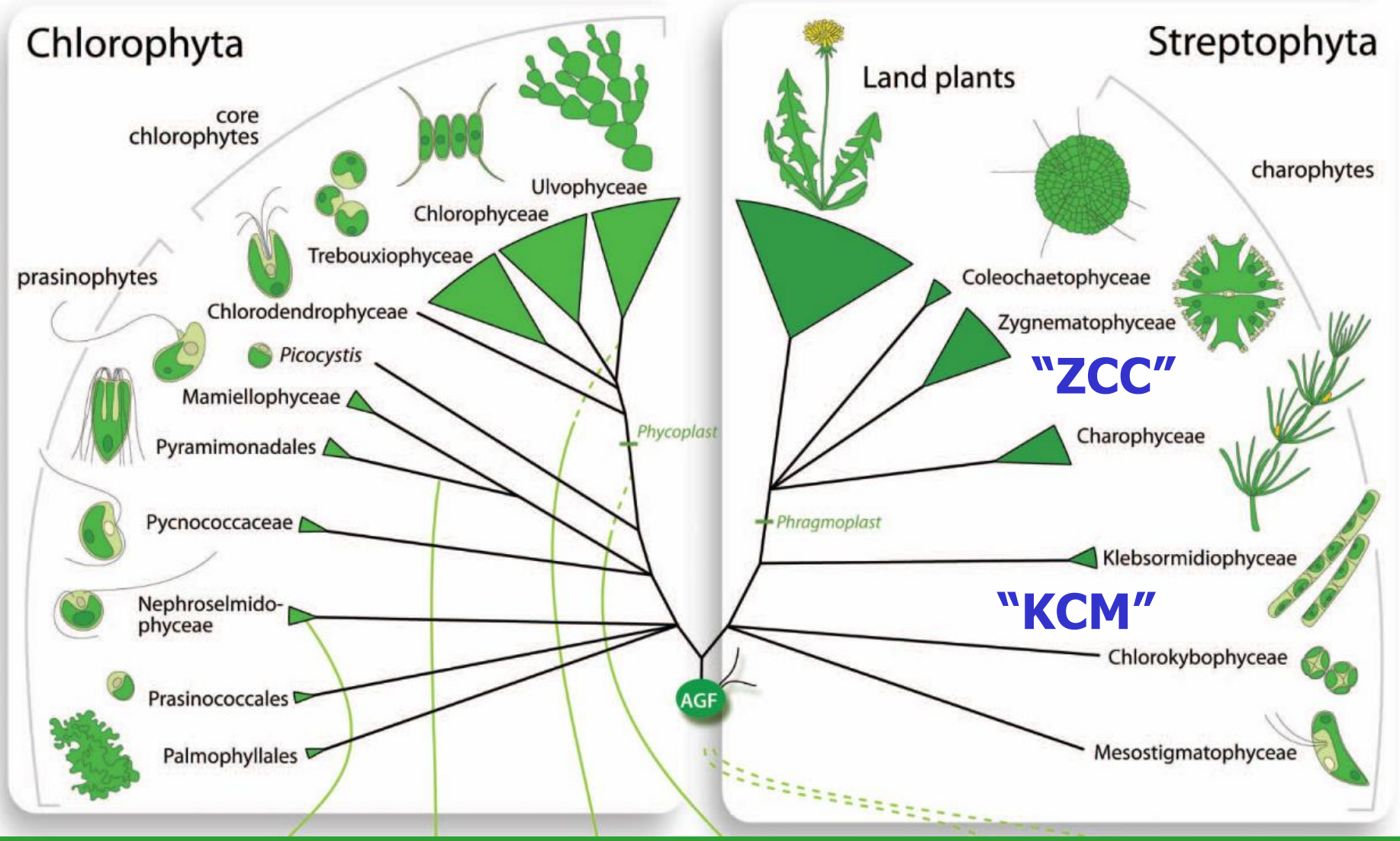
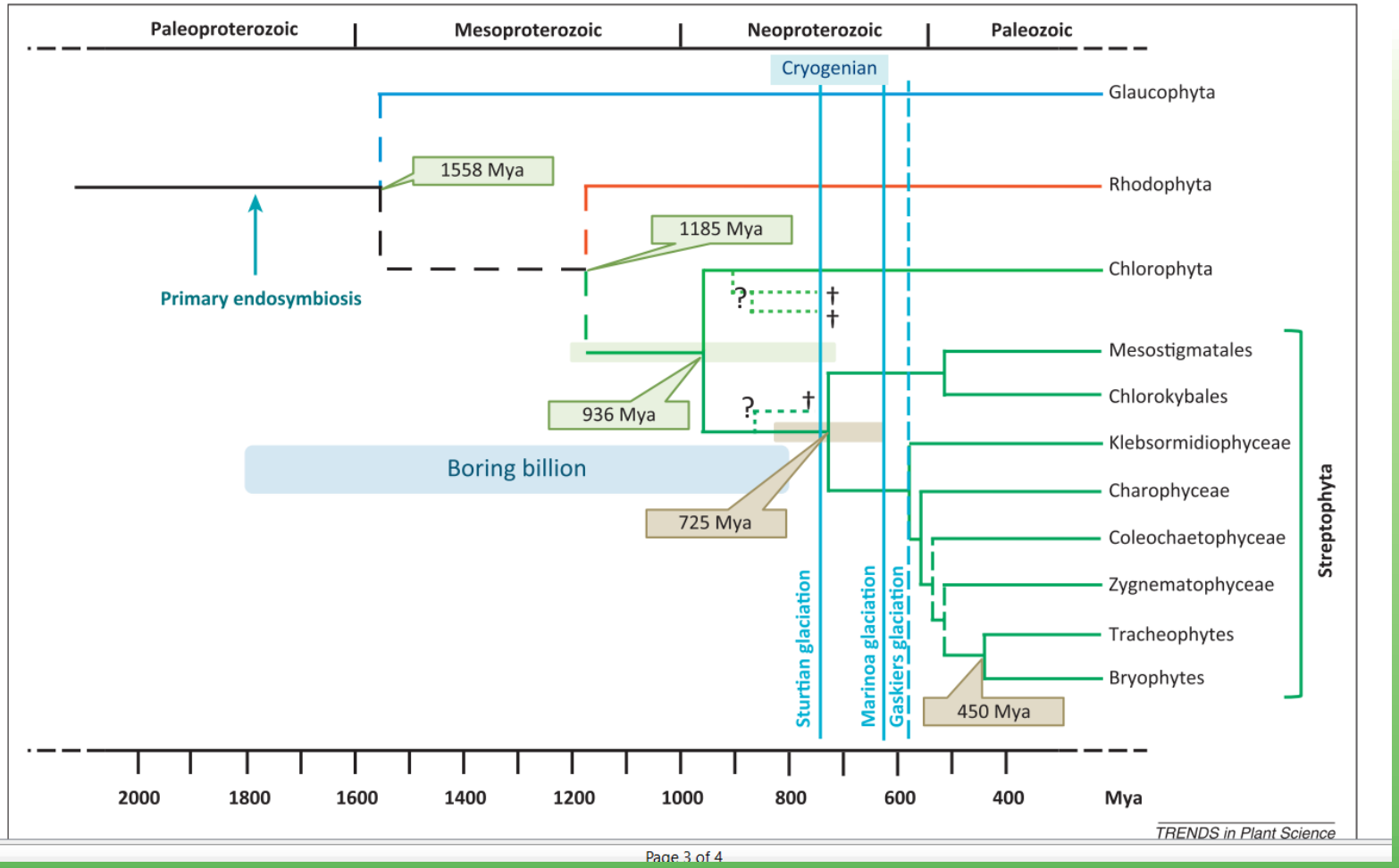
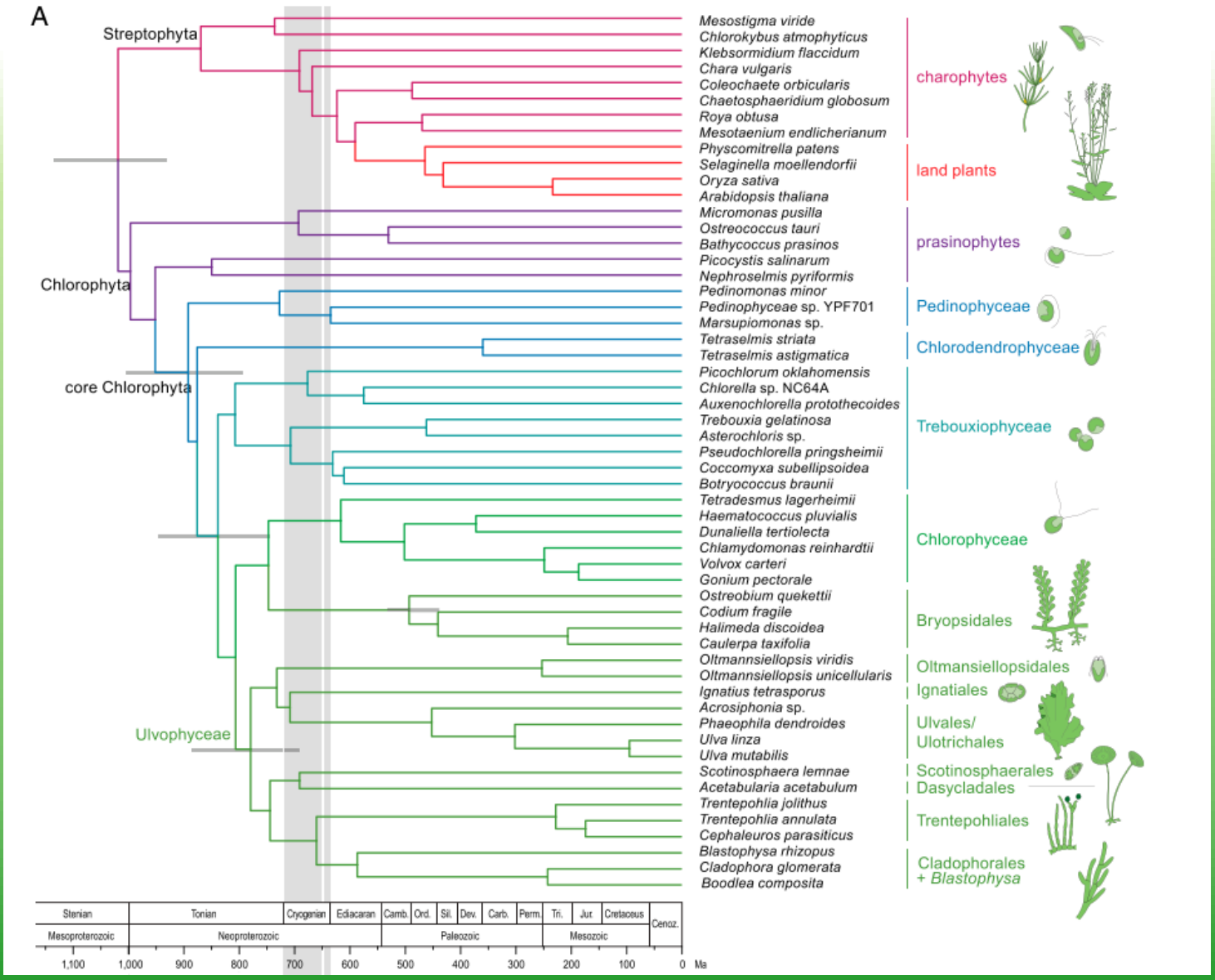
Introduction to plant systematics, evolution and ecology

Viridiplantae
Streptophyta


Chlorophyta
core chlorophytes
Ulvophyceae
Chlorophyceae
Trebouxiophyceae
prasinophytes
Chlorodendrophyceae
Picocystis
Mamiellophyceae
Pyramimonadales
Pycnococcaceae
Nephroselmido-phyceae
Prasinococcales
Palmophyllales
Phycoplast
AGF
Streptophyta
Land plants
charophytes
Coleochaetophyceae
Zygnematophyceae
"ZCC"
Charophyceae
Phragmoplast
Klebsormidiophyceae
"KCM"
Chlorokybophyceae
Mesostigmatophyceae


Paleoproterozoic
Mesoproterozoic
Neoproterozoic
Paleozoic
Cryogenian
Glaucophyta
Rhodophyta
Chlorophyta
1558 Mya
1185 Mya
Primary endosymbiosis
?
†
†
936 Mya
?
†
Boring billion
725 Mya
Mesostigmatales
Chlorokybales
Klebsormidiophyceae
Charophyceae
Coleochaetophyceae
Zygnematophyceae
Tracheophytes
Bryophytes
Streptophyta
450 Mya
Sturtian glaciation
Marinoa glaciation
Gaskiers glaciation
2000
1800
1600
1400
1200
1000
800
600
400
Mya
TRENDS in Plant Science
Page 3 of 4

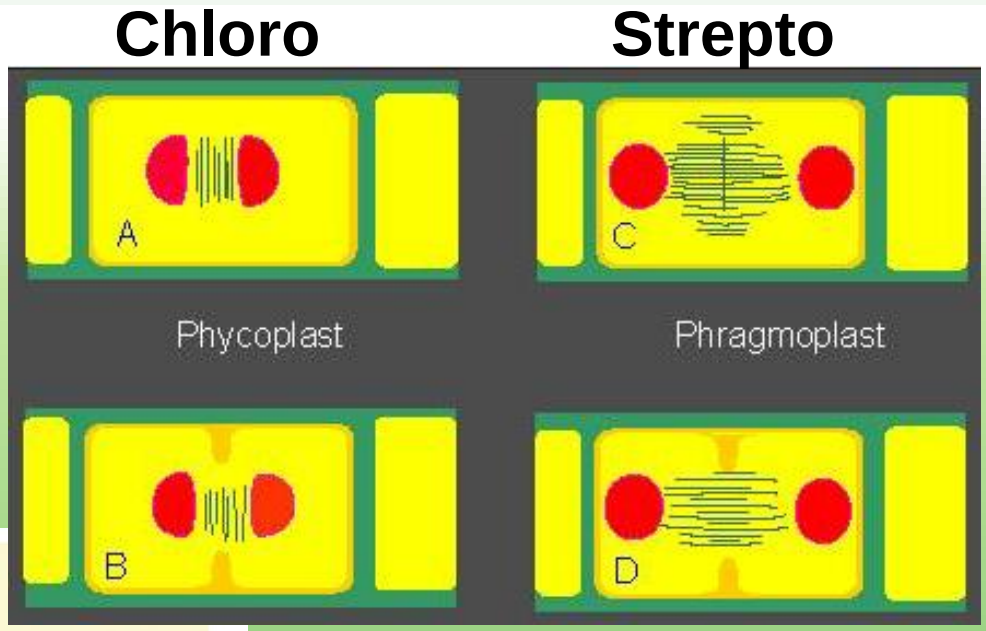
Becker (2013)

