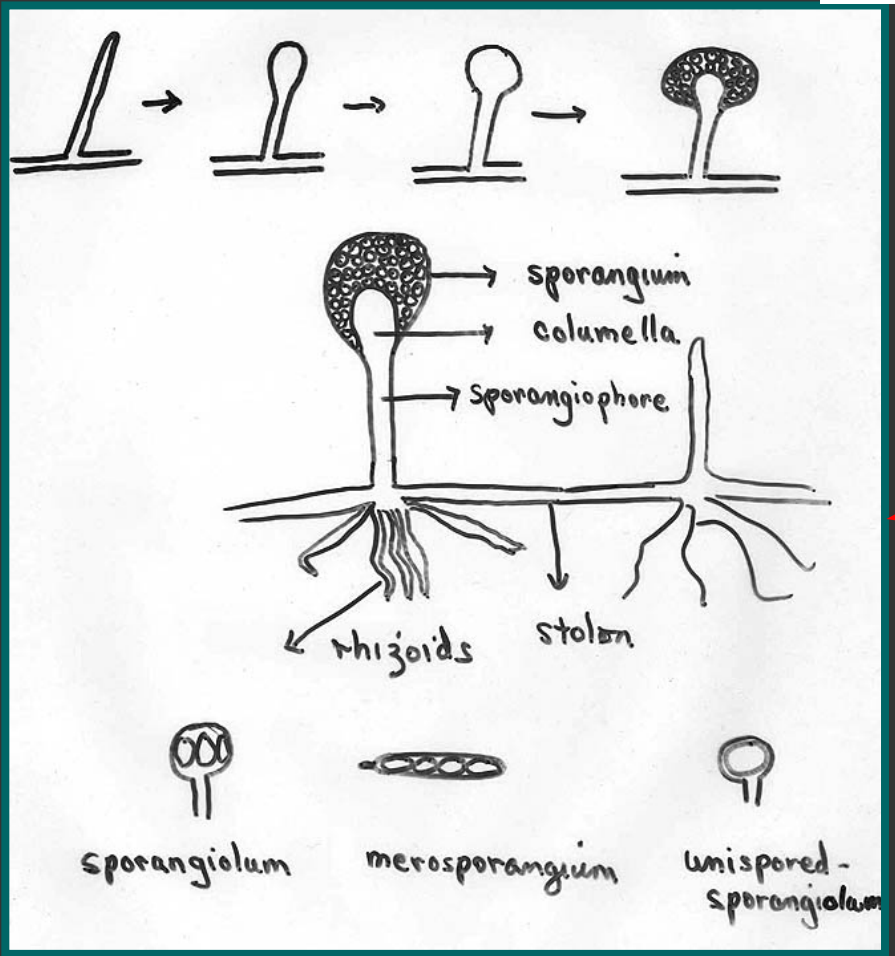
- Vegetative stage – well developed aseptate (coenocytic) hyphae
- Asexual reproduction by nonmotile sporangiospores
- Sexual reproduction – Zygospore produced in a zygosporangium from fusion of two similar gametangia

Zygomycete fruiting body anatomy and terminology

You'll see these terms in the readings.



Sexual reproductive anatomy

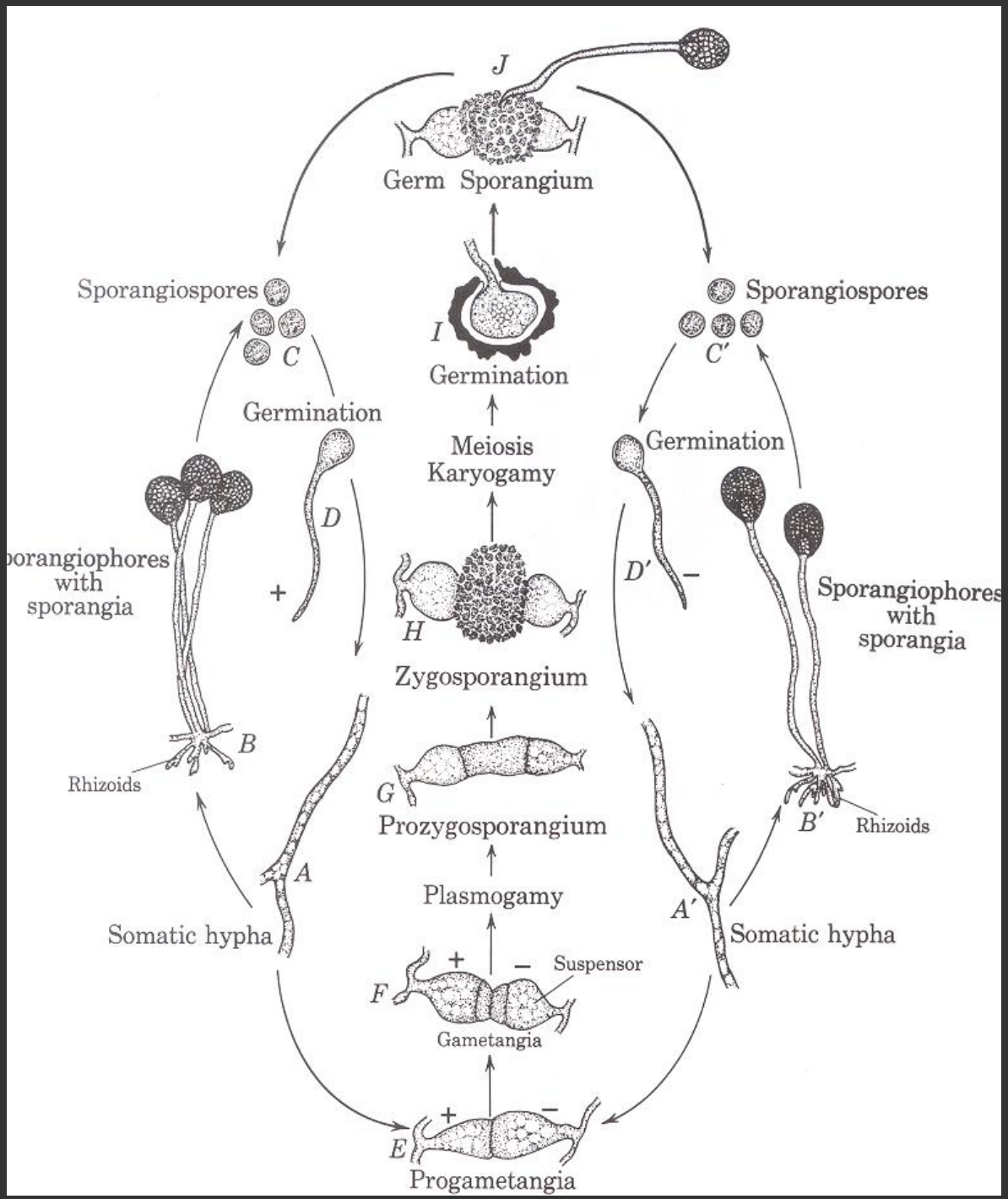


Asexual reproductive anatomy

What's the biological difference between a macrogametangium and microgametangium?

