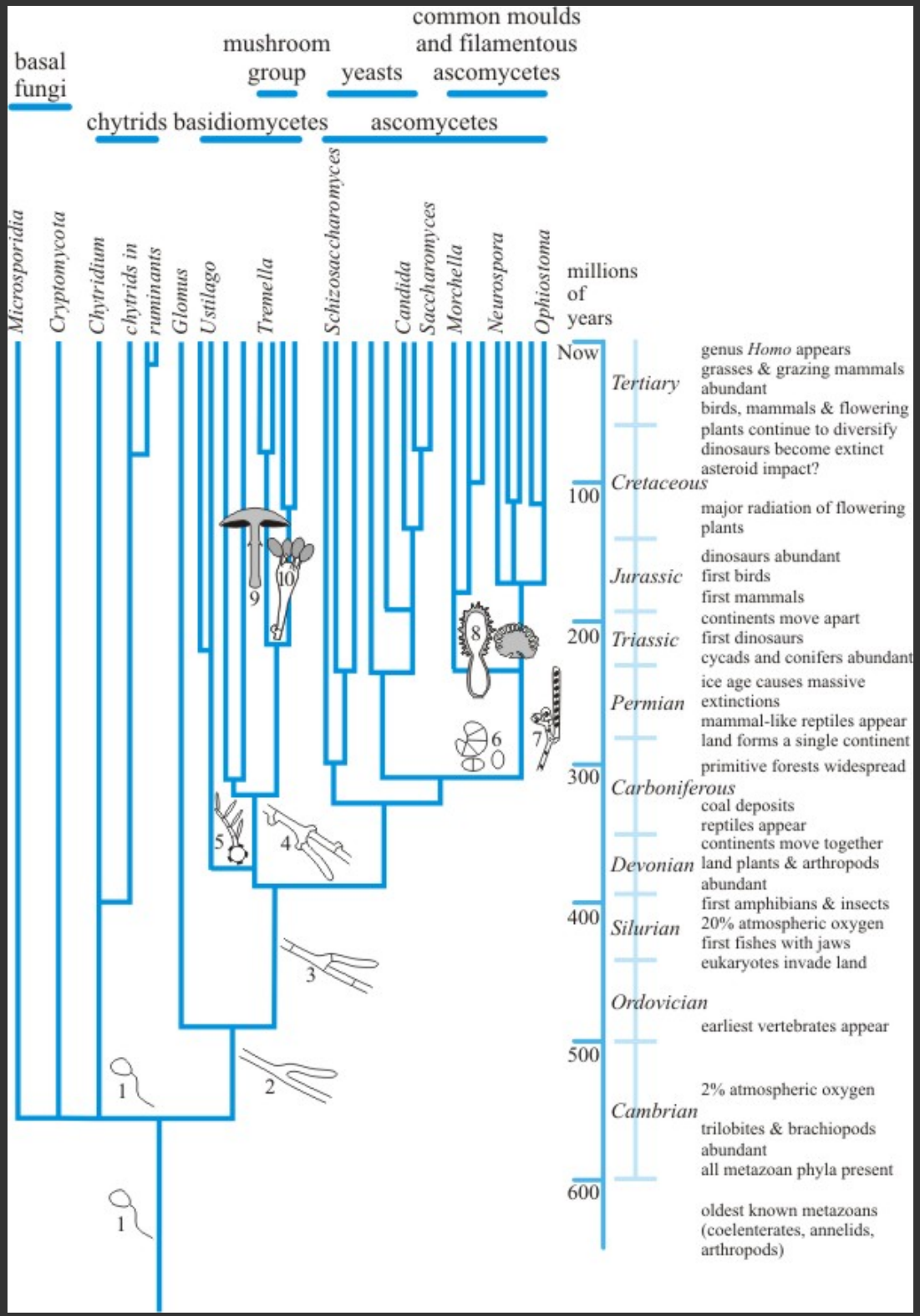
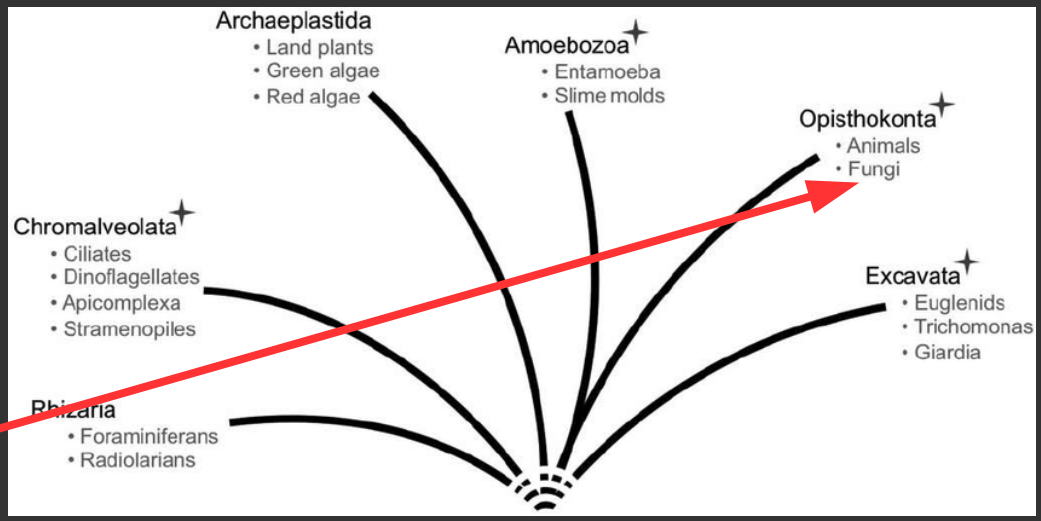
The beginnings of fungi

Topics (just the very basics):

- What are fungi?
- Evolutionary history
- Growth habits
- Physiology
- Diversity
- Chytridiomycota



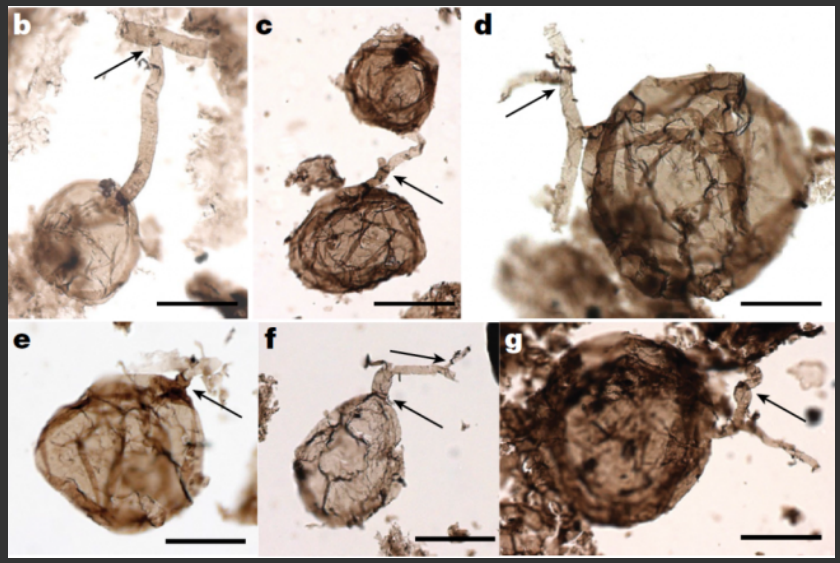
What are fungi?



The short answer is that eukaryote phylogeny over there. The long answer is this entire course!

Generally, though, fungi are closely related to animals. The most recent common ancestor (MRCA) of all fungi was single-celled, heterotrophic, flagellated, and sexual... Just like the MRCA of metazoans.

But, the ancestors of modern fungi diverged from the metazoan branch a loooong time ago (>1000 MYA).

