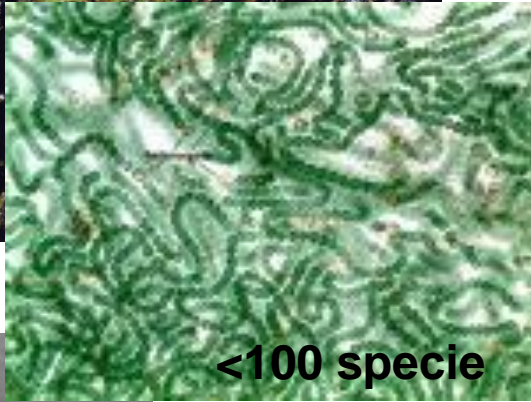




LICHENI



<100 specie



~ 15.000 specie

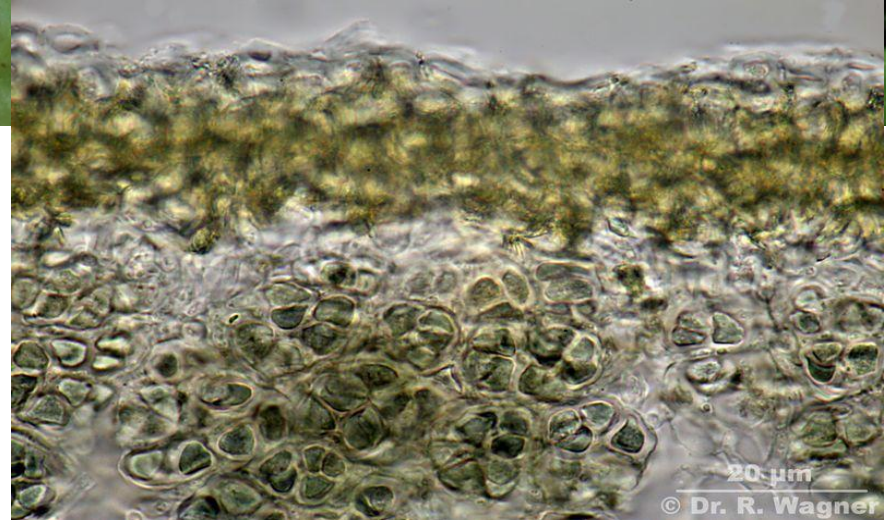
~10% dei
licheni

~90% dei
licheni



<1.000 specie

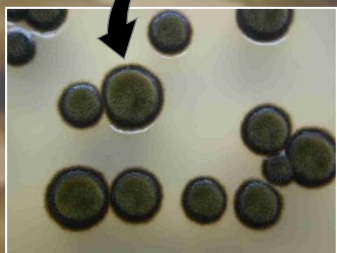
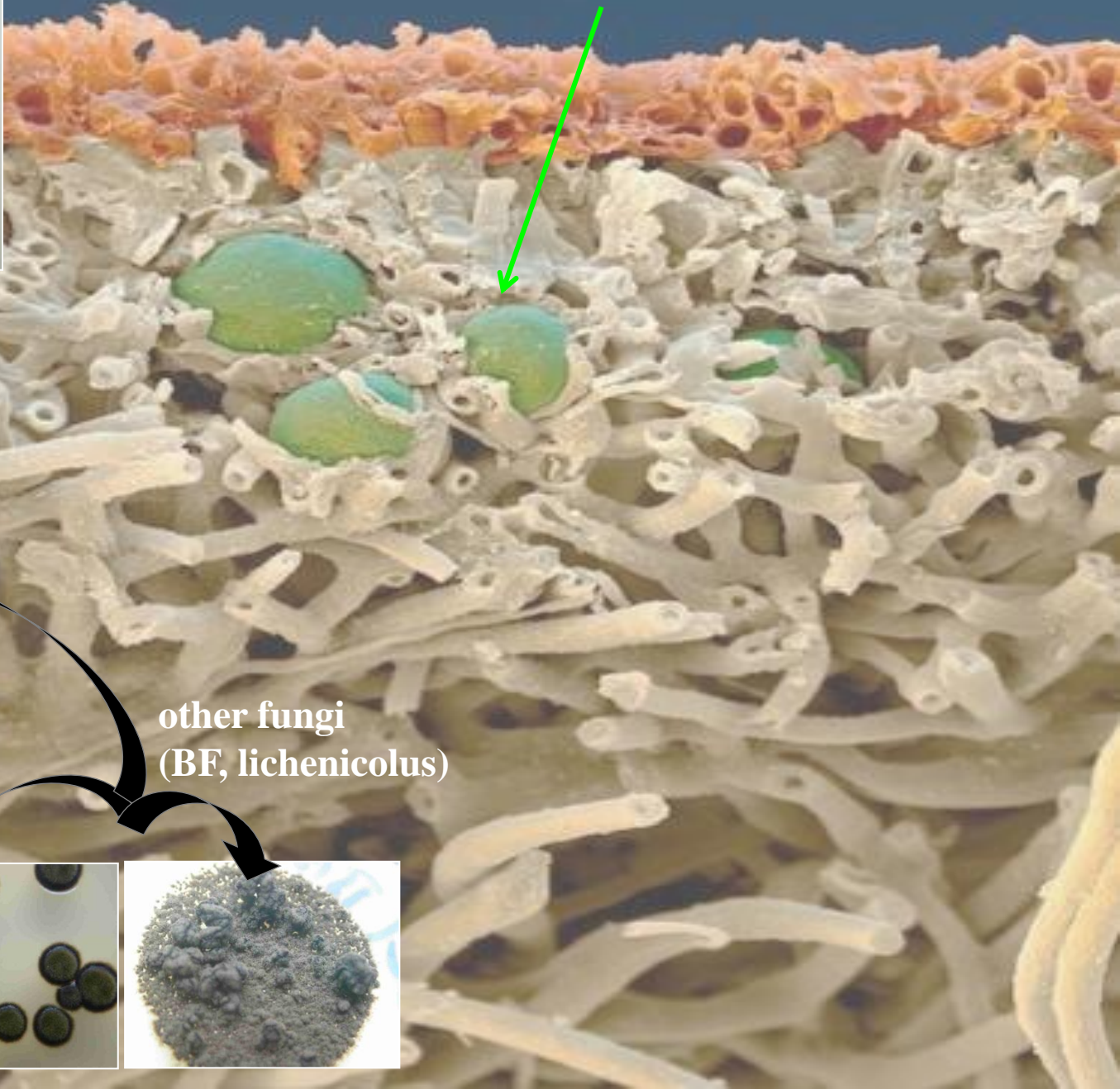
Simbiosi
tripartite:
micobionte,
clorobionte e
cianobionte.

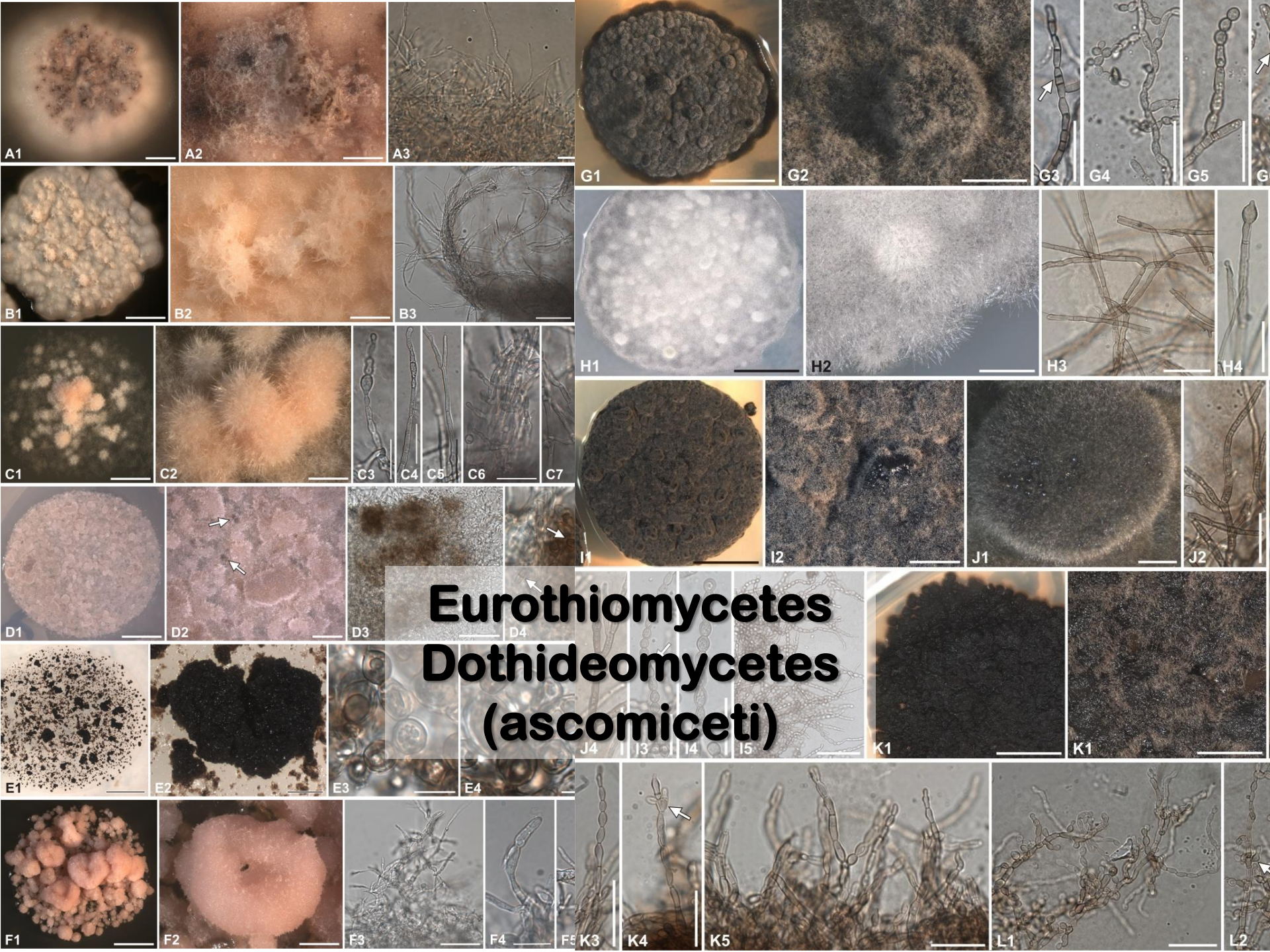


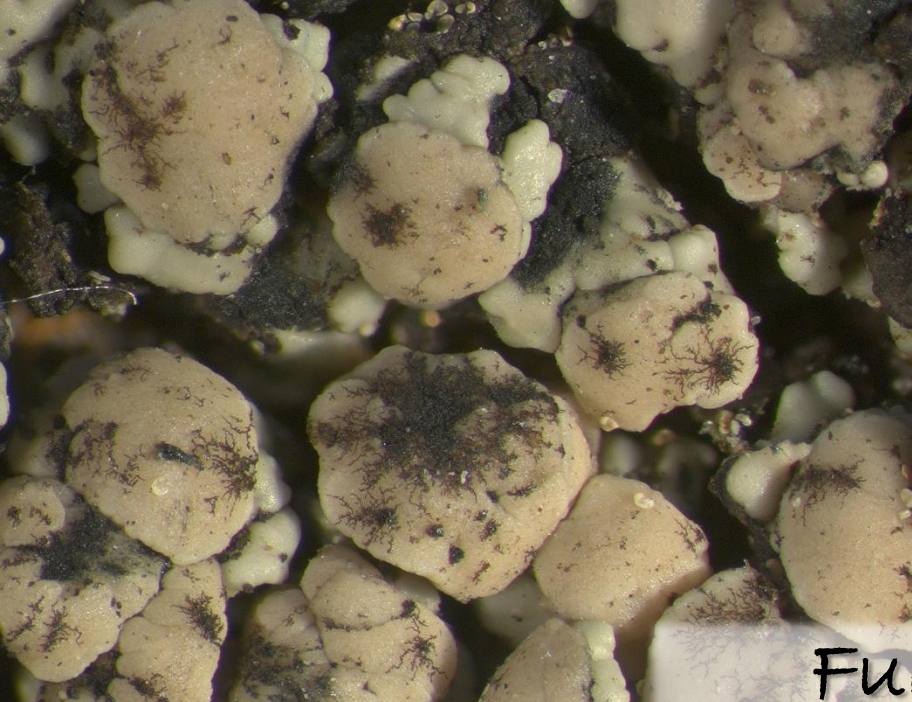
FOTOBIONTE

MICOBIONTE

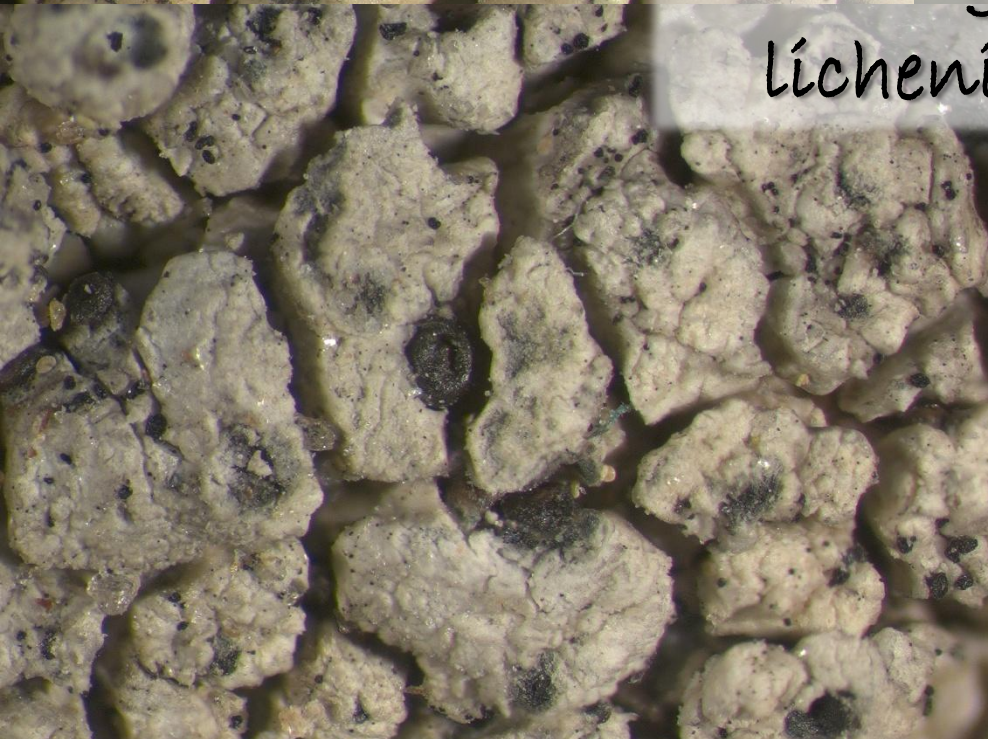
other fungi
(BF, lichenicolus)





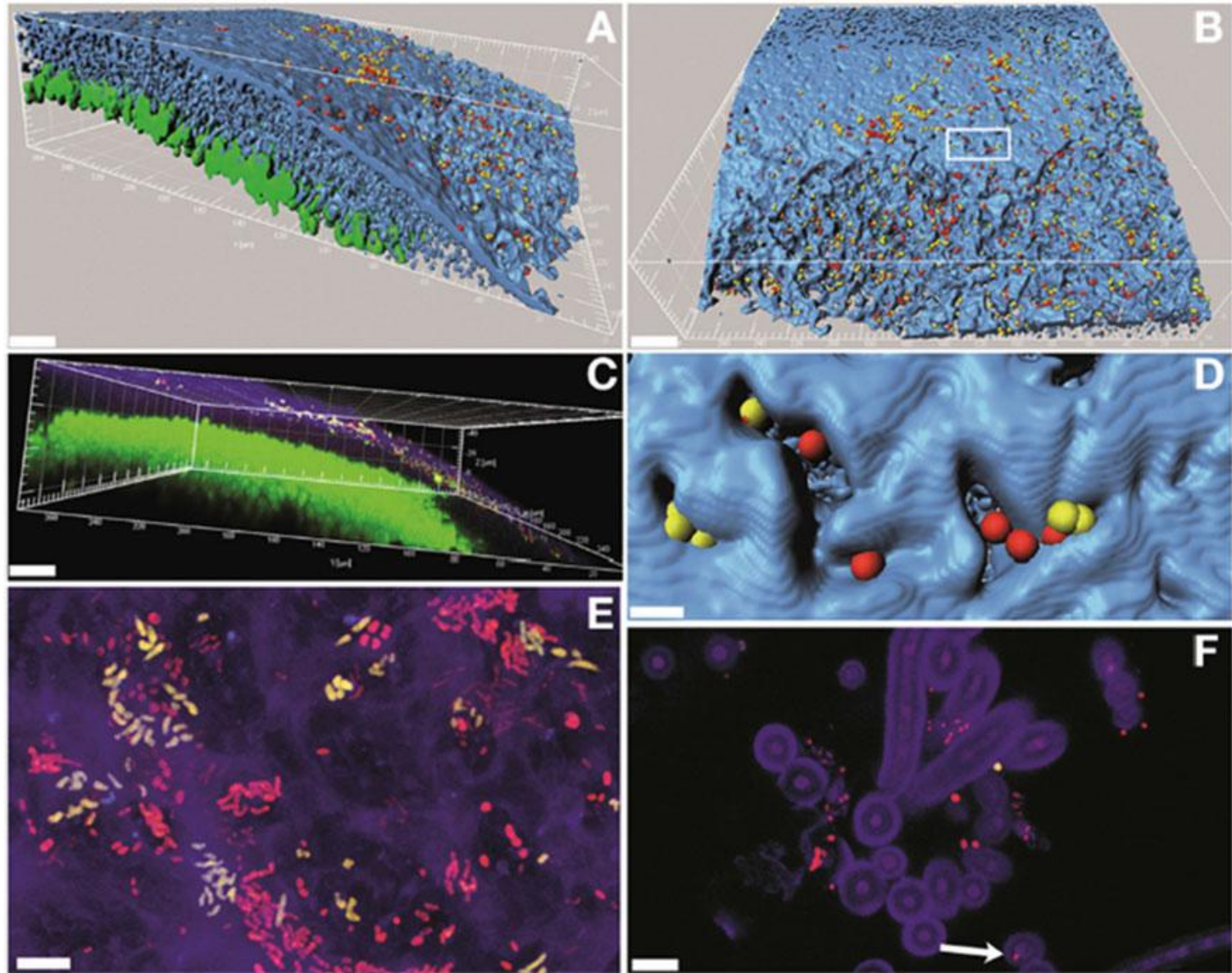


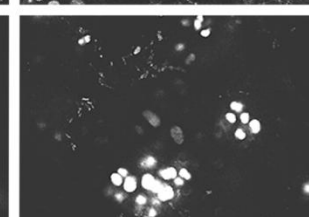
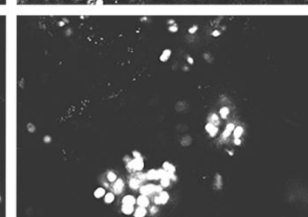
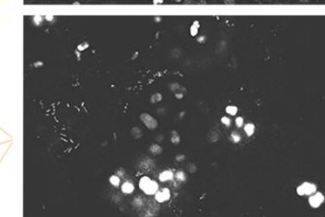
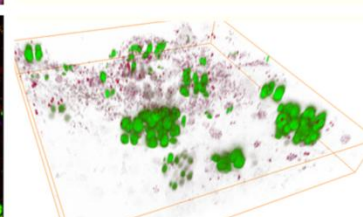
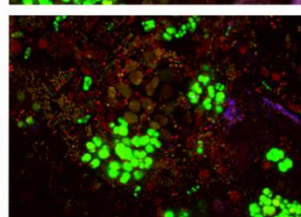
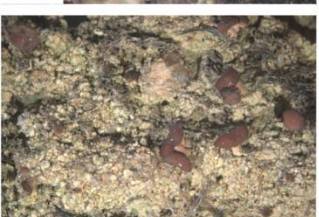
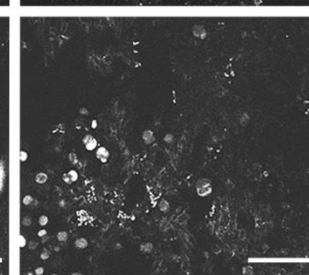
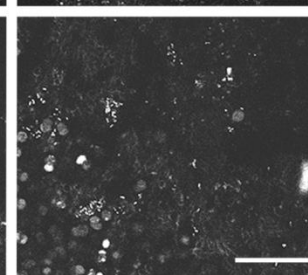
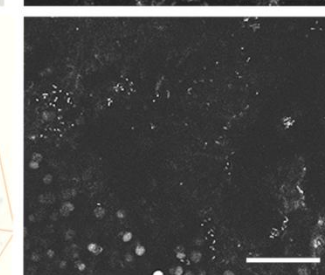
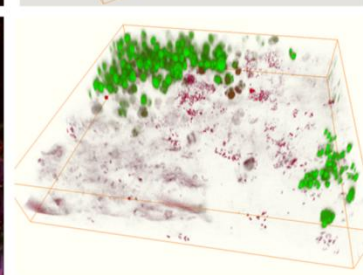
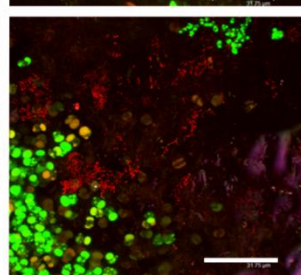
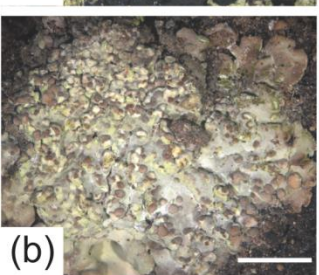
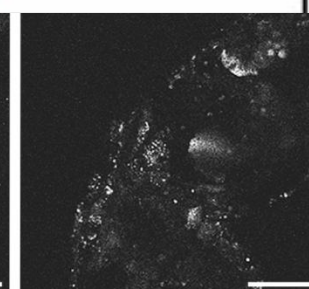
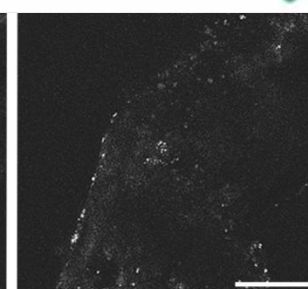
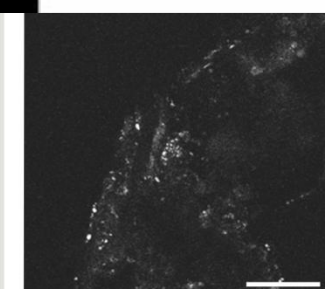
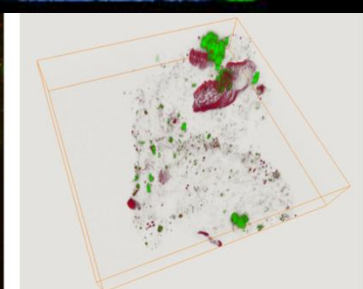
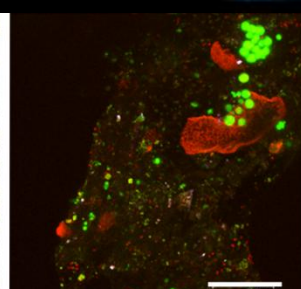
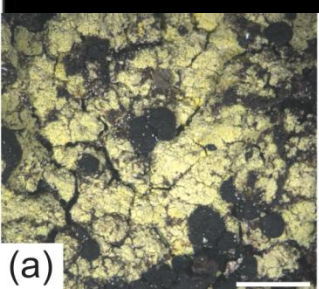
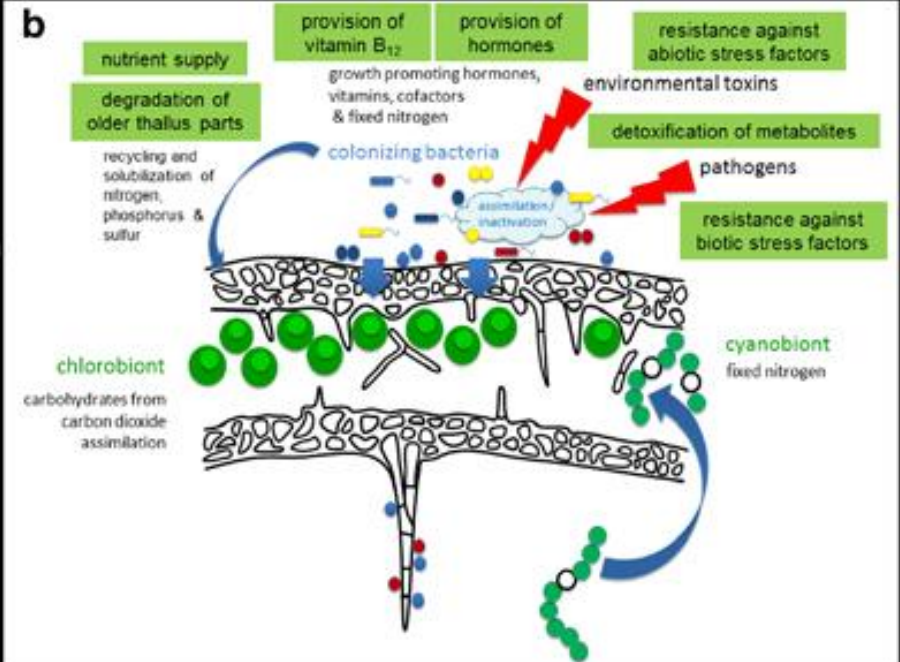
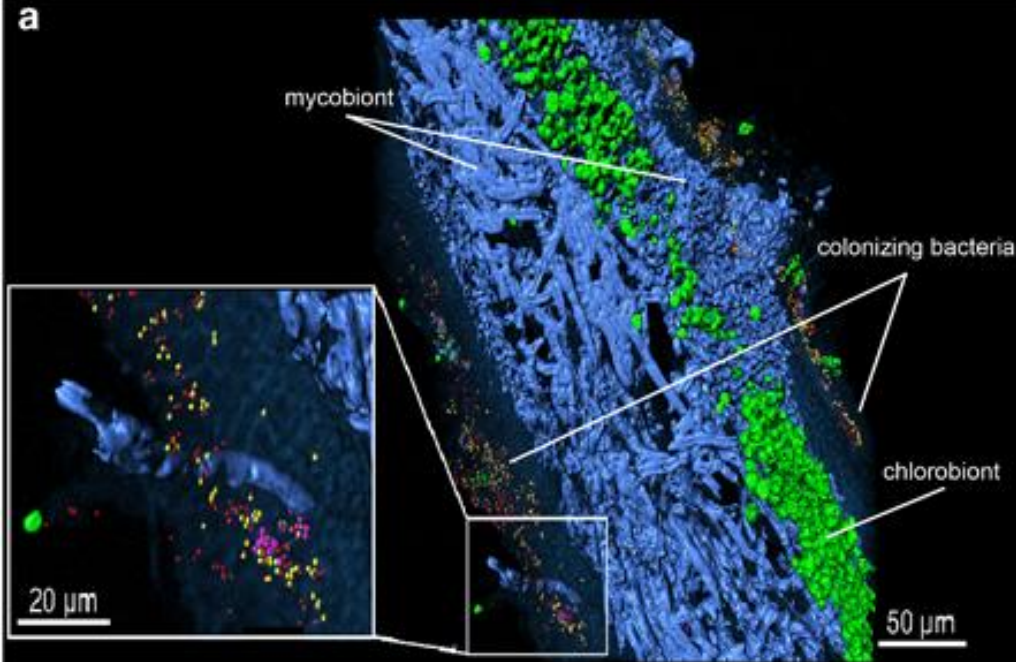
Funghi
líchenicoli



