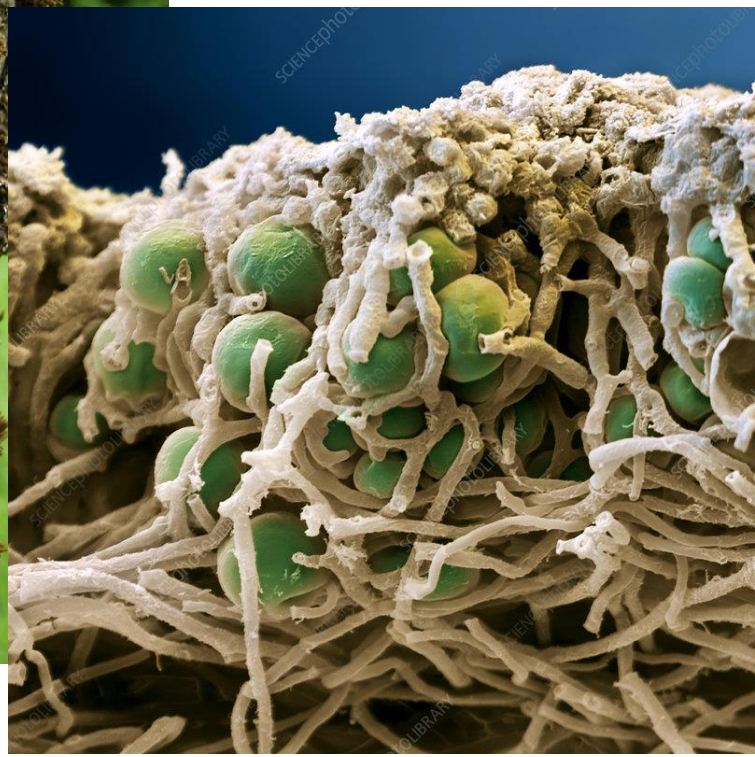
Botanika bezcévných rostlin a protistologie pro učitelské kombinace 2025

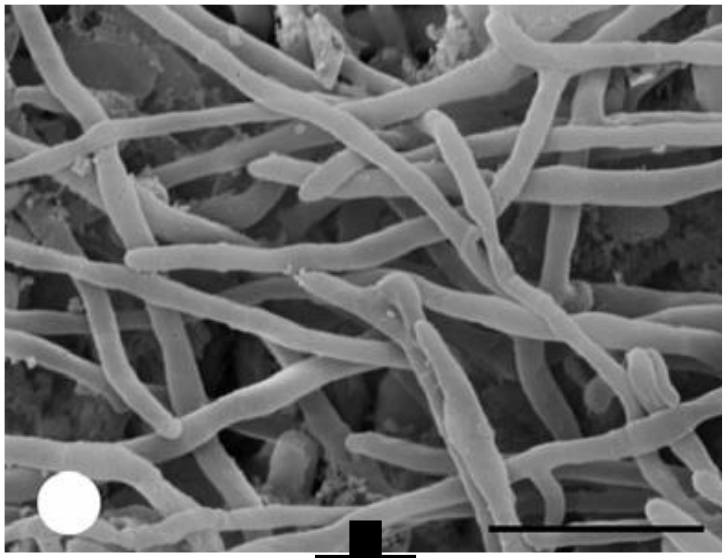
Lišejníky 1

David Svoboda

Co je lišejník?



Mycobiont/mycosymbiont



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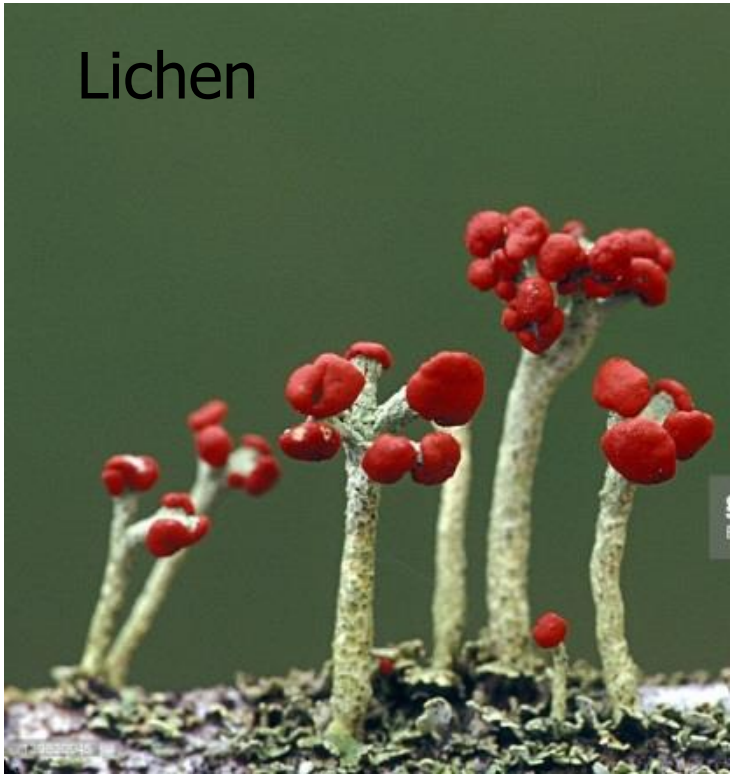
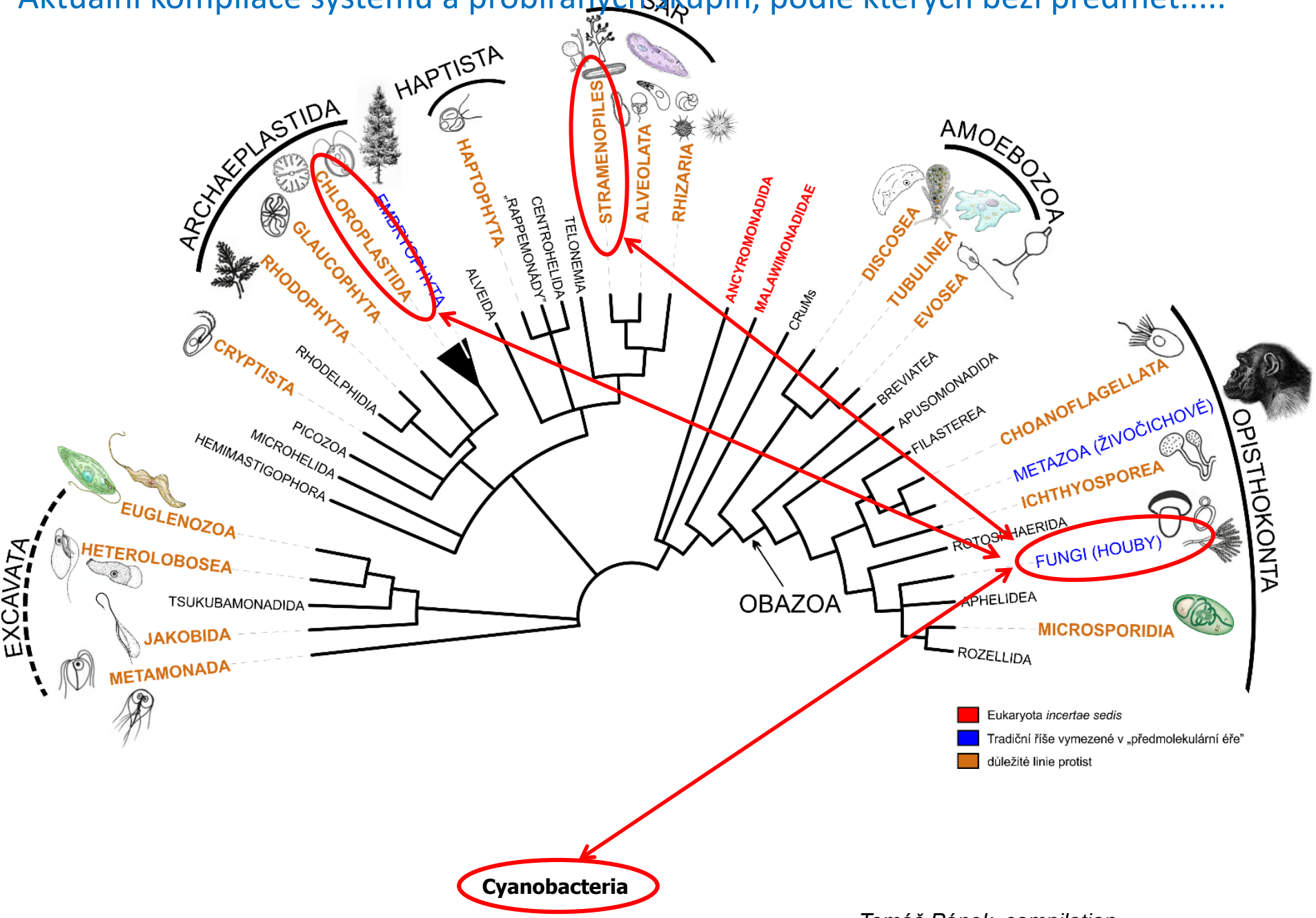
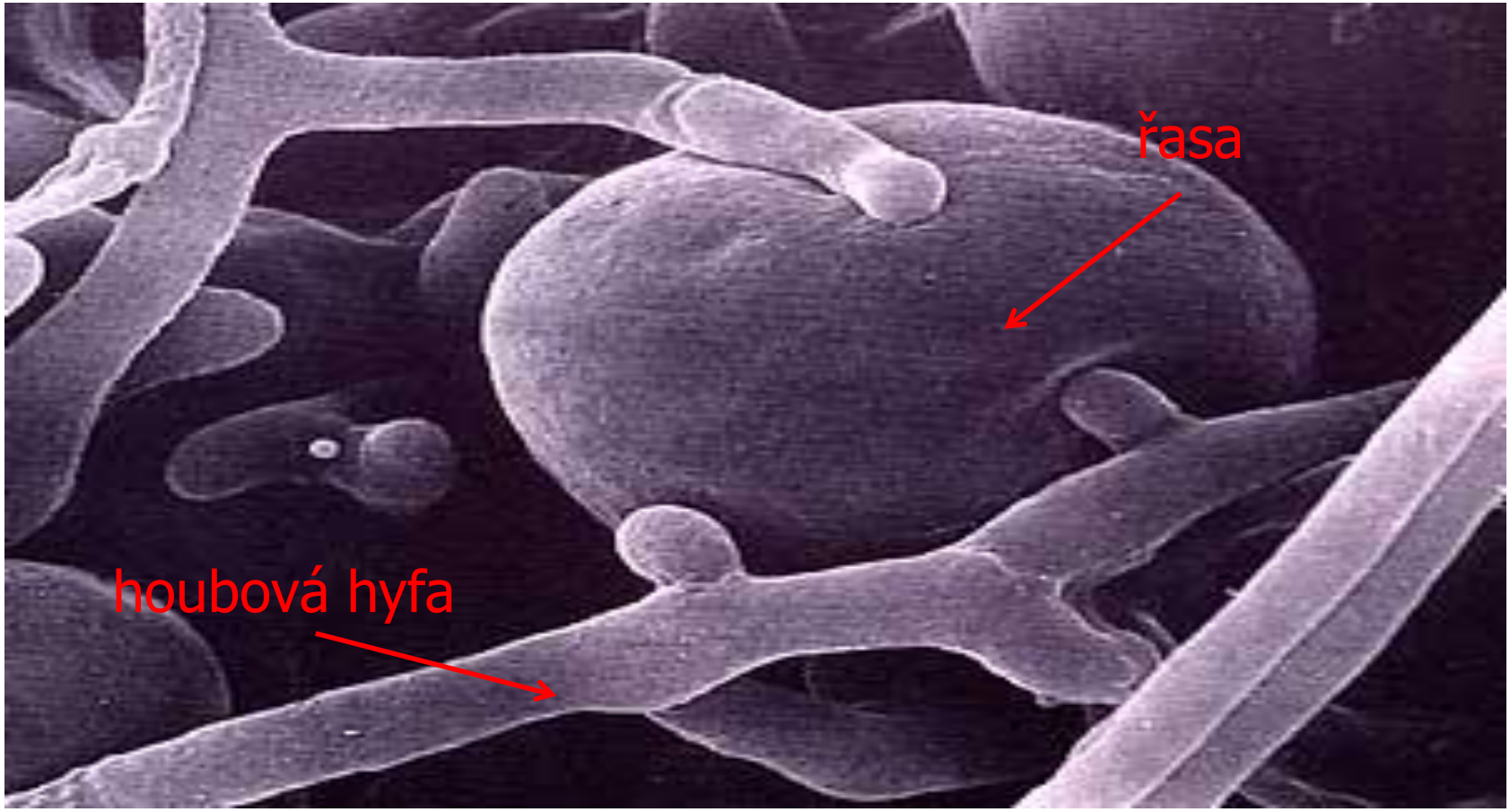


Photobiont/phycobiont/phycosymbiont

Aktuální kompilace systému a probíraných skupin, podle kterých běží předmět.....



Tomáš Pánek, compilation



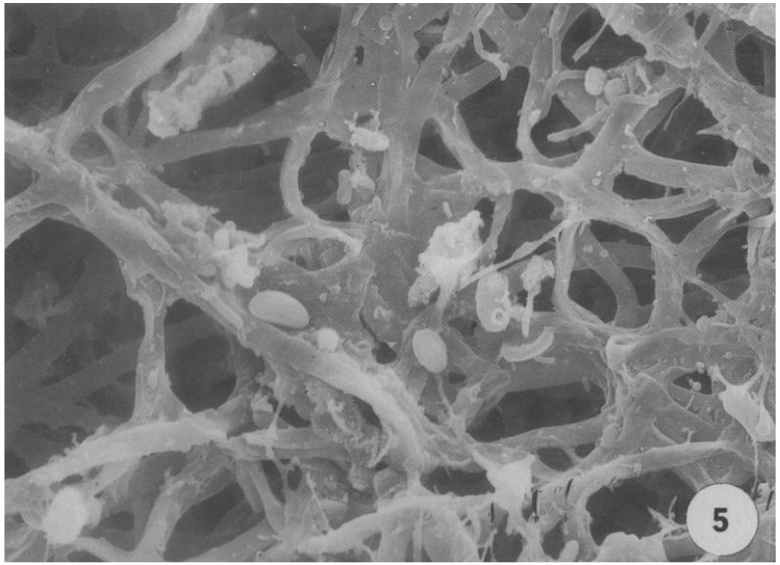
Lichenismus – asociace houby a zelené řasy/sinice za tvorby specifické stélky

Demi-lichenization
částečná lichenizace, volné soužití

Ne všechna soužití řasy a houby jsou lišejníky

choroš Trametes versicolor

nahoře: řasa v horní části plodnice



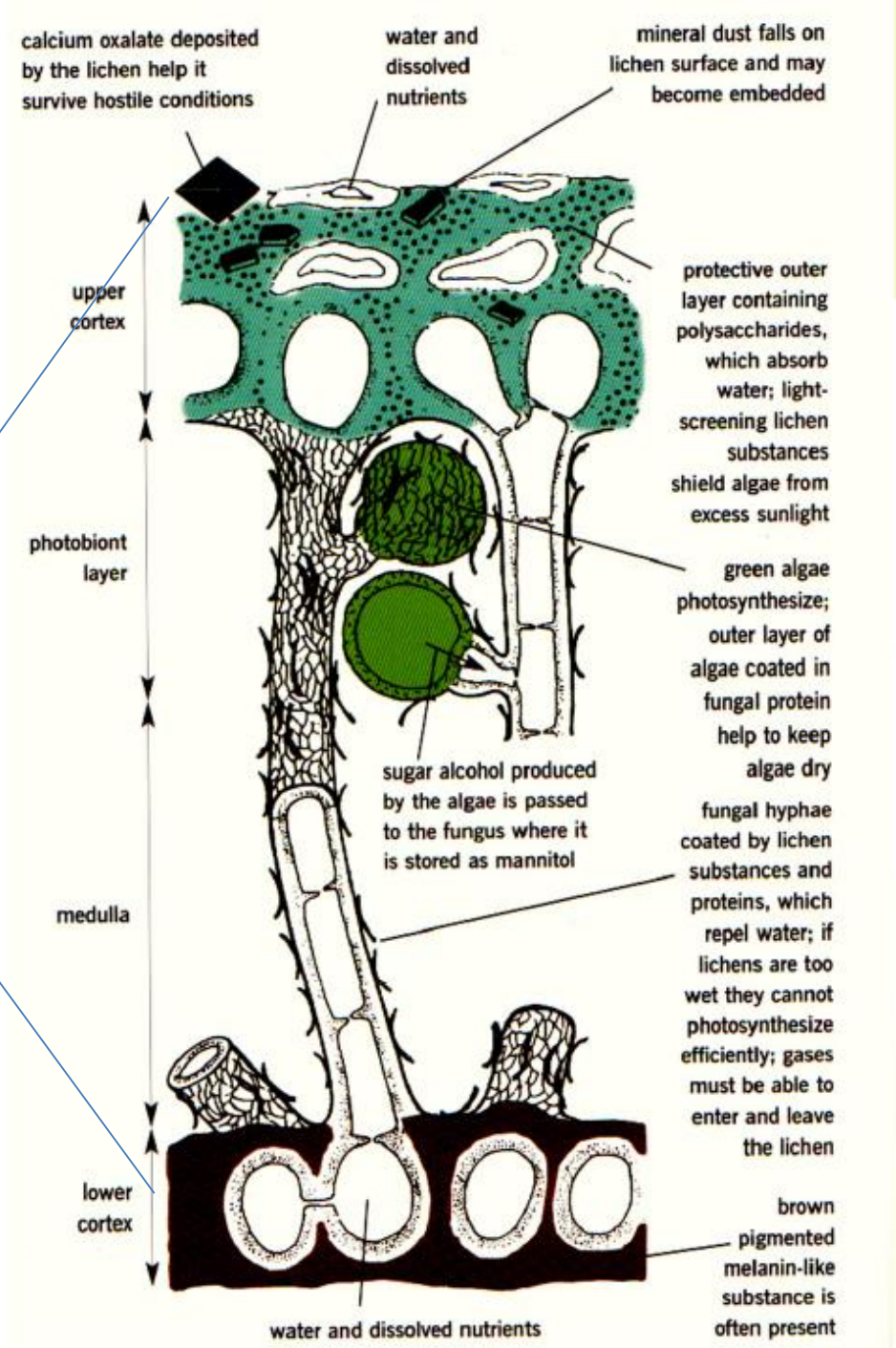
Zavada & Simoes 2001: SEM showing the loosely arranged hyphae with ovoid Trebouxia-like cells attached to the hyphae, X 1,000.

Characteristika asociace:

Symbióza?
Mutualismus?
Parasitismus?
Kontrolovaný parasitismus?
„zemědělství“?

volně žijící: - fotobionti jen zřídka
- mykobionti nikdy (?)

Jak to funguje?



Fotobiont

součást struktury lišejníku

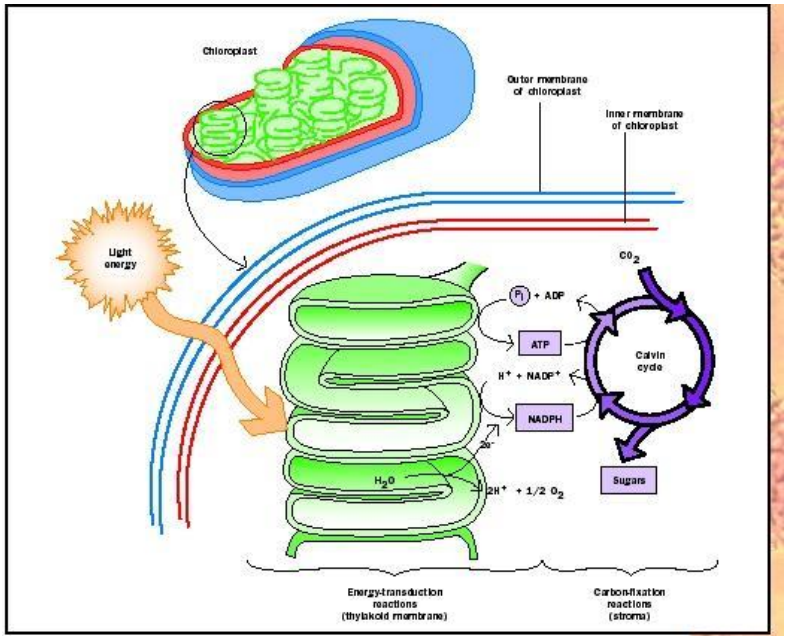
chráněn mykobiontem (UV, vyschnutí, herbivoři)

rozšíření niky

fotosyntéza

modifikovaná struktura (menší bb, větší chloroplasty)

nepohlavní rozmnožování (velmi vzácně i pohlavní)



Mykobiont

tvoří strukturu („tělo lišejníku")

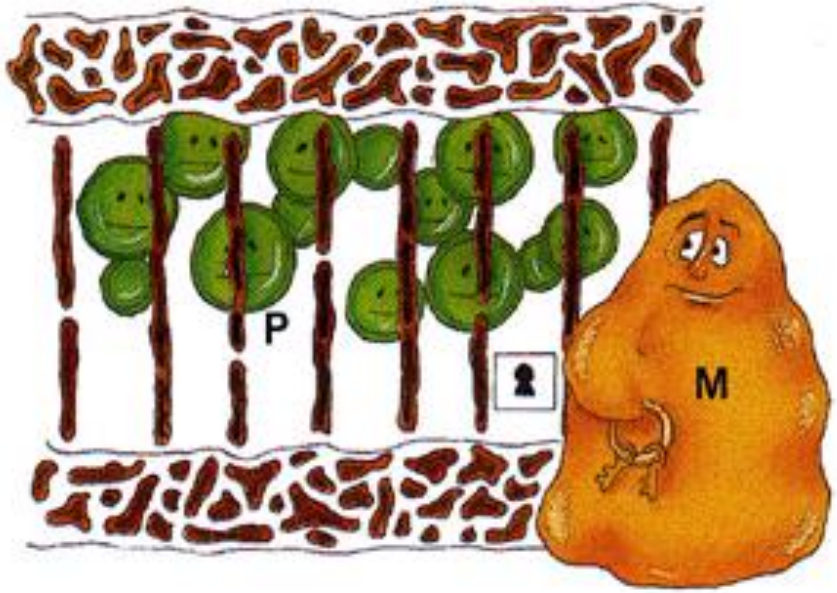
od fotobionta výživa

výživa a ochrana fotobionta (UV, vyschnutí, ...)

rozšíření niky (chladná, suchá místa)

stavba stélky

pohlavní rozmnožování



Lichens are fungi that discovered agriculture
(T. Goward)

