Botanika bezcévných rostlin pro učitelské kombinace

Lišejníky – přednáška 1

David Svoboda

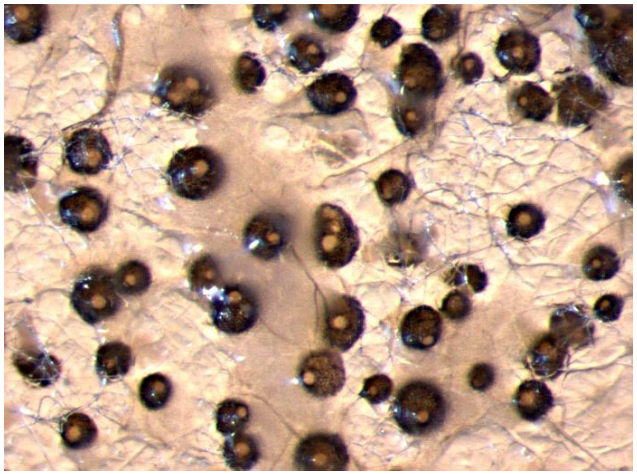
Kde v systému se nacházíme?

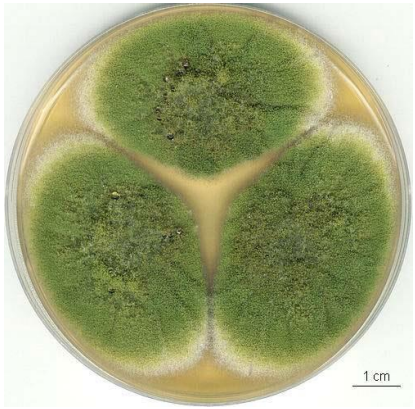
„Impérium": Eukaryota

„Nadříše": Opisthokonta

*„Říše": **Fungi***

Ascomycota





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© A. Kubátová

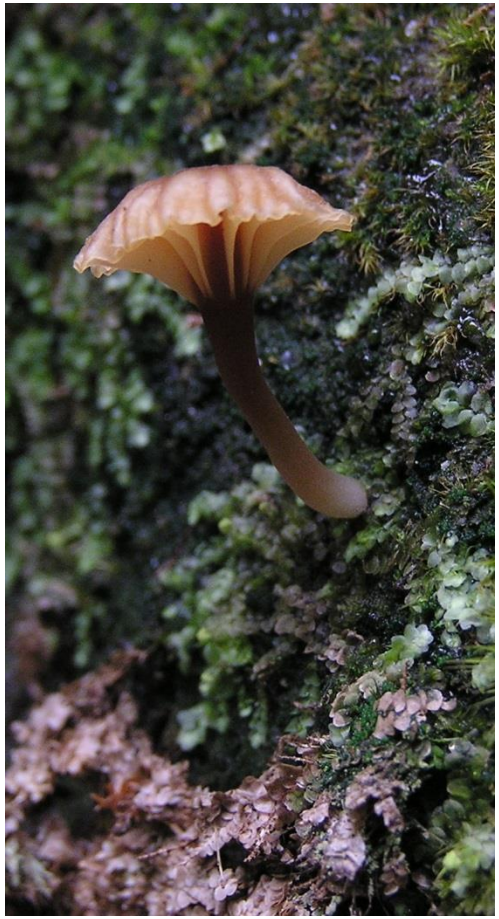
Kde v systému se nacházíme?

Eukaryota

Opisthokonta

Fungi

Basidiomycota



Kde v systému se nacházíme?

Eukaryota

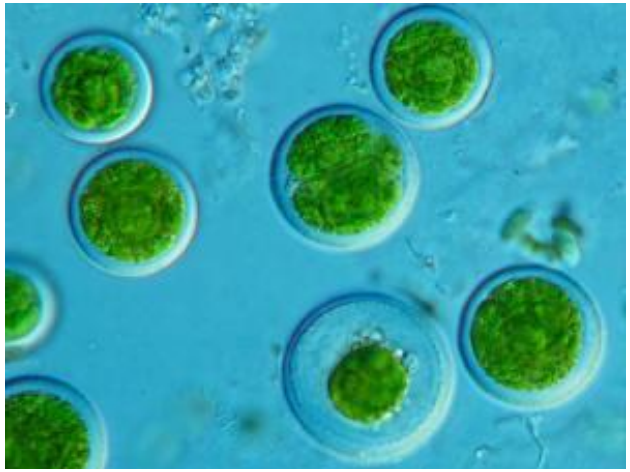
Plantae (Archaeplastida)

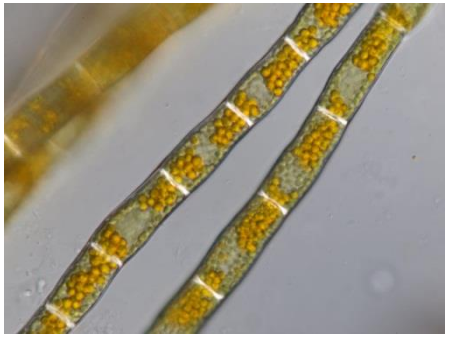
Chlorophyta

Trebouxiophyceae

Ulvophyceae

Trebouxia





Trentepohlia

Kde v systému se nacházíme?

Eukaryota

SAR

Chromista (Chromalveolata)

Stramenopila

Xanthophyceae (Heterococcus)

Phaeophyceae (Petroderma)

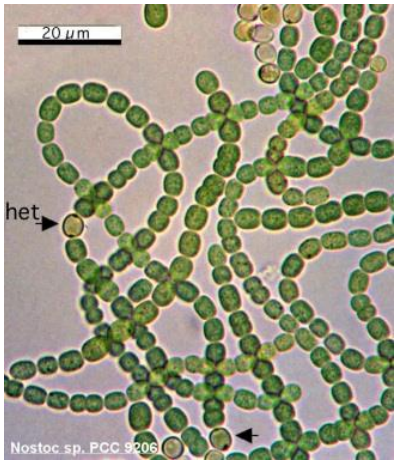
Kde v systému se nacházíme?

Prokaryota

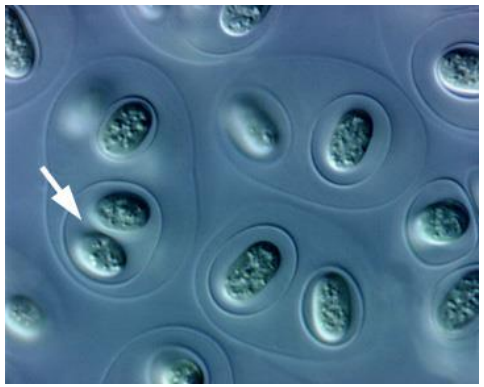
Bacteria

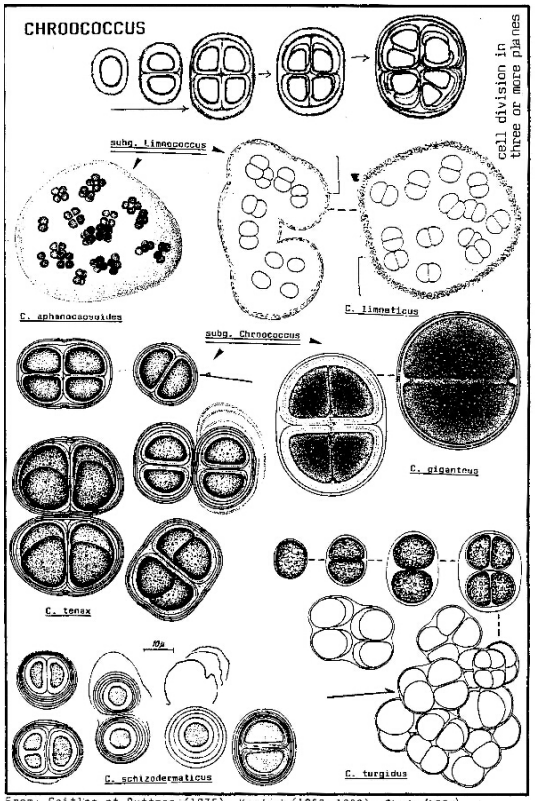
Cyanobacteria *(Cyanophyta)*

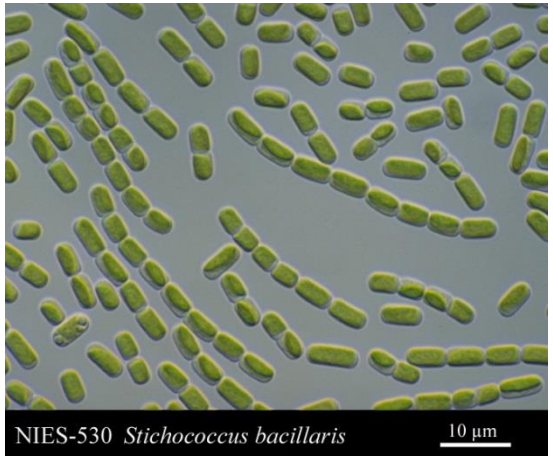
Cyanophyceae

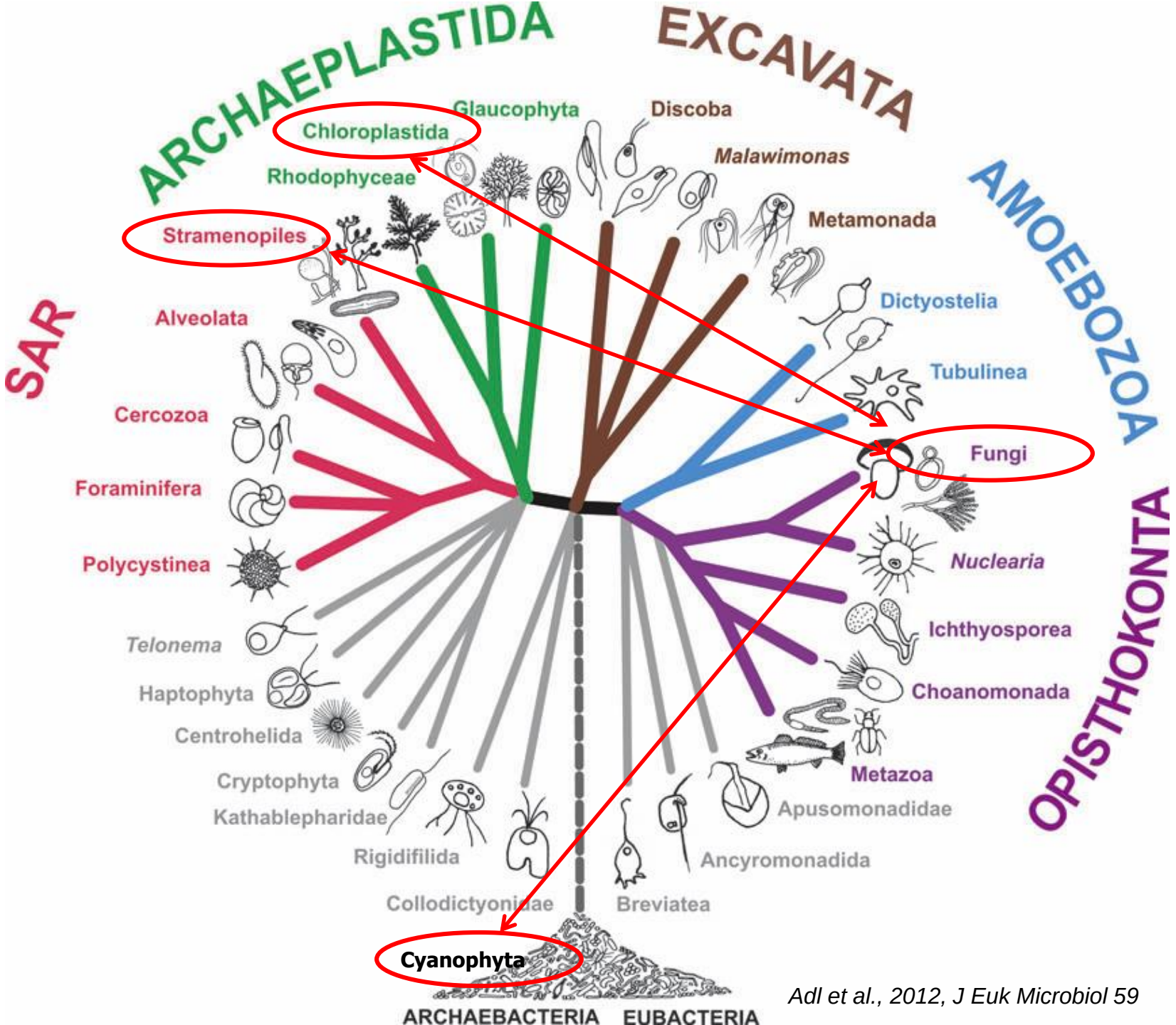


Gloeocapsa

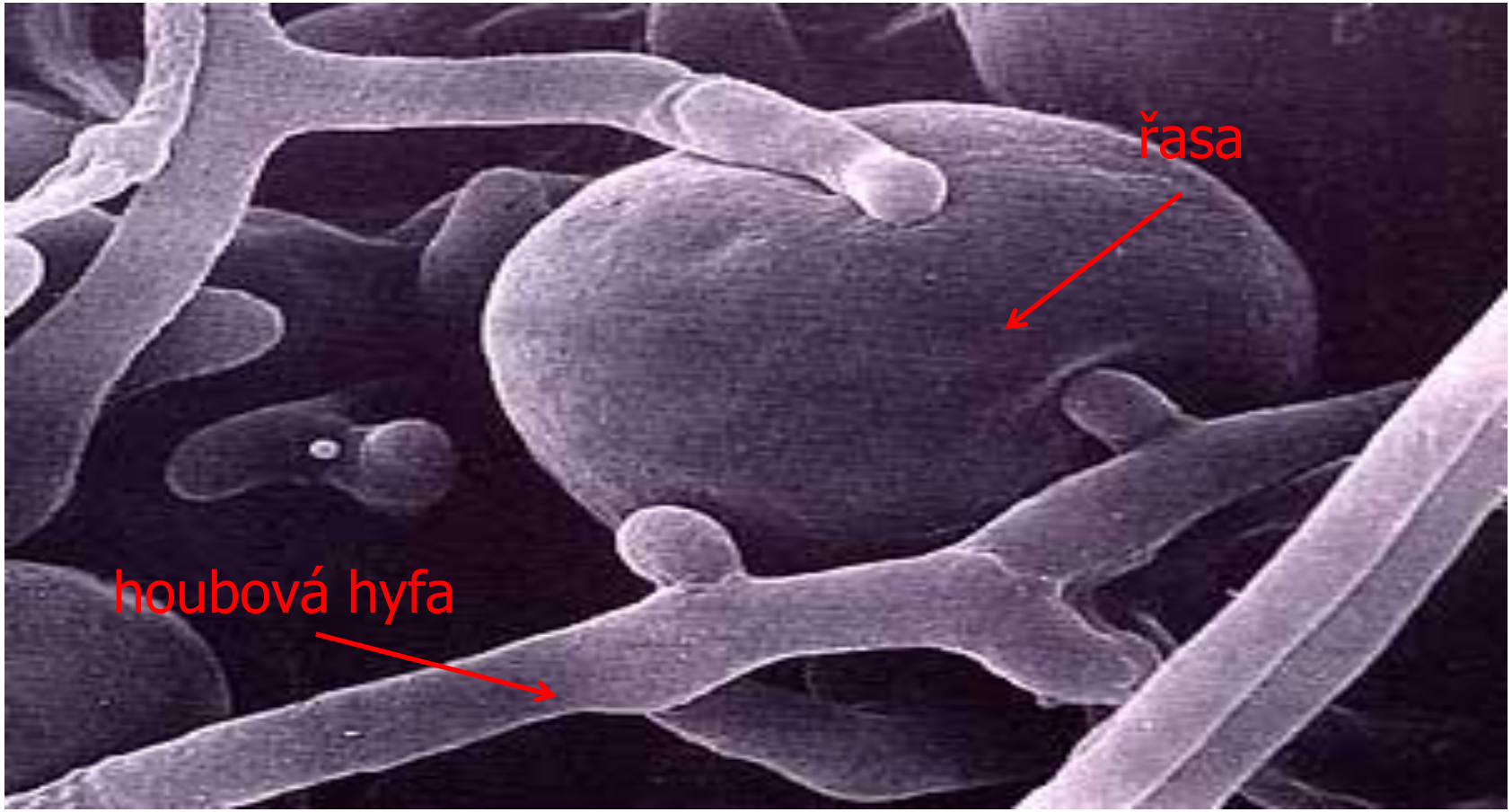








Adl et al., 2012, J Euk Microbiol 59



Lichenismus – asociace houby a zelené řasy/sinice za tvorby specifické stélky

Lišejník = lichenizovaná houba

"Lichens are fungi that have discovered agriculture"
(T. Goward)

Mykobiont

(mykosymbiont)

Fotobiont

(fykobiont)

(fykosymbiont)

Lichen symbiosis

versus

řasa v horní vrstvě plodnice

Trametes versicolor

přechodné typy
bez tvorby stélky

Lišejníky = lichenizované houby
Jméno dává lišejníku houba, nikoliv řasa:

(***Sticta damaecornis*** **f.** ***canariensis***)

(***Sticta dufourii***)

Sticta canariensis (Bory) Bory ex. Delise

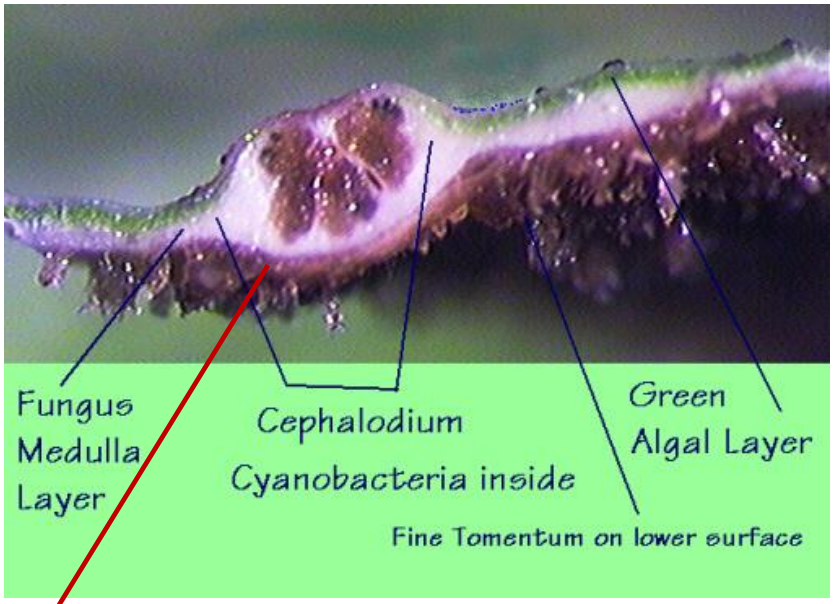
forma se zelenou řasou

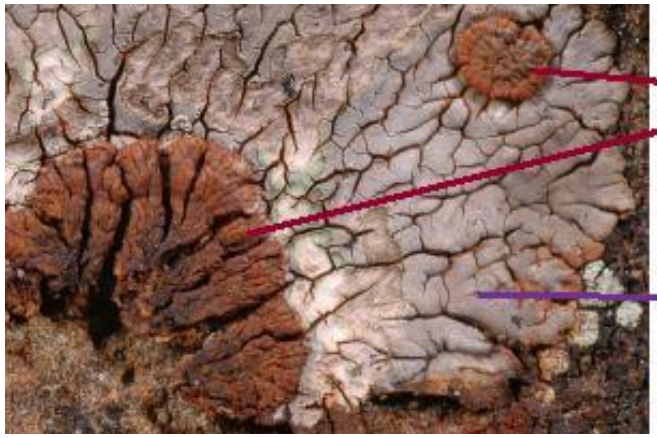
forma se sinicí

Vztah není jen 1 : 1 …

Lobaria amplissima* a *Dendriscocaulon umhausense

forma se zel. řasou a na ní forma se sinicí dohromady – více fotobiontů



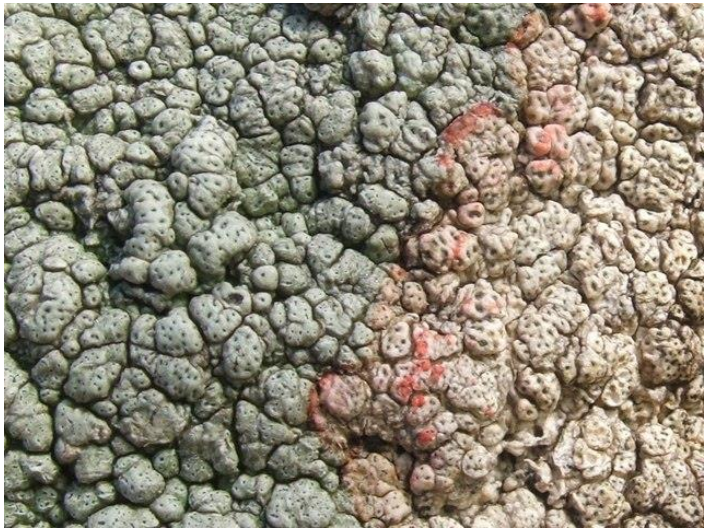


Cephalodia containing cyanobacteria

Thallus containing green algae

cephalodia – útvary s jiným fotobiontem (sinicí) na stélce

Caloplaca thallincola na *Verrucaria maura*



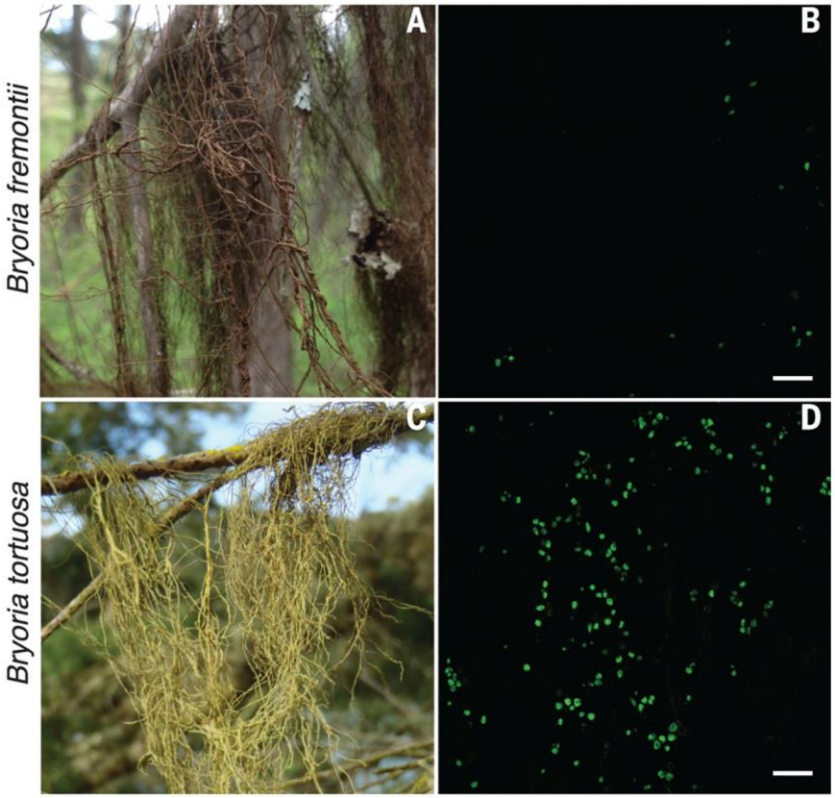
lichenikolní houba na *Pertusaria pertusa*