Lichen–Bacterial Interactions

Grube *et al.* (2009-2016) Environmental and Microbial Relationships, 3rd Edition, The Mycota IV. I.S. Druzhinina and C.P. Kubicek (Eds.) Springer International Publishing Switzerland 2016



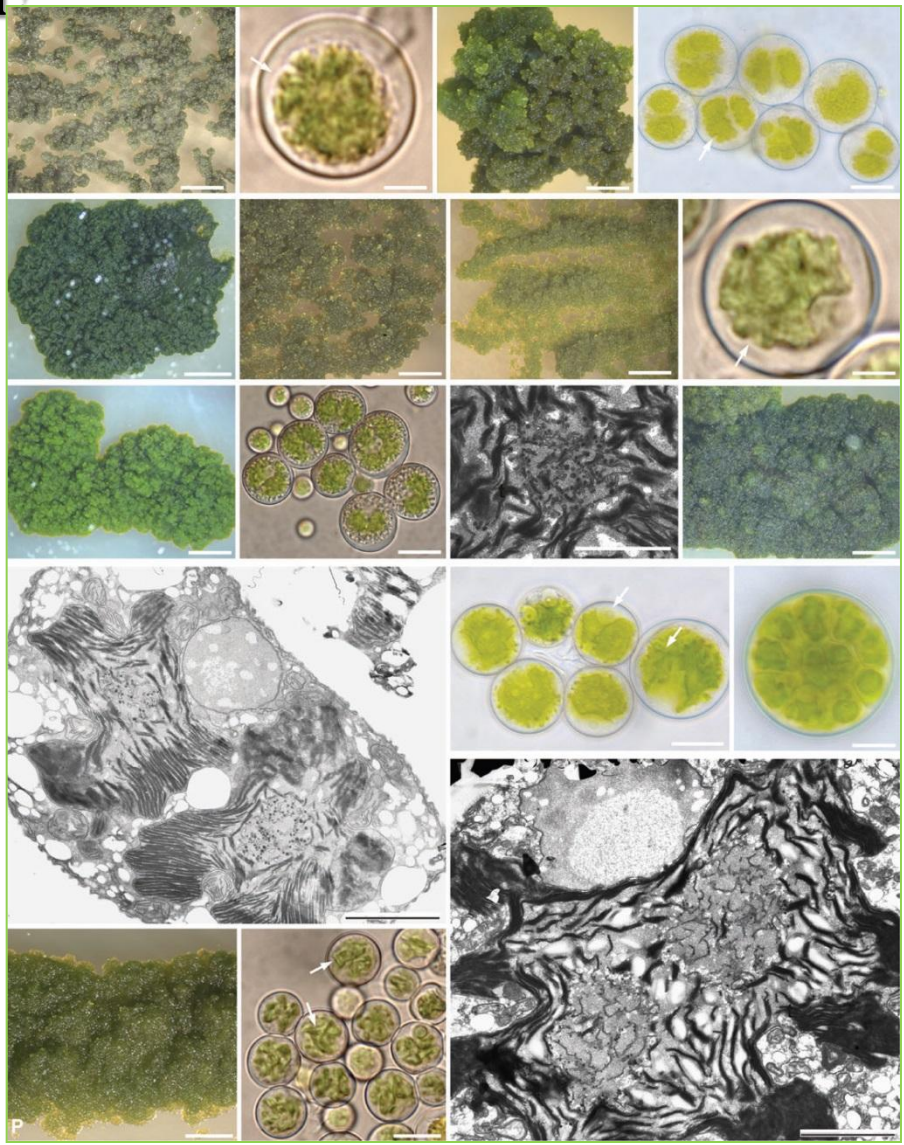
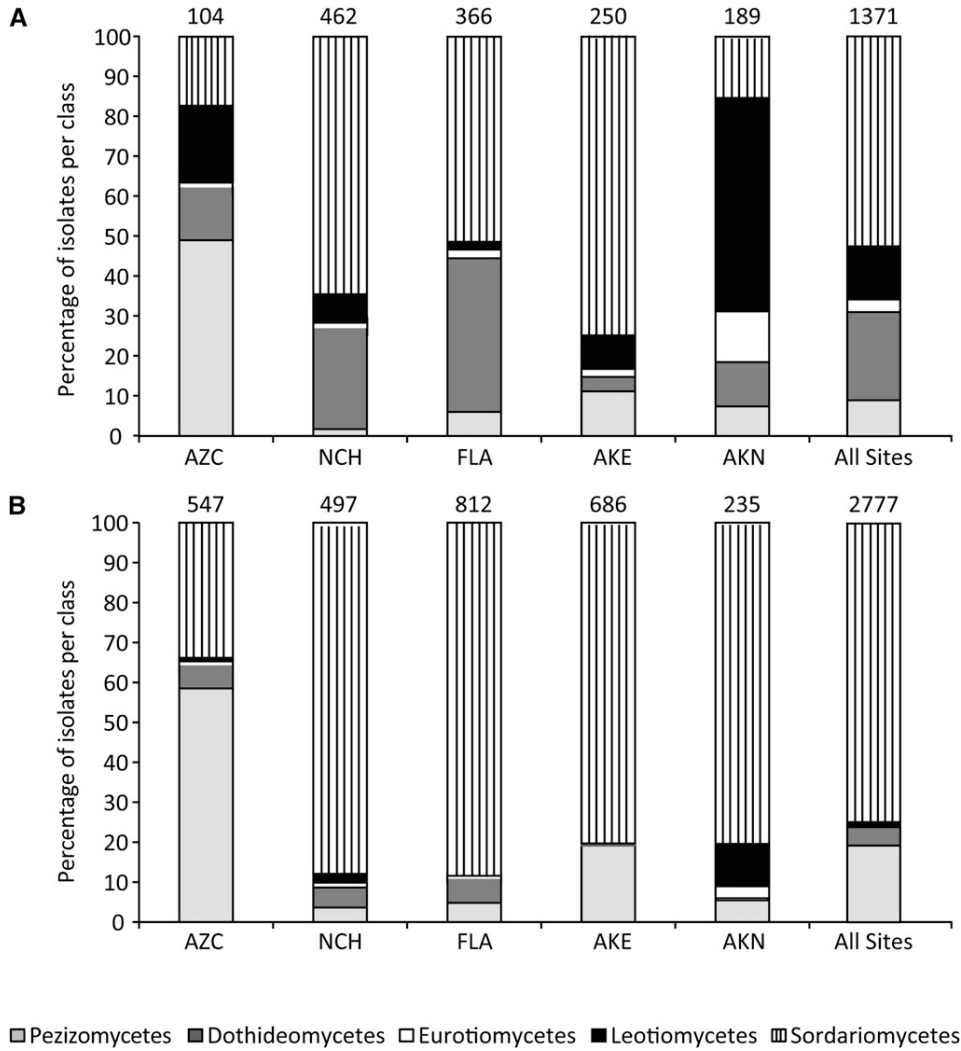


A phylogenetic estimation of trophic transition networks for ascomycetous fungi: are lichens cradles of symbiotrophic fungal diversification?

Arnold et al. (2009) Systematic Biology 58: 283–297.

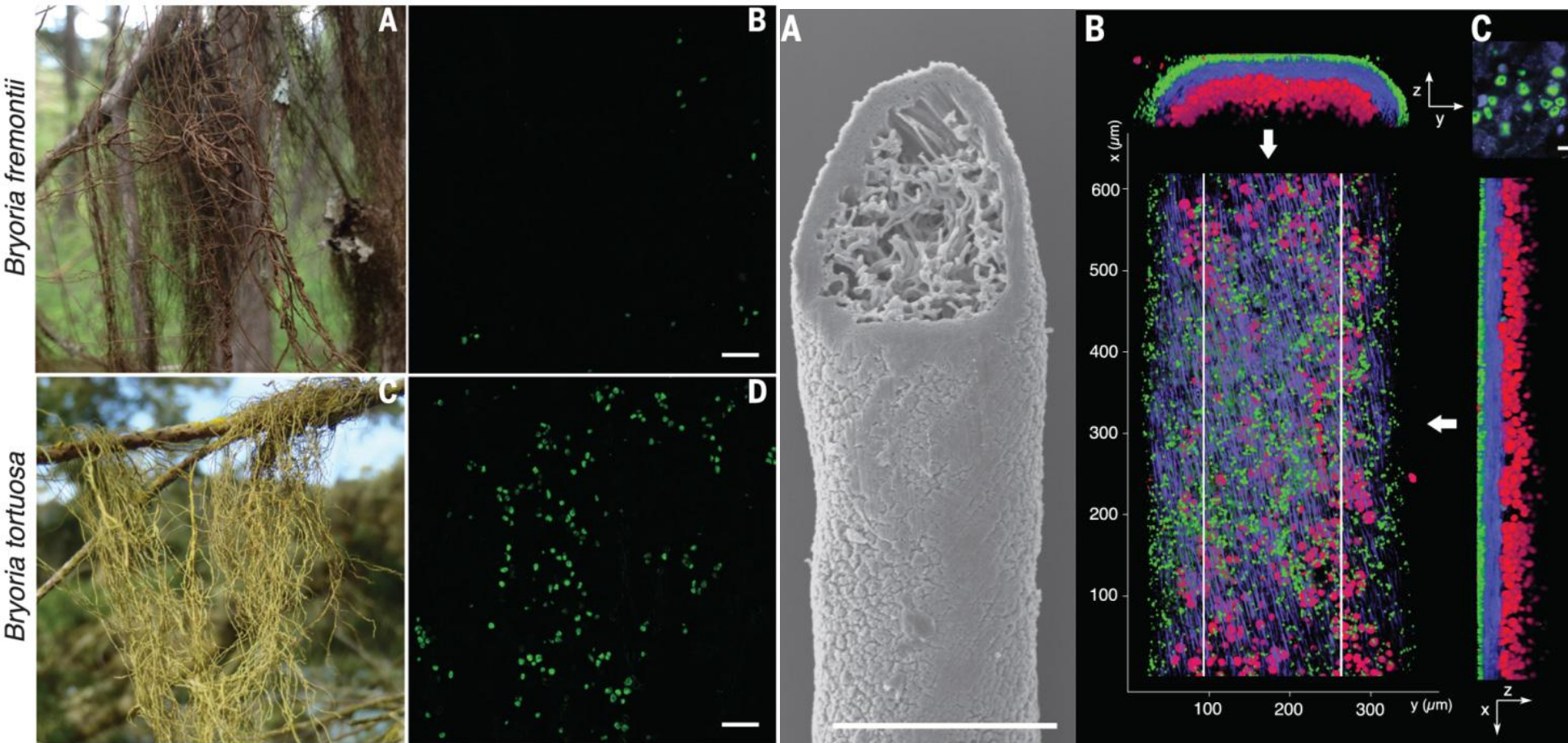
Multiplicity of photobionts within individual lichen thalli

Muggia *et al.* (2008-2014)
Barreno *et al.* (2009-2016)

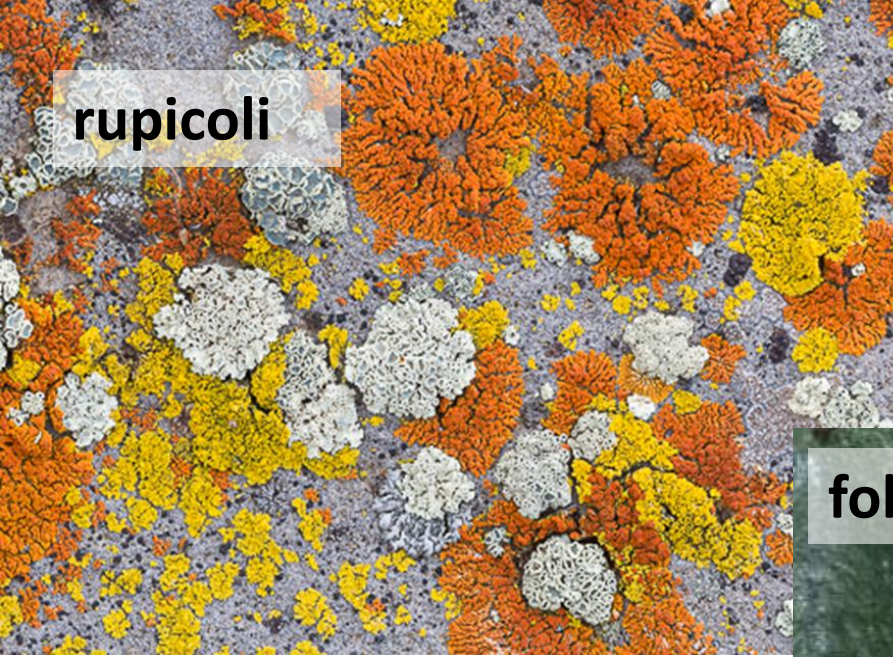


Basidiomycete yeasts in the cortex of ascomycete macrolichens

Spribille *et al.* (2016) *Science*



rupicoli



terricoli



foliicoli



lignicoli



muscicoli



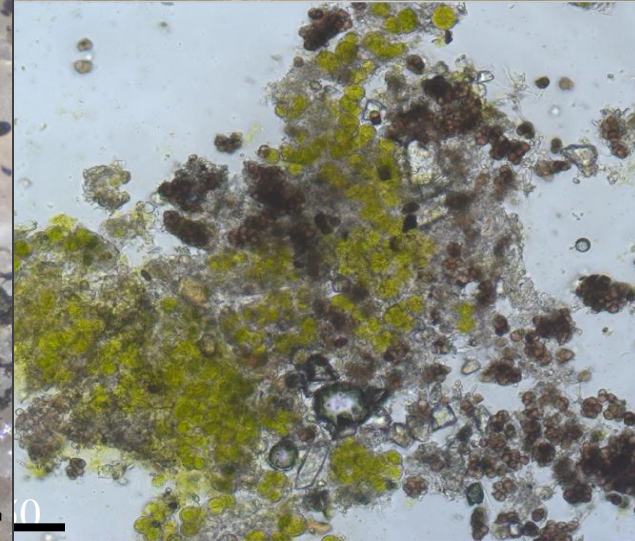
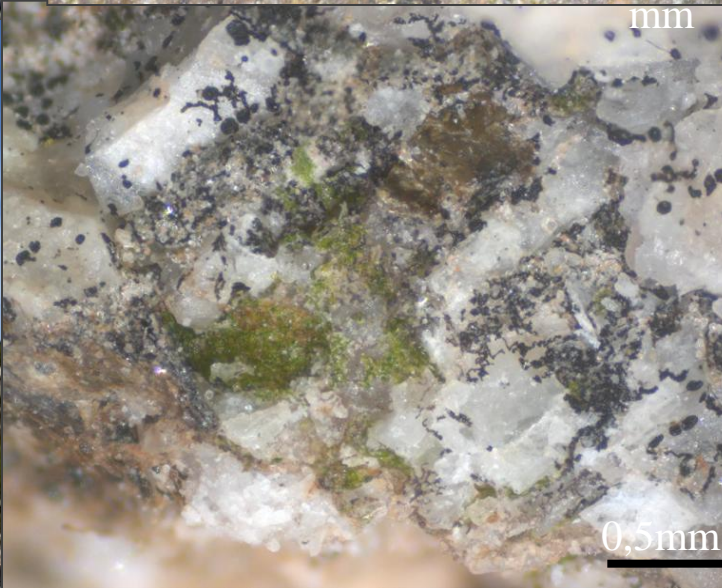
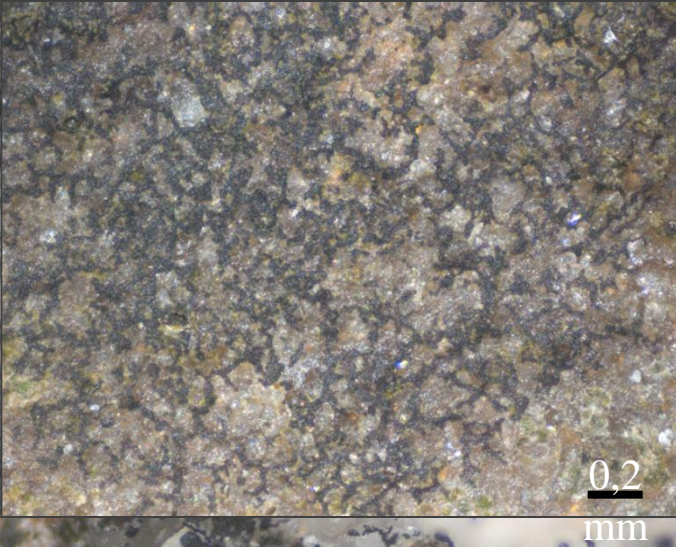


In alcuni deserti la copertura lichenica può essere imponente
←→ apporto di umidità (nebbie),
e.g. regione costiera del Namib
(Africa), deserto di Atacama (tra
Cile e Bolivia), deserto del Sonora
(Messico nord-occidentale).





Specie licheniche più primitive colonizzano ambienti “estremi” (rocce nude, alta radiazione UV, alte temperature)



Nelle regioni artica e boreale la biomassa lichenica rappresenta una frazione elevata ed importante → cicli biogeochimici di molti elementi, sostanze e H₂O.

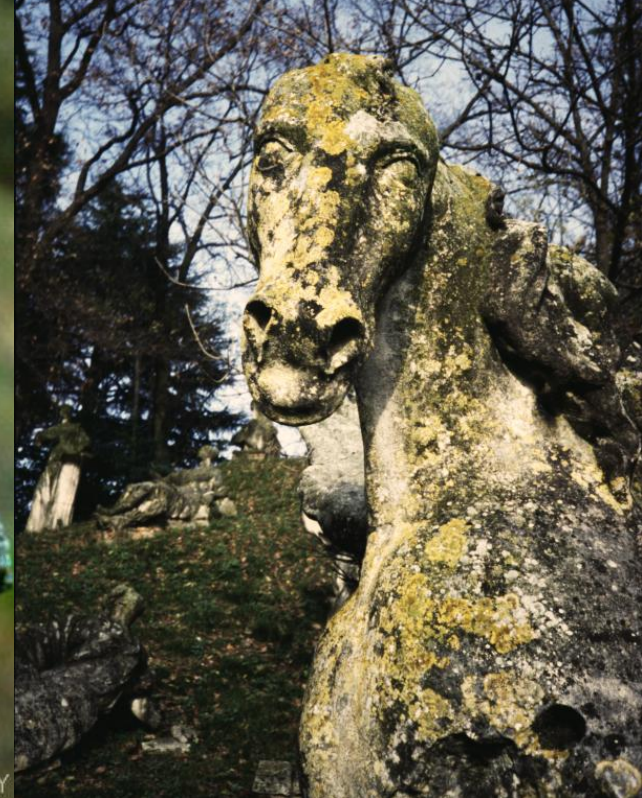


Il numero di specie non è necessariamente elevato.... poche specie, con tantissimi individui!!

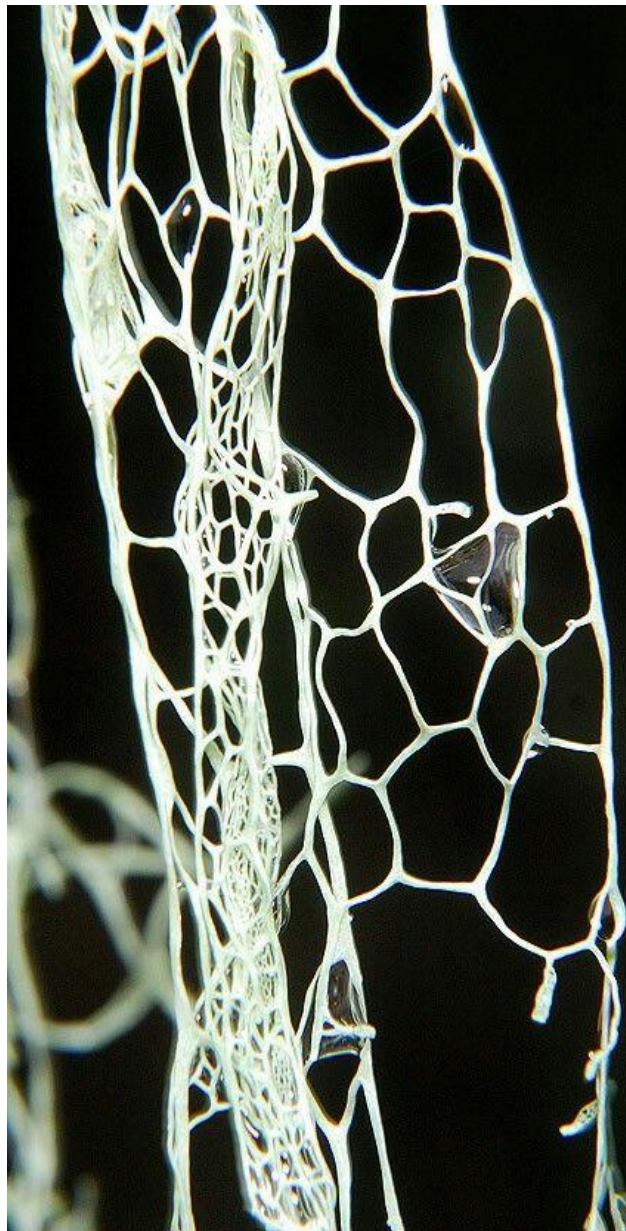
.... i licheni sono in grado di colonizzare addirittura il vetro, la plastica o i metalli.



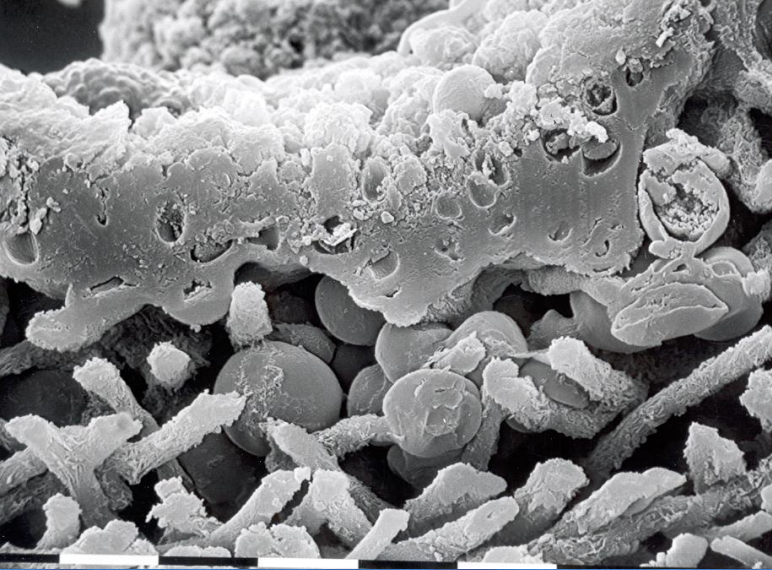
.....siamo circondati da licheni, sugli alberi, sui muri e ... sui monumenti !



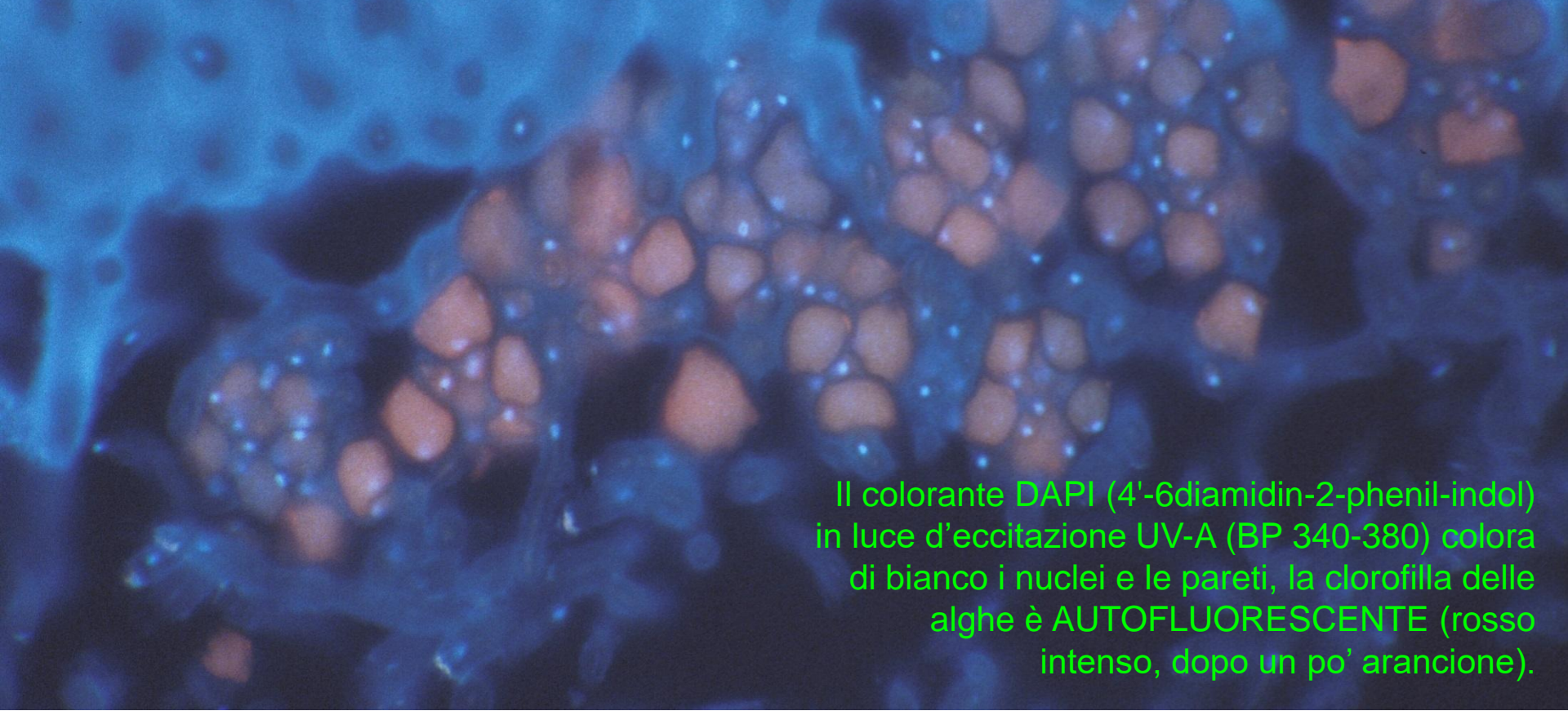
I “deserti lichenici” sono dove c’è un inquinamento ambientale troppo elevato di anidride solforosa (SO_2) ossidi di azoto (NO , NO_2 , NO_x), acido fluoridrico, ecc., e.g. nei grandi agglomerati urbani e pianure industrializzate.



