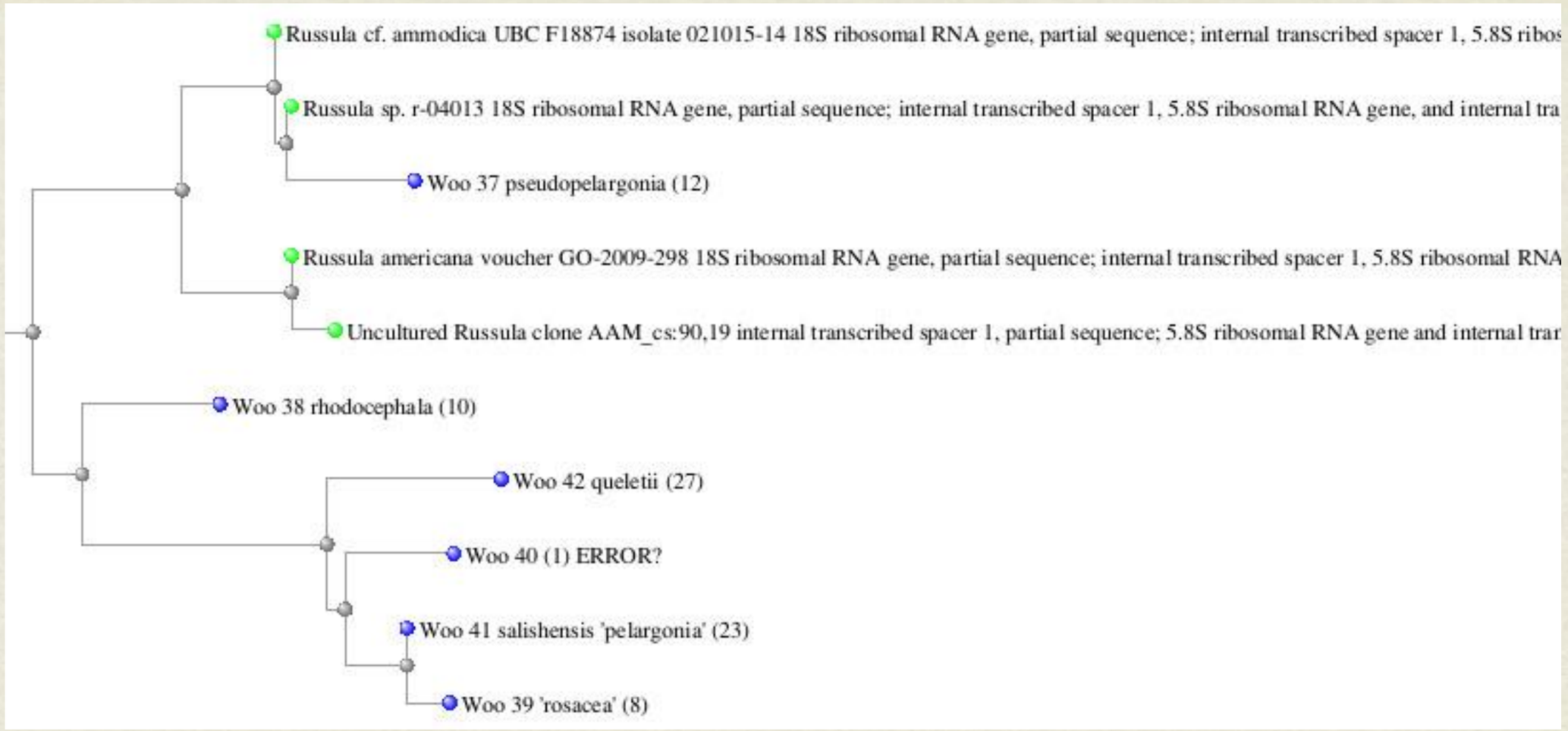
2025 WA Botanical Symposium

DNA: The Secret History of Mushrooms

Danny Miller Mar. 5, 2025

Humans love to classify things…



Just knowing the thousands of different organisms in the world was never enough.

Since the dawn of time, we've made diagrams like this tree to guess at how they might be related to each other.

1. In the beginning, all you could do was assume that related things looked similar.

Elias Fries
Systema Mycologicum
(1821-1832)

Agaricus – has gills

Boletus – has pores

Decided to group them by their most obvious differences

1) what was under the cap

Some tough decisions had to be made

Agaricus
- gills
- soft
- often terrestrial

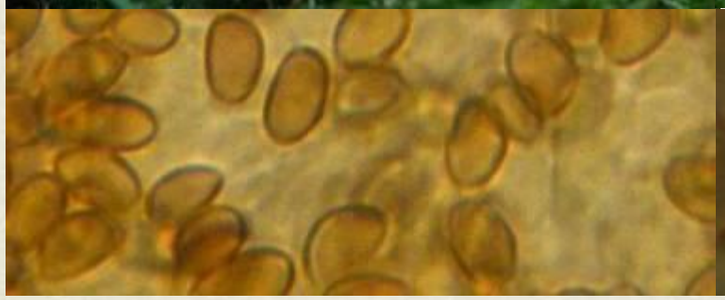
???
- gills
- hard
- on wood

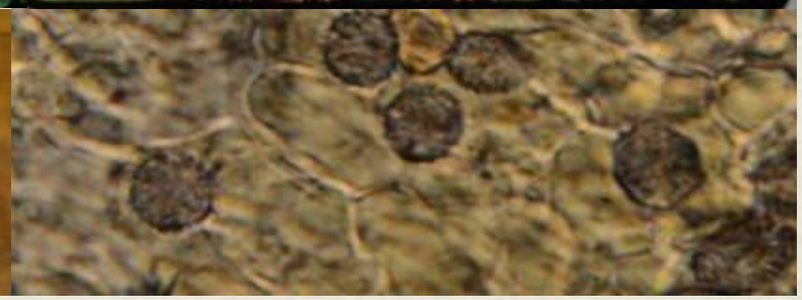
Polyporus
- pores
- hard
- often on wood

The rules said “Agaricus”. But nobody knew for sure.

2. The invention of the microscope shook things up





Most gilled spores are elliptical, with other tissues being long and stringy.

Russulas have round spores with “black” warts and other tissues are round!

What was invisibly small could be more important than any obvious difference.

2. The invention of the microscope shook things up

Boletes have long narrow spores.

But so does this gilled mushroom!

It is really a ‘bolete’… and Russula is a third thing altogether!

And so every mushroom was classified.