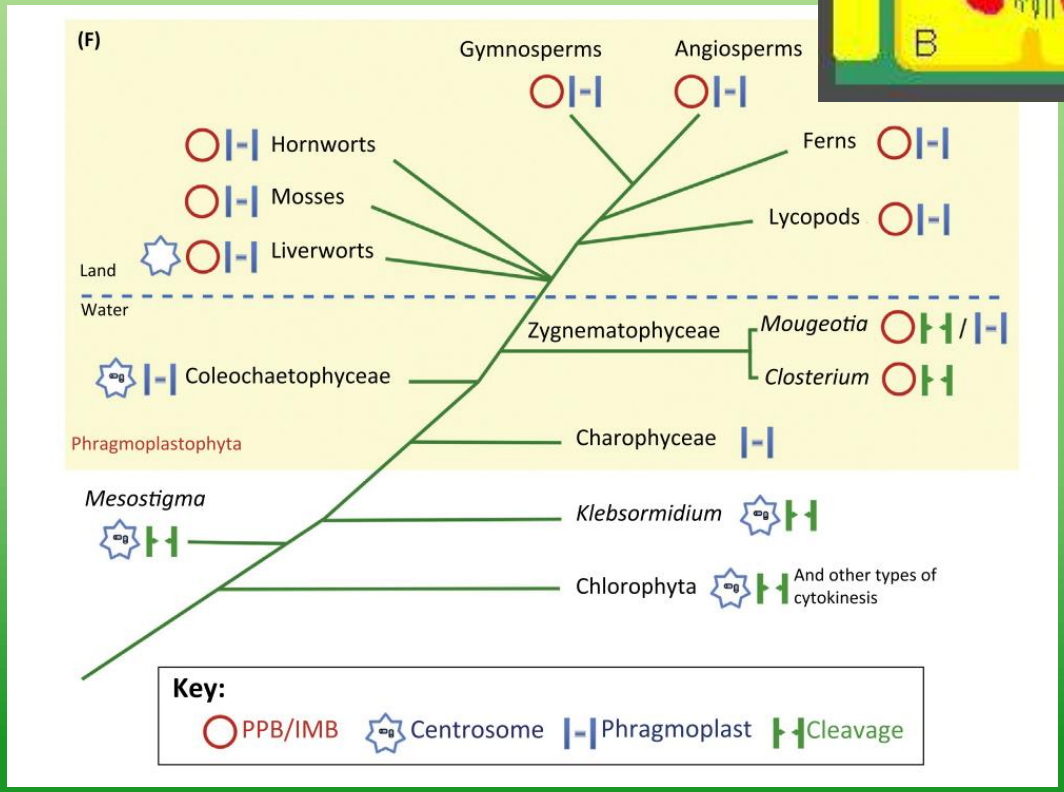


Cortona et al. (2020)

Streptophyta
- new traits -

Microtubular orientation during cell division

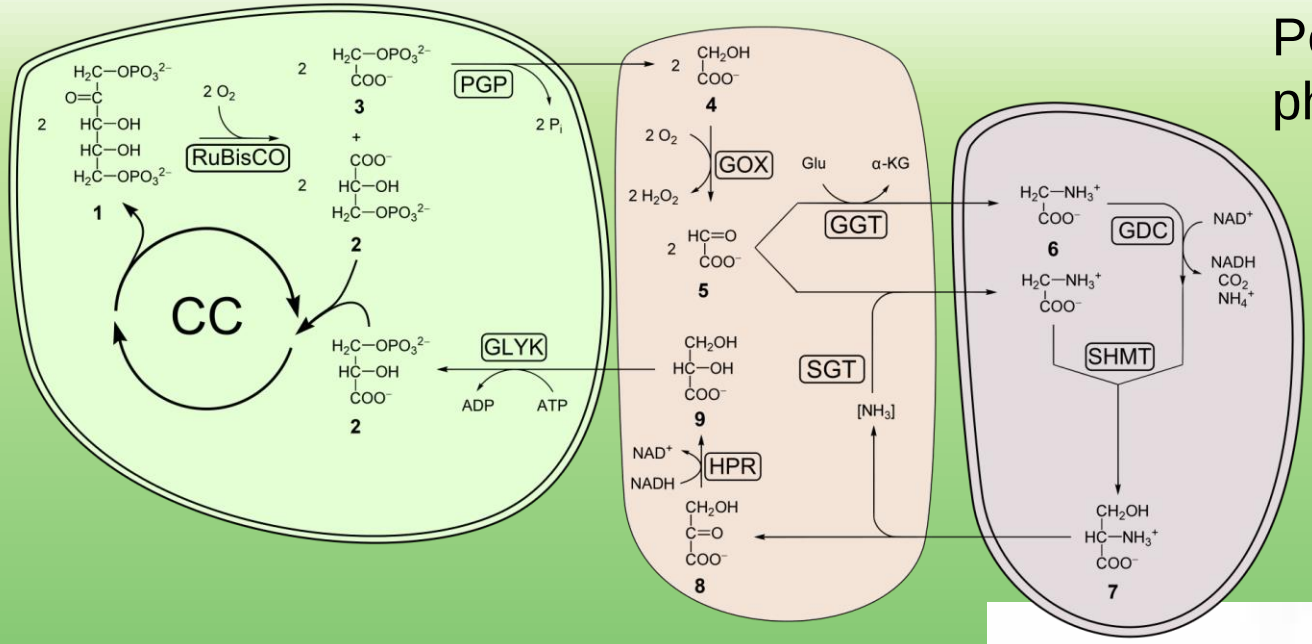


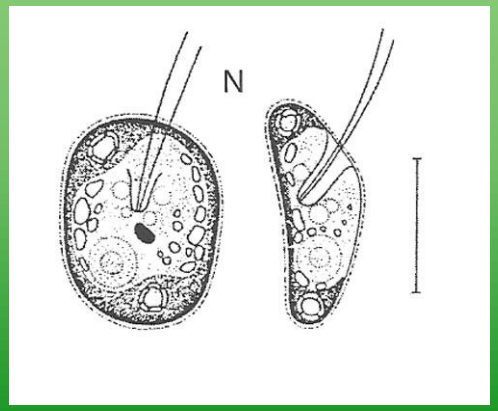


Buschmann & Zachgo (2016)

Streptophyta – new traits

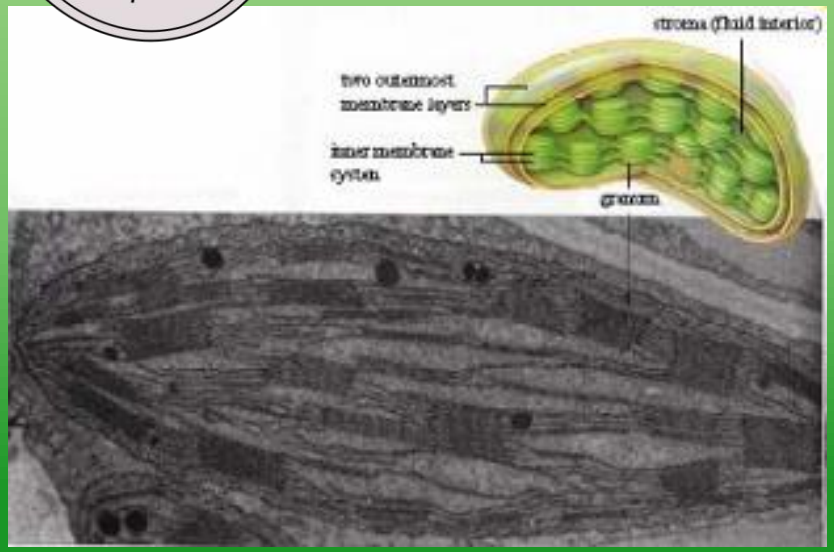
Peroxisomal photorespiration





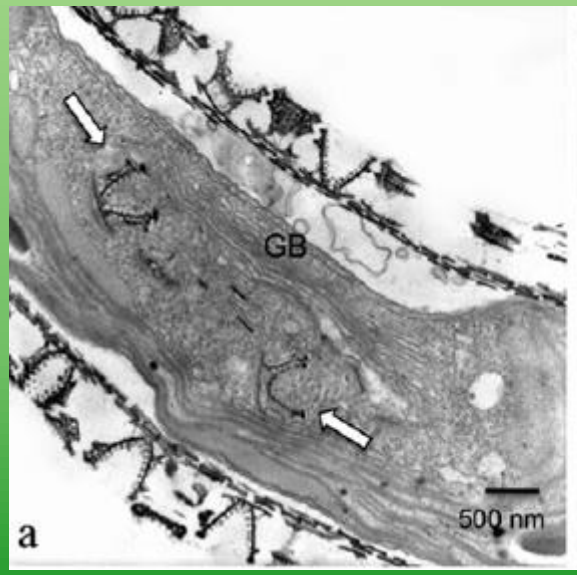
lateral flagella

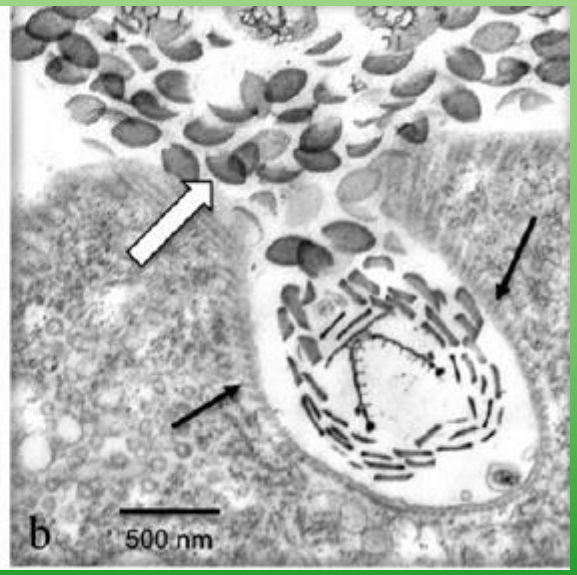
thylakoids form grana



Mesostigmatophyceae

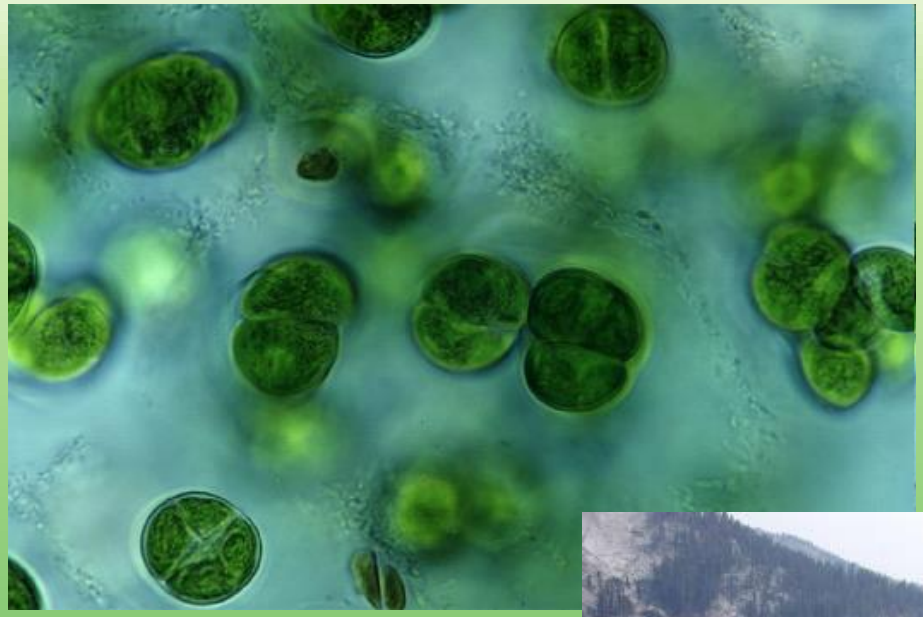
Mesostigma viride





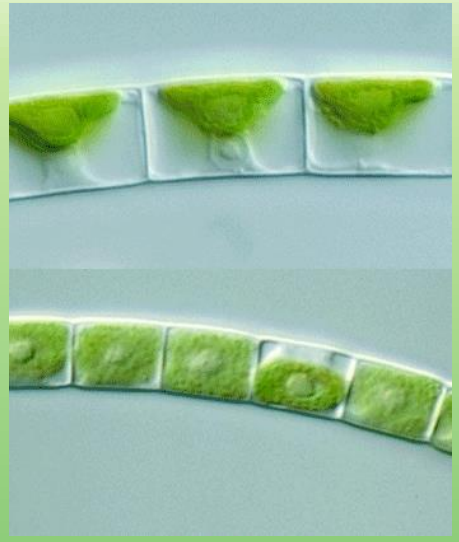
Chlorokybophyceae

Chlorokybus atmophyticus



Klebsormidiophyceae

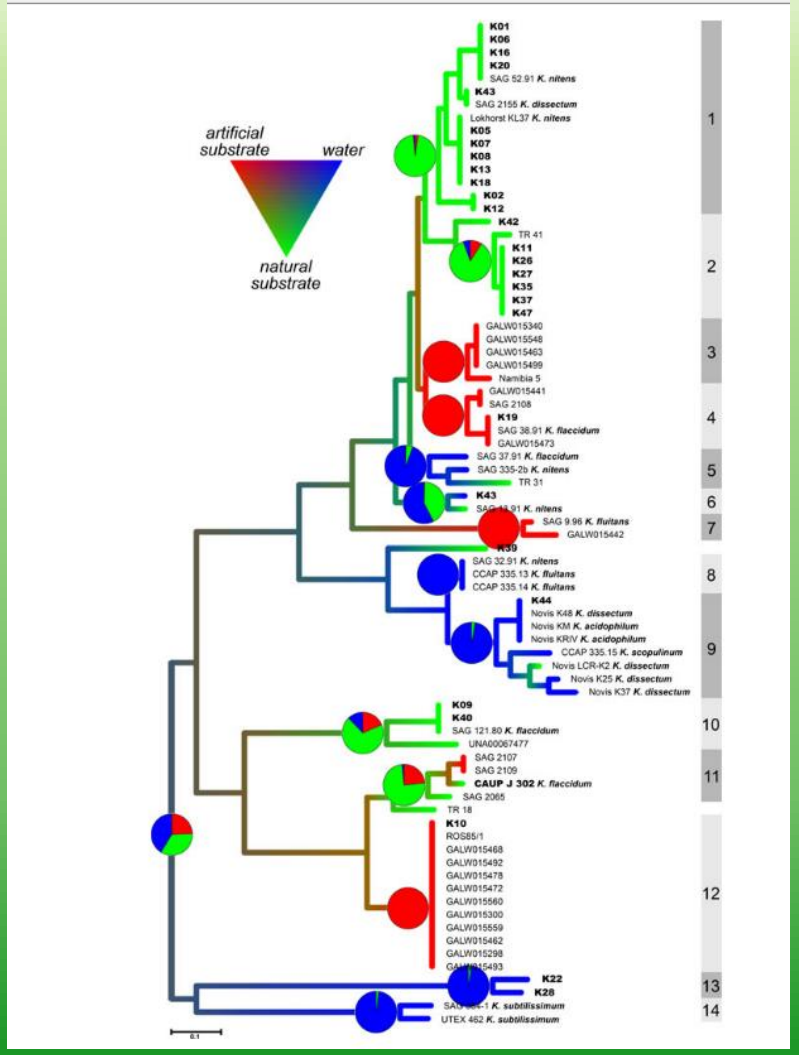
Klebsormidium



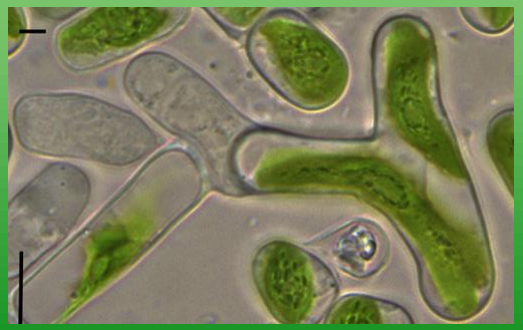
Callose in the cross cell walls

Holzinger et al. (2011)