Ramalina menziensis,
«lace lichen».

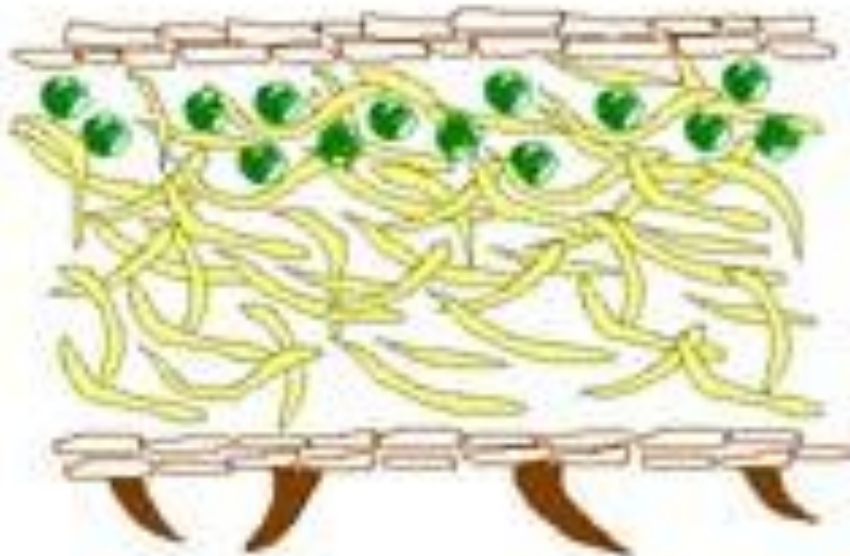


Sezione trasversale del tallo

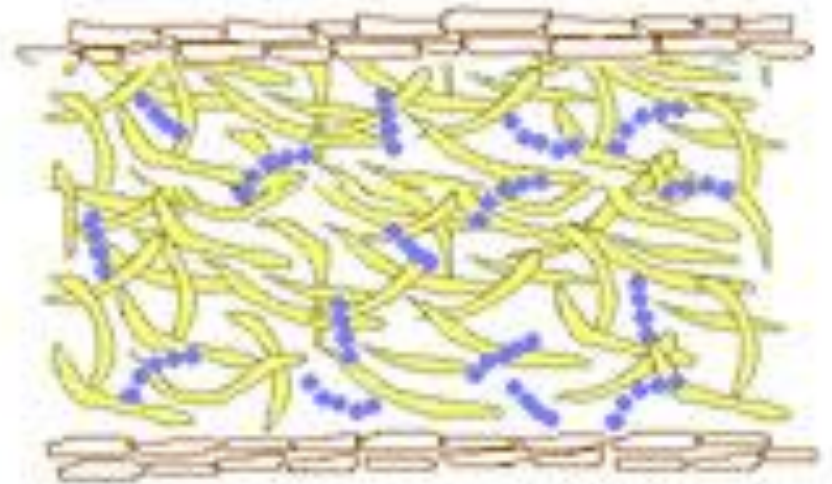


Il colorante DAPI (4'-6diamidin-2-phenil-indol) in luce d'eccitazione UV-A (BP 340-380) colora di bianco i nuclei e le pareti, la clorofilla delle alghe è AUTOFLUORESCENTE (rosso intenso, dopo un po' arancione).

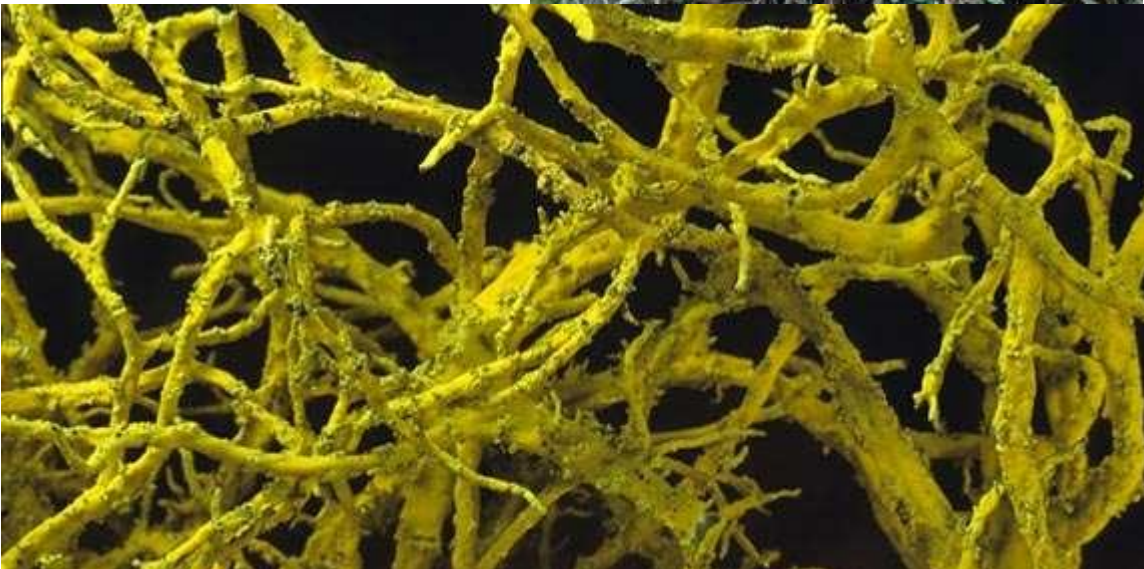
TALLO ETEROMERO



TALLO OMEOMERO



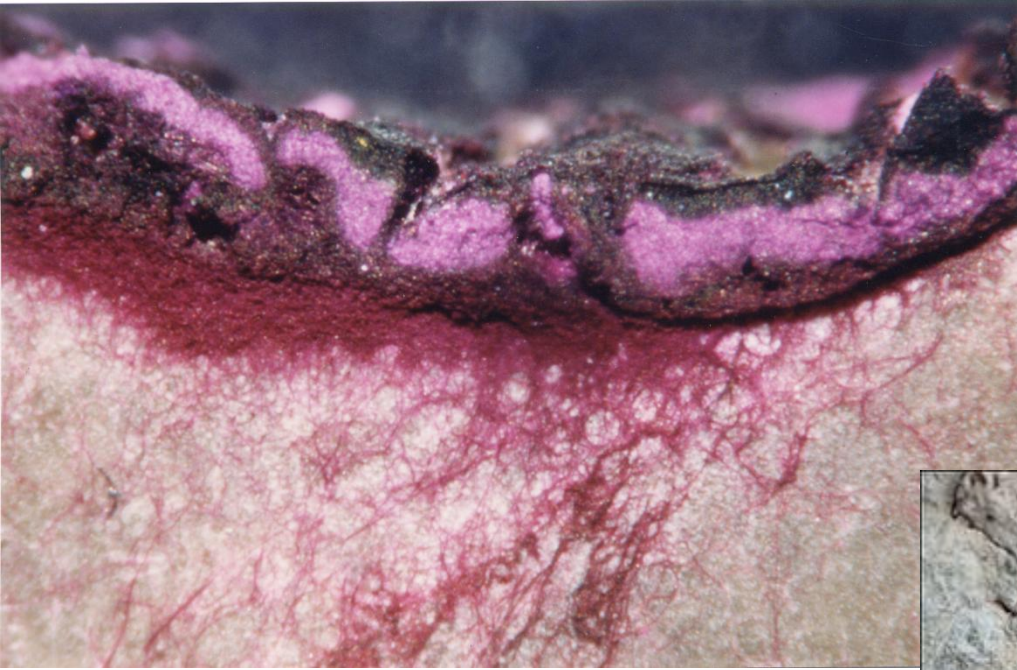
FRUTICOSO



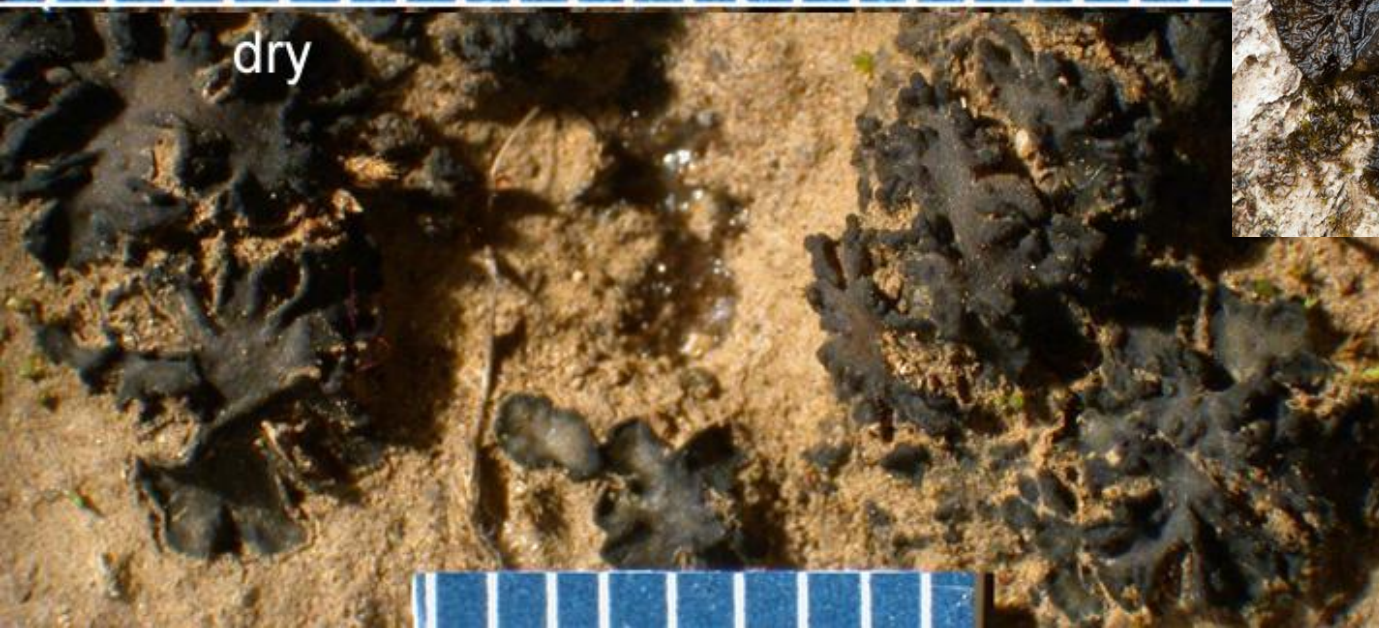
FOGLIOSO

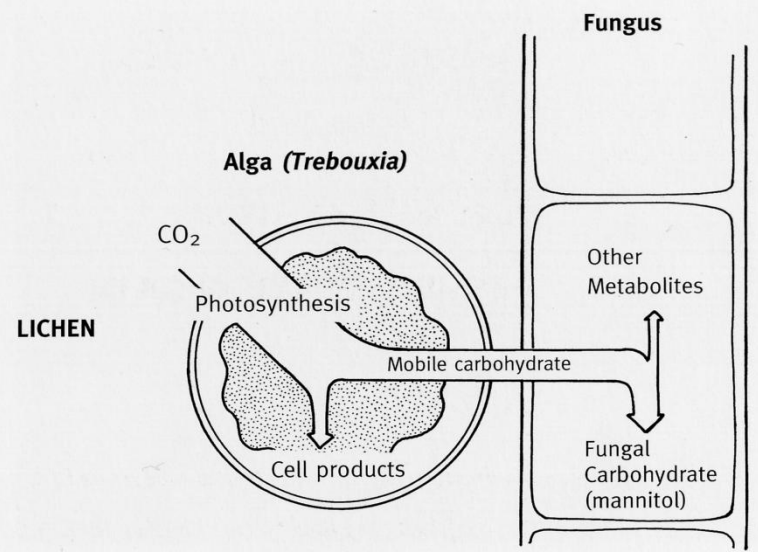
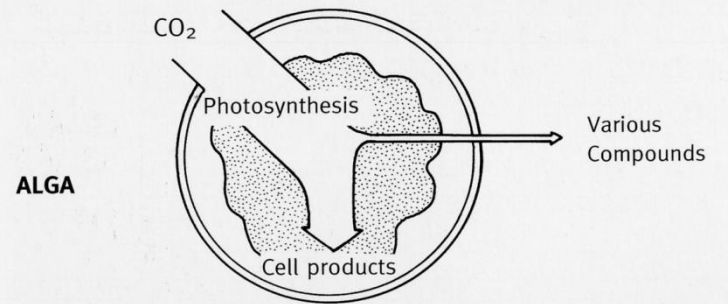


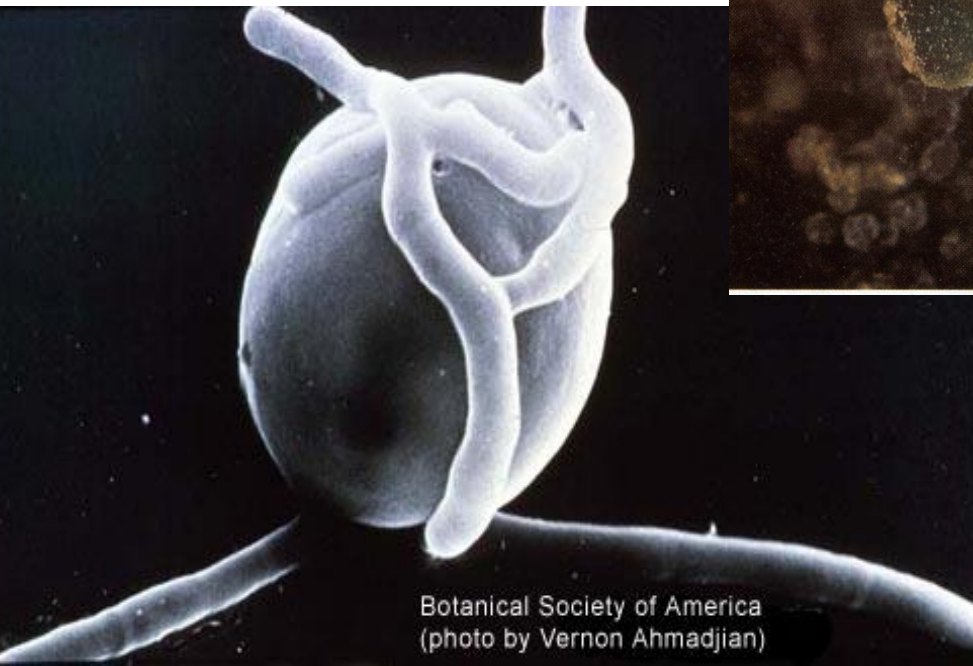
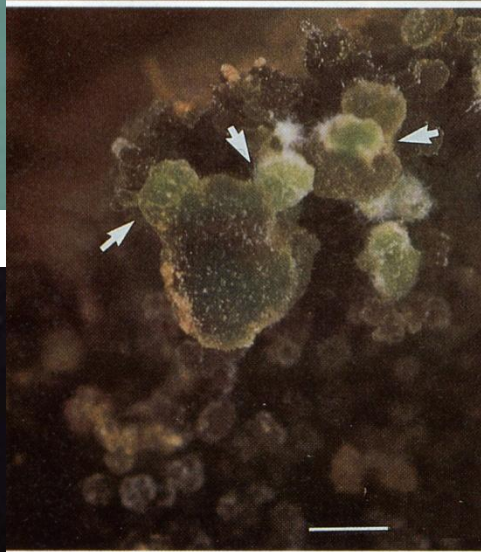
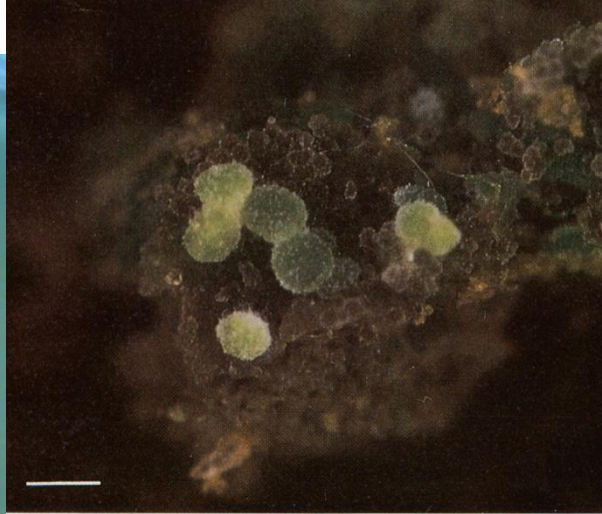
CROSTOSO



GELATINOSO o non gelatinoso (tallo omeomero)

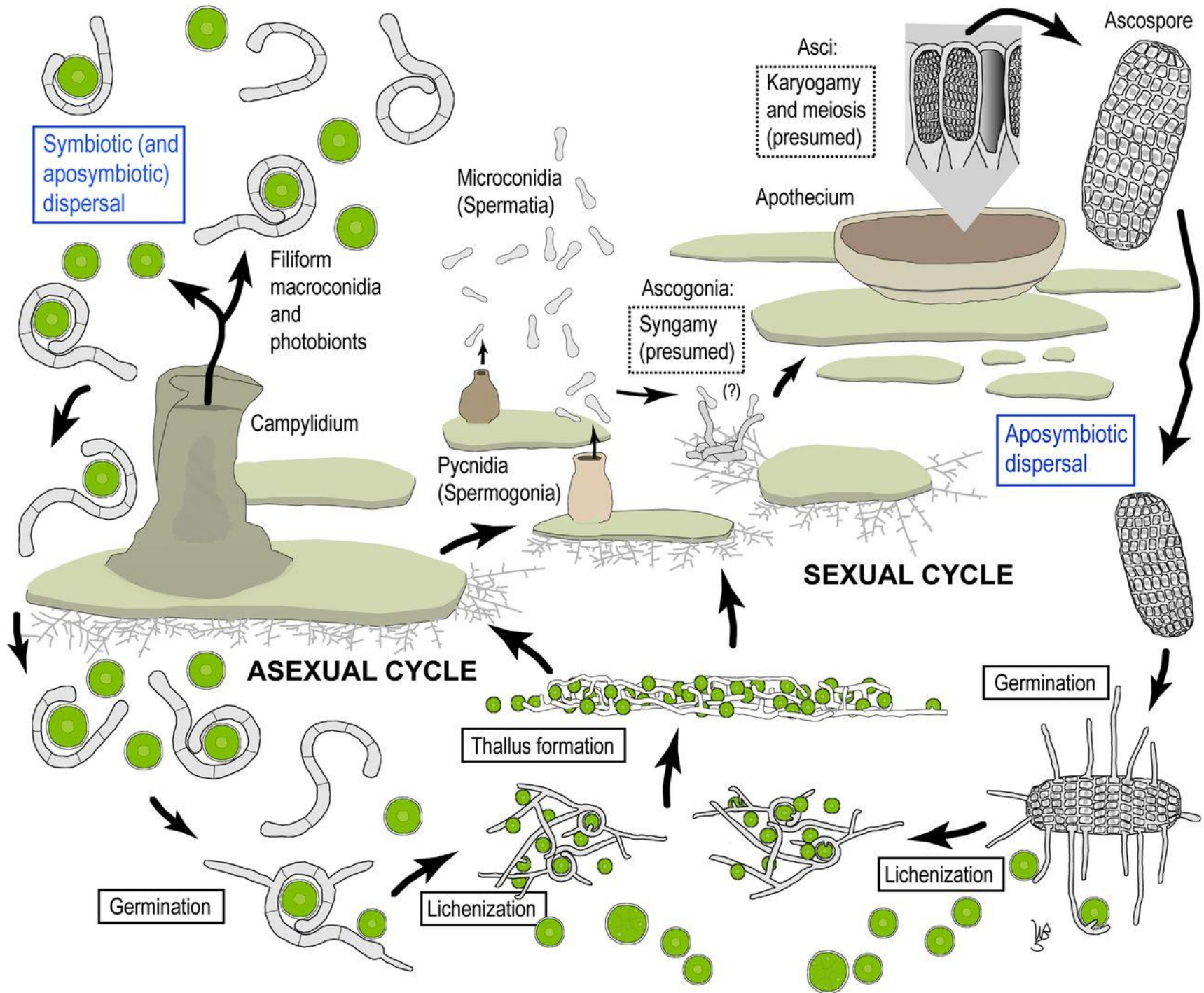






Botanical Society of America
(photo by Vernon Ahmadjian)

I processi morfogenetici iniziano quando un'ifa incontra il partner giusto.



Symbiotic (and aposymbiotic) dispersal

Filiform macroconidia and photobionts

Campylidium

ASEXUAL CYCLE

Germination

Lichenization

Thallus formation

Microconidia (Spermatia)

Pycnidia (Spermatogonia)

Ascogonia: Syngamy (presumed)

Asci: Karyogamy and meiosis (presumed)

Apothecium

Ascospore

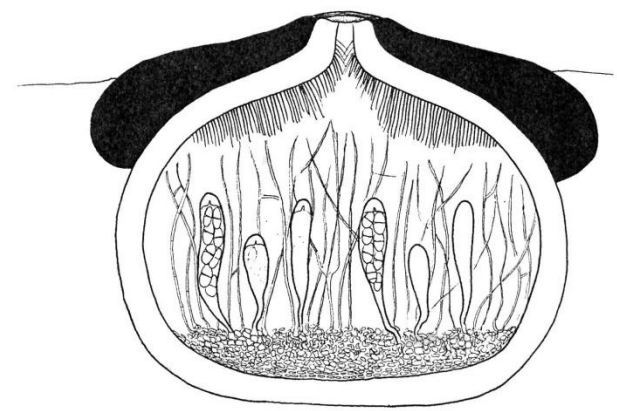
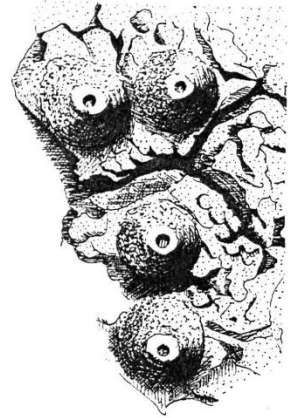
Aposymbiotic dispersal

SEXUAL CYCLE

Germination

Lichenization

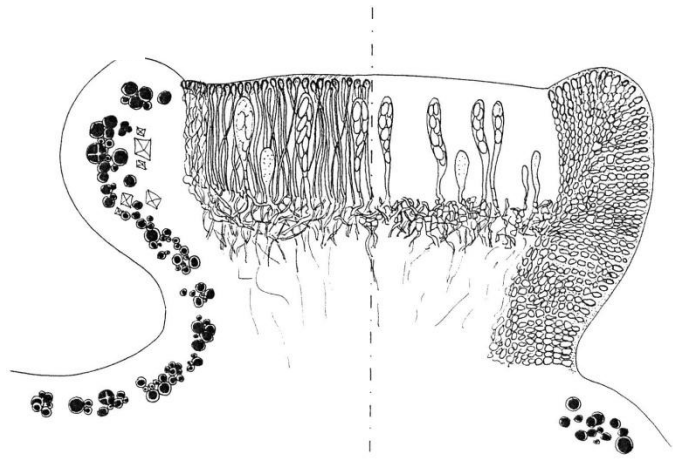
Solo il fungo si riproduce sessualmente. Le alghe (e i cianobatteri) si riproducono vegetativamente.



PERITECI,

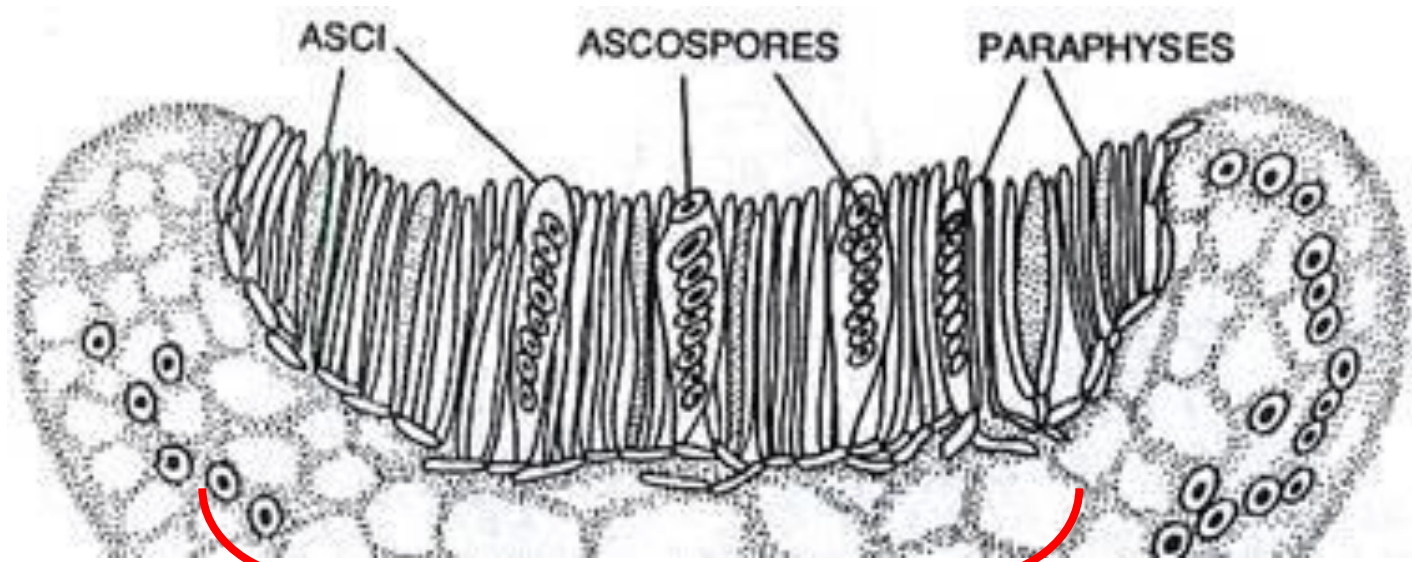


1371 A pruinose lichen (*Physcia alpeola*). A thin layer of calcium oxalate crystals gives a bluish-grey appearance to the surface of the fruiting body. On aspen, *Populus tremula*, Hälsingland, Sweden.