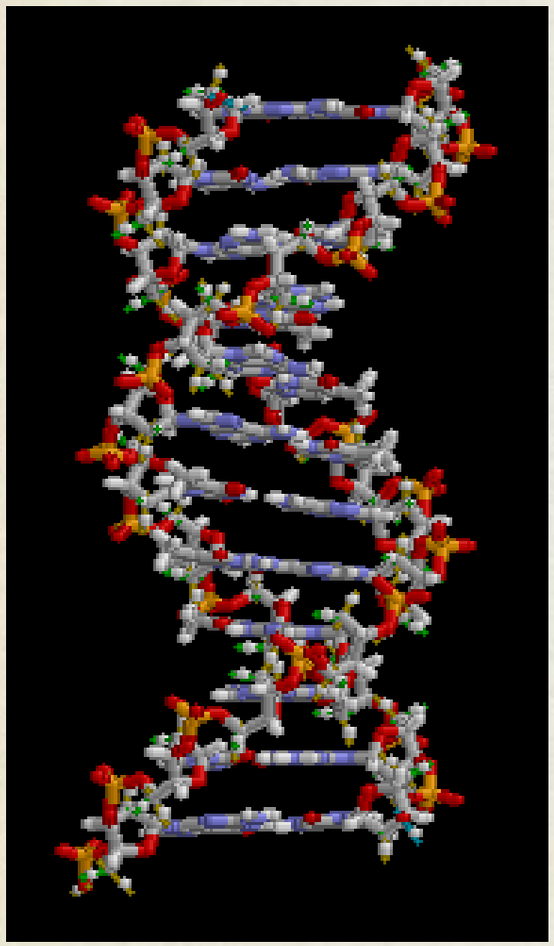
They relaxed the rules if the microscope showed that similar looking mushrooms were probably very different, and vice versa.

But did they get it right?

Is there even any such thing as the right answer?

Isn’t it all just a matter of opinion?

DNA – the “real” answer

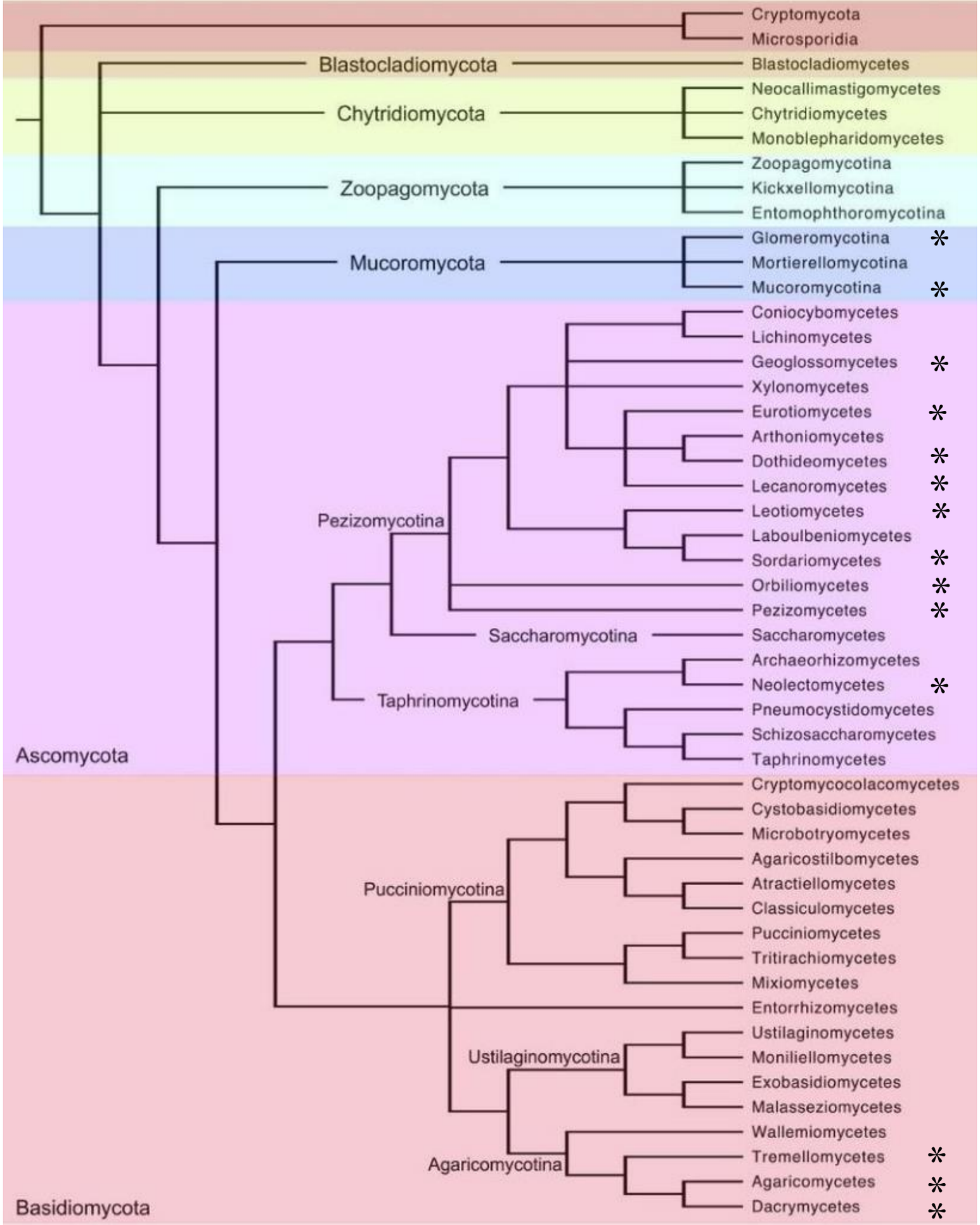


It has been officially decided that if you are related, you are ‘related’.

If two mushrooms share the same g-g-g-g-g-g-g-grandparent, they are more closely related than those that don’t.

This probably has the most meaning. These related mushrooms may share important toxins, ecology and habitat.