lichenikolní houba na *Sticta*

lichenikolní houba na *Cladonia arbuscula*

více mykobiontů – parasitické houby, parasitické lišejníky

...u Parmeliaceae někde prokázáno 2:1, ale Lecanoromycet + kvasinka (Basidiomycet) : Trebouxia



Differential abundance of Cyphobasidiales yeasts in *B. fremontii* and *B. tortuosa*.

Bryoria fremontii – no vulpinic acid, brown, *B. tortuosa* – vulpinic acid, yellow colour.

(**A**) *B. fremontii*, with (**B**) few FISH-hybridized live yeast cells at the level of the cortex. (**C**) *B. tortuosa*, with (**D**) abundant FISH-hybridized cortical yeast cells (scale bars, 20 µm).

Toby Spribille et al. Science 2016;science.aaf8287

Toby Spribille et al. (2016): Basidiomycete yeasts in the cortex of ascomycete macrolichens, Science

„We show that many common lichens are composed of the known ascomycete, the photosynthesizing partner, and, unexpectedly, specific basidiomycete yeasts. These yeasts are embedded in the cortex, and their abundance correlates with previously unexplained variations in phenotype. Basidiomycete lineages maintain close associations with specific lichen species over large geographical distances and have been found on six continents. The structurally important lichen cortex, long treated as a zone of differentiated ascomycete cells, appears to consistently contain two unrelated fungi.

Bryoria fremontii – no vulpinic acid, brown, *B. tortuosa* – vulpinic acid, yellow colour.

videa:

http://science.sciencemag.org/content/sci/suppl/2016/07/20/science.aaf8287.DC1/aaf8287-Spribille-SM-movie-s1.mp4

http://science.sciencemag.org/highwire/filestream/681751/field_highwire_adjunct_files/2/aaf8287-Spribille-SM-movie-s2.mpg

Lichenikolní houby, endolichenické houby – interagují s fotobiontem?

Muggia et al., 2018: The thallus structure of the lichen symbiosis provides a fungal shelter for the growth of algal partners. The long-living thallus also provides a habitat for other fungi, but experimental studies, which could inform us about the details of their interactions have hardly been conducted.

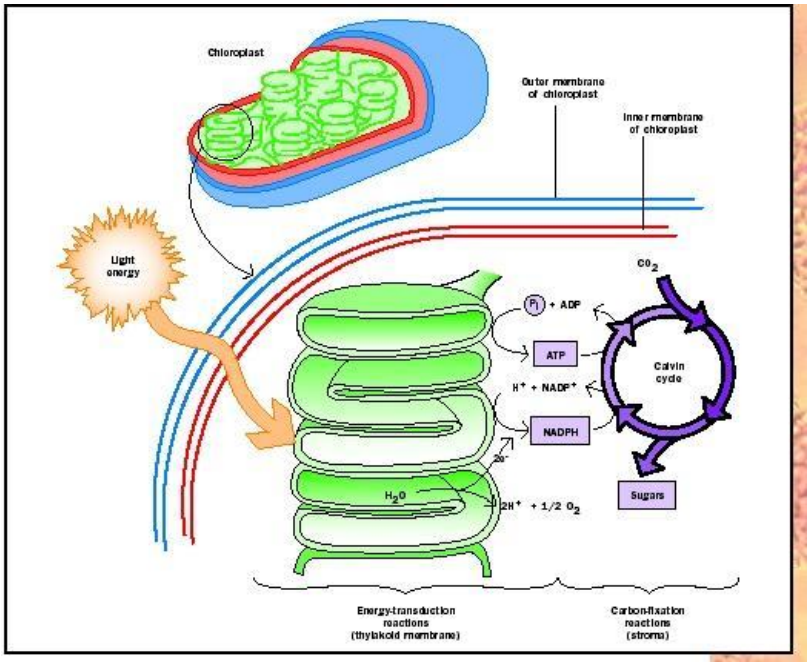
(**J**–**L**) *Muellerella atricola* (L1993) and *Trebouxia* sp.1 (L1379) 3 months (J), six months (K) and one year (L) after inoculation on malt yeasts medium (MY).

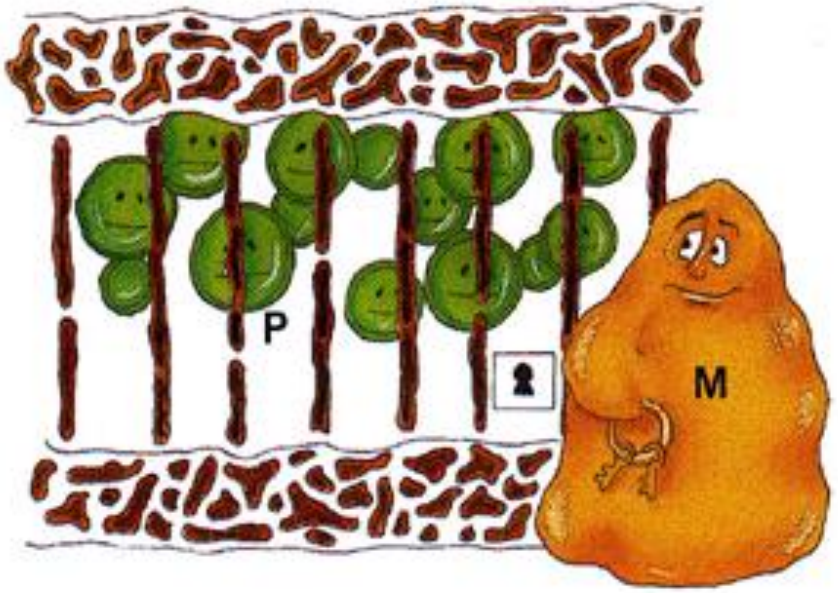
Fotobiont

- fotosyntéza
- modifikovaná struktura
- nepohlavní rozmnožování (velmi vzácně i pohlavní)

Mykobiont

- výživa a ochrana fotobionta (UV, vyschnutí, ...)
- stavba stélky
- pohlavní rozmnožování





Důležité vlastnosti lišejníků :

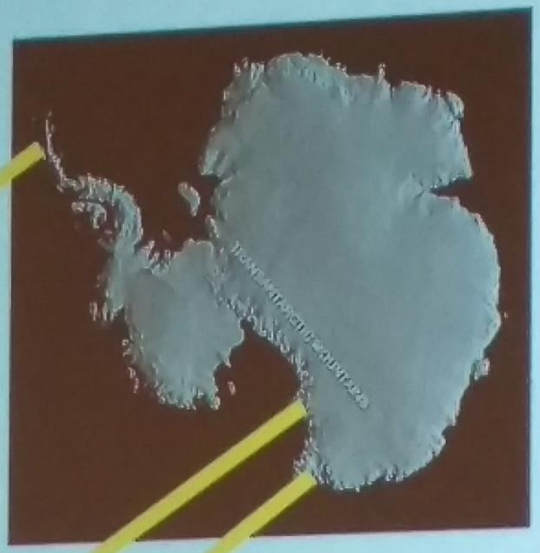
- **reviviscence**: schopnost rychle a reversibilně přecházet ze suchého do hydratovaného stavu

- **odolnost proti nízkým teplotám**:
  asimilace až do - 40 °C (naměřený extrém)
- **schopnost růst na různých (nehostinných) substrátech**

- schopnost **produkce sekundárních metabolitů**, z nichž většinu houba ani řasa nejsou schopné samostatně vyrábět (barevné pigmenty, lišejníkové kyseliny).

- **schopnost tvorby stélky s dlouhou životností** (korovité lišejníky řádově stovky let).

Lichen growth in 100 years



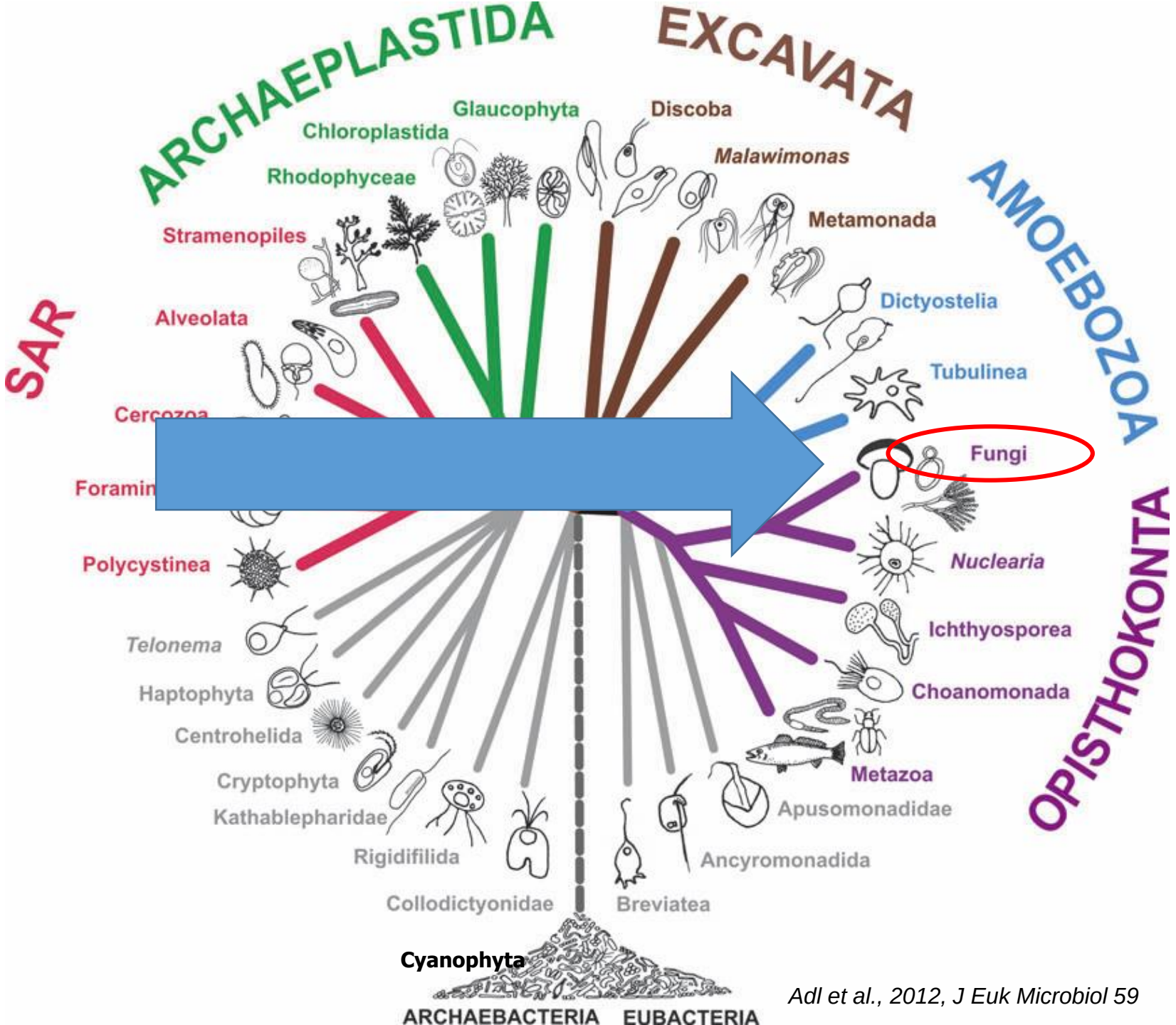
100 years = 80 mm diameter
Livingston Island

100 years = 6 mm diam.
Hallett

100 years = 1 mm diam.
Taylor Valley

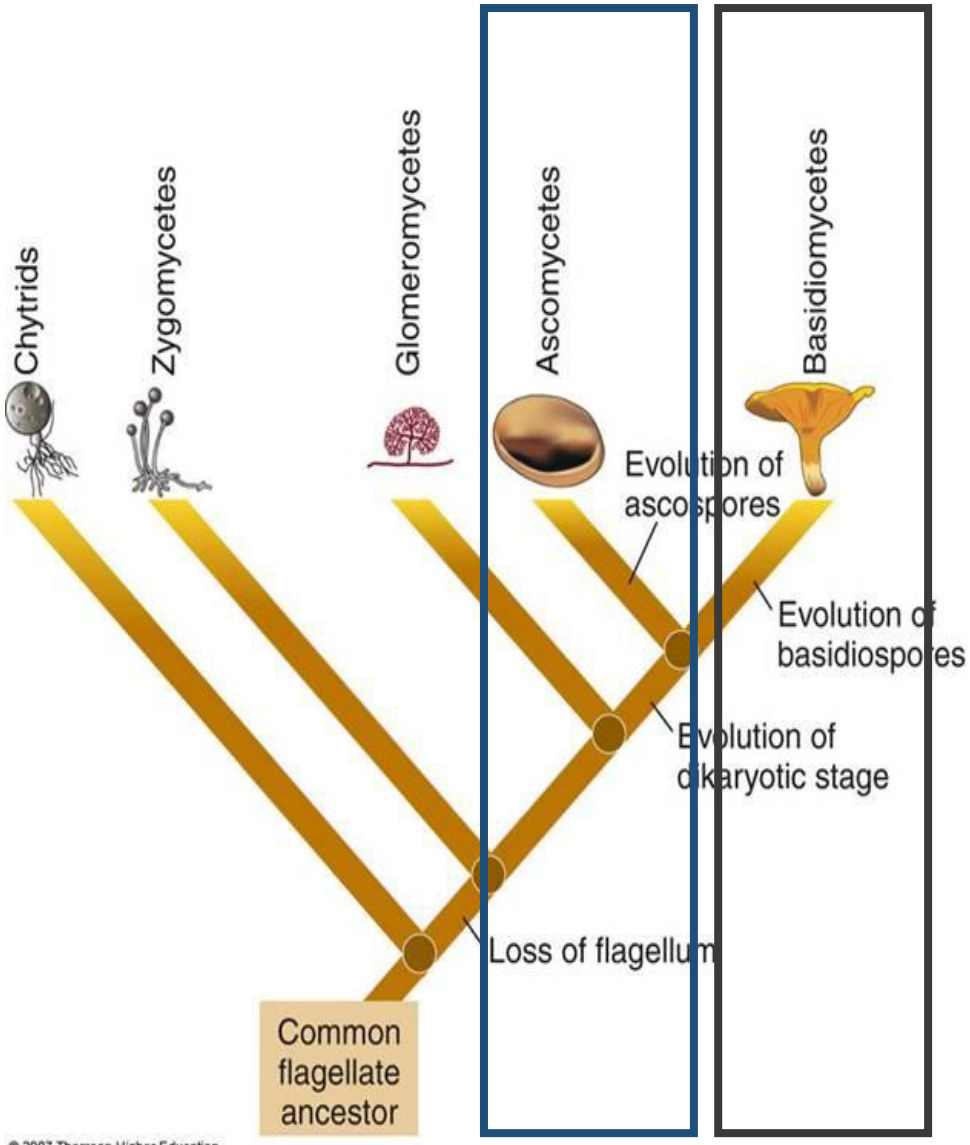
Gradient 3: growth rates (about 100 times for lichens)

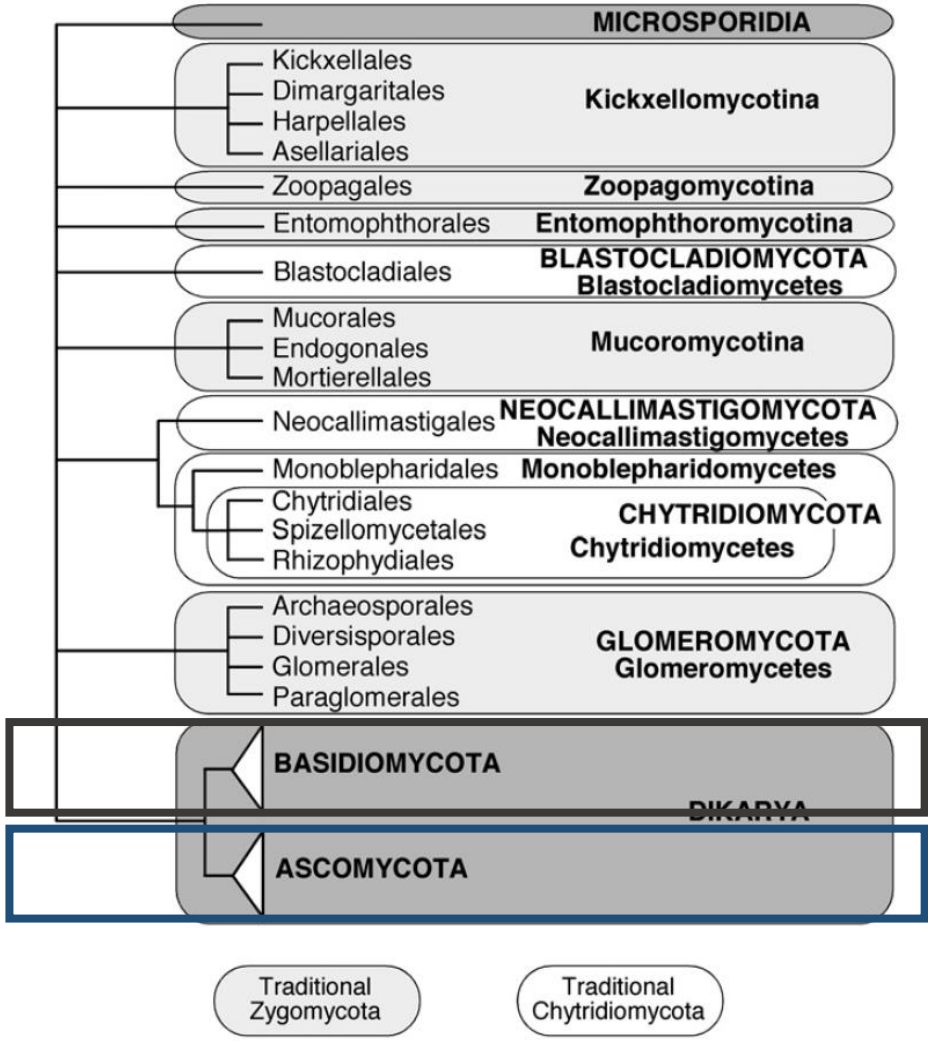
Sancho, L. G., Green, T. A., & Pintado, A. (2007). Slowest to fastest: extreme range in lichen growth rates supports their use as an indicator of climate change in Antarctica. *Flora202*(8), 667-673.