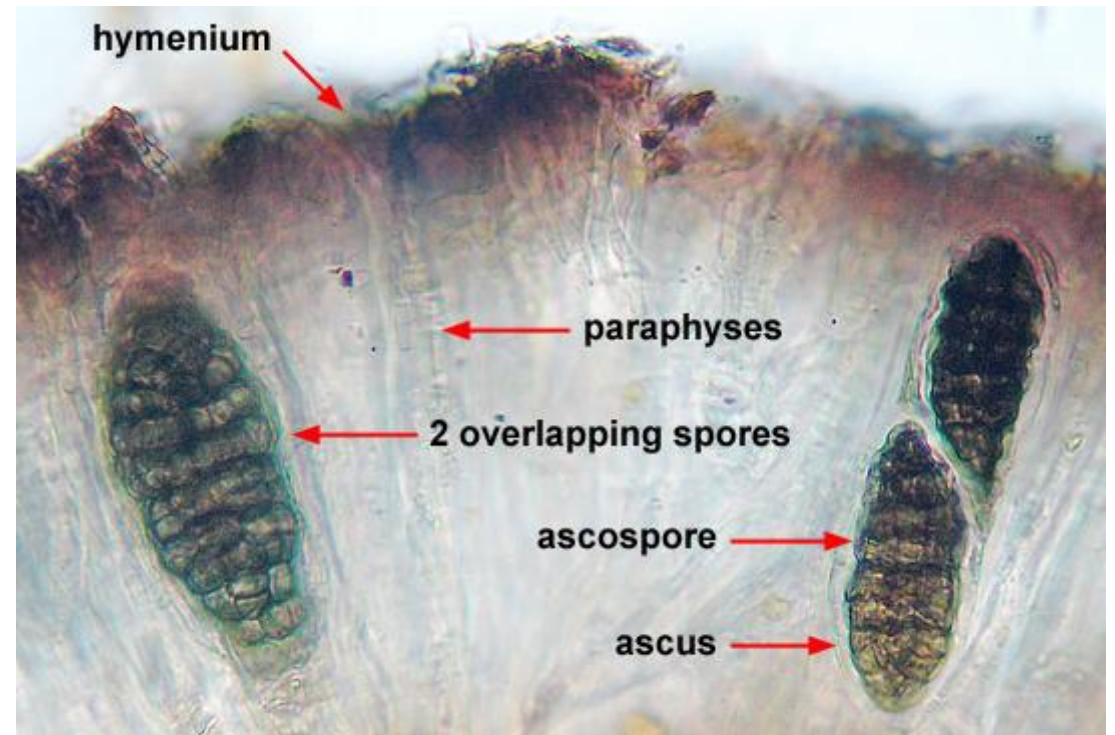


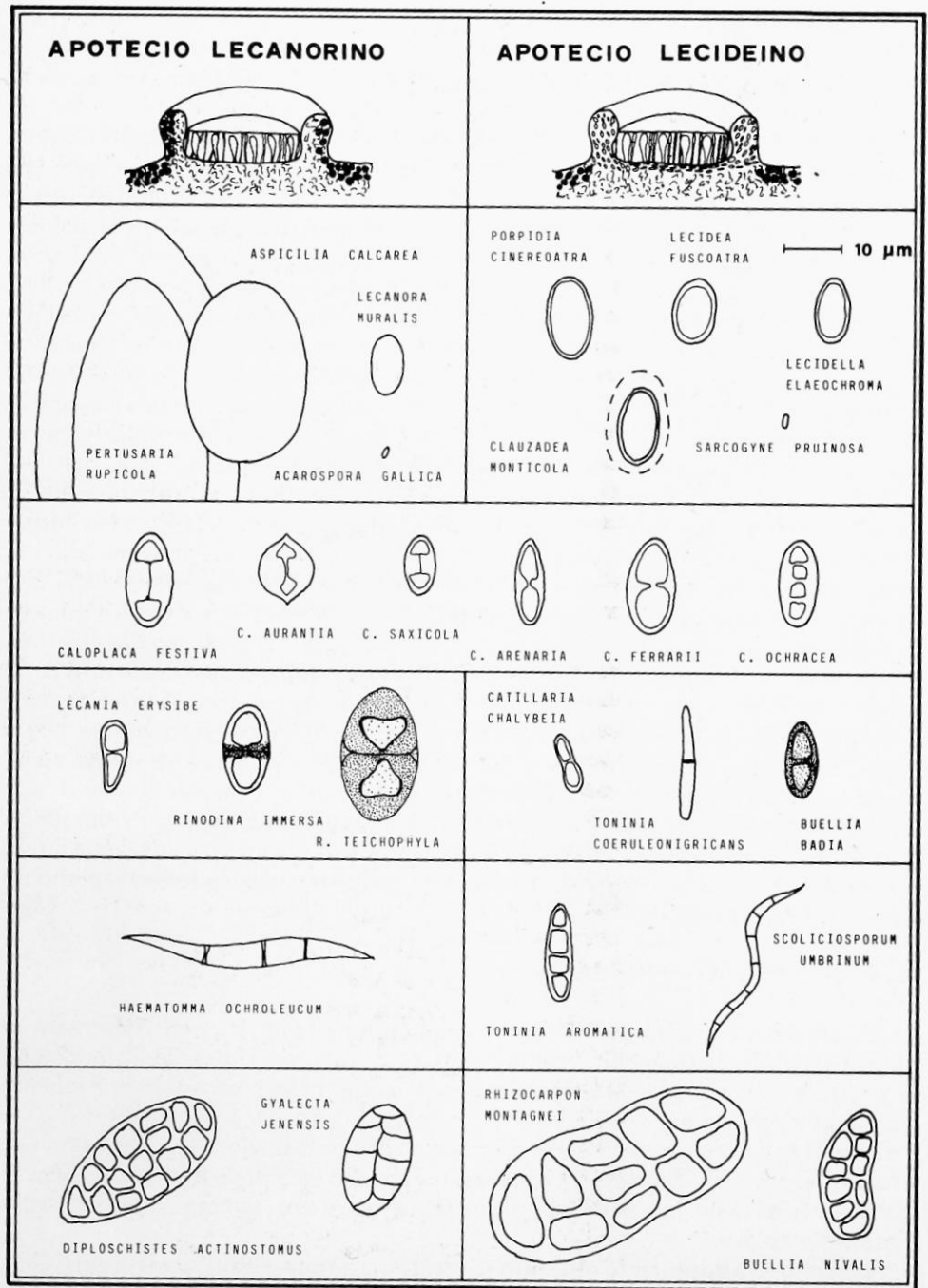
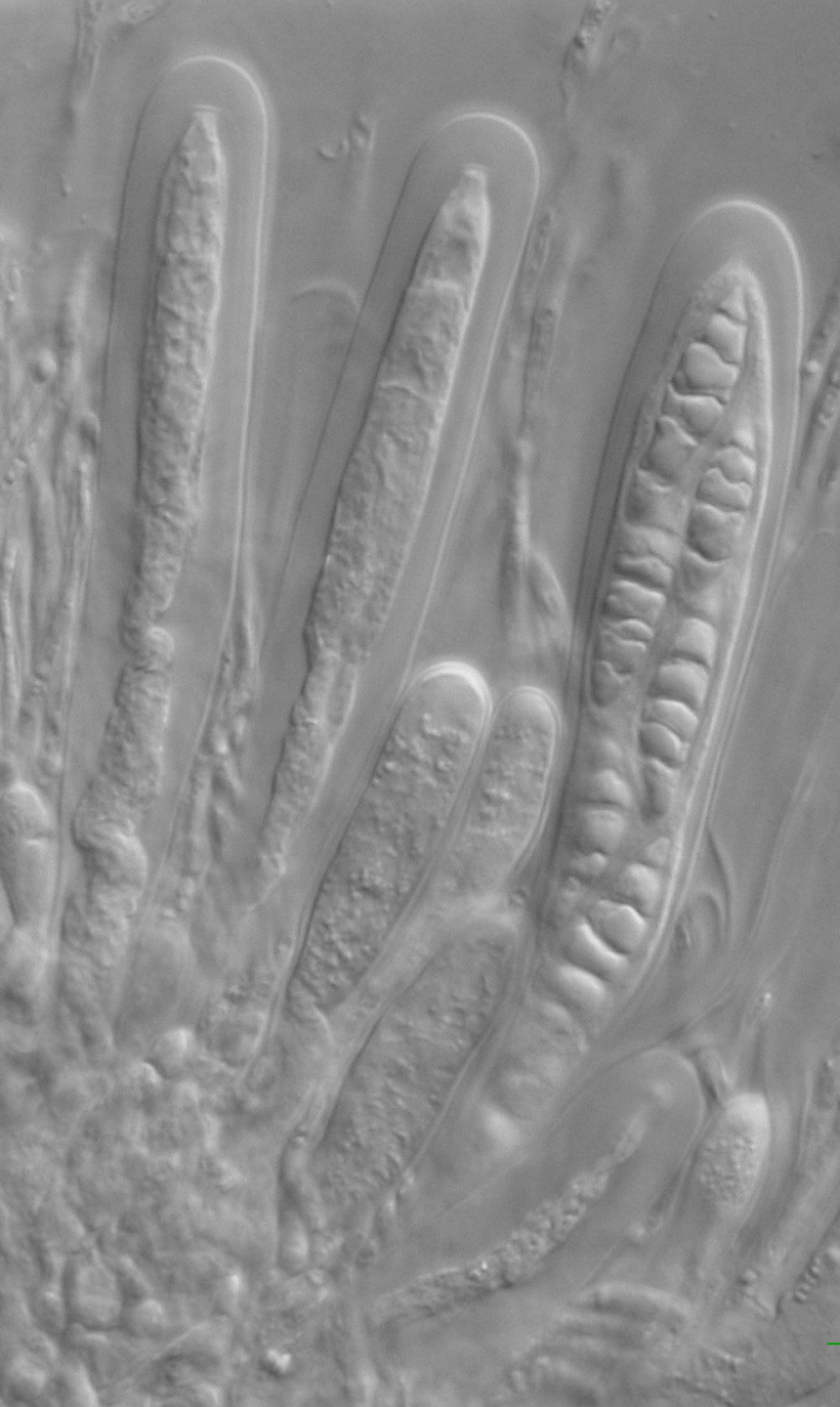
APOTECI

Nel 99% dei casi sono strutture perennanti (a differenze dei funghi non lichenizzati!!!).

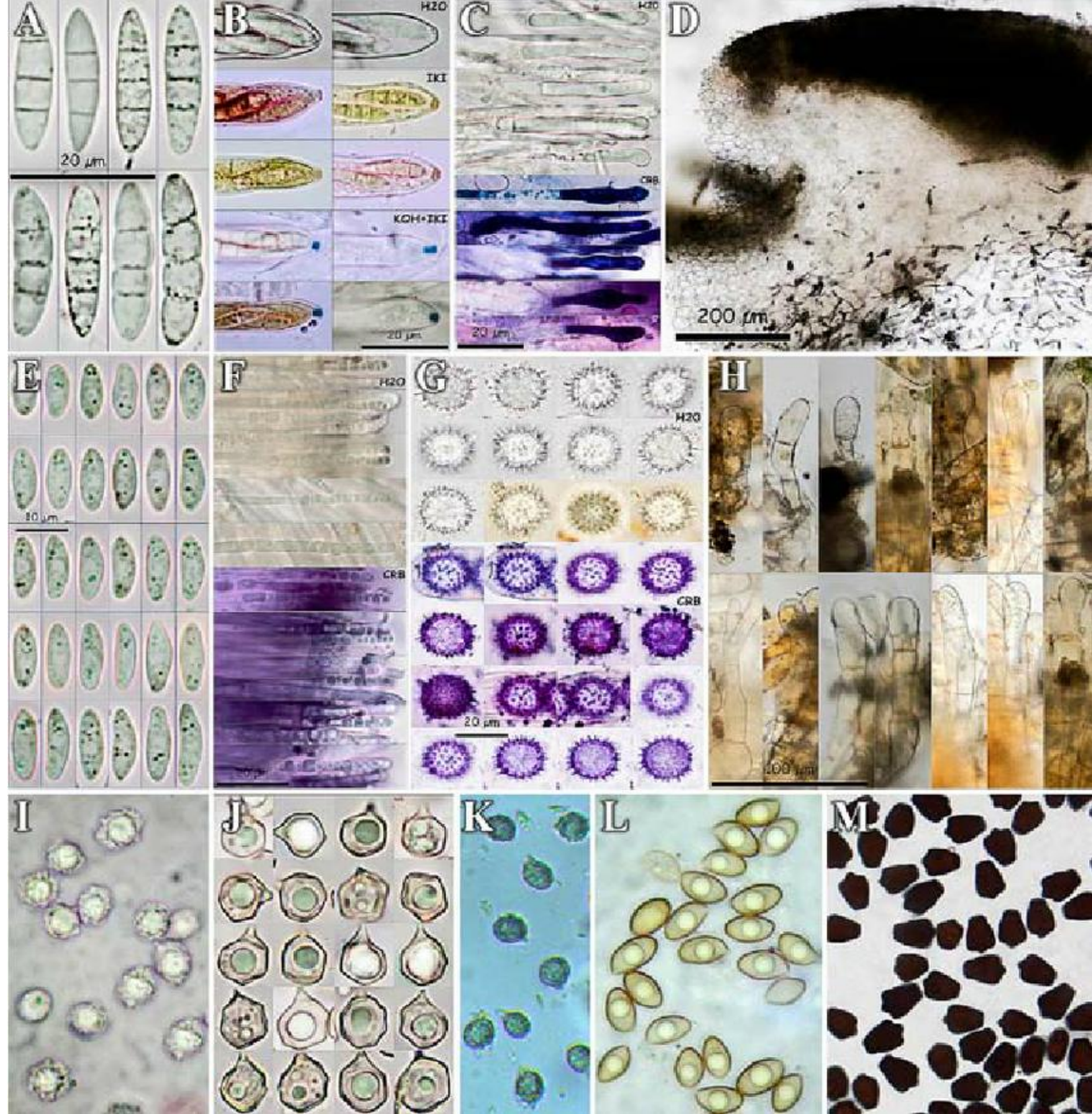


hymenium

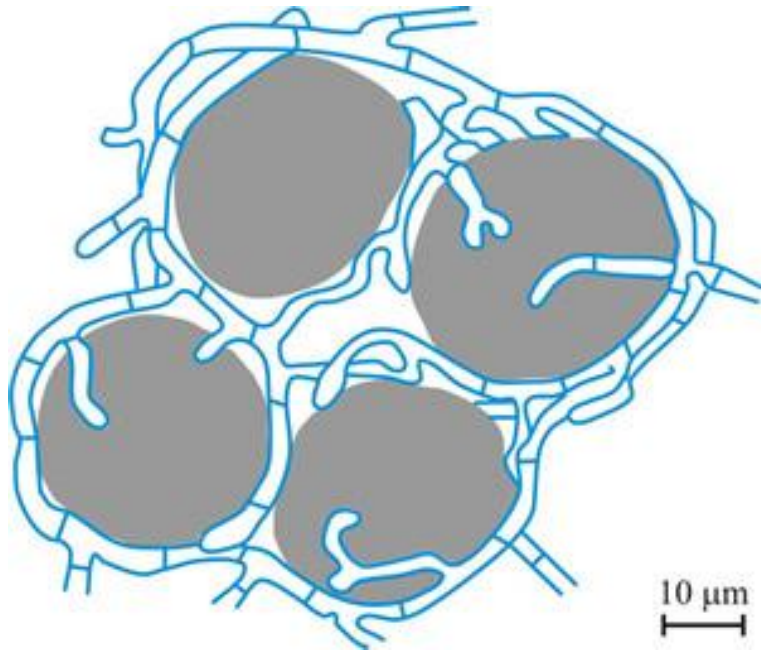




Tav. I Diversi tipi di spore di specie ad apotecio lecanorino (sinistra) e lecideino (destra).

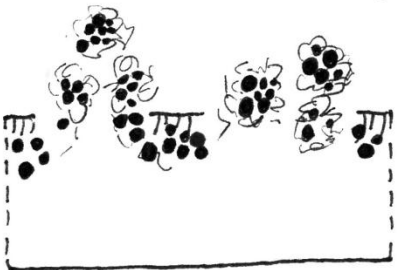


SOREDI: diaspore, sono strutture NON corticate, spesso formate in zone delimitate del tallo (**sorali**).

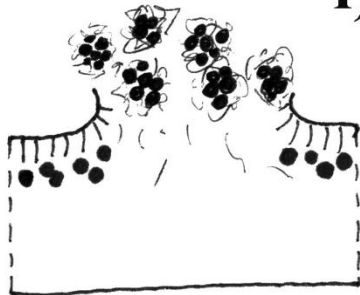


Prendono origine da interruzioni del cortex, attraverso cui proliferano verso l'esterno le ife della medulla che intrappolano le cellule algali.

e)



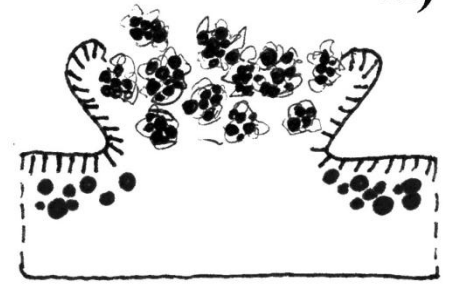
f)

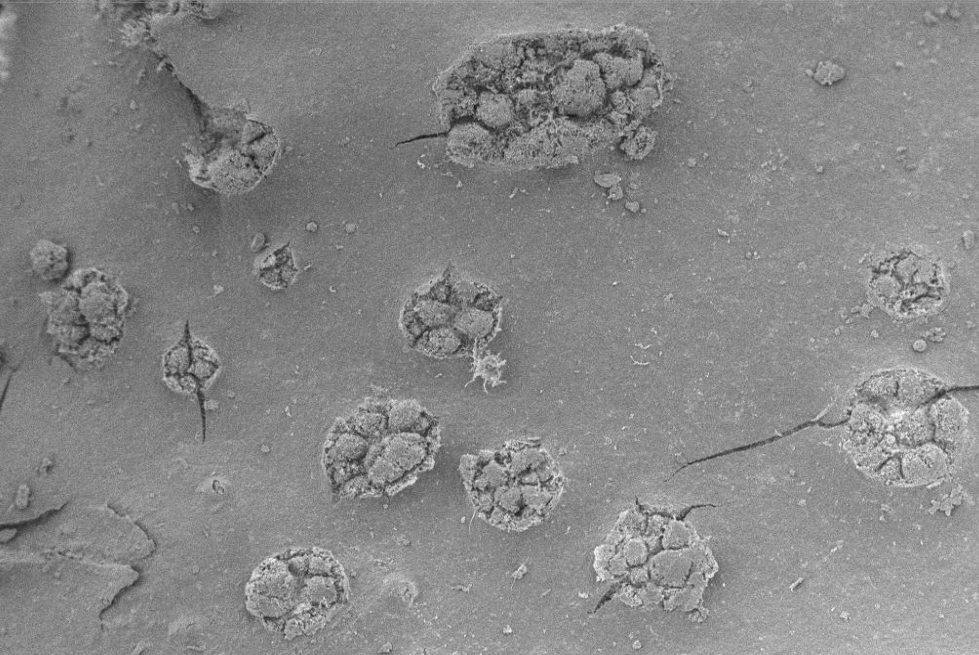


g)

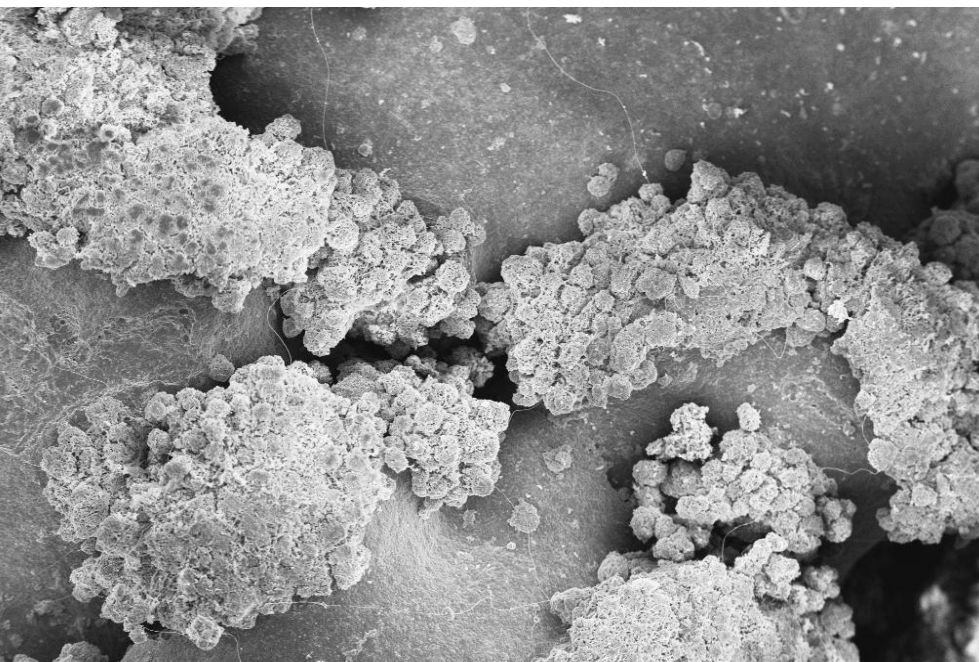


h)





EHT=12.78 kV WD= 13 mm Mag= 62 X
100µm | Photo No. =9694 Detector= SE1

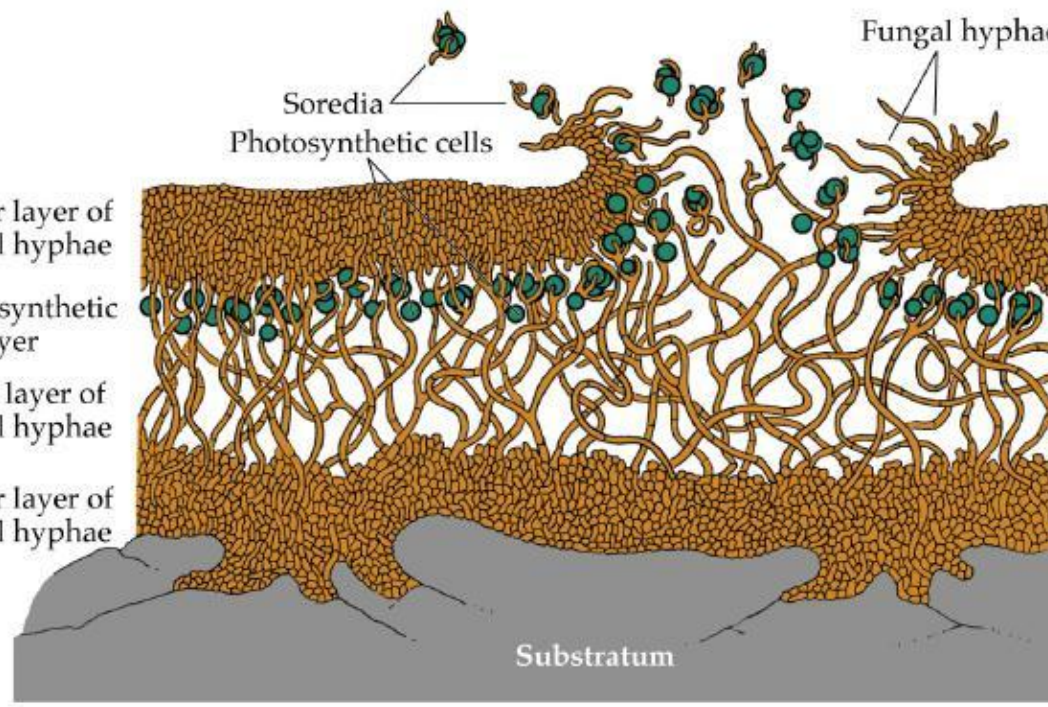


EHT=12.78 kV WD= 18 mm Mag= 66 X
100µm | Photo No. =9628 Detector= SE1

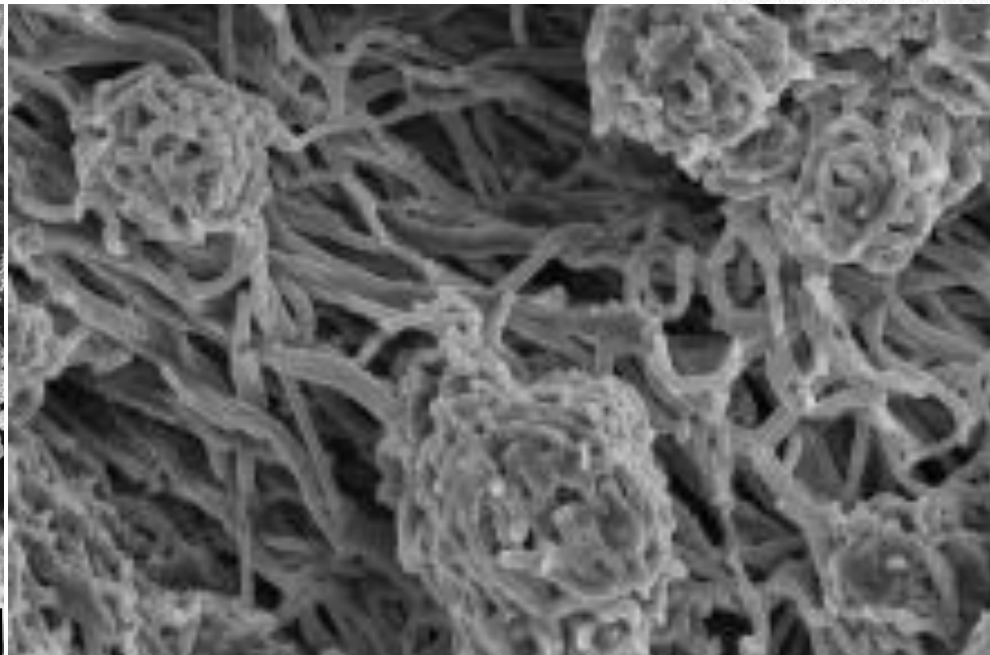
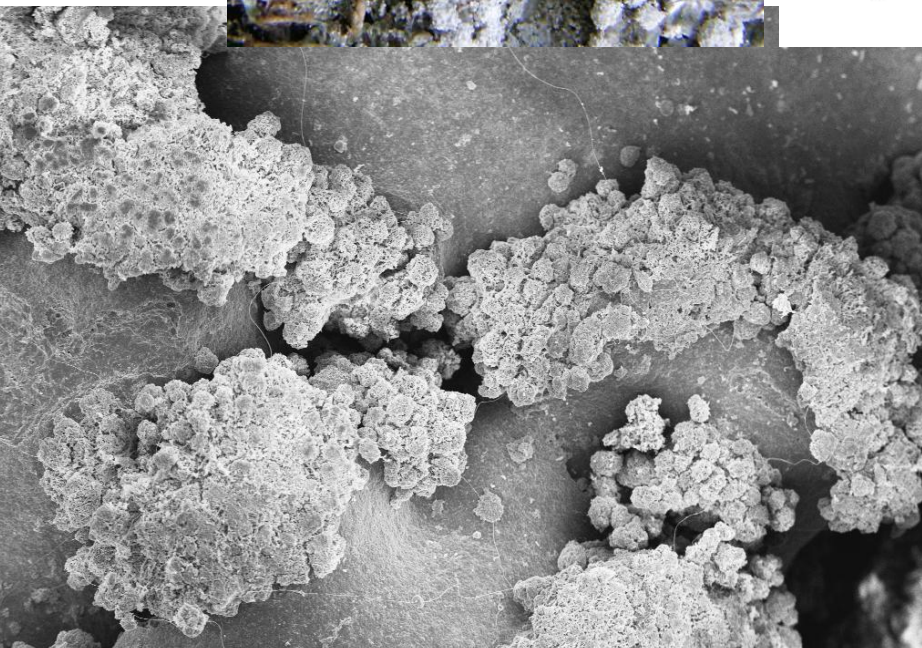
Hanno l'aspetto di granuli soffici e spesso idrofobi. I **sorali** spesso appaiono come delle punteggiature, linee o aree biancastre e pulverulente, che contrastano con la superficie del tallo.