Some Phyla and Classes of Kingdom Fungi

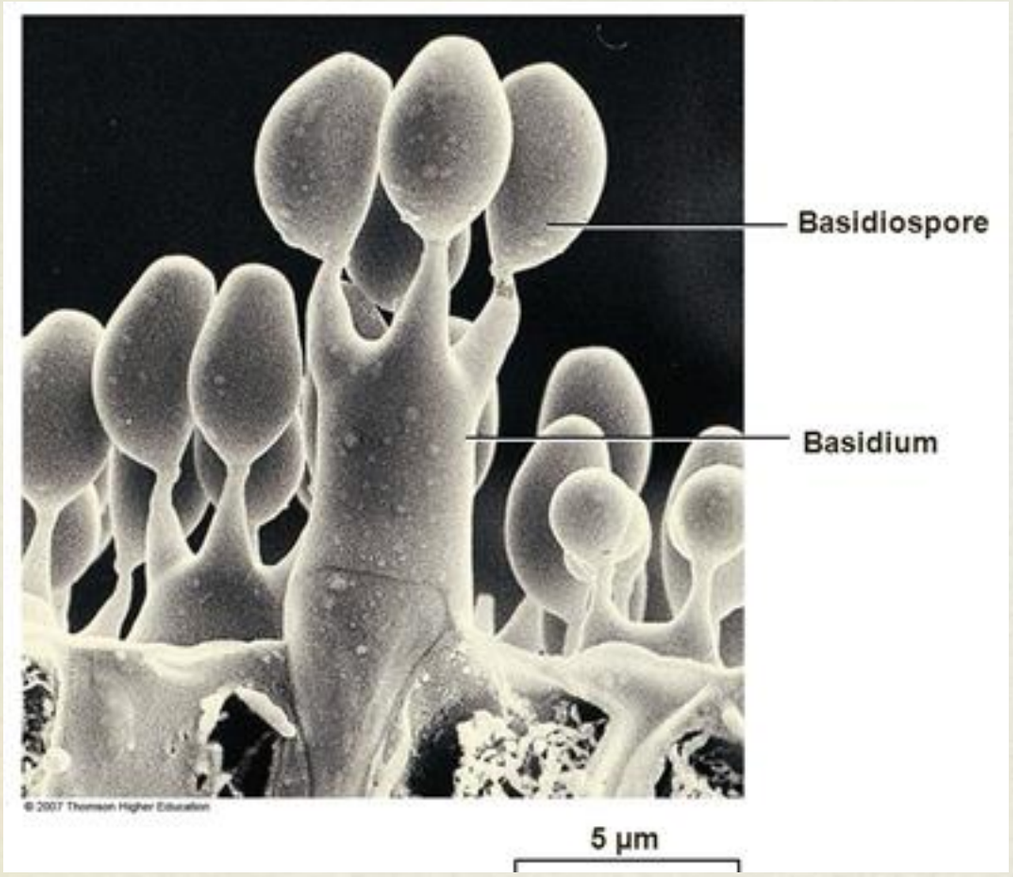


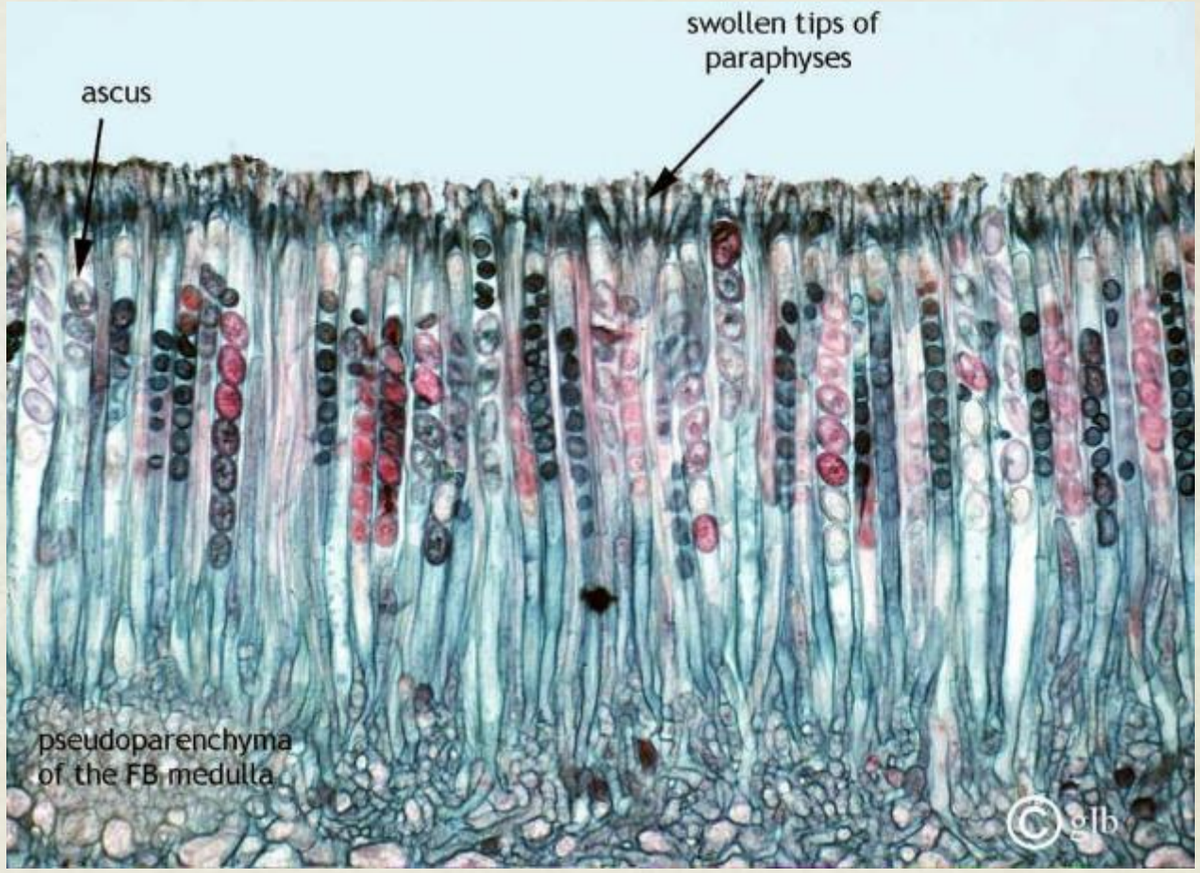
*=macro

Ascos

Basidios

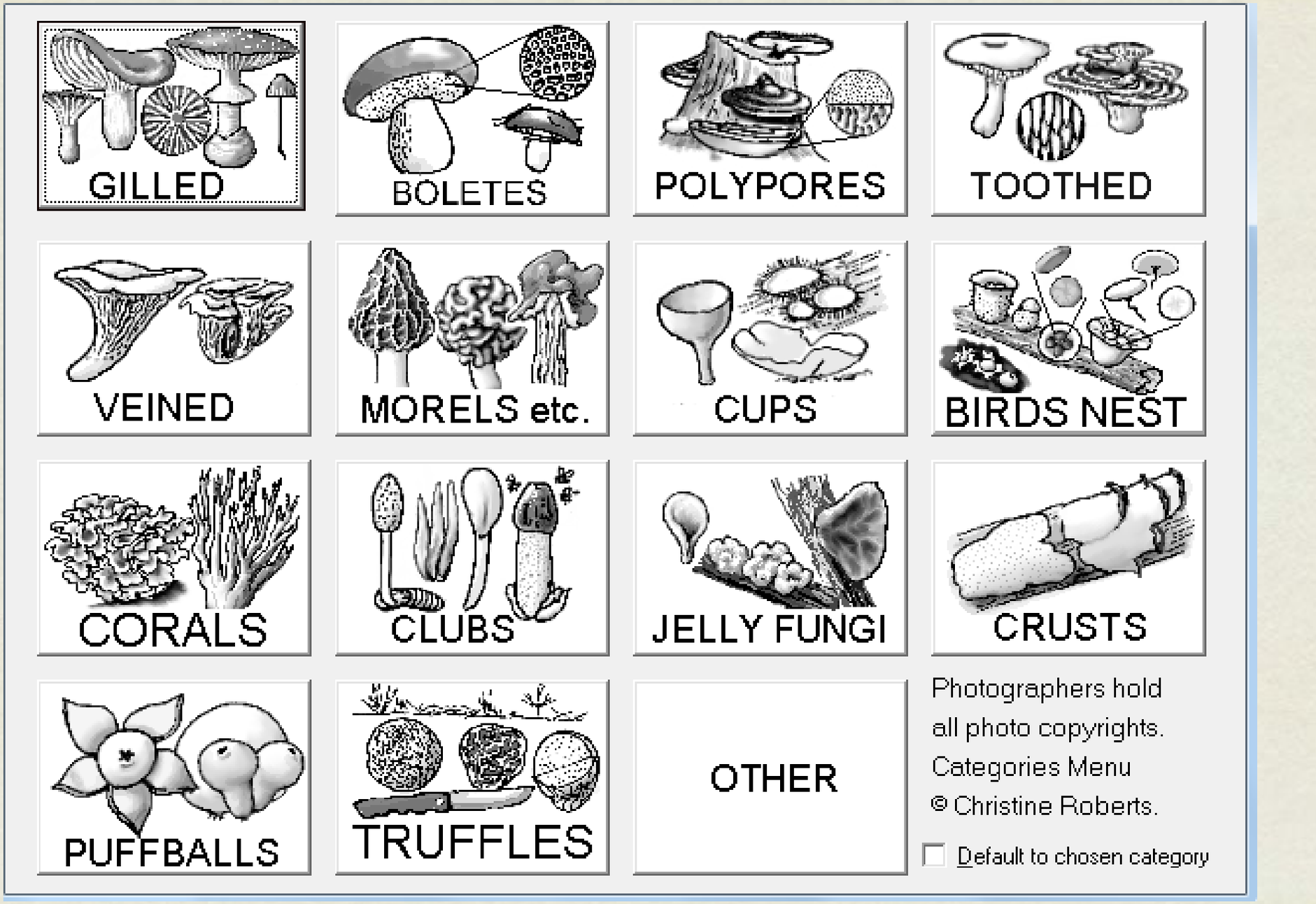
Most are Basidiomycota (“Basidios”) or Ascomycota (“Ascos”)

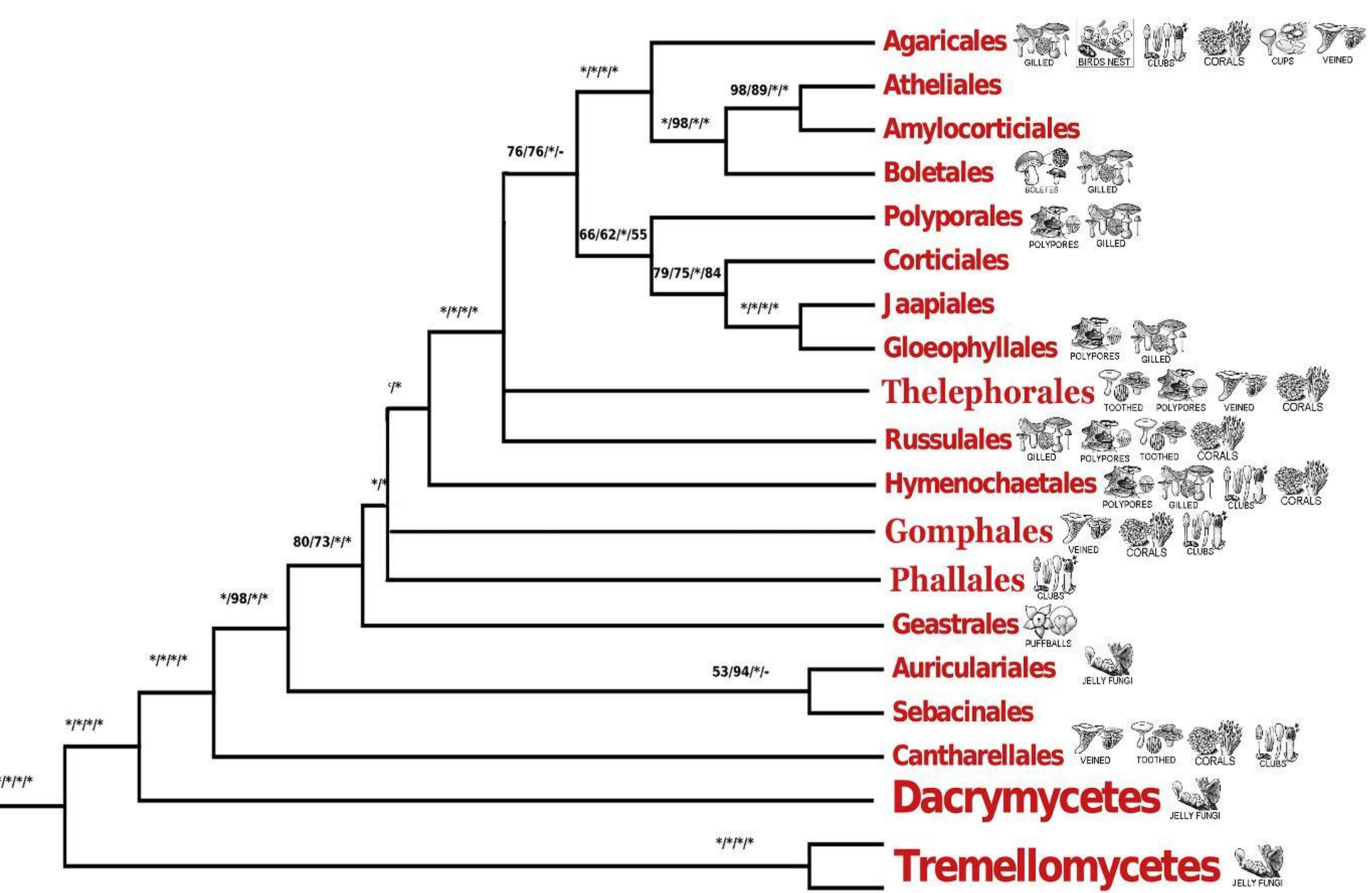




These structures are only found in the sexual stage

So many different macro kinds!!!





“Macro Basidios”

The Evolution of Basidios

Some theories and examples

Crusts

Textured, coherent

“Basal” Found Everywhere in the Tree

Wrinkled and Reflexed Crusts

To make more spores
To help them travel further

Stems help with this too

Crusts – almost every family has some (basal)

Identification often to be despaired of.