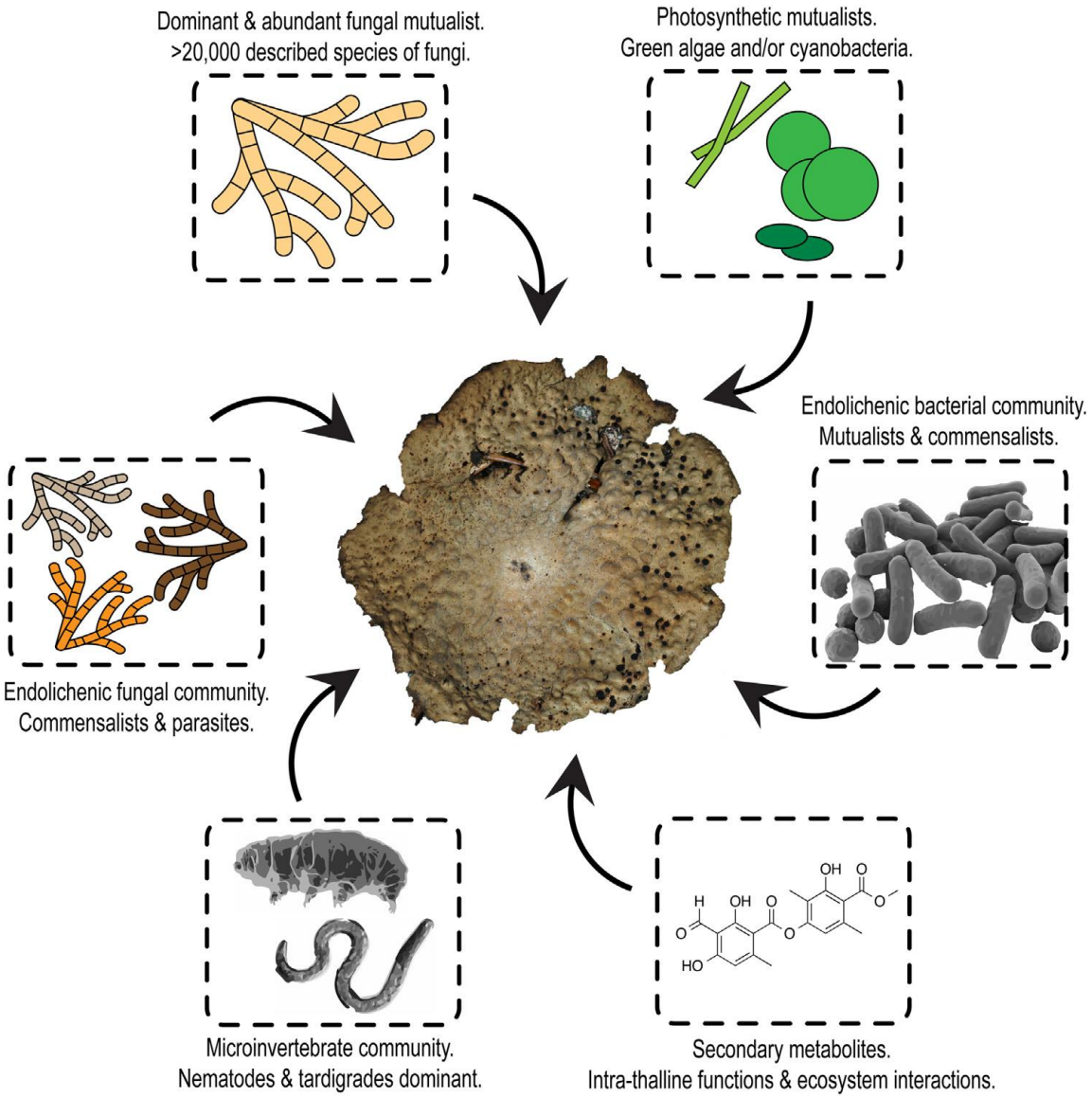
But…

A lichen is a **self-sustaining ecosystem** formed by **the interaction of an exhabitant fungus and an extracellular arrangement of one or more photosynthetic partners and an indeterminate number of other microscopic organisms**.

Hawksworth & Grube (2020) - New Phytologist

Současná pojetí

- Lišejníky dnes vnímány jako **meta-organismy, v kterých žije mnoho rozličných „spolubydlících“, kteří různými způsoby přispívají k prosperitě celku**
- Další potenciální partneři:
  - **mikroskopické houby**
  - **bakterie**



Allen & Lendemer 2022: A call to reconceptualize lichen symbioses- Trends in Ecology & Evolution, Month 2022, Vol. xx, No. xx (in press)

Lichen thallus deconstructed. Each individual lichen is comprised of a multitude of organisms that together constitute a miniature ecosystem. One primary mutualistic fungal symbiont contributes the majority of the biomass and structure to the thallus, and one or more photosynthesizing symbionts constitute the most important photosynthetic partners. Other species of fungi and microalgae, along with bacteria and micro-invertebrates, grow as commensalists in and among the scaffold of the dominant symbionts. Some species of fungi grow as pathogens and parasites. Secondary chemistry produced by the main fungal symbiont drives the functional interactions among organisms in the thallus and with the environment.

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

Cladonia rangiformis

+

Asterochloris mediterranea/lobophora/italiana/woessiae

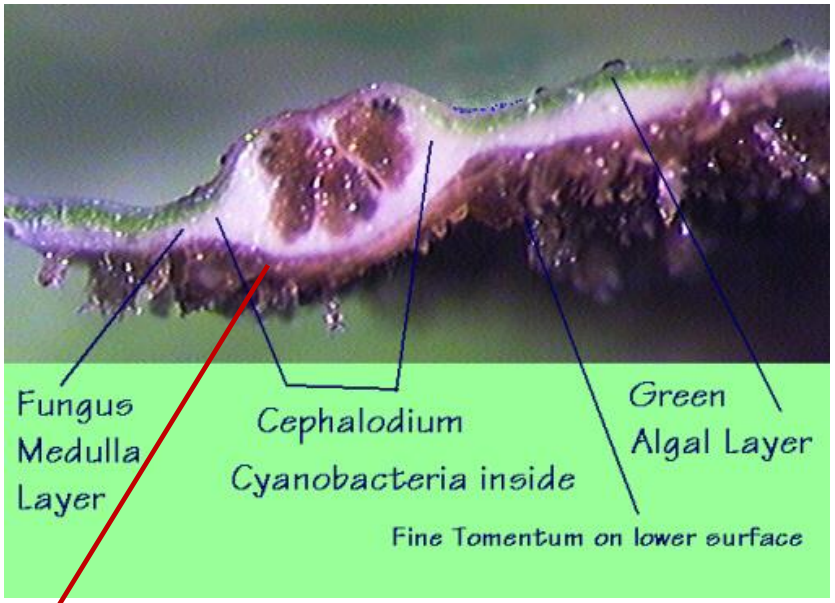
=

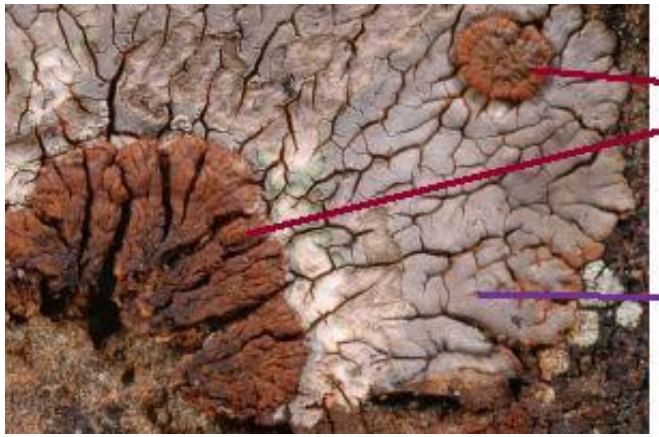
Cladonia rangiformis

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

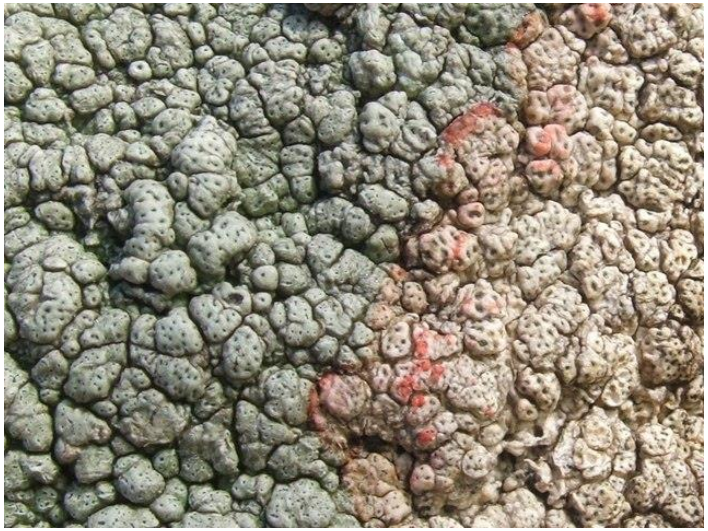
cephalodia – útvary s jiným fotobiontem (sinicí) na stélce

Jméno dává lišejníku houba – ale která houba?

Diversita hub v lišejnících

- parasitické houby
- parasitické lišejníky
- asymptomatické endothallické/endolichenické houby
- povrchový biofilm
- třetí, čtvrtý, … symbiotický partner?

Caloplaca thallincola na *Verrucaria maura*



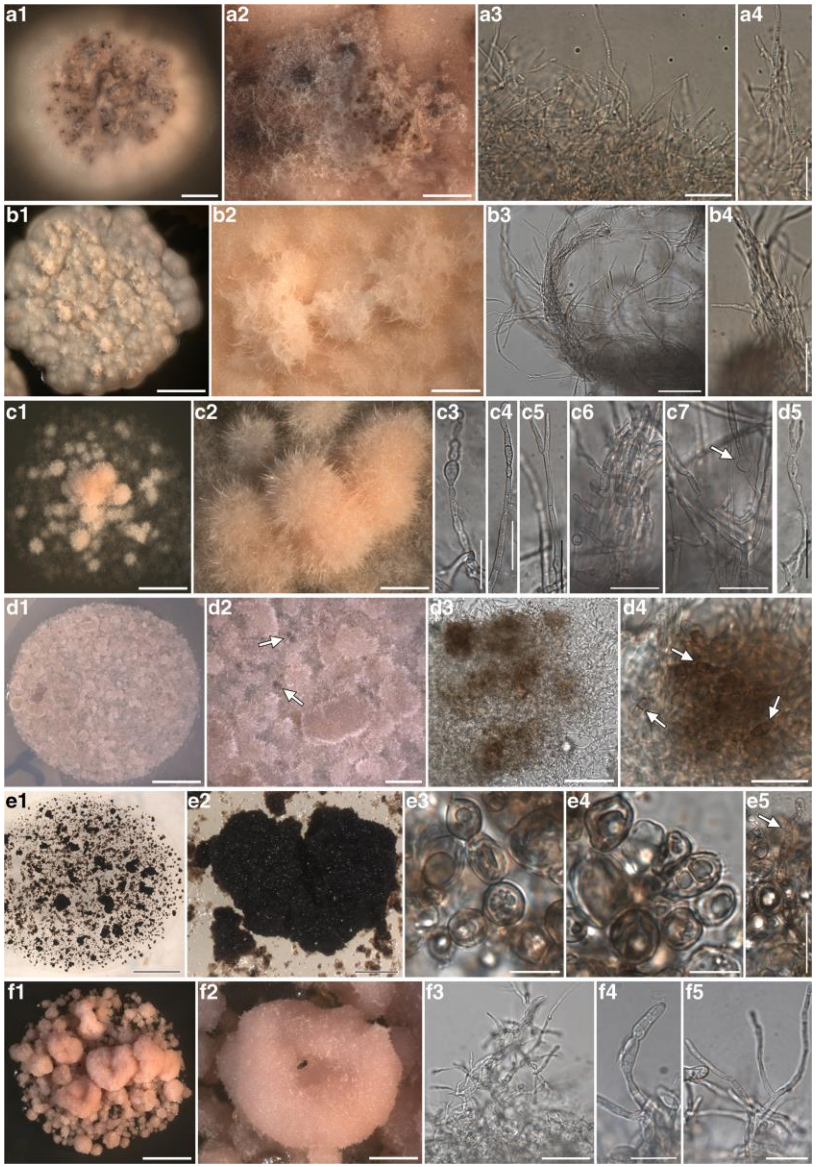
lichenikolní houba na *Pertusaria pertusa*

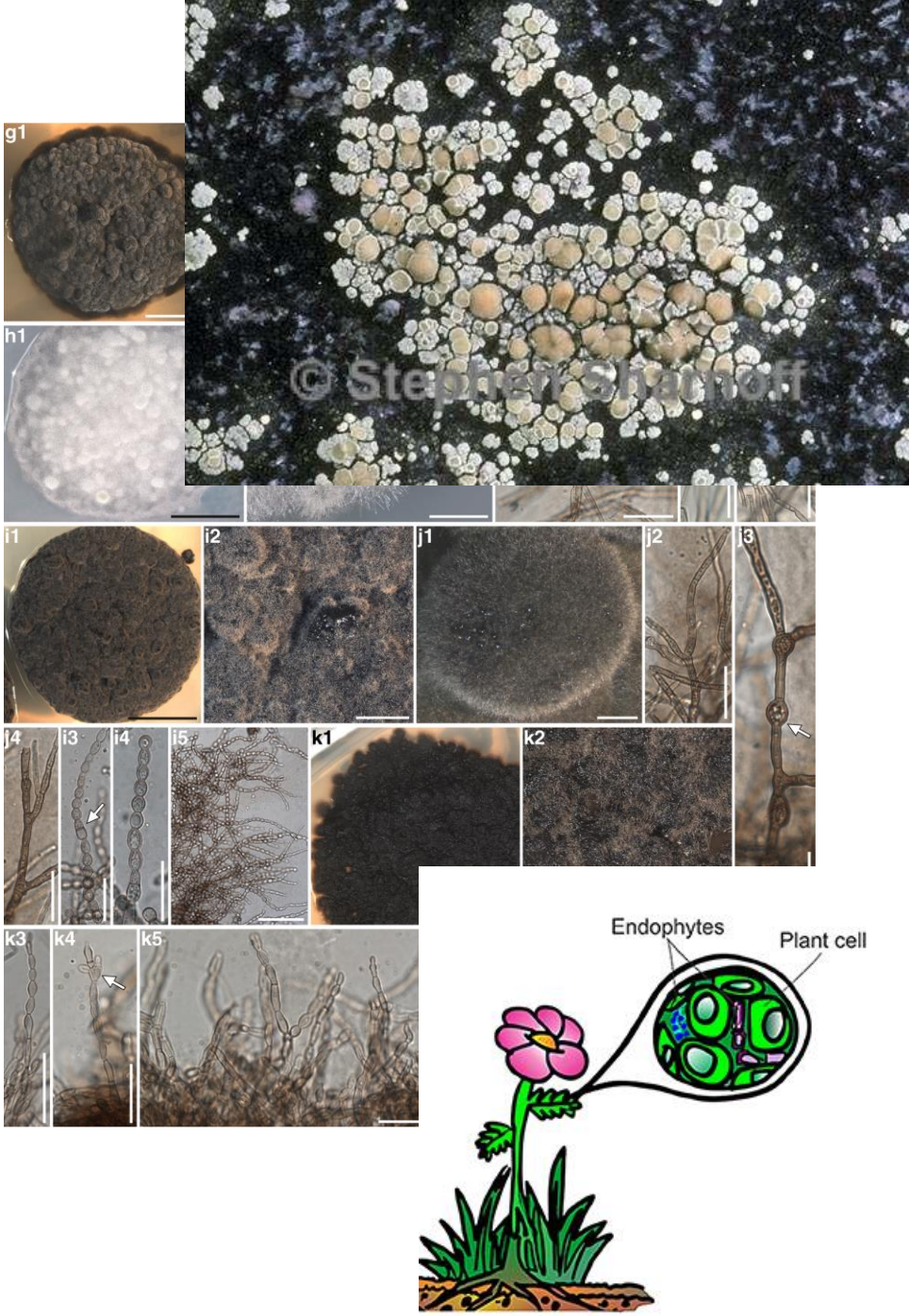
lichenikolní houba na *Sticta*

lichenikolní houba na *Cladonia arbuscula*

více mykobiontů – parasitické houby, parasitické lišejníky

Symptomless lichenicolous fungi





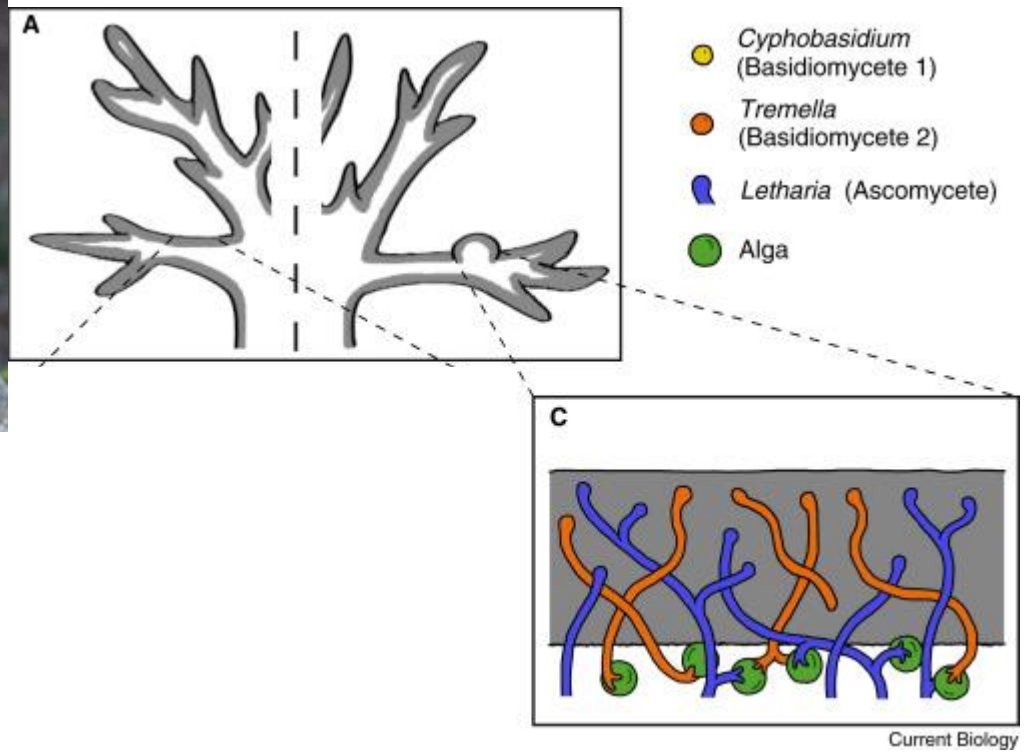
Muggia et al. 2016

Endolichenic fungi or „endolichenic lichens“?

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).

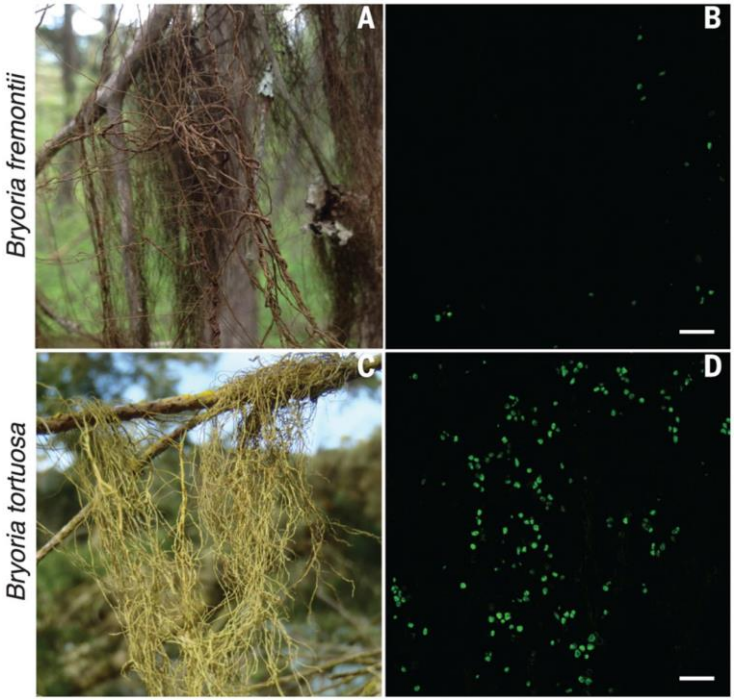
Multiple mycobionts in one lichen thallus?



Letharia vulpina

Tuovinen et al. 2019

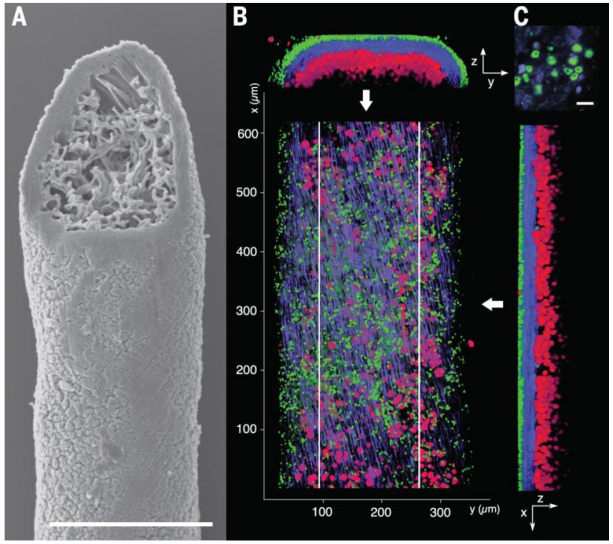
Basiodiomycete yeasts influencing ascomycete lichen phenotype



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).



"more than one fungus may be involved in its (cortex) construction"

Spribille et al. 2016; science.aaf8287

...kvasinka coby další partner?

- tento silný závěr byl posléze kritizován: **“In summary, it is obvious that basidiomycetous yeasts in lichen thalli are not a third component of symbiosis, but rather the vegetative propagules of mycoparasites.”** (Oberwinkler, Pucciniomycotina: 2017)
- Dnes určitá zdrženlivost v pojetí kvasinek jako třetího partnera.

Shrnutí

- Lišejník má jméno podle dominantního mykobionta, nezávisle na řase/řasách.

- Lišejníky je ekosystém – je zde mnoho doprovodných hub, některé mohou být velmi důležité pro celek

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).