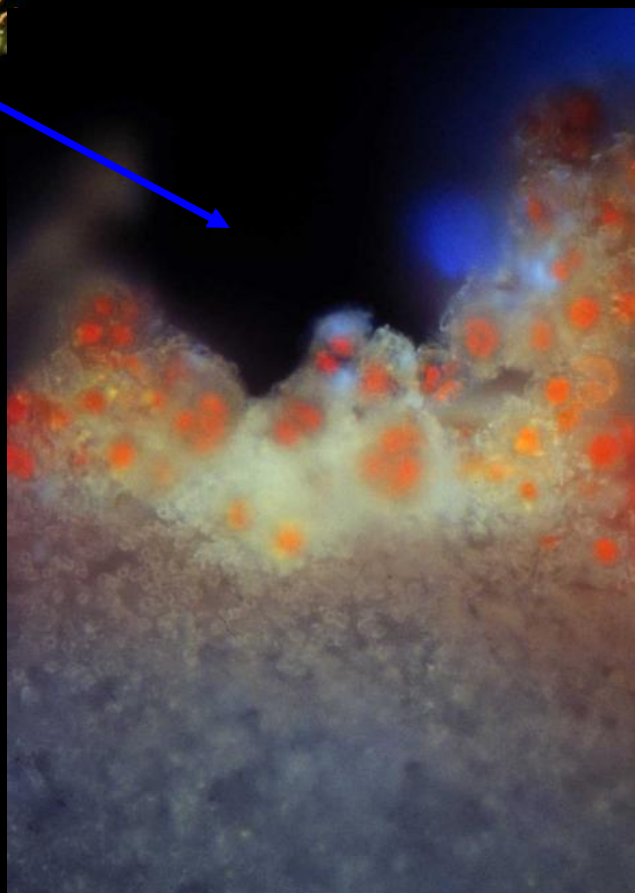
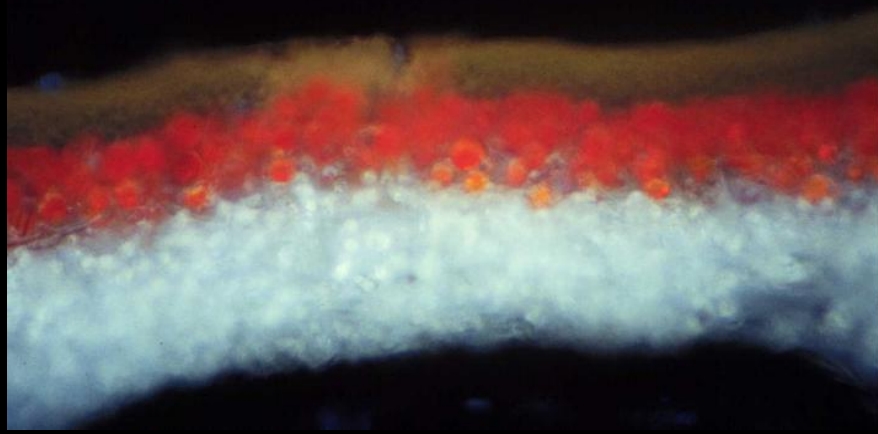
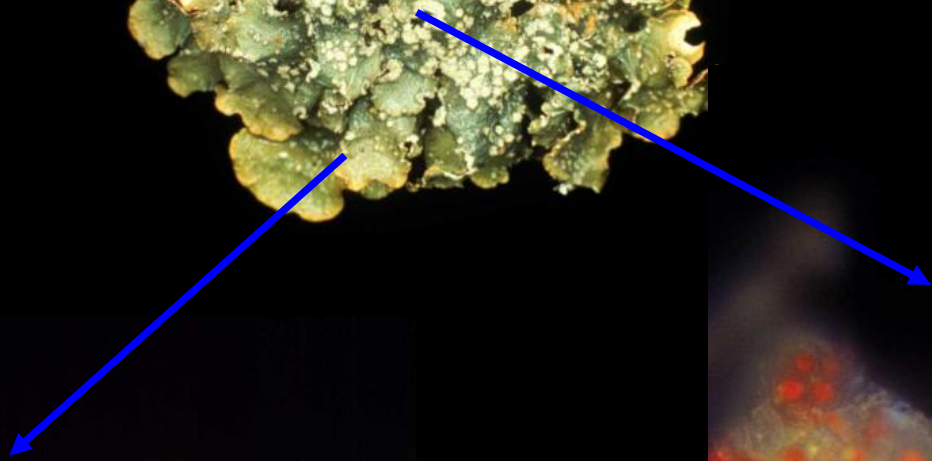
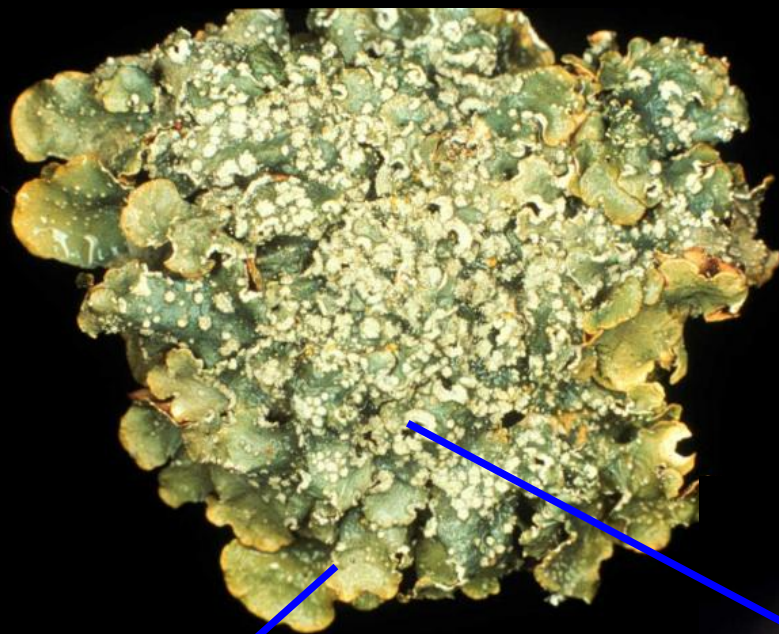
Upper layer of fungal hyphae
 Photosynthetic cell layer
 Loose layer of fungal hyphae
 Lower layer of fungal hyphae



© 1998 Sinauer Associates, Inc

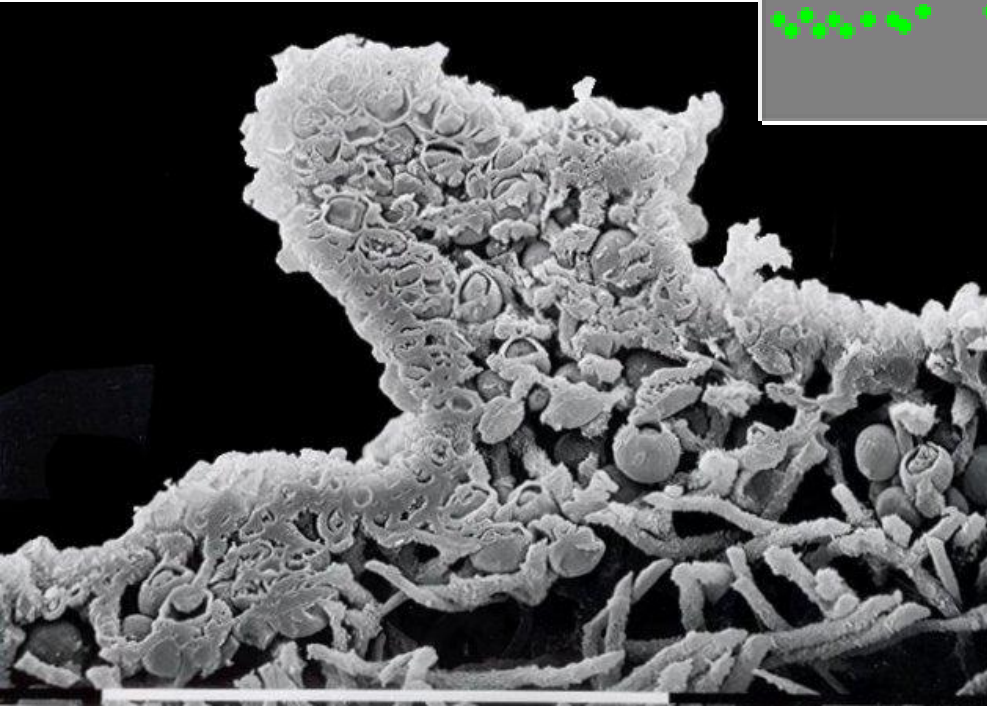
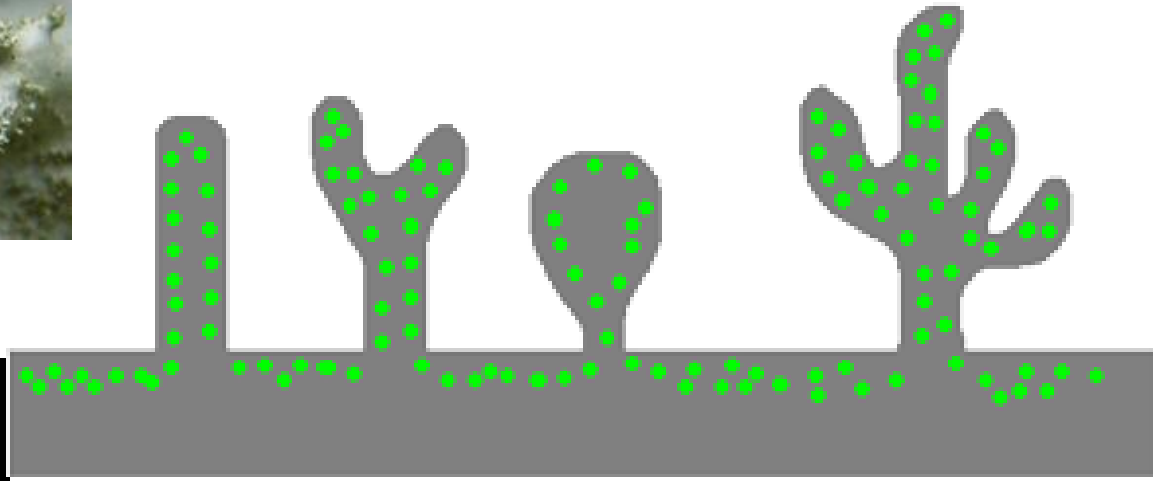


EHT=12.78 kV WD= 18 mm Mag= 66 X
 100µm Photo No.=9628 Detector= SE1

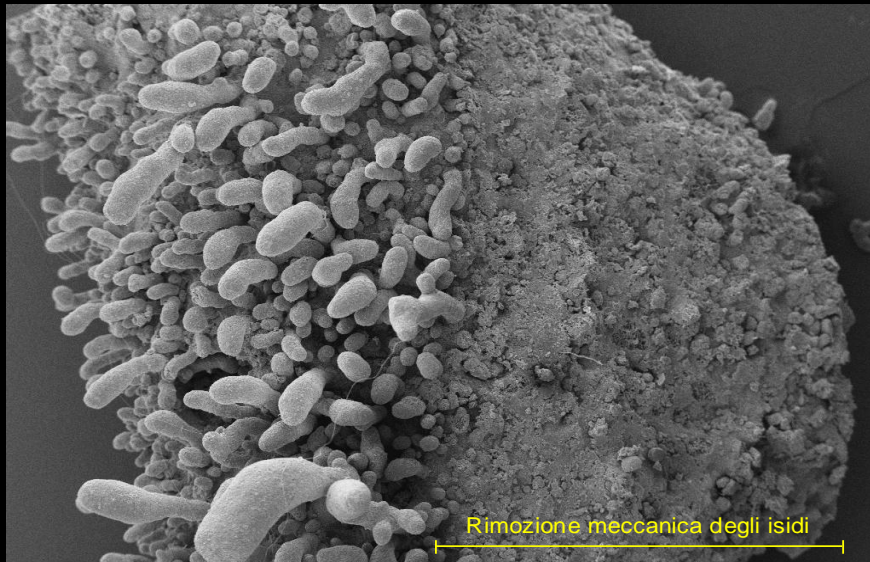




ISIDI: diaspora, sono strutture corticate, dello stesso colore della superficie esterna, o più scuri, soprattutto all'apice.



Originano per una proliferazione di ife medullari, che si accompagna ad una crescita delle ife del cortex, per cui essi sono sempre corticati.



EHT=12.97 kV
200µm

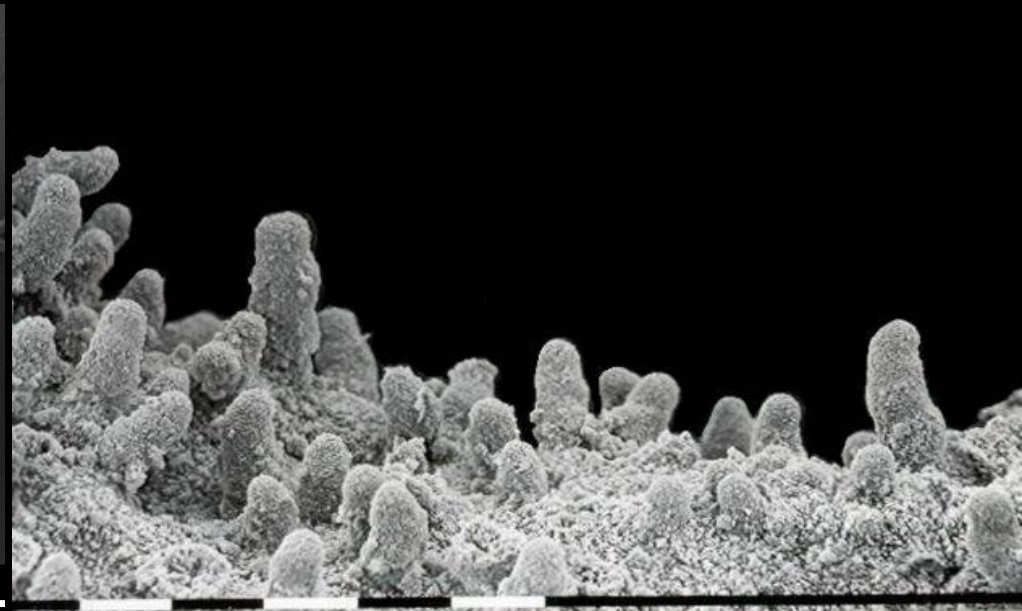
WD= 16 mm

Photo No.=3808

Mag= 29 X

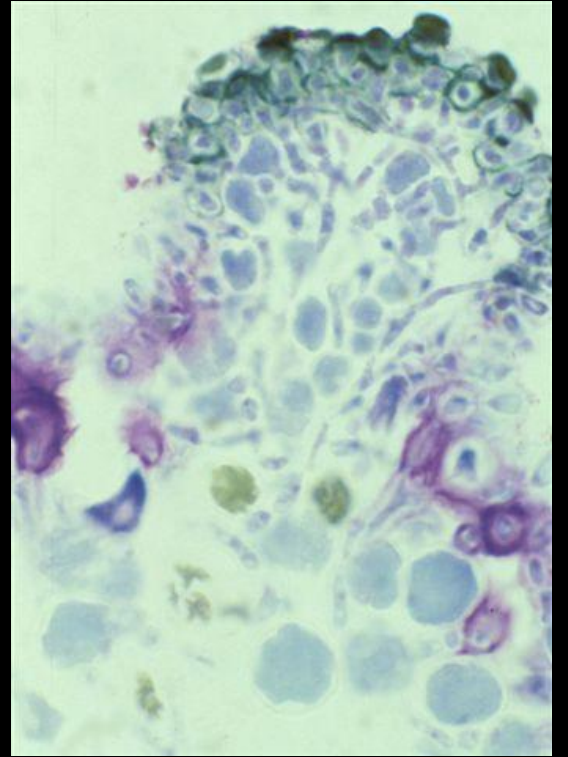
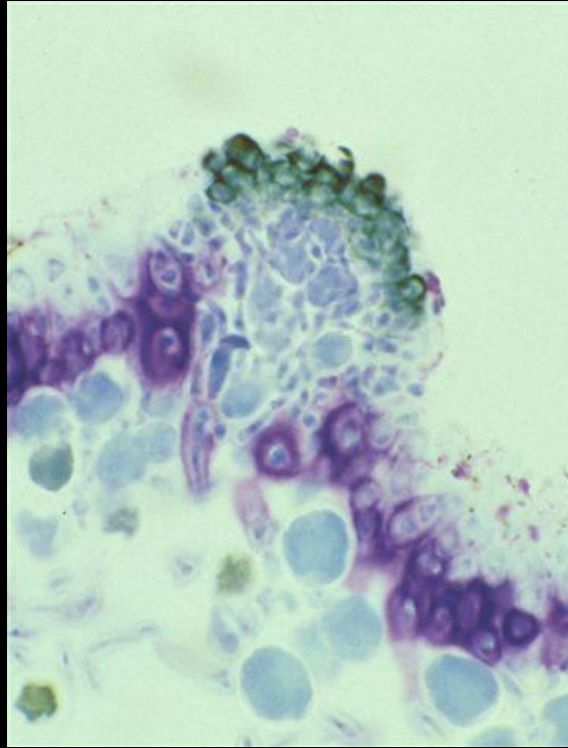
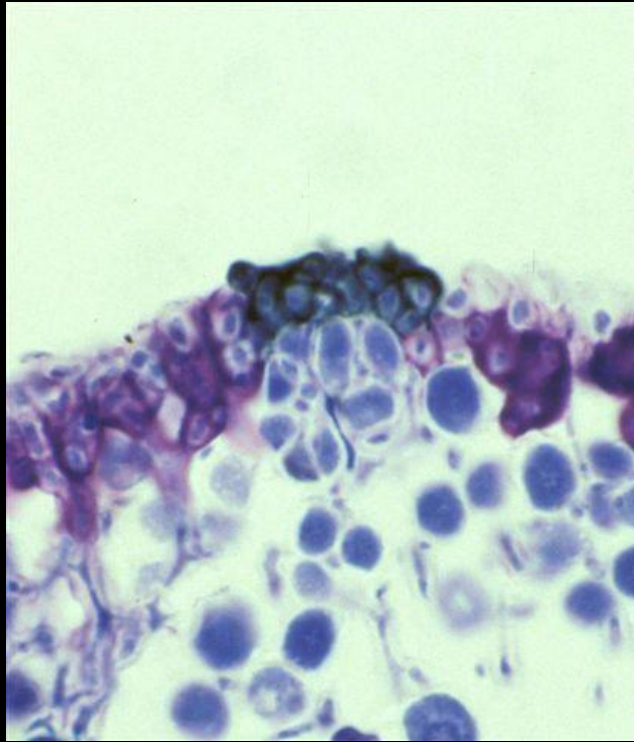
Detector= SE1

Rimozione meccanica degli isidi

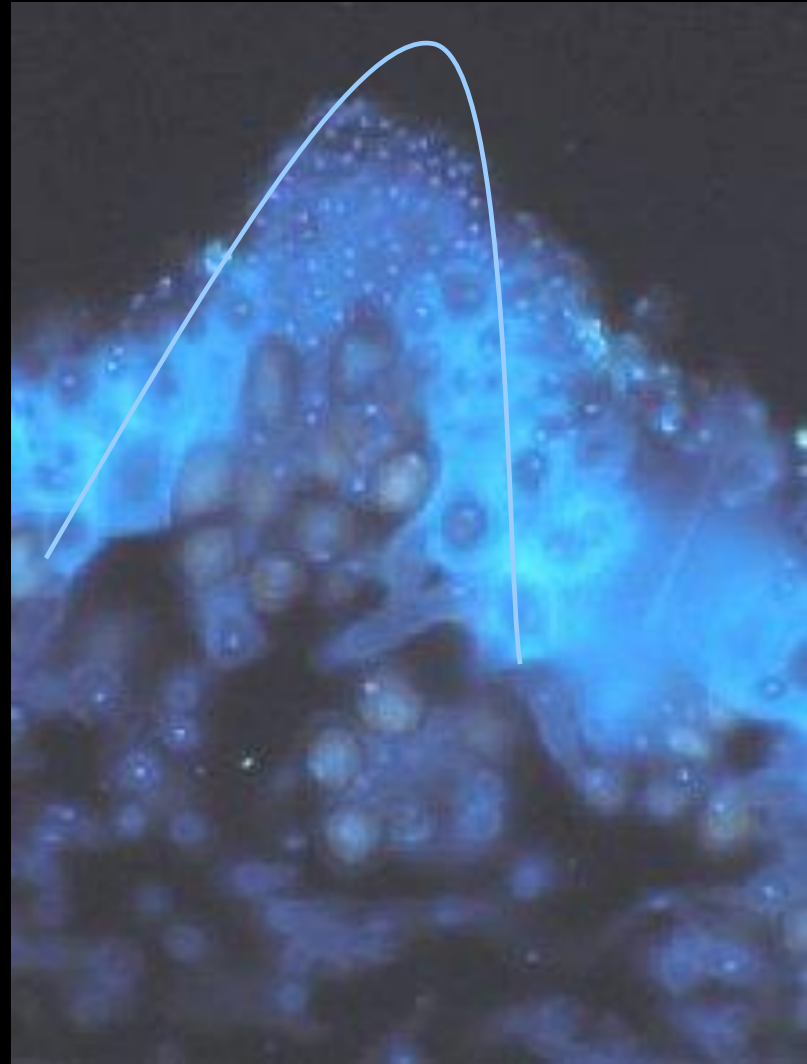
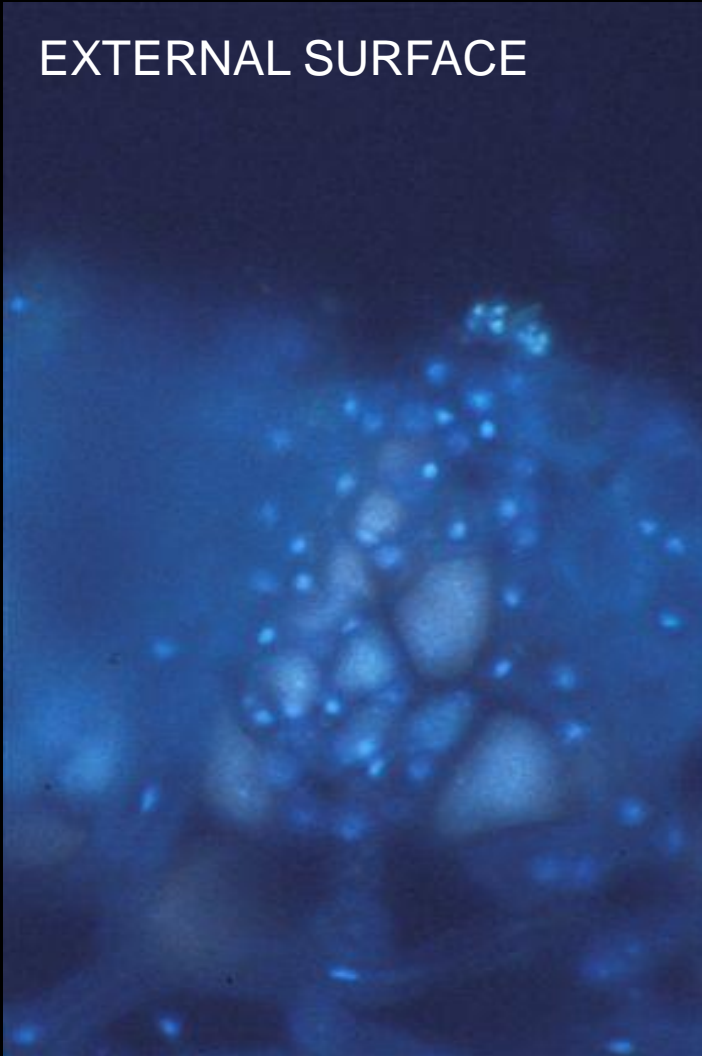


1 mm

© AJ Silverside



EXTERNAL SURFACE



DAPI (4'-6diamidin-2-phenil-indol) in UV-A excitation light (BP 340-380)

Technovit-encasted sections - DAPI was used to stain nuclei, being specific for double-stranded DNA; also cell walls may appear whitish.

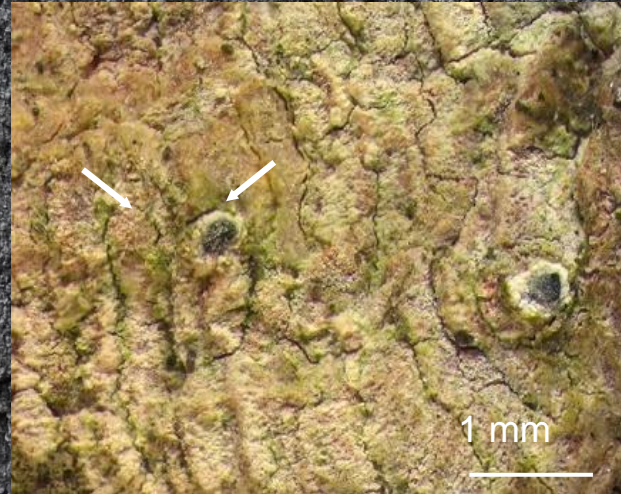
Schizoxylon albescens

Stictidaceae (Ostropales, Lecanoromycetes): saprotrophic, parasitic and lichenized species; several taxa were found to live either as saprotrophs or as lichens.