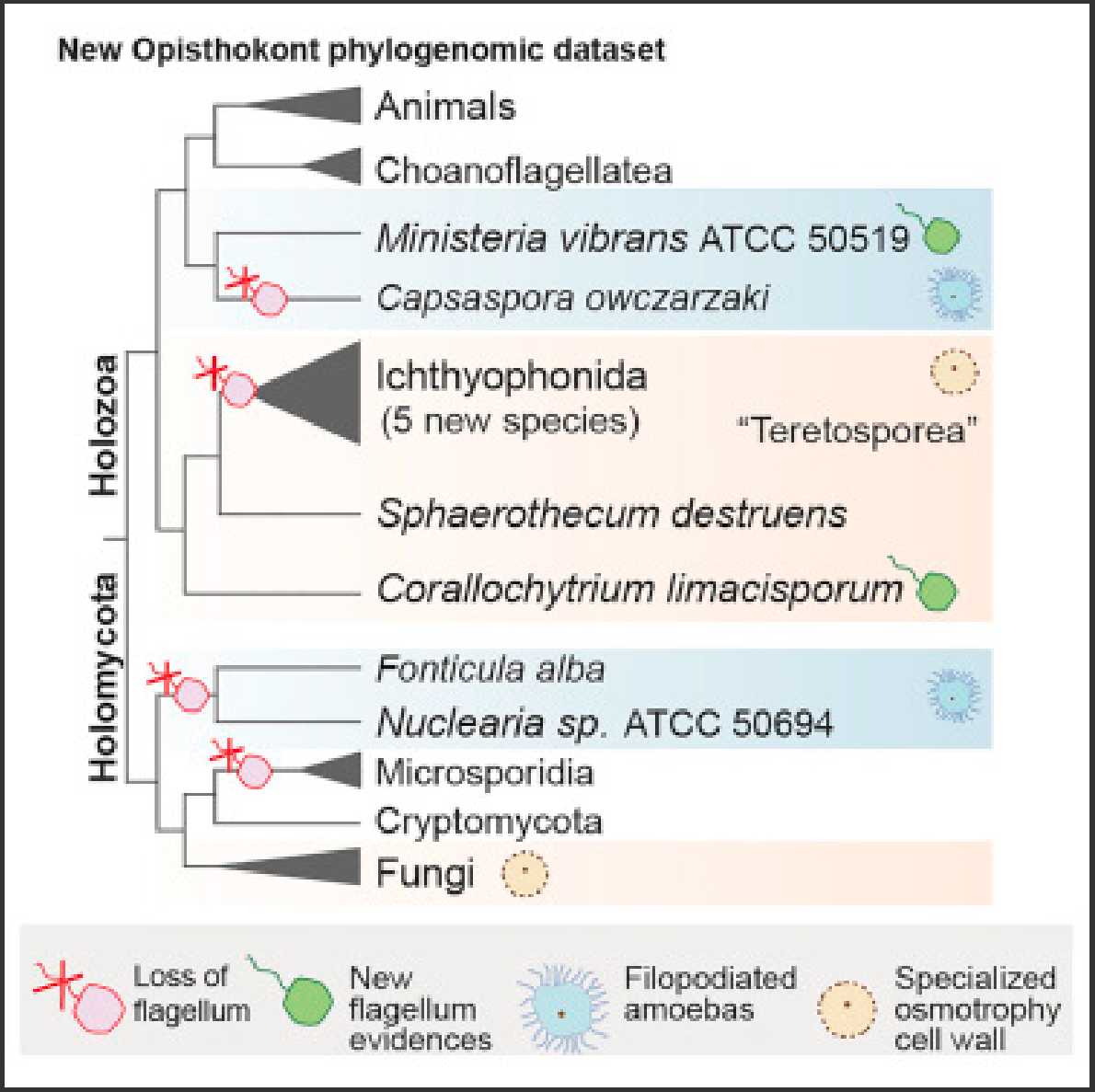


Fossil fungi from 1BYA
Credit: Loron et al. 2019 Nature

Of course, it's not as simple as just "animals and fungi" in Opisthokonta.

Phylogenomic evidence indicates that the MRCA of fungi and animals (and all the other groups shown here) had a complex suite of chitin synthase genes, and very similar flagellum genes.

This makes sense... after all, arthropods and fungi are some of the only organisms that synthesize chitin, and they do it differently than the rare bacteria that can do it.



Credit: Torruella, et al., 2015

Fungi made it to land the same time as the earliest algae

Evidence shows clearly that fungi and plants are very closely intertwined, and have been from the start.

It can be said that plants are really just algae that figured out how to live with fungi.

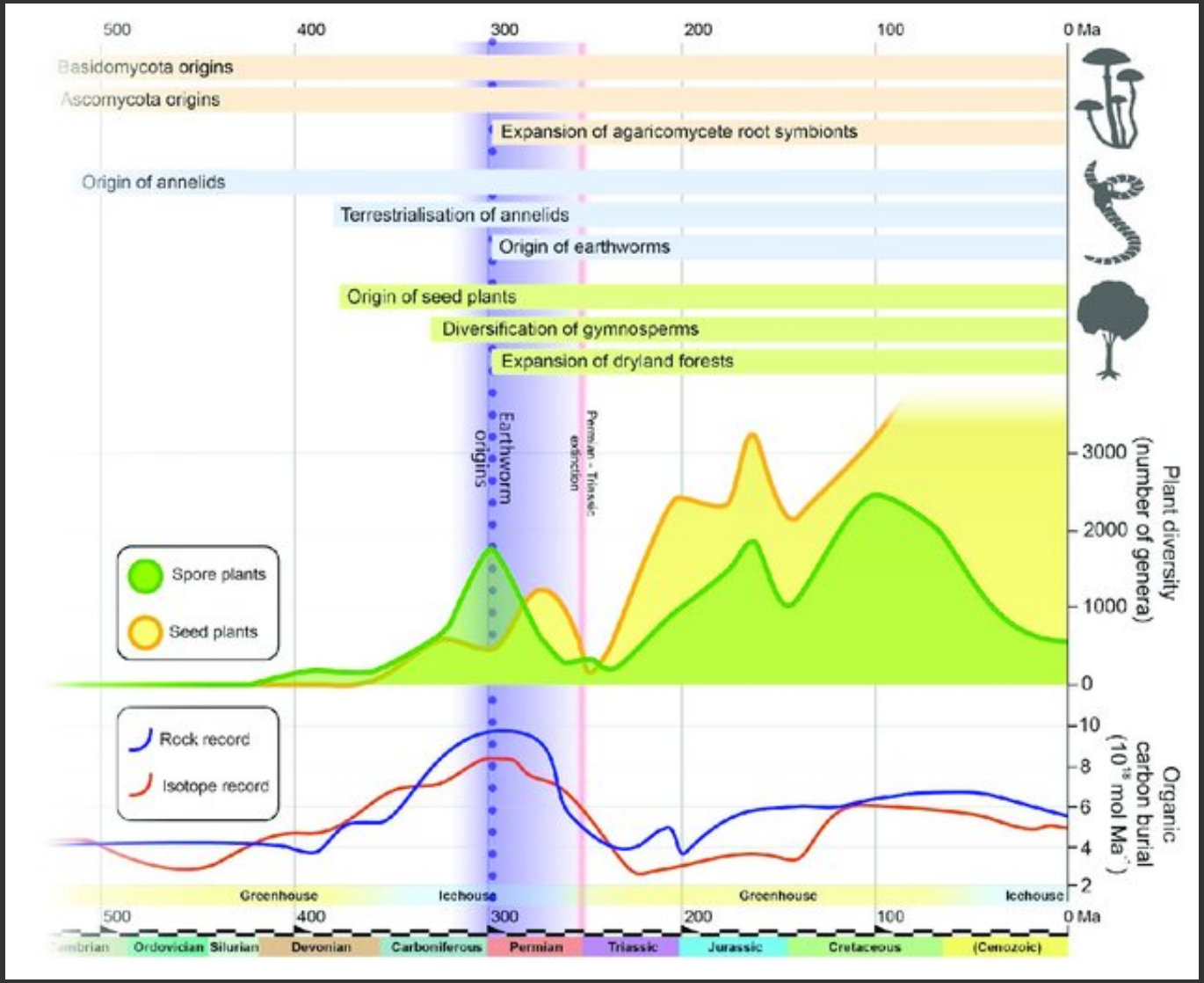


Figure credit: Alastair R Tanner

In this figure, earthworm origins are shown because that signifies that soil was fully established on land. Soil is only possible through fungal biochemical processes.

Fungi are some of the only things that can oxidize lignin, a major biomolecule in vascular plants.

Fungal fossils show a weird landscape

~420-350 MYA, the largest living things on land were *Prototaxites,* giant fungi.

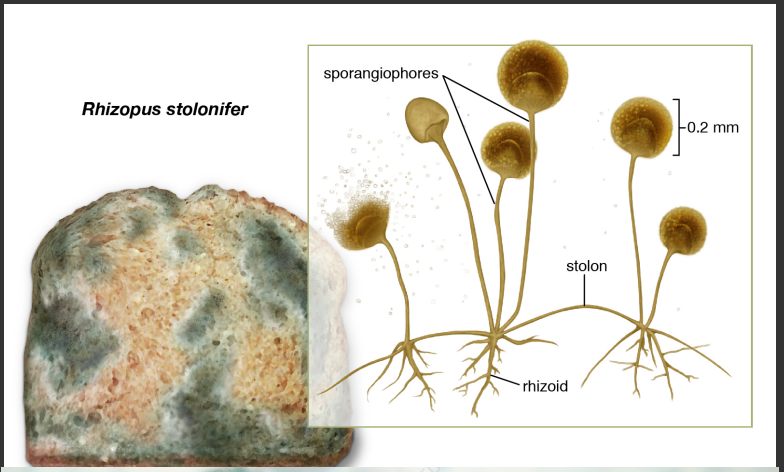
First animals on land (millipedes, etc.) were there ~500 MYA. Fungi was there too, long before, but by 450 MYA, fungi were the largest things on land.