Růst lišejníků:

korovité zhruba milimetry za rok

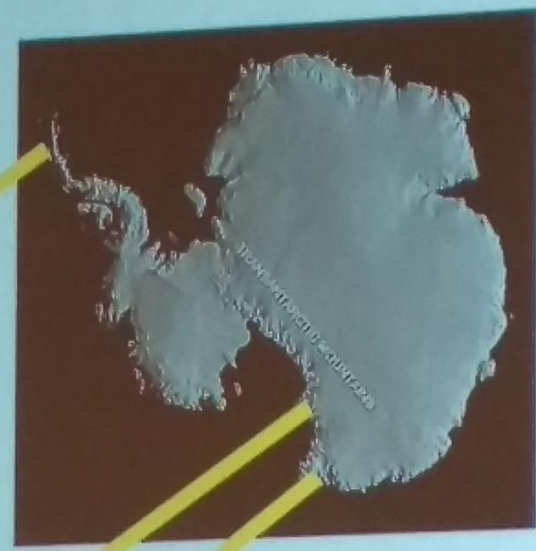
lupenité desetiny až jednotky centimetrů

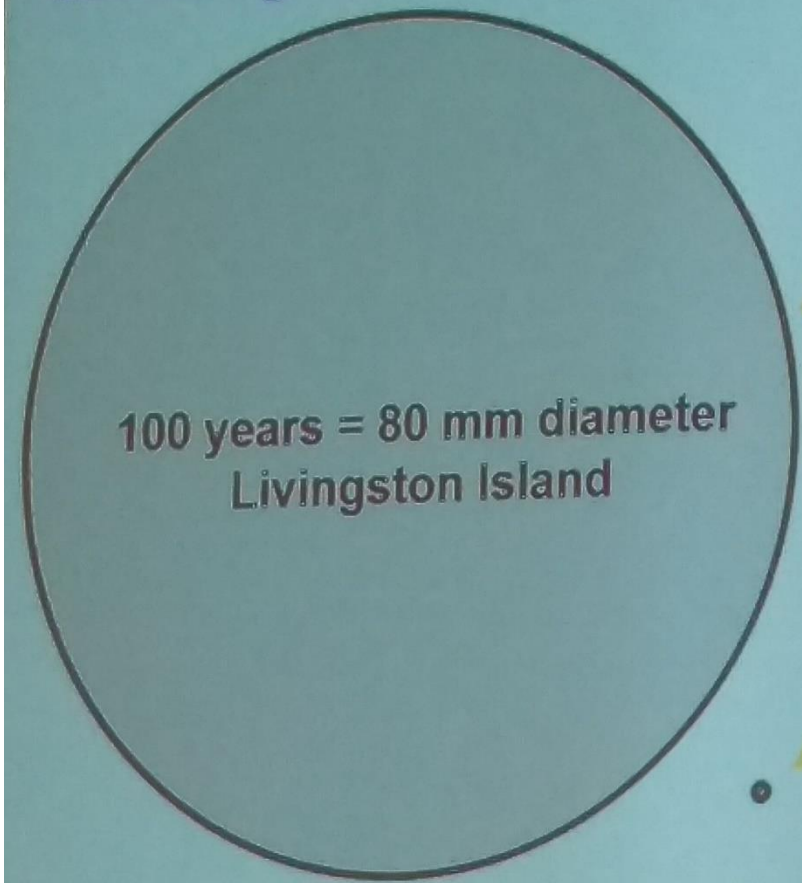
keříčkovité desetiny až jednotky centimetrů

mezofytní hávnatky až několik cm za rok

korovité druhy i desetiny mm ročně

Lichen growth in 100 years





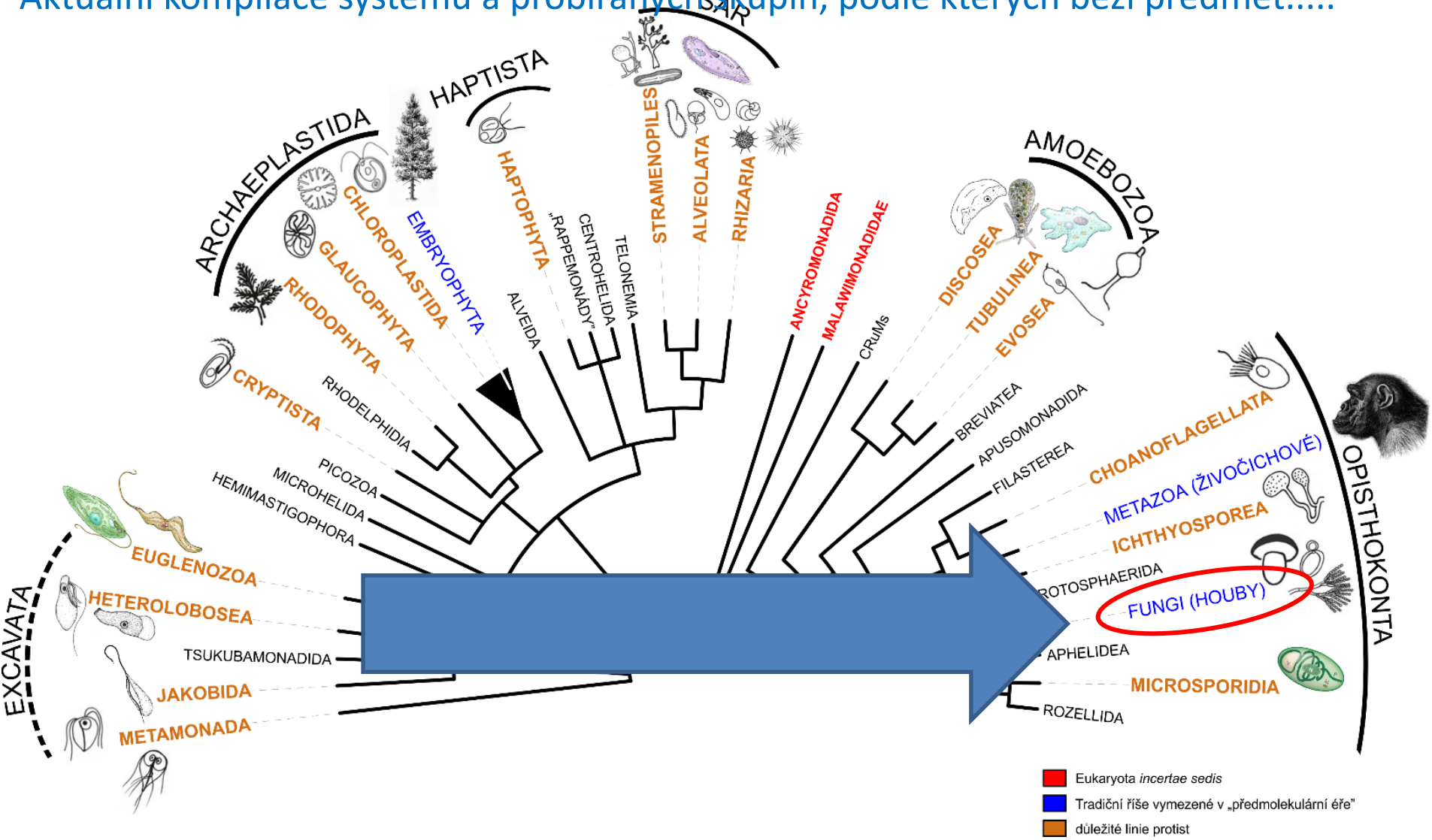
100 years = 6 mm diam.
Hallett

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.

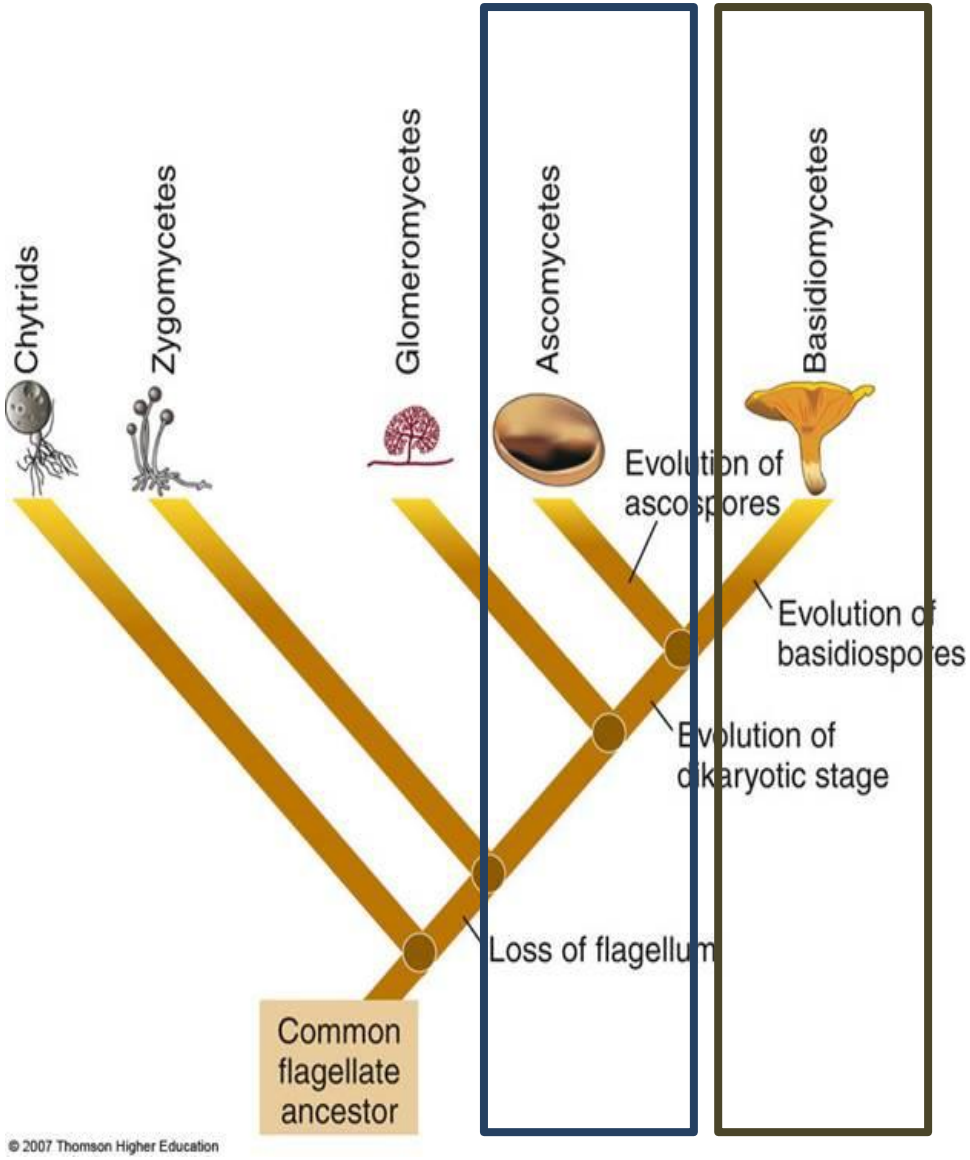
Aktuální kompilace systému a probíraných skupin, podle kterých běží předmět.....

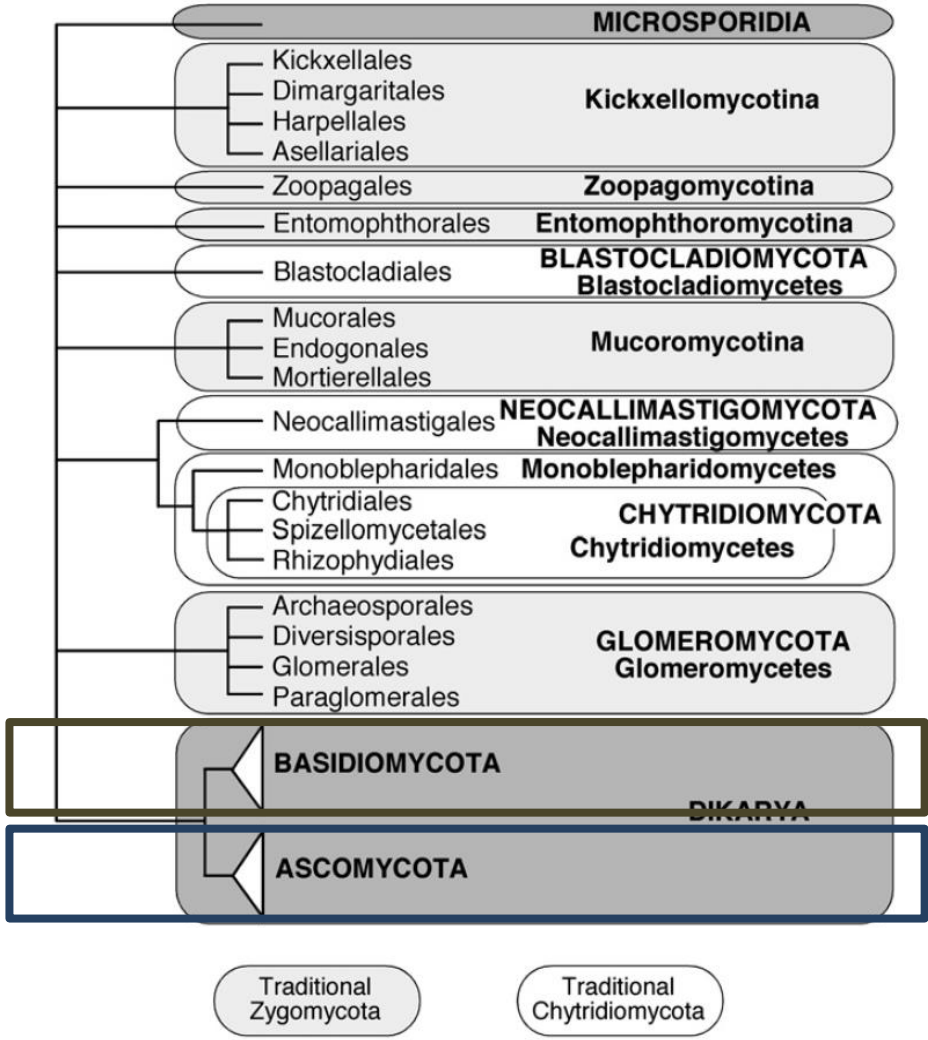


Cyanobacteria

Tomáš Pánek, compilation

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**

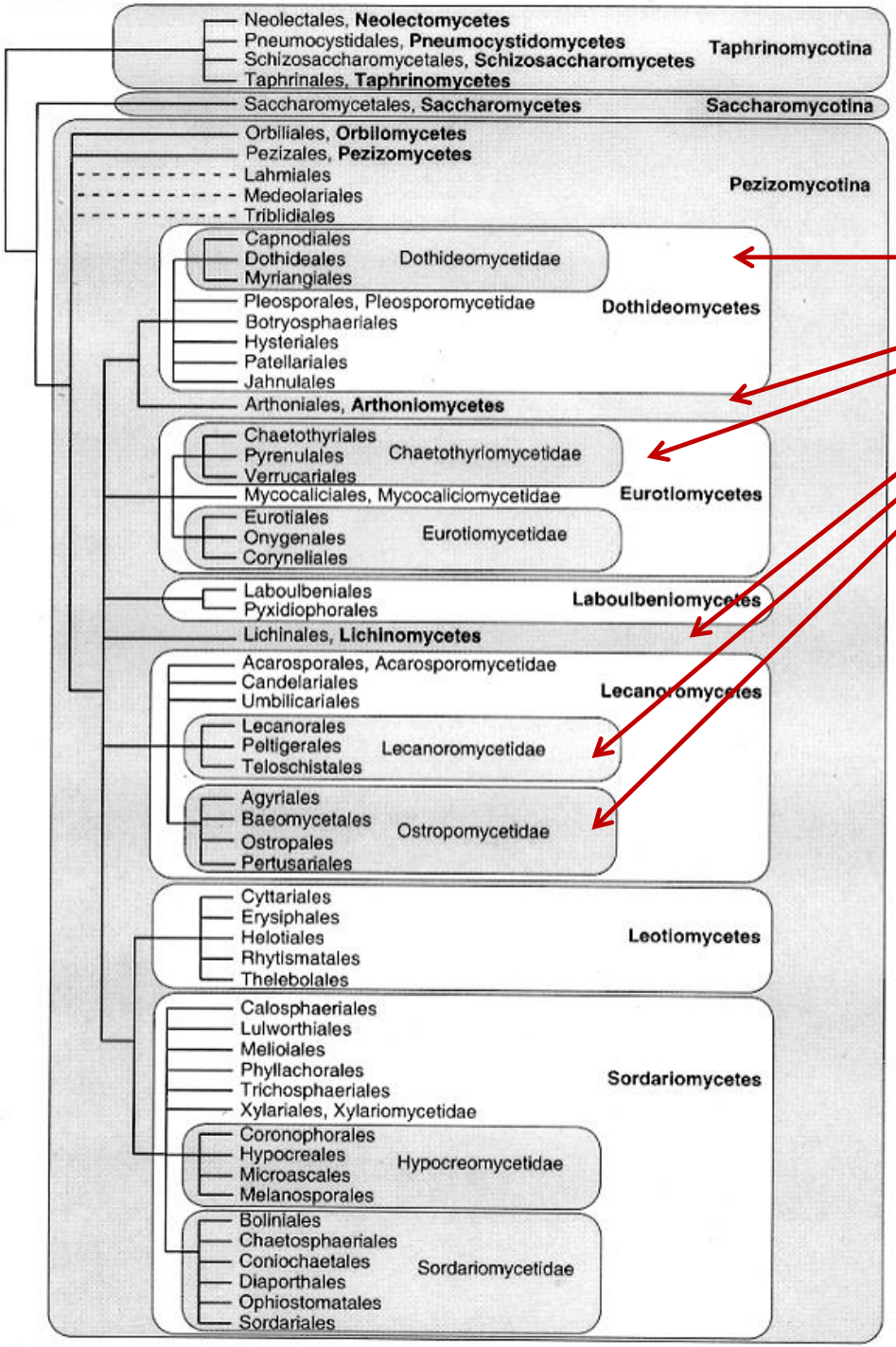
- výživa **absorbční**, heterotrofní, zásobní látkou **glykogen**

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

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

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

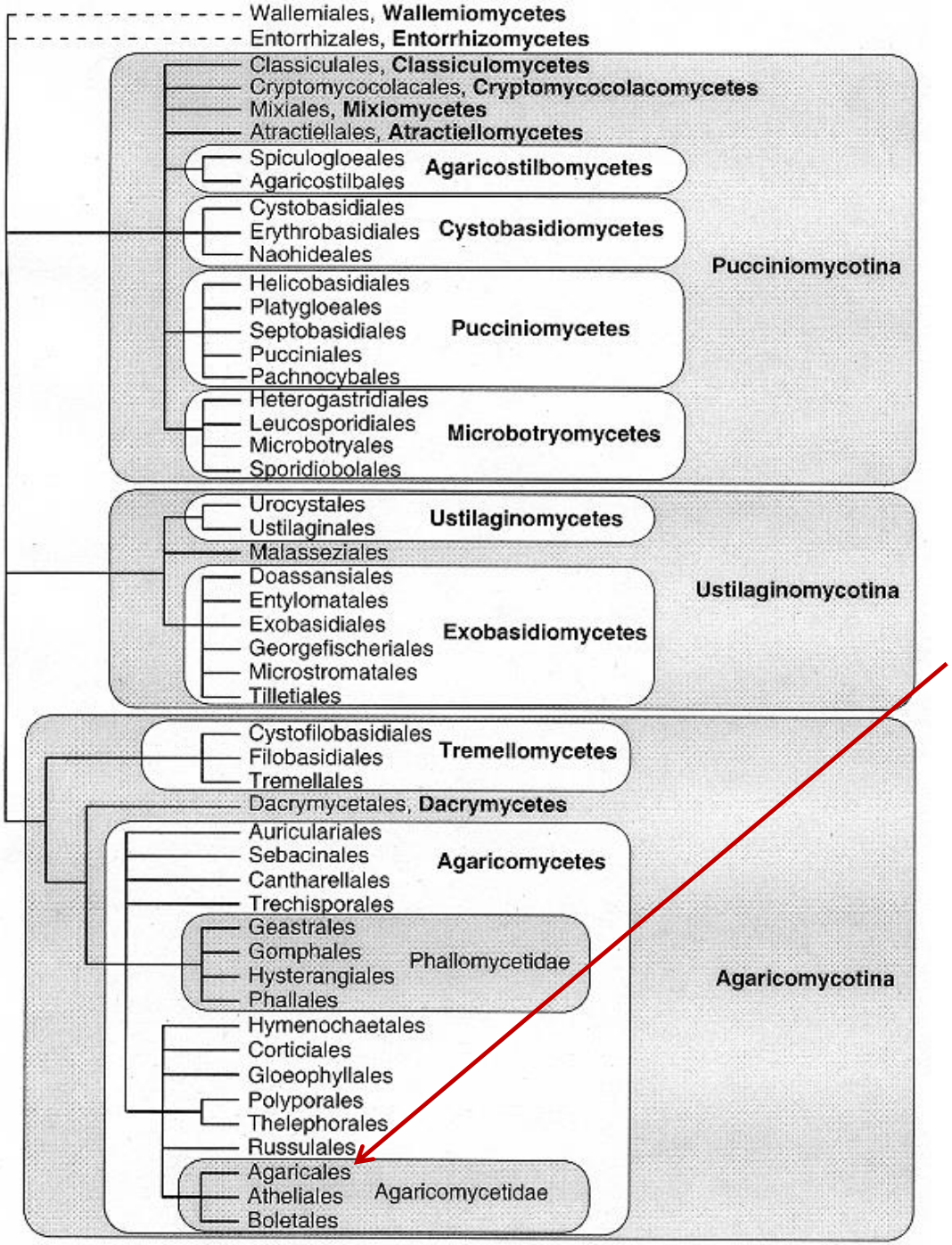
- nepohlavní rozmnožování - **úlomky hyf**, **pučení**, **spory (sporangia, nepohlavní struktury)**



mycobiont: Ascomycota

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

Hibbet et al. 2007



mycobiont: Basidiomycota

ca 100 species lichenized

Multiclavula mucida

Lichenomphalia umbellifera

more than 99 % of mycobionts are Ascomycetes

Ascomycota

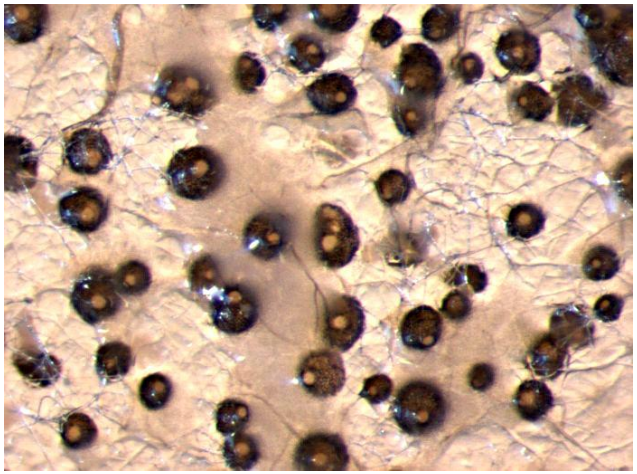
Kde v systému se nacházíme?