Ecological differentiation



Streptosarcina

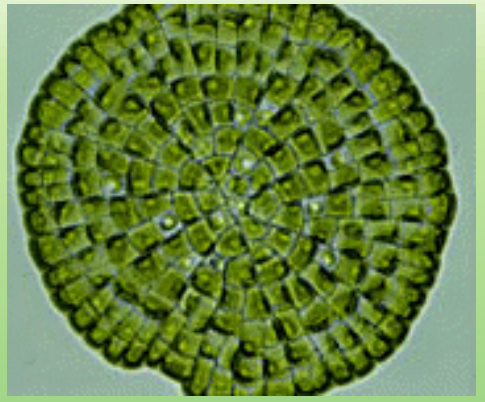


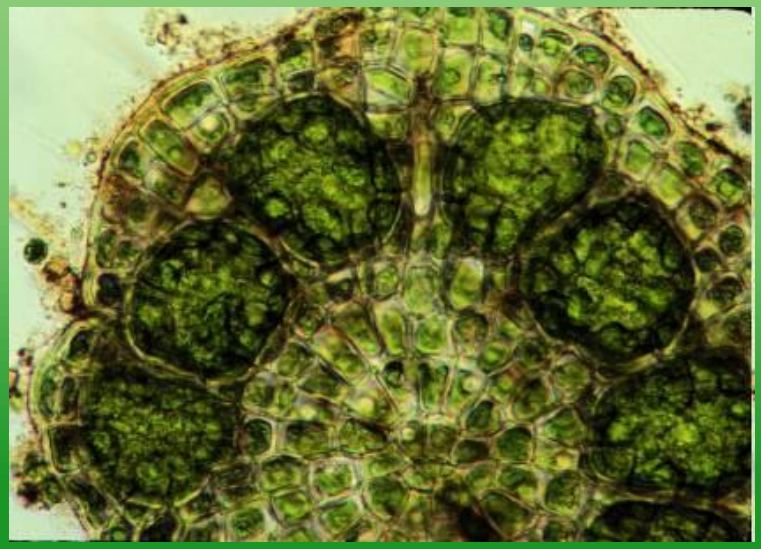
Mikhailyuk et al. (2018)

Škaloud & Rindi (2013)

Coleochaetophyceae

Coleochaete

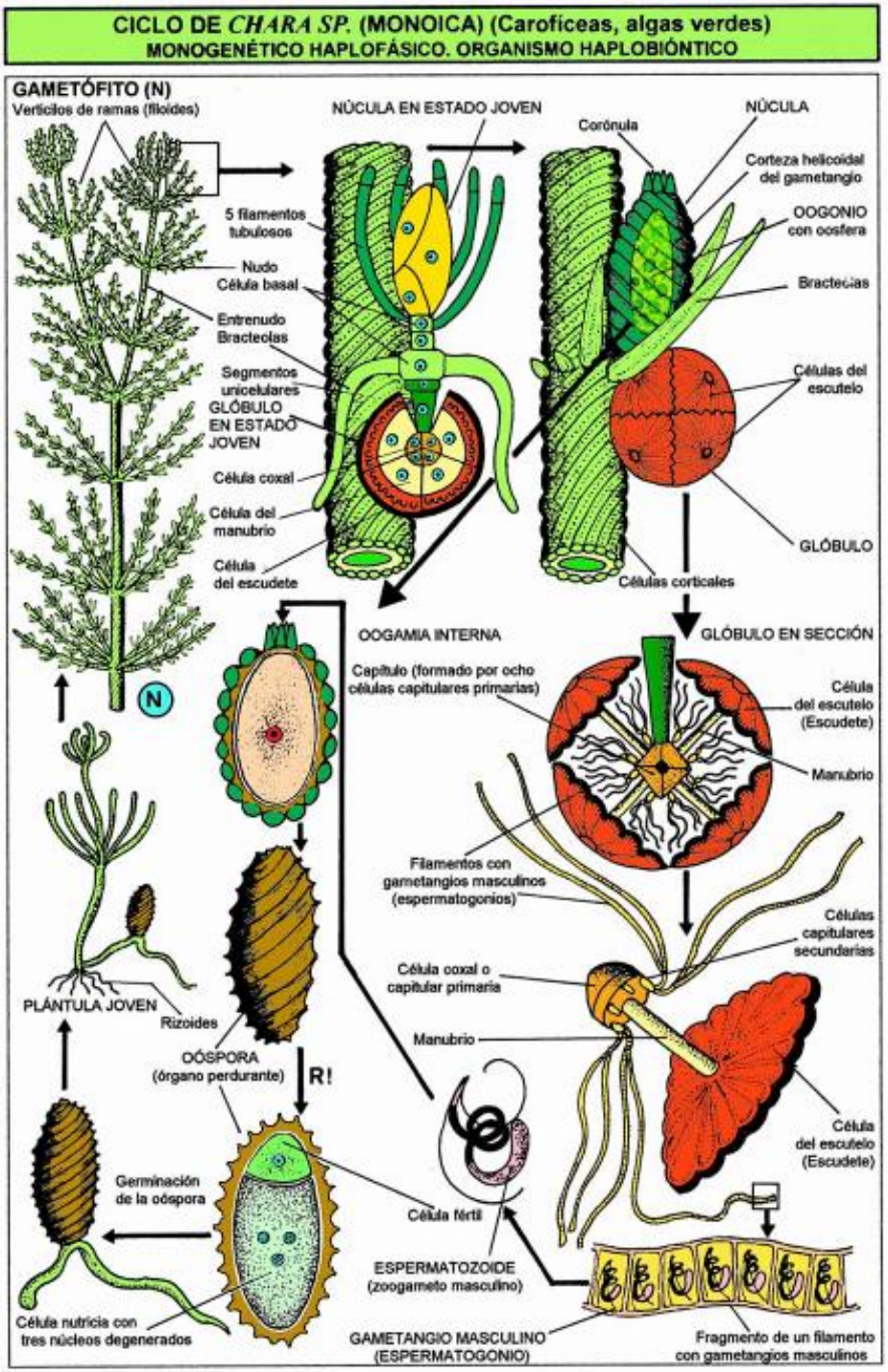




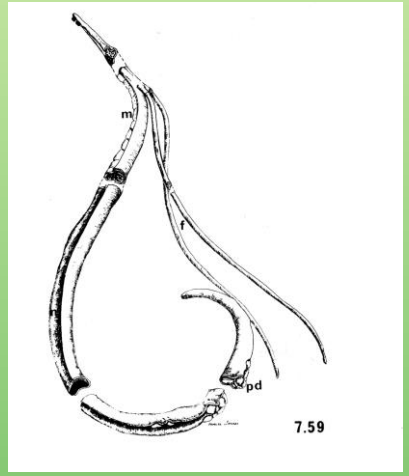
Charophyceae

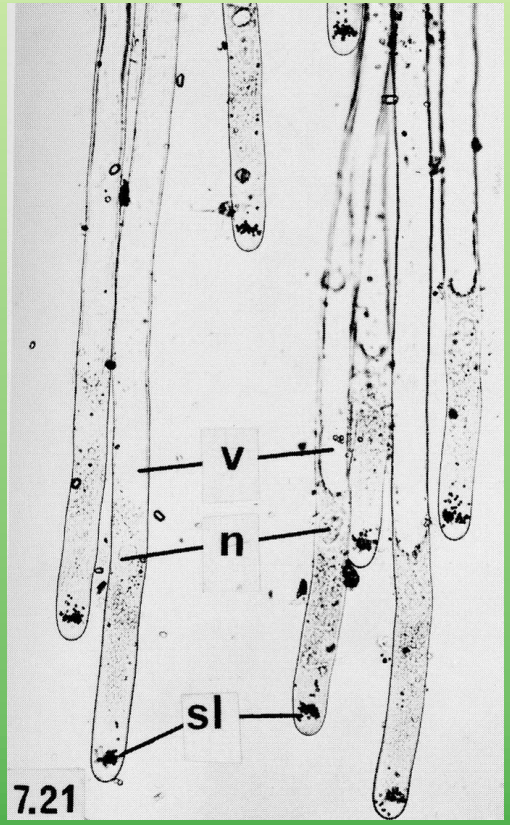
Chara

Nitella



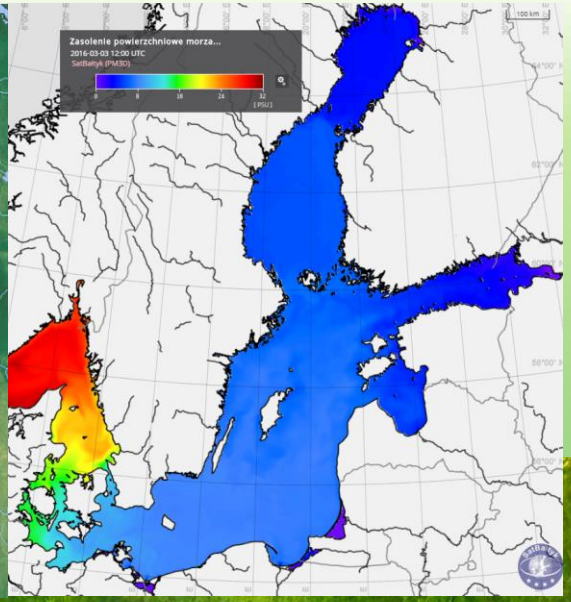
Charophyceae



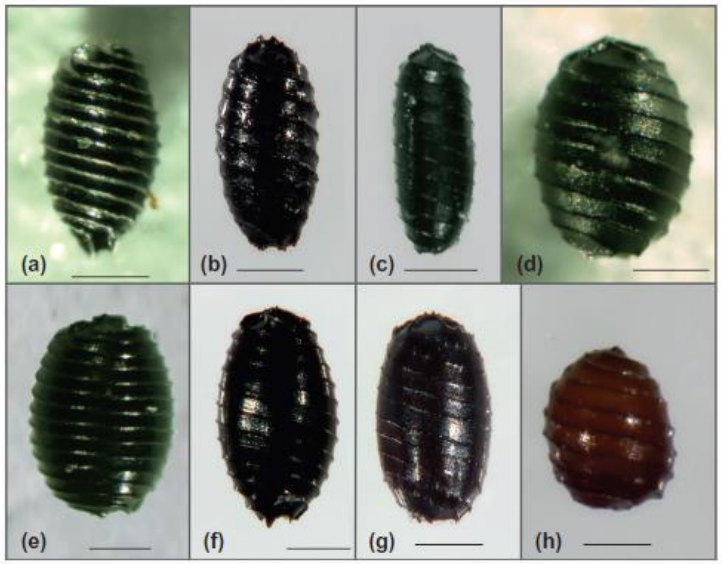


Charophyceae

„habitat forming“ macroalgae in the Baltic



Charophyceae



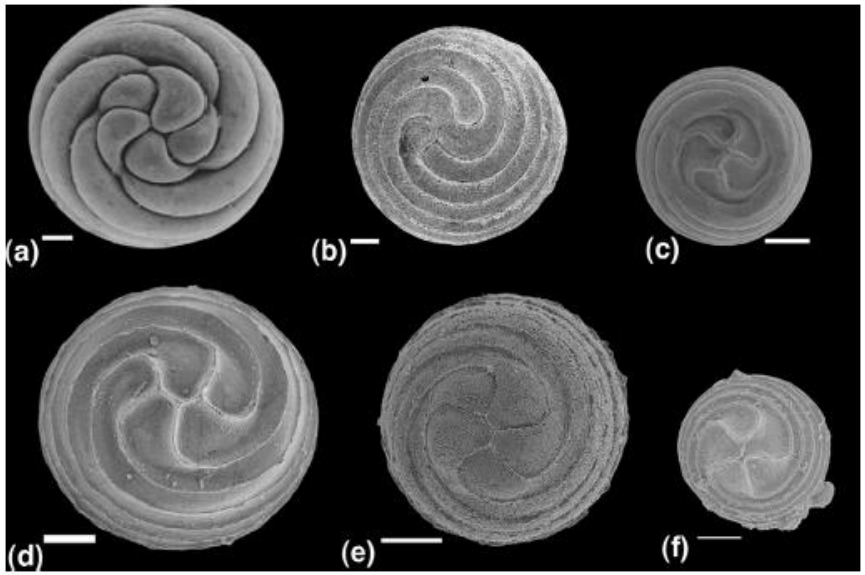
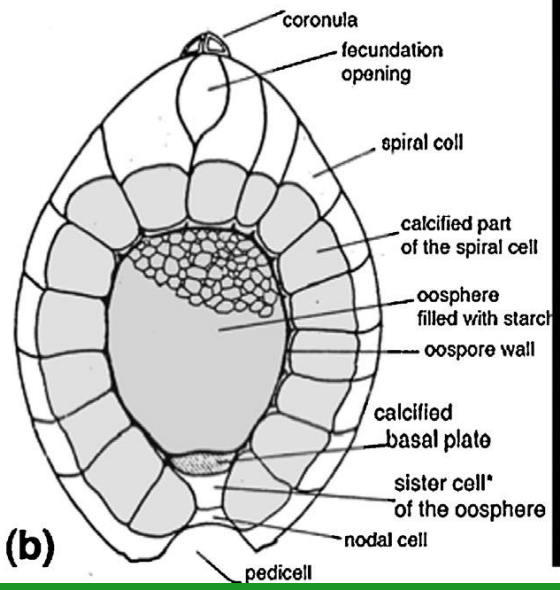
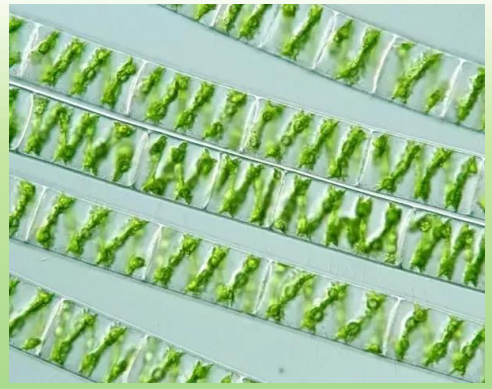


Figure 3. Lateral view of t
(Michaelsdorf, 0–5 cm sec
5–10 cm sediment depth
(Orth, 0–5 cm sediment
group with a apical roset
(h) *T. nidifica* (Breitling/St