Gomphales


VEINED


CORALS


CLUBS

Phallales


CLUBS

Geastrales

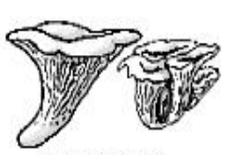

PUFFBALLS

Auriculariales


JELLY FUNGI

Sebacinales

Cantharellales


VEINED


TOOTHED


CORALS


CLUBS

Dacrymycetes


JELLY FUNGI

Tremellomycetes


JELLY FUNGI

Naematelia

Phaeotremella

Stereum

Naematelia

Jelly Parasites

A good short term but not long term strategy

Tremellomycetes

Basidia

- Basidia divided into two types depending on whether they are septate
- Septate basidia – phragmobasidia
  - Septa can be transverse or longitudinal
- Aseptate basidia - holobasidia

Long sterigmata protrude from the jelly

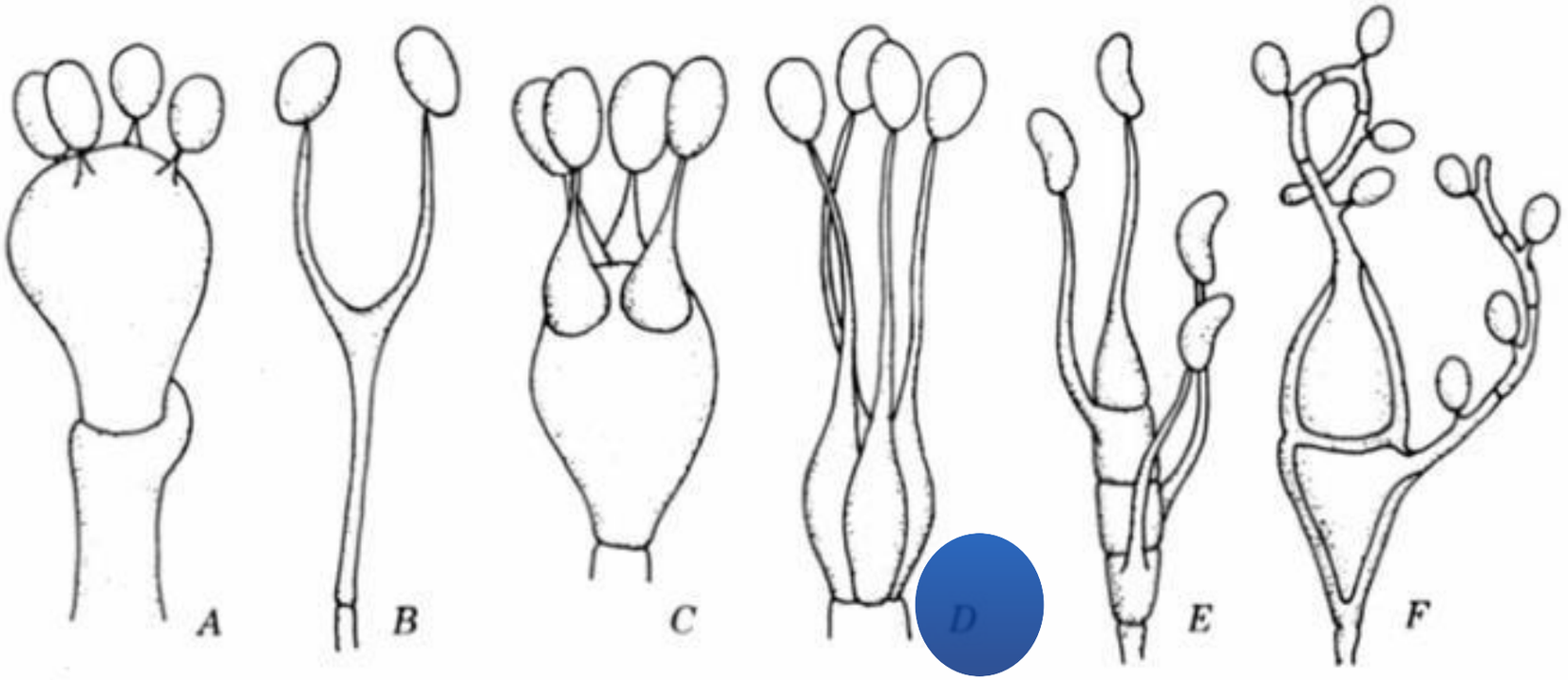


Figure 20-7. **Diagrammatic representation of various types of basidia. *A*. Typical holobasidium. *B*. Tuning fork basidium of *Dacrymyces*. *C*. Basidium of *Tulasnella*. *D*. Basidium of *Tremella*. *E*. Basidium of *Auricularia*. *F*. Basidium of *Puccinia*. Drawings by R. W. Scheetz.**

Gomphales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Sebacinales

Cantharellales


VEINED


TOOTHED


CORALS


CLUBS

Dacrymycetes


JELLY FUNGI

Tremellomycetes


JELLY FUNGI

Jelly Saprobes

Helpful, not just ‘not hurtful’

Less primitive shapes (stems)