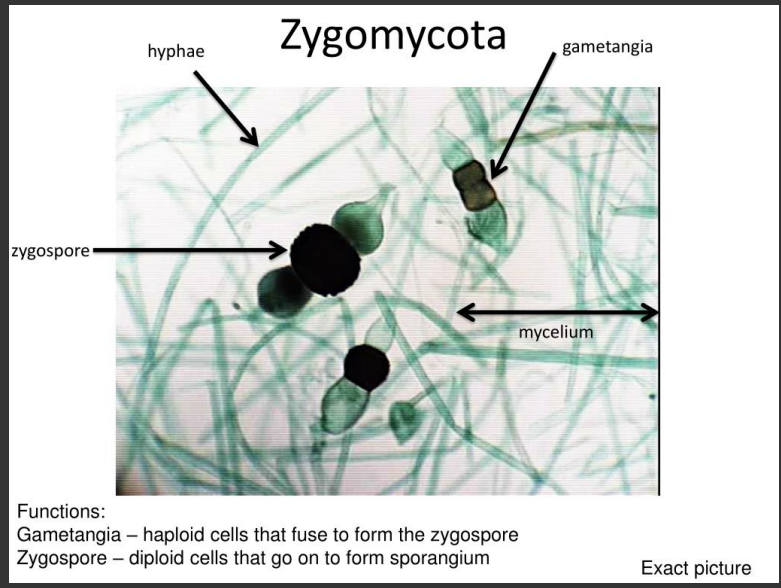
Think back to your botany terms...

Life cycle (typical)



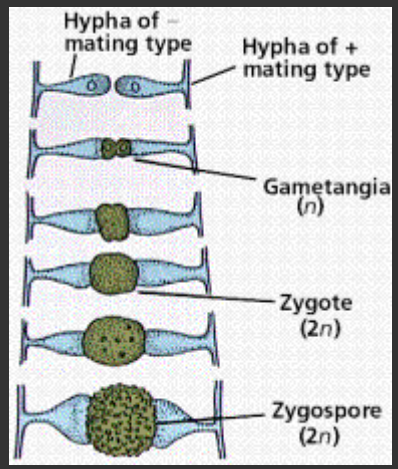
Note the alternate life cycle pathways

This group is named after the sexual zygospore structure



Functions:
Gametangia – haploid cells that fuse to form the zygospore
Zygospore – diploid cells that go on to form sporangium

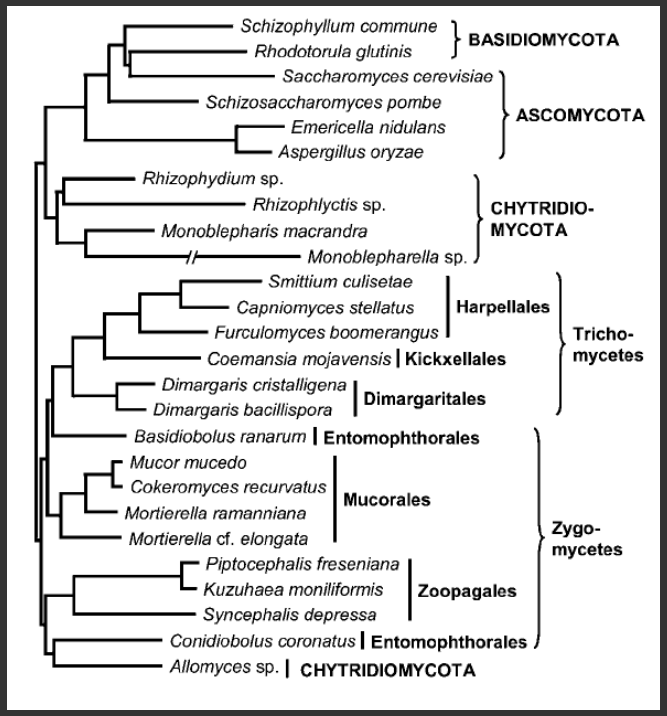
Exact picture



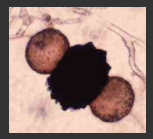
"Zygomycota" is not monophyletic

There seems to be general confusion about where these fit and their relationships to each other, but a few things are pretty clear:

1. "Zygos" are paraphyletic
2. Probably sister to "chytrids"
3. Or at least all mixed up with "chytrids"
4. Zygospores are a trait inherited from the common ancestor of Zoopagomycota, Mucoromycota, and Dikarya
5. Two main phyla:
   Mucoromycota and Zoopagomycota
6. I'm so confused