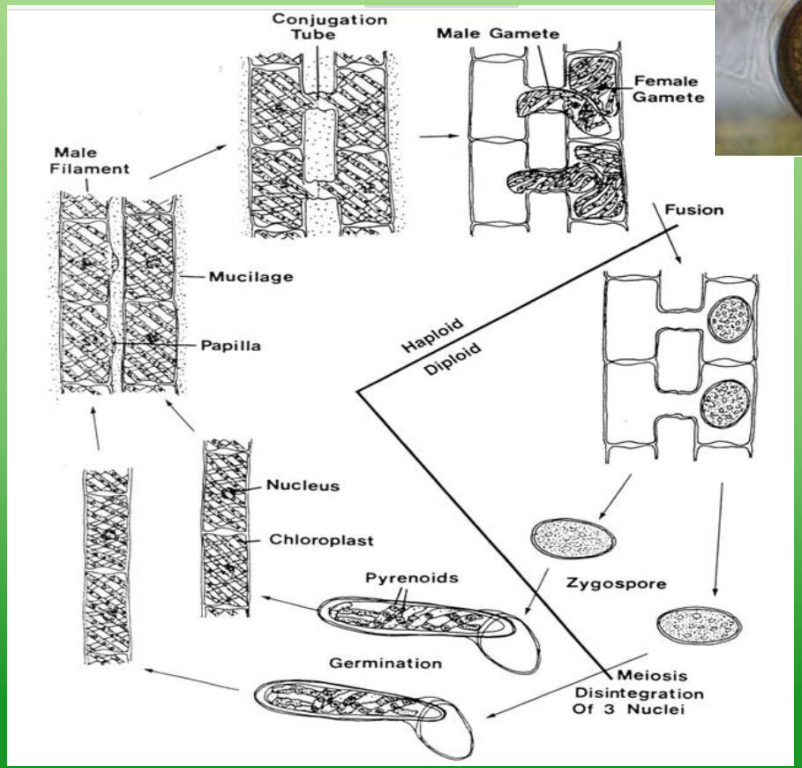


gyrogonites

Zygnematophyceae

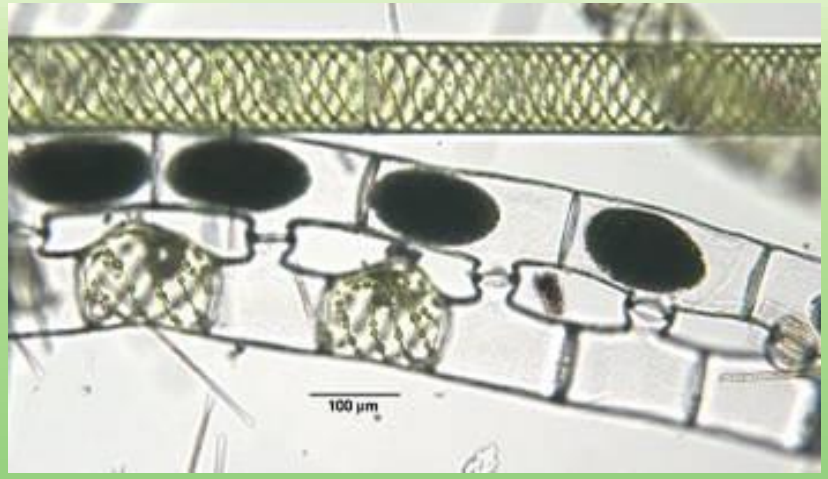


conjugation
zygospore

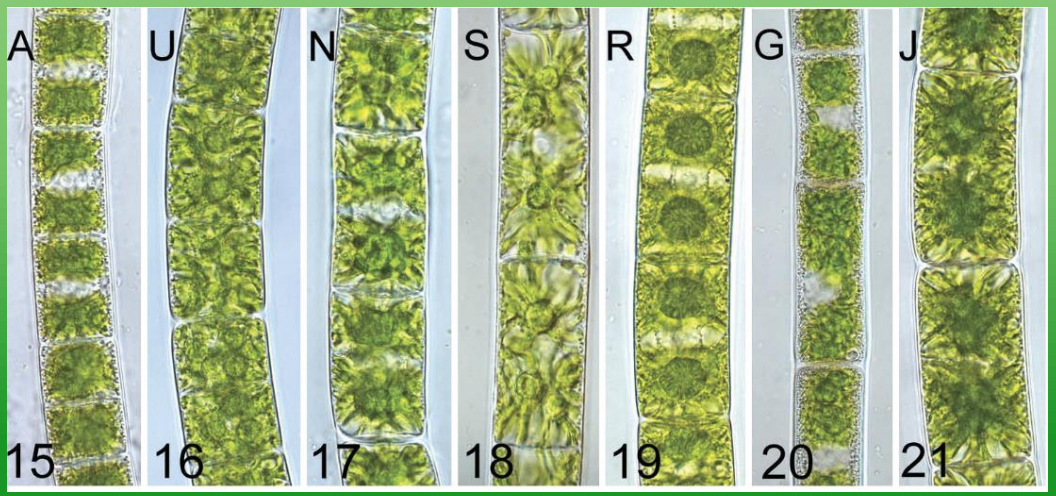


Zygnematophyceae

Spirogyra

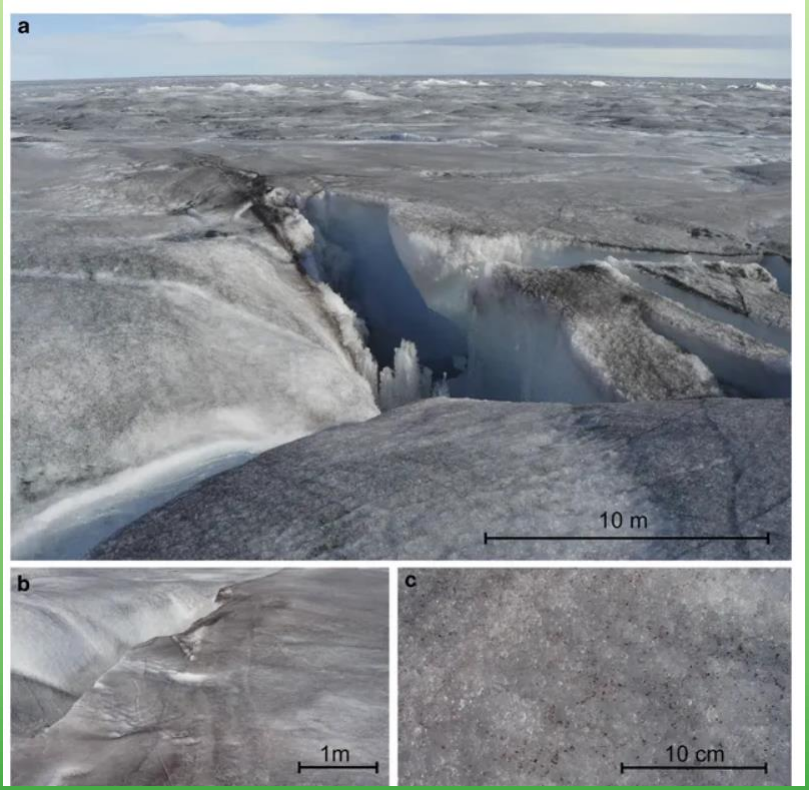


Zygnema

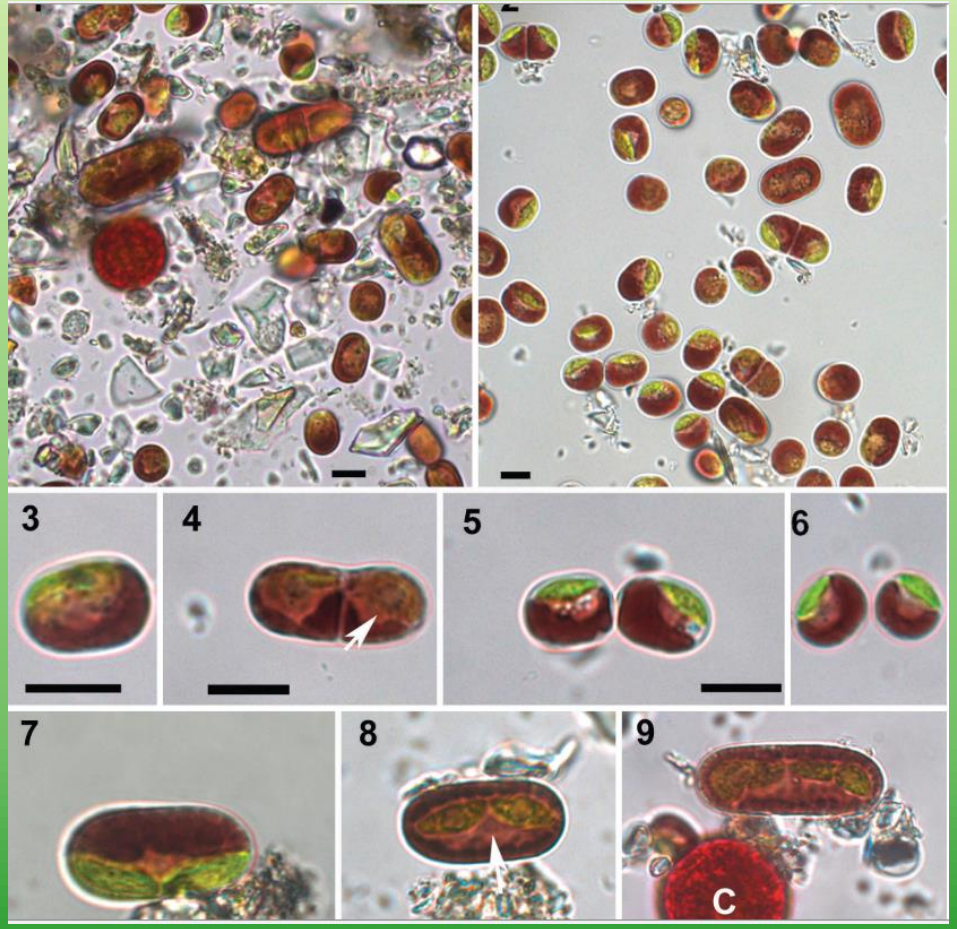


Zygnematophyceae

Mesotaenium berggrenii



Yallop et al. (2012)