Saprotrophic morphs
on dead, decorticated
Populus- and *Salix*-
branches

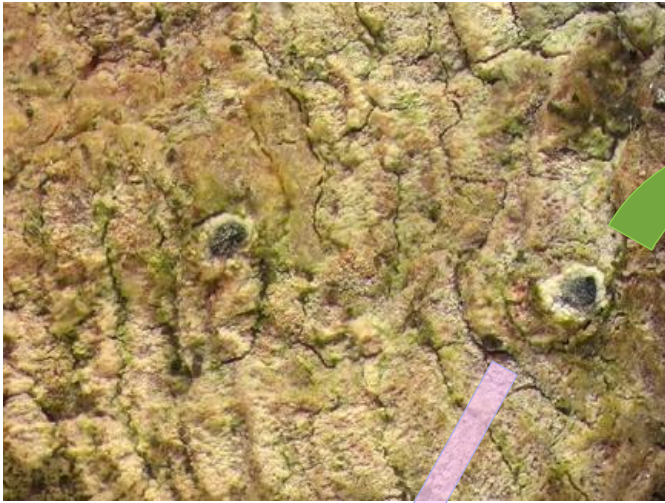


Lichenized forms
in and around cracks in the rough
bark of older *Populus* trunks

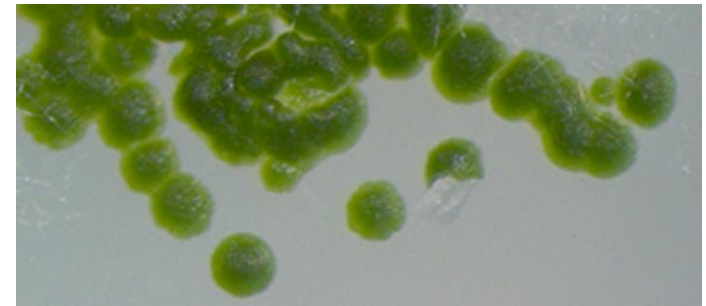


“optional lichenization”
(Wedin et al. 2004, 2006)

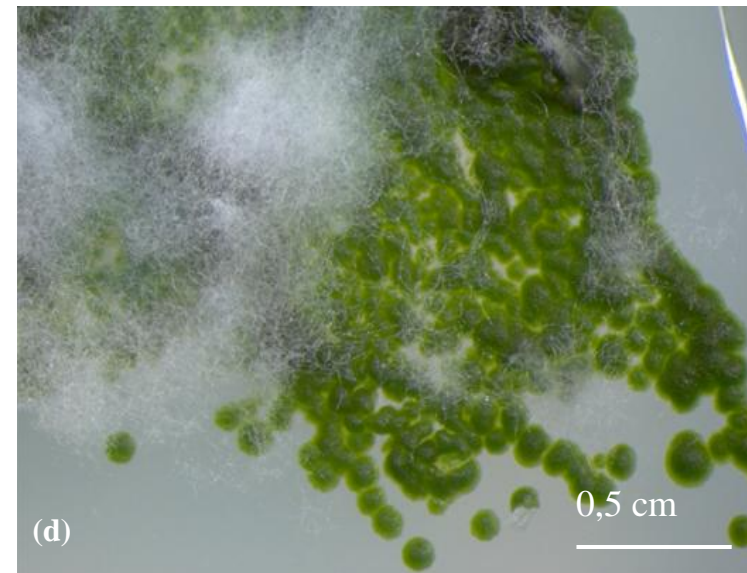
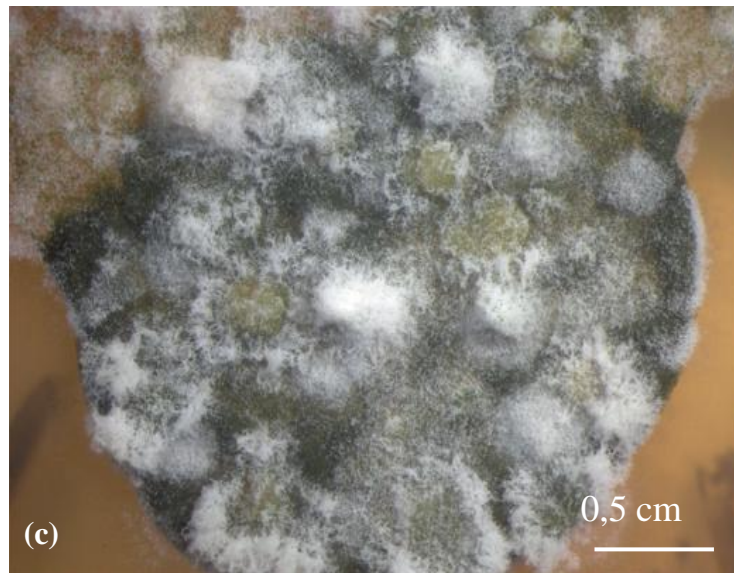
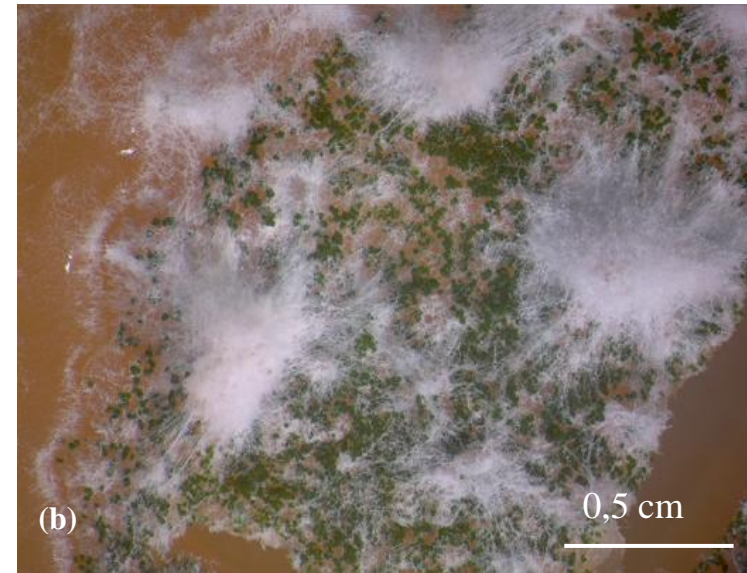
Isolation of the fungus and the algae in axenic culture



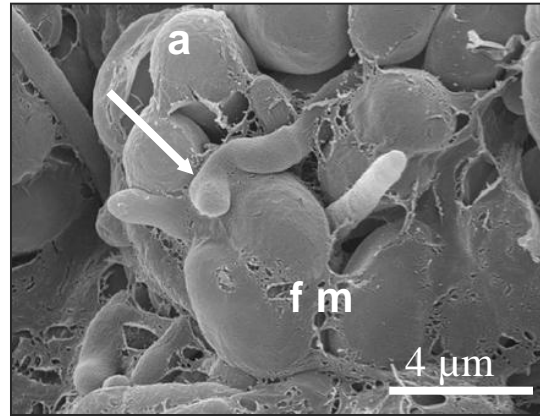
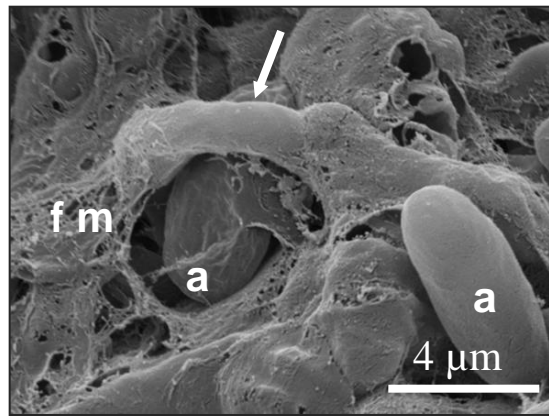
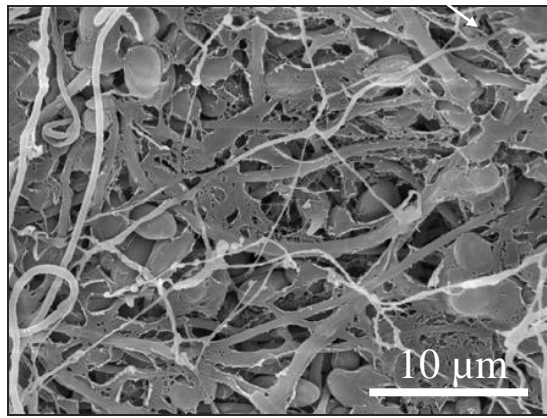
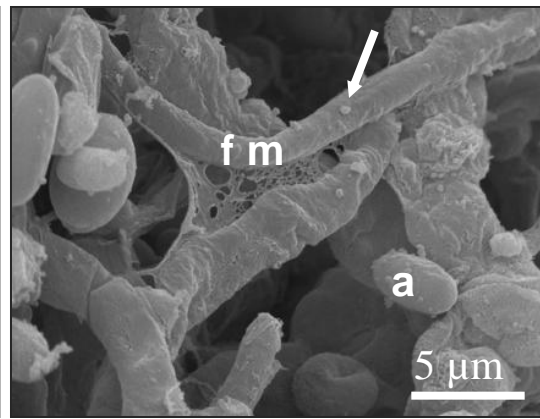
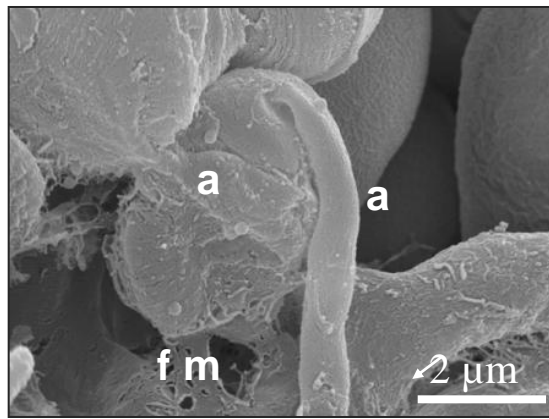
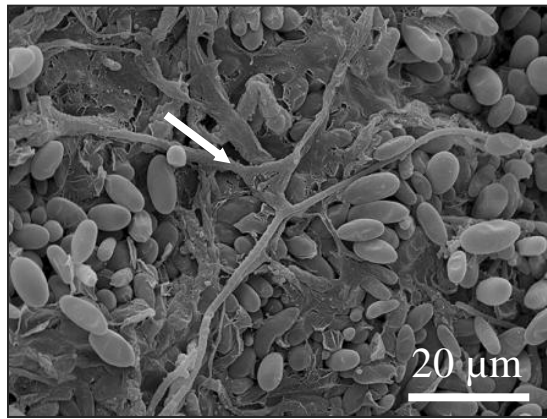
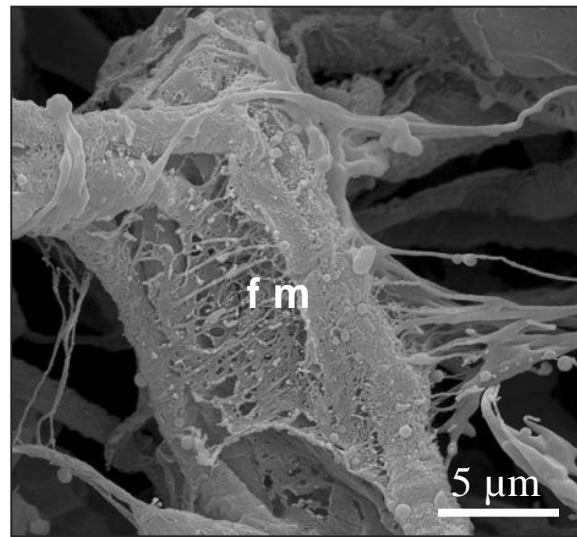
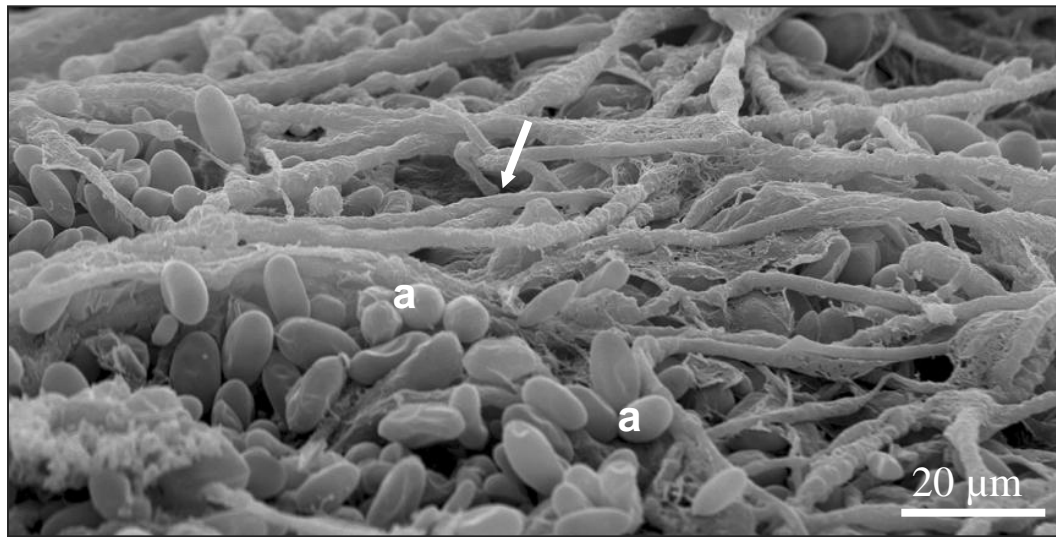
- i) one fruiting body was taken with a sterile razor blade, isolation according Yamamoto *et al.* (2002);
- ii) algal clumps were removed with a sterile needle and transferred directly on the agar medium;
- iii) algae clumps were diluted in sterile water and plated by pipetting.



Interaction fungus-algae in culture

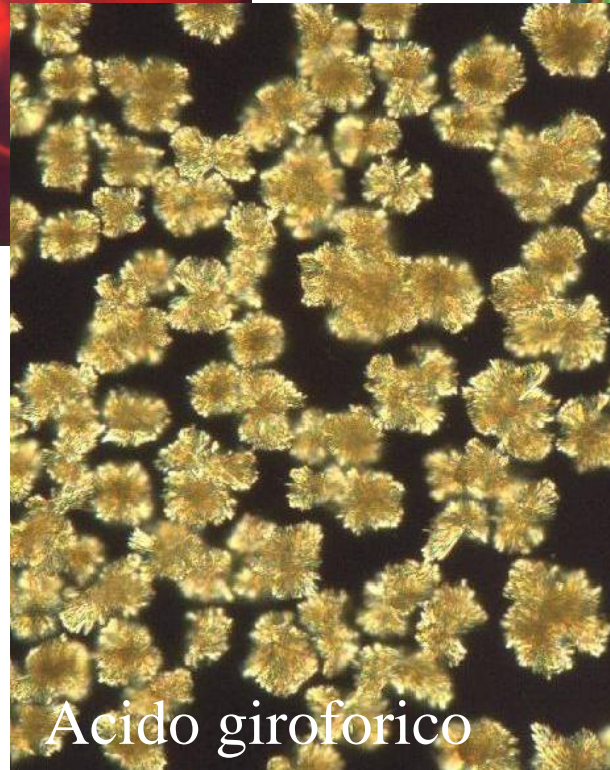


LB, MY, TM media, also on bark pieces

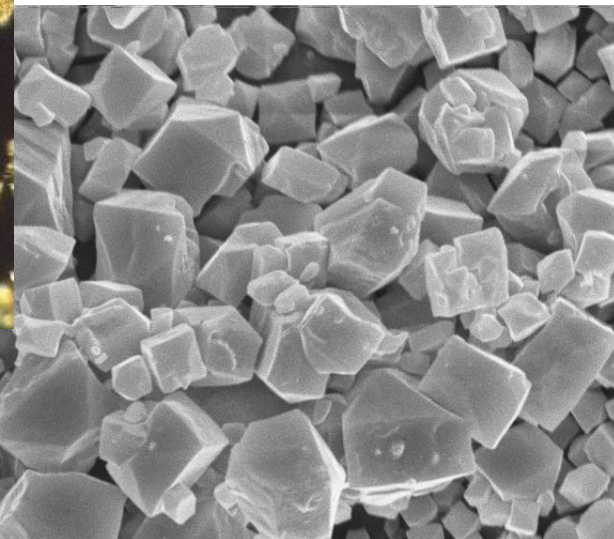




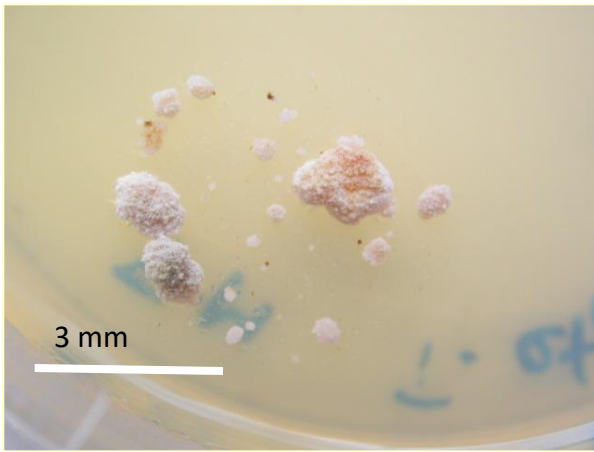
Acido lecanorico



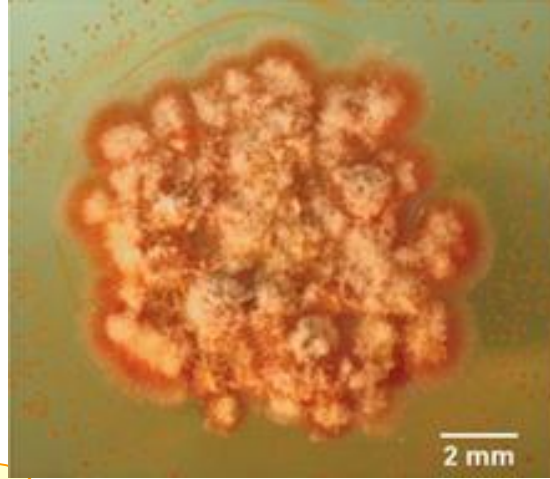
Acido giroforico



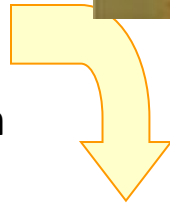
I licheni producono una ampia gamma di **metaboliti secondari**, chiamati «**acidi lichenici**», con funzioni molto diverse, accumulati nello spazio apoplastico.



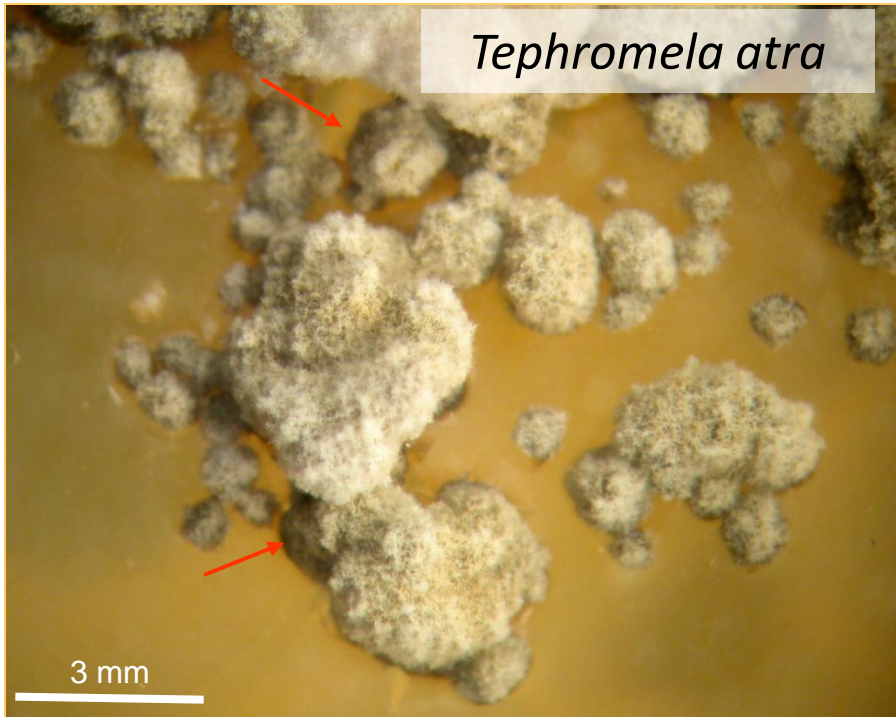
...after almost 1 year of growth in culture (MY medium)



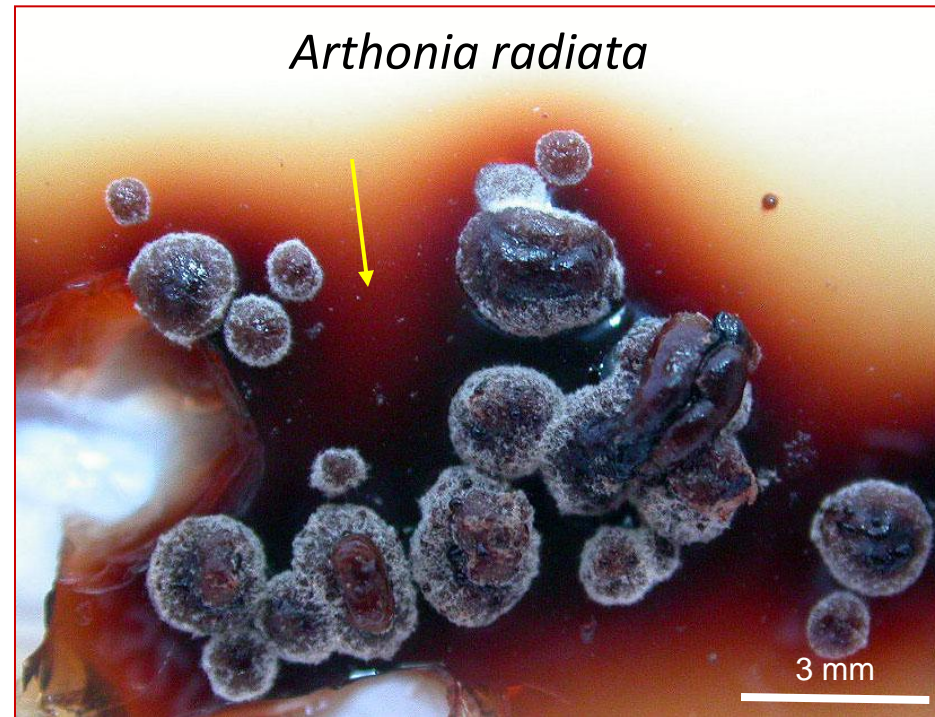
!!! The metabolic pattern of the cultured mycobiont can differ from the one in the symbiosis.



Tephromela atra



Arthonia radiata



I LICHENI SONO TOLLERANTI AL DISSECCAMENTO:
licheni sensibili al disseccamento (pochissimi), licheni
mediamente tolleranti (tanti), licheni incredibilmente tolleranti
(un discreto numero); occupano nicchie ecologiche diverse.

**“Homoiochlorophyllous
poikylhydric”**



bagnato



secco



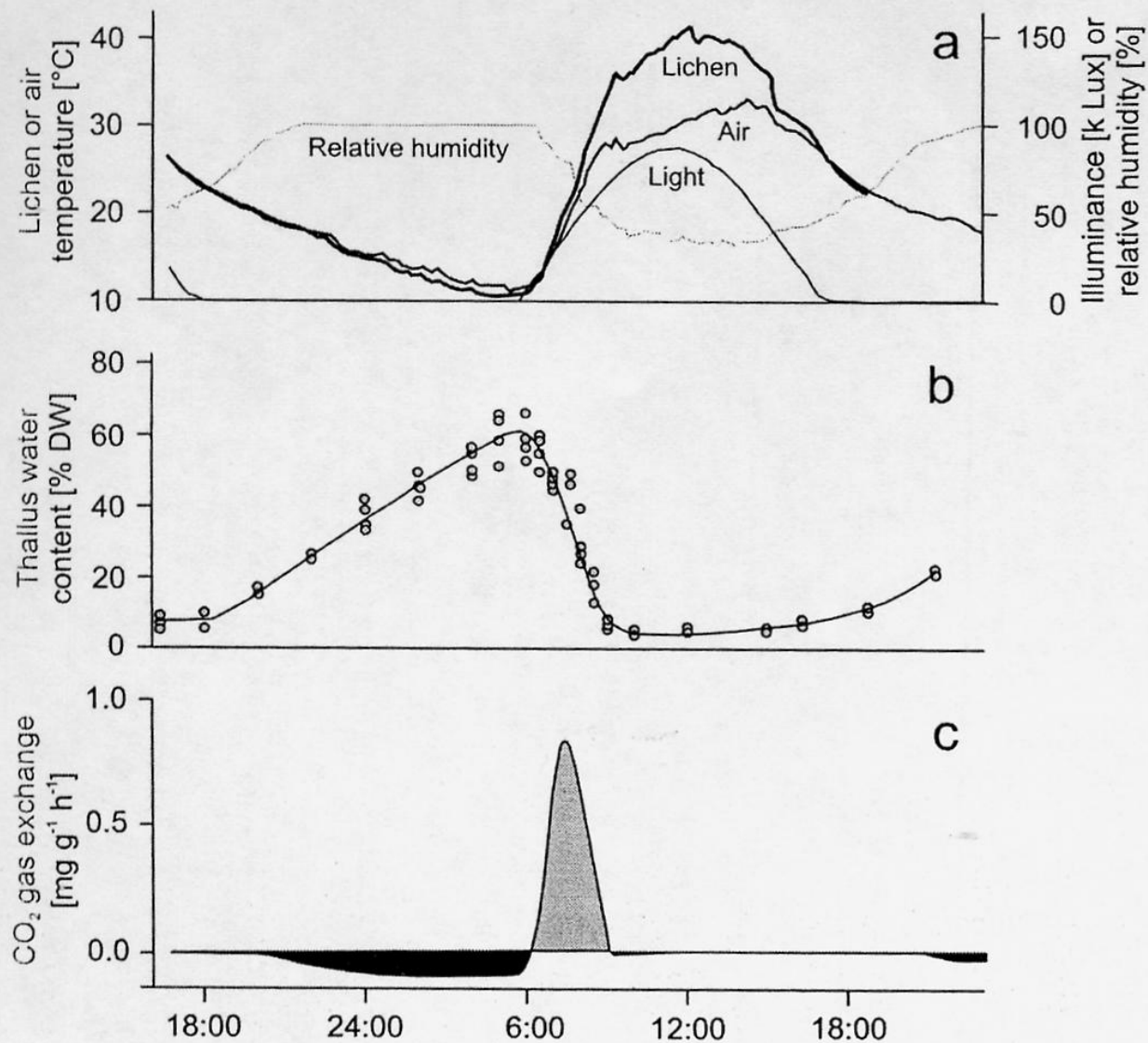
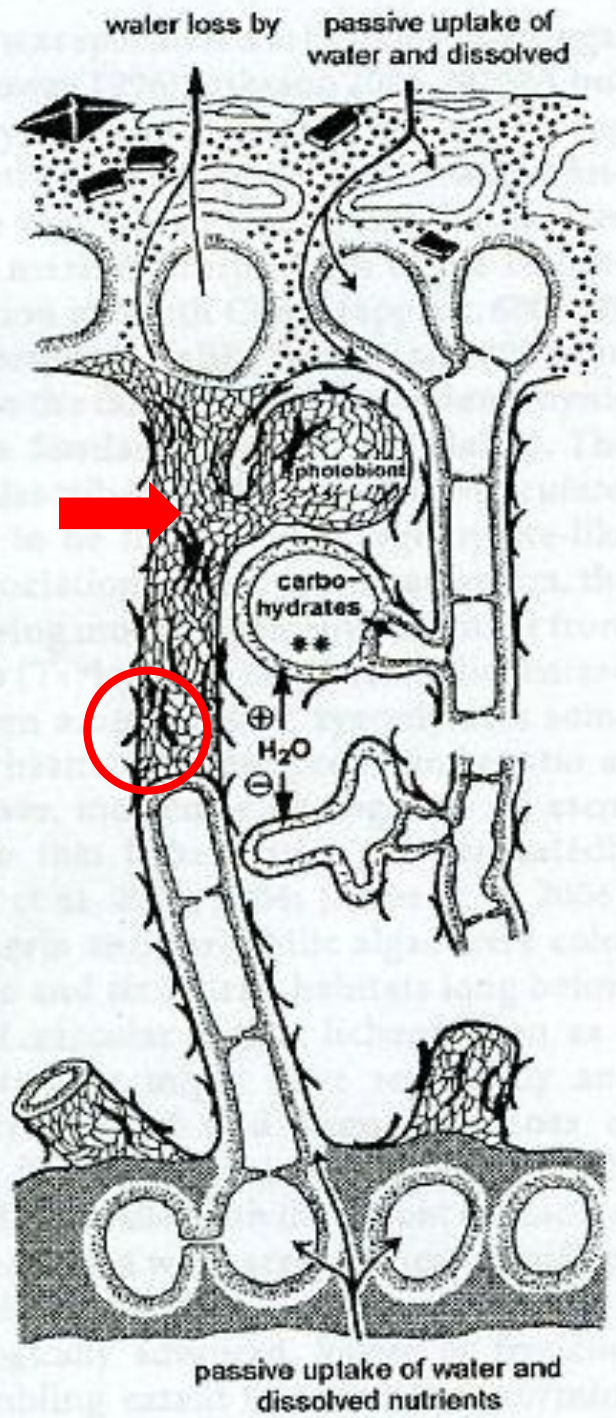


Figure 1. CO₂ gas exchange of *Ramalina maciformis* in relation to environmental parameters during and after dewfall in the Negev Desert. Figure redrawn and modified after Lange (1970). (a) Lichen and air temperature, illuminance and

relative humidity (thick to thin lines) at the experimental site. (b) Thallus water content given as a percentage of dry weight; (c) CO₂ balance curves; values below zero (black) indicate net respiration and above zero (gray) they denote net photosynthesis.