Excavating a giant fungus fossil in Saudi Arabia
Photo credit: Francis Hueber

Growth habits

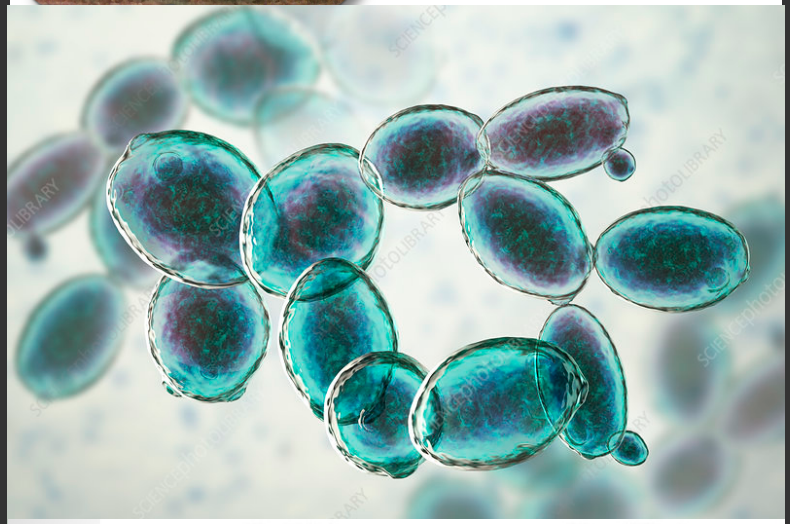
Mycelial growth

filaments known as "hyphae"



Yeast growth

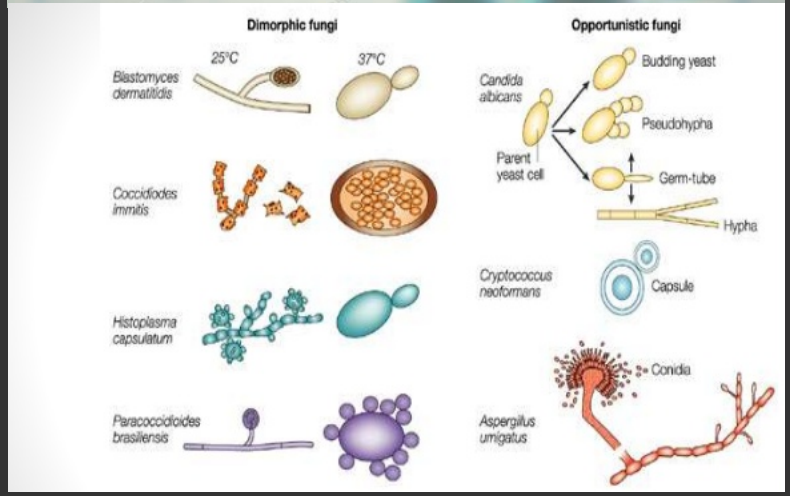
single-celled



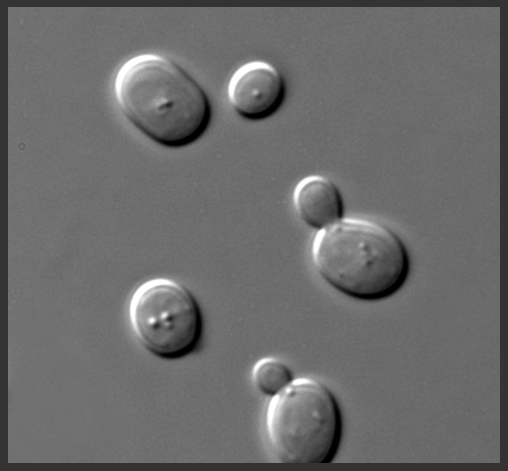
Dimorphic growth

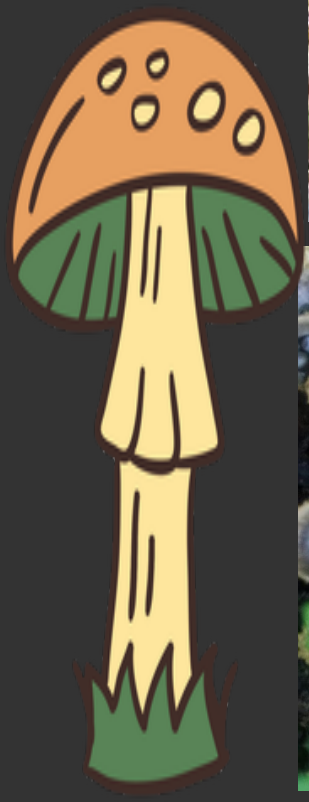
Variously hyphal or yeast-like

medically important



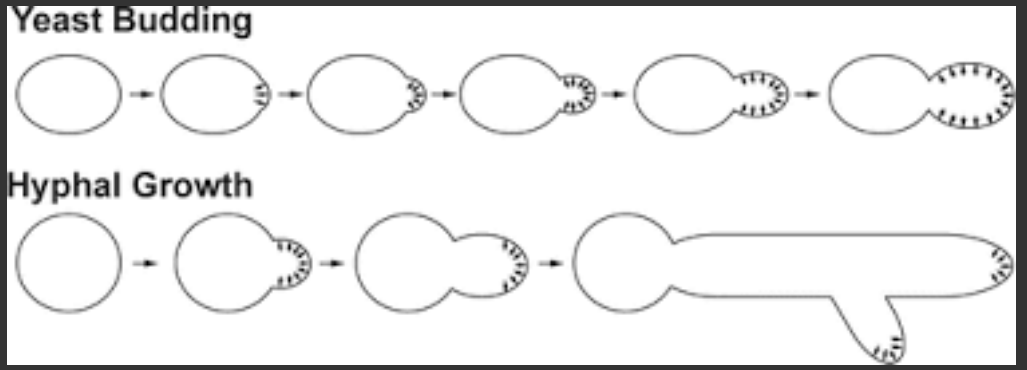
Can you name the fungal growth habits shown here?

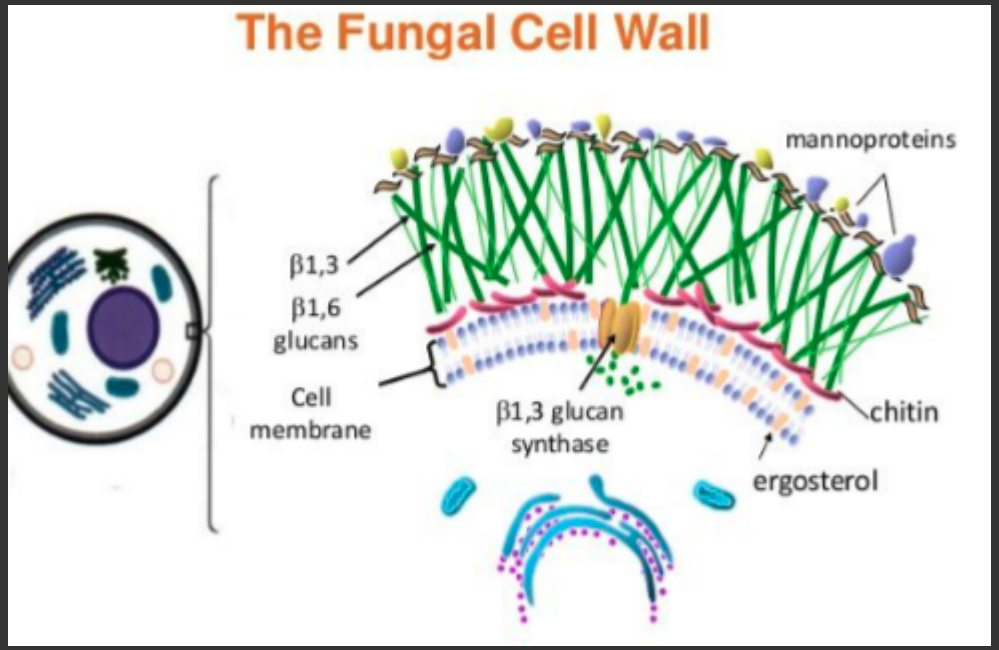


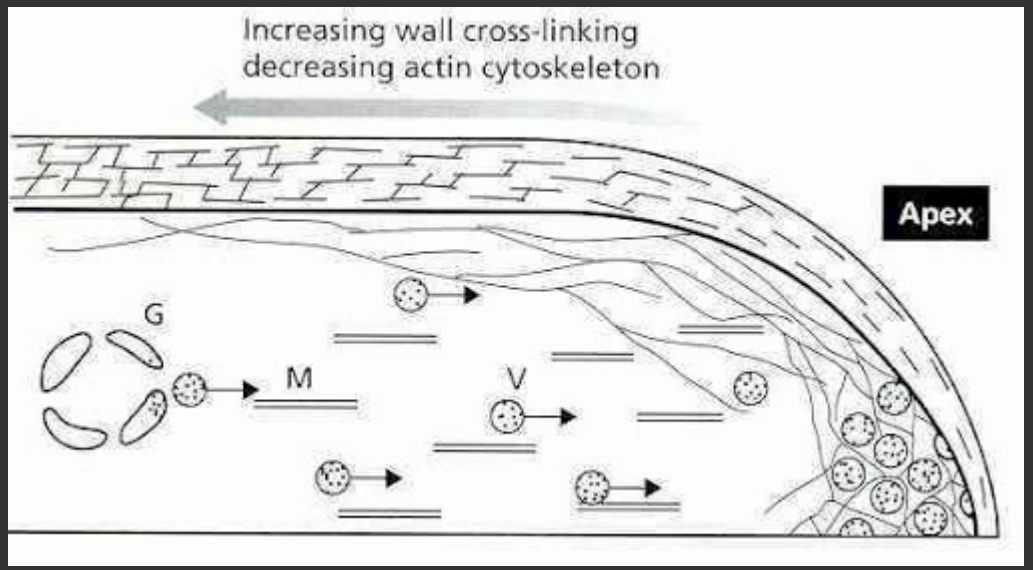


Physiology

- Cell wall is made of chitin, linked by β-glucans
- Cell membranes have ergosterols, not cholesterols
- Absorptive nutrition intake
- Tons of secondary compounds for degrading complex molecules can be excreted
-