Adl et al., 2012, J Euk Microbiol 59

Fungi - mykobiont





Hibbett & al. (2007)

Fungi

http://science.kennesaw.edu/~jdirnber/Bio2108/Lecture/LecBiodiversity/31_Labeled_Images/31_UN06-Summary-L.jpg

Fungal Phylum	Distinguishing Features of Morphology and Life Cycles	
Chytridiomycota (chytrids)	Flagellated spores	
Zygomycota (zygote fungi)	Resistant zygosporangium as sexual stage	
Glomeromycota (arbuscular mycorrhizal fungi)	Form arbuscular mycorrhizae with plants	
Ascomycota (sac fungi)	Sexual spores (ascospores) borne internally in sacs called asci; ascomycetes also produce vast numbers of asexual spores (conidia)	
Basidiomycota (club fungi)	Elaborate fruiting body (basidiocarp) containing many basidia that produce sexual spores (basidiospores)	

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Fungi – obecně

- **eukaryotické jednobuněčné / mnohobuněčné**; **buněčná stěna** z **chitinu** nebo ß-polyglukanu

- **hyfa** tvořící **mycelium** (+ někde někdy **kvasinkovité** pučící buňky), **sporangia**

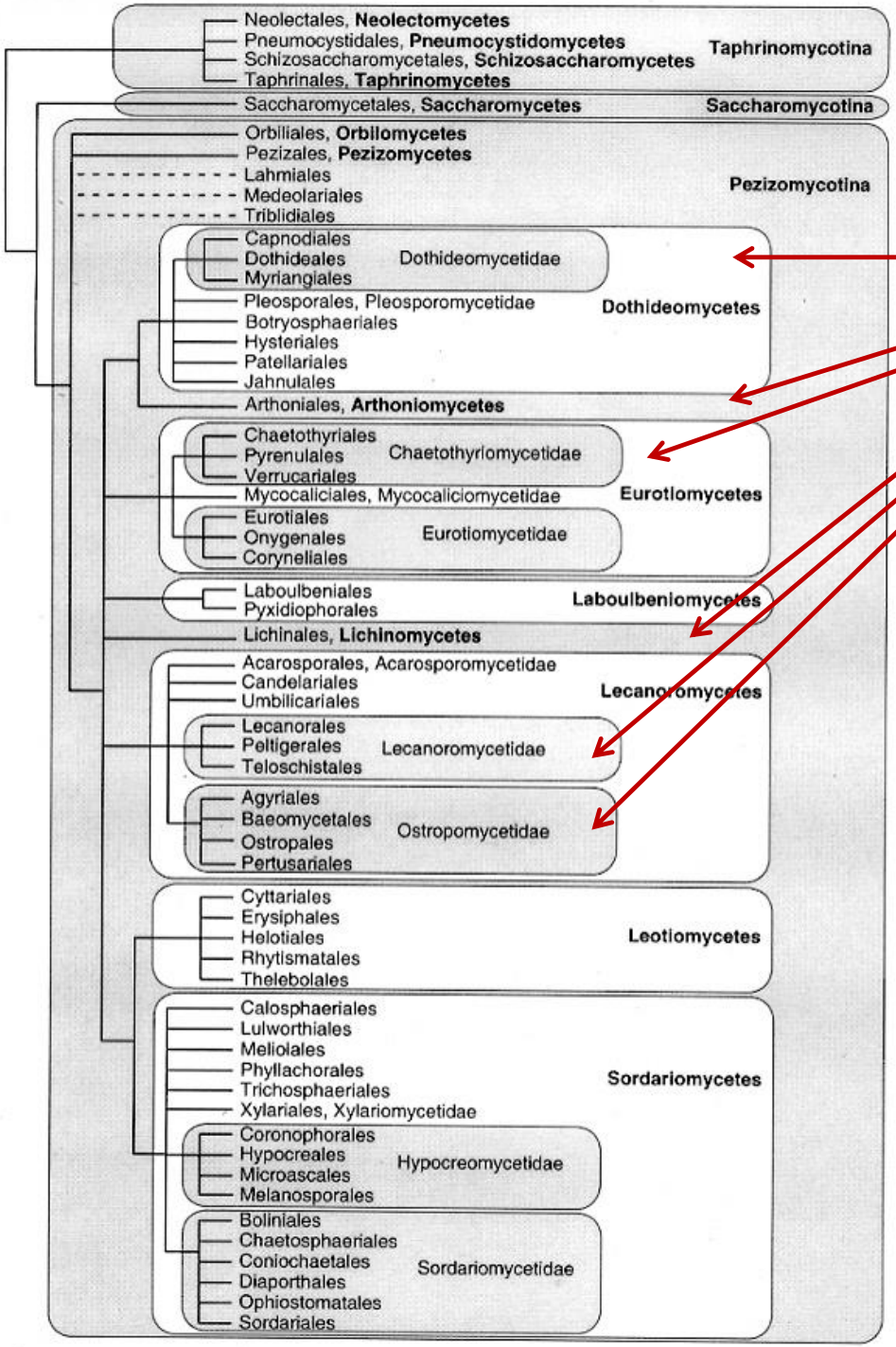
- výživa **absorbční**, heterotrofní, zásobní látkou **glykogen**

- energie **oxidací organických** látek (nebo fermentativní metabolizmus)

- pohlavní proces od **gametogamie, gametangiogamie**, **somatogamie**

- pohlavní rozmnožování **sporami** z **gametangií**, **plodnic**

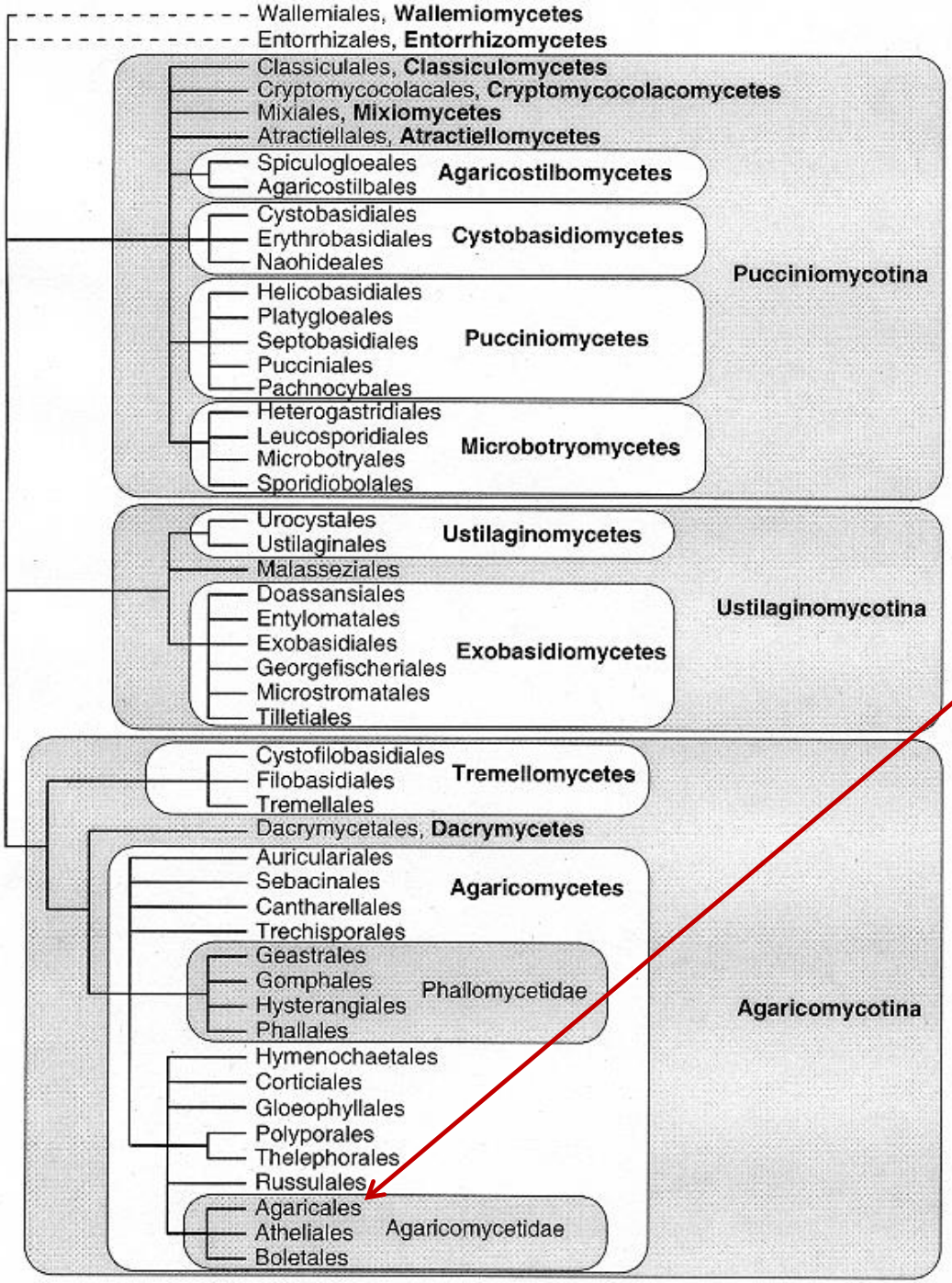
- nepohlavní rozmnožování - **úlomky hyf**, **pučení**, **spory (sporangia, nepohl. struktury)**



mycobiont: Ascomycota

40 % of known fungal species are lichenized (Schoch et al. 2009)

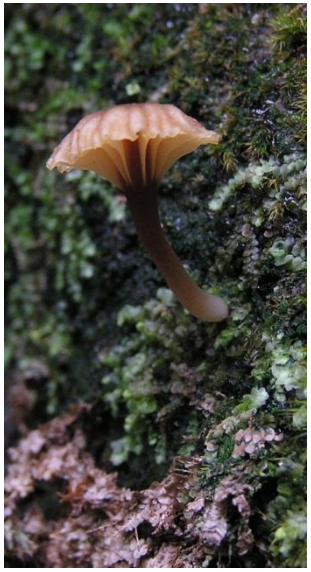
Hibbet et al. 2007



mycobiont: Basidiomycota

ca 20 species lichenized

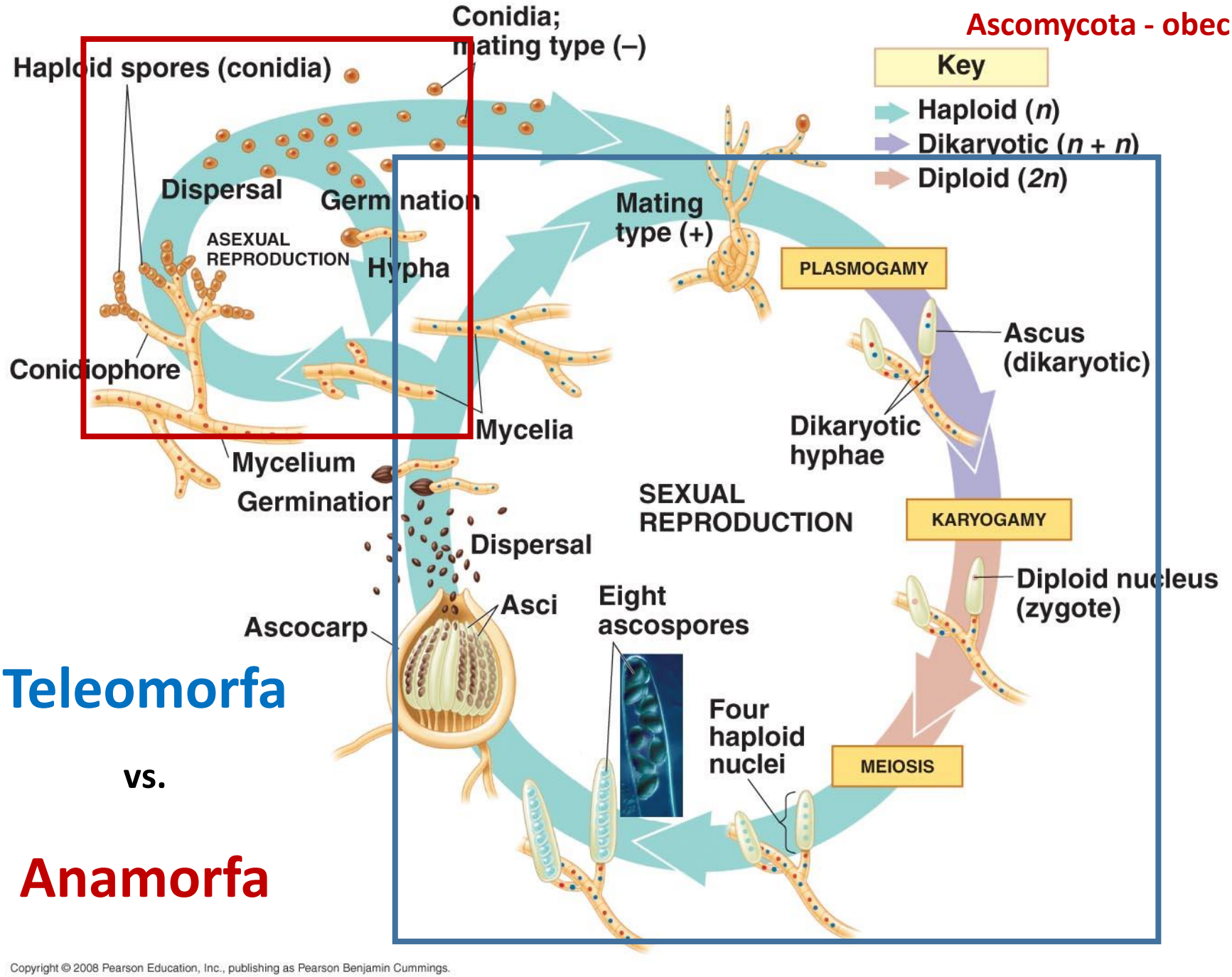
Multiclavula mucida



Lichenomphalia umbellifera

more than 99 % of mycobionts are Ascomycetes

Ascomycota



Teleomorfa

vs.

Anamorfa

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http://science.kennesaw.edu/~jdirnber/Bio2108/Lecture/LecBiodiversity/31_Labeled_Images

Ascomycota

-pohlavní proces v plodnici

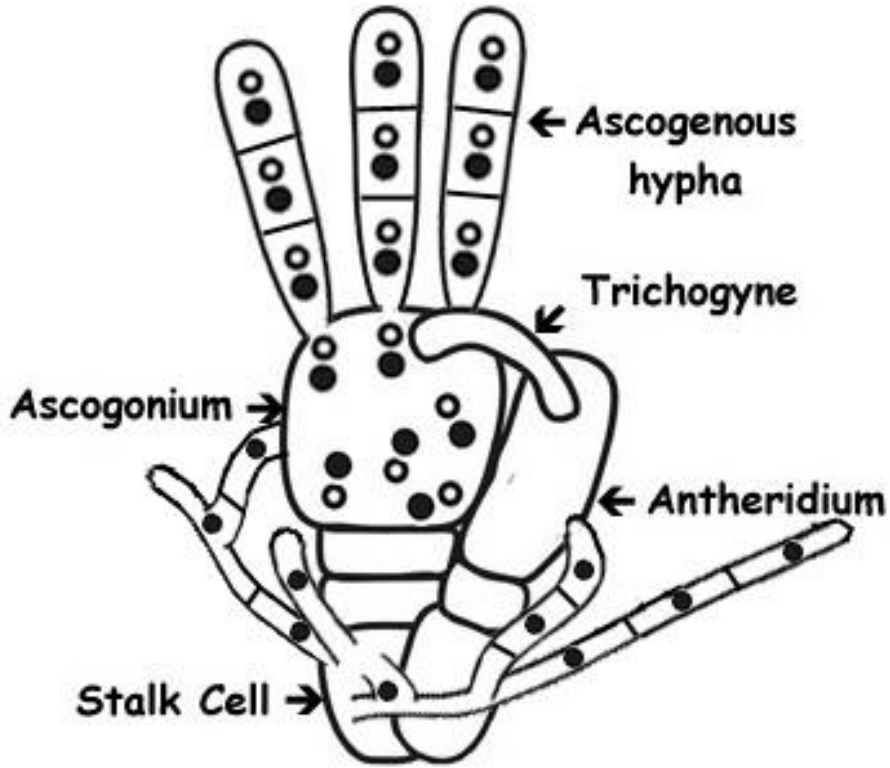
- **gametangiogamie**, **gametogamie** nebo **somatogamie**

- samičí **askogon** s **trichogynem** oplozen ze samčího **antheridia**, nebo **spermacií**

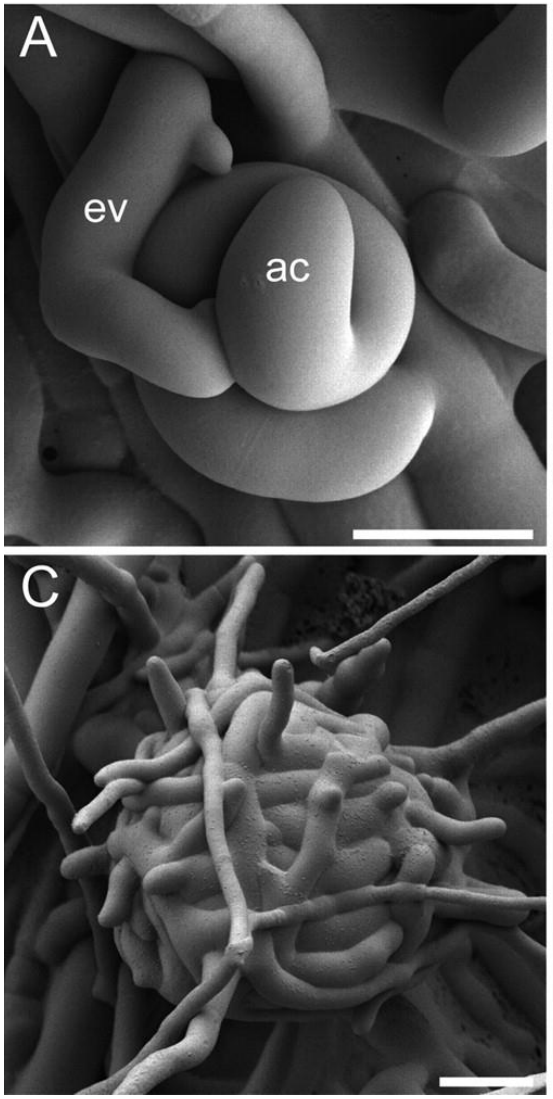
-dikaryotická fáze krátká (**askogenní hyfy**)

- na askogenních hyfách mladá **vřecka (ascus)**, uvnitř **karyogamie**, **R!** a **konjugovaná mitóza**

- **vřecko s 8 askosporami**



(A) Ascogonium (ac) of the *Sordaria macrospora*, which is just starting to be enwrapped by an enveloping hypha (ev).



Bloemendal S et al. Eukaryotic Cell 2010;9:1856-1866

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Ascomycota

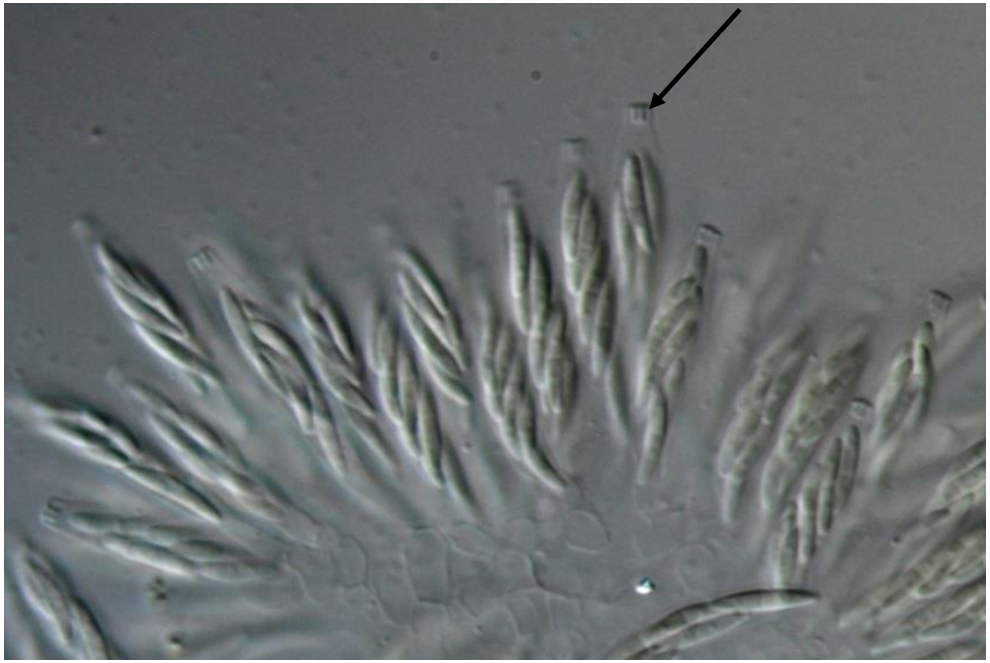
základní počet **askospor ve vřecku** je **8**

- možná redukce až na 1 nebo další mitózy a až stovky askospor

- otevírání **prasknutím stěny** (primitivnější skupiny), **víčkem** a nebo vytlačením askospor přes askoapikální aparát

Anthostomella formosa

askoapikální aparát



Niesslia sp.

