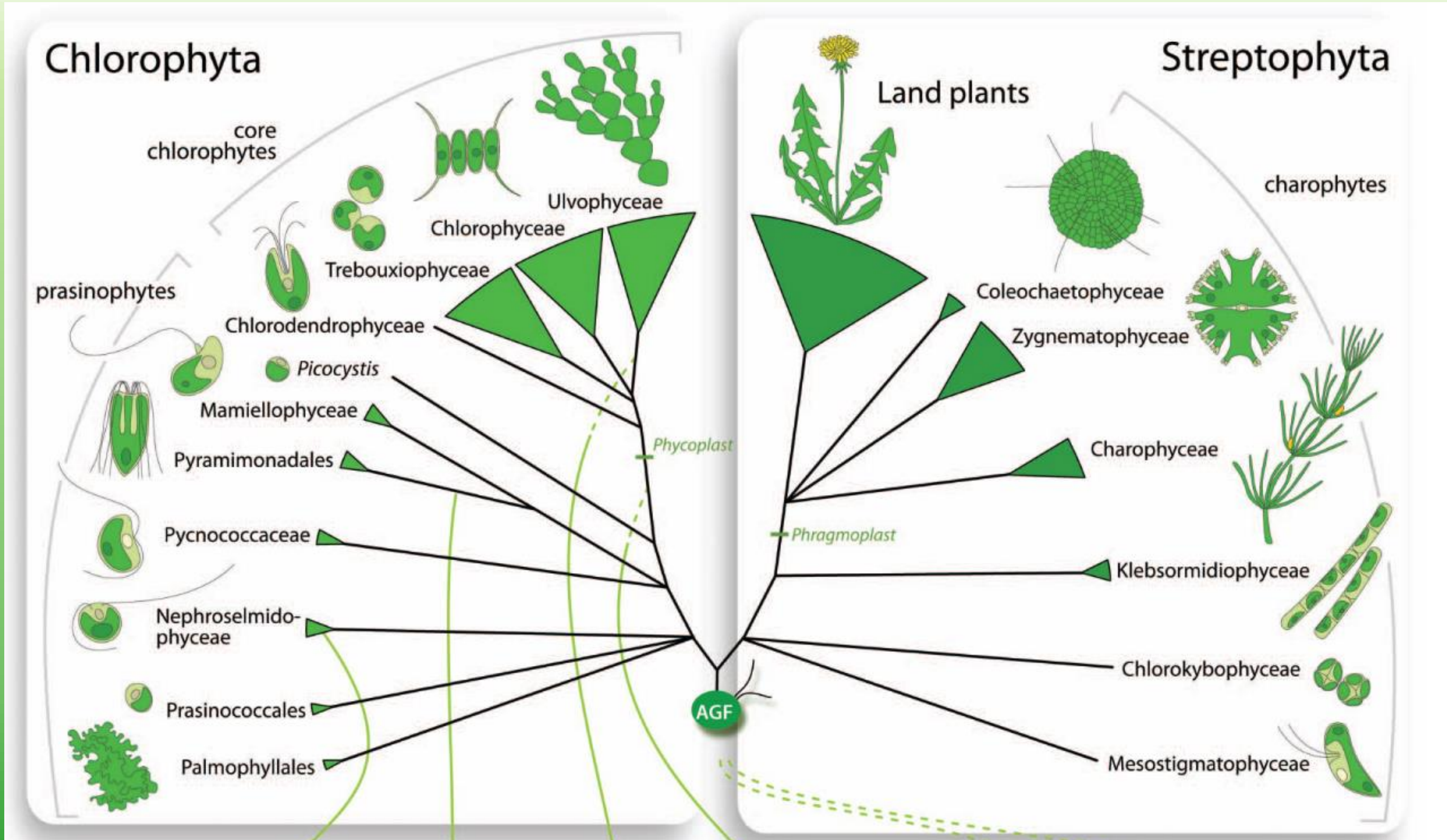
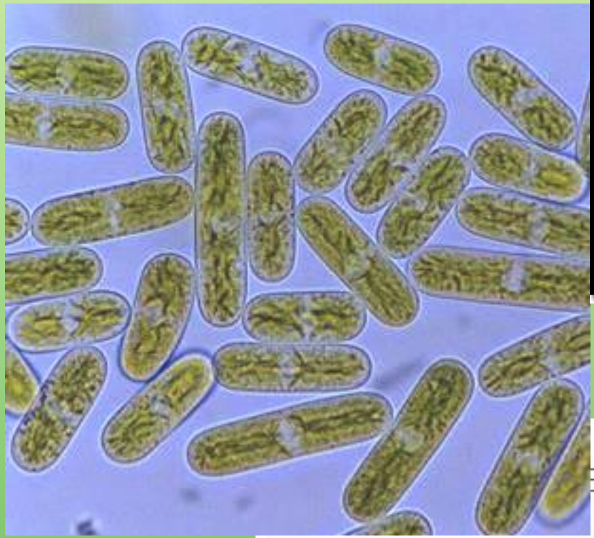
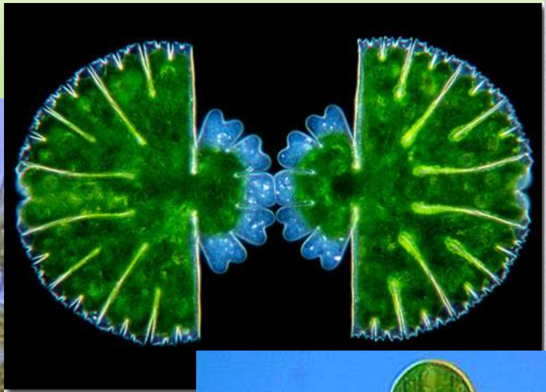
Streptophyta II