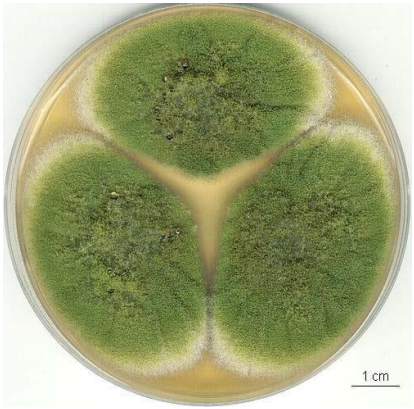
„Impérium": Eukaryota

„Nadříše": Opisthokonta

*„Říše": **Fungi***

Ascomycota





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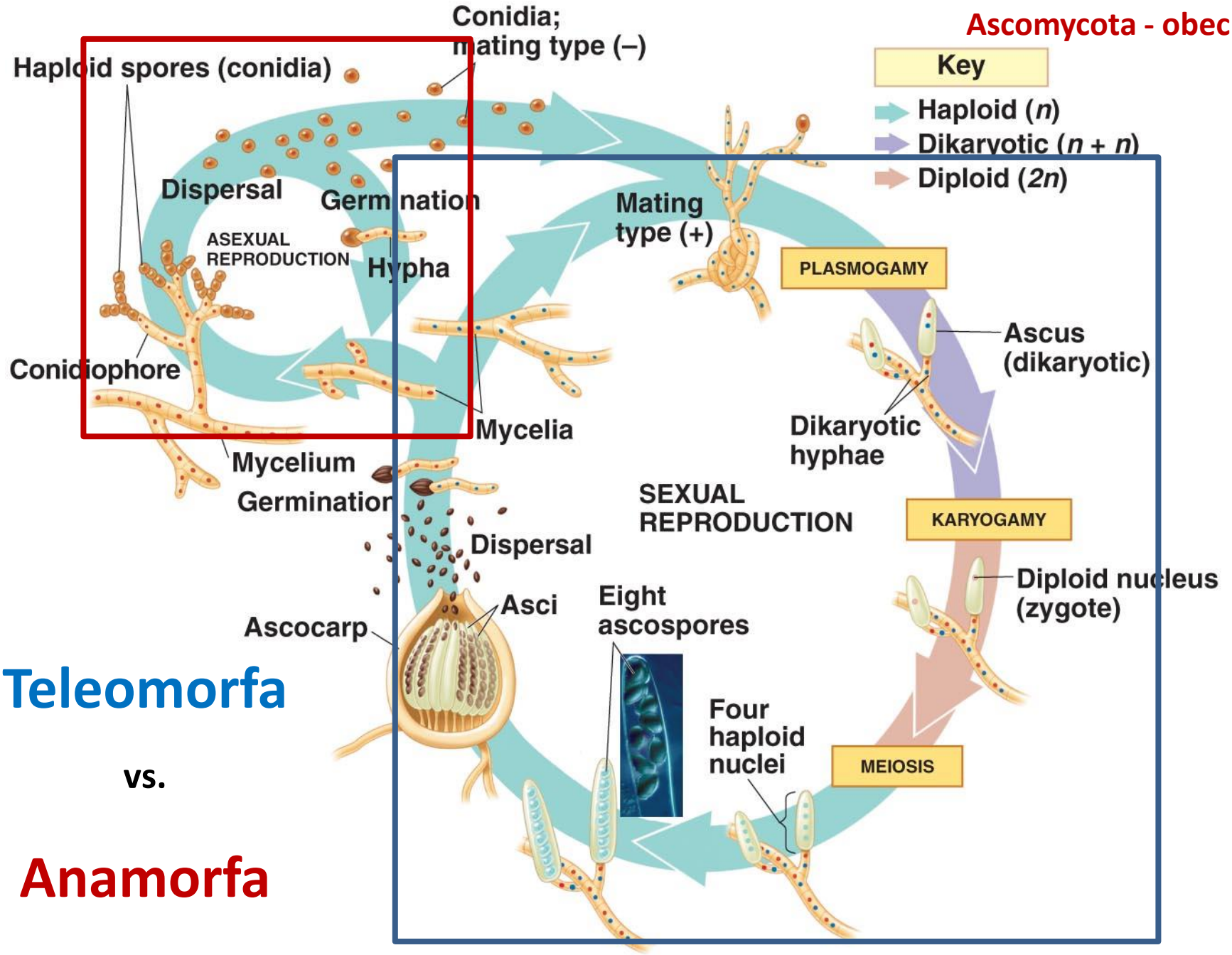
Ascomycota - obecné



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Teleomorfa

vs.

Anamorfa

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

Ascomycota

-pohlavní proces v plodnici

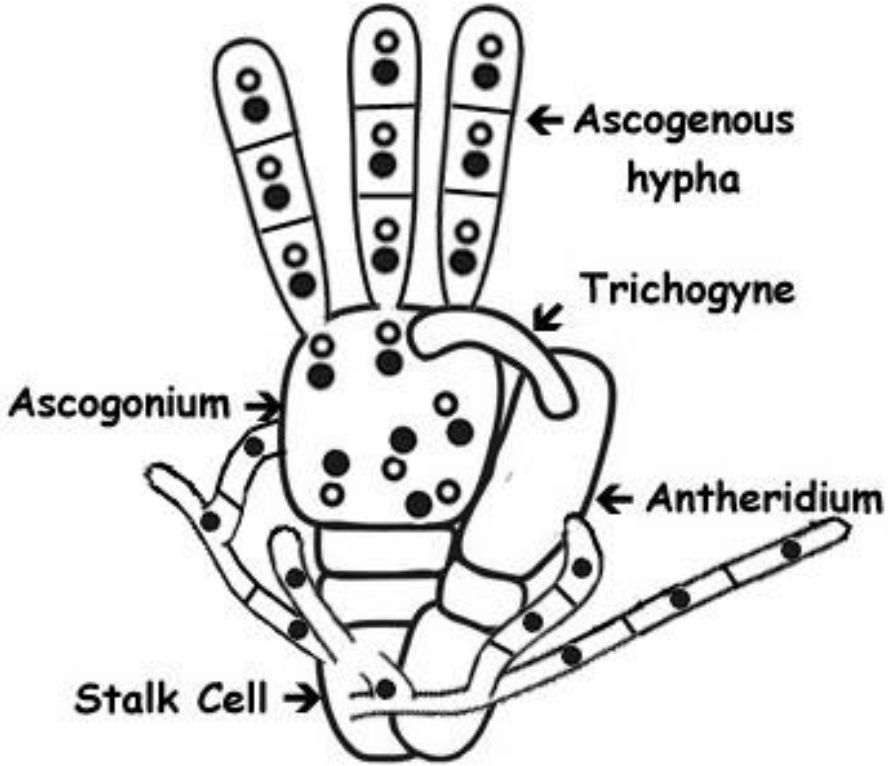
- **gametangiogamie**, **gametogamie** nebo **somatogamie**

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

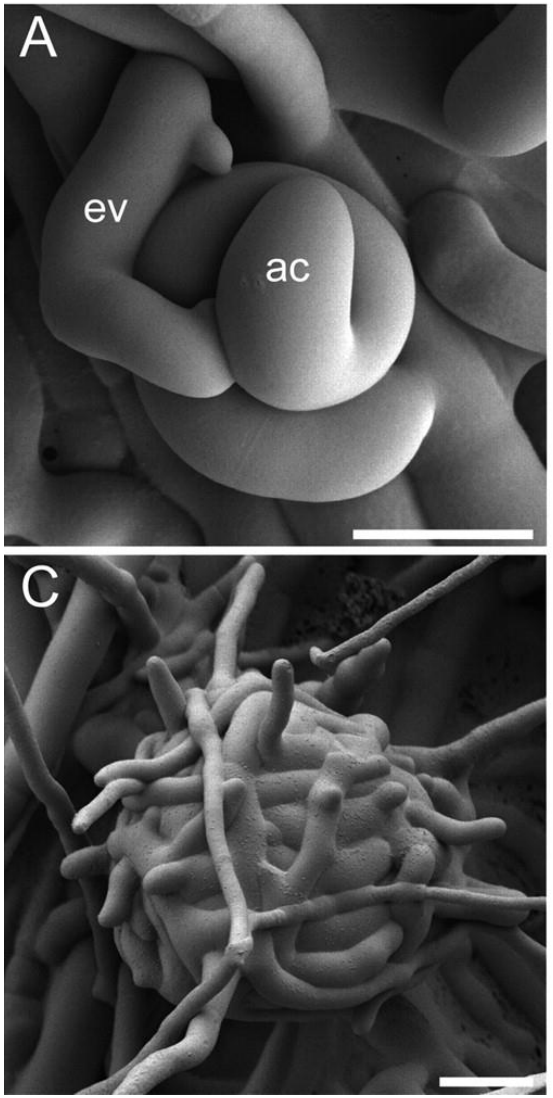
-dikaryotická fáze krátká (**askogenní hyfy**)

- 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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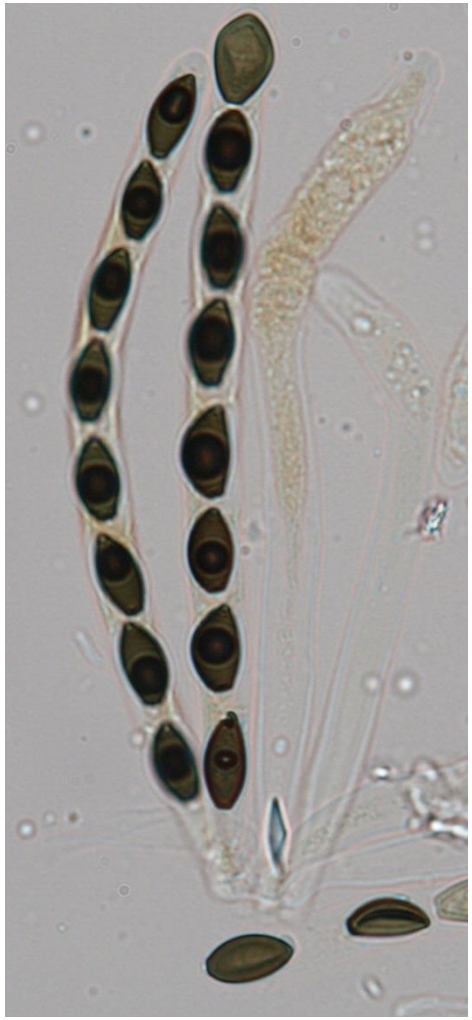
Ascomycota

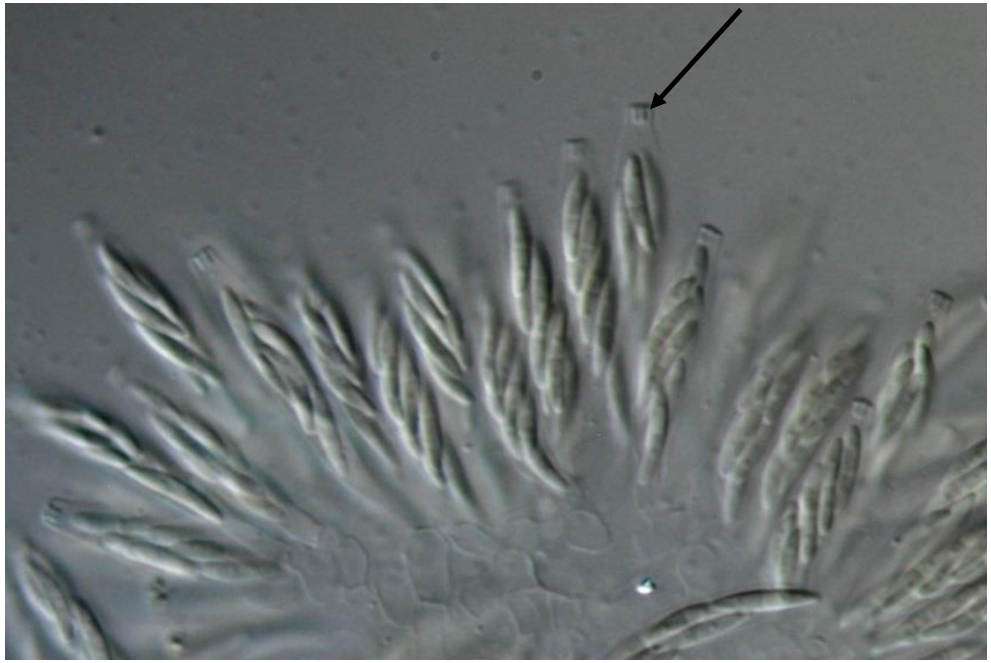
základní počet **askospor ve vřecku** je **8**

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



Anthostomella formosa

askoapikální aparát



Niesslia sp.

Ascomycota

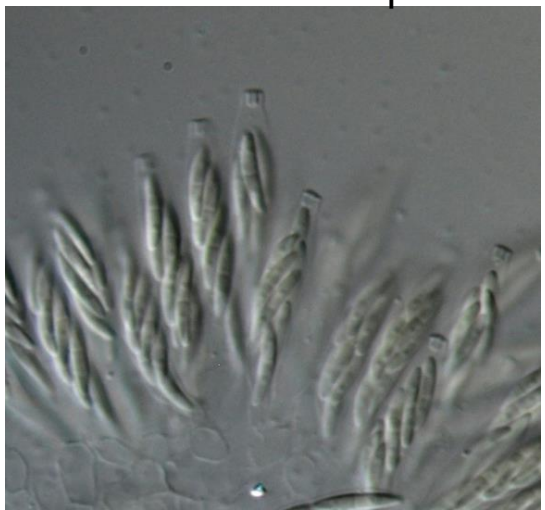
Teleomorfa

- vřecka prototunikátní (otevírají se **rozpadem stěny**)
  unitunikátní (**víčko** nebo skrz **askoapikální aparát**)
  bitunikátní (**jack-in-the-box**)

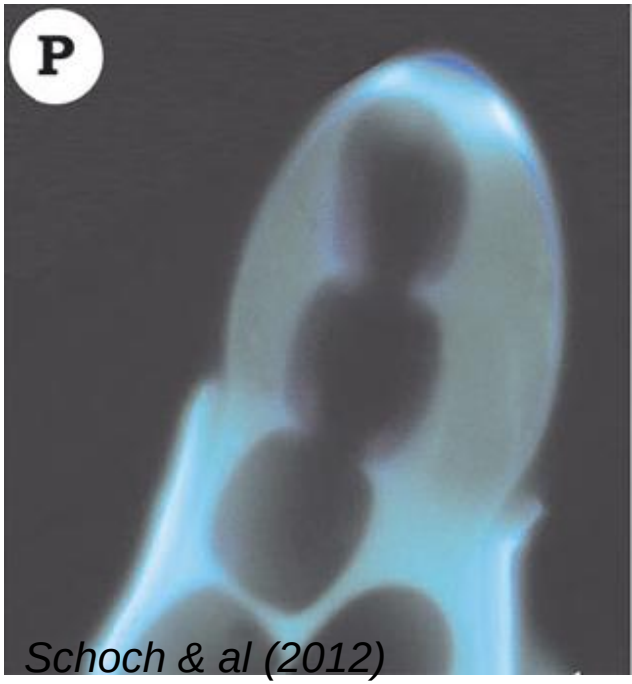
unitunikátní operkulátní

prototunikátní

unitunikátní inoperkulátní



bitunikátní



Schoch & al (2012)

Ascomycota

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

Caloplaca asserigena

Propolis versicolor

Mytilinidion mytilinelum

Basidiomycota

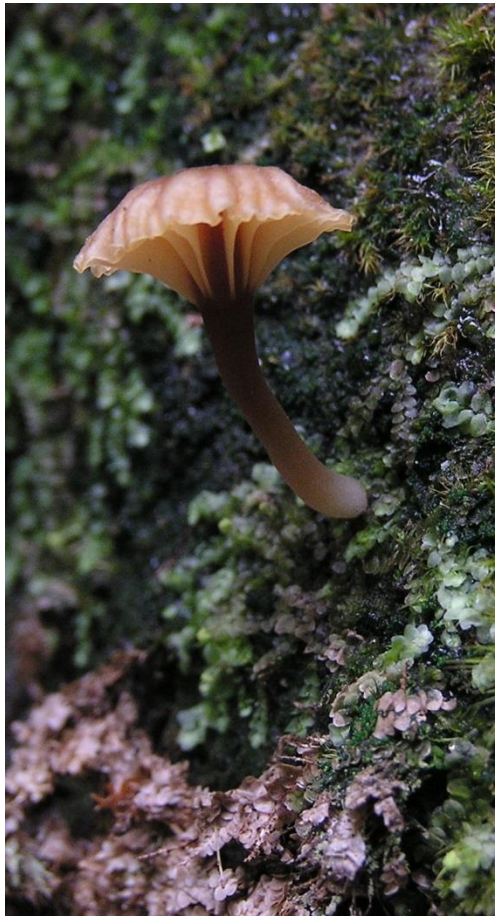
Kde v systému se nacházíme?

Eukaryota

Opisthokonta

Fungi

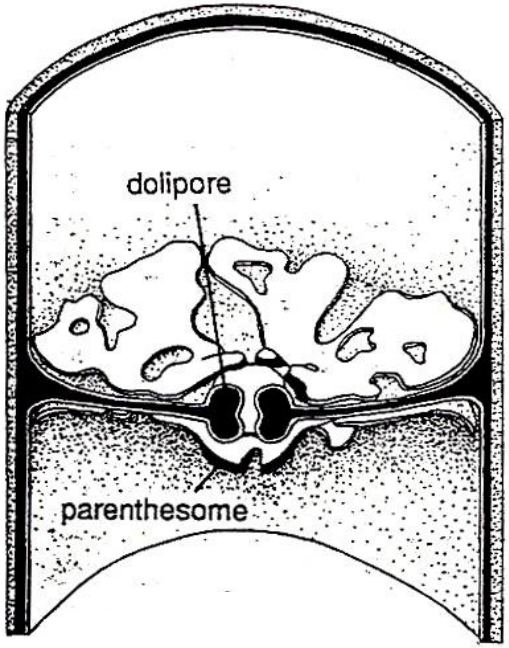
Basidiomycota



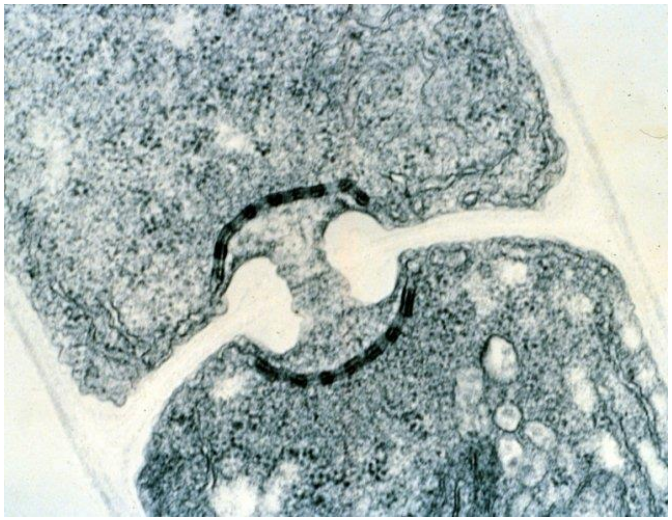
Basidiomycota

- nejpokročilejší skupina hub
- vegetativní stélka - septované mycelium,

septa (přehrádky) s **dolipórem**



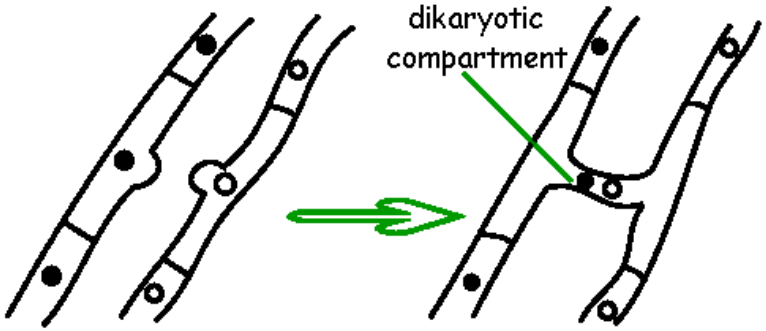
- buněčná stěna z **chitinu**
- **primární mycelium** (jednojaderné) krátkodobé
- **nepohlavní rozmnožování** málo časté
- životní cyklus **haplodikaryotický**



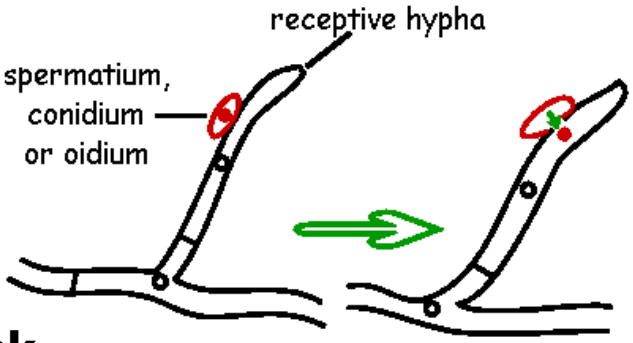
http://www.bsu.edu/classes/ruch/msa/blackwell/9-33.jpg

Basidiomycota

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

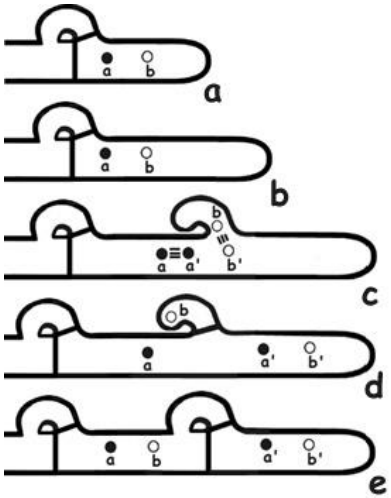


- nebo **gametosomatogamie** (splynutí specializované spory a hyfy)
- časově oddálená karyogamie