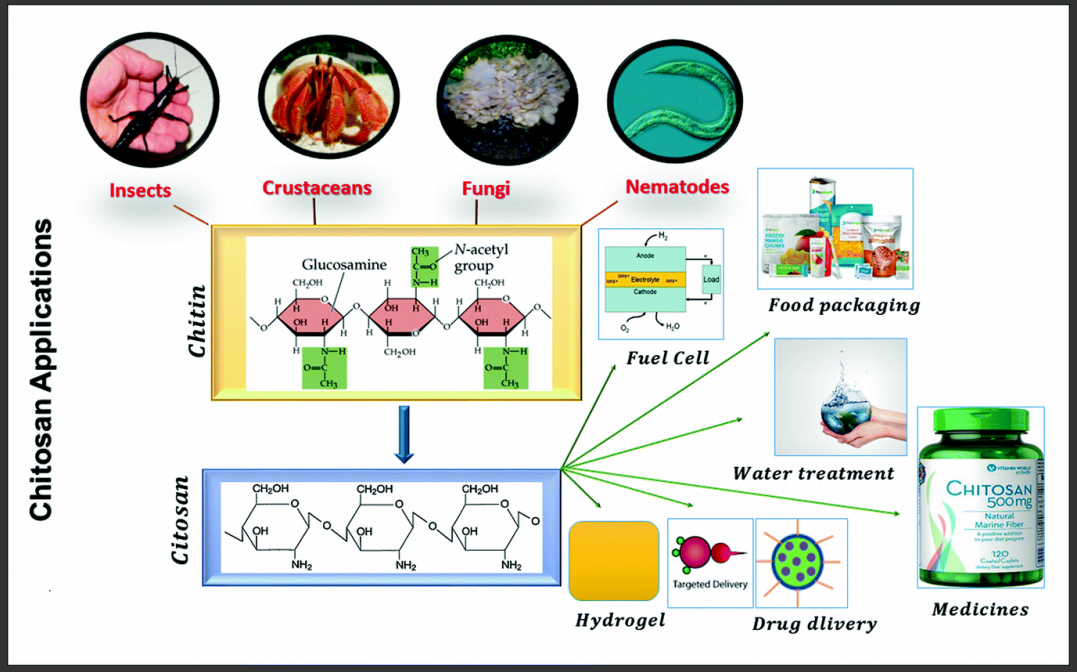


Chitin ...

It's basically cellulose, but with an acetyl-amine group replacing a hydroxyl group on each monomer

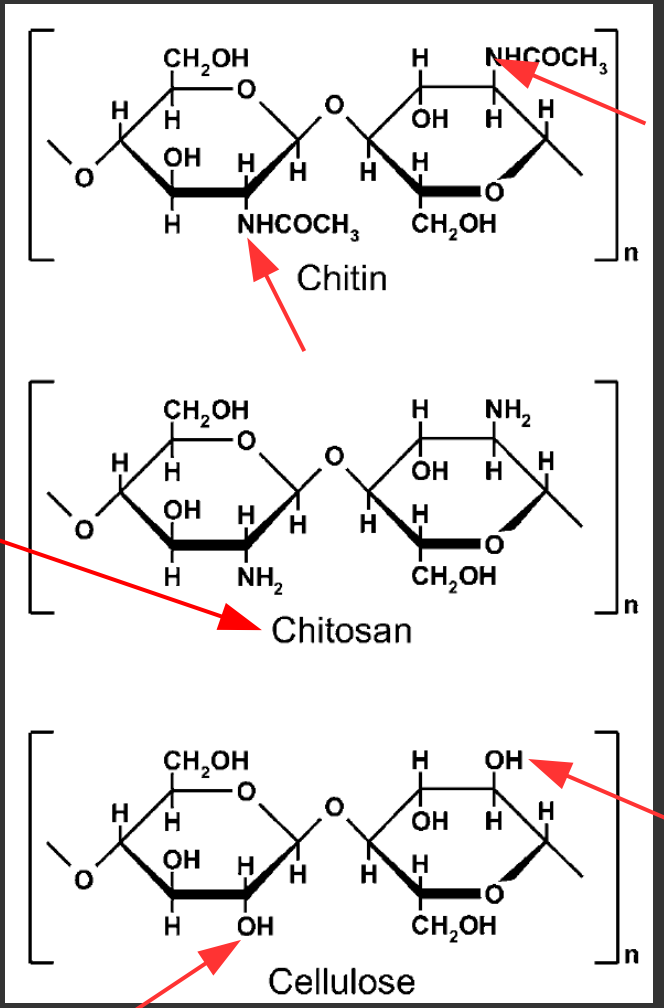
Made from modified glucose (*N*-acetyl-D-glucosamine monomers) chained together

Take out the acetyl group from chitin and you get chitosan... used extensively in biomedical applications!

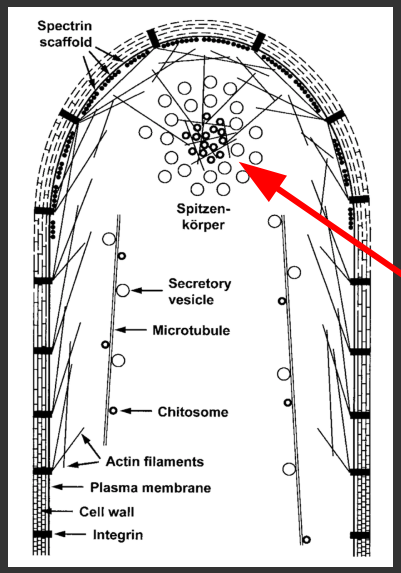


anti-microbial

but found in Zygomycetes

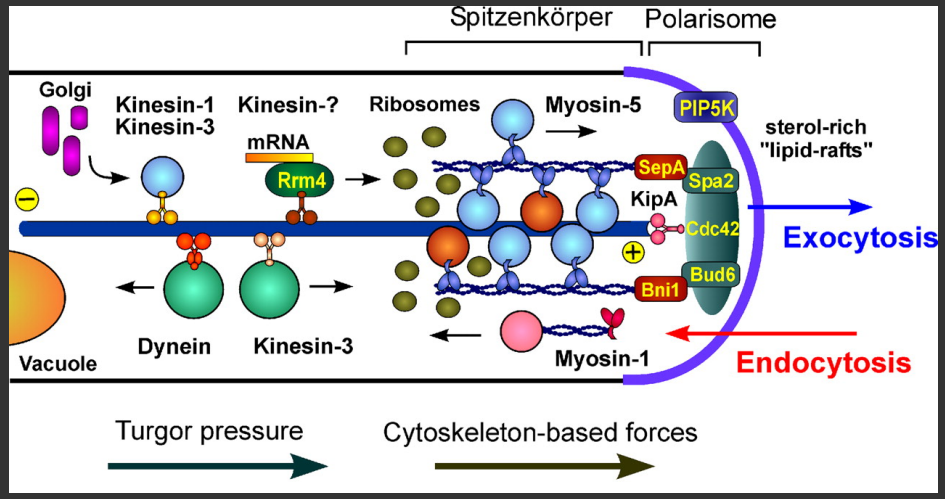


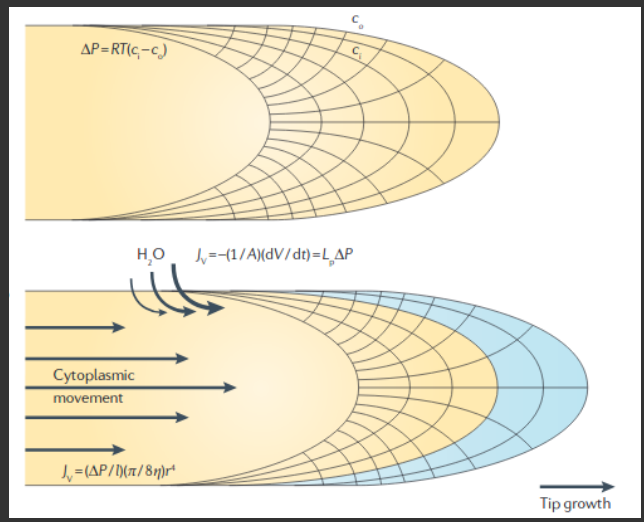
Hyphae grow from the tip (only)



Spitzenkörper: organizing center for hyphal growth;
found in germinating spores, hyphal tips, and branch points
(almost only found in Basido- and Asco-mycetes