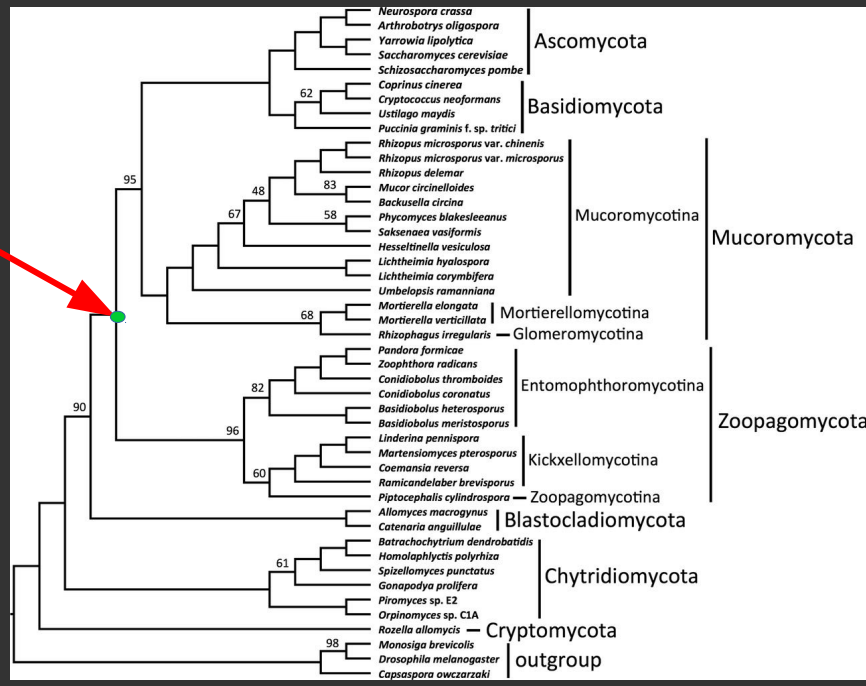
Tanabe, et al., 2004



Zygospores

Mucoromycota Doweld (2001)
- Glomeromycotina (C. Walker & A. Schüßler) Spatafora & Stajich, subphylum and stat. nov.
  - Glomeromycetes Caval.-Sm. (1998)
    - Archaeosporales C. Walker & A. Schüßler (2001)
    - Diversisporales C. Walker & A. Schüßler (2004)
    - Glomerales J. B. Morton & Benny (1990)
    - Paraglomerales C. Walker & A. Schüßler (2001)
- Mortierellomycotina Kerst. Hoffm., K. Voigt & P.M. Kirk (2011)
  - Mortierellales Caval.-Sm. (1998)
- Mucoromycotina Benny (2007)
  - Endogonales Moreau ex R.K. Benj. (1979)
  - Mucorales Fr. (1832)
  - Umbelopsidales Spatafora & Stajich, ord. nov.

Zoopagomycota Gryganskyi, M.E. Smith, Stajich & Spatafora, phylum nov.
- Entomophthoromycotina Humber (2007)
  - Basidiobolomycetes Doweld (2001)
    - Basidiobolales Jacz. & P.A. Jacz. (1931)
  - Entomophoromycetes Humber (2012)
    - Entomophthorales G. Winter (1880)
  - Neozygitomycetes Humber (2012)
    - Neozygitales Humber (2012)
- Kickxellomycotina Benny (2007)
  - Asellariales Manier ex Manier & Lichtw. (1978)
  - Dimargaritales R.K. Benj. (1979)
  - Harpellales Lichtw. & Manier (1978)
  - Kickxellales Kreisel ex R.K. Benj. (1979)
- Zoopagomycotina Benny (2007)
  - Zoopagales Bessey ex R.K. Benj. (1979)



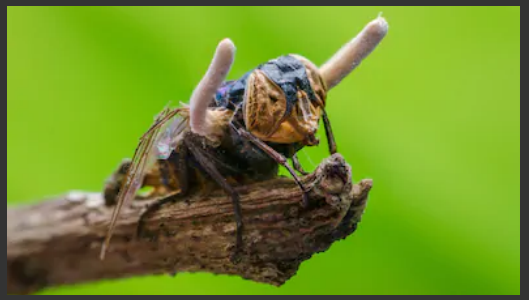
Spatafora, et al., 2016

Zoopagomycota

Earliest diverging lineage of zygomycetes and contains species that are primarily parasites and pathogens of small animals (e.g. amoeba, insects, etc.) and other fungi, i.e. mycoparasites

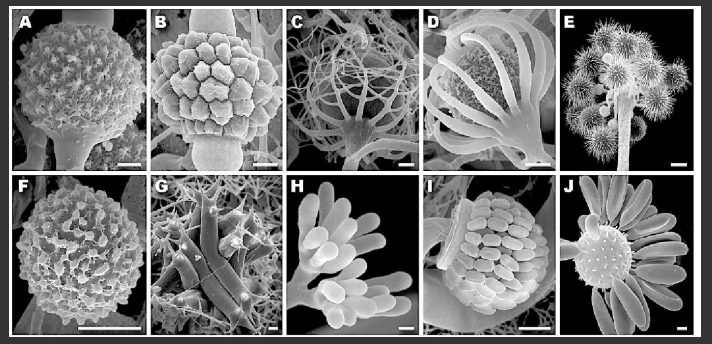
Entomophtoromycotina

Saprobic and insect pathogenic fungi



Kickxellomycotina

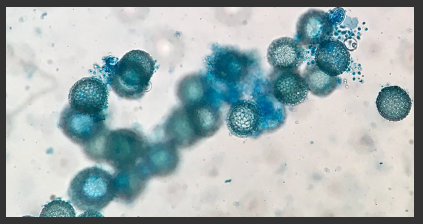
Saprobes, mycoparasites, and symbionts of insects



Zoopagomycotina

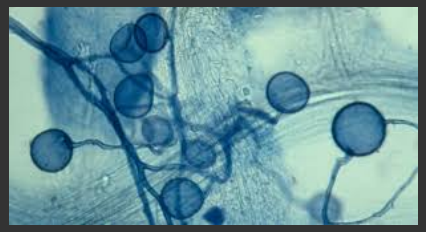
Mycoparasites and predators or parasites of small invertebrates and amoebae

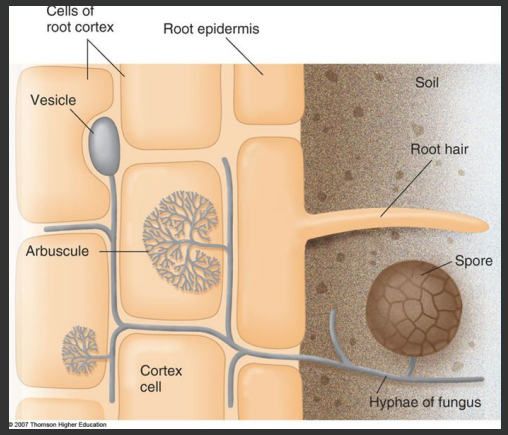
Very hard to grow in lab



Mucormycota

Sister to dikarya - mainly consists of mycorrhizal fungi, root endophytes, and decomposers of plant material





Glomeromycotina

http://www.amf-phylogeny.com/

All form mycorrhizal associations with plant roots

Make arbuscles (thus, AMF - Arbuscular mycorrhizal fungi)

Most successful plant-fungal symbiosis on Earth

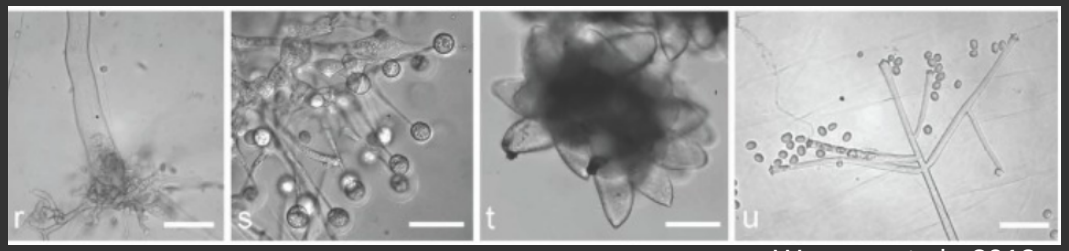
Might not belong in Mucormycota!