Dacrymycetes

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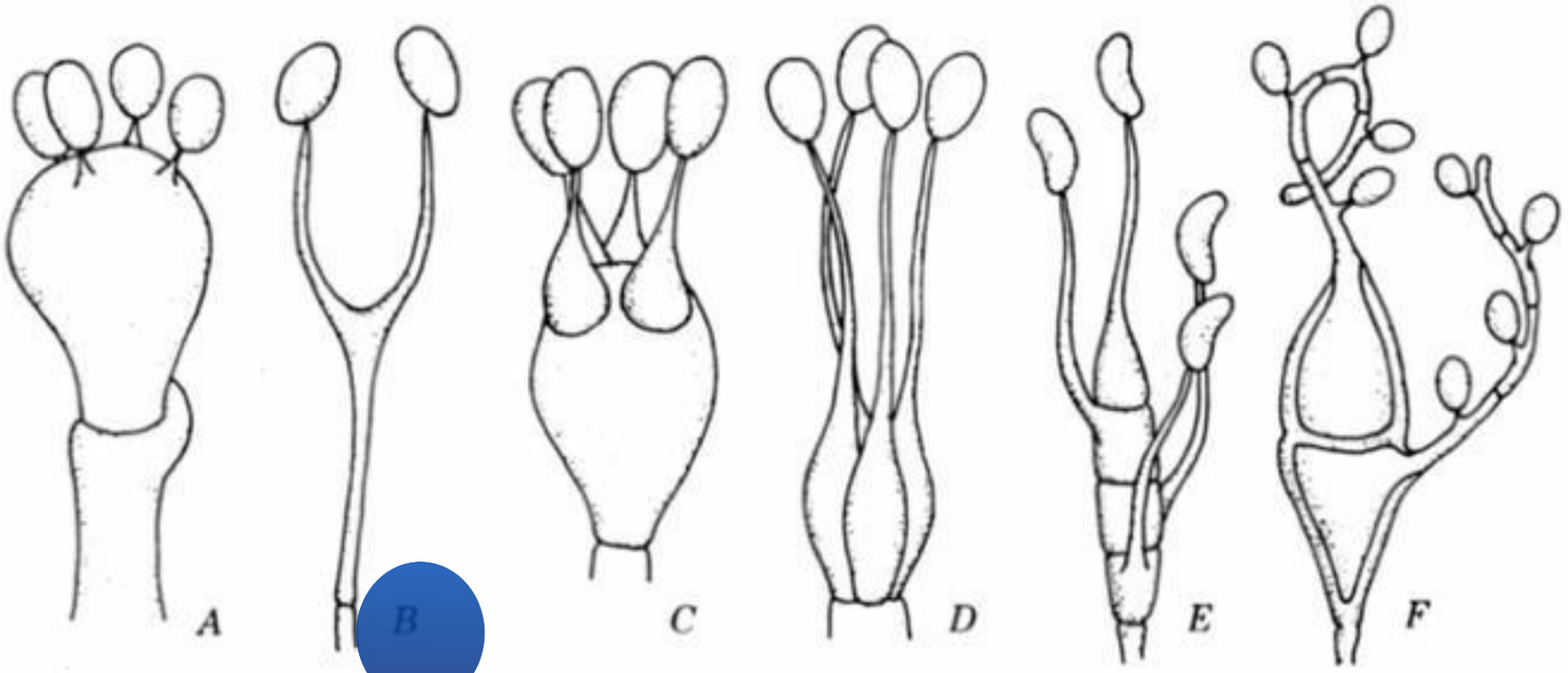

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Brown Rot – digesting cellulose

That’s all that they did

Gomphales


VEINED


CORALS


CLUBS

Phallales


CLUBS

Geastrales


PUFFBALLS

Auriculariales


JELLY FUNGI

Sebacinales

Cantharellales


VEINED


TOOTHED


CORALS


CLUBS

Dacrymycetes


JELLY FUNGI

Tremellomycetes


JELLY FUNGI

More Jelly Saprobes

Even more advanced shapes
Some “white rot”

Auriculariales

Basidia

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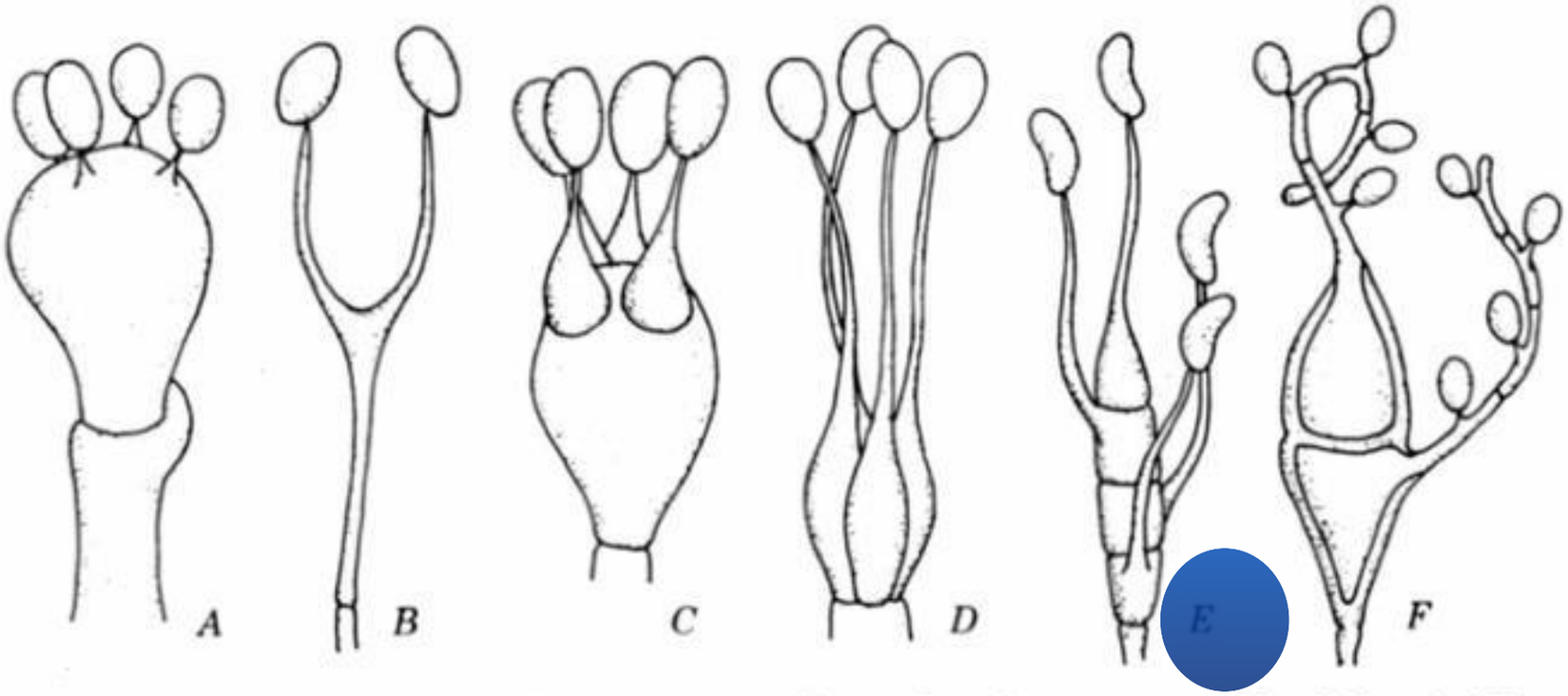

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White Rot – digesting lignin

Probably evolved as Auriculariales split

Mycorhizal Relationship with Trees

Leaving wood to grow throughout the ground

Let the Diversity Begin

Basidiomycota (“Basidios”)

The simpler the shape, the more orders it evolved in?