Internal water pressure pushes on "weak point" at tip

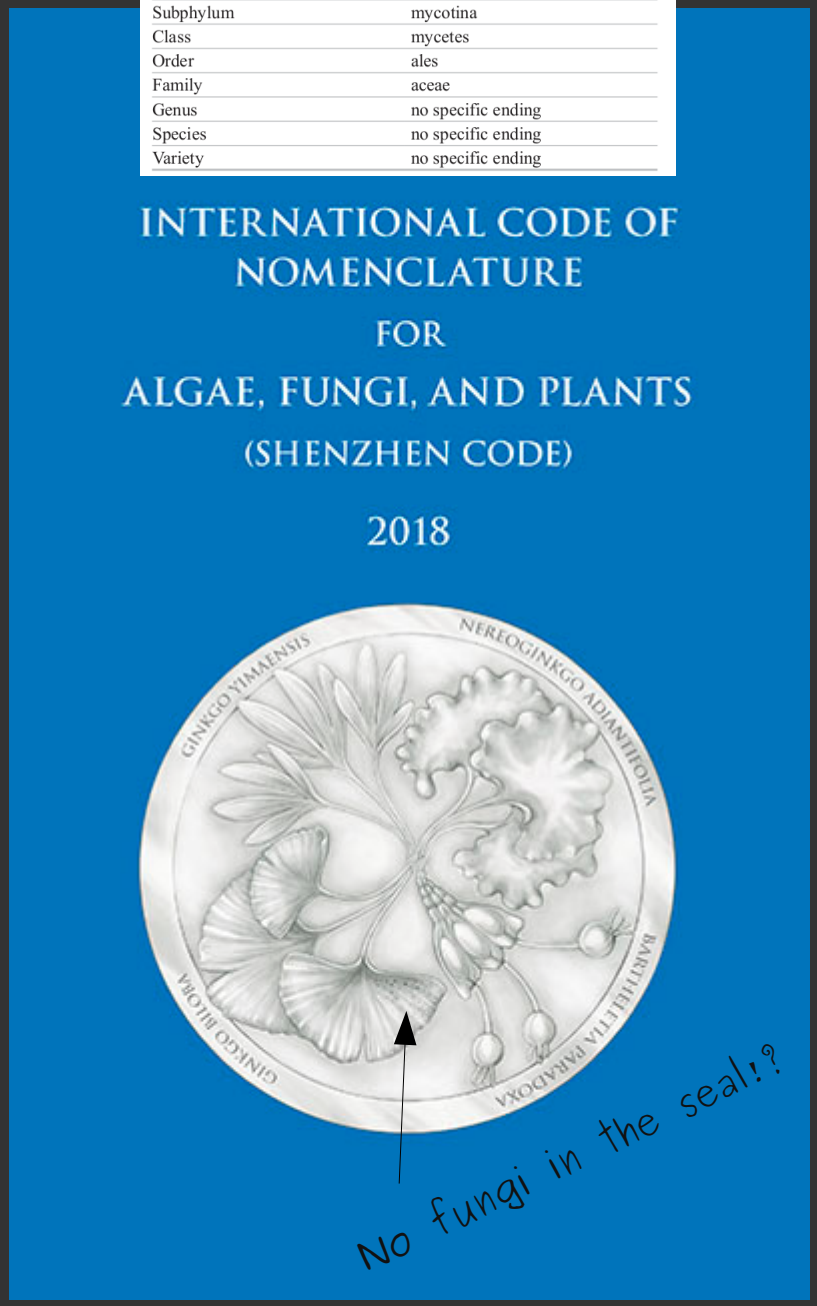




Credit: Lew, 2011

Fungal nomenclature

Group	Group Ending
Kingdom	none
Subkingdom	none
Phylum	mycota
Subphylum	mycotina
Class	mycetes
Order	ales
Family	aceae
Genus	no specific ending
Species	no specific ending
Variety	no specific ending



You'll be seeing a LOT of confusing-looking terms. But they're easy once you get used to them.

A few notes of fungal names:

myco = ancient greek root for "fungi" or "fungal"
eu = ancient greek root meaning "true" (usually implies a group is monophyletic)

-mycota (divisions or phyla)
-mycotina (subdivisions or subphyla)
-mycetes (classes)
-mycetales (orders)

Examples:

Basidiomycota = Phylum of fungi that have "basidia"
Agaricomycotina = Major group of fungi *within* basidiomycota
Eumycota = Group containing *all* of the "true fungi"

Fungi are named and classified according to strict rules made by plant scientists, since people used to think fungi were plants. Why this is still the case is a mystery.

Sometimes fungal taxonomy/naming breaks because they have different life cycles than plants.

This is allowed to happen because.... Tradition? Recalcitrance? I have no idea.

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A new dawn for the naming of fungi: impacts of decisions made in Melbourne in July 2011 on the future publication and regulation of fungal names[1]

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Abstract: A personal synopsis of the decisions made at the Nomenclature Section meeting of the International Botanical Congress in Melbourne in July 2011 is provided, with an emphasis on those which will affect the working practices of, or will otherwise be of interest to, mycologists. The topics covered include the re-naming of the *Code*, the acceptance of English as an alternative to Latin for validating diagnoses, conditions for permitting electronic publication of names, mandatory deposit of key nomenclatural information in a recognized repository for the valid publication of fungal names, the discontinuance of dual nomenclature for pleomorphic fungi, clarification of the typification of sanctioned names, and acceptability of names originally published under the zoological code. Collectively, these changes are the most fundamental to have been enacted at a single Congress since the 1950s, and herald the dawn of a new era in the practice of fungal nomenclature.

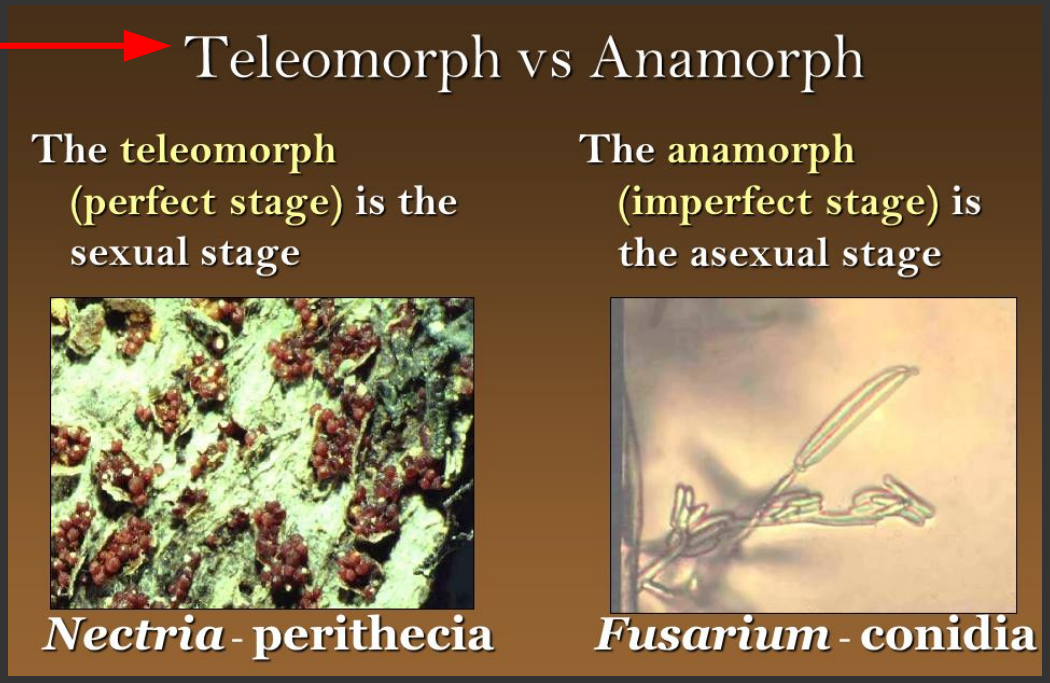
Key words:
Amsterdam Declaration
Code of Nomenclature
electronic publication
MycoBank
nomenclature
pleomorphic fungi
registration
sanctioned names
taxonomy

Article info: Submitted 12 September 2011; Accepted 20 September 2011; Published 11 November 2011.

We will cover these terms later when we look at life cycles. Suffice it to say that many fungal species currently have more than one latin name.

This is because fungi have been traditionally identified morphologically by reproductive structures... and they can reproduce sexually and asexually.