Mortierellomycotina

Mostly soil-dwelling saprotrophs

Some plant-root endophytes

Cryptic species complexes

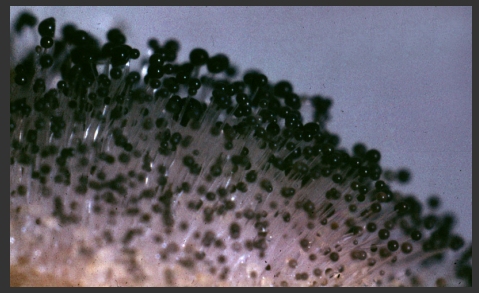


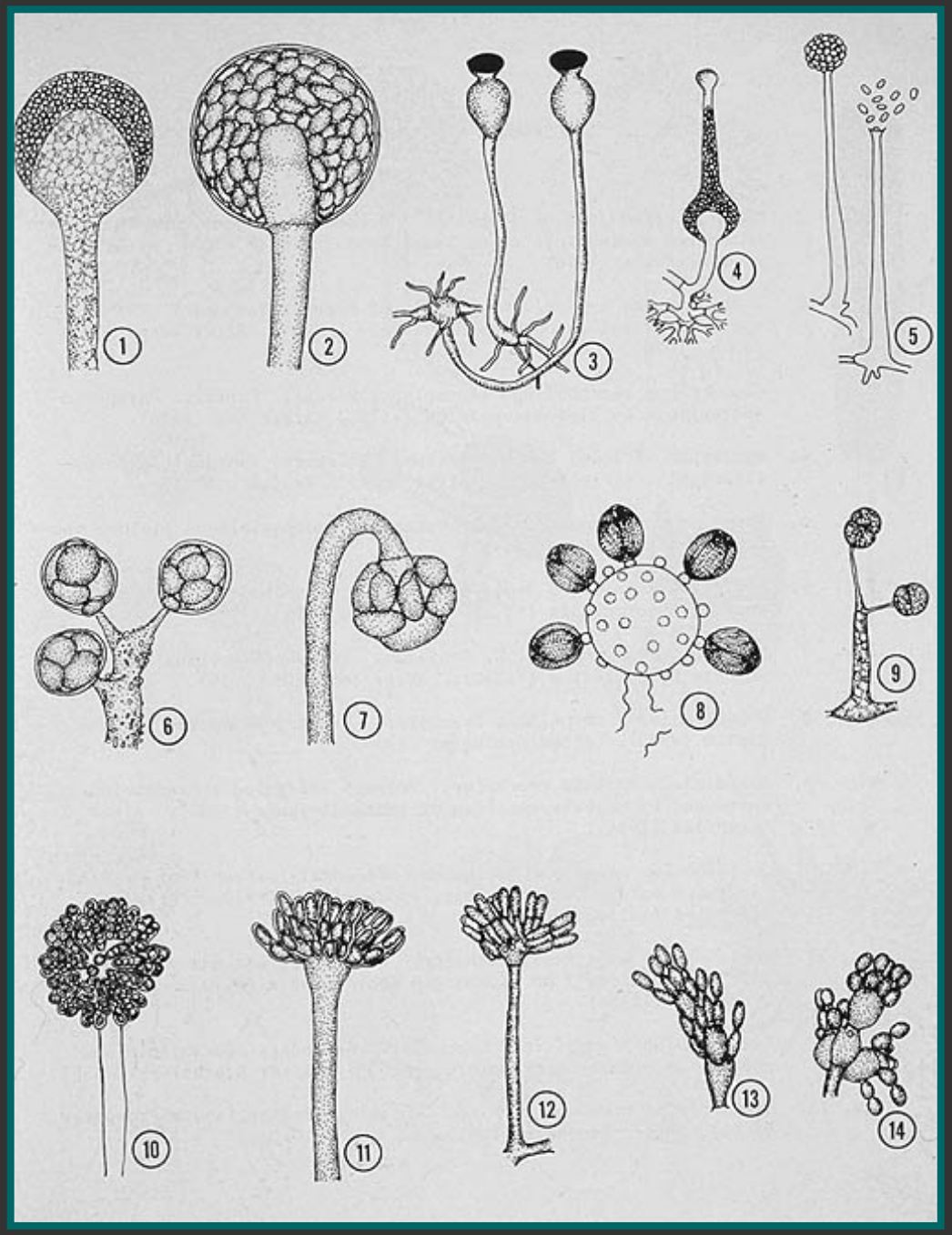
Wagner, et al., 2013

Mucoromycotina