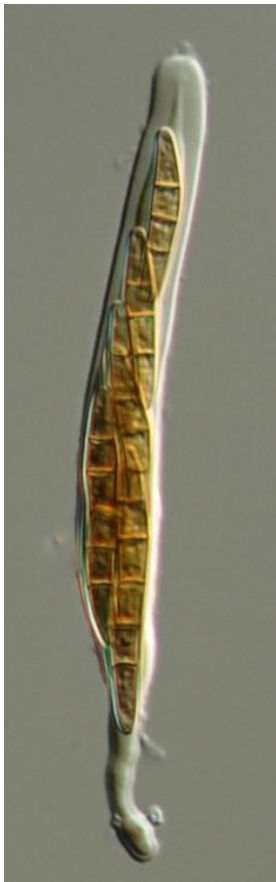
Ascomycota

askospory 1-více buněčné, světlé či tmavé, ornamentované, slizové obaly,....

Caloplaca asserigena

Propolis versicolor

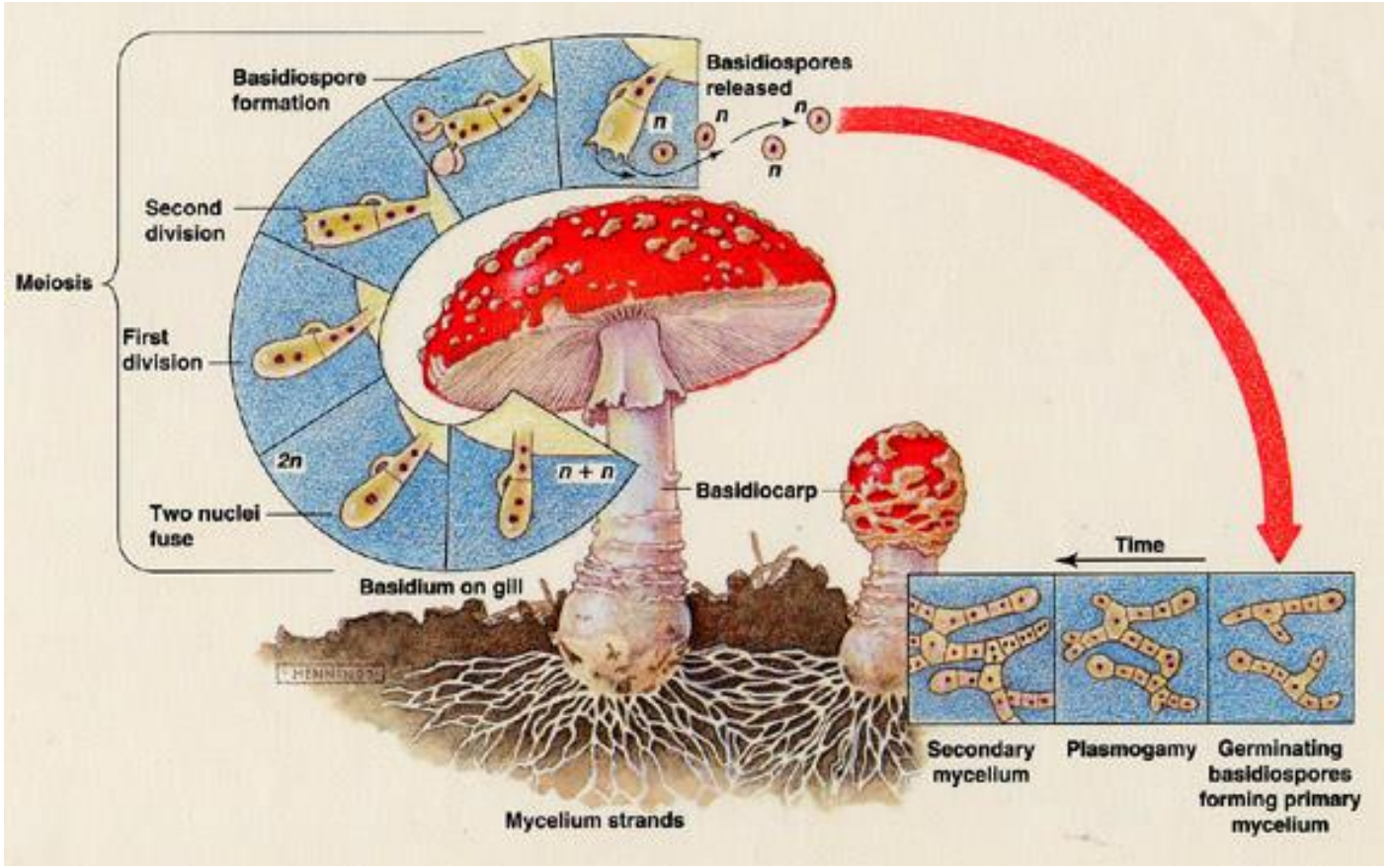
Mytilinidion mytilinelum



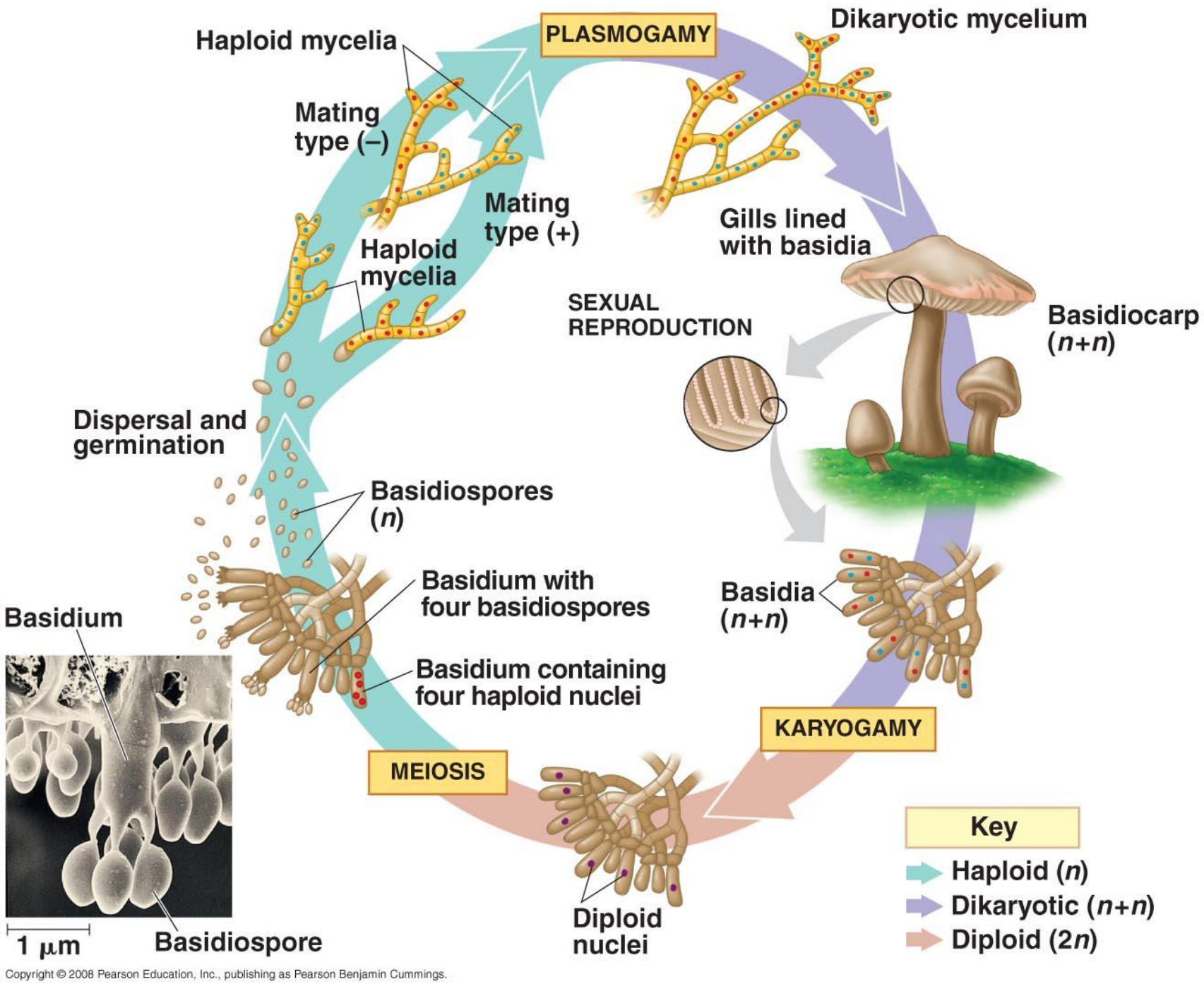
Basidiomycota

Agaricomycotina

- jak vhodně znázornit životní cyklus pro studenty?



http://legacy.lclark.edu/~seavey/bio210/images%20for%20210/fungi/basidiomycete_l.c.jpg



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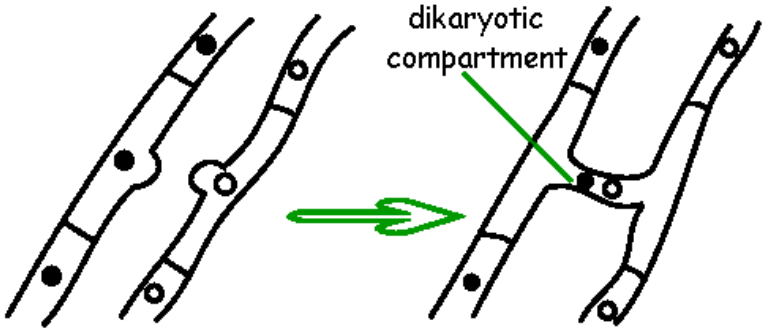
http://science.kennesaw.edu/~jdirnber/Bio2108/Lecture/LecBiodiversity/31_Labeled_Images/31_19BasidioLifeCycle_4-L.jpg

Basidiomycota

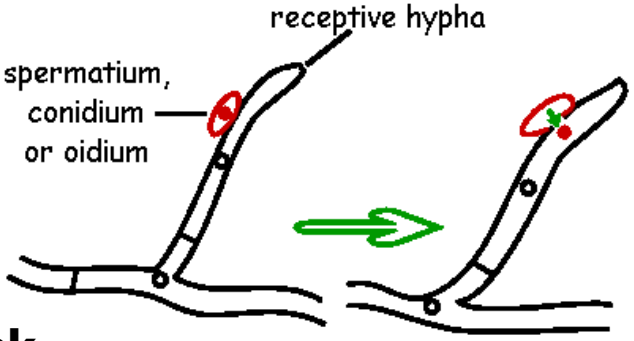
- pohlavní rozmnožování **somatogamie** (splývání hyf)



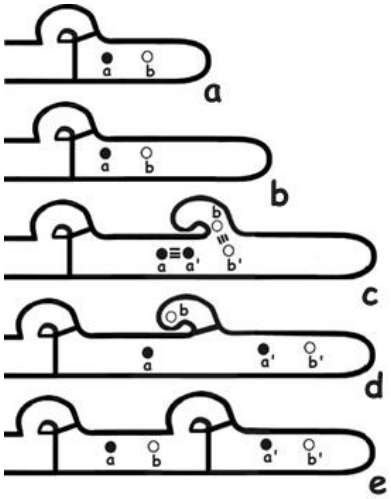
- nebo **gametosomatogamie** (splynutí specializované spory a hyfy)
- časově oddálená karyogamie

= **sekundární dikaryotické mycelium**

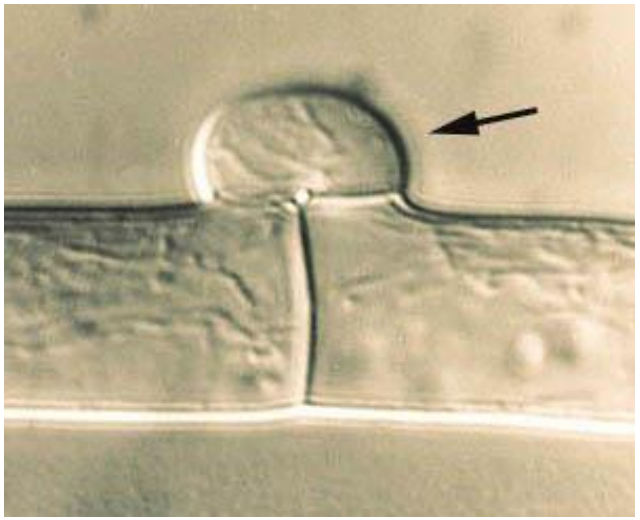
- konjugované mitózy jader a rozchod pomocí **přezek**



http://www.fungionline.org.uk/7sexual/5dikaryon.html



http://www.botany.hawaii.edu/faculty/wong/Bot201/Basidiomycota/Clamp_connection_formation.htm



http://www.apsnet.org/edcenter/illglossary/Pages/A-D.aspx

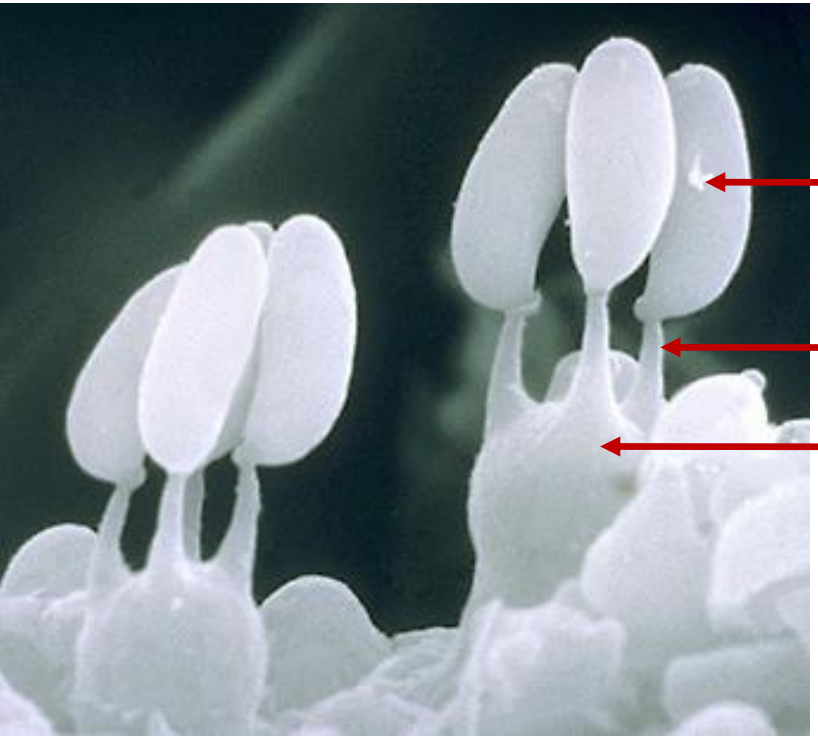
Basidiomycota

- karyogamie až v **bazidii**
= bazidie jedinou diploidní buňkou

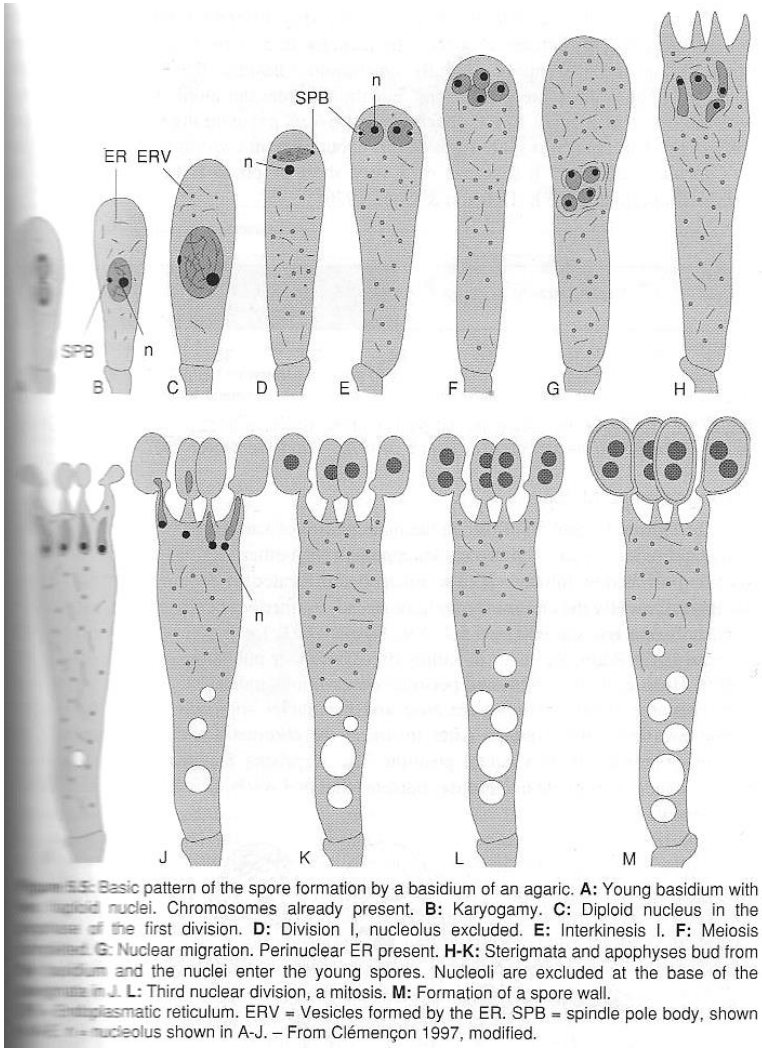
- **R!**

- čtyři haploidní **bazidiospory** na **sterigmatech**
(může být redukce na 2)

- **bazidie** u všech **Basidiomycota**



http://www.apsnet.org/online/Archive/1998/sem088.htm



Basic pattern of the spore formation by a basidium of an agaric. **A:** Young basidium with haploid nuclei. Chromosomes already present. **B:** Karyogamy. **C:** Diploid nucleus in the prophase of the first division. **D:** Division I, nucleolus excluded. **E:** Interkinesis I. **F:** Meiosis completed. **G:** Nuclear migration. Perinuclear ER present. **H-K:** Sterigmata and apophyses bud from the basidium and the nuclei enter the young spores. Nucleoli are excluded at the base of the sterigmata in J. **L:** Third nuclear division, a mitosis. **M:** Formation of a spore wall. Endoplasmatic reticulum. ERV = Vesicles formed by the ER. SPB = spindle pole body, shown with nucleolus shown in A-J. – From Clémençon 1997, modified.

Clémençon (2004)

vznik lišejníků

Lutzoni et al. 2004: Lichenizace vznikla vícekrát nezávisle na sobě

Lutzoni et al. 2001: ztráta lichenismu během evoluce (Eurotiomycetes)

Tehler et al. 2003: Lichenizace primárně ve vodě před vstupem hub na souš

stáří lišejníků?