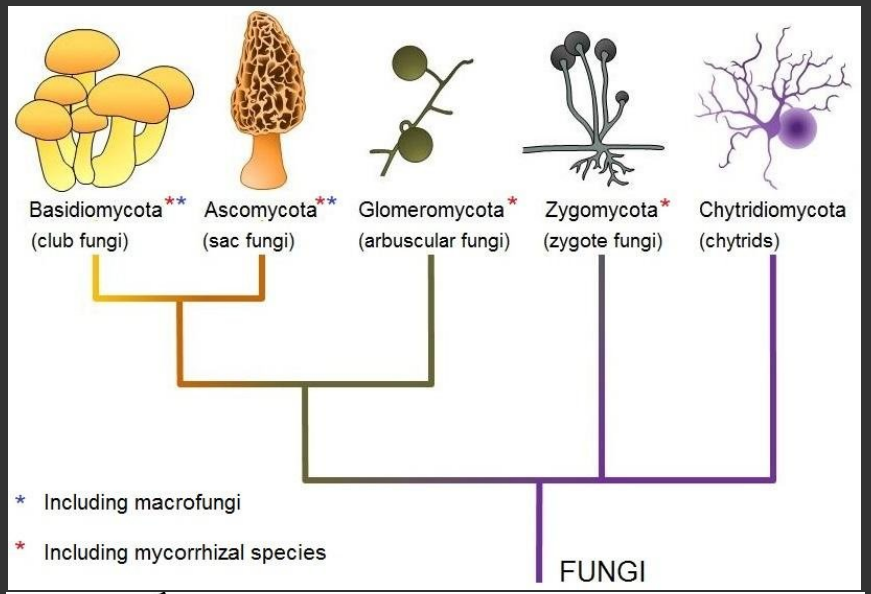
oops!



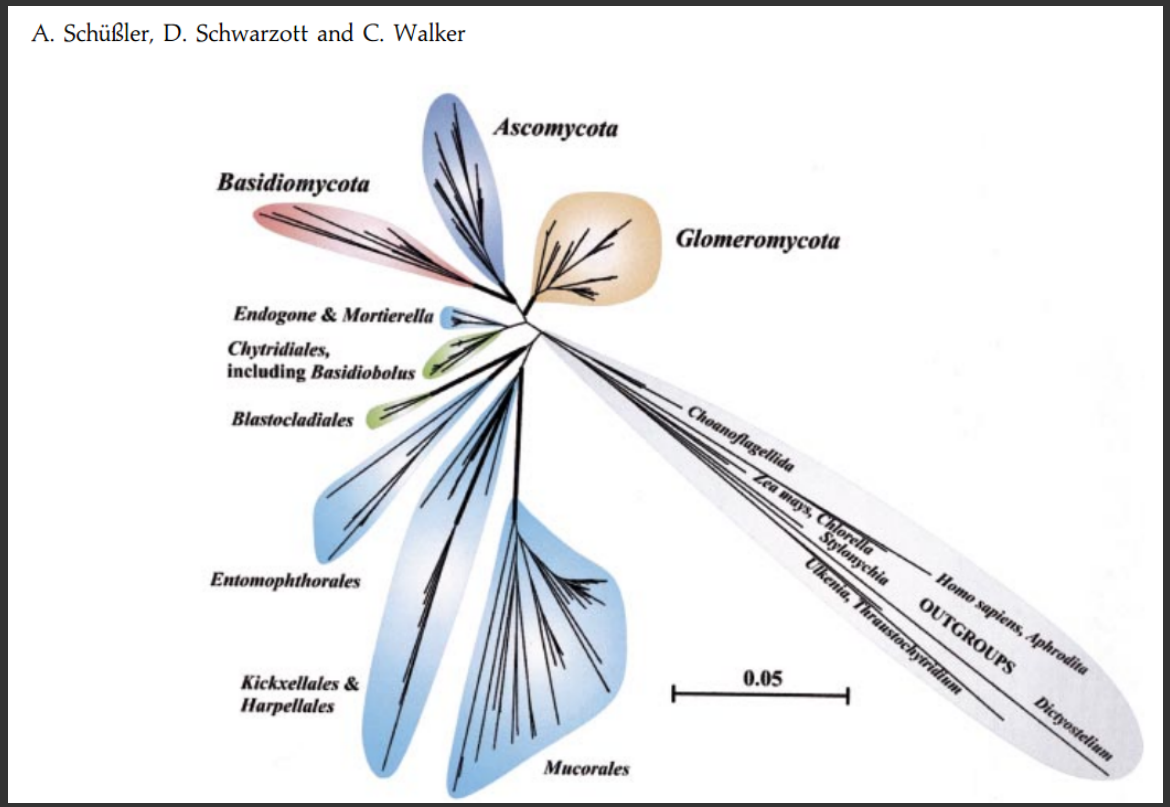
These are the same species

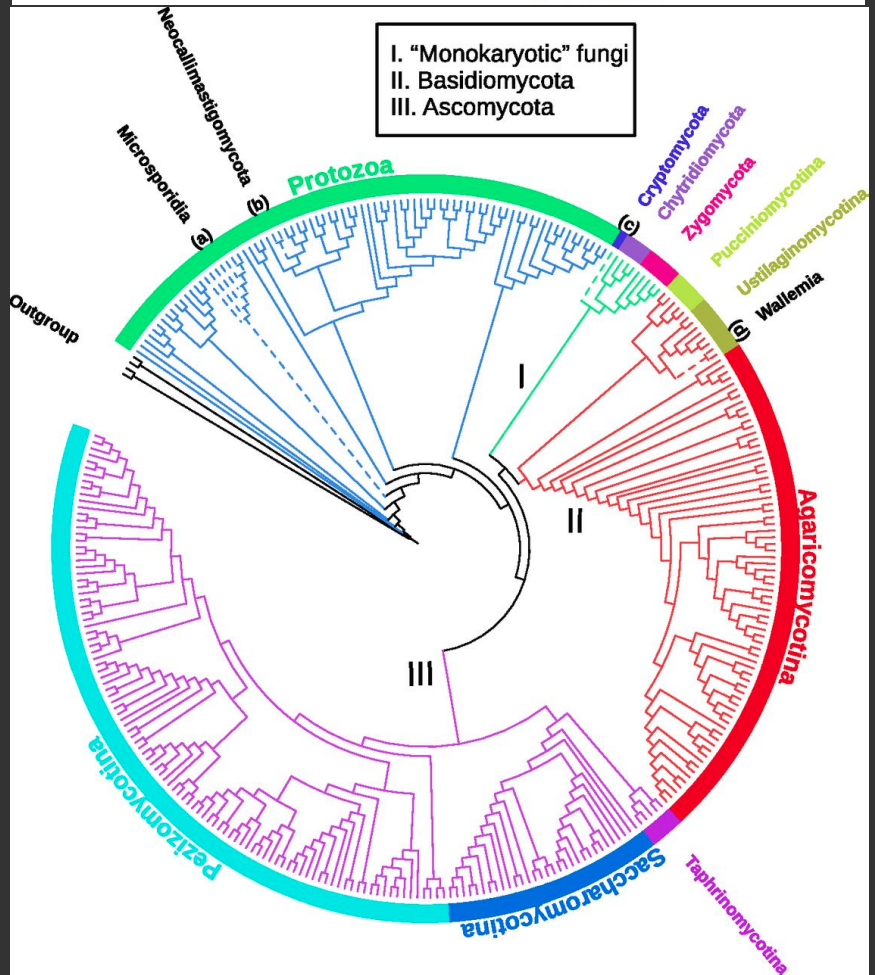
Extant eumycota groups

The cool kids call these:
- Cytrids
- Zygos
- AMFs (Glomeros)
- Ascos
- Basidios



These trees all include different groups



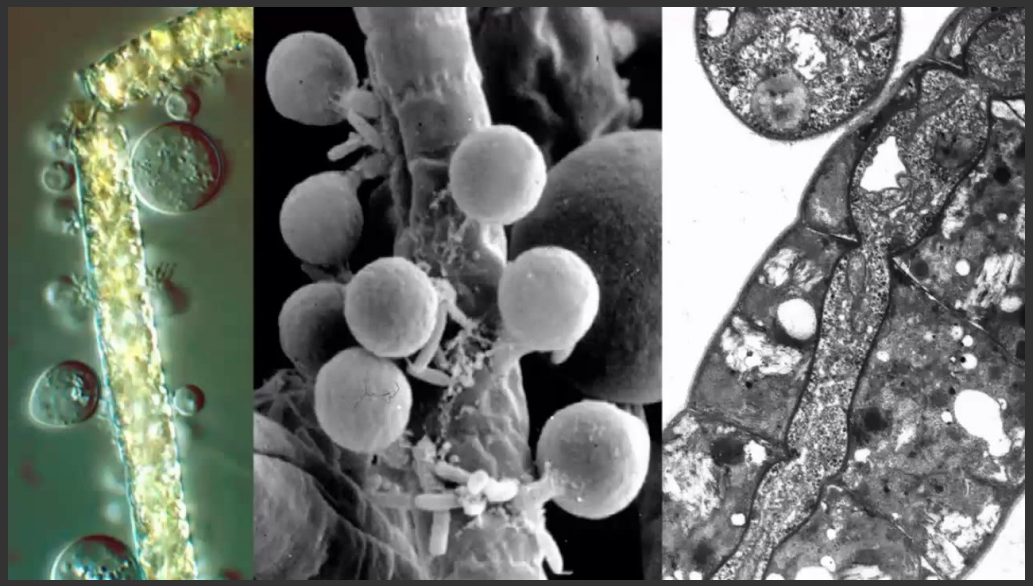


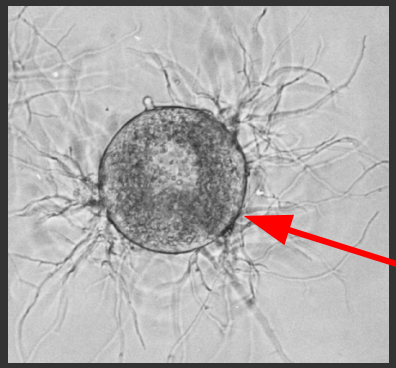
Of the extant eumycota, the earliest-diverging group is known as the Chytridiomycota.