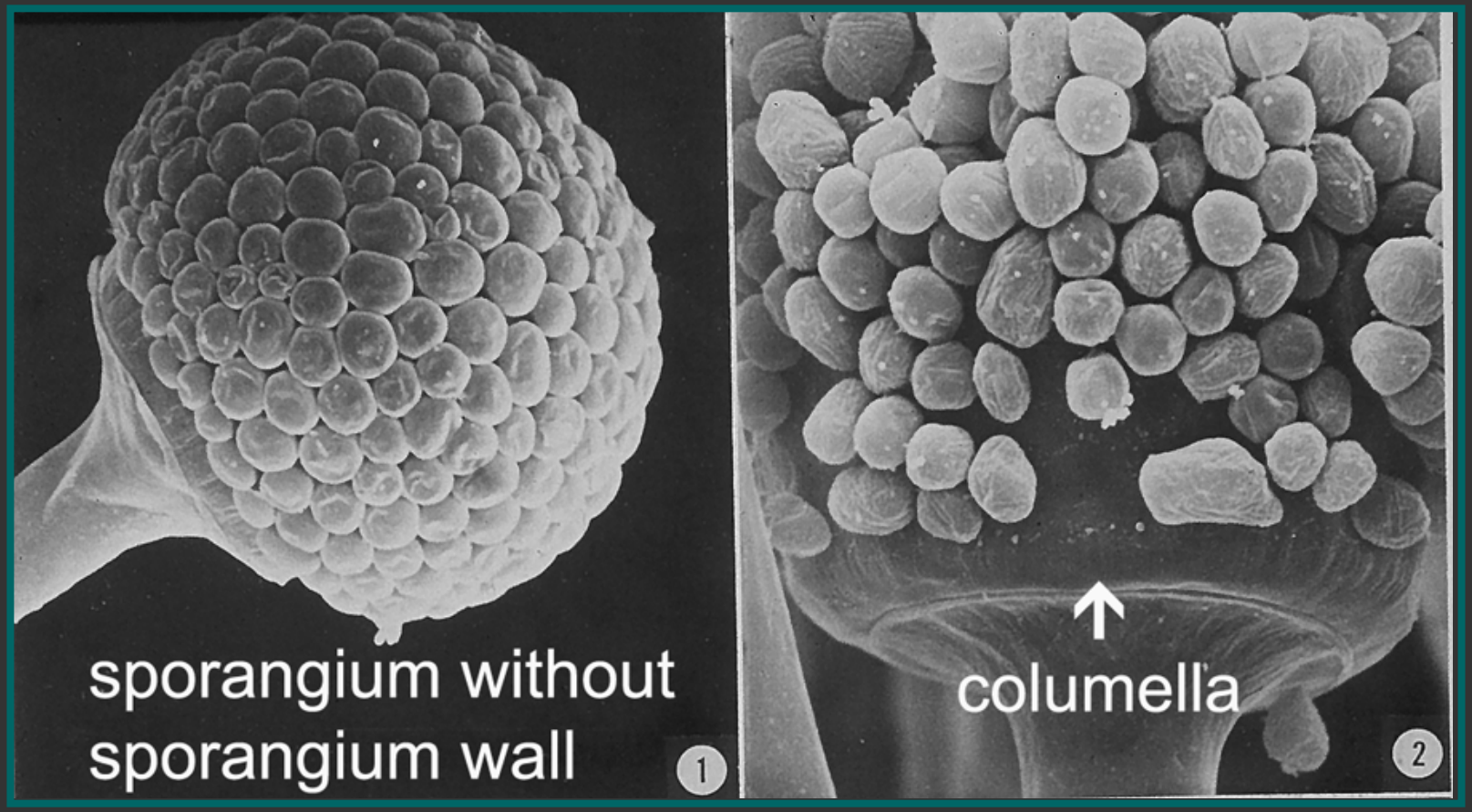
Most commonly-found "zygos" and contains tons of described species

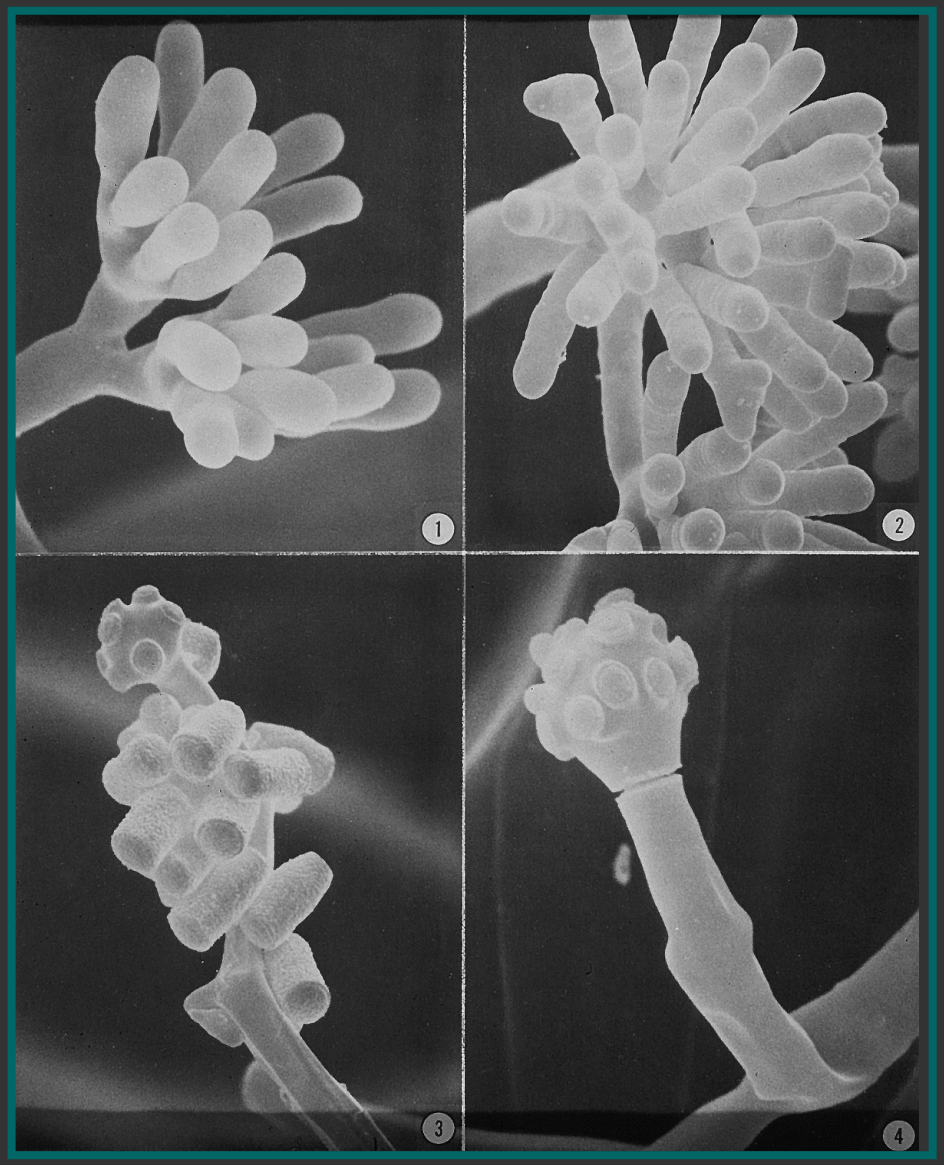
Frequently isolated from soil, dung, plant debris, and sugar-rich plant parts