Zygnematophyceae

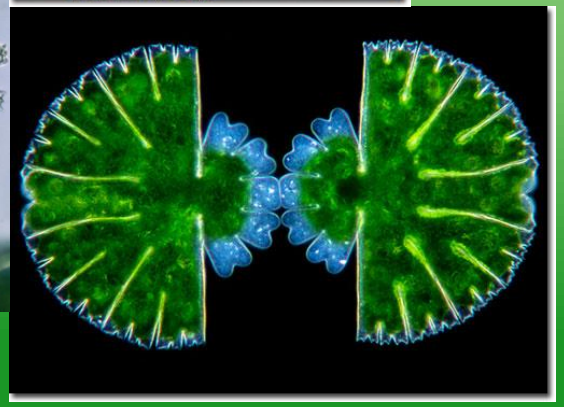
desmids

Zygnematophyceae

Cosmarium

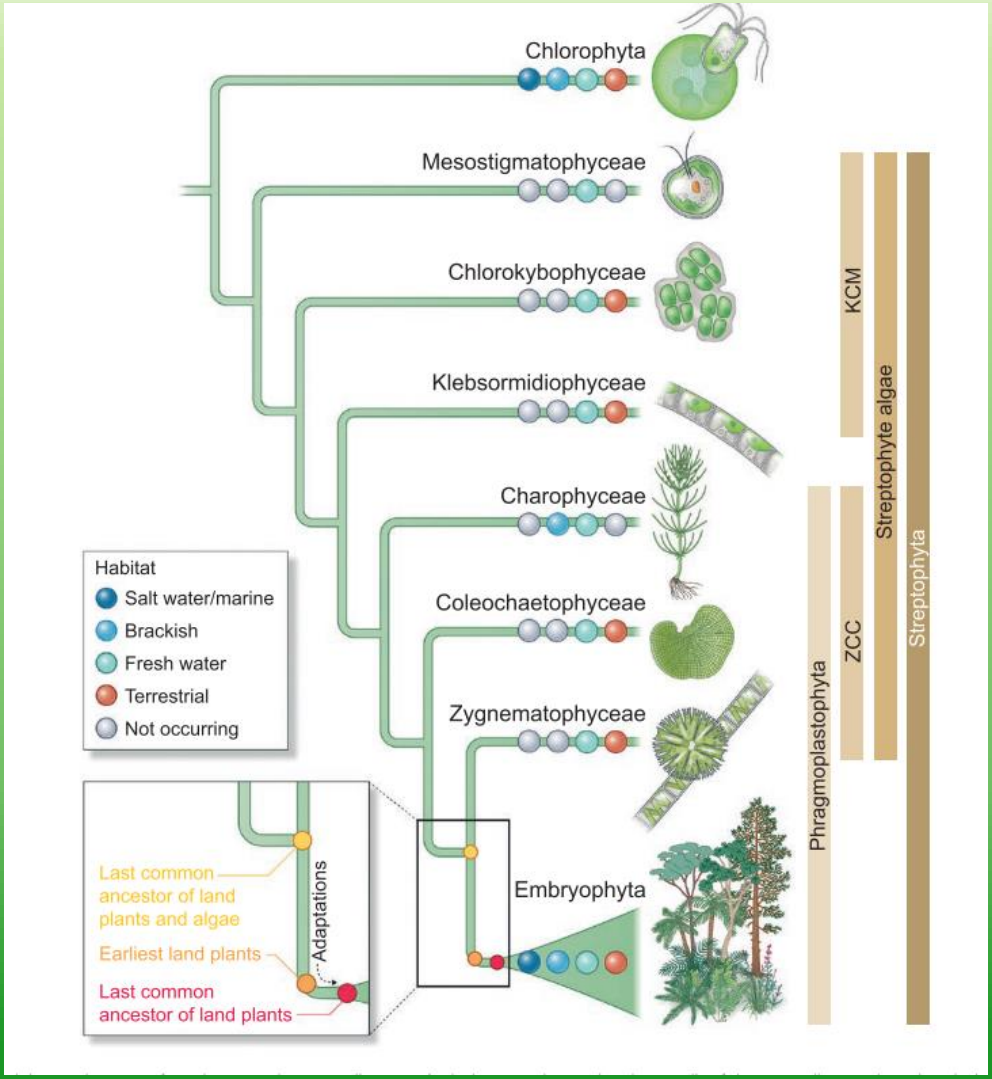
Closterium

Micrasterias



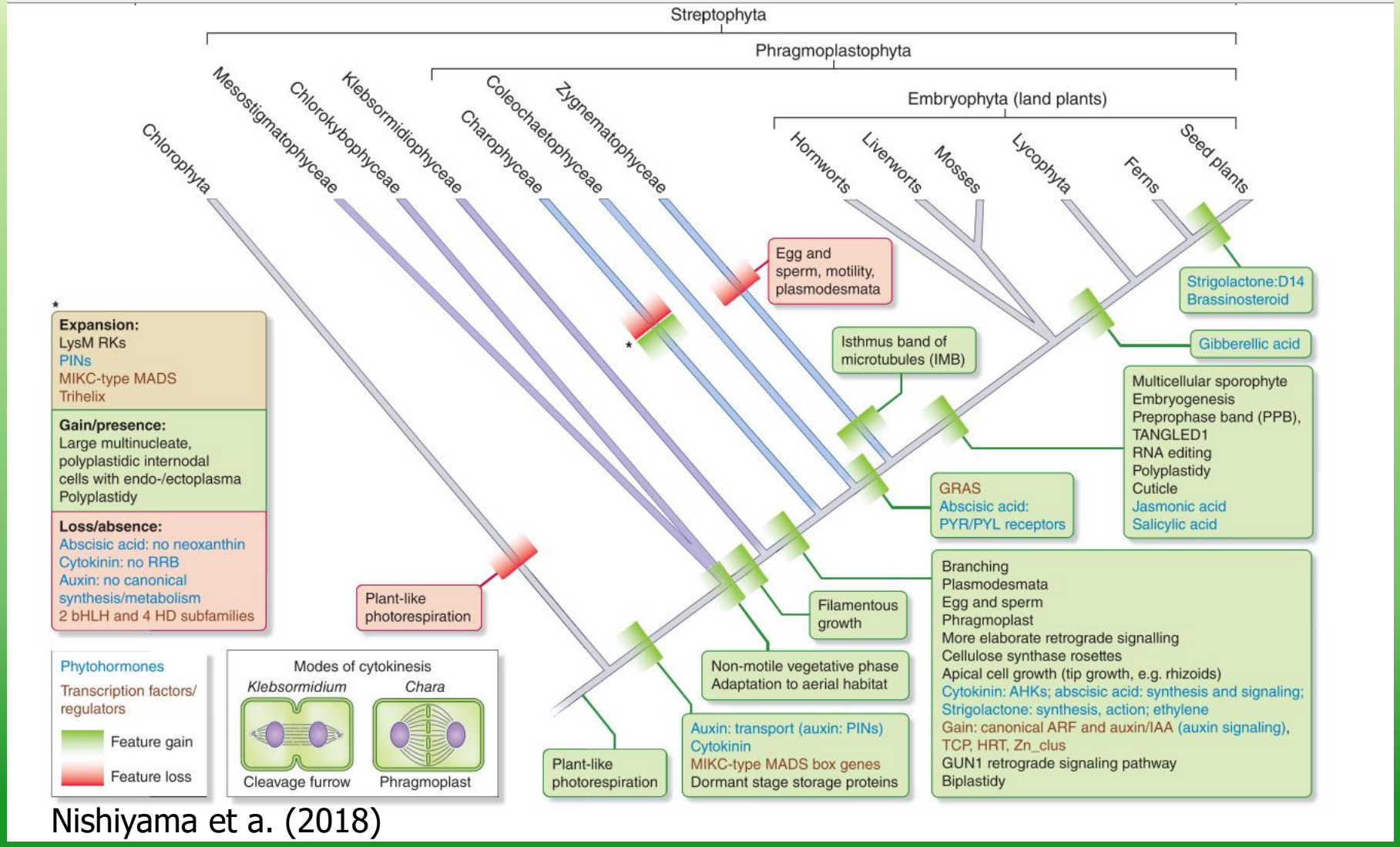
Xanthidium

Terrestrialization and origin of land plants



Fürst-Jansen et al. 2020

Terrestrialization and origin of land plants



Nishiyama et a. (2018)

Terrestrialization and origin of land plants

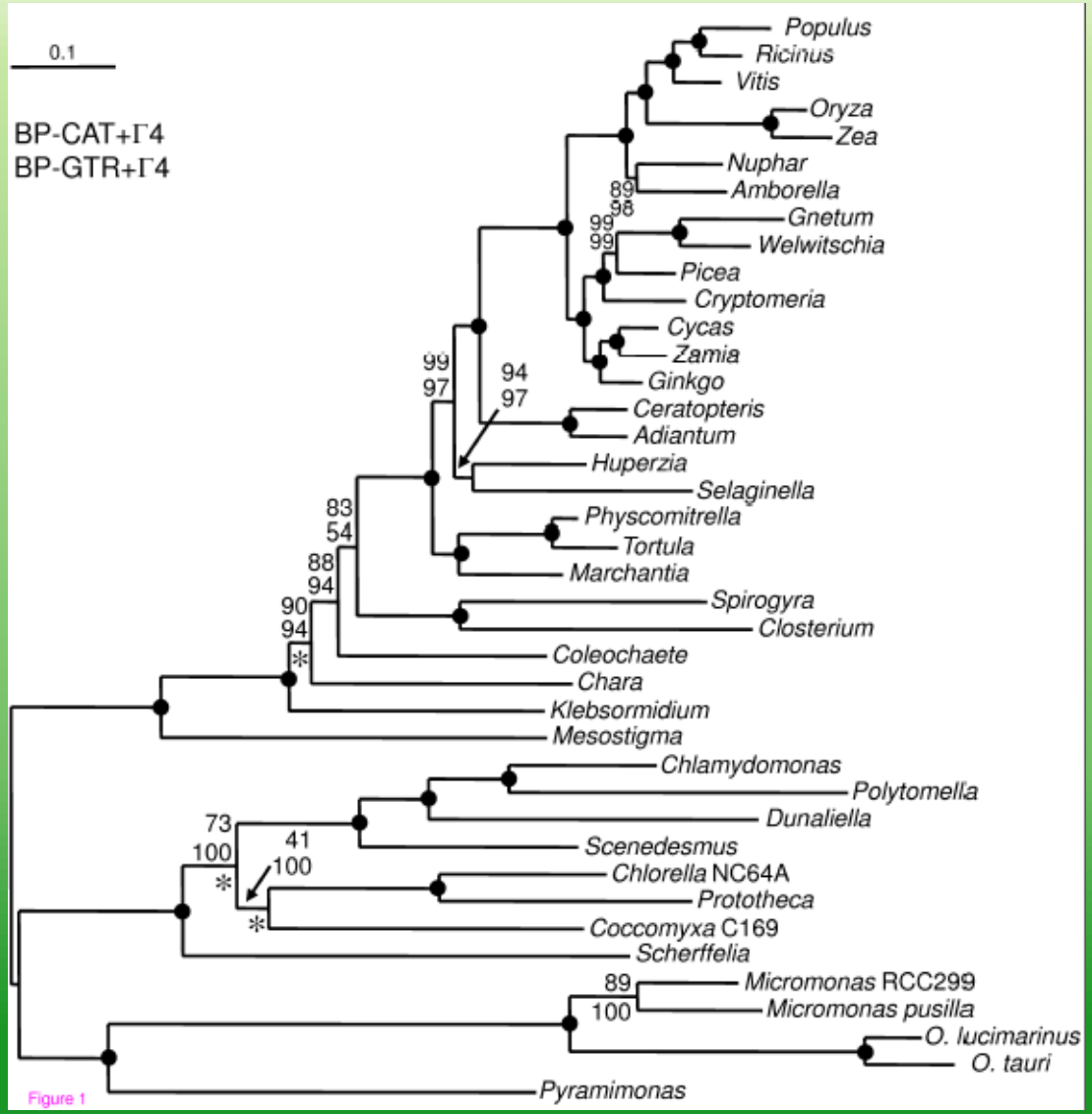
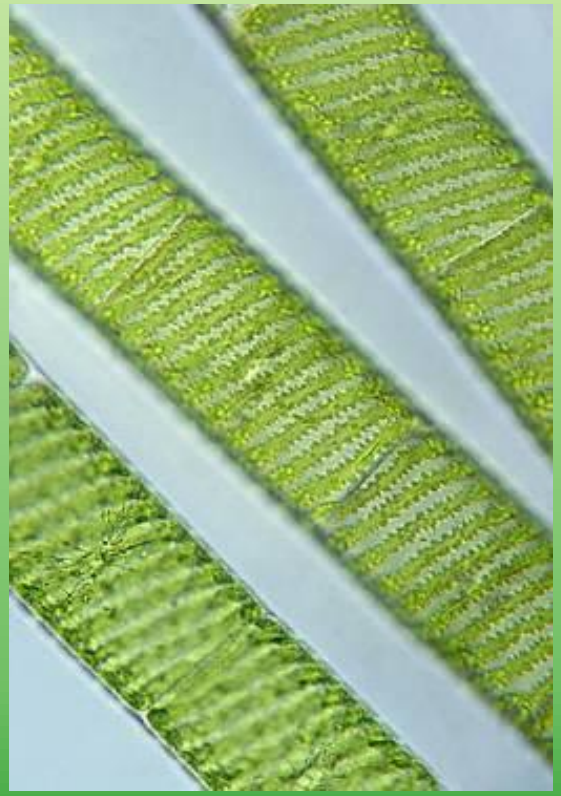
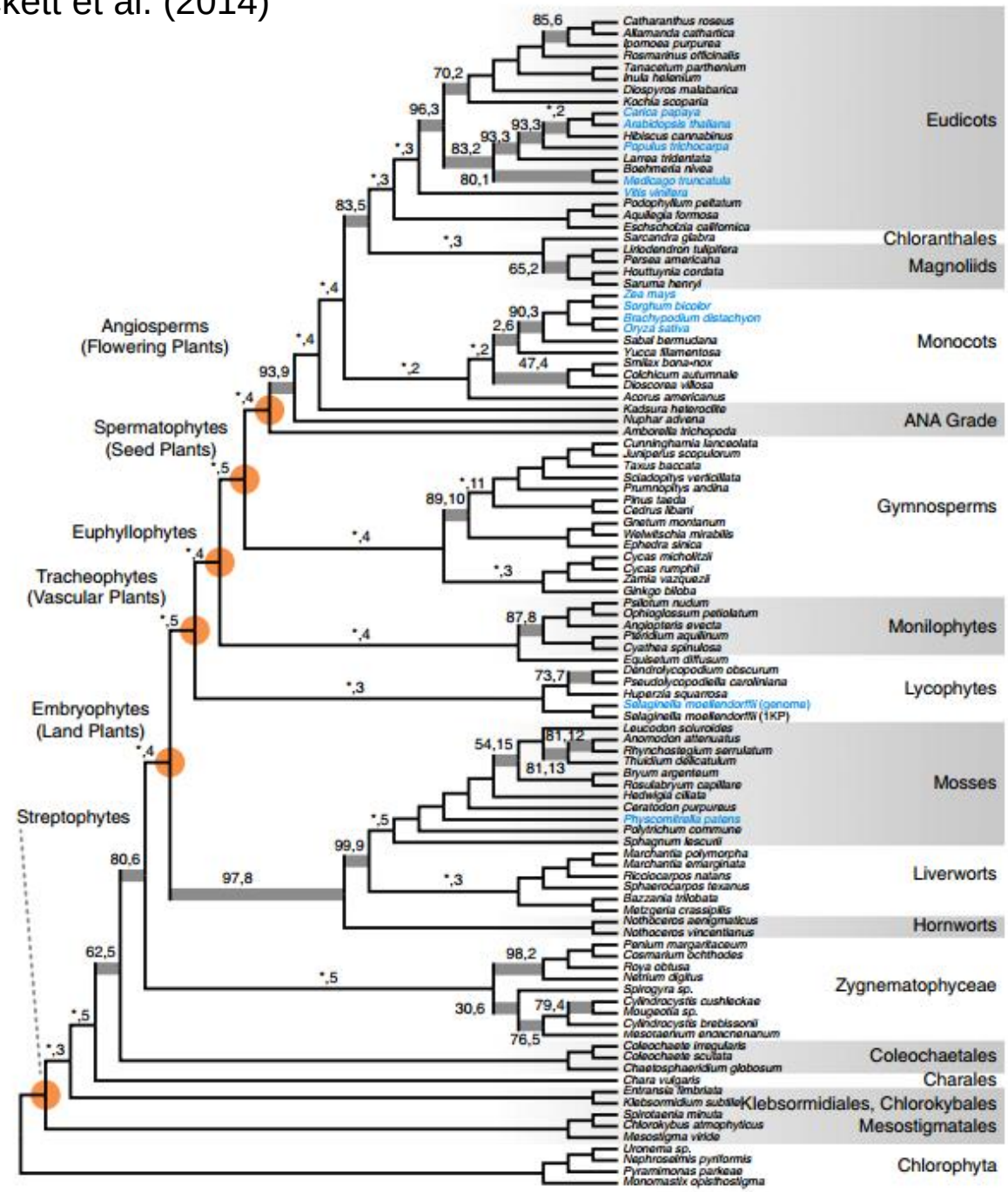


Figure 1



Wodniok et al. (2011)

Wickett et al. (2014)



Zygnematophyceae confirmed as sister to land plants

Terrestrialization and origin of land plants

Becker & Marin (2009)