"little pots"

You've got a nice paper to read about chytrids and the loss of the fungal flagellum. I won't repeat that material here.

"Chytrid" means "little pot," referring to the zoospore-containing structure. They are predominantly aquatic and still have opisthokont-like flagella during a life stage known as "zoospores."



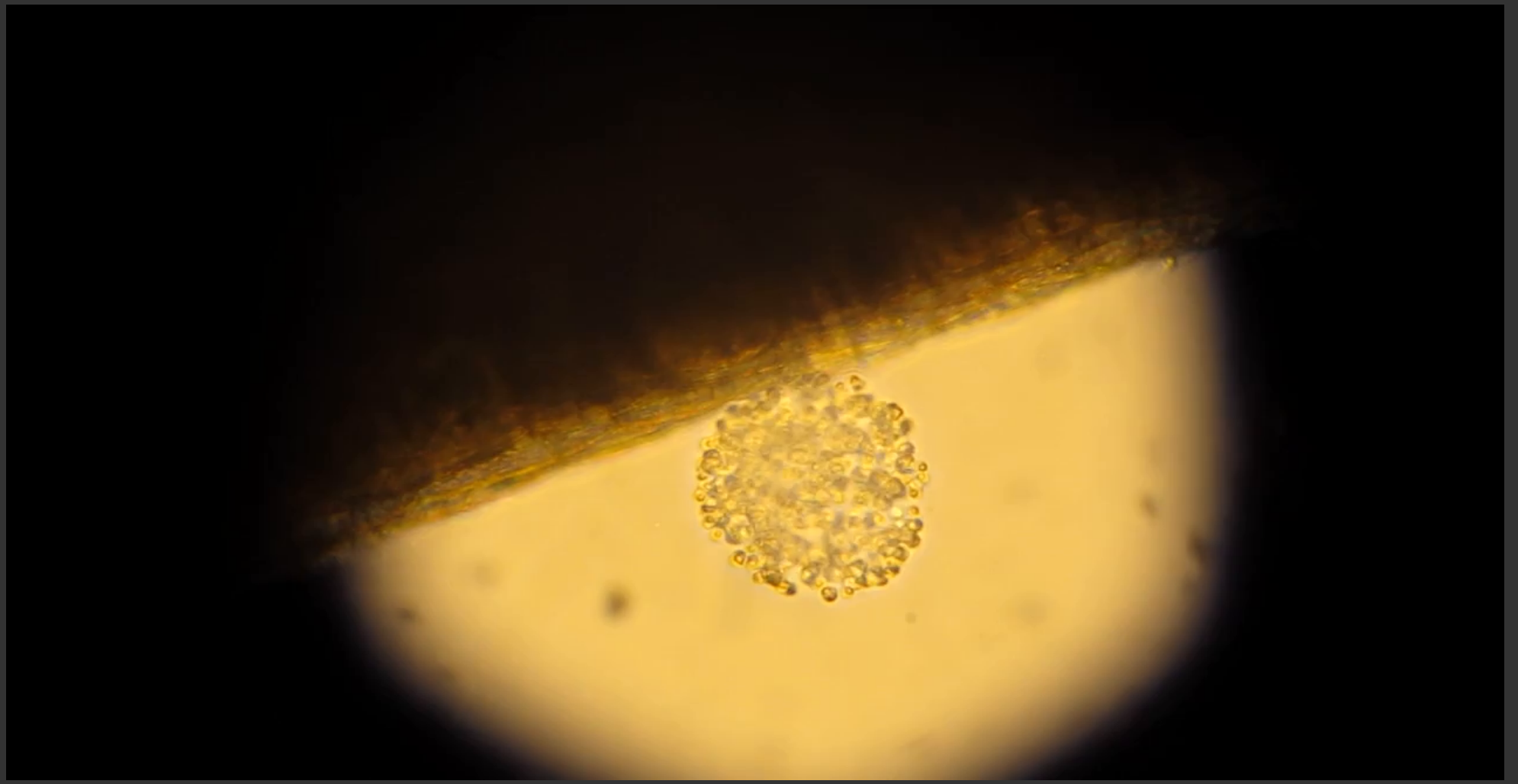


Zoosporangium of Spizellomycetales

(getting the hang of the terminology yet? No worries, you'll get used to it.)

Zoospores (pronounced: zō ▪ ō ▪ spores) being "hatched" from a chytrid zoosporangium

Chytrids are a polyphyletic group of fungi... everything with zoospores.

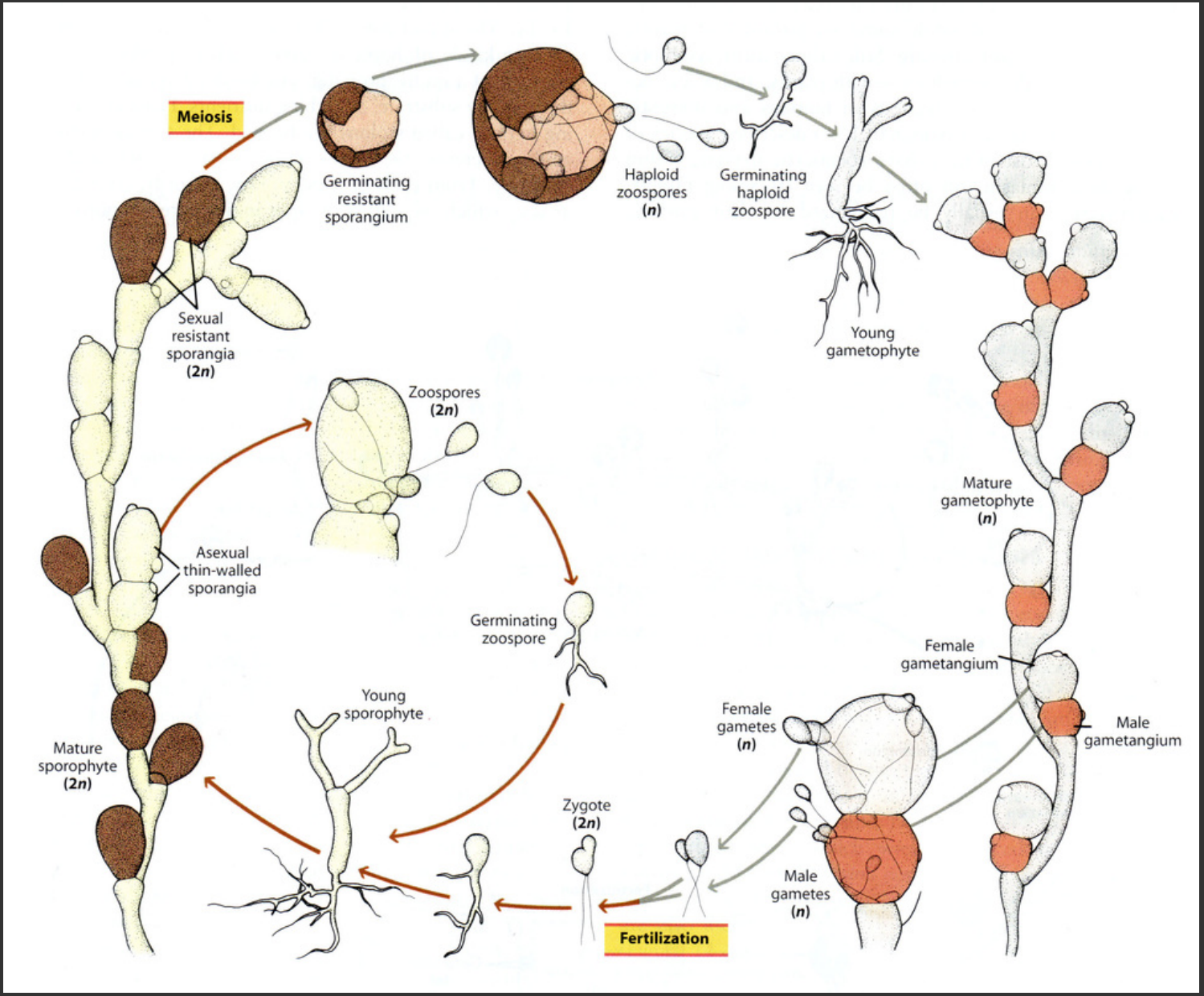


Generic Chytrid life-cycle

Note the asexual and sexual life cycles.