Sporangia (asexual reproductive structures) can take many diverse forms

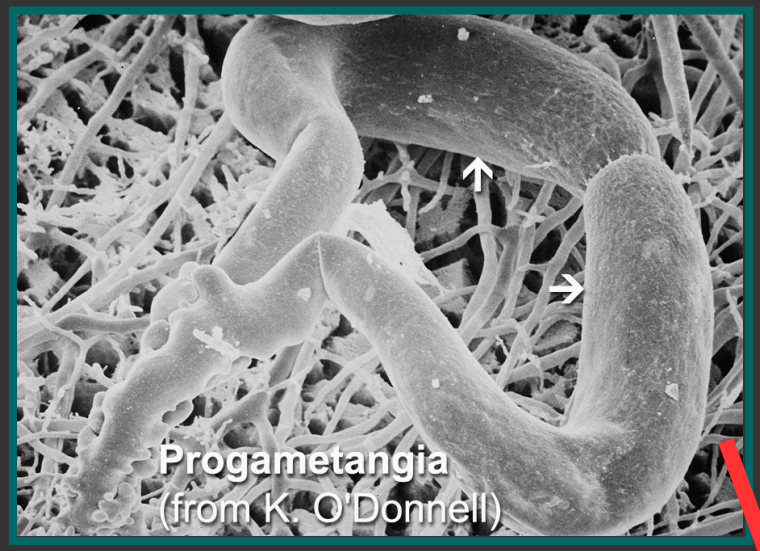

sporangium without
sporangium wall
1
columella
2

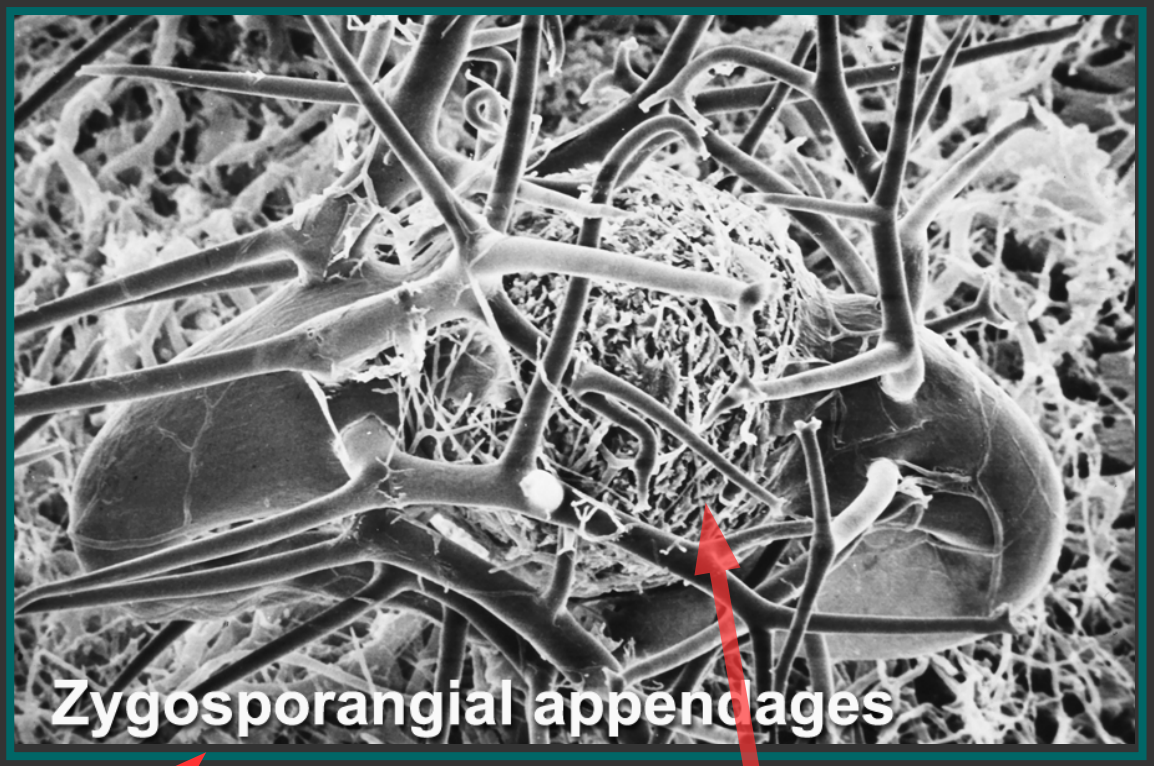


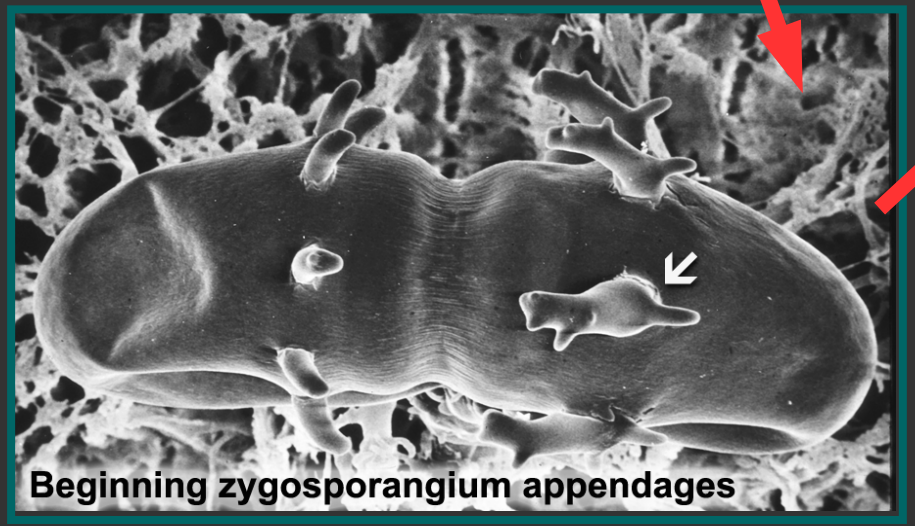
Evolutionary trend is toward reduced sporangia

←“merosporangia”

Sexual reproduction is via zygospores. These take on a wide variety of morphologies as well.