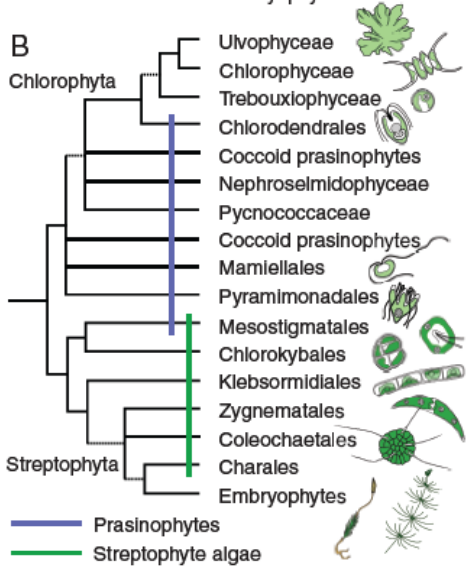
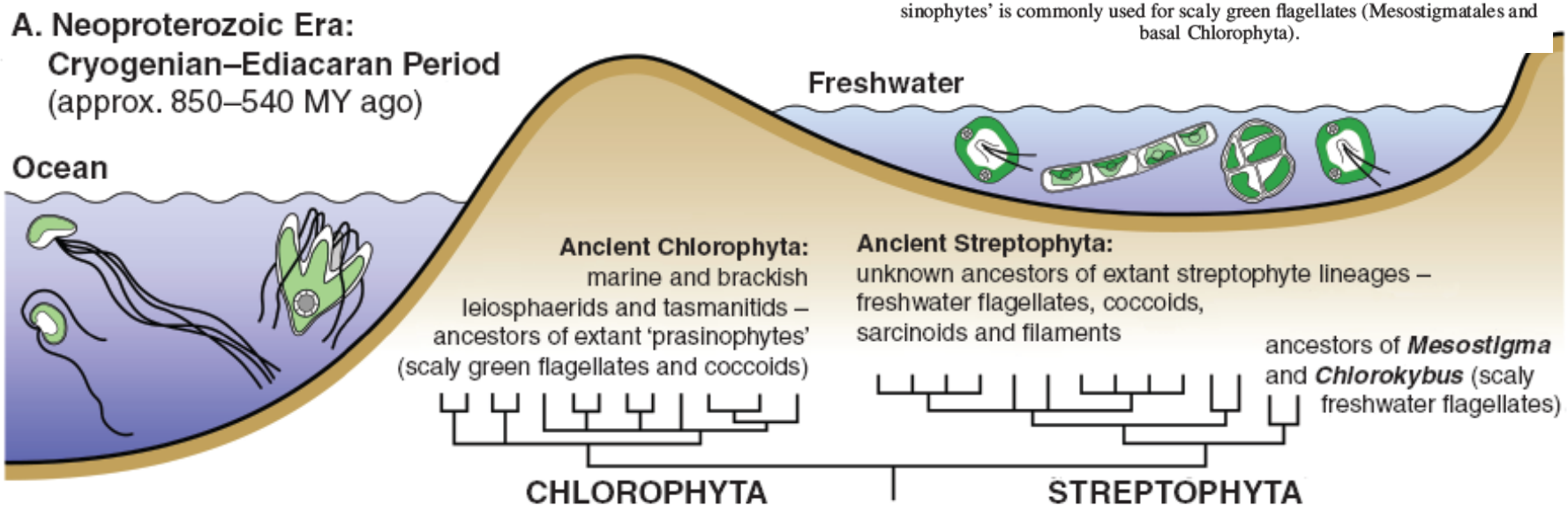
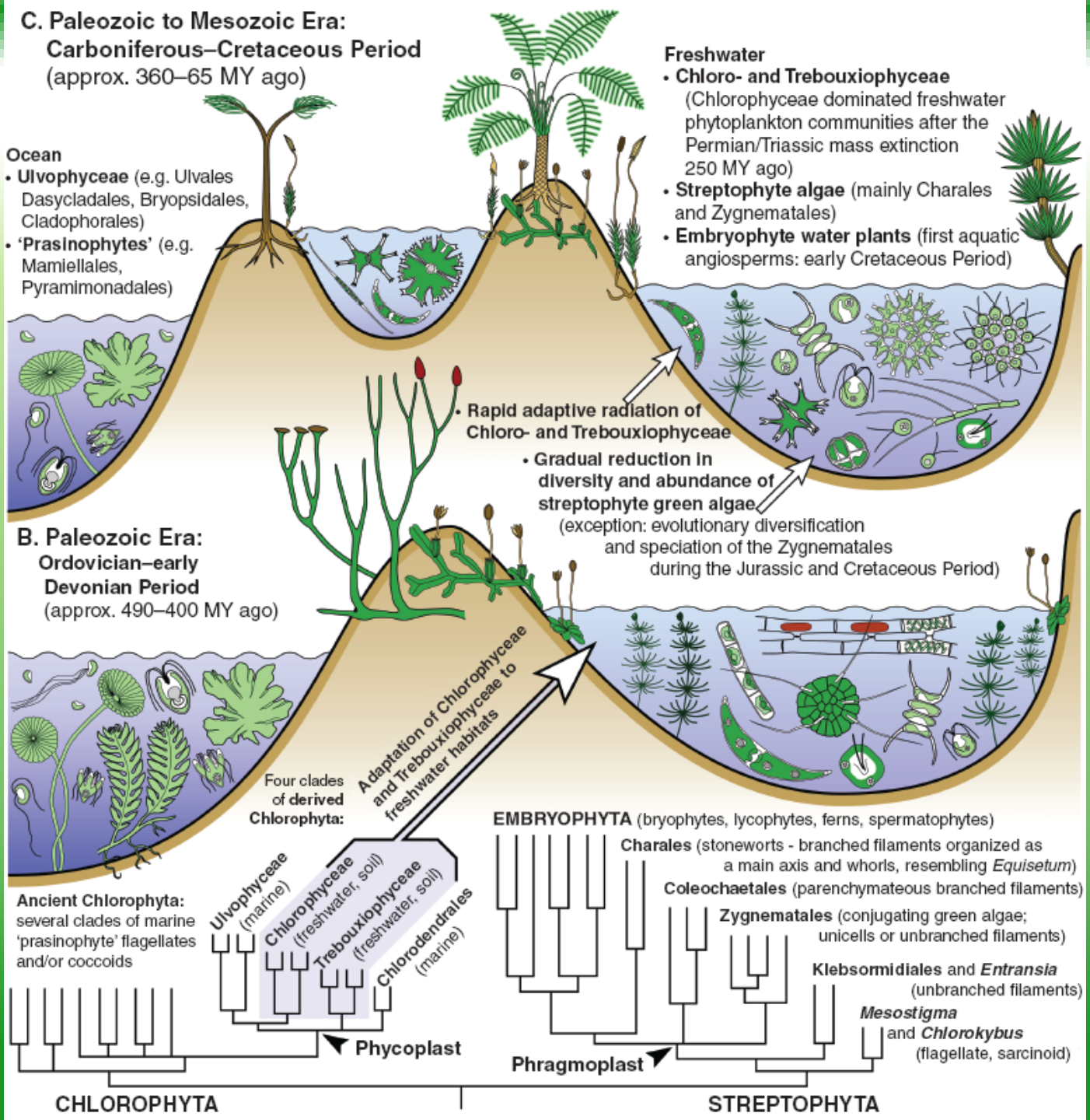
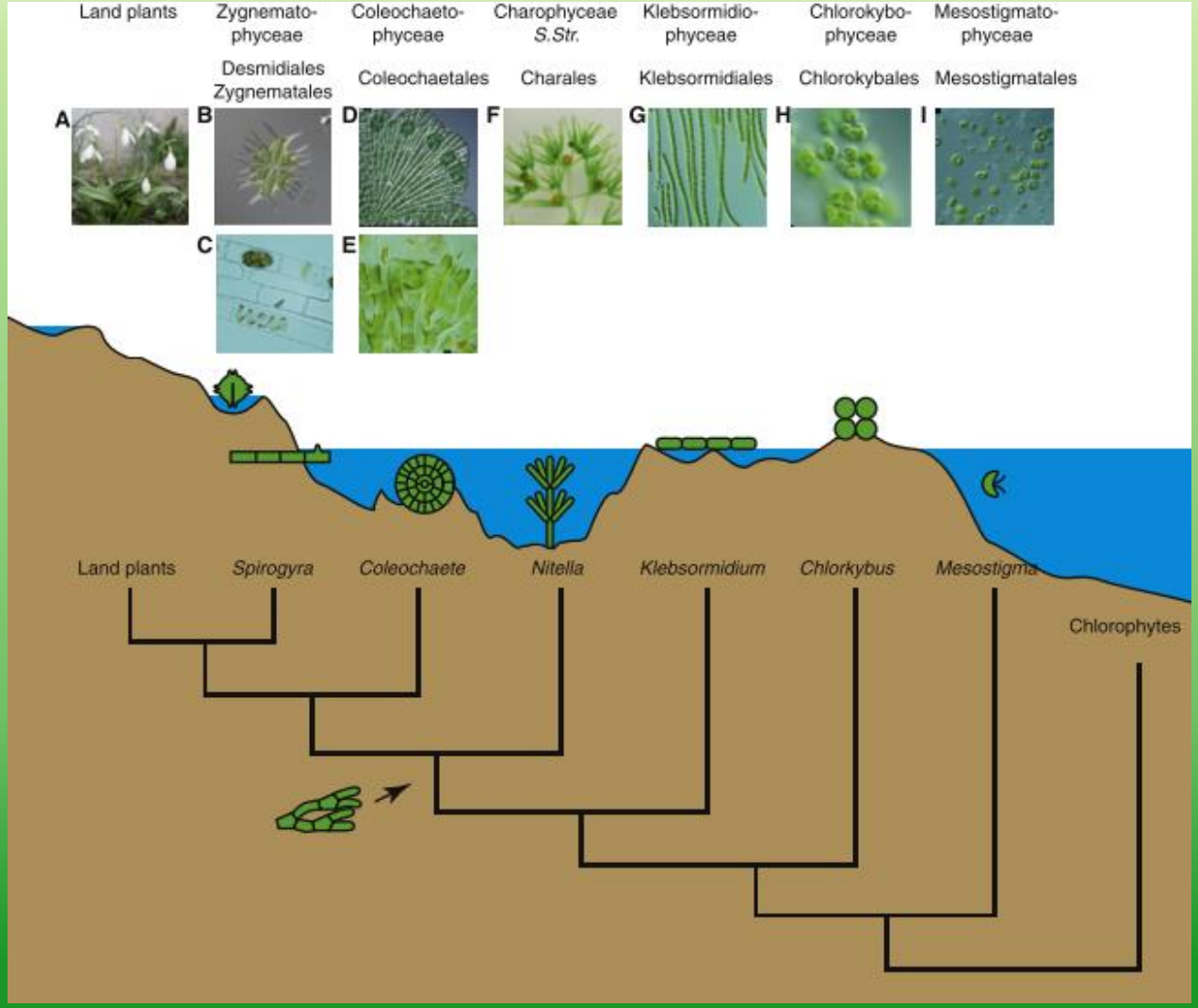


FIG. 1. Phylogenetic relationships among the major lineages of the Viridiplantae. Branches indicated by dotted lines are not well supported. (A) According to Lewis and McCourt (2004), and (B) based on unpublished, ongoing work by the authors. Some of the class names used by Lewis and McCourt (2004) have never been validly described, and for this reason we use order designations in (B) and throughout the text. The informal term 'prasinophytes' is commonly used for scaly green flagellates (Mesostigmatales and basal Chlorophyta).

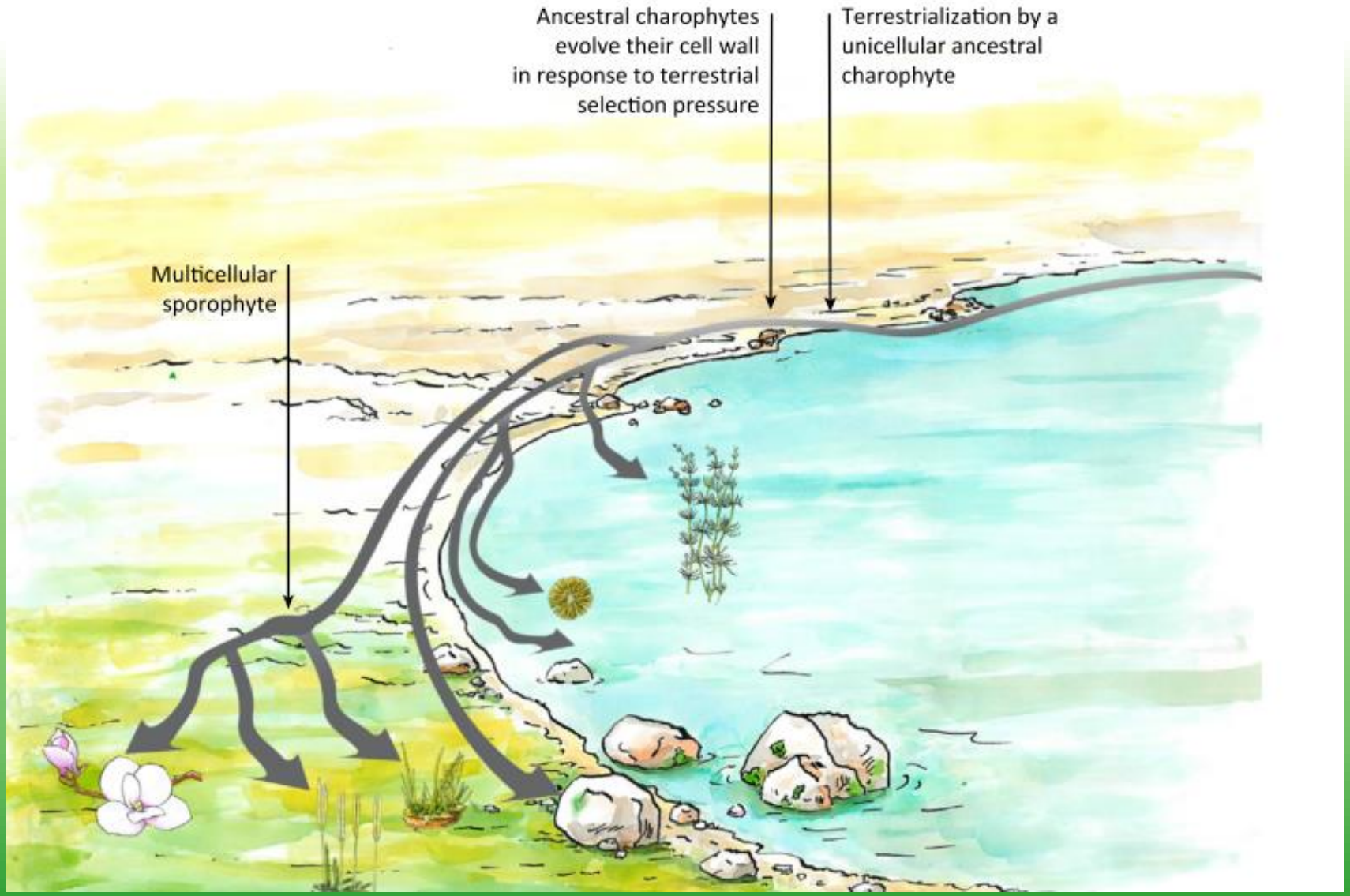



C. Paleozoic to Mesozoic Era:
Carboniferous–Cretaceous Period
(approx. 360–65 MY ago)
Ocean
• Ulvophyceae (e.g. Ulvales Dasycladales, Bryopsidales, Cladophorales)
• 'Prasinophytes' (e.g. Mamiellales, Pyramimonadales)
Freshwater
• Chloro- and Trebouxiophyceae (Chlorophyceae dominated freshwater phytoplankton communities after the Permian/Triassic mass extinction 250 MY ago)
• Streptophyte algae (mainly Charales and Zygnematales)
• Embryophyte water plants (first aquatic angiosperms: early Cretaceous Period)
• Rapid adaptive radiation of Chloro- and Trebouxiophyceae
• Gradual reduction in diversity and abundance of streptophyte green algae (exception: evolutionary diversification and speciation of the Zygnematales during the Jurassic and Cretaceous Period)
B. Paleozoic Era:
Ordovician–early Devonian Period
(approx. 490–400 MY ago)
Adaptation of Chlorophyceae and Trebouxiophyceae to freshwater habitats
Four clades of derived Chlorophyta:
Ulvophyceae (marine)
Chlorophyceae (freshwater, soil)
Trebouxiophyceae (freshwater, soil)
Chlorodendrales (marine)
Ancient Chlorophyta: several clades of marine 'prasinophyte' flagellates and/or coccoids
Phycoplast
EMBRYOPHYTA (bryophytes, lycophytes, ferns, spermatophytes)
Charales (stoneworts - branched filaments organized as a main axis and whorls, resembling Equisetum)
Coleochaetales (parenchymateous branched filaments)
Zygnematales (conjugating green algae; unicells or unbranched filaments)
Klebsormidiales and Entransia (unbranched filaments)
Mesostigma and Chlorokybus (flagellate, sarcinoid)
Phragmoplast
CHLOROPHYTA
STREPTOPHYTA