IDROFILO

Tranne che per quelle poche specie intolleranti al disseccamento, i ripetuti cicli “secco-umido” sono fondamentali per la sopravvivenza della simbiosi, in quanto permettono lo scambio di sostanze tra i due (o più) partner.

**IDROFOBICO
(micobionte)**

Parete con sottile strato idrofobico di natura proteica

Metaboliti secondari in cristalli sulla superficie della parete

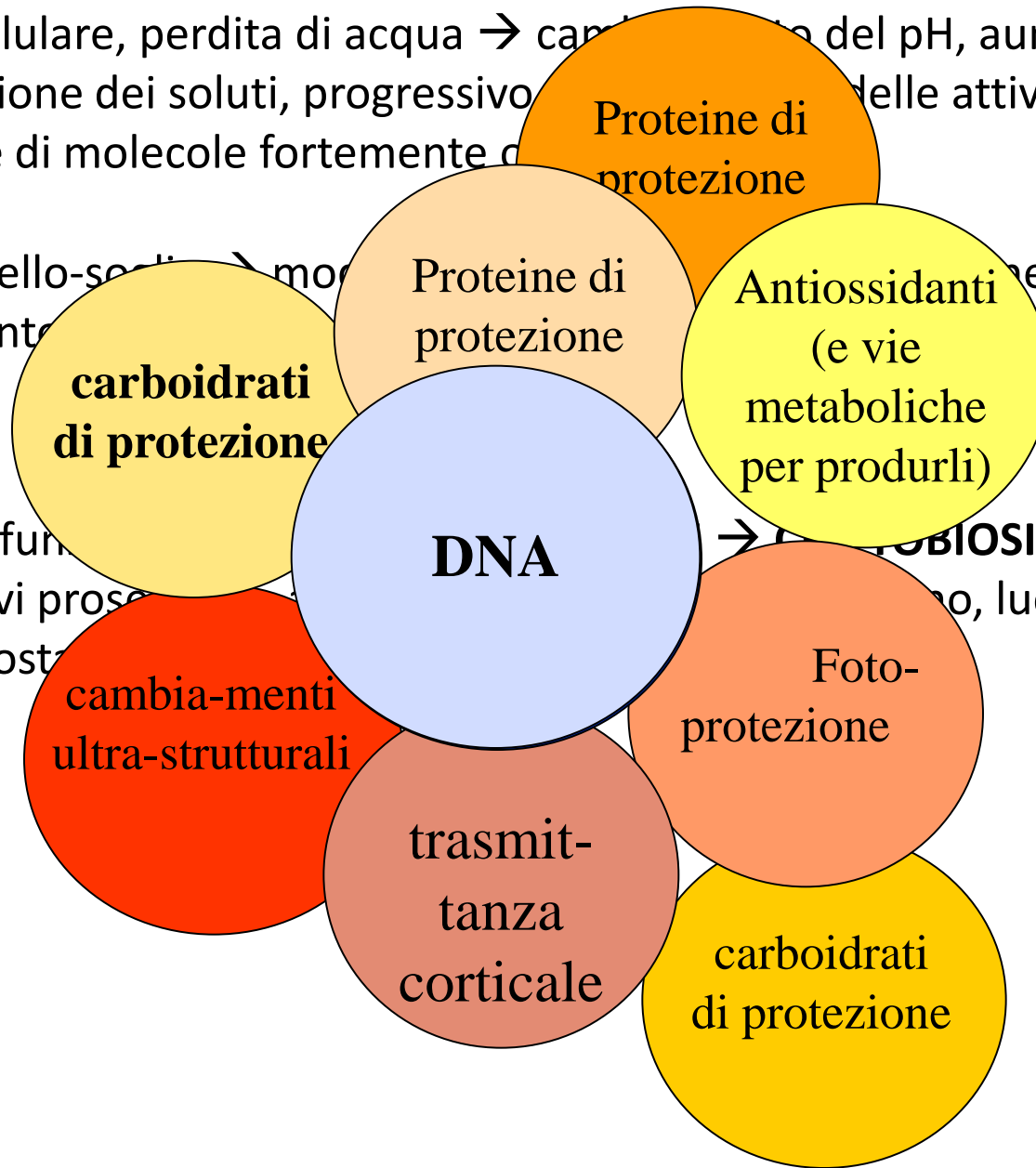
IDROFILO

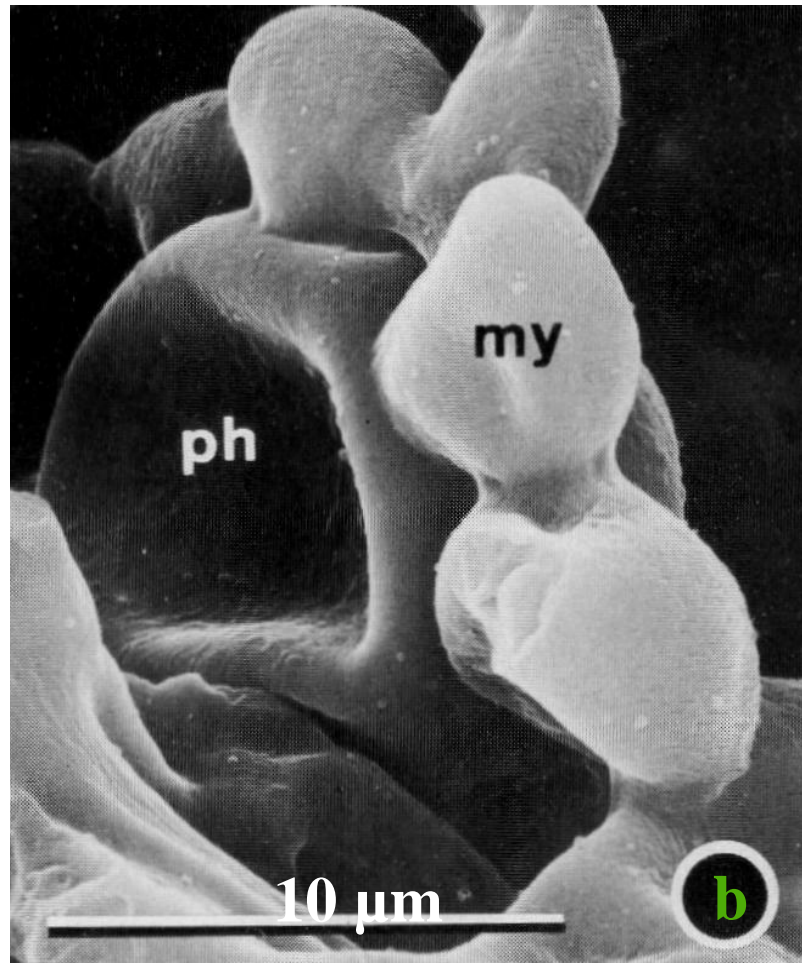
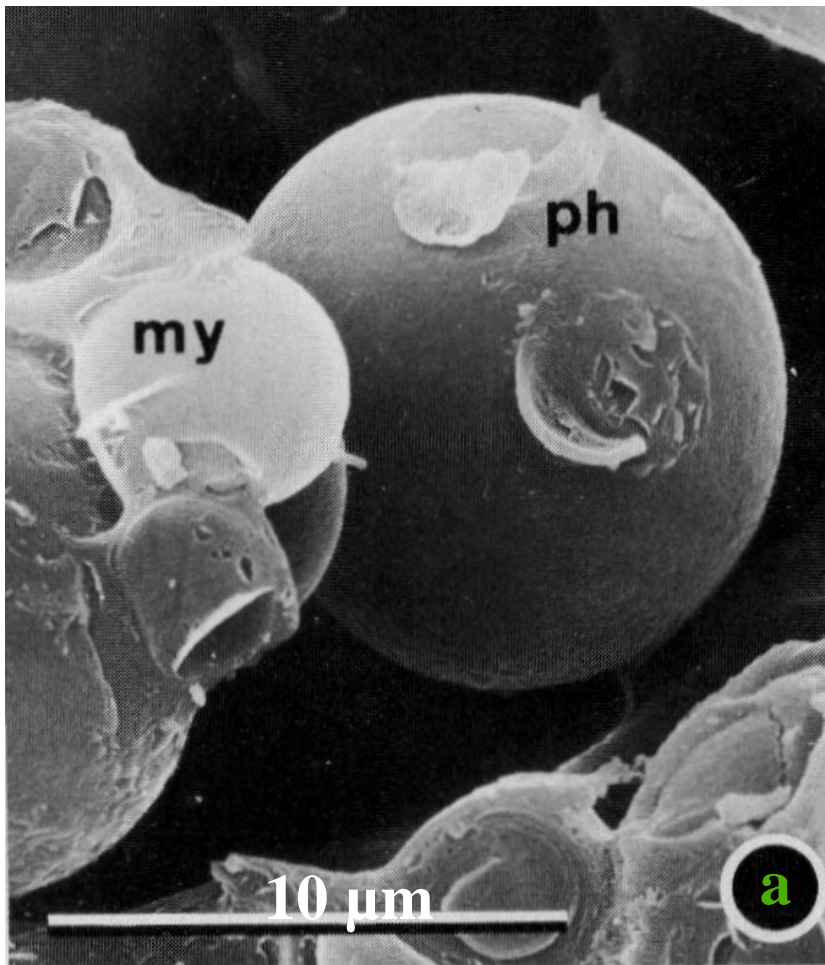
EFFETTI DEL DISSECCAMENTO SUL METABOLISMO DEL LICHENE

A livello cellulare, perdita di acqua → cambiamento del pH, aumento della concentrazione dei soluti, progressivo arresto delle attività enzimatiche, formazione di molecole fortemente c

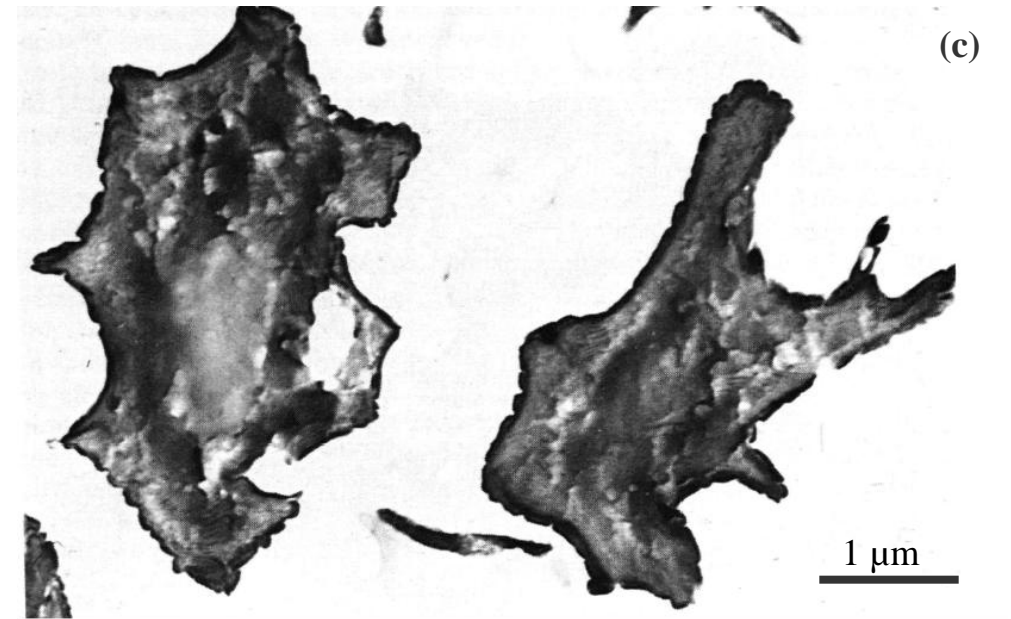
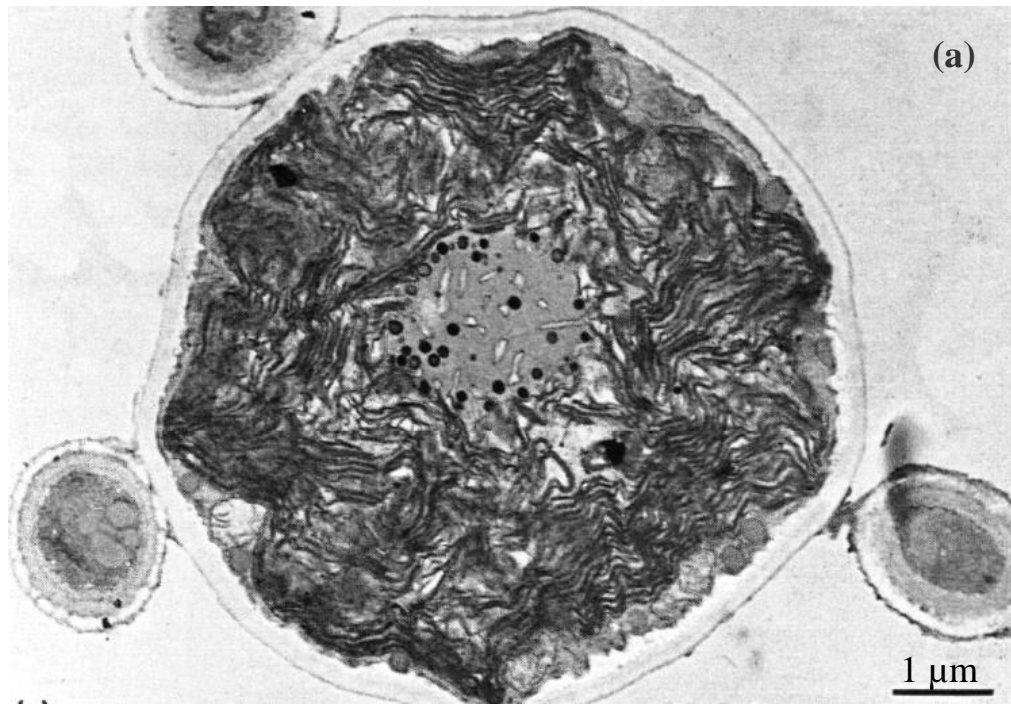
Oltre un livello-seccità → morte cellulare (per eccesso di proteine e proteine) → collassamento

Cessano le funzioni metaboliche, si accumulano prodotti di degradazione, degenerativi processi, eventuali sostanze nocive



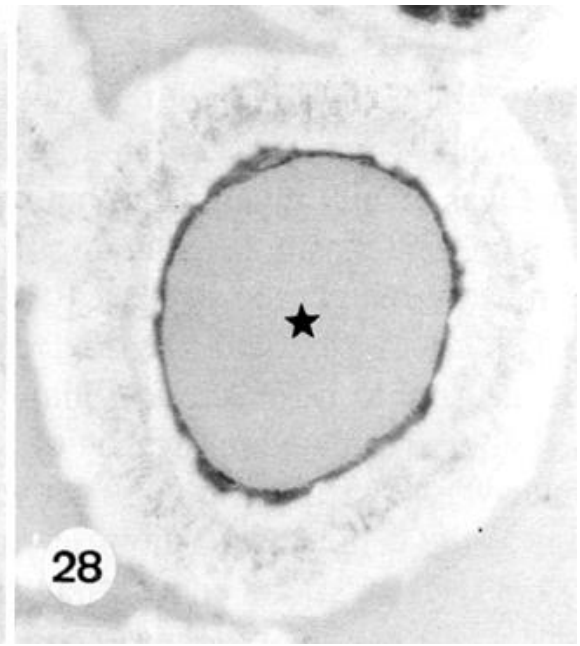
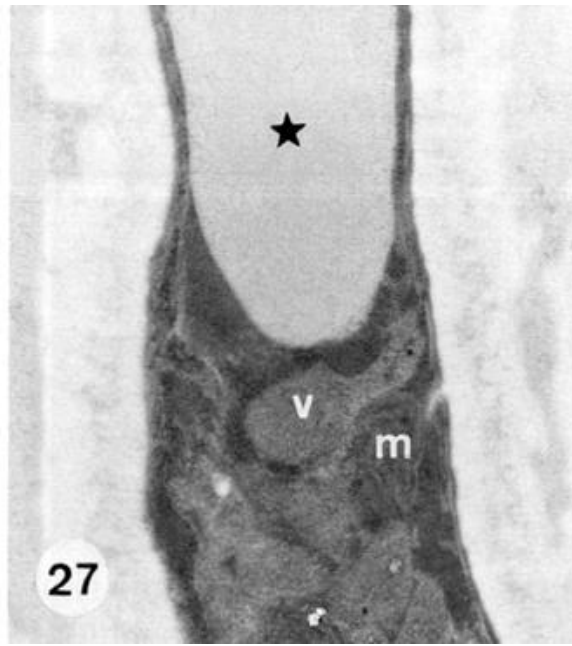
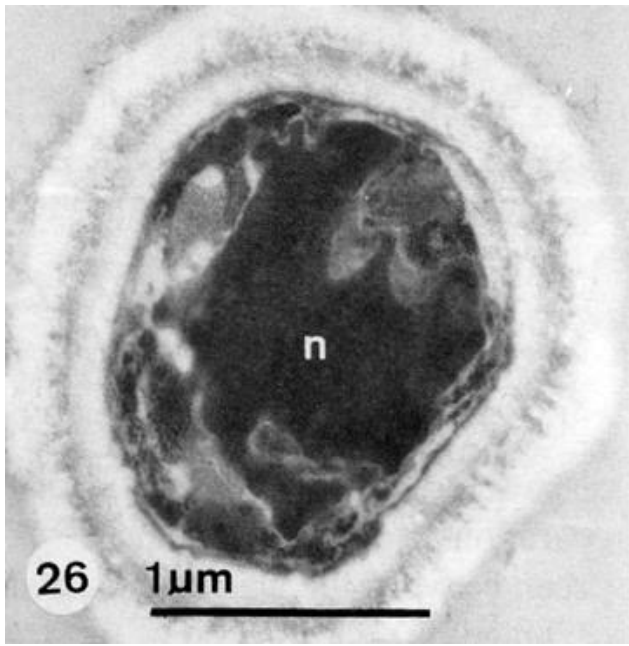


Immagini al LTSEM del lichene foglioso *Xanthoria parietina* perfettamente idratato (c. 150% di contenuto idrico relativo) (a) e secco (c. 30% di contenuto idrico relativo) (b). Da Honegger, *New Phytol.* 125: 659-677, modif.



Fotobionti del genere *Trebouxia* fissati in glutaraldeide in tampone fosfato al 100%RH (a) e al 0%RH (b), e con vapori di tetrossido di osmio allo 0%RH (c).

Brown DH, Rapsch S, Beckett A, Ascaso C (1987) The effect of desiccation on cell shape in the lichen *Parmelia sulcata* Taylor. *New Phytologist* **105**: 295-299.

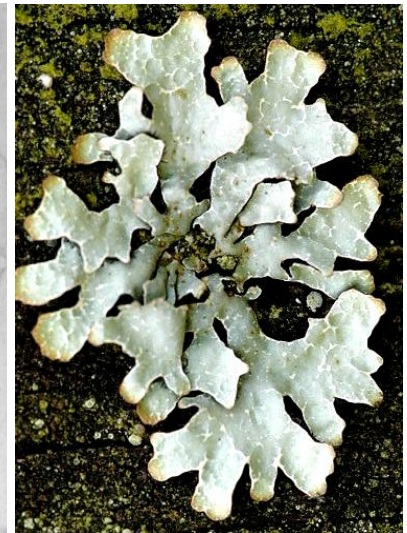
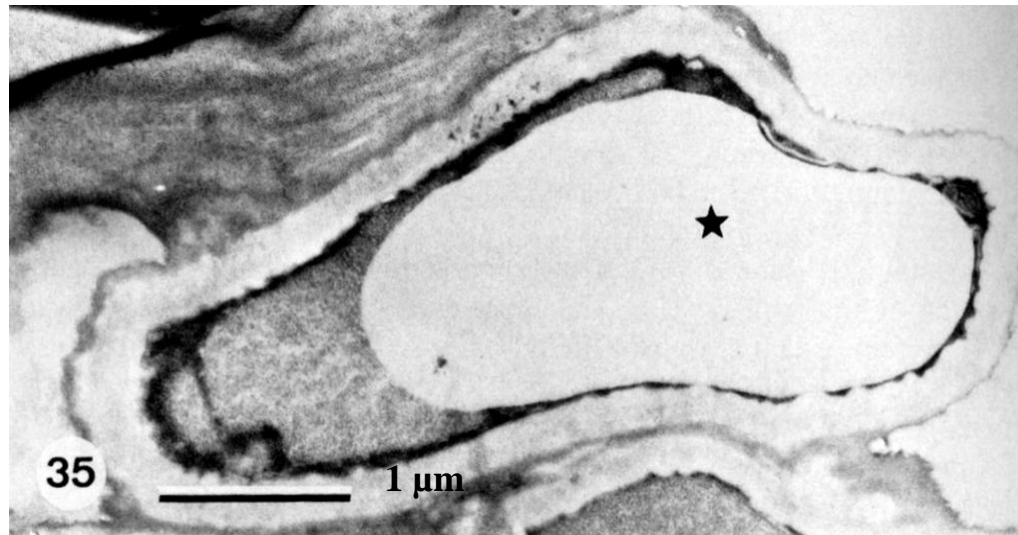


n: nucleo

v: vacuolo

m: mitocondrio

*: bolla gassosa



Il pericolo forse maggiore del disseccamento, insieme alla denaturazione delle proteine enzimatiche, è legato alla **formazione di molecole fortemente ossidanti**, in particolare di **ROS, “Reactive Oxygen Species”**.

- I radicali liberi sono atomi o molecole con elettroni spaiati e sono particolarmente reattivi;
- prodotti da reazioni metaboliche (respirazione aerobia, fotosintesi), fenomeni di stress e molecole ossidanti (es. O_3 ; H_2O_2)
- i radicali dell'ossigeno includono:

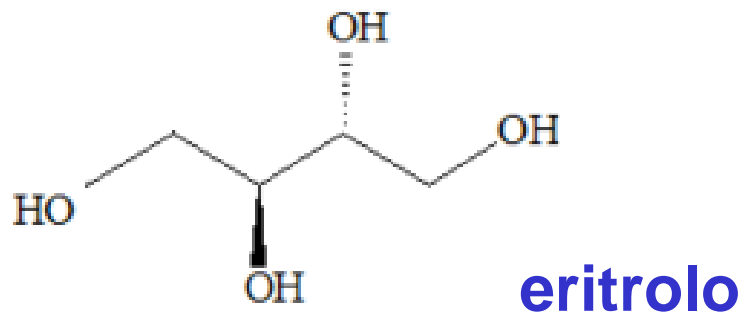
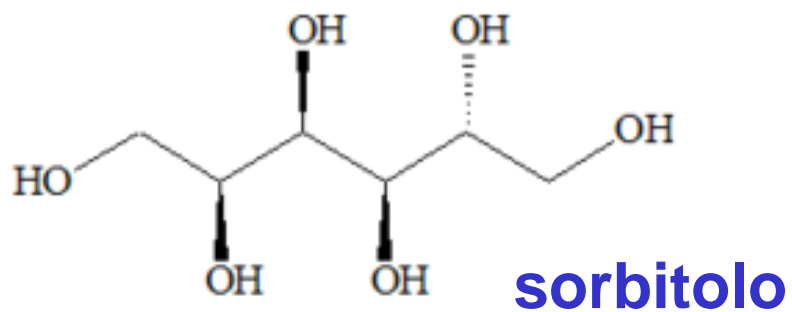
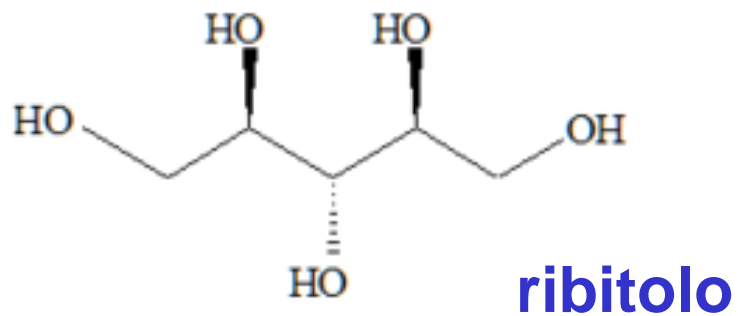


Eliminare i ROS – è compito di complessi enzimatici e molecole organiche a basso peso molecolare, quali il tripeptide GLUTATIONE(GSH), l'ASCORBATO, i TOCOFEROLI.

“Halliwell/Foyer/Asada cycle” - Nel 1976 è stato proposto un ciclo, che vede l'azione integrata di superossido dismutasi, glutatione, ascorbato, glutatione reduttasi, ascorbato perossidasi, mono- e di-deidroascorbato reduttasi.

Nei licheni - La capacità di far fronte ai ROS dipende da:

- tempo richiesto dagli enzimi per diventare funzionanti con la reidratazione del tallo;
- capacità di mobilizzare potere riducente (NADPH);
- quantità di molecole anti-ROS costitutive, in particolare la coppia GSH - GSSG.