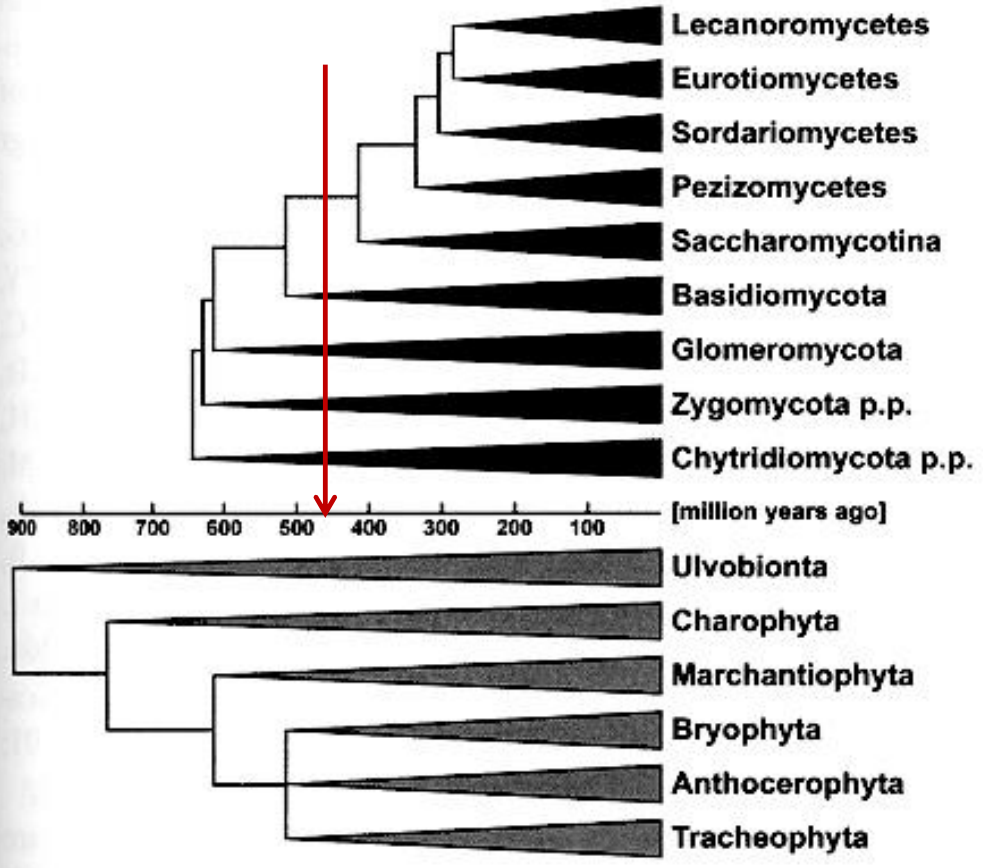


FIG. 2. The recalibrated fungal tree of life compared to the evolution of green plants, based on our most conservative estimates (TABLE IV). Green plant phylogeny and dating combined and simplified from various sources (Wang et al 1999; Heckman et al 2001; Hedges et al 2004; Yoon et al 2004, 2008; Steencamp et al 2006; Berbee and Taylor 2007; Moreira et al 2007: Zimmer et al 2007).

Eriksson 2005:

Protolichenes hypothesis (Pezizomycotina from lichenized ancestors)

Eriksson OE (2005) Ascomyceternas ursprung och evolution – Protolichenes-hypotesen. [Origin and evolution of *Ascomycota* – the Protolichenes hypothesis.] *Svensk Mykologisk Tidskrift* 26: 22–33.

vs.

Lücking RL, Huhndorf S, Pfister DH, Rivas-Plata E, Lumbsch HT (2009) Fungi evolved right on track. *Mycologia* 101: 810–822.

nejstarší fosilie lišejníku?

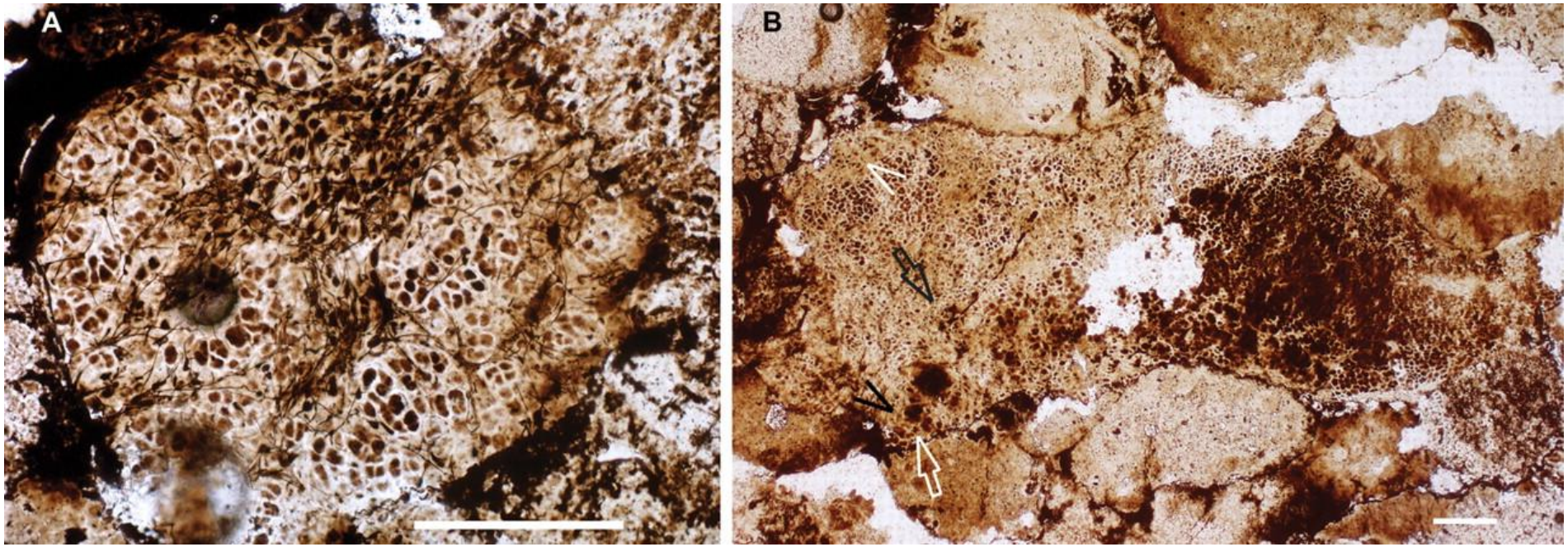
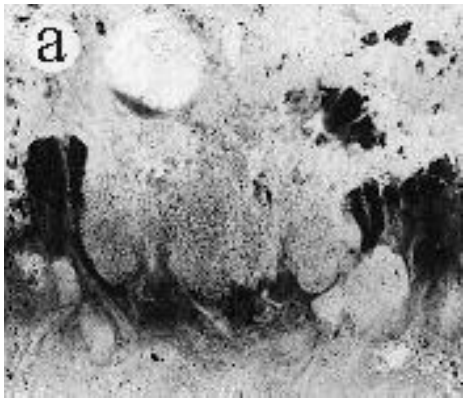


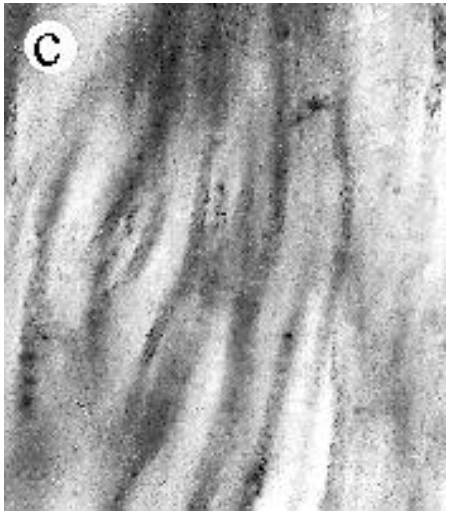
Fig. 1. Thin-section photomicrographs of two better-preserved specimens - Coccoidal thallus divided by dense filaments in the middle. Further compartmentalization of coccoidal thallus by less densely packed filaments is visible at higher magnification**. (551-635 MaBP)**

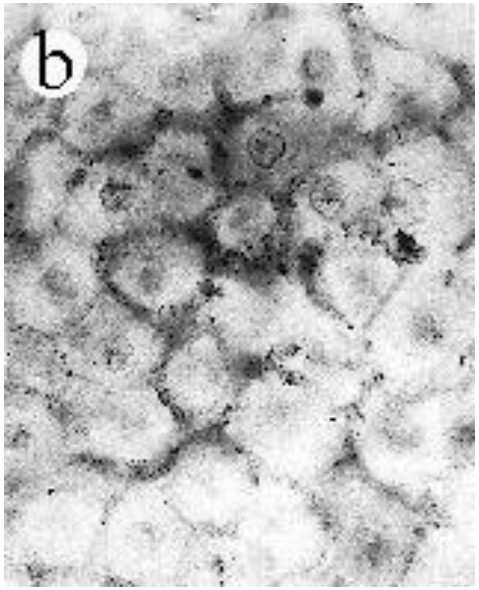
X. Yuan et al. Science 2005; 308:1017-1020.

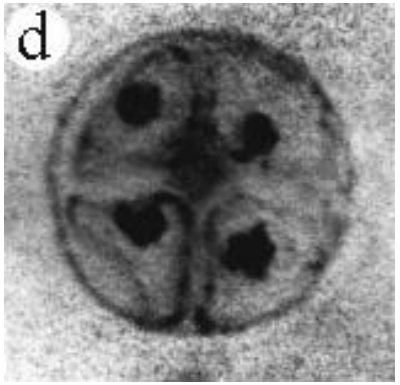
Science
AAAS

Lobaria - miocén





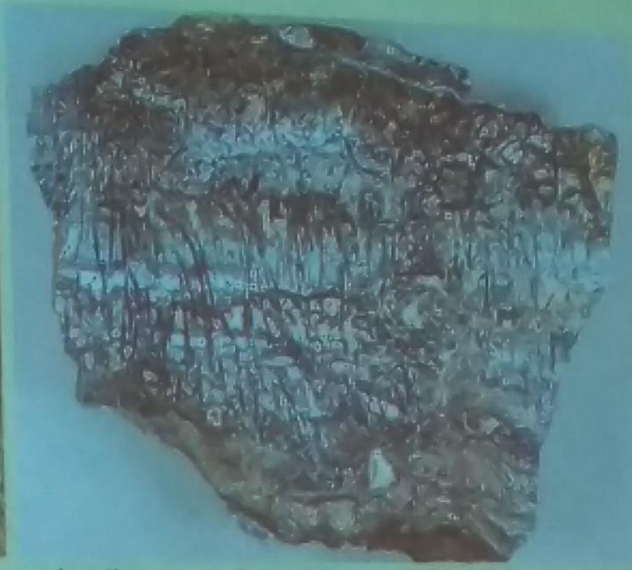




Rhynia chert – cyanolichen *Winfrenatia reticulata* (Copyright owned by University Münster). (Devon)

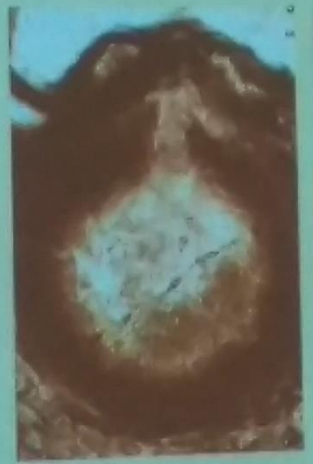
Lifelike preservation of diverse organisms: chert

Rhynie Chert, Scotland (early Devonian, 411.5 Ma)



Preservation of soft-bodied microorganisms and arthropods in microscopic fidelity

VA mycorrhizae



Paleopyrenomycites devonicus

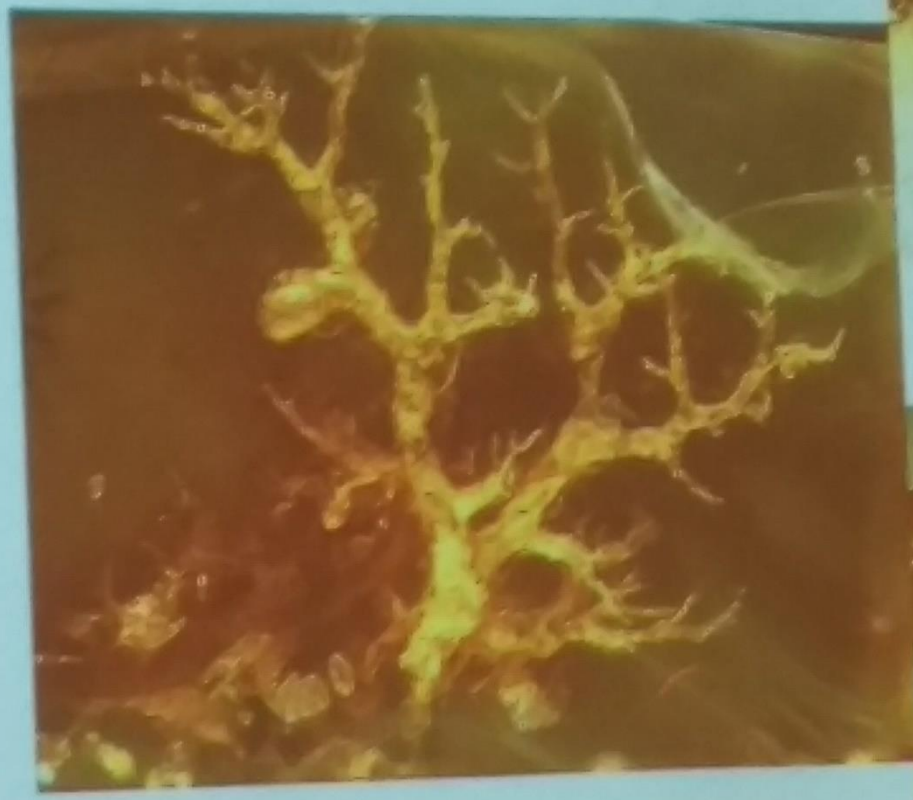
Nematode *Palaeonema* sp.

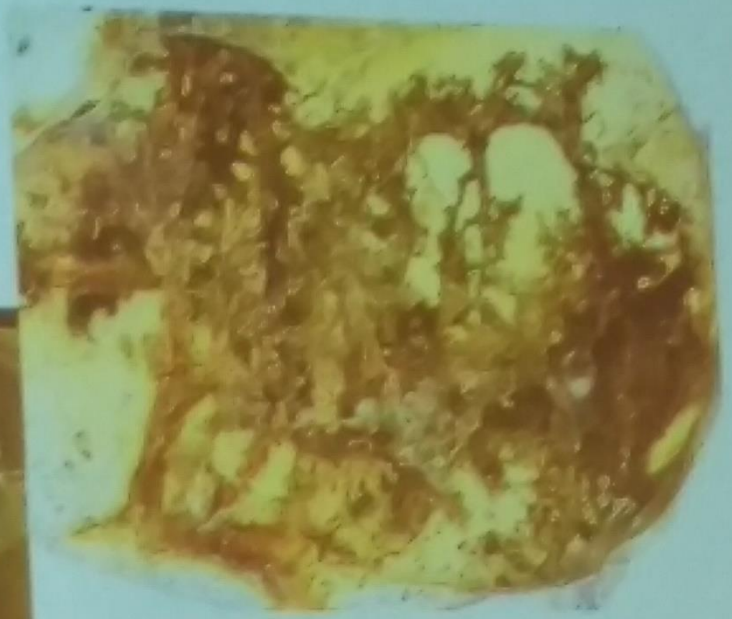
Harvestman *Eophalangium* (Opiliones)

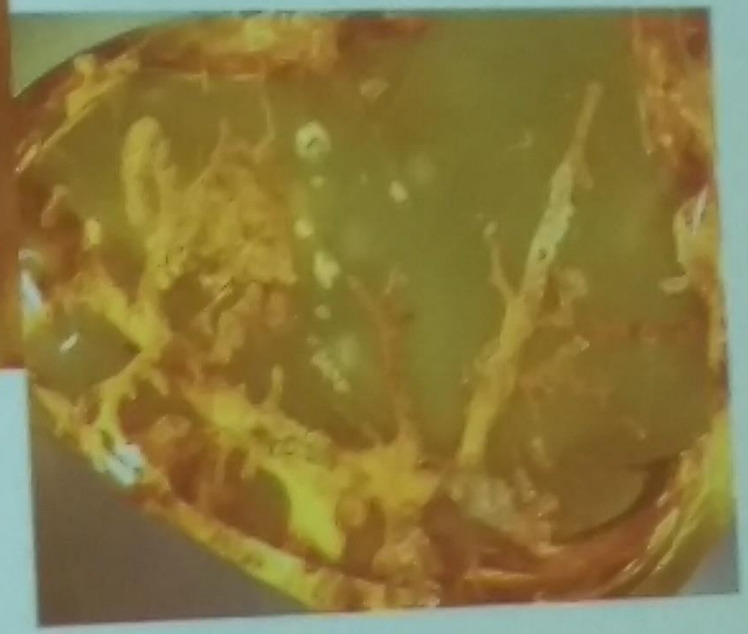
Images: courtesy of Hans Kerp (Münster)

Growth forms

Fruticose

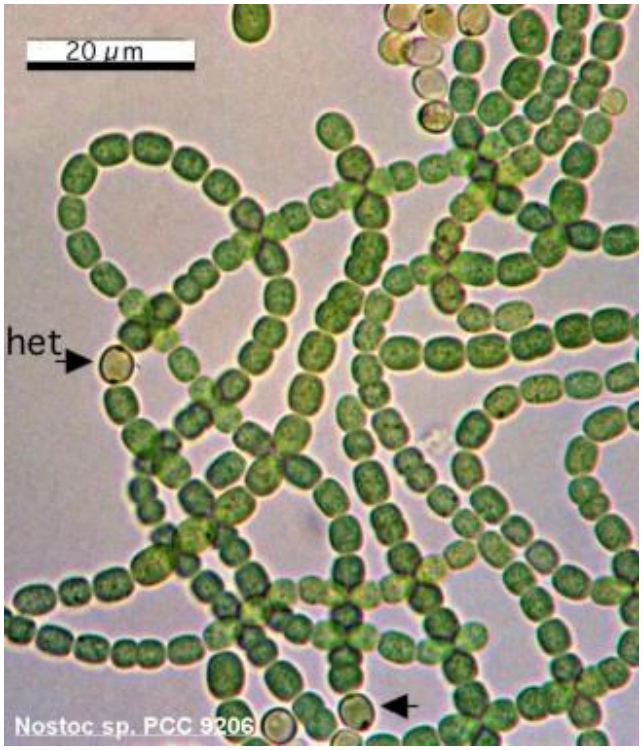




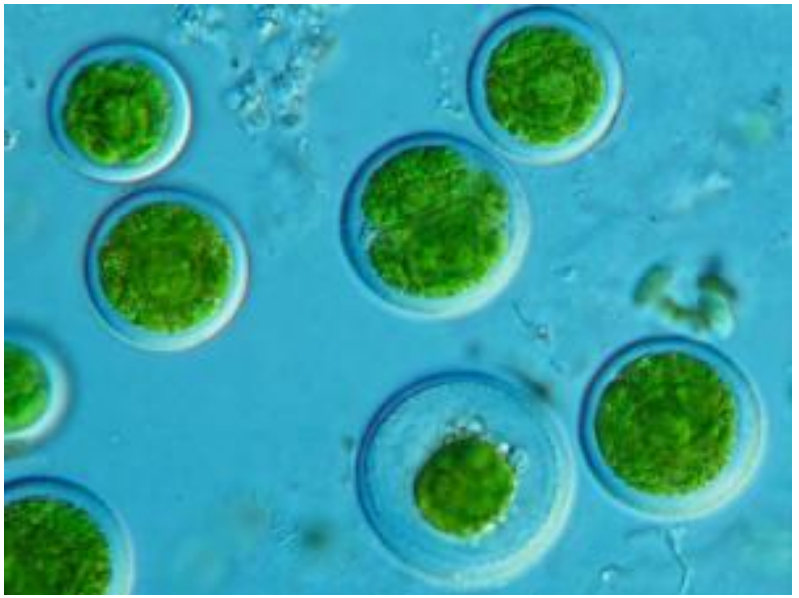


Fotobionti:

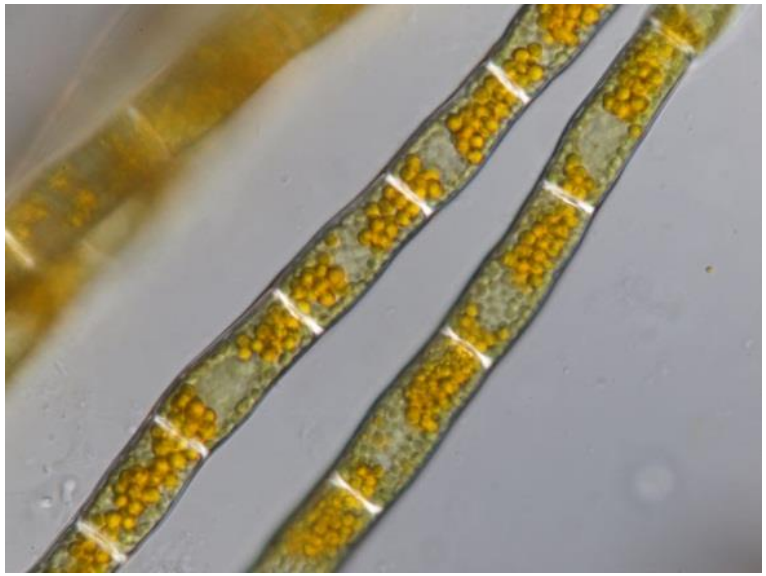
3 nejběžnější



sinice *Nostoc*



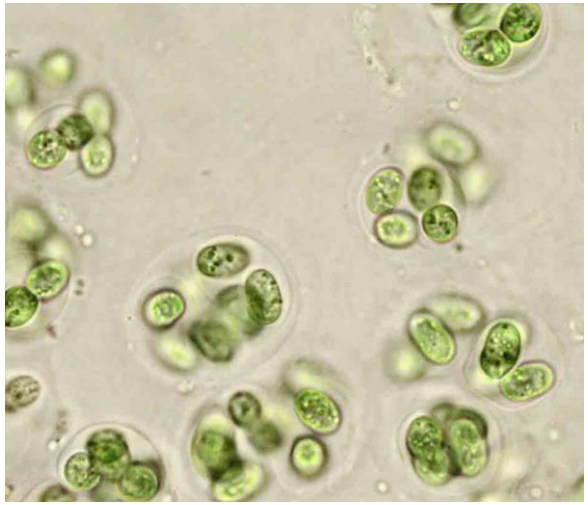
Trebouxia



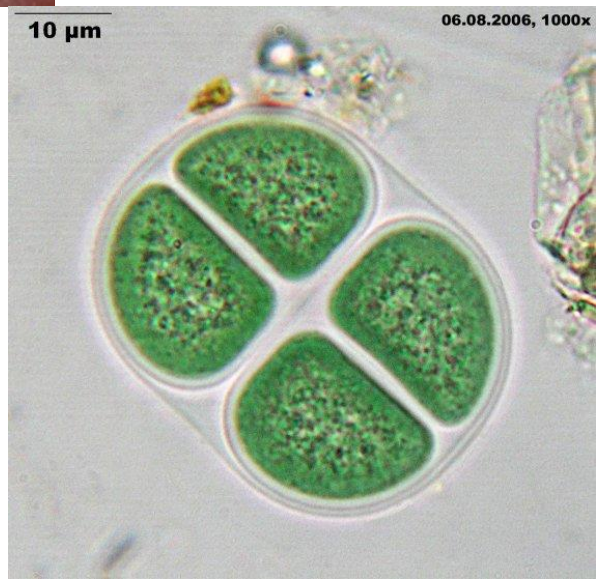
Trentepohlia

fotobionti sinice: ***Nostoc***, *Gloeocapsa, Chroococcus*

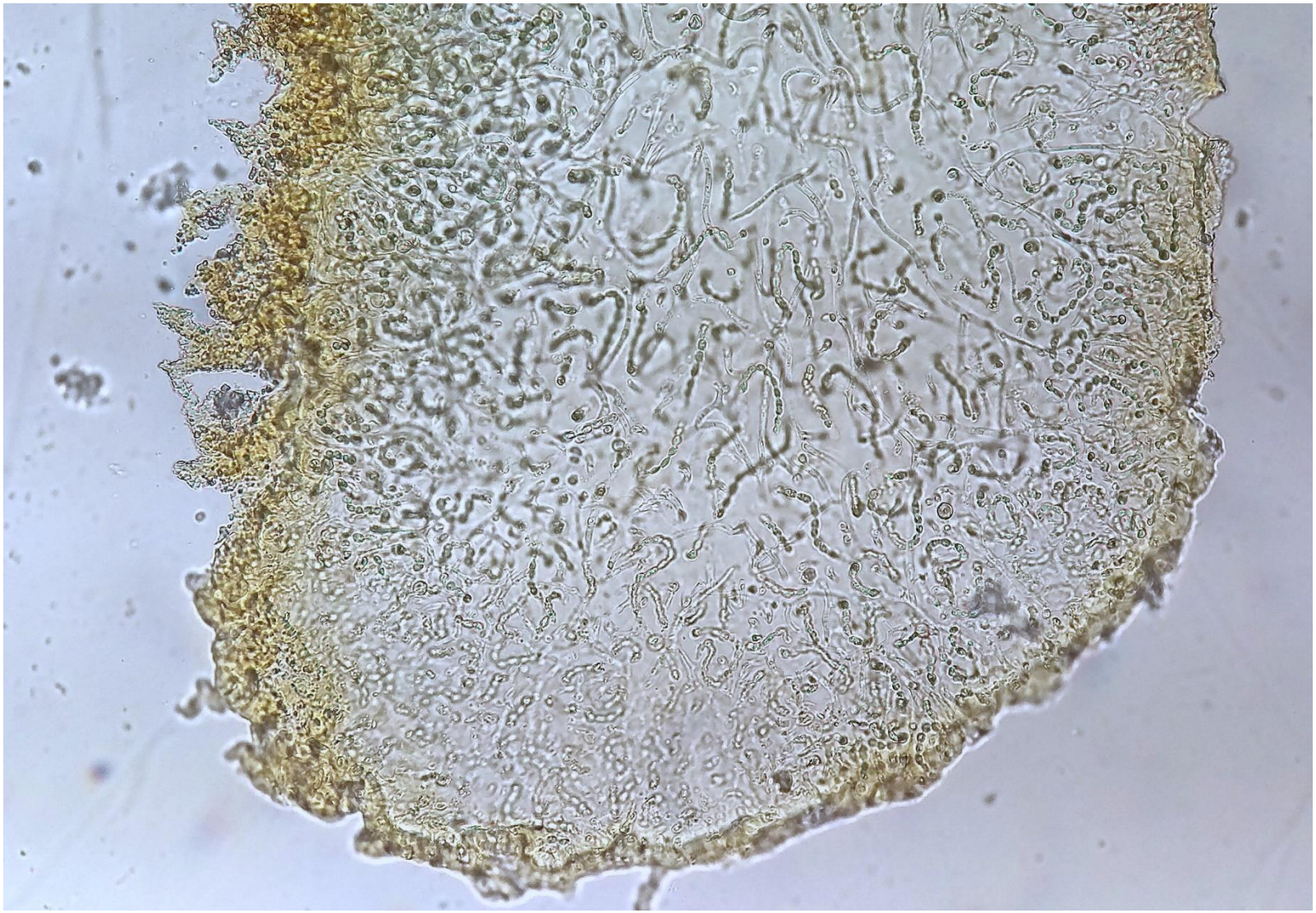
Nostoc



Gloeocapsa



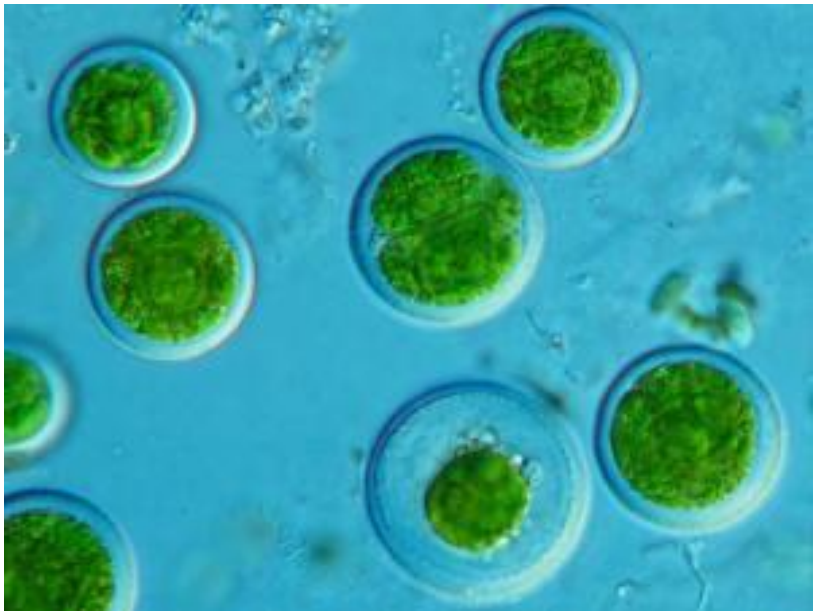
Chroococcus



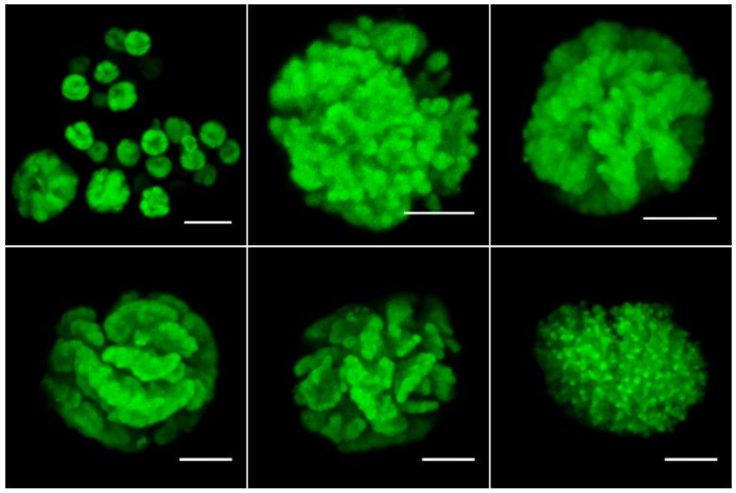
Collema

Lišejníky se sinicí (příklady)

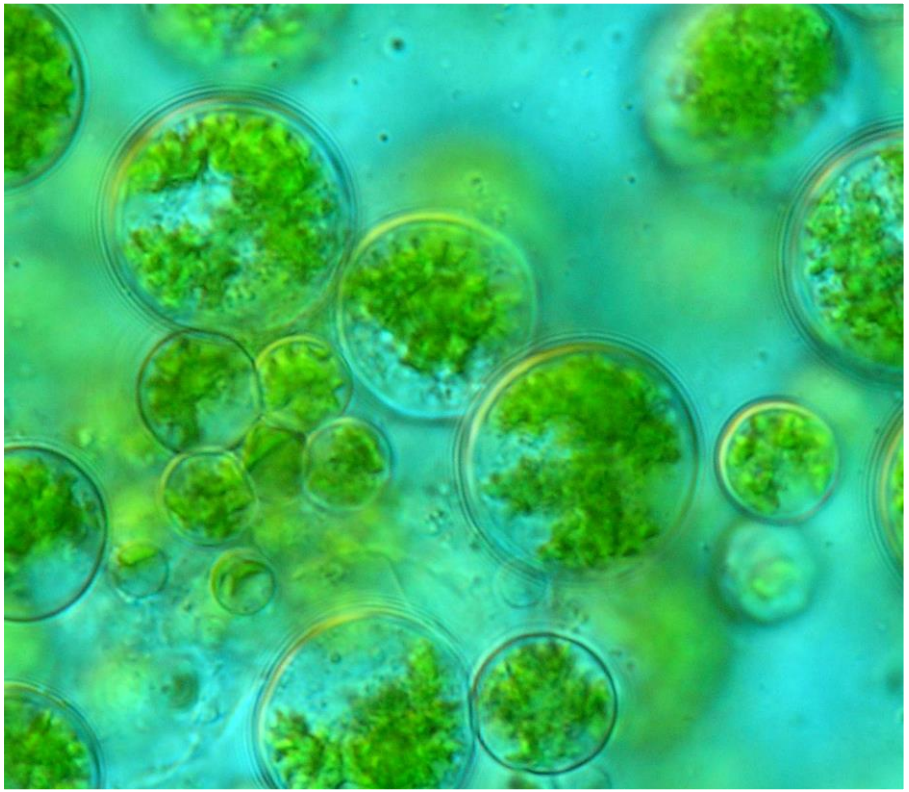
fotobionti: ***Trebouxia,*** *Asterochloris, Myrmecia*

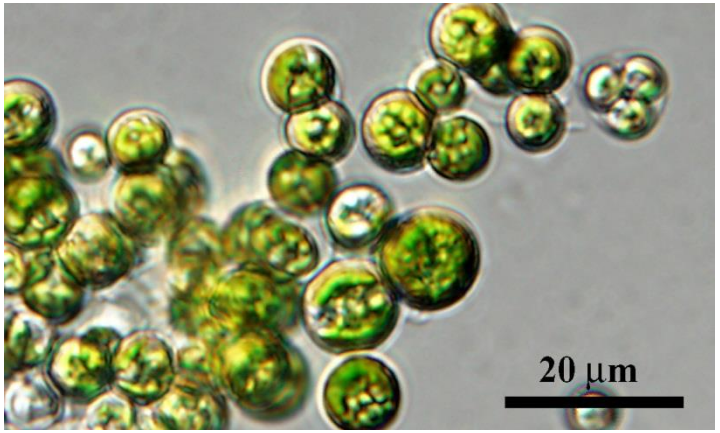


Trebouxia **(dole vývoj chloroplastu)**



Asterochloris





Myrmecia

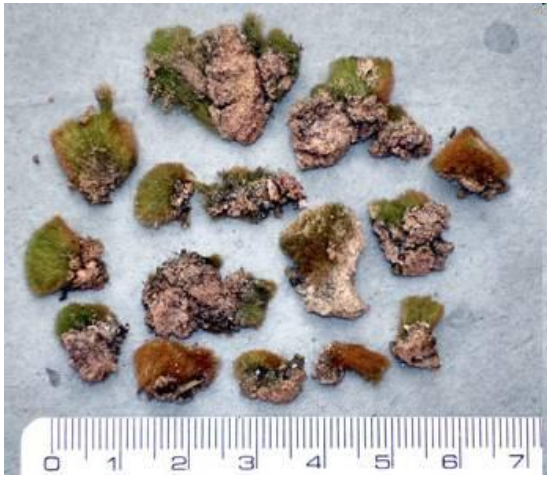
lišejníky s *Trebouxia*

zelené hávnatky (Peltigera)

***Parmelia* s. lat.**

Usnea

fotobionti: ***Trentepohlia***



lišejníky s *Trentepohlia*

Dirina

folikolní tropické lišejníky

Opegrapha

Anatomie, morfologie

Typy stélek dle anatomie:

heteromerická

homeomerická

Typy stélek dle morfologie:

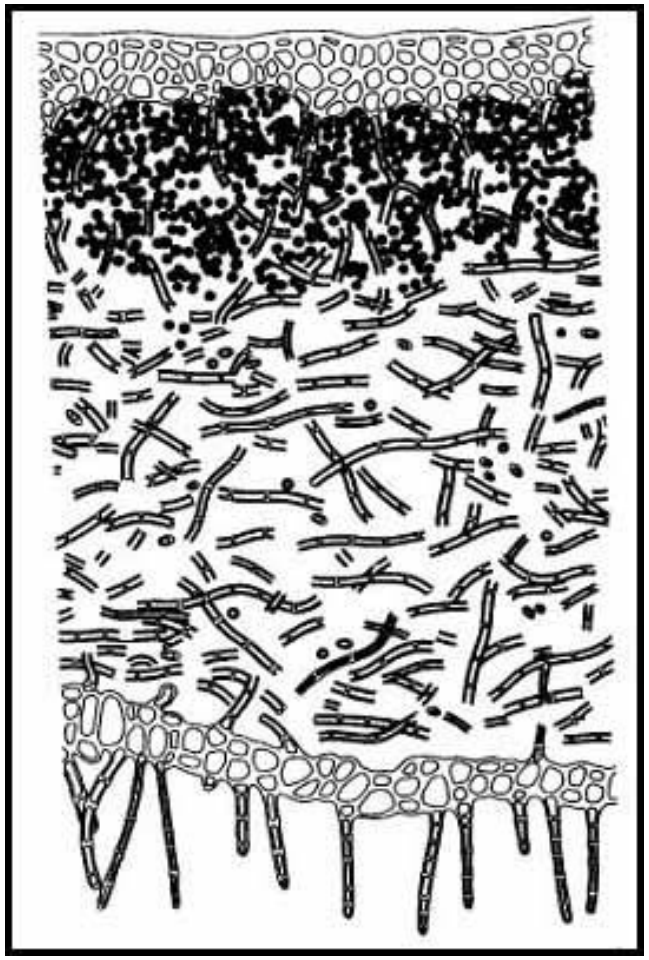
korovitá

lupenitá

keříčkovitá

Heteromerická stélka

Obecné schéma příčného řezu heteromerickou stélkou



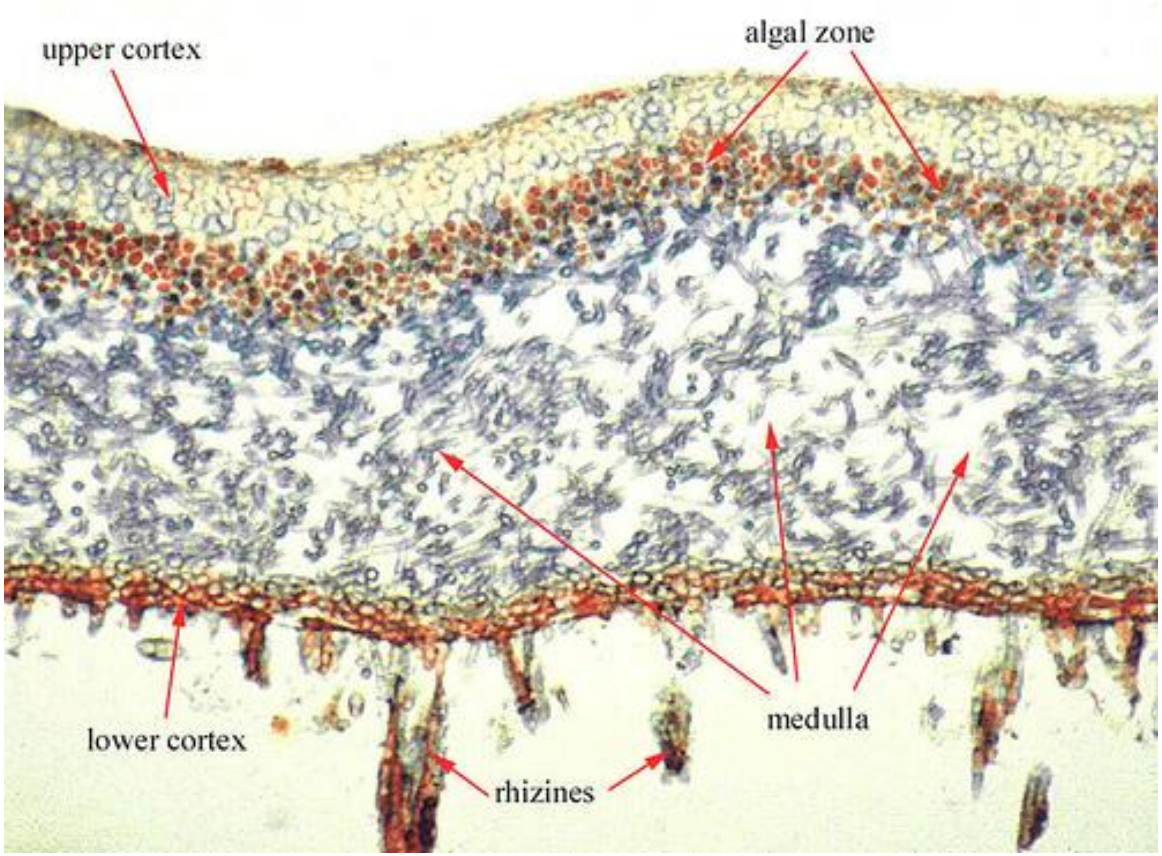
svrchní korová vrstva (epidermis)

řasová vrstva (vrstva fotobionta)