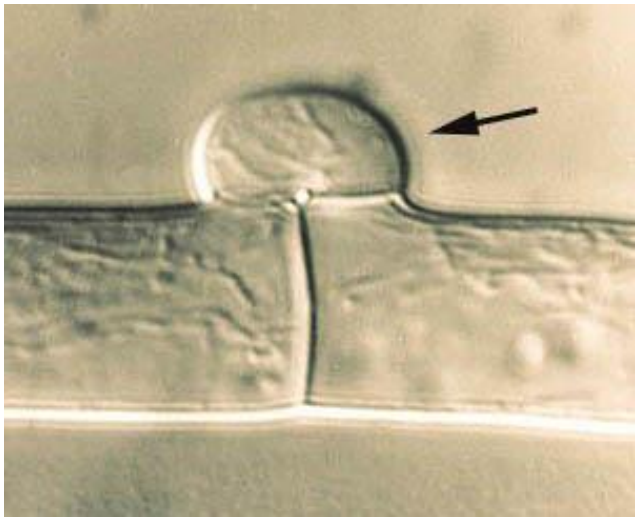


http://www.fungionline.org.uk/7sexual/5dikaryon.html

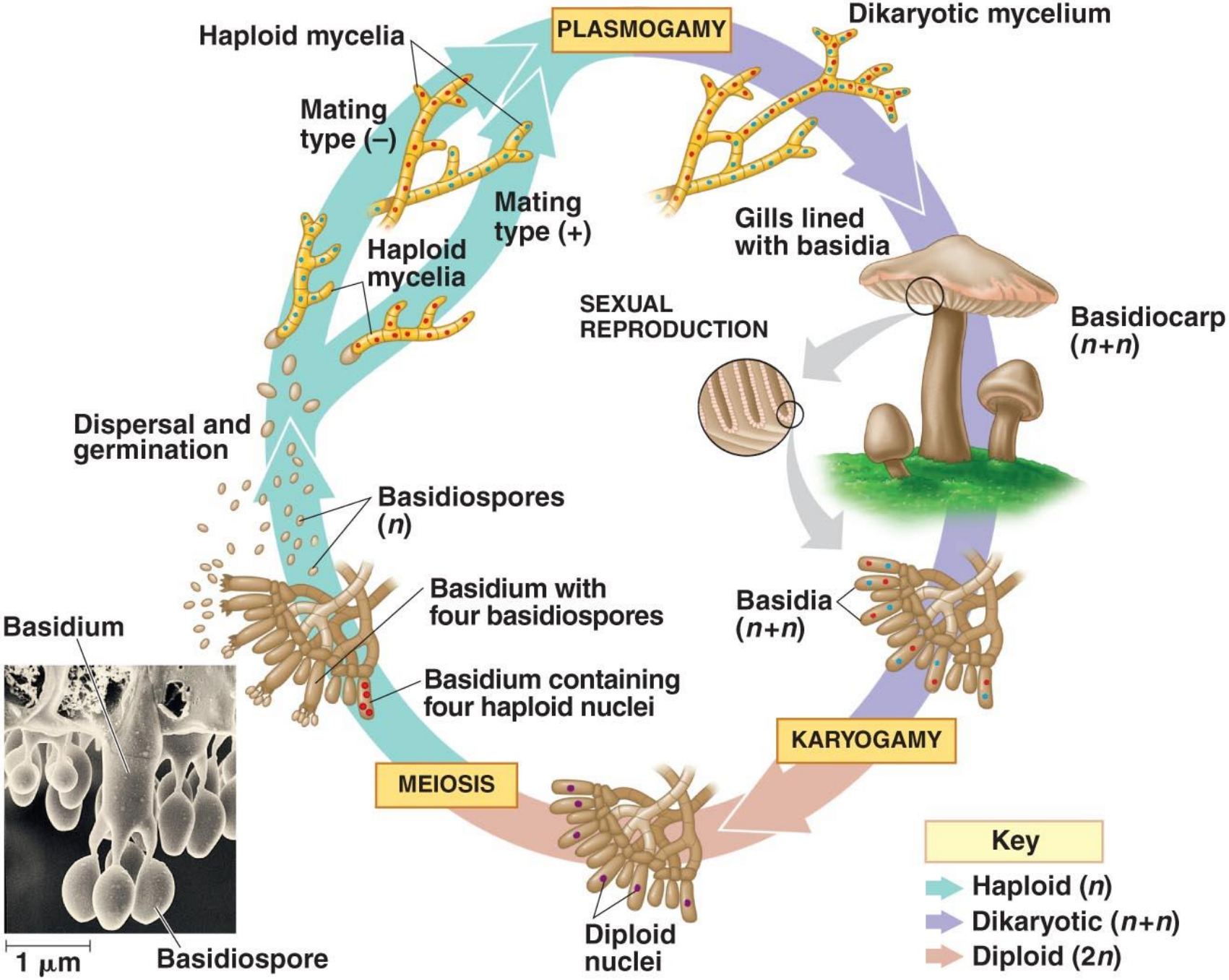
= **sekundární dikaryotické mycelium**
- konjugované mitózy jader a rozchod pomocí **přezek**



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



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



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

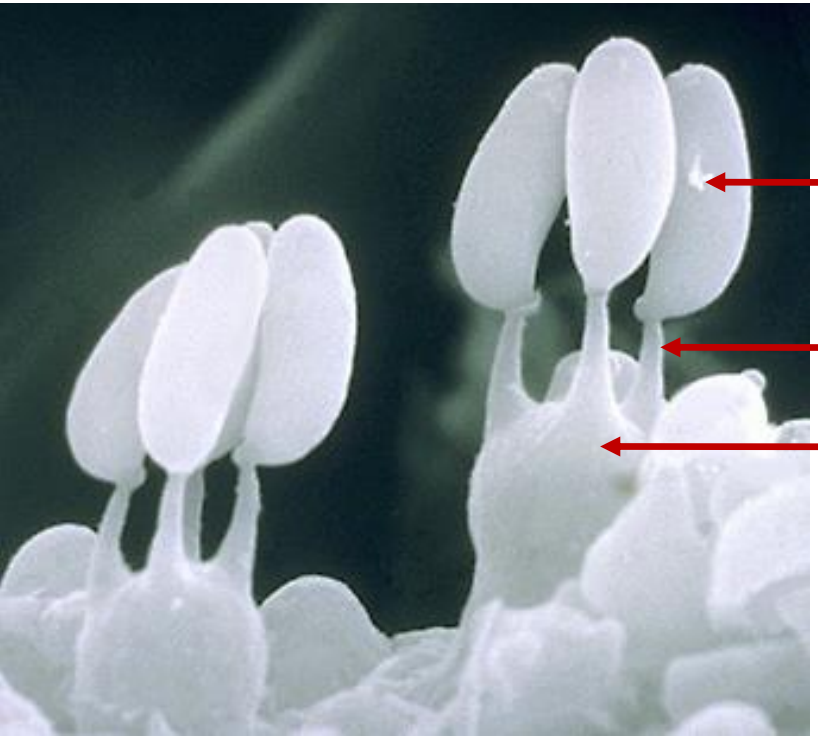
Basidiomycota

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

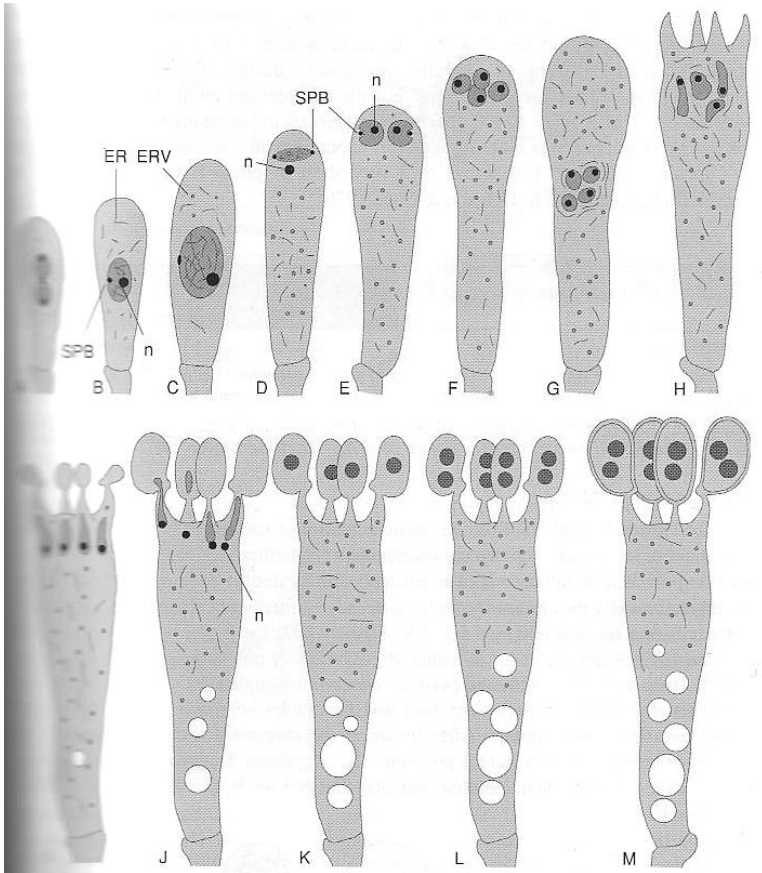
- **R!**

- 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 phase 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 in J. n = nucleolus shown in A-J. – From Clémençon 1997, modified.

Clémençon (2004)

Kde v systému se nacházíme?

Eukaryota

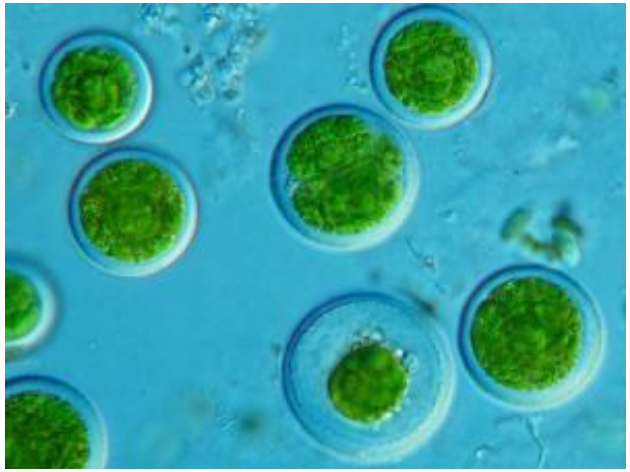
Plantae (Archaeplastida)

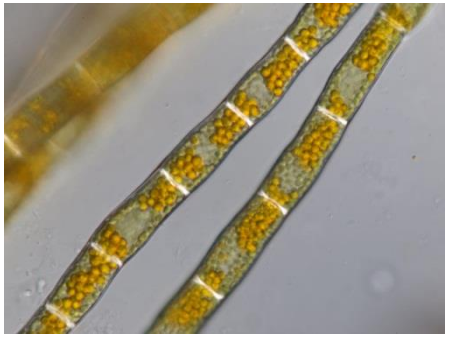
Chlorophyta

Trebouxiophyceae

Ulvophyceae

Trebouxia





Kde v systému se nacházíme?

Eukaryota

SAR

Chromista (Chromalveolata)

Stramenopila

Xanthophyceae (Heterococcus)

Phaeophyceae (Petroderma)

Trentepohlia

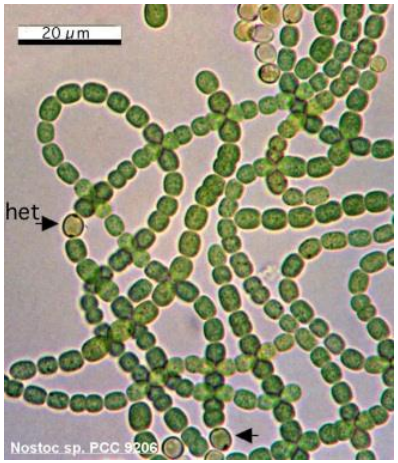
Kde v systému se nacházíme?