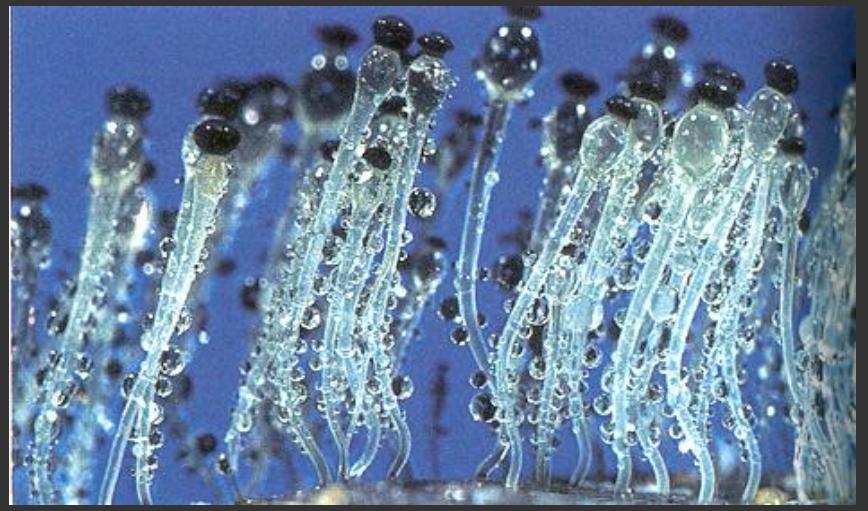


Zygospore

Pilobolus

[Mucoromycotina]

- Passage through gut of herbivore activates spore germination
- Sporangium is dark in color to prevent damage from UV when attached to grass



Pilobolus

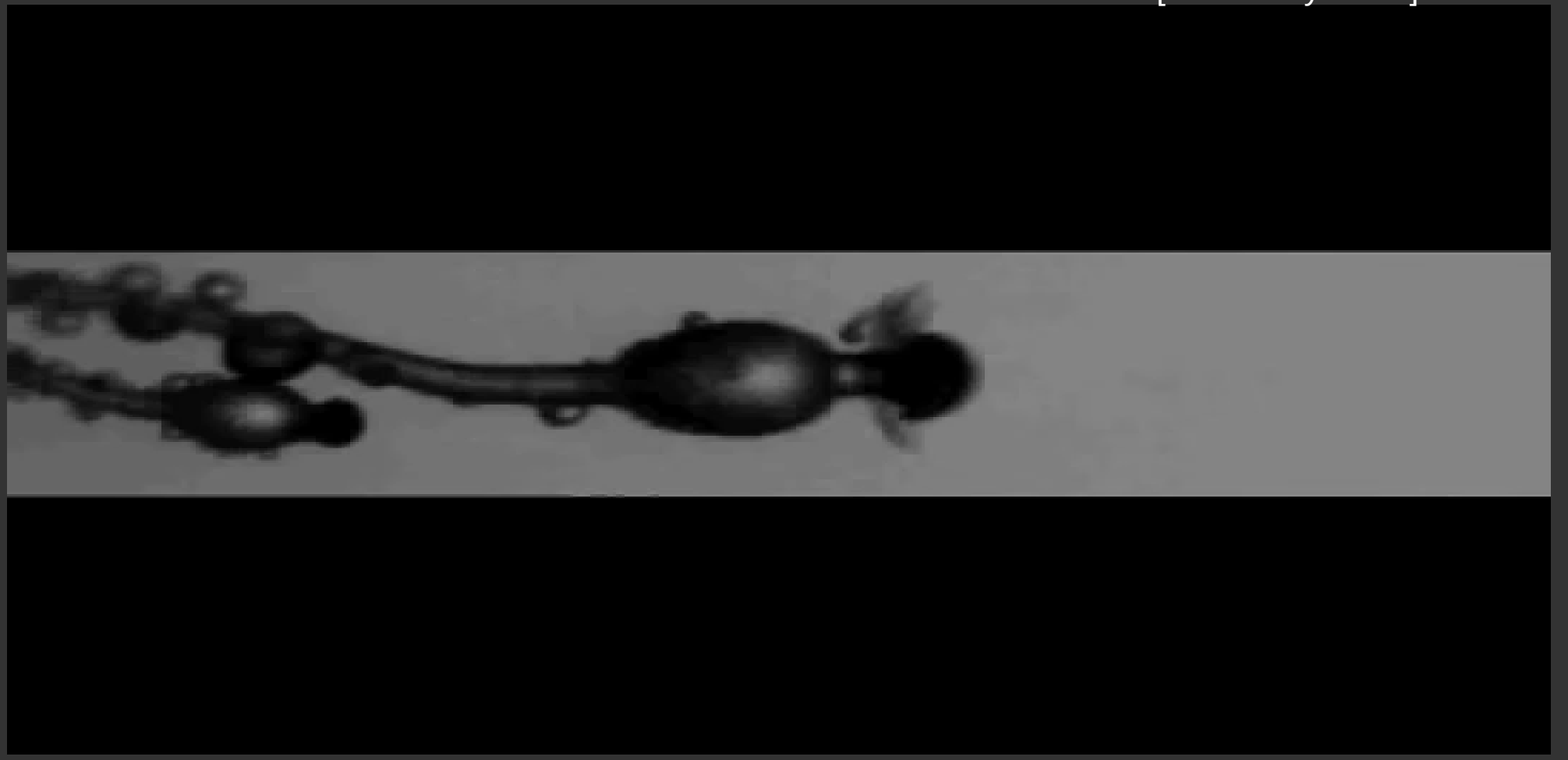
[Mucoromycotina]

Uses water pressure to launch sticky spore mass great distances

By excreting sugars into the terminus of the spore-bearing hypha, water moves there through osmosis

Pilobolus

[Mucoromycotina]



Can launch spores at 20,000 G (equivalent to a human launching at 100x the speed of sound in 2 μs!)