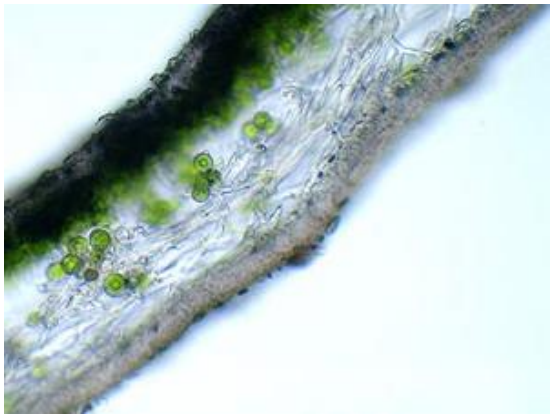
dřeňová vrstva

spodní korová vrstva

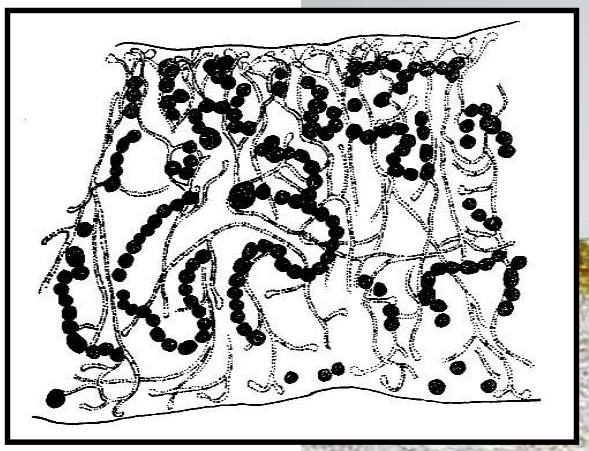
rhiziny

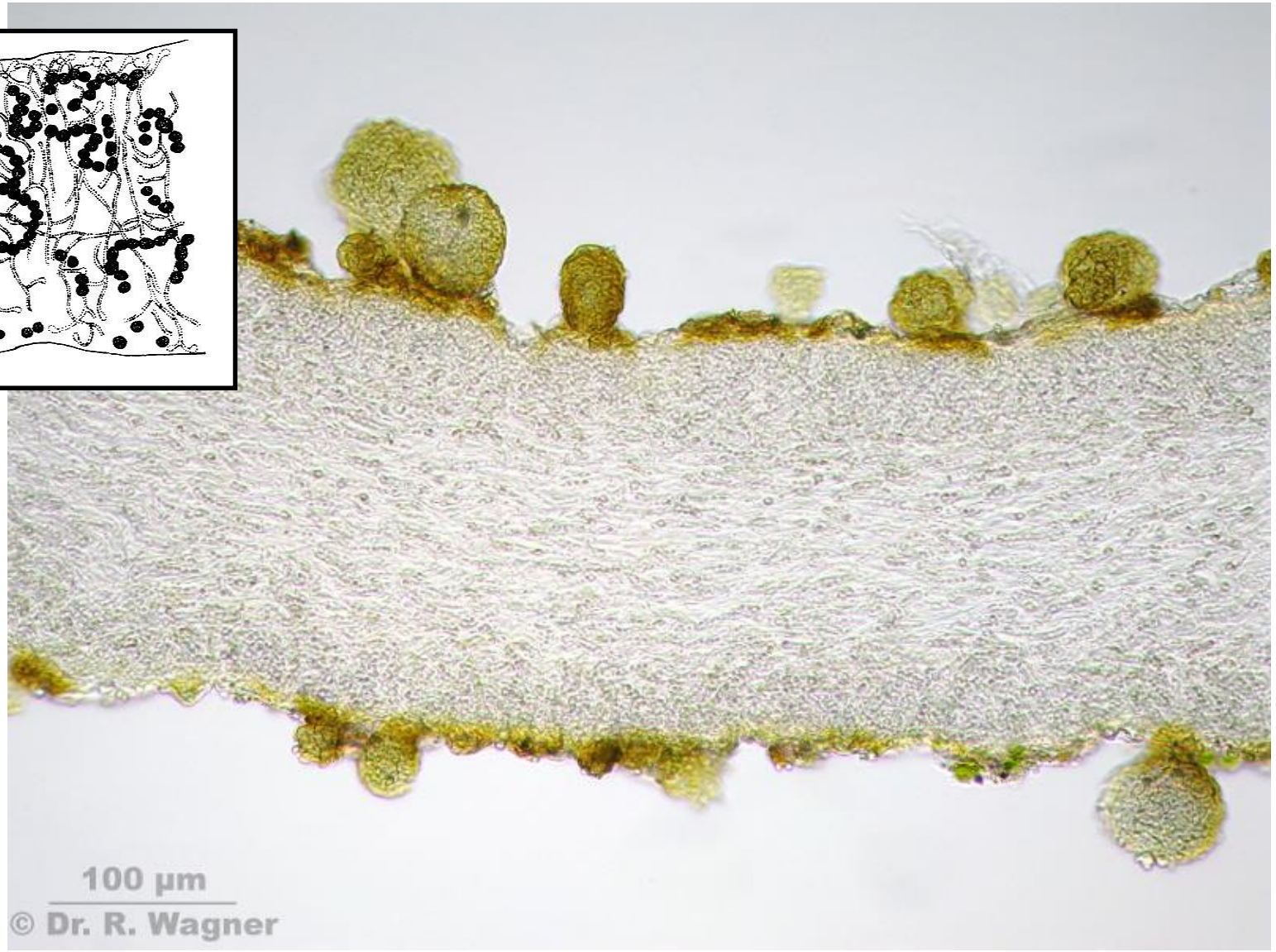


Heteromerická stélka



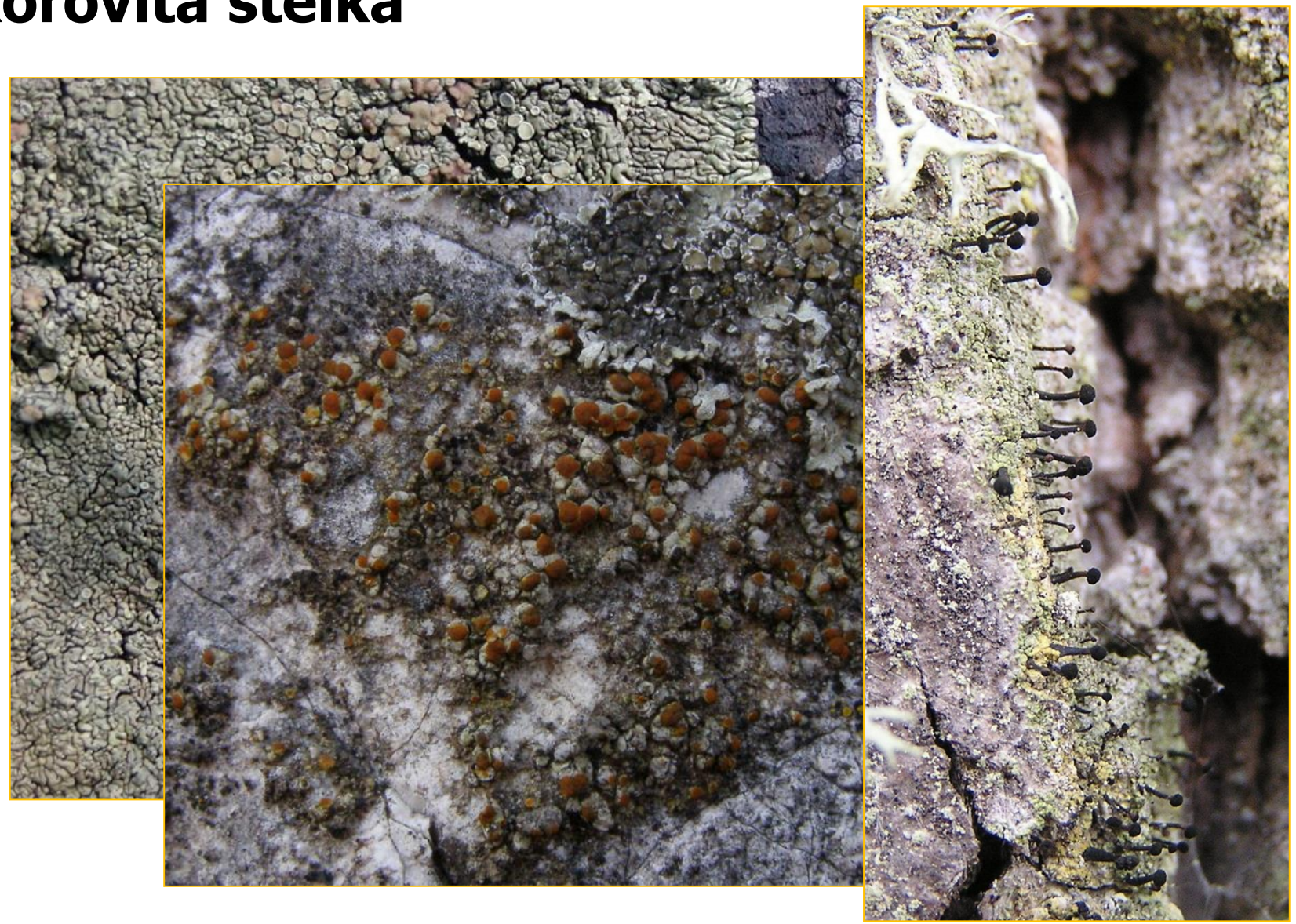
Homeomerická stélka (*Collema* sp.)





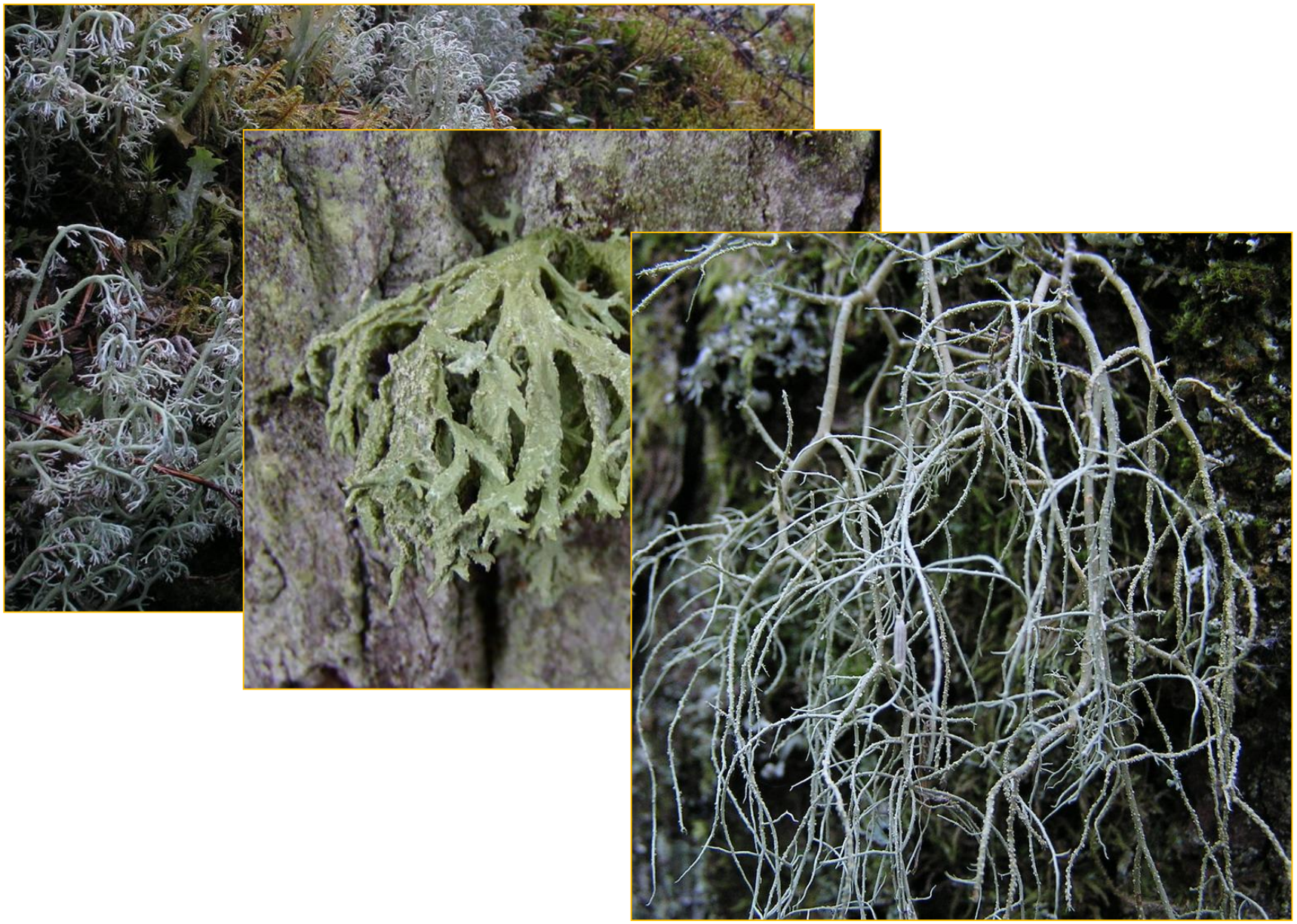
vrstvy nejsou rozlišeny

korovitá stélka



lupenitá stélka

keříčkovitá stélka



Dimorfická, smíšená stélka

keříčkovitá podetia (kmínky)

korovité či lupenité přízemní šupiny

Leprosní (práškovitá) stélka

řasové buňky obalené hyfami houby bez kompaktní struktury

Rozmnožování a rozmnožovací útvary lišejníků:

Rozmnožování:

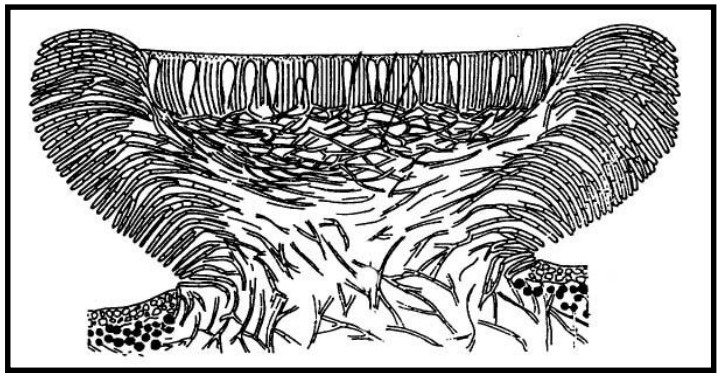
pohlavní – plodnice jako u hub (apothecia, perithecia, plodnice basidiomycet…)

nepohlavní – konidie (nepohlavní spory) nejčastěji v pyknidách

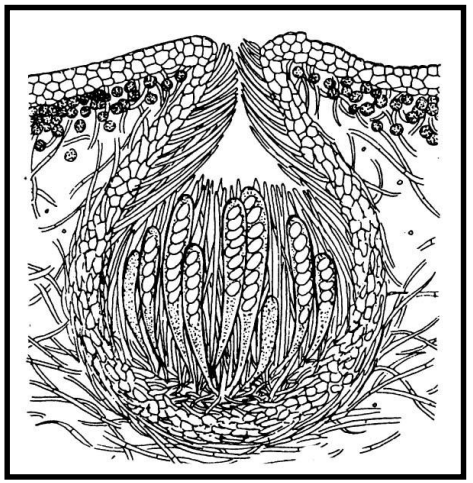
– vegetativní útvary

Pohlavní rozmnožování - základní typy plodnic (Ascomycota)

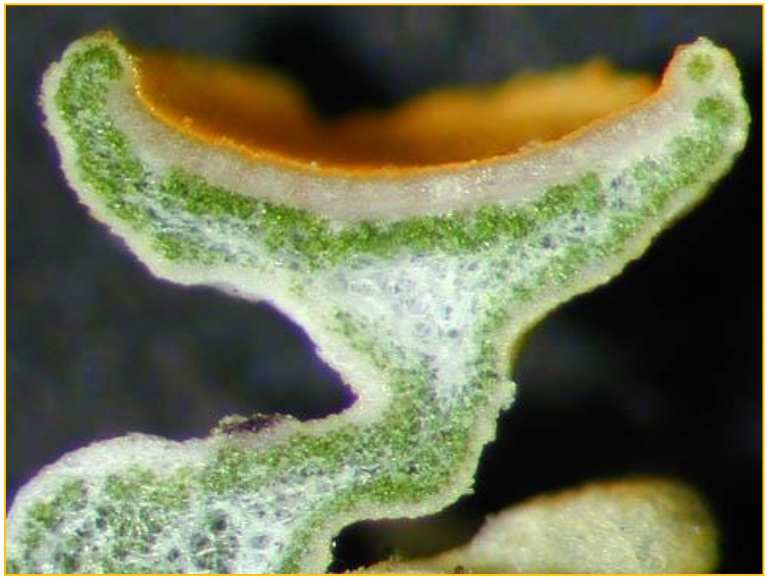
APOTHECIUM – diskovitá plodnice

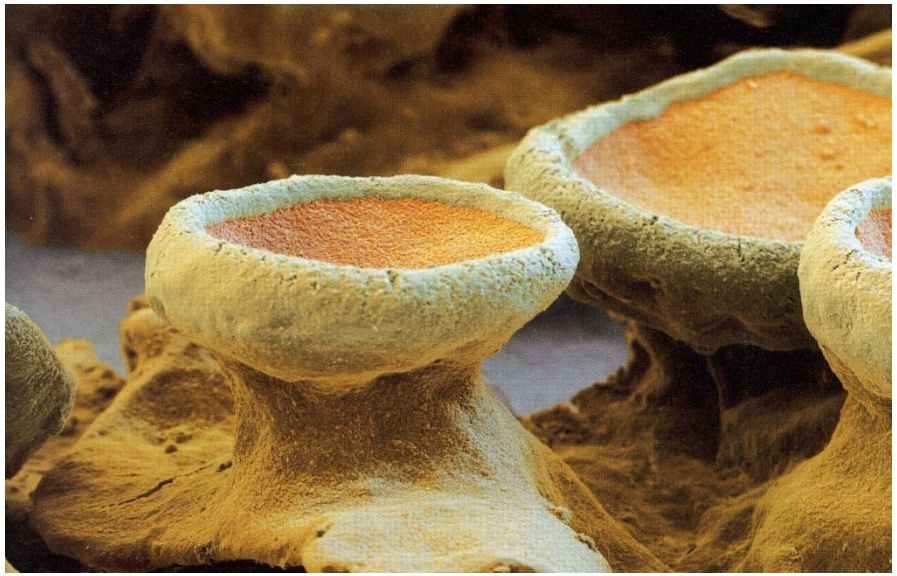


PERITHECIUM – hruškovitá plodnice



Apothecium



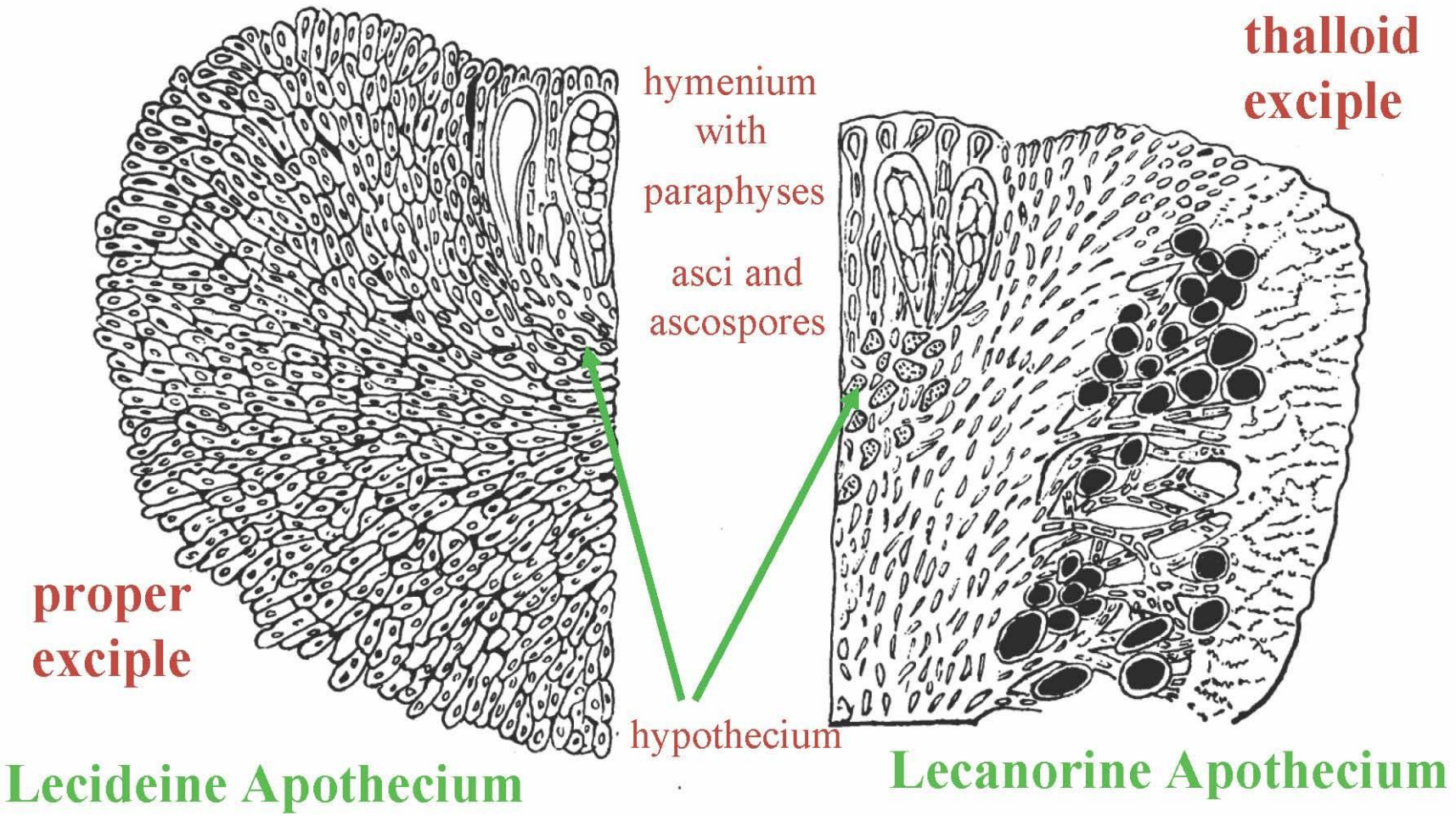


Apothecium

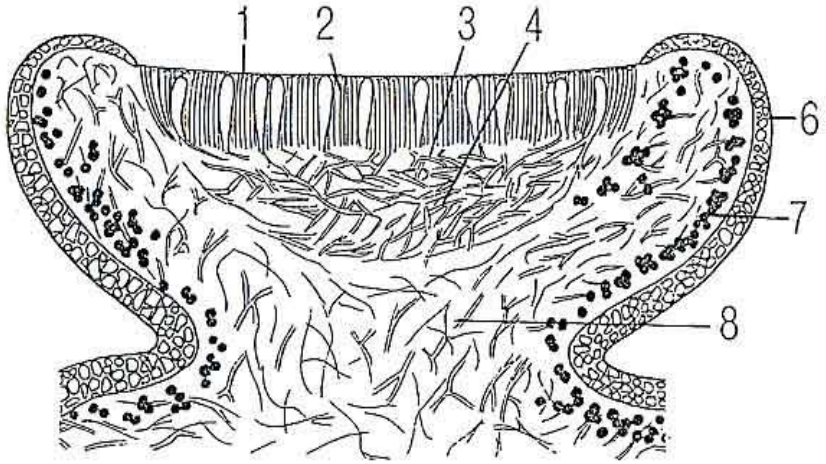
Thelotrema lepadinum

Peltigera horizontalis

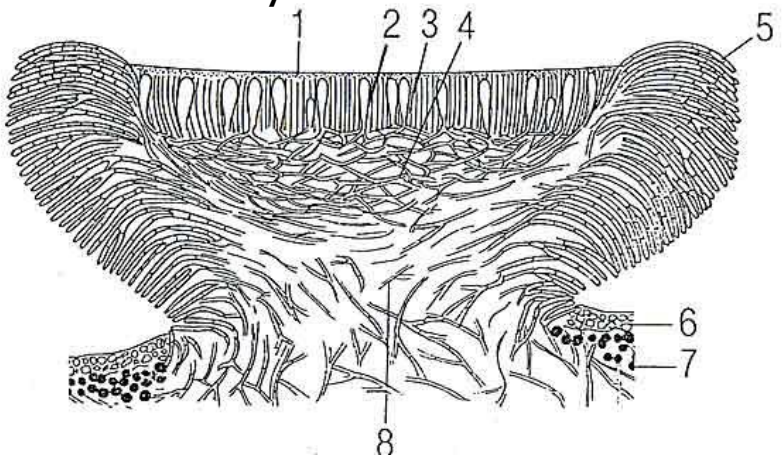
Cladonia callosa


thalloid exciple
hymenium with paraphyses
asci and ascospores
proper exciple
hypothecium
Lecideine Apothecium
Lecanorine Apothecium