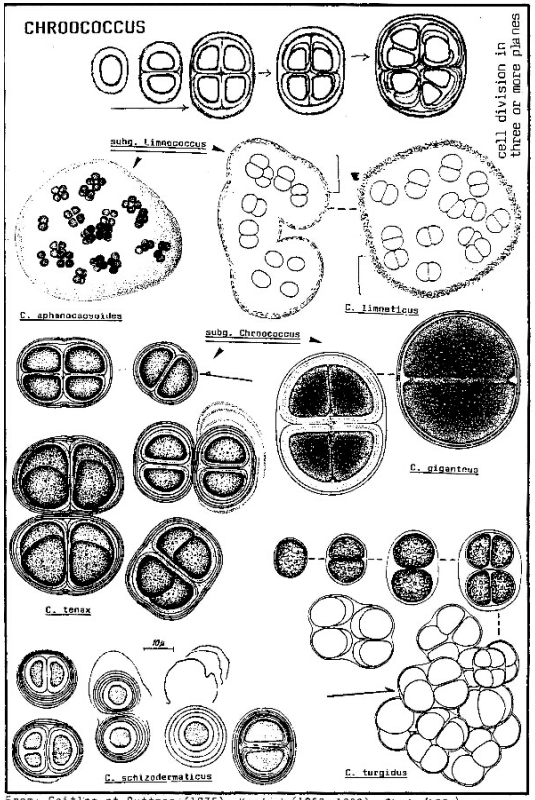
Prokaryota

Bacteria

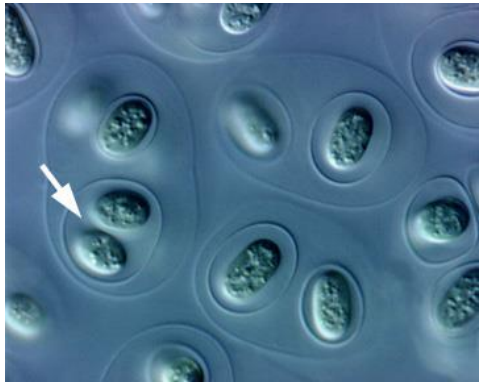
Cyanobacteria *(Cyanophyta)*

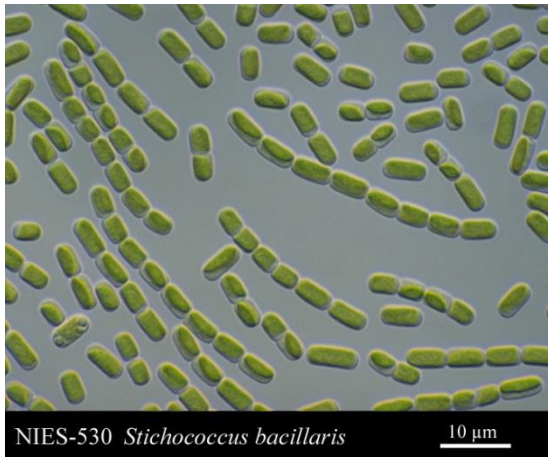
Cyanophyceae



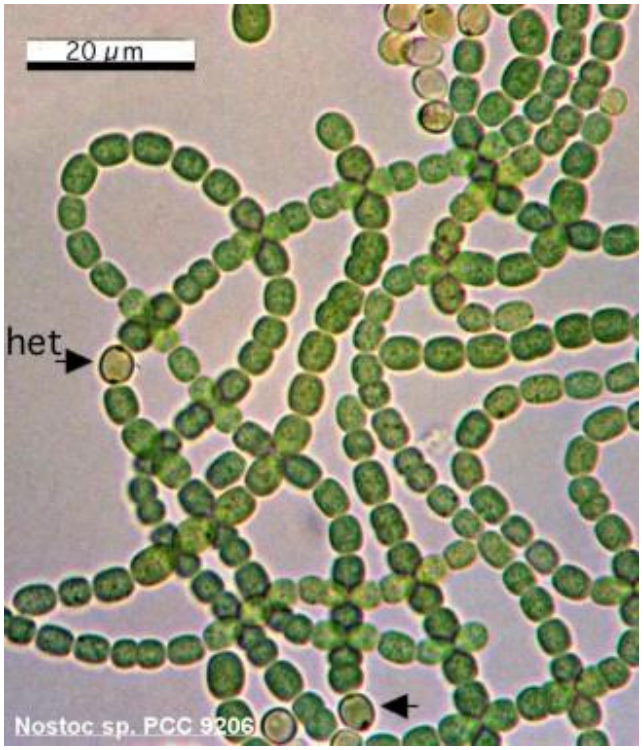


Gloeocapsa

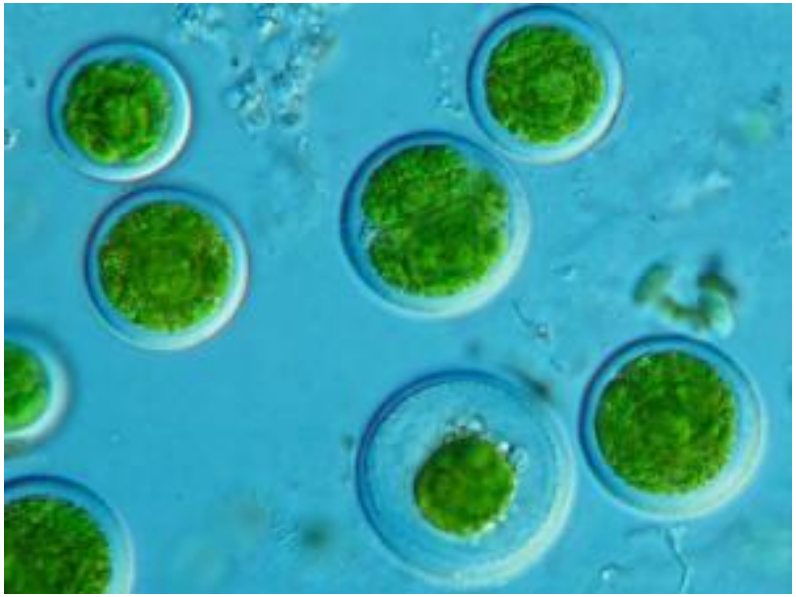




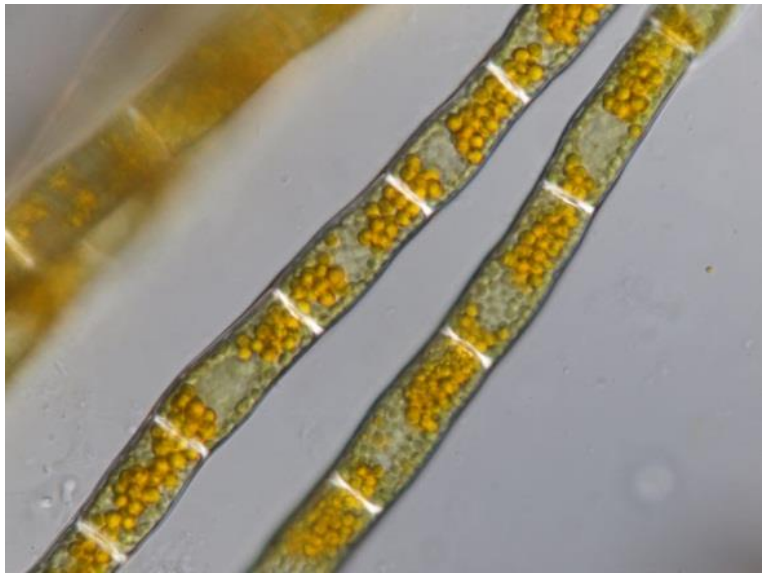
Fotobionti:
3 nejběžnější



sinice *Nostoc*



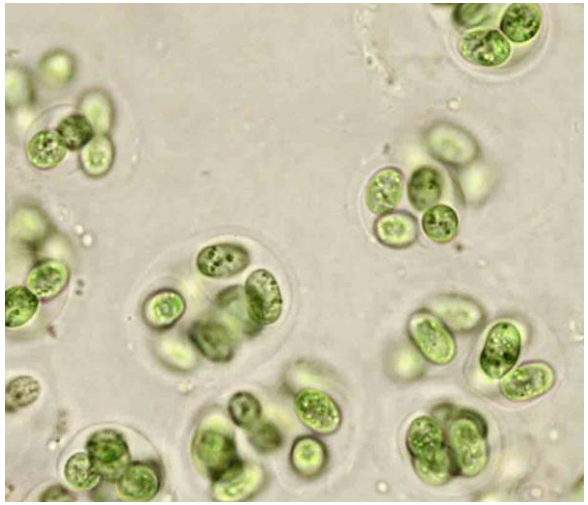
Trebouxia



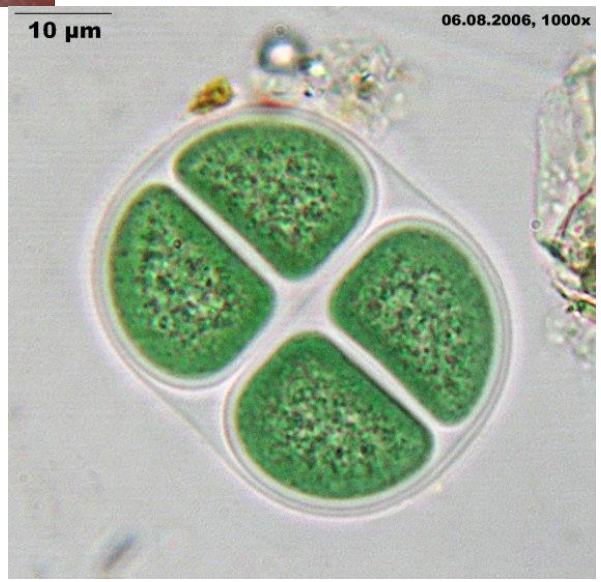
Trentepohlia

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

Nostoc

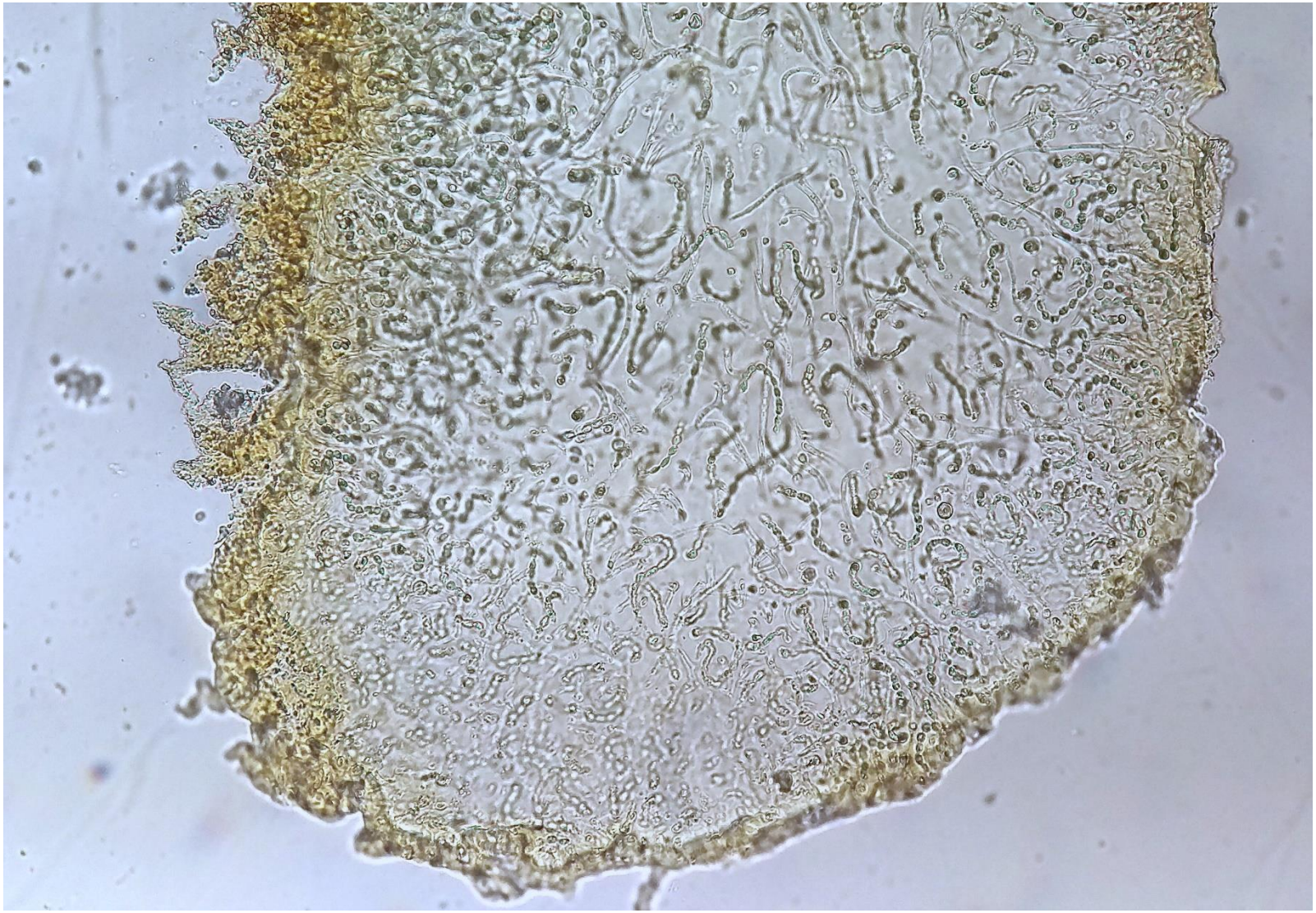


Gloeocapsa



Chroococcus

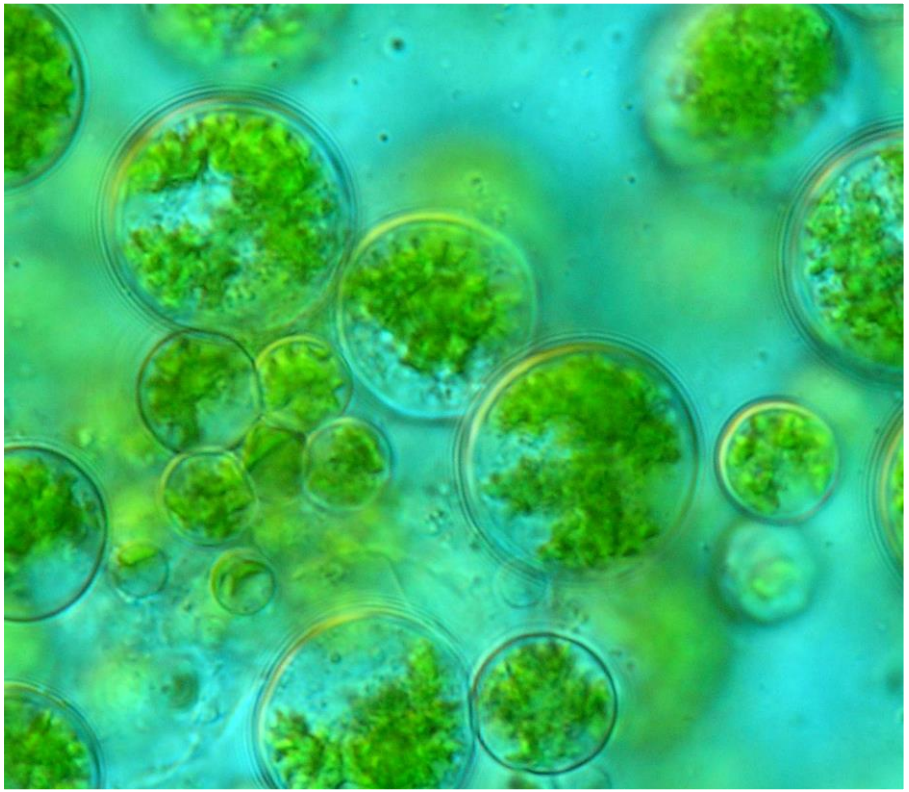
Lišejníky se sinicí (příklady)

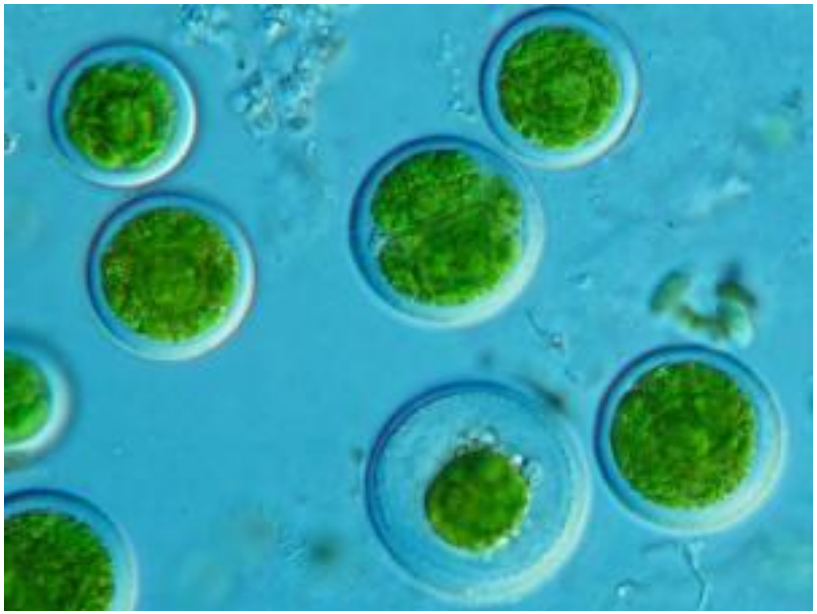


Collema

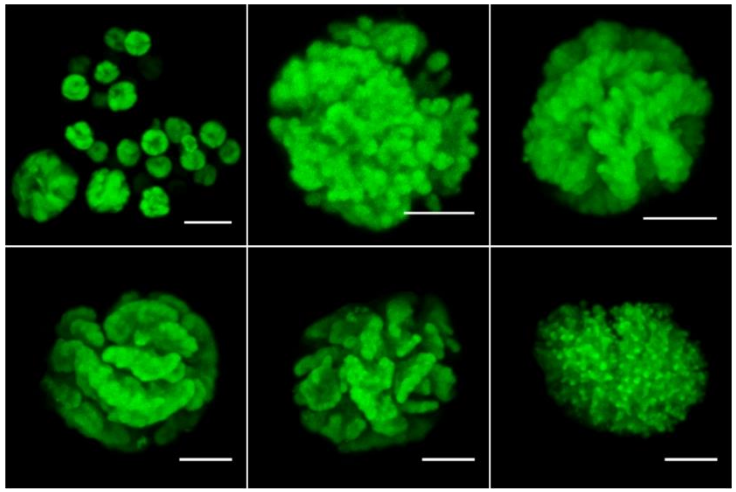
fotobionti: ***Trebouxia,*** *Asterochloris, Myrmecia*

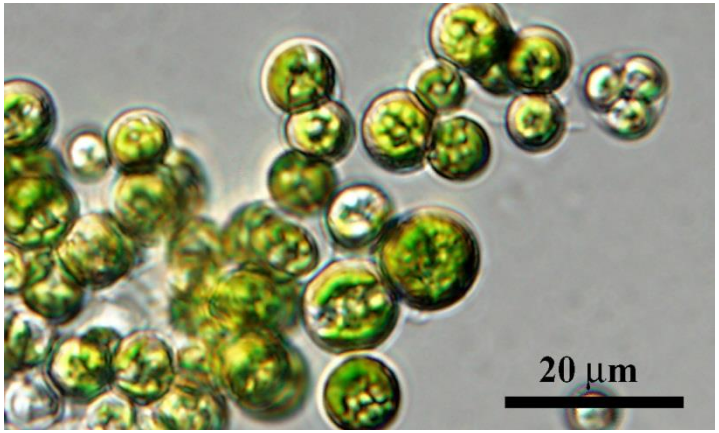
Asterochloris





Trebouxia **(dole vývoj chloroplastu)**





Myrmecia

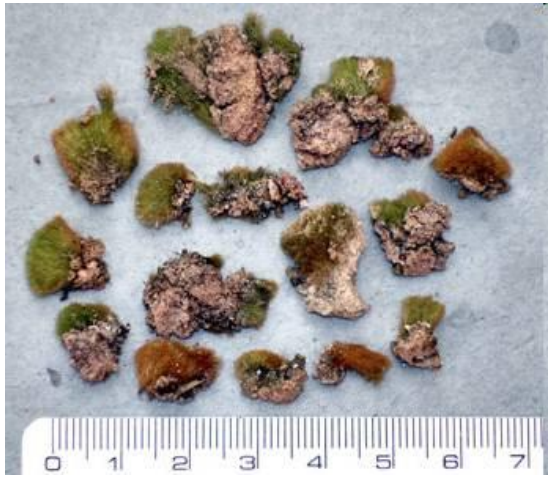
lišejníky s *Trebouxia*

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:

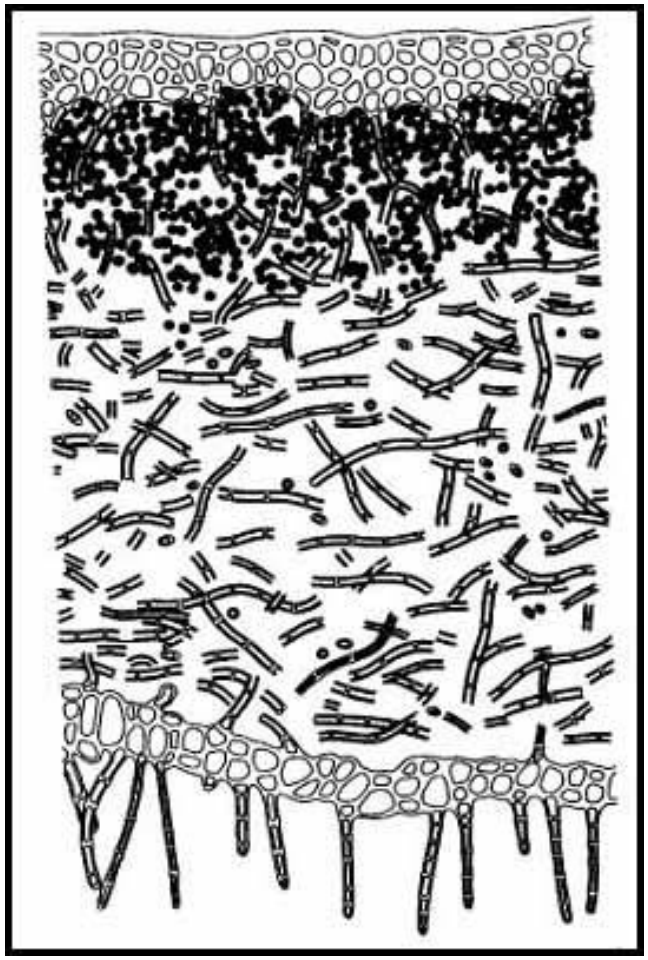
korovitá

lupenitá

keříčkovitá

Heteromerická stélka

Obecné schéma příčného řezu heteromerickou stélkou



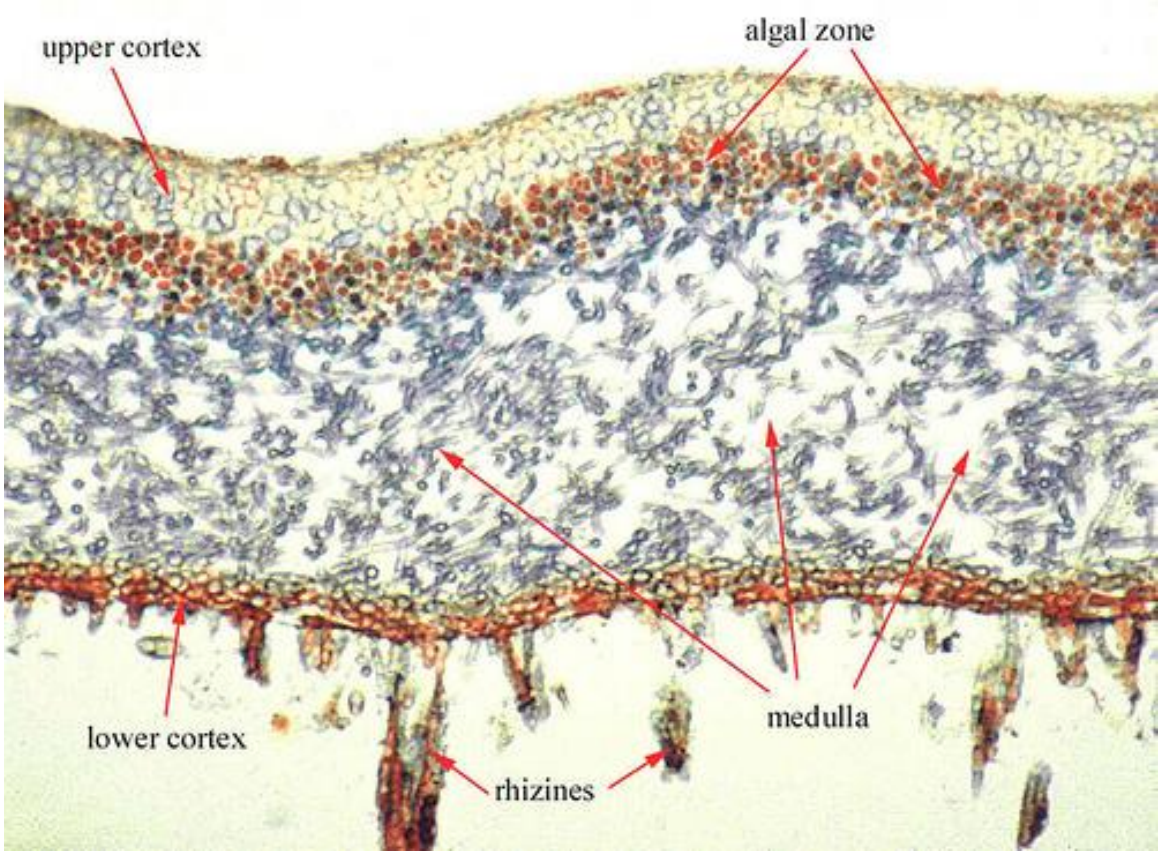
svrchní korová vrstva (epidermis)

řasová vrstva (vrstva fotobionta)

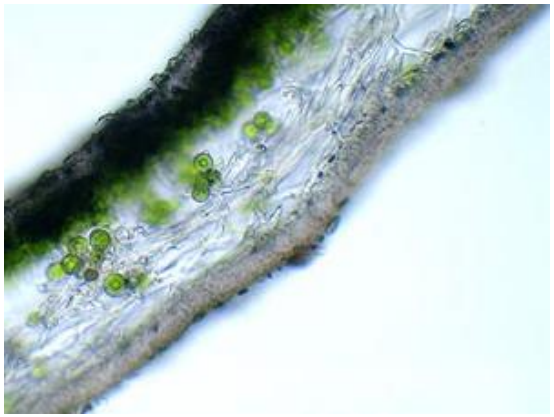
dřeňová vrstva

spodní korová vrstva

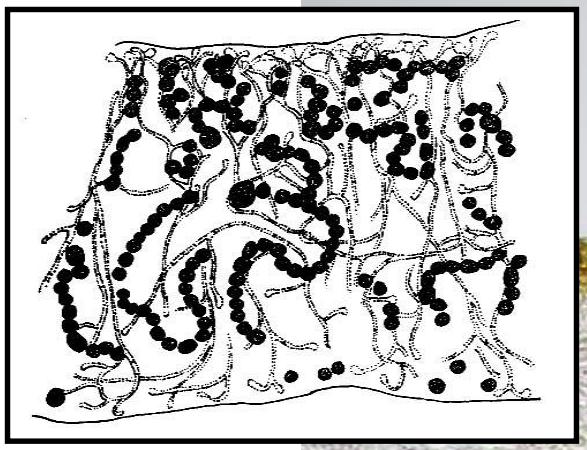
rhiziny

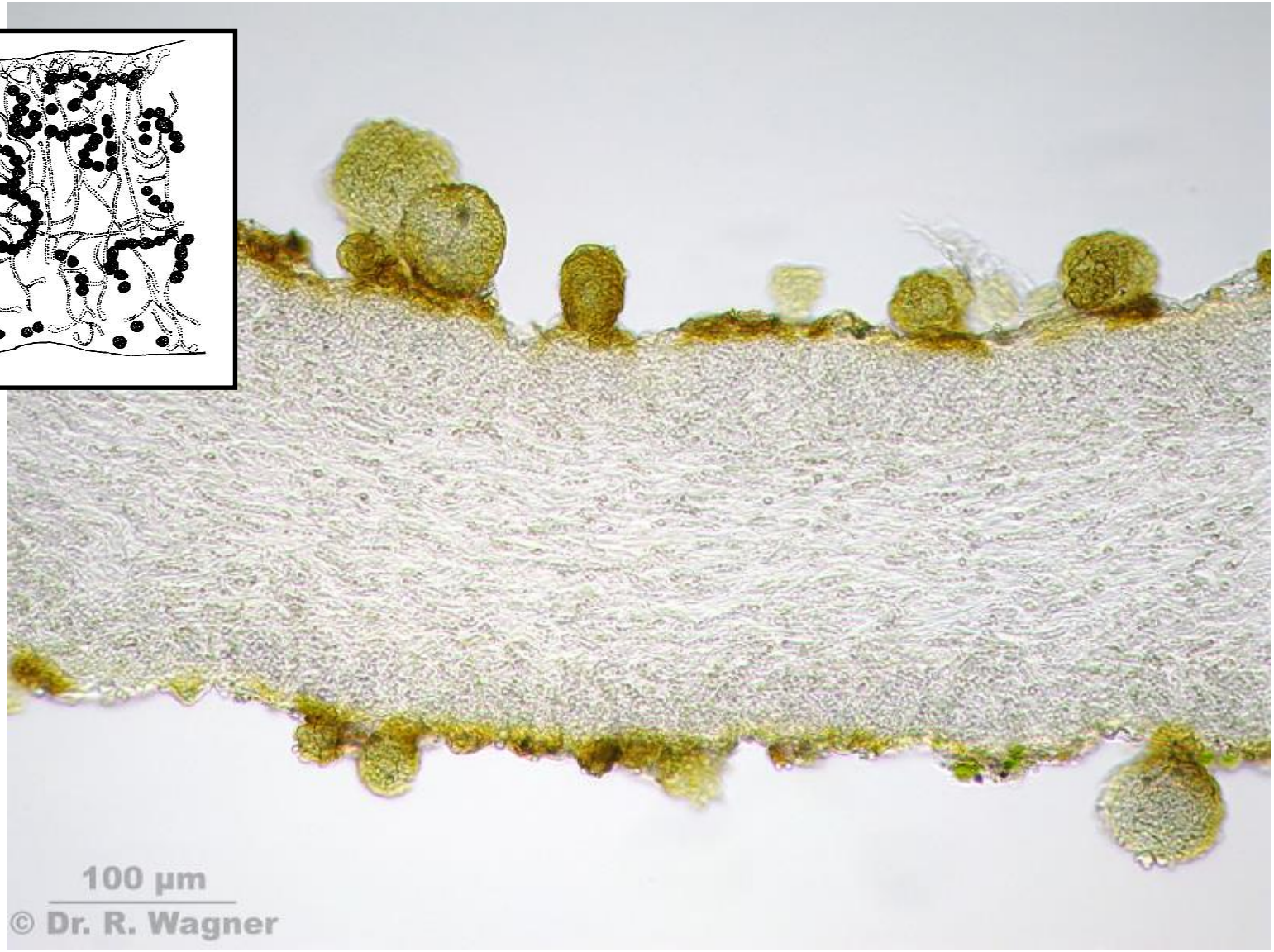


Heteromerická stélka



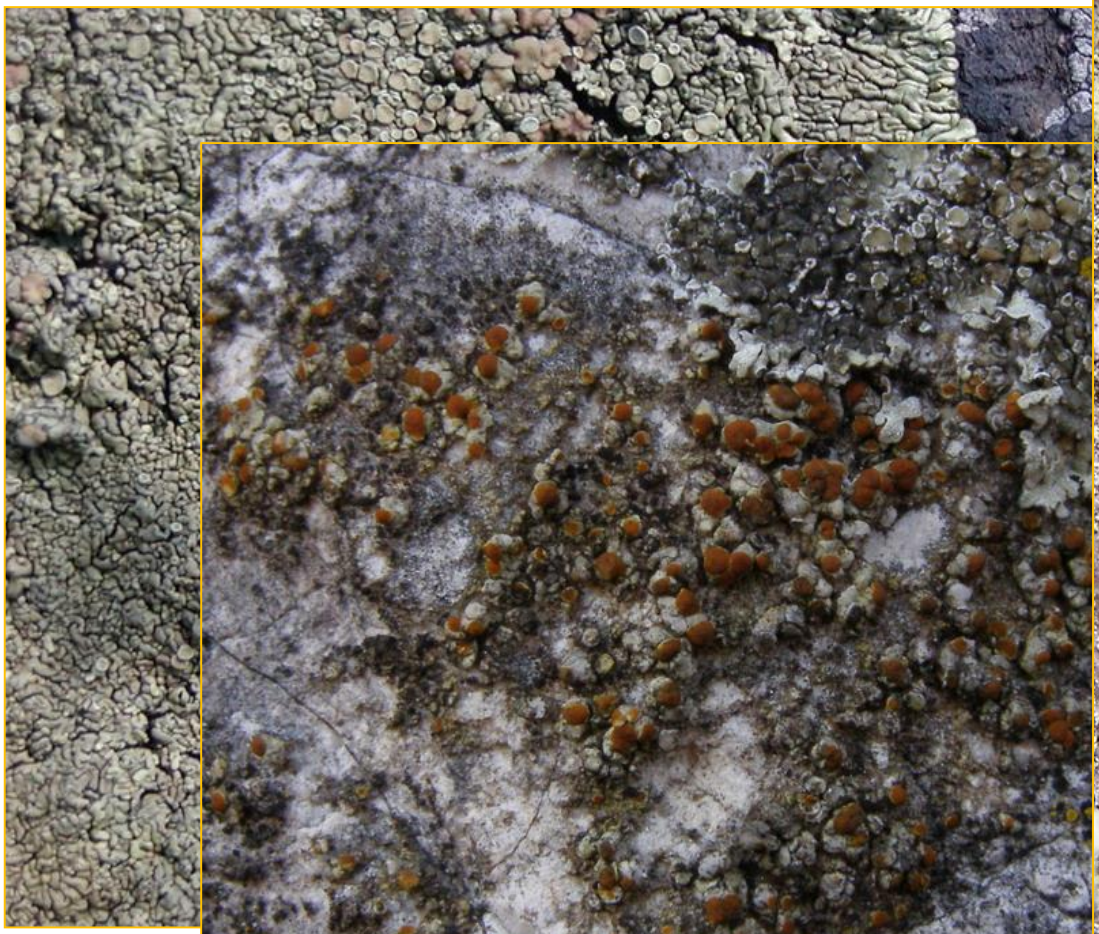
Homeomerická stélka (*Collema* sp.)