Veined - easily confused with gilled

←Cantharellus
orange/white
with shallow ribs

Craterellus→
small winter
(rare black)

Polyozellus→
blue clustered
false chanterelle

←Gomphus/ Turbinellus
purple/orange
“wooly” false

Cantharellales - Gomphales – Thelephorales - Agaricales

Clubs and Corals

←Clavariadelphus
(Ramaria relative)

Alloclavaria→
(polypore relative)

←Stinkhorns

cool but rare

Cordyceps→
(Asco)

Cantharellales – Phallales - Gomphales – Hymenochaetales – Russulales - Thelephorales - Agaricales

Clubs and Corals

←Clavulina
(chanty relative)

Ramaria→
(purple, red, orange, yellow)

←Thelephora
(Polyozellus Hydnellum)

Sparassis→
(polypore)

Cantharellales – Phallales - Gomphales – Hymenochaetales – Russulales - Thelephorales - Agaricales

Toothed Fungi

←Hydnum
(chanty relative)

Hydnellum→
(toy top, Thelephora relatives)

←Phellodon
delicate top

Sarcodon→
sordid Hydnum

Cantharellales - Russulales – Thelephorales

Toothed Fungi

Echinodontium→
(Russulales paint polypore)

←Auriscalpium
(Russulales earpick)

Hericium→
Russulales icicles on trees

Cantharellales - Russulales – Thelephorales

Polypores (tough, not removable)

Too many to cover here: odd pores, soft and cheesy, stemmed

Polyporales - Hymenochaetales – Gloeophyllales - Russulales

Boletes – soft, removable sponge

←Suillus
either a veil or viscid

Leccinum→
scaber-stalked birch (or red in the wild)

“Boletus”
everything else (17 genera)

Boletales

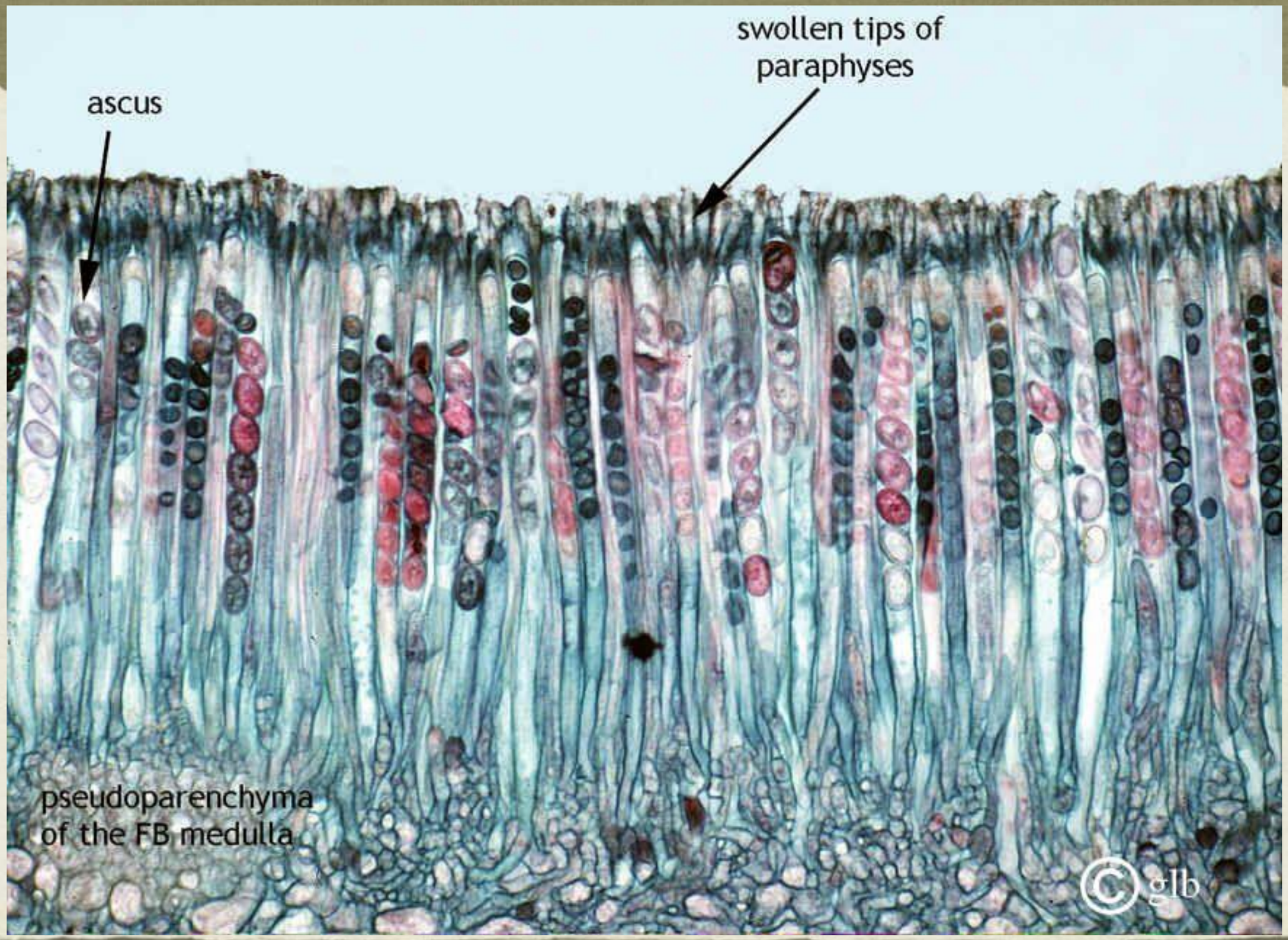
Birds-nest fungi


Cyathus


Nidula

Dark spored Agaricales (!?!)

Ascomycota (“Ascos”)



Developed even more shapes

True morels

Morchella

False morels

Gyromitra

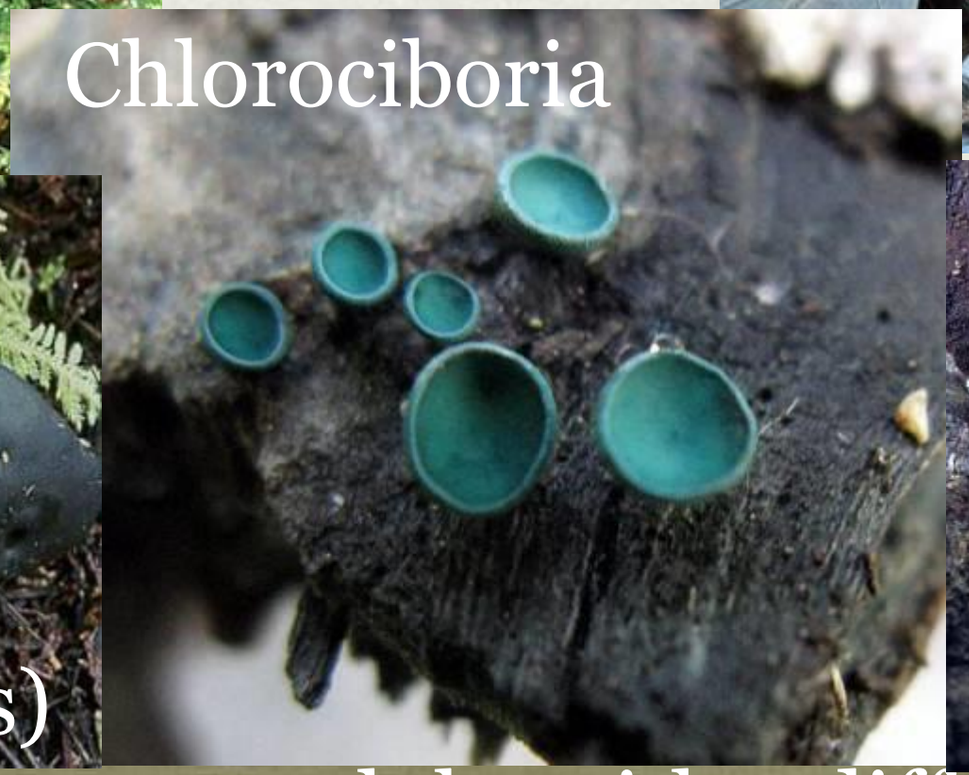
Helvella

Verpa

Ascomycota – large cups (and small cups not on wood)

Basidios have cups too (Agaricales)

Ascomycota – Earth Tongues and small cups on wood are a separate class



Earth Tongues are clubs with a differentiated head.