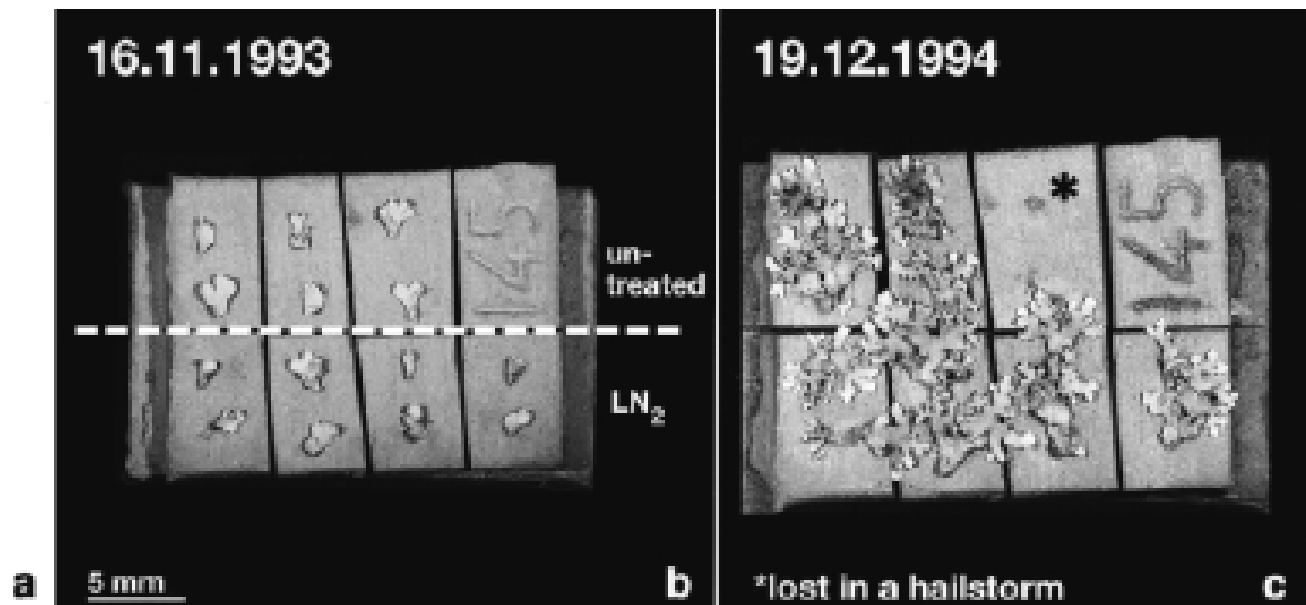
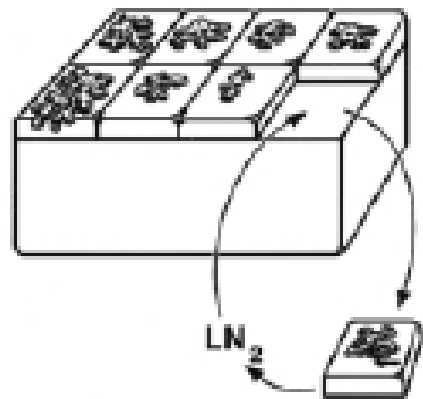
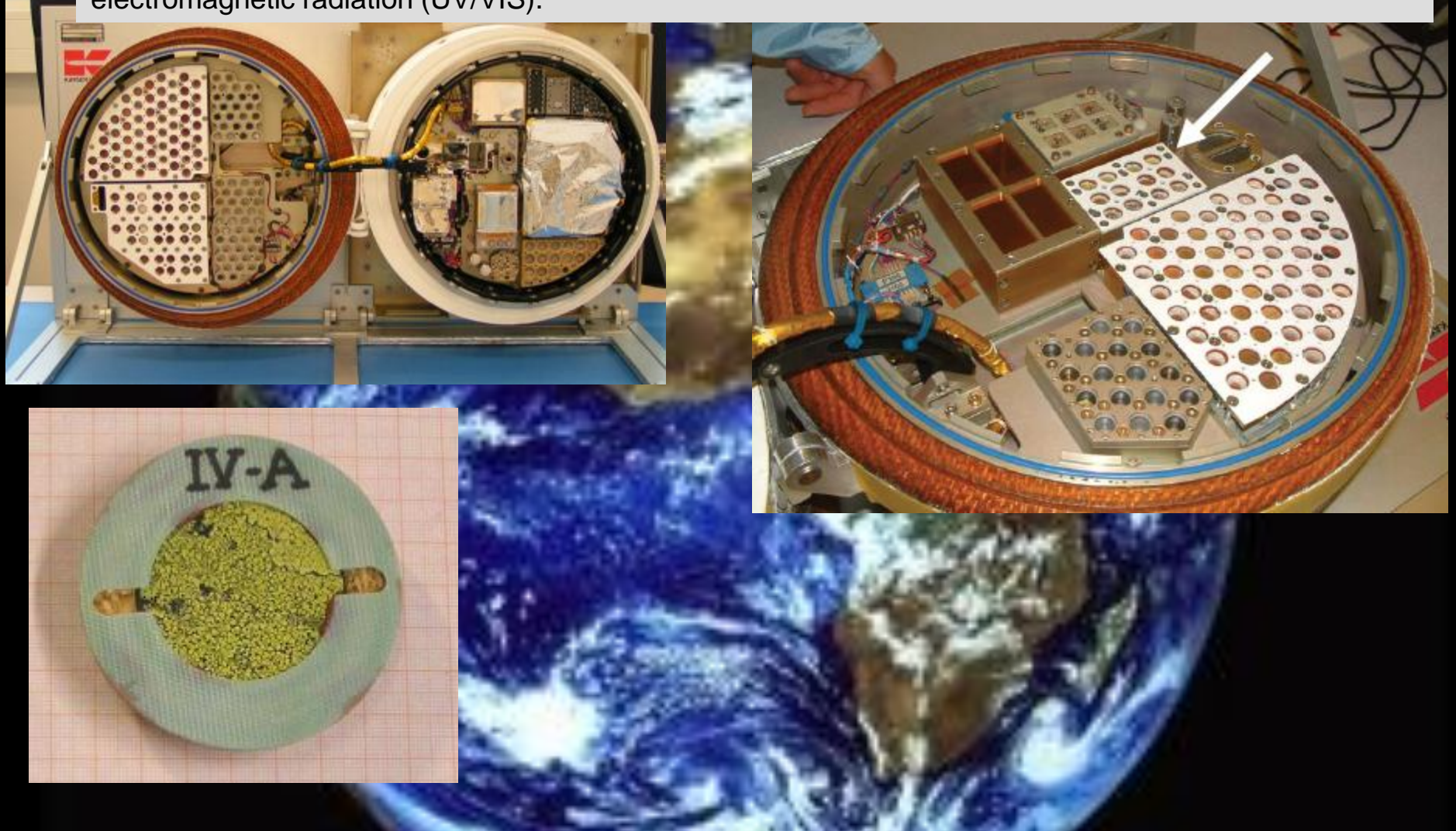


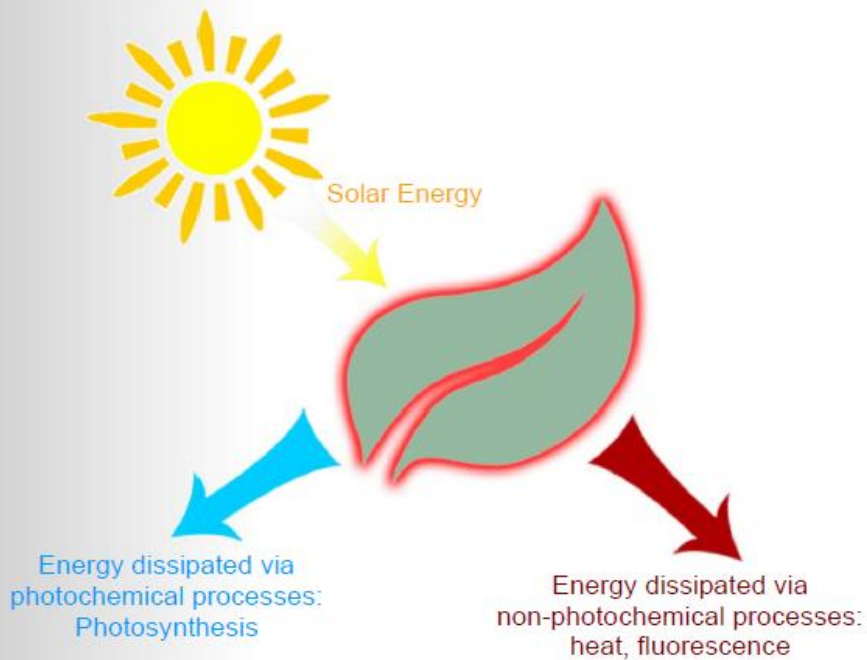
Fig. 4 Reviviscence and growth of lobules of *X. parietina* after one week of LN_2 storage (lower half in **b,c**) in comparison with un-treated specimens (upper half in **b,c**). Lobules were fixed to detachable ceramic slabs with cyanoacrylate glue (**a**).

Biological test systems of the **Lithopanspermia/Biopan experiment**; all samples were exposed to space vacuum, cosmic radiation and selected wavelength ranges of solar extraterrestrial electromagnetic radiation (UV/VIS).

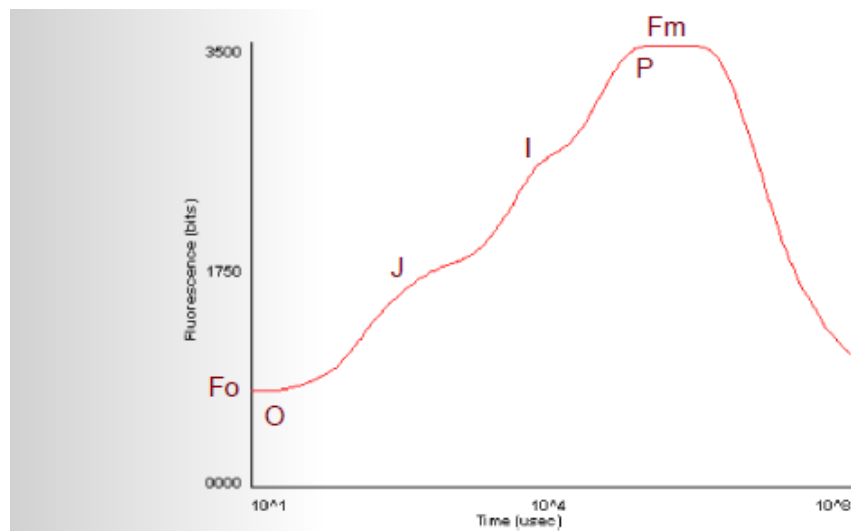


“The data from the Lithopanspermia/Biopan experiment clearly demonstrates the extraordinary survival capacity of lichens in outer space.”

What is Chlorophyll Fluorescence?



The Kautsky Fluorescence Induction.

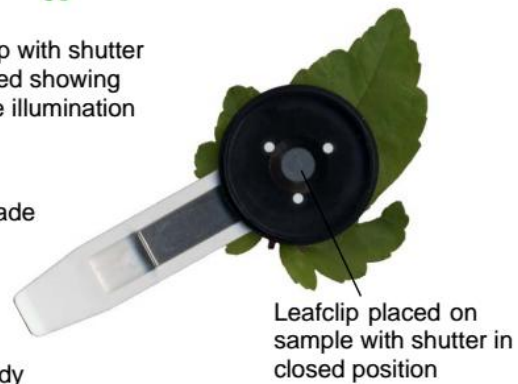


16

p with shutter
ed showing
illumination

ade

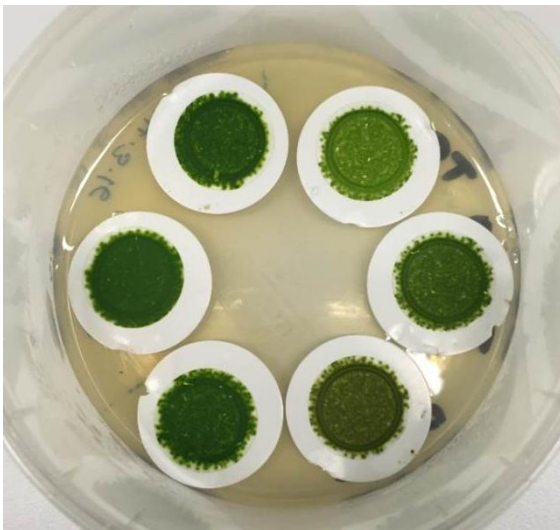
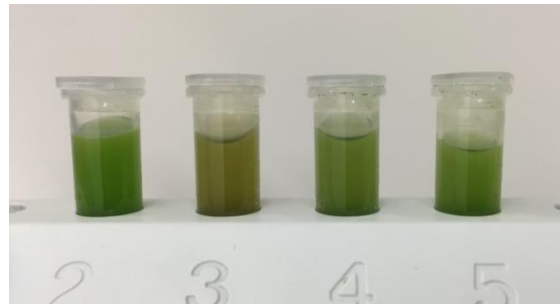
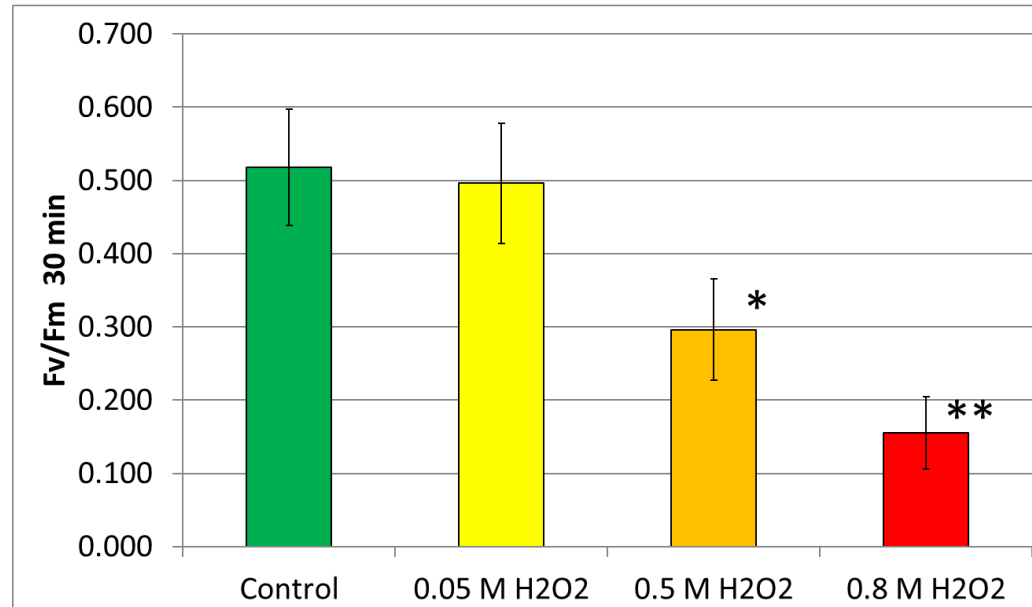
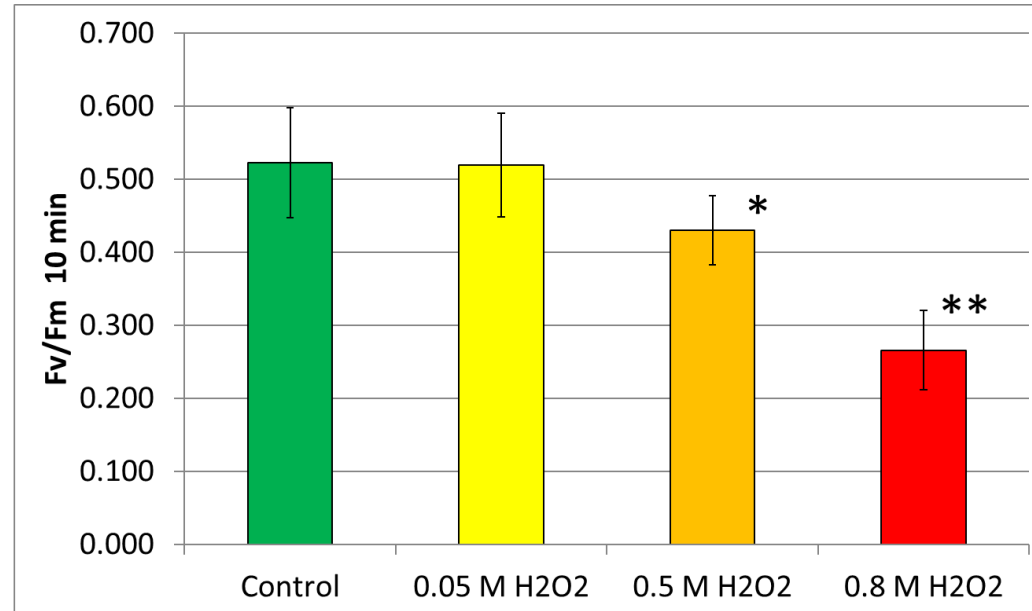
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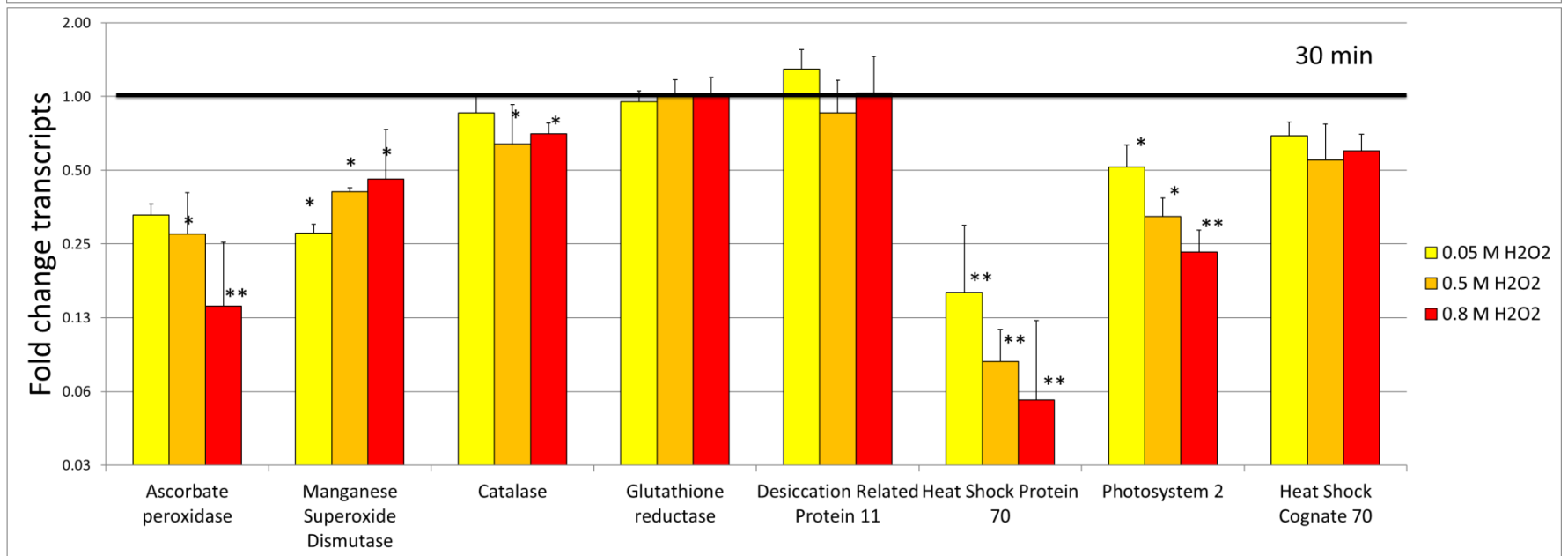
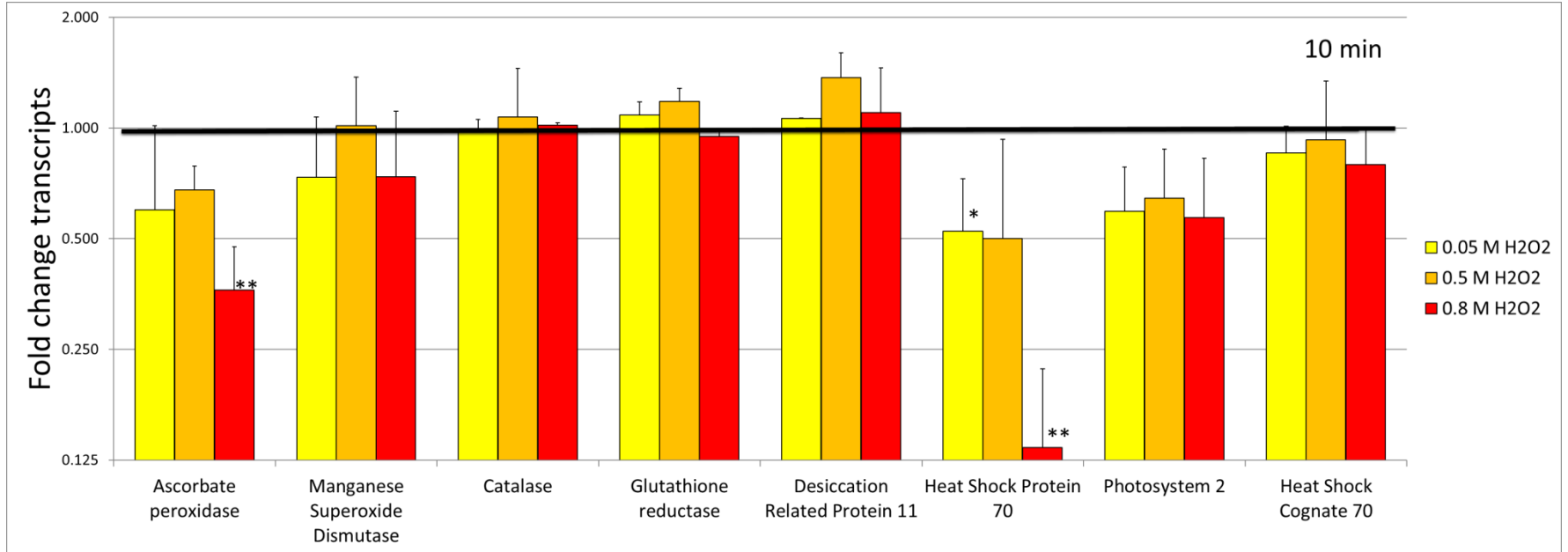
Case study: oxidative stress in a lichen photobiont

Handy PEA (Hansatech)

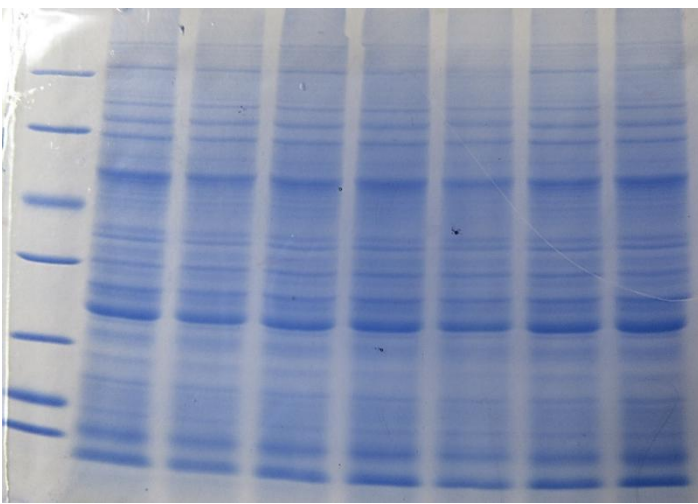
- *Trebouxia gelatinosa* algal suspension
- 3 H₂O₂ concentrations
- 2 exposure times (10' and 30')



Gene expression at transcript level – HSP70

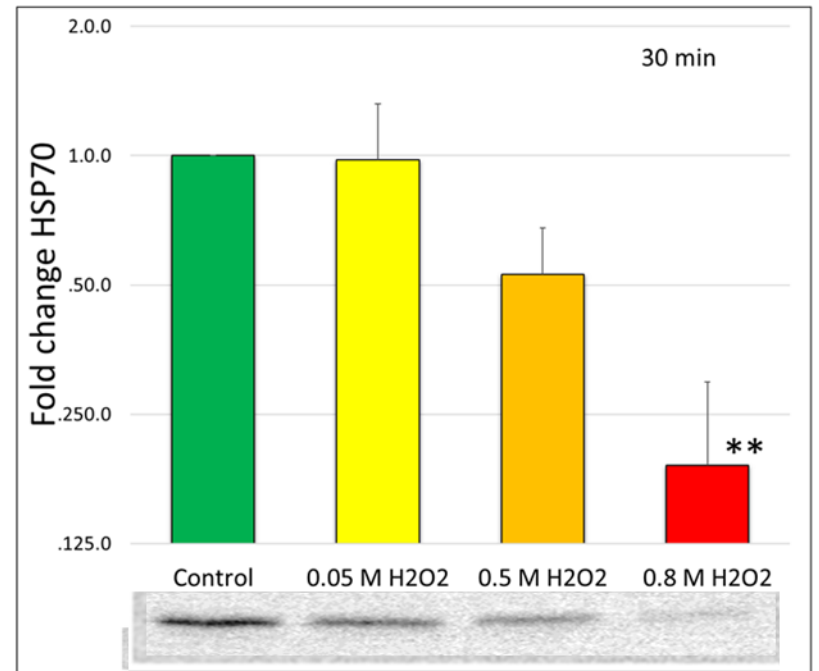
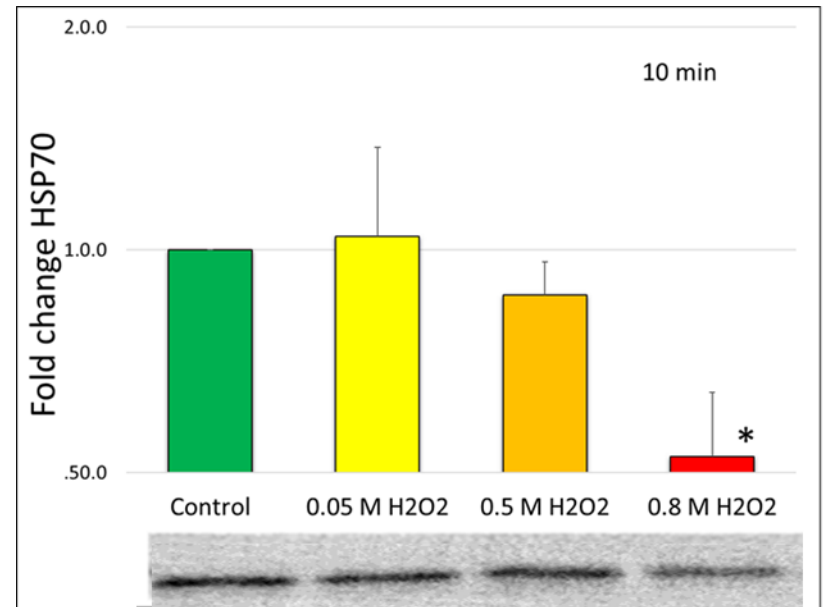


Gene expression at protein level – HSP70



Coomassie staining

Western blot





- La **Società Lichenologica Italiana** è stata fondata proprio a Trieste, nel 1987.
- Il DSV ha il più grande erbario lichenologico d'Italia, ed il più numeroso gruppo di ricercatori che studiano licheni in Italia.
- Siamo un centro di eccellenza per questo soggetto di ricerca, soprattutto per lo studio della biodiversità, della biologia e degli aspetti applicativi (es.: biomonitoraggio ambientale).

XXIX  **Convegno**
Società Lichenologica Italiana
Trieste 28-30 Settembre 2016



Convegno
SL 
13-15 settembre 2017