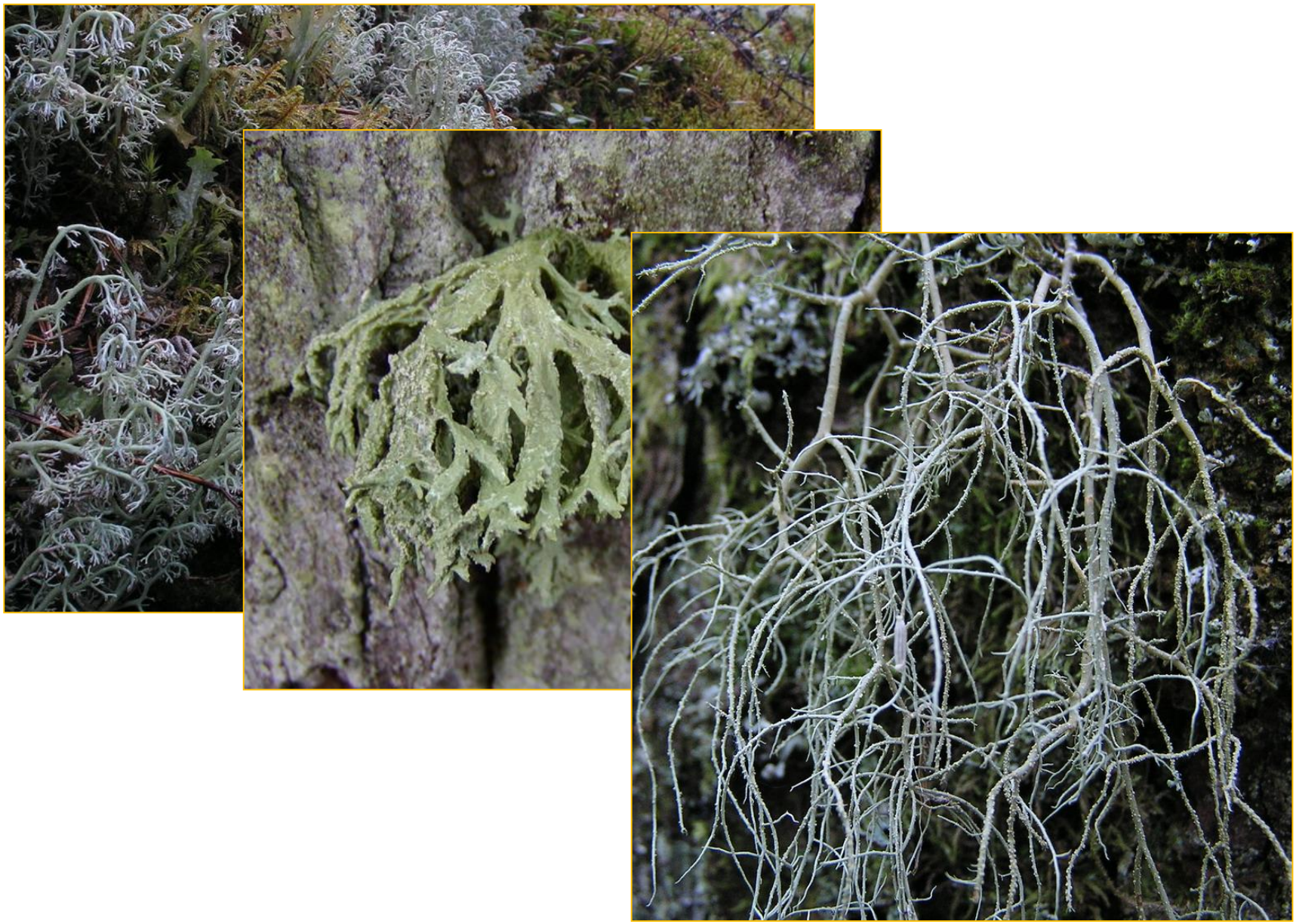
vrstvy nejsou rozlišeny

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:

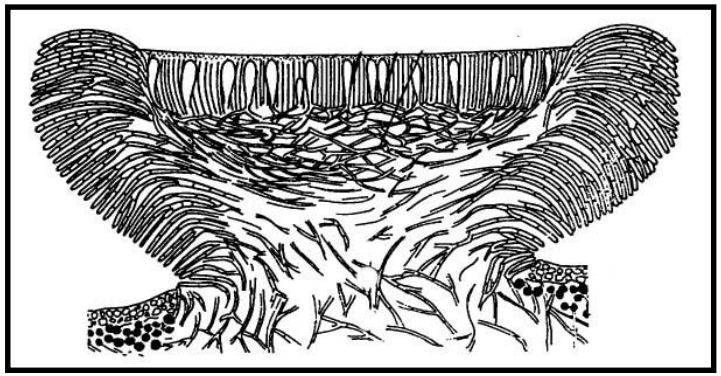
pohlavní – plodnice jako u hub (apothecia, perithecia, plodnice basidiomycet…)

nepohlavní – konidie (nepohlavní spory) nejčastěji v pyknidách

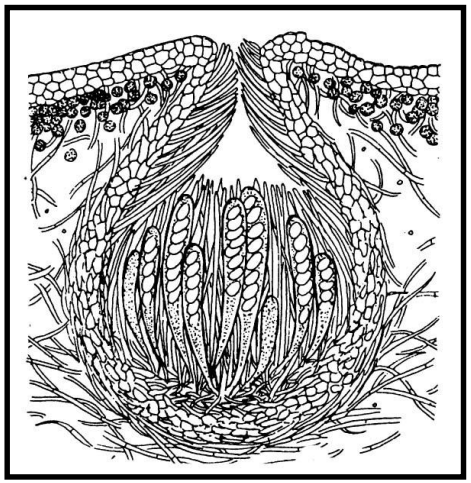
– vegetativní útvary

Pohlavní rozmnožování - základní typy plodnic (Ascomycota)