Jellies appear in both classes.

30. Ascomycota – Flasks (clubs and crusts) with pimples are a separate class

Xylaria

usually asexual

w/o pimples

(carbonous)

Hypomyces

More forcibly ejected

Cordyceps

Convergent Evolution

Only so many shapes can successfully reproduce

Mushrooms always find one of them that works

Shapes evolve back and forth more easily than we originally thought

Think of pores as pinched gills?

Inky Caps evolved in two familes

←Agaricus

Psathyrella→
fragile

←Coprinus
shaggy mane
(Agaricaceae)

Inky Caps→
pleated!
(Psathyrellaceae)

Gills too closely spaced?

Optimum for wind dispersal?

Why haven't I mentioned Puffballs/Truffles?

- The simplest ball shape "gastroid" is not basal (they would be on wood)
- Actually they are the most derived form due to environment pressure (desert climate change)
- A "hymenomycete" (forcibly discharged spores) has never been known to evolve from a "gastroid" (Hibbett et. al. 1997)
- HINT: If they were a basal (primitive) mushroom, they'd be attached to wood

Found in almost every mycorrhizal order

Stages of Trufflizing Fungi – as the pressure continues

Secotioid
trufflizing
mushrooms

← Agaric
Bolete →

False Truffle
w/columella

← Bolete
Agaric →

The spores don't go far, but they're safe

Eventually they are uniform inside

←Stalked
(kept the stem)

Puffball →
(Agaricaceae)

←Puffballs→

(marshmallows that turn to dust)

Gastroid Fungi

←Earthballs
(Boletales)

Bird's Nest →
(Agaricales)

← Earth Stars
(Geastrales)

Hygroscopic Earth Star →
(Boletales)

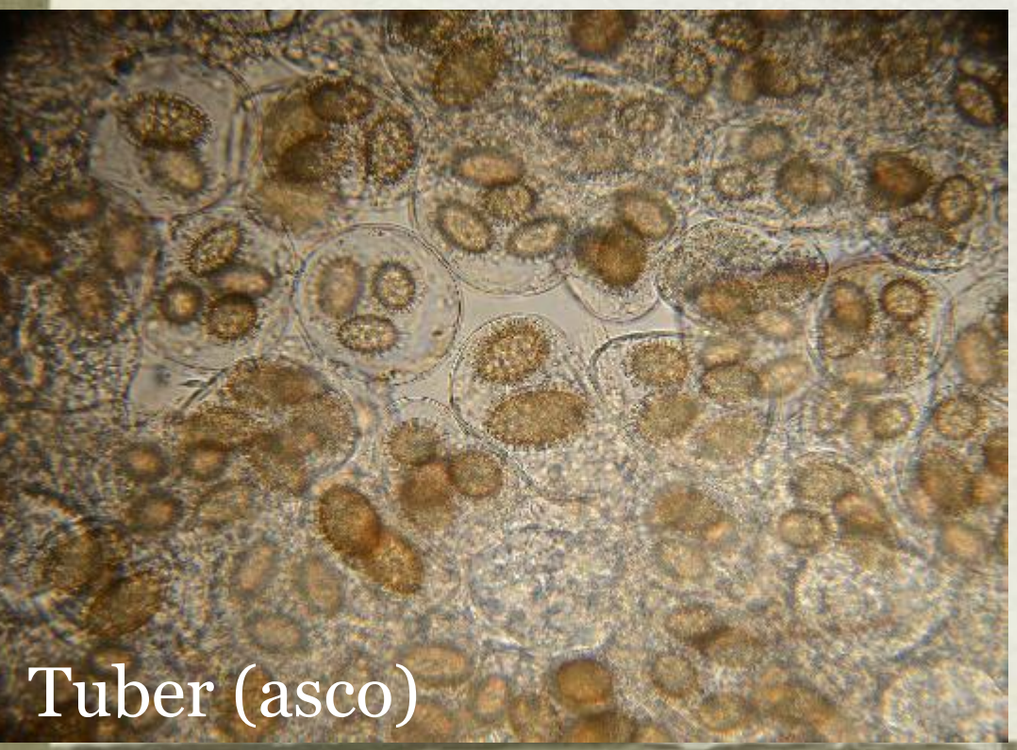
False truffles are not uniform inside, or if they are, they are spongy and gelatinous.

Finally, they might stay underground

Russula! (yellow spores)

False Truffles
(underground,
many families)

Hymenogaster


Tuber (asco)

Warts or thick walls help a spore survive a trip through a digestive system.

(Dung might not be around long enough to get colonized)

If they simultaneously develop strong odors to be found and eaten (and digestible spores)

Thick, Double-Walled spores – Dung Mushrooms

Dark pigments only! (helps)

The outer wall breaks down, then germination is easier
(small mushrooms only?)

Ascomycota – True Truffles (True=tasty to humans, close to Morels!, other animals aren't as fussy)

Tuber – Oregon white
Leucangium – Oregon black

Elaphomyces - Deer Truffle
Geopora
Sarcosphaera

True truffles are marbled, empty, chambered, or gooey with a thick rind

The most derived shape is the “blob”

Centuries-long mysteries have now been solved

- Sometimes there were clues and we already knew (Gilled Boletes, Russula)

- Sometimes we found a clue we missed in hindsight (2 families of inky caps for 2 different reasons)

- Most often, we would never have known without DNA

Genetic diversity is extremely complicated!

Conclusion

Scientists have spent their whole lives trying to figure out how some mushrooms were related to each, and never thought they'd find some of the answers.

"...this matter will probably continue to remain one of opinion, as it has in the past."
"...the end is not yet in sight."

- Hesler & Smith, N. Am. Species of Hygrophorus, 1963

The end *is* now in sight. We will soon know much of how all mushrooms relate to each other.

It's fascinating to find out where the earlier scientists were right, and where they were wrong.

I wish I could go back and tell them.