Zoospores can be either 2n or 1n, though in most chytrid groups they are haploid

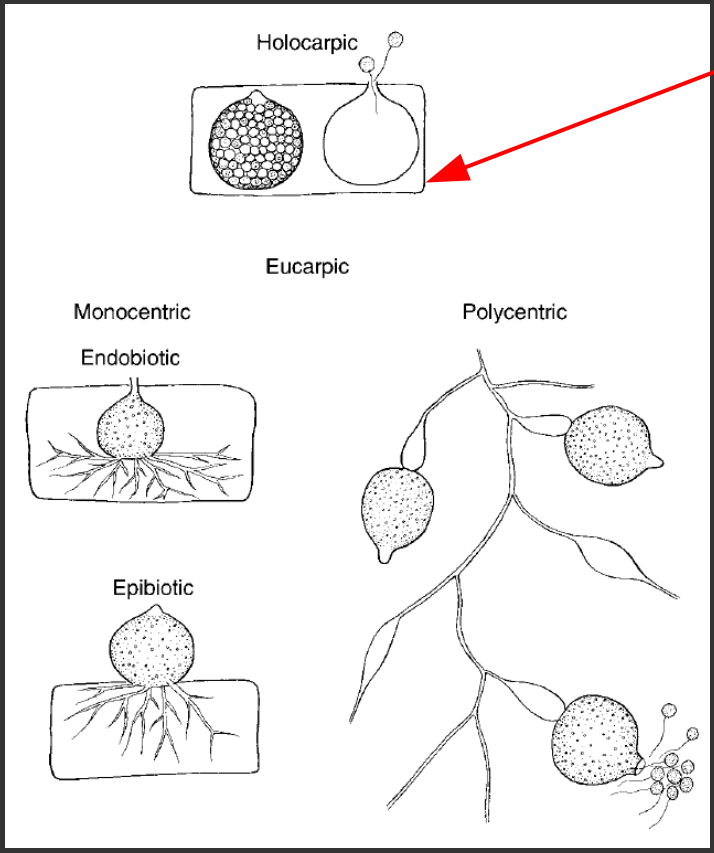
Environment often determines whether a fungus undergoes meiosis

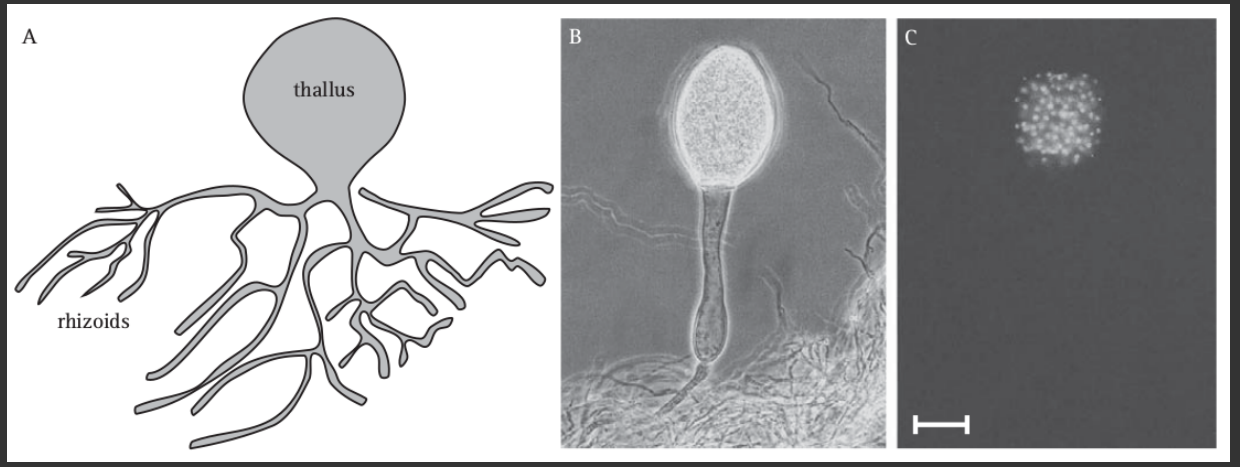


Allomyces *sp.*, a group of chytrid fungi depicted here. Note the botanical terms like "gametangium."

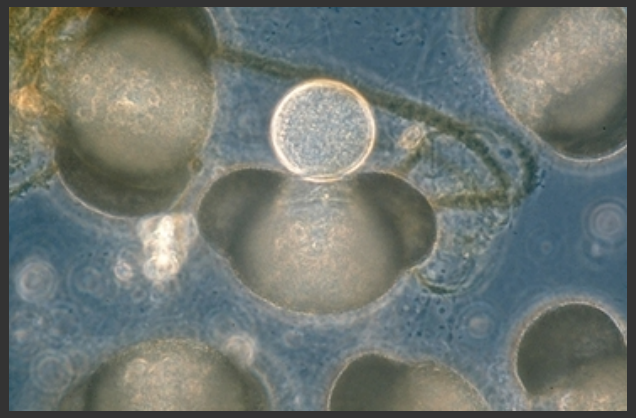
General morphology of chytrids

Shown parasitizing an algal cell





Chytrid ecological modes



eating pine pollen

eating algae

eating something

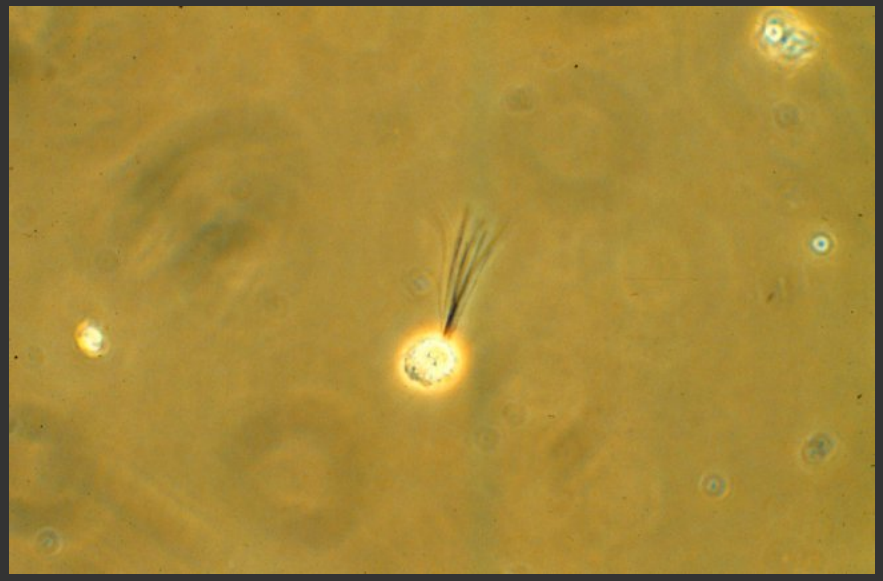
Chytridiomycosis: chytrids are wiping out entire amplibian populations around the world!

Chytrids have lots of ecological modes:

Saptrotrophs - eat dead stuff
Biotrophs - require living tissue to parasitize
Necrotrophs - kill stuff and then eat it

Even some obligate anaerobes (Neocallimastigales)

See Webster & Weber chapter 6 for an overview of how truly biochemically diverse chytrids are



This is *Neocallimastix,* a chytrid that lives in ruminant guts. It's the reason cows can digest grass, and you can eat cheeseburgers. It's got funky multi-flagellate zoospores and is an obligate anaerobe.

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

Evolution - Polyphyletic, early-diverging group; split from rest of fungi before the Cambrian radiation

Morphology - Have primitive hyphae, flagellated spores, can do both sexual and asexual reproduction,

Physiology - Cell walls and membranes resemble other extant fungi; simpler "hyphae"; contain many highly complex secondary compounds and excretory proteins; can digest a wide range of materials

Diversity - Represent at least 1000 species (possibly many many more). Many "species" are actually cryptic species complexes that are difficult to study.

Ecology - Examples include important plant pathogens and devastating animal parasites; Facultative and obligate anaerobes; Most are obligate aerobes

Table 6.1. Orders of Chytridiomycota following D. J. S. Barr (2001) and Kirk *et al.* (2001).

Order	Number of described taxa	Examples
Chytridiales (see Section 6.2)	80 genera 600 spp.	*Cladochytrium*, *Nowakowskiella*, *Rhizophydium*, *Synchytrium*
Spizellomycetales (see Section 6.3)	13 genera 86 spp.	*Olpidium*, *Rhizophlyctis*
Neocallimastigales (see Section 6.4)	5 genera 16 spp.	*Anaeromyces*, *Caecomyces*, *Neocallimastix*, *Orpinomyces*, *Piromyces*
Blastocladiales (see Section 6.5)	14 genera 179 spp.	*Allomyces*, *Blastocladiella*, *Coelomomyces*, *Physoderma*
Monoblepharidales (see Section 6.6)	4 genera 19 spp.	*Gonapodya*, *Monoblepharella*, *Monoblepharis*

Credit: Webster & Weber

Assignments

1. Read Webster & Weber, sections: 1.1, 1.5, and 6.1
   - These cover an introduction to fungi and their classification, and then an introduction to chytrids

2. Read the James, et al., paper (link on course website)
   - This paper looks at the early evolution of fungi with a focus on how only a few fungi now have flagellae
   - It also gives a nice detailed phylogeny of all known fungal groups
   - This will help you think like an evolutionary biologist

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 also need to order "Mr. Bloomfield's Orchard." We will be reading that together during the second half of the course. Might as well get it now.

5. Finally, you will need to start isolating zygomycete fungi. You'll need a plastic bag and some bread (without a ton of preservatives). Details on Canvas. This will be due next week, but it takes up to a week to work.