Crazy cool positive phototropism
(opposite of plant mechanism)

Pilobolus

[Mucoromycotina]

See Webster & Weber
Section 7.2

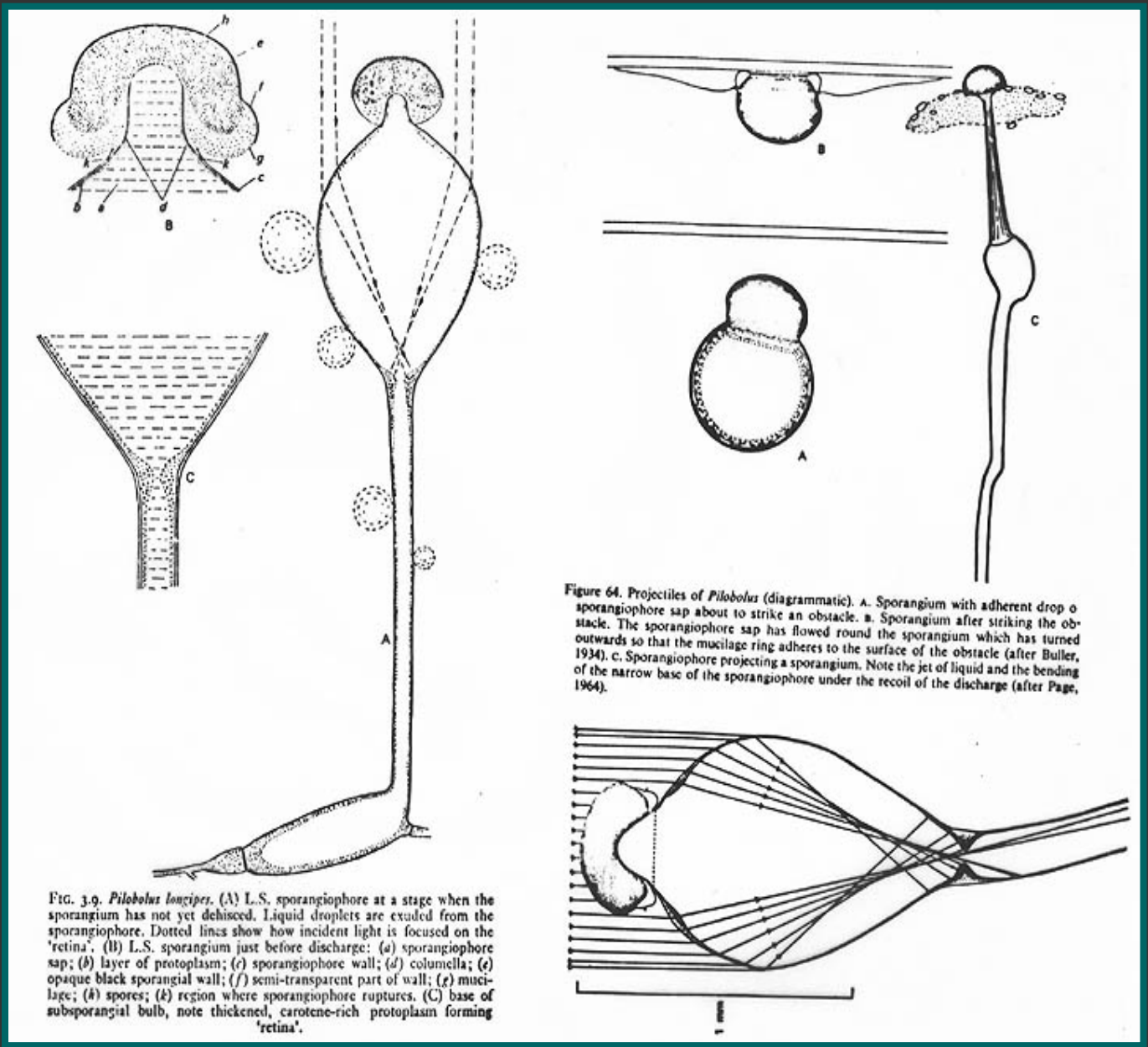


FIG. 3.9. *Pilobolus longipes*. (A) L.S. sporangiophore at a stage when the sporangium has not yet dehisced. Liquid droplets are exuded from the sporangiophore. Dotted lines show how incident light is focused on the 'retina'. (B) L.S. sporangium just before discharge: (*a*) sporangiophore sap; (*b*) layer of protoplasm; (*c*) sporangiophore wall; (*d*) columella; (*e*) opaque black sporangial wall; (*f*) semi-transparent part of wall; (*g*) mucilage; (*h*) spores; (*k*) region where sporangiophore ruptures. (C) base of subsporangial bulb, note thickened, carotene-rich protoplasm forming 'retina'.

Figure 64. Projectiles of *Pilobolus* (diagrammatic). A. Sporangium with adherent drop o sporangiophore sap about to strike an obstacle. B. Sporangium after striking the obstacle. The sporangiophore sap has flowed round the sporangium which has turned outwards so that the mucilage ring adheres to the surface of the obstacle (after Buller, 1934). C. Sporangiophore projecting a sporangium. Note the jet of liquid and the bending of the narrow base of the sporangiophore under the recoil of the discharge (after Page, 1964).

Zygos are commercially and industrially important

Rhizopus oligosporus

\+

Soybeans

=

Delicious tempeh

Questions you should be able to figure out:

(from slides and readings)

Are sporangiospores haploid, diploid, or dikaryotic?

Glomeromycotina are not known to have zygospores. Is this trait derived from or homologous with other Mucoromycotina species?

Some zygomycetes have evolved "conidia" (merosporangia) secondarily from a primarily sporangial asexual reproduction mode. What might this say about evolutionary pressures on sporangia?

The spore mass shot from Pilobolus... what kind of spores are those? What is their ploidy level?

Explain why filamentous growth is so common across the microbial tree of life.

When did the Spitzenkörper likely evolve? Was it just once or multiple times?

What's the difference between homothallic and heterothallic zygomycete species?

So, how do zygomycetes fit into our picture of fungal evolution, morphology, physiology, diversity, and ecology?

Evolution -

Morphology -

Physiology -

Diversity -

Ecology -

Assignments

1. Read Webster & Weber, sections: 1.2, 1.3, 1.4, 7.1, 7.2, 7.3.1, and 7.3.2
   - These cover an introduction to fungalphysiology, and then an introduction to zygomycetes and a couple major zygomycete groups

2. Read the Fisher, et al., 2018 paper (link on course website)
   - This paper uses an obscure zygomycete species to investigate the evolution of the Spitzenkörper and polarized hyphal growth
   - Keep a phylogeny of the Zygomycetes handy when reading. That will help you keep this paper in the context of evolutionary biology

3. You will have a Canvas quiz on the assigned readings and will also have to participate in a Slack discussion about them.

4. You should be able to photgraph your Zygomycetes on your bread trap by now. Photo of that is due Thursday (On Canvas)