Terrestrialization and origin of land plants

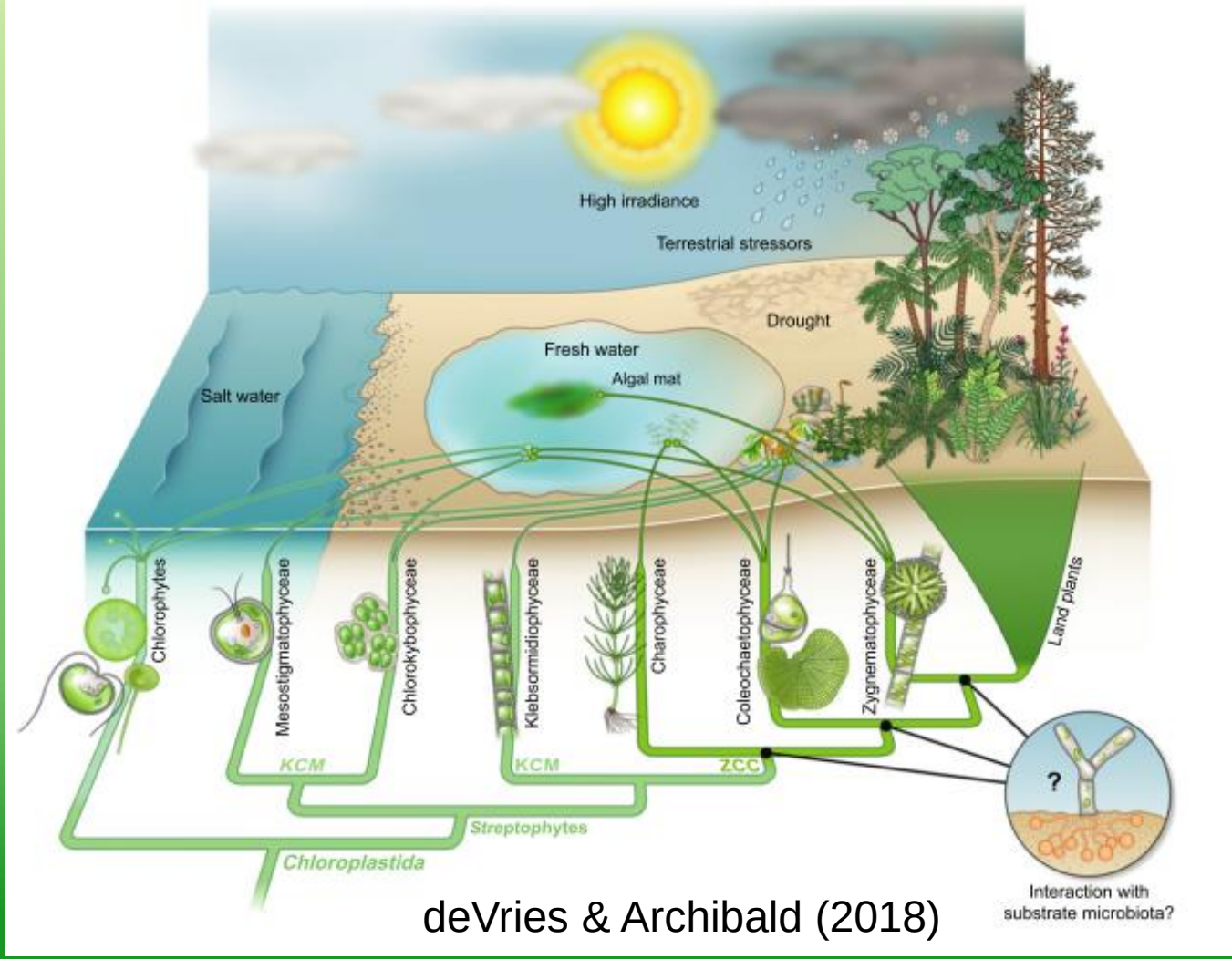


Delwiche & Cooper (2015)



Harholt et al. (2015)

Terrestrialization and origin of land plants



deVries & Archibald (2018)

Embryophyta - Bryophyta

Bryophyta

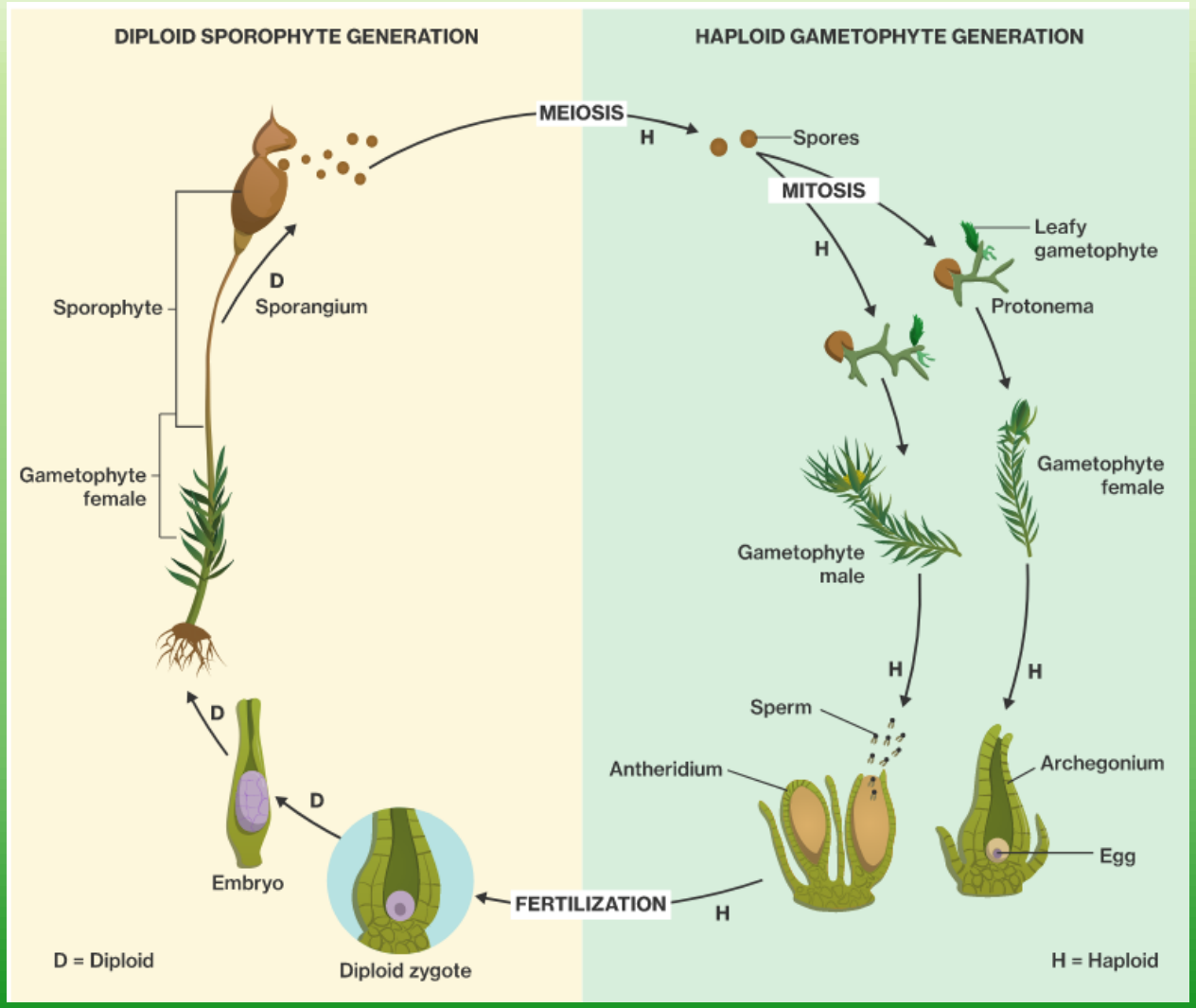
Embryophyta = Bryophyta + higher plants:

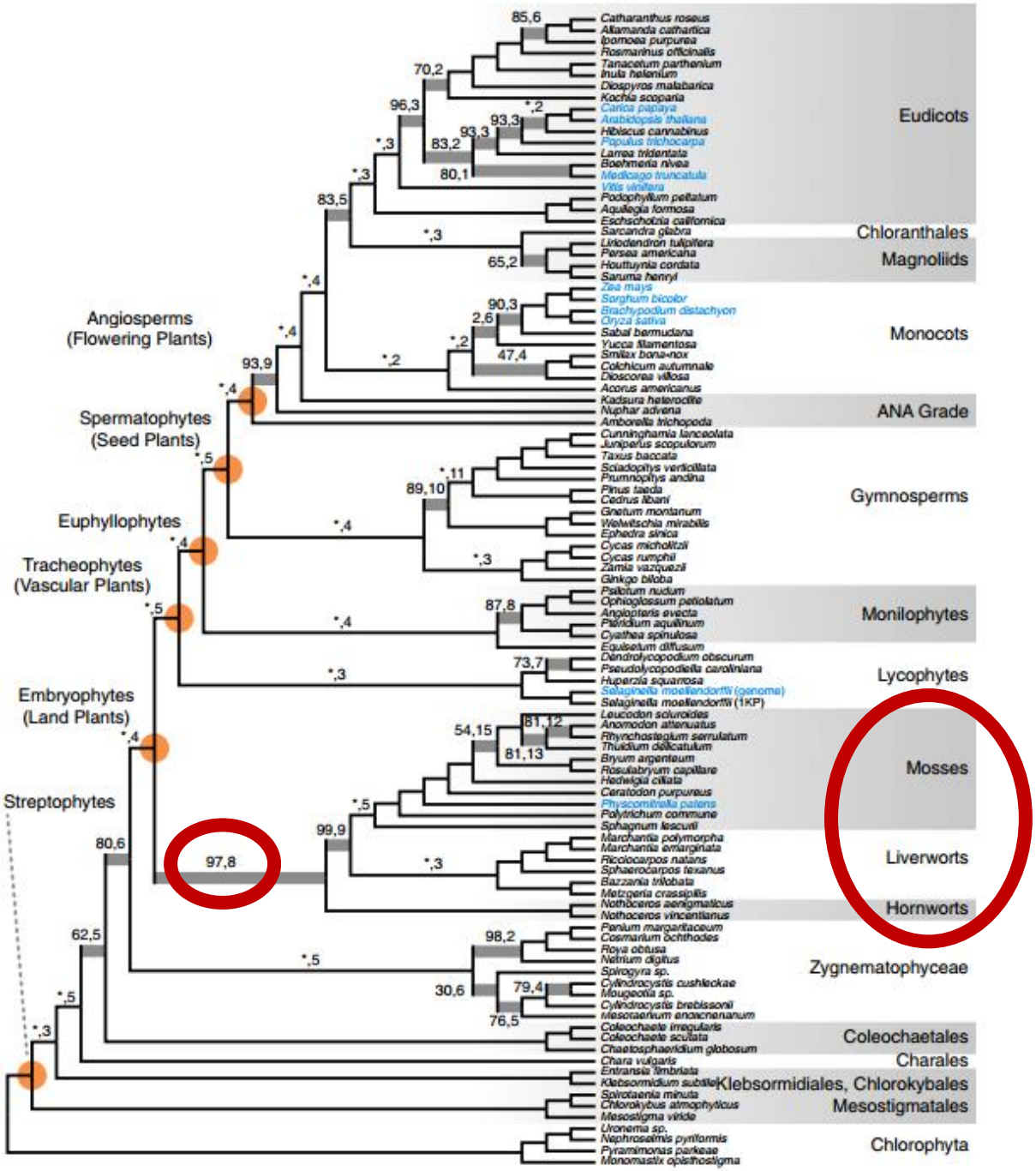
- Formation of embryo
- Multicellular gametangia with sterile outer layers
- Cuticle
- Sporopollenin in spore walls
- Two distinct multicellular generations
- Symbiosis with fungi

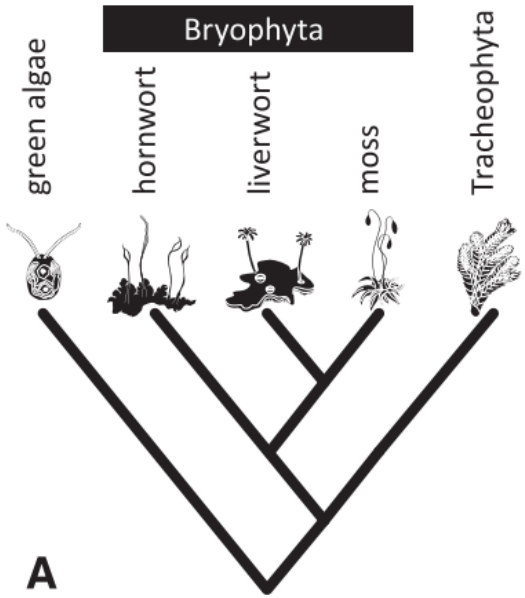
Only Bryophyta:

- Dominance of gametophyte
- No lignin
- Sporophyte dependent on gametophyte
- Poikilohydric

Bryophyta


DIPLOID SPOROPHYTE GENERATION
HAPLOID GAMETOPHYTE GENERATION
MEIOSIS
H
Spores
MITOSIS
H
Leafy gametophyte
Protonema
Sporophyte
D
Sporangium
Gametophyte female
Gametophyte male
Gametophyte female
H
H
Sperm
Antheridium
Archegonium
Egg
FERTILIZATION
H
D
D
D
Embryo
Diploid zygote
D = Diploid
H = Haploid





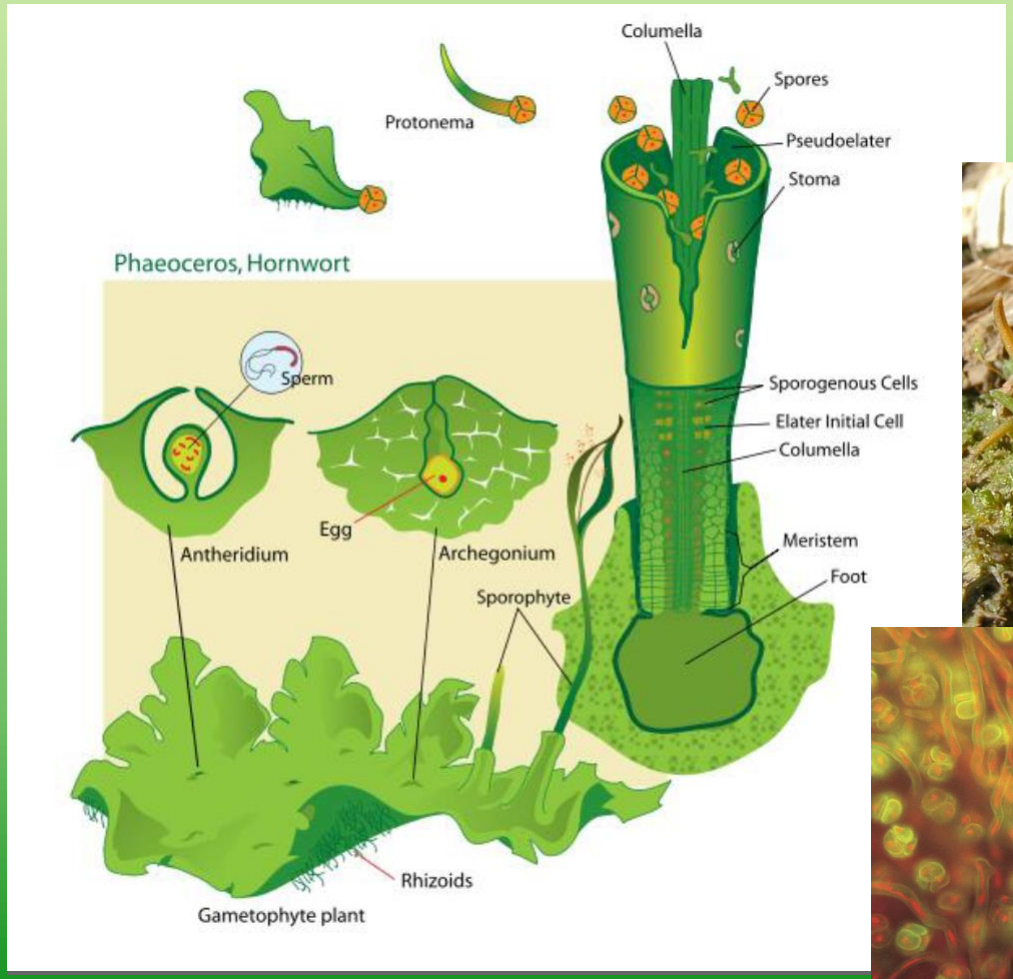
Puttick et al. (2018)