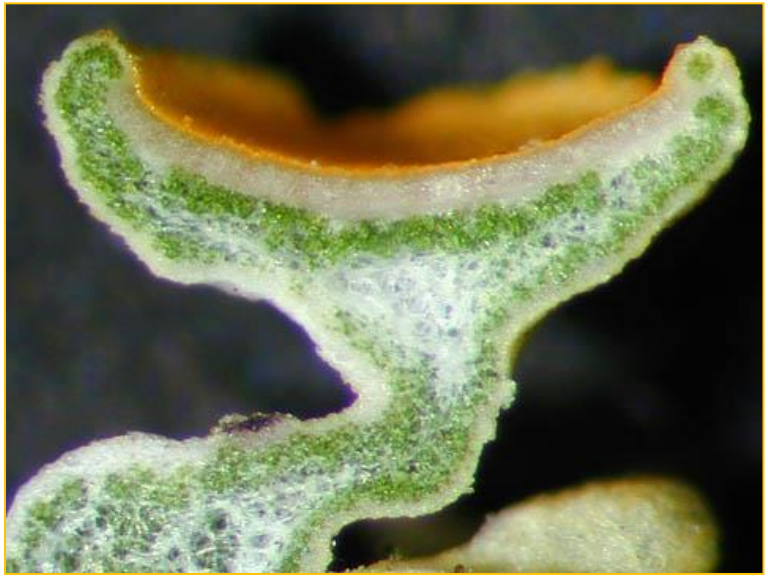
APOTHECIUM – diskovitá plodnice

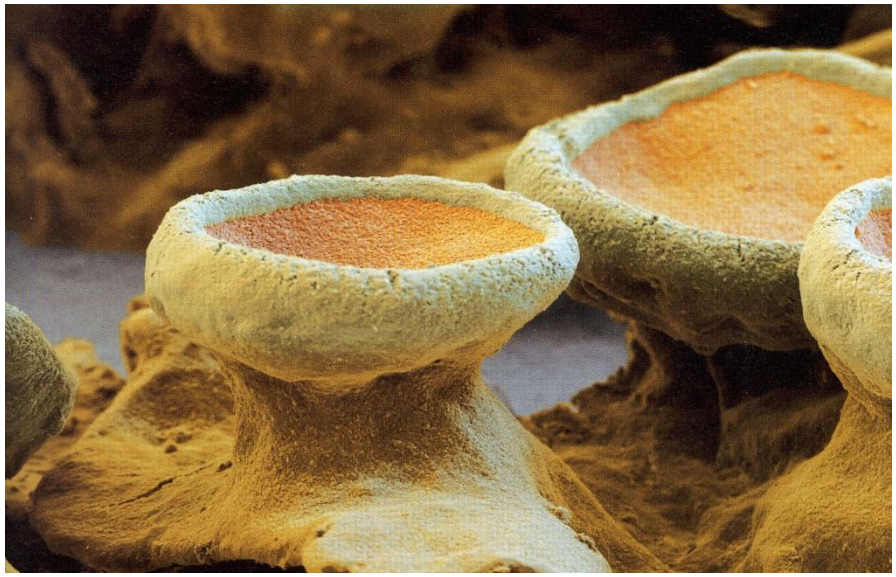


PERITHECIUM – hruškovitá plodnice



Apothecium



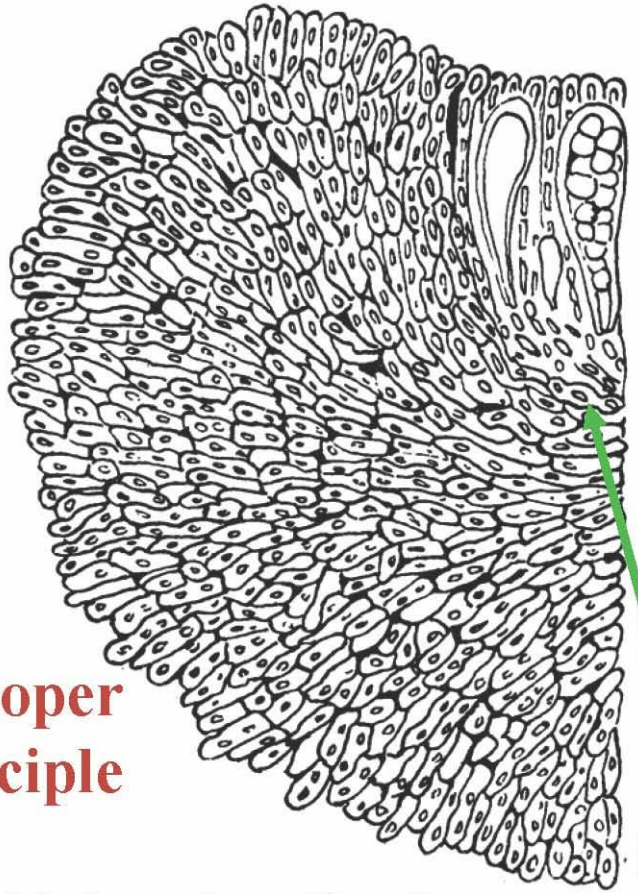


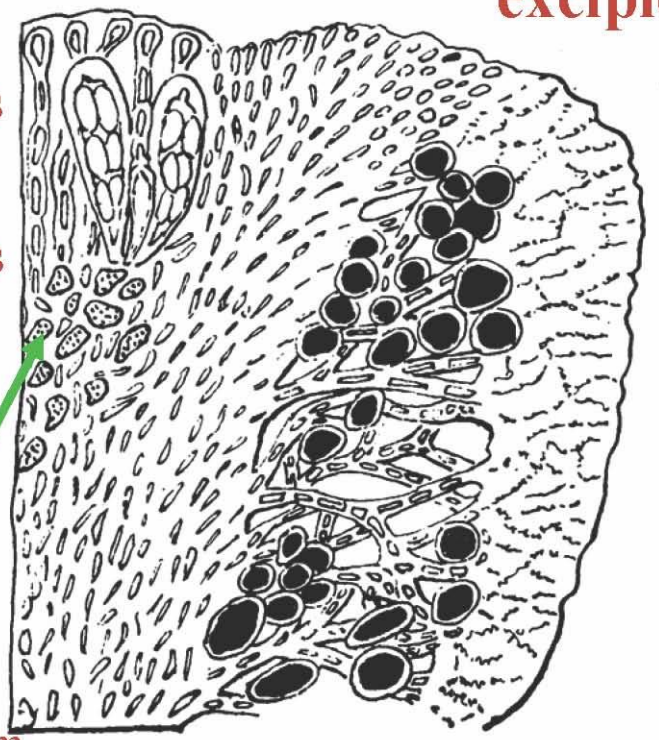
Apothecium

Thelotrema lepadinum

Peltigera horizontalis

Cladonia callosa





hymenium with paraphyses

asci and ascospores

thalloid exciple

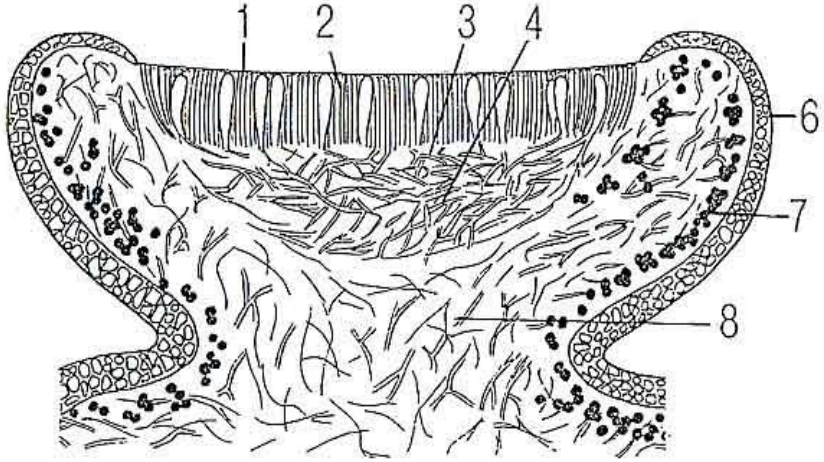
proper exciple

hypothecium

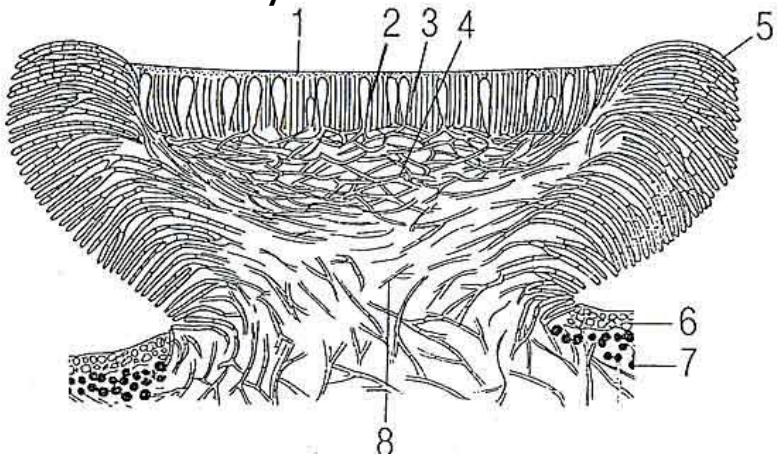
Lecideine Apothecium

Lecanorine Apothecium

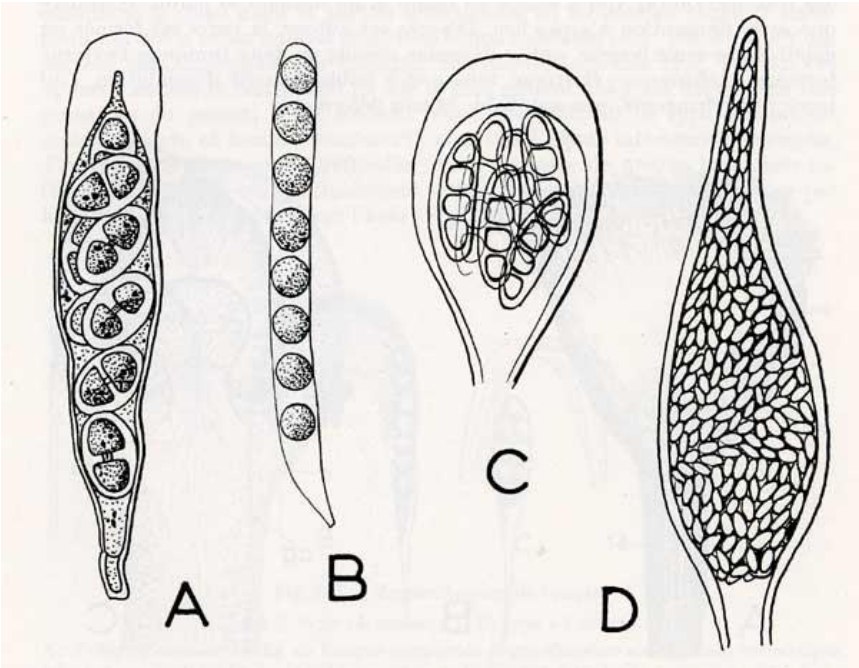
lekanorovité - stélkový okraj

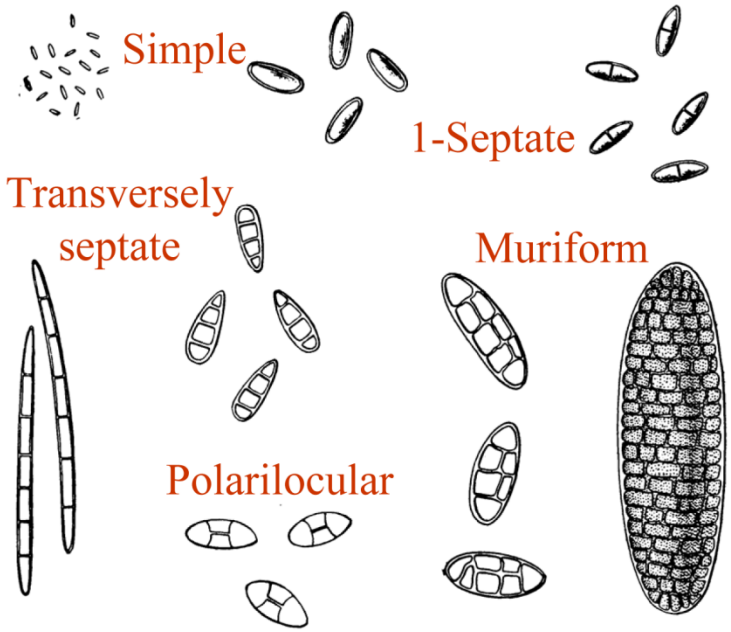


lecideovité – vlastní okraj karbonizovaný



vřecka a spory lišejníků

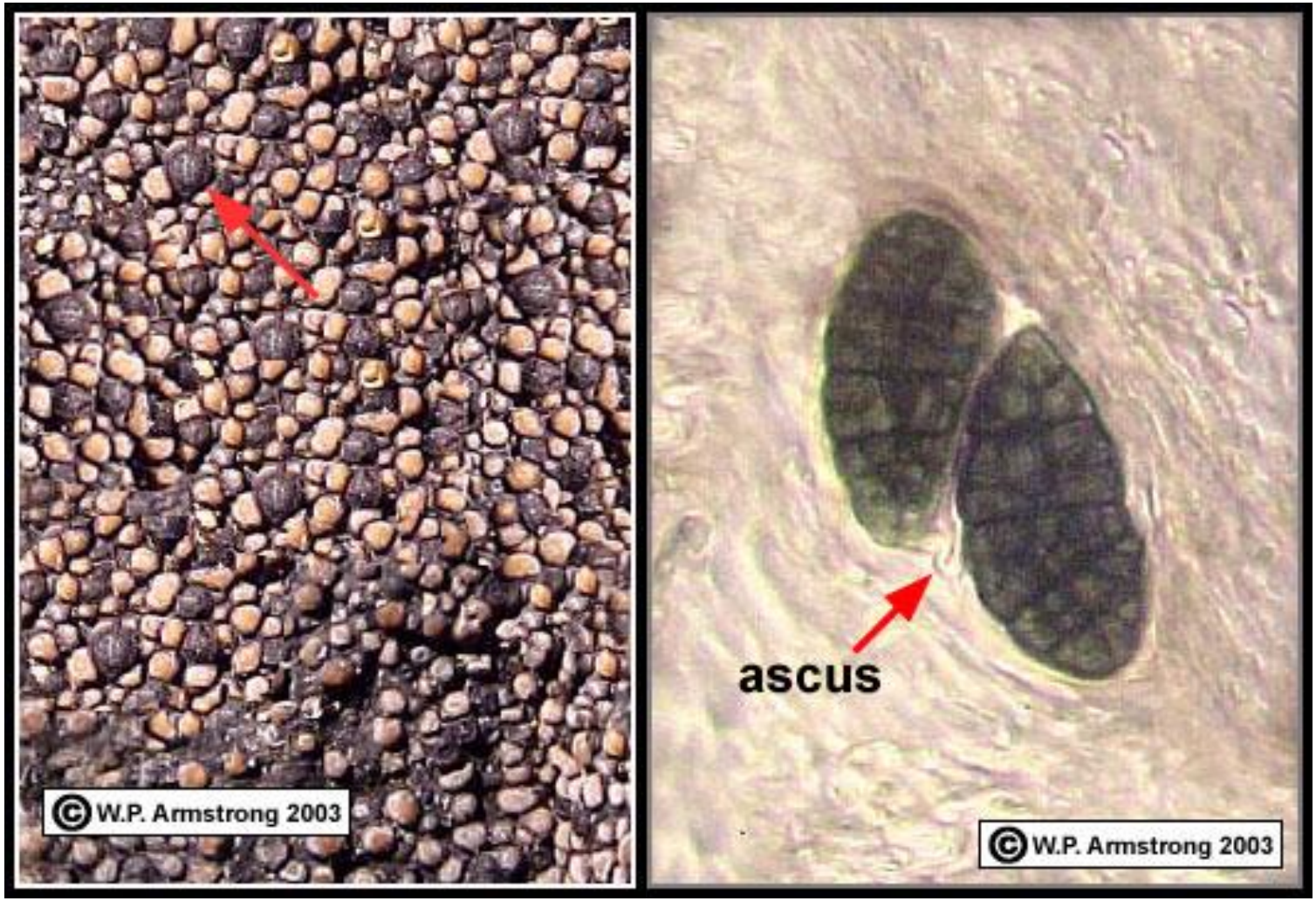




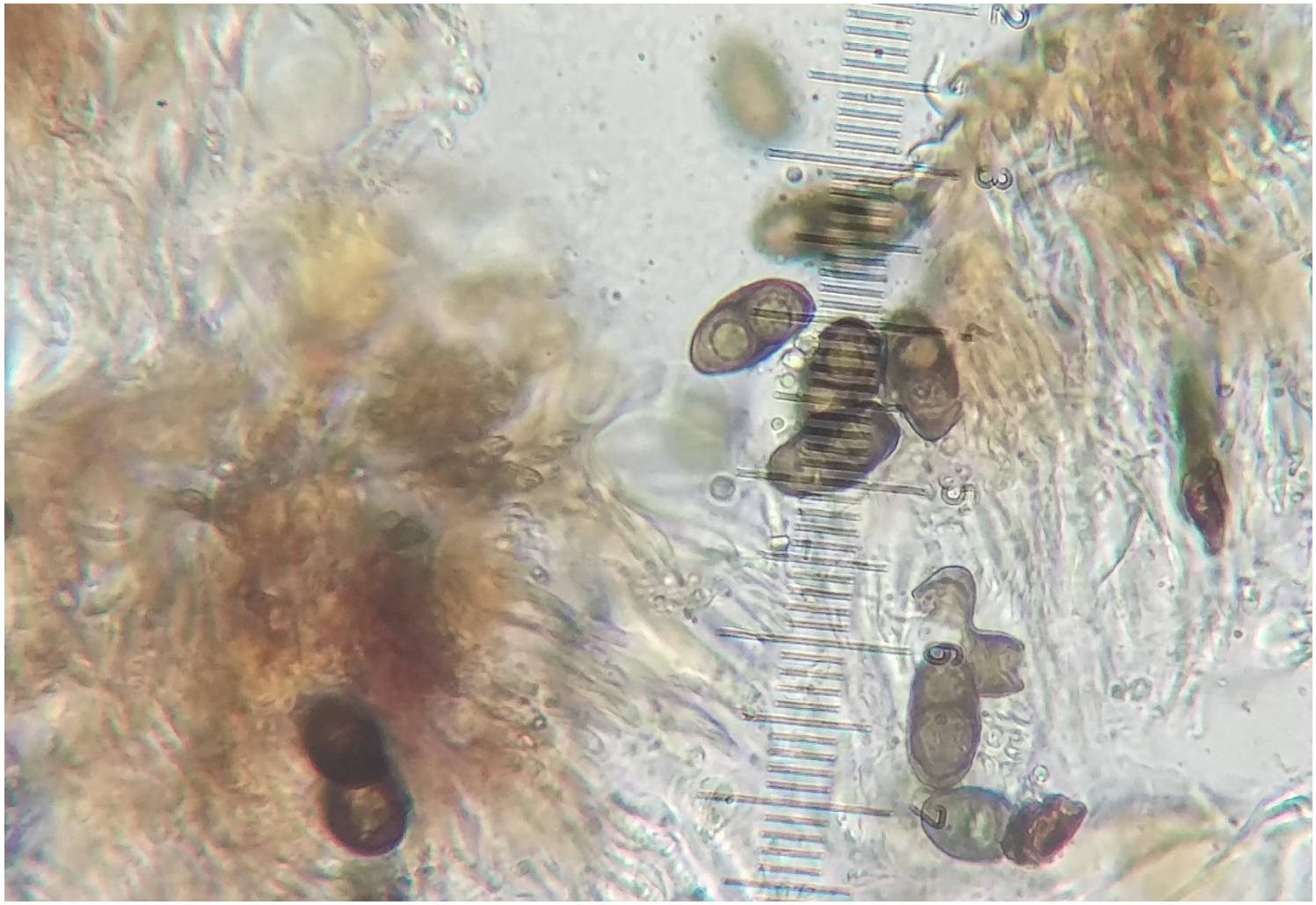
Pertusaria – vřecka a spory

Cladonia – vřecka a spory

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



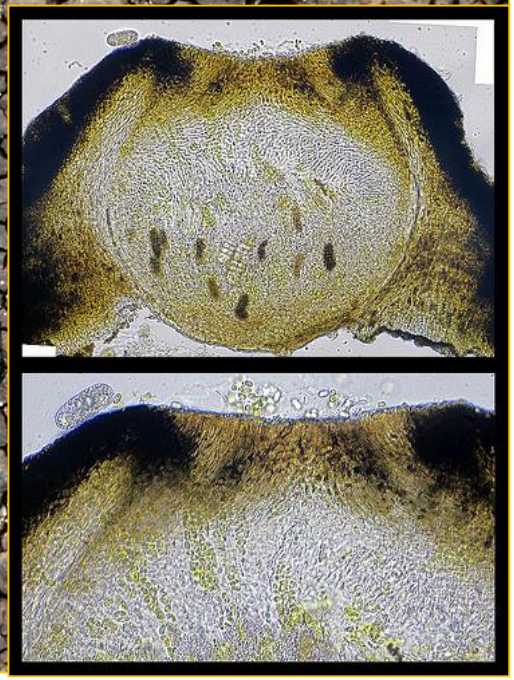
Rhizocarpon geminatum



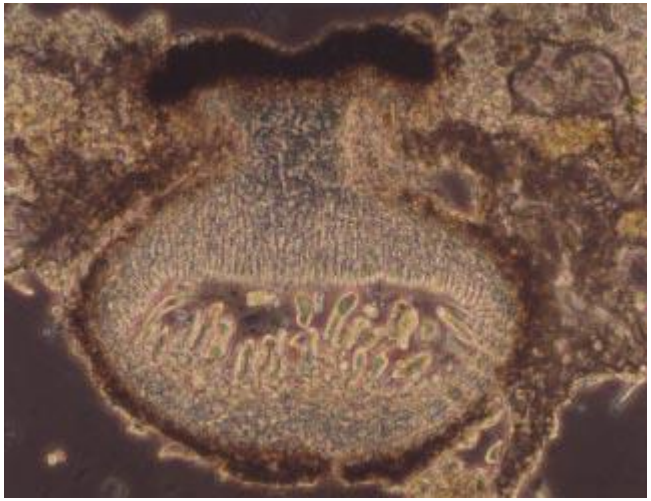
Rinodina lecanorina

Scoliciosporum chlorococcum

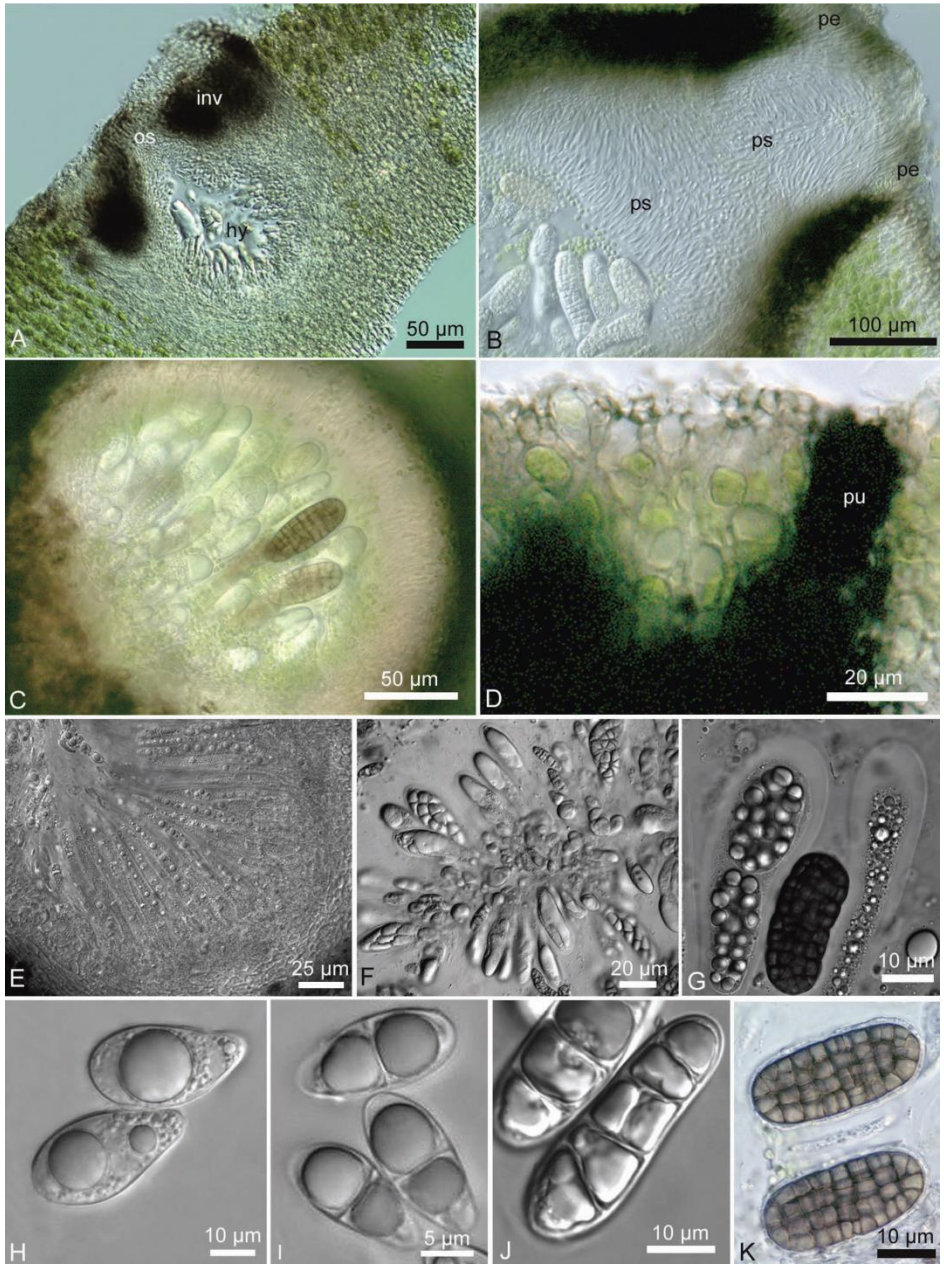
Perithecium



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.

Rozmnožování a rozmnožovací útvary lišejníků:

Rozmnožování:

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

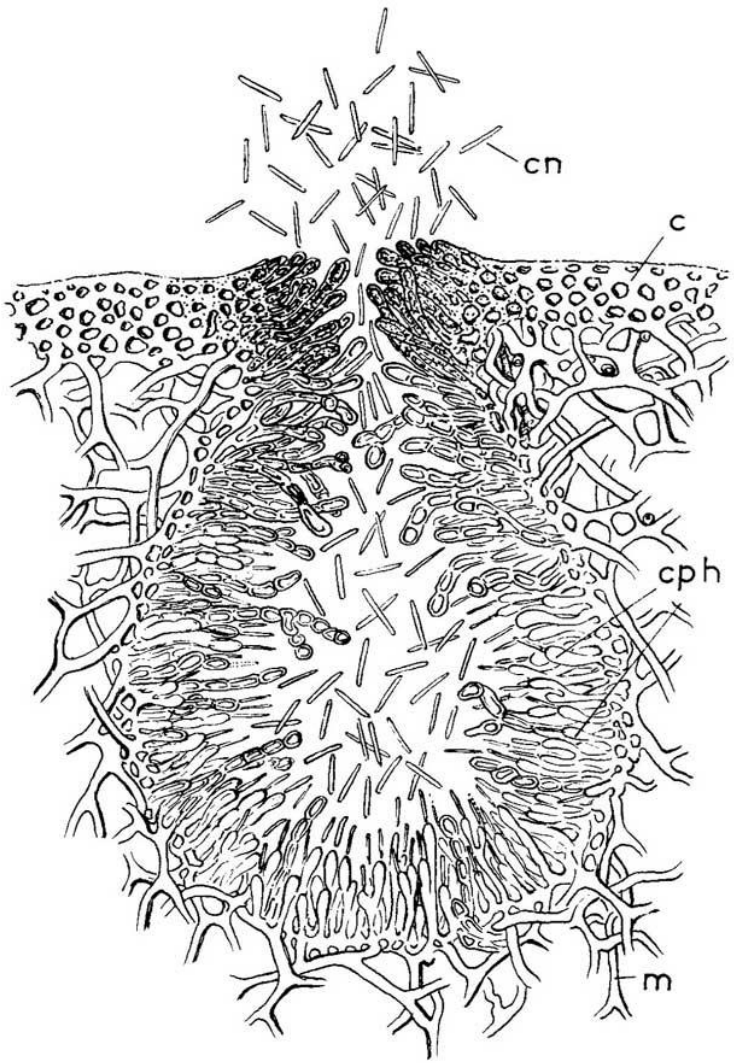
nepohlavní – konidie (nepohlavní spory) nejčastěji v pyknidách

– vegetativní útvary:

sorédie

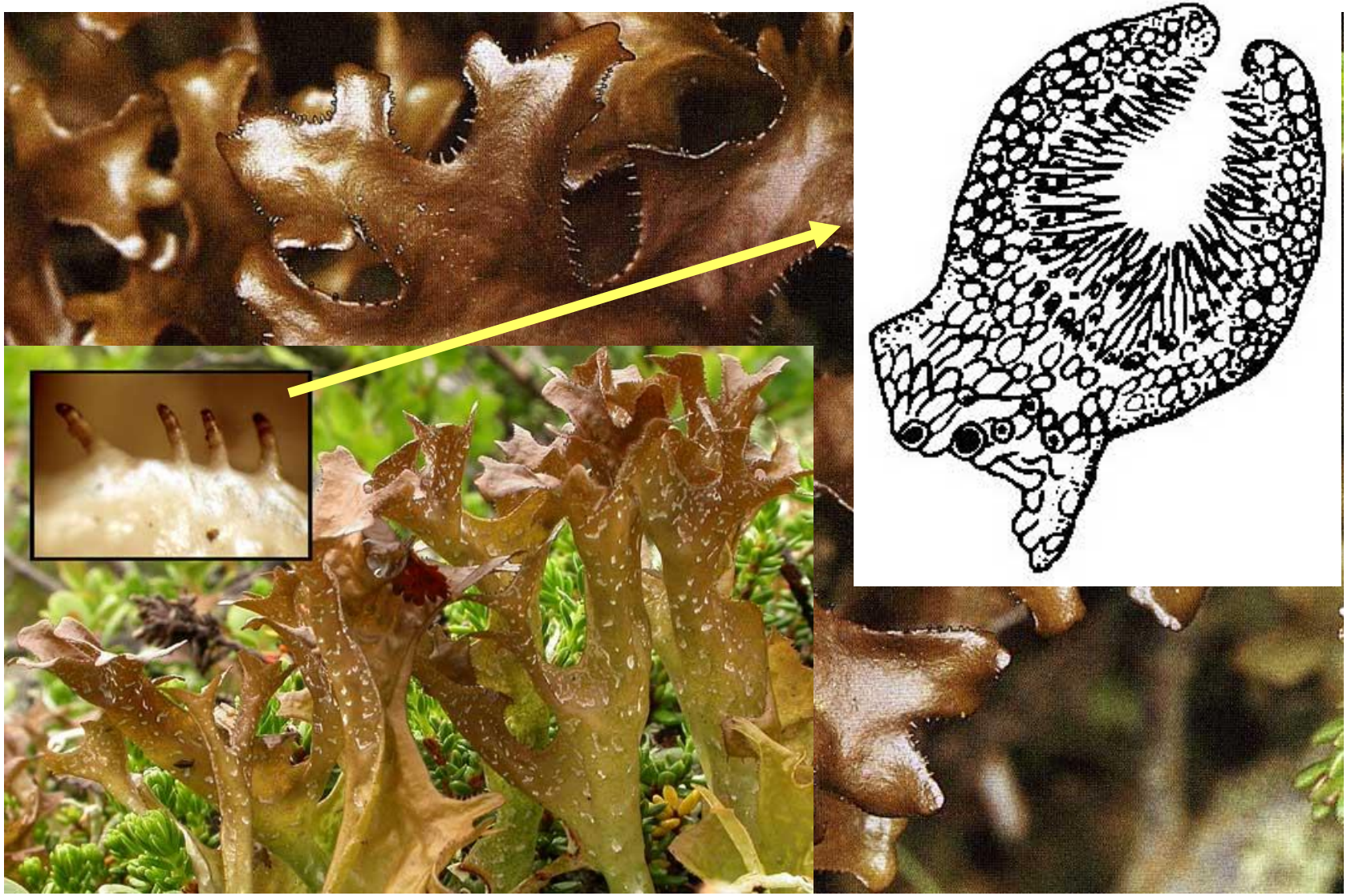
izídie (isidie)

Pyknidy (pyknospory = konidie)



Nepohlavní rozmnožování houby

Pyknidy (pyknospory = konidie)

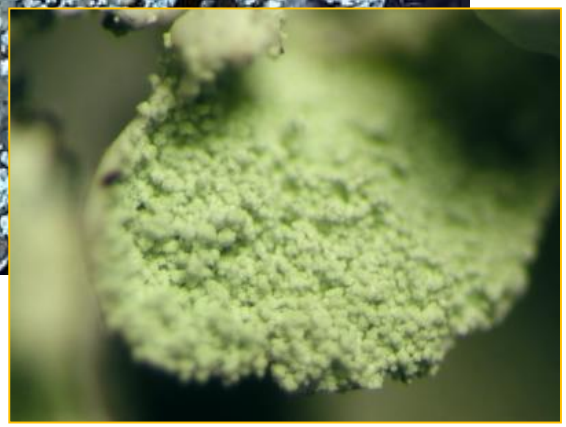


Nepohlavní rozmnožování houby

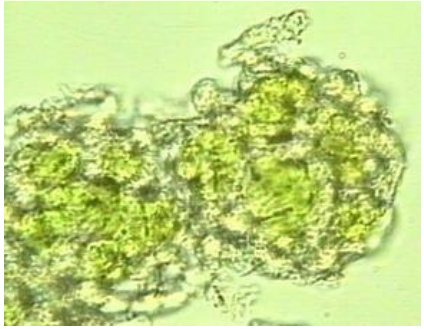
Pyknidy

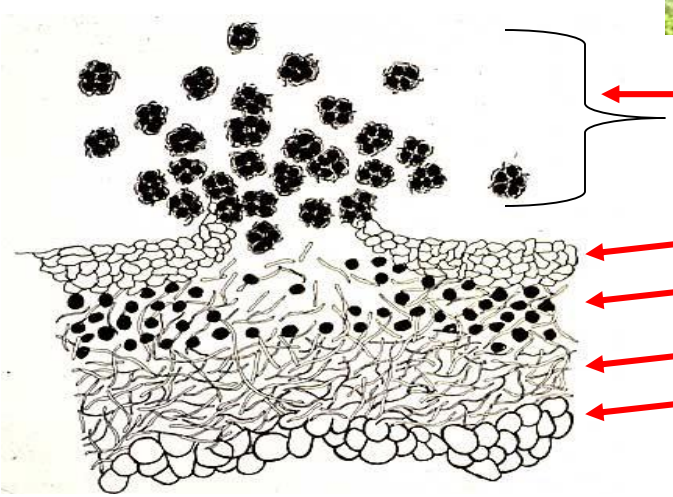
(černá ústí – tečky)

Vegetativní rozmnožování - sorály a sorédie



Skrze praskliny v kůře se uvolňují řasové buňky obalené hyfami mykobionta - *sorédie*. Často v útvarech zvaných *sorály.*





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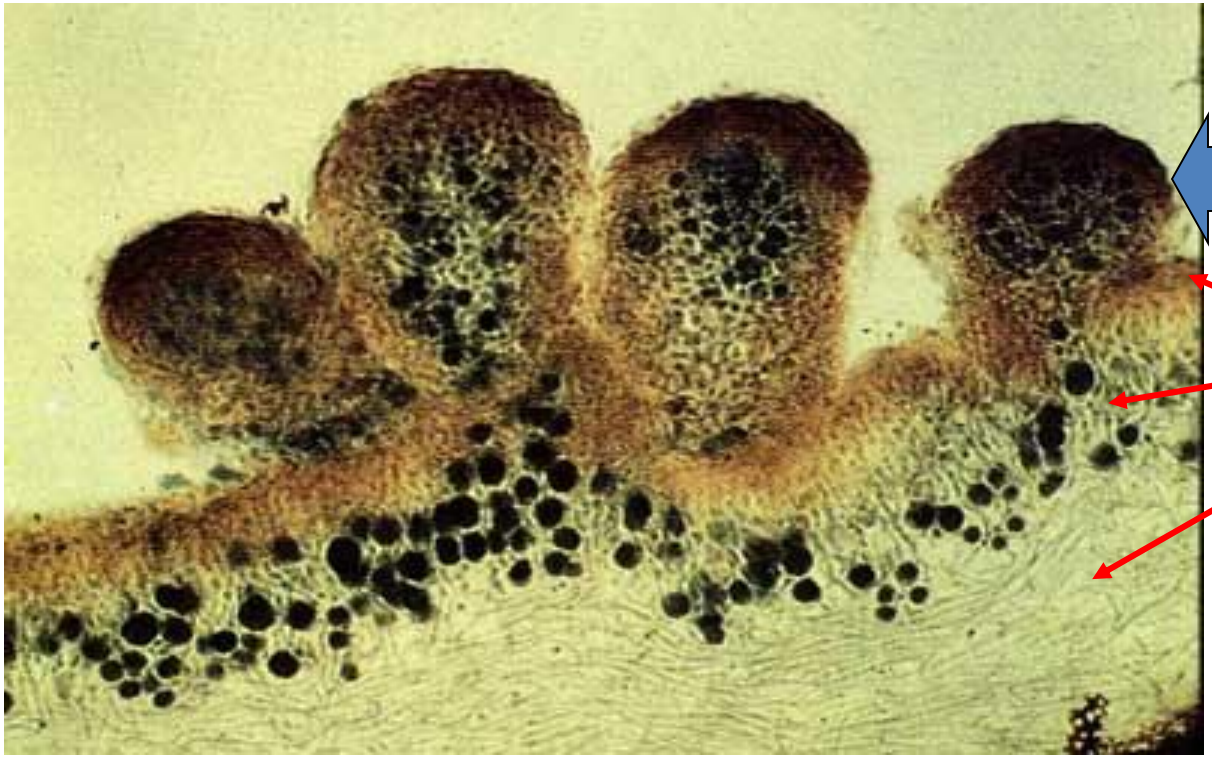
SEM of soredia of *Cladonia* sp.

sorédie *Physcia adscendens*

blogs.reading.ac.uk

sorédie *Cladonia cornuta* na podétiích

Vegetativní rozmnožování - izídie



výrůstky, které zachovávají strukturu stélky, tzn. mají kůru, řasovou vrstvu i dřeň (popř. mají strukturu jako homeomerická stélka).

Izídie

www.stridvall.se

https://calphotos.berkeley.edu