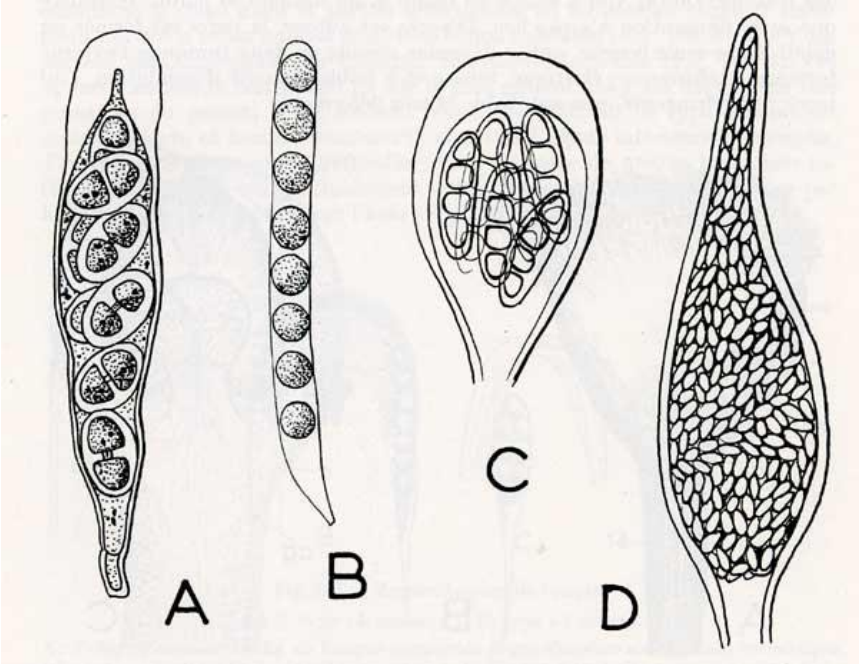
lekanorovité - stélkový okraj

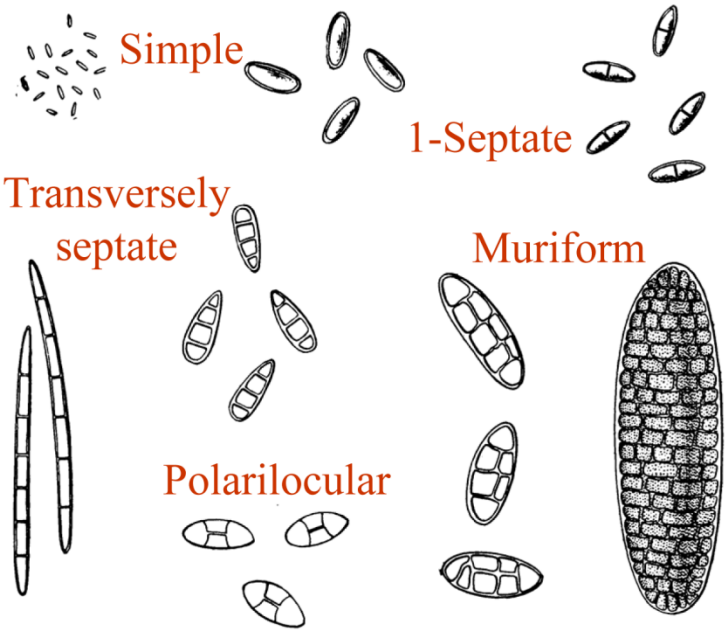


lecideovité – vlastní okraj karbonizovaný



vřecka a spory lišejníků

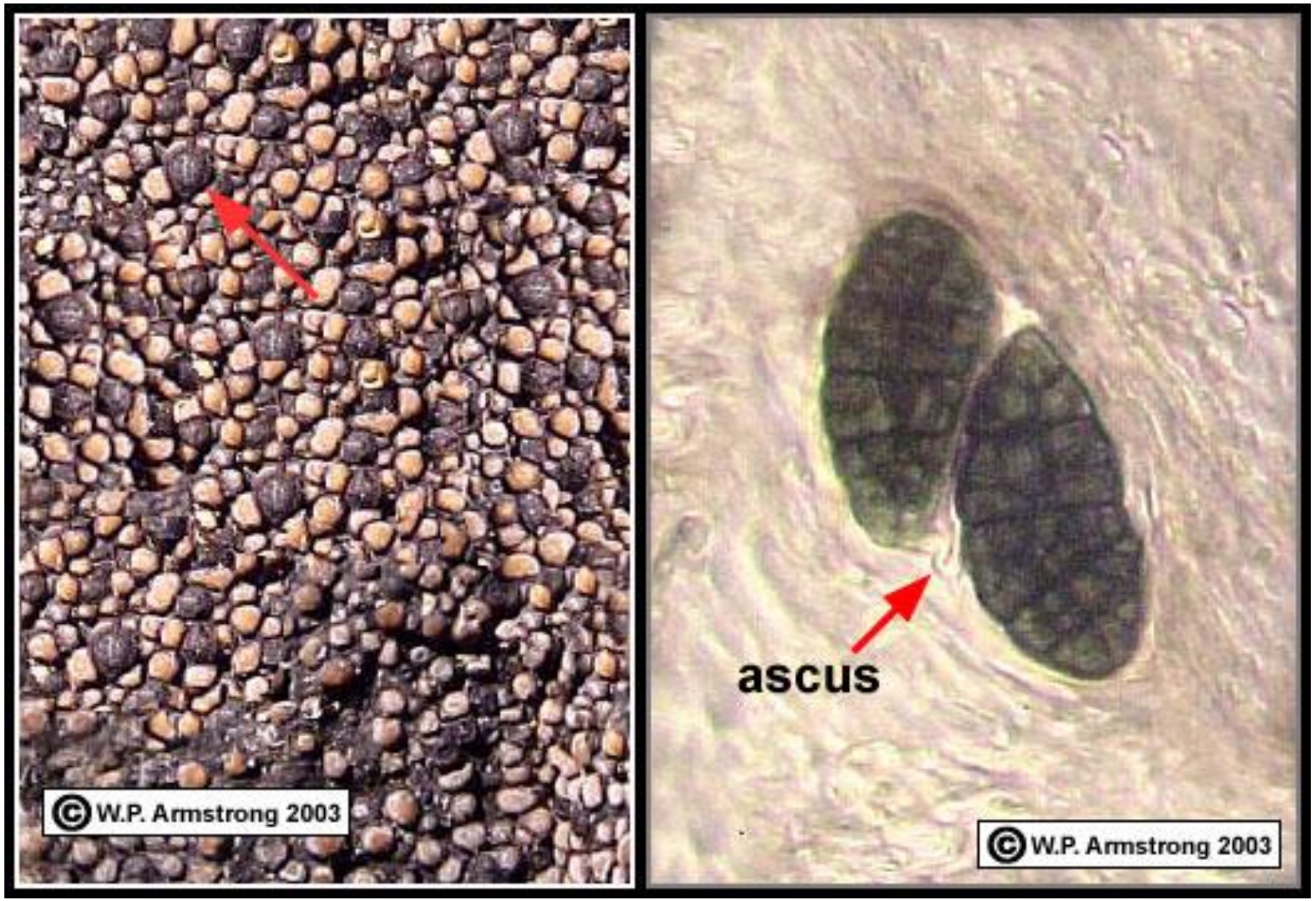




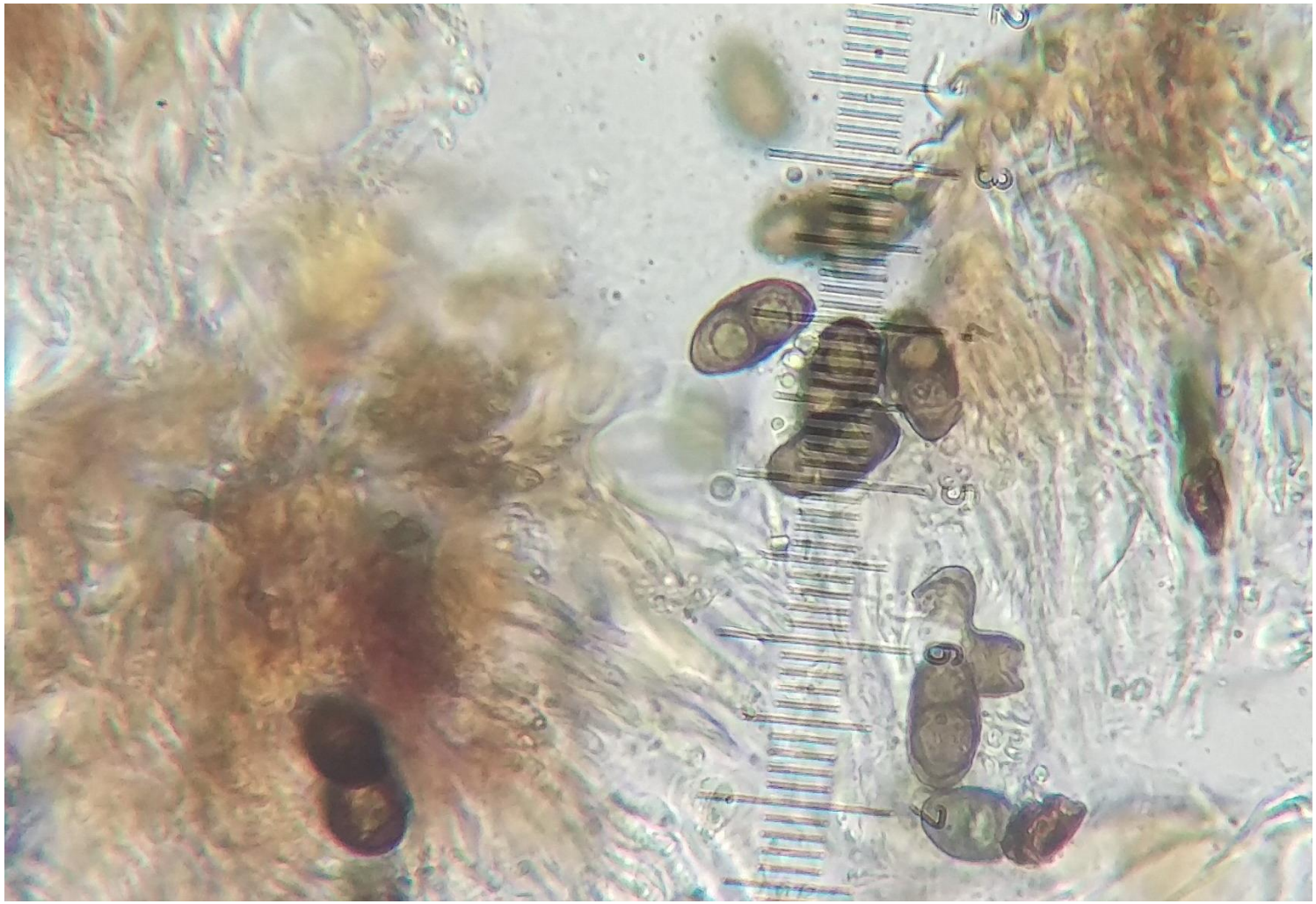
Pertusaria – vřecka a spory

Cladonia – vřecka a spory

Lichen =
algue +
champignon
Xanthoria parietina
(c) Jacques Beck Ceccaldi



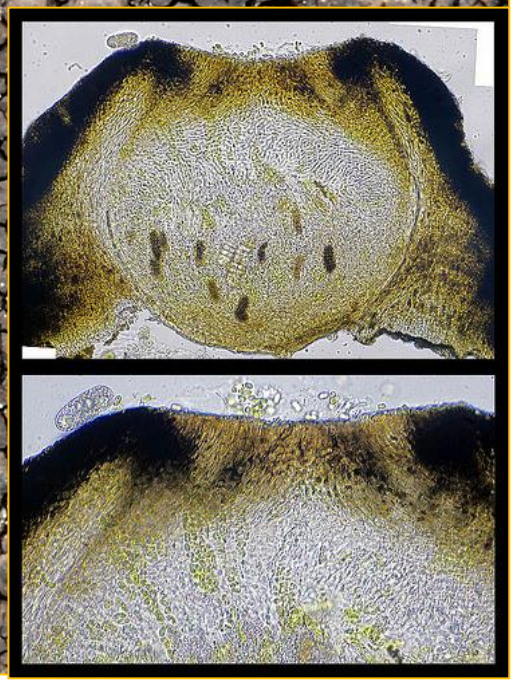
Rhizocarpon geminatum



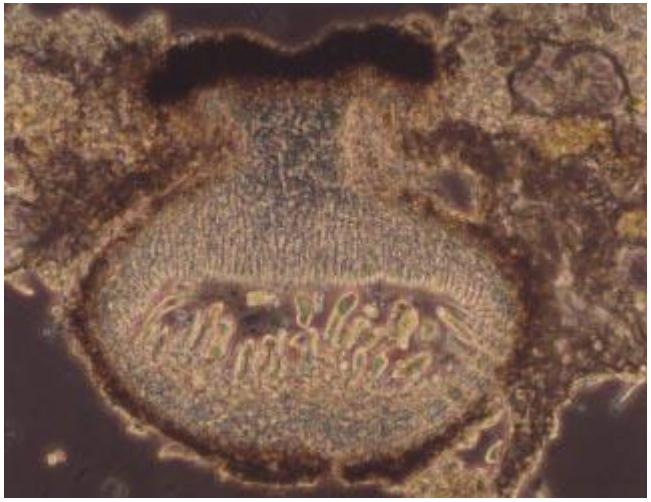
Rinodina lecanorina

Scoliciosporum chlorococcum

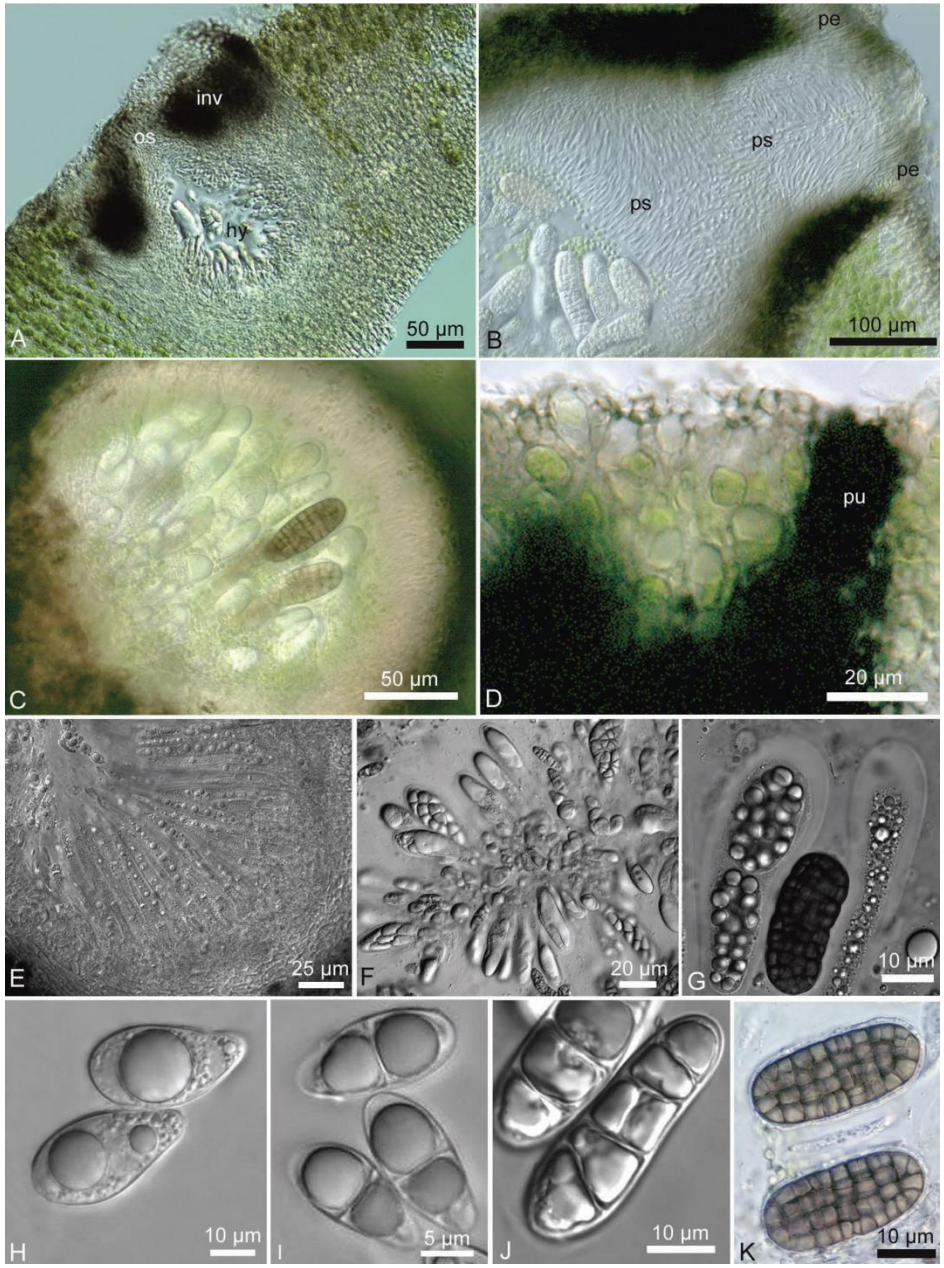
Perithecium



Perithecium, spory



Halda J. (2003):A taxonomic study of the calcicolous endolitic species of the genus Verrucaria Ascomycotina, Verrucariales) with the lid-like and radiately opening involucrellum. – Acta mus. Richnov. 10:1-148.



Gueidan et al. 2009: Generic classification of the Verrucariaceae (Ascomycota) based on molecular and morphological evidence: recent progress and remaining challenges. – Taxon 58:184-208.