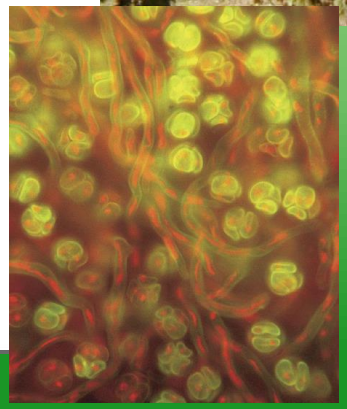
Bryophyta *s. str.*

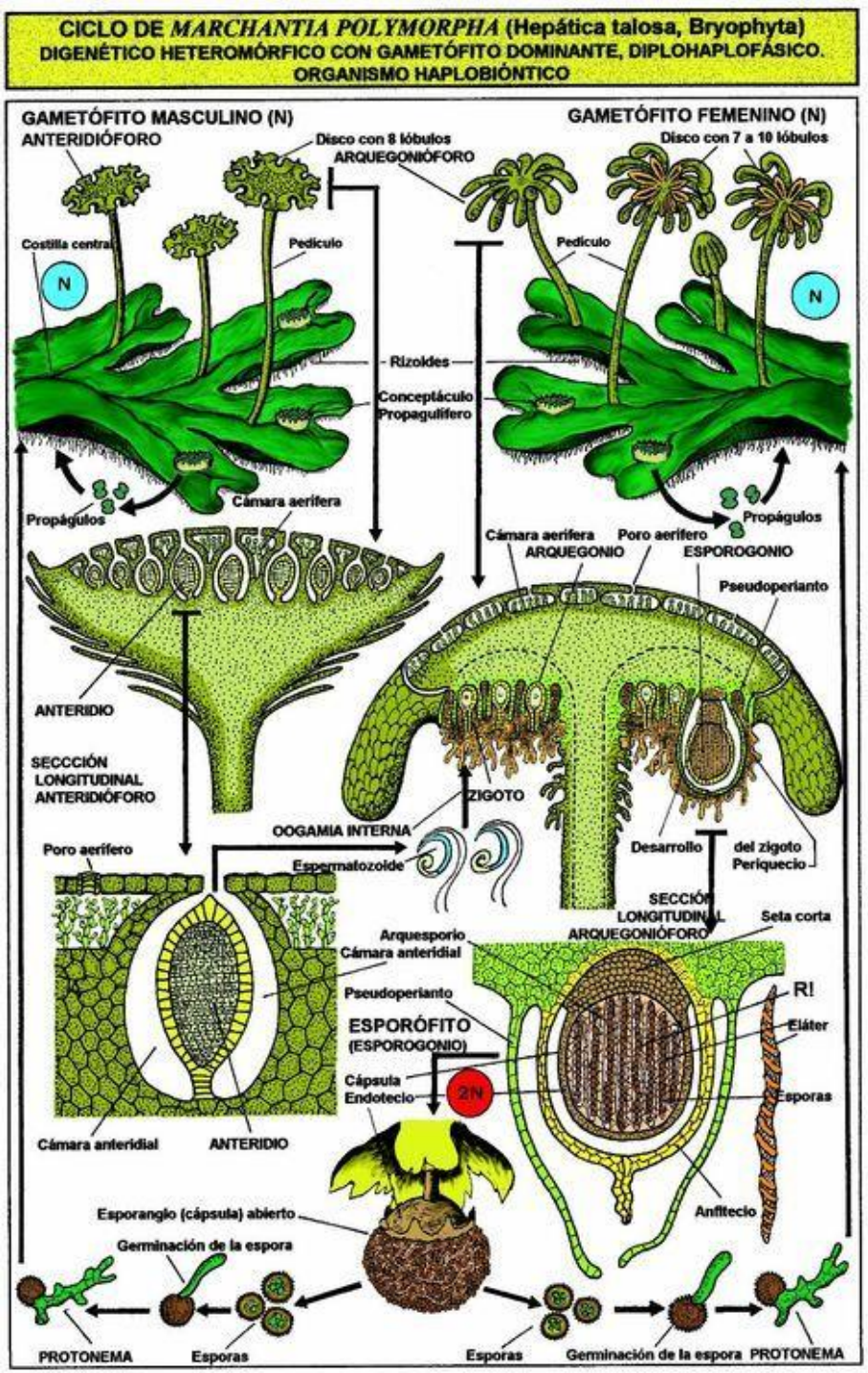
Marchantiophyta
Anthocerotophyta

Wickett et al. (2014)

Anthocerotophyta (hornworts)



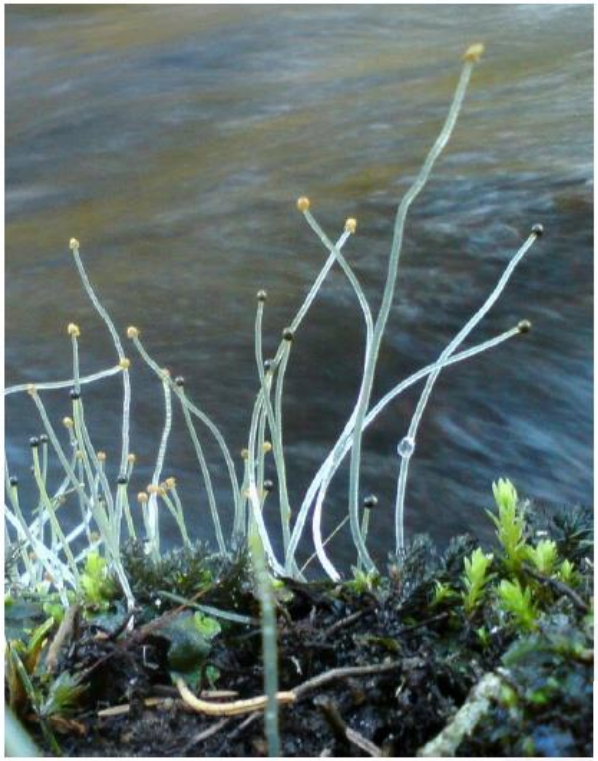




Marchantiophyta (liverworts)

Marchantia polymorpha

Marchantiophyta



- Ephemerous, hyaline sporophyte
- Foot, seta (stalk), capsule

Marchantiophyta

Examples of leafy species

Bazzania stolonifera

Chiloscyphus coadunatus

Plagiochila asplenioides

Trichocolea tomentella

Marchantiophyta

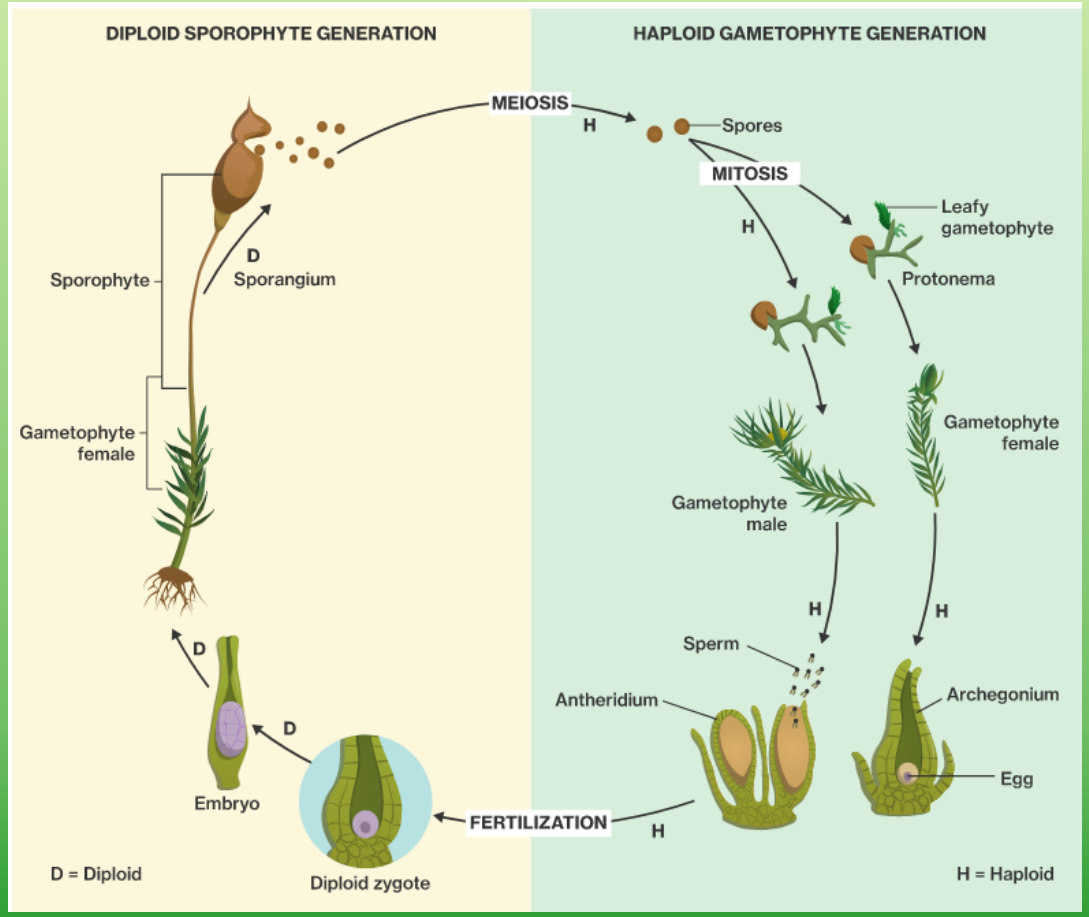
Examples of thallose species

Conocephalum

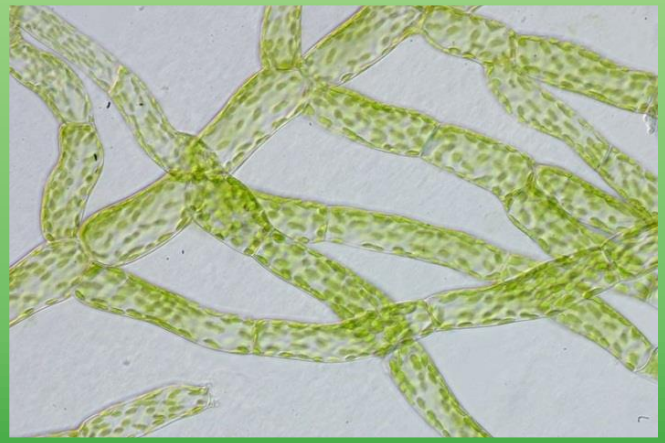
Riccia

Metzgeria

Bryophyta *s. str.* (mosses)



Dioicous and monoicous species

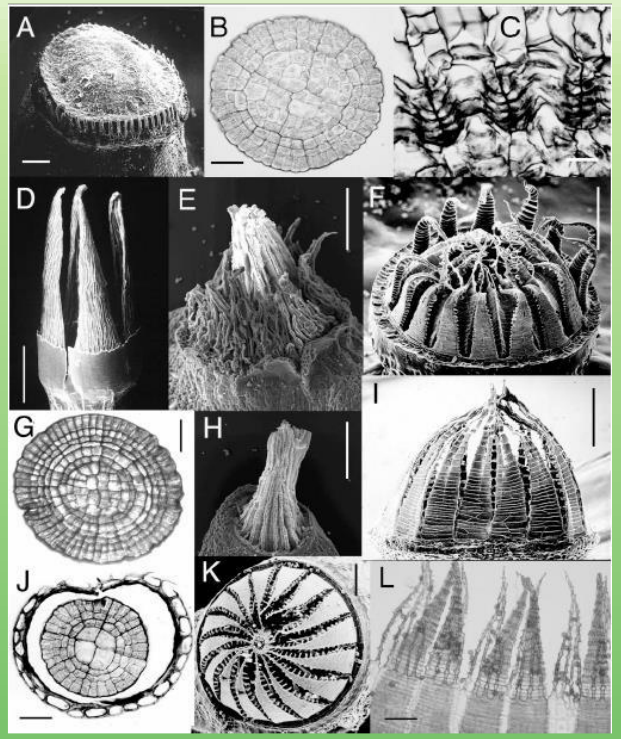


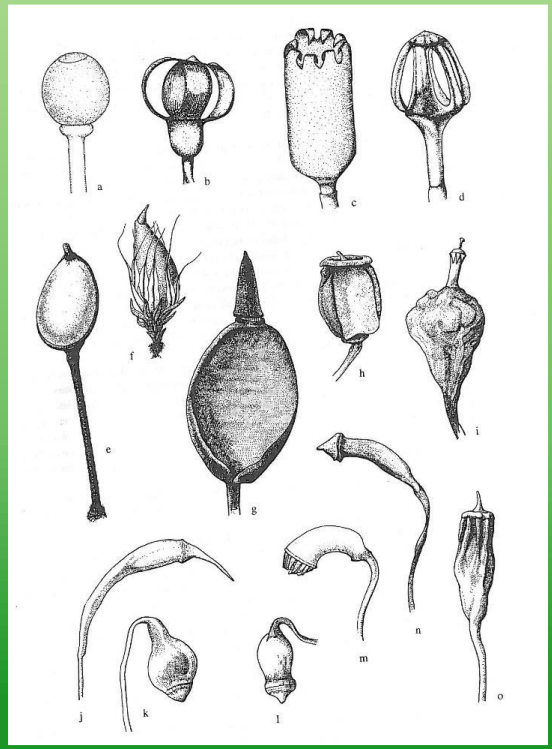
protonema

Bryophyta *s. str.* (mosses)

sporophyte

Foot, stalk, capsule





Bryophyta *s. str.* (mosses)

gemmae

Bryophyta *s. str.* (mosses)

Grimmia

Ulota

Fontinalis

Splachnum

Bryophyta (mosses)

Sphagnum

Peat bog

Bryophytes (utilization, importance)

- Food – insects, reindeer, whisky
- Peat
- Decoration
- Stone age – *Neckera pennata* – ceramics
- India – mats, cigarette filters (*Herbetus*)
- *Dicranum elongatum* – candles
- *Fontinalis antipyretica* – sealing, isolation
- Packaging material, wrapping, food protection
- Mattresses (*Hypnum*)
- toilet „paper“
- Liverworts in medicine – antibiotic, traditional Chinese medicine

Figure 2. *Neckera crispa*, a large, pleurocarpous moss of ree trunks that has been used as a mordant in pottery. Photo by Michael Lüth.

Figure 3. A piece of ancient pottery with the impression of *Neckera crispa* that has been used as a mordant. Photo courtesy of Heinjo During of Universiteit Utrecht and Wim Kuijper from Archeological Centre of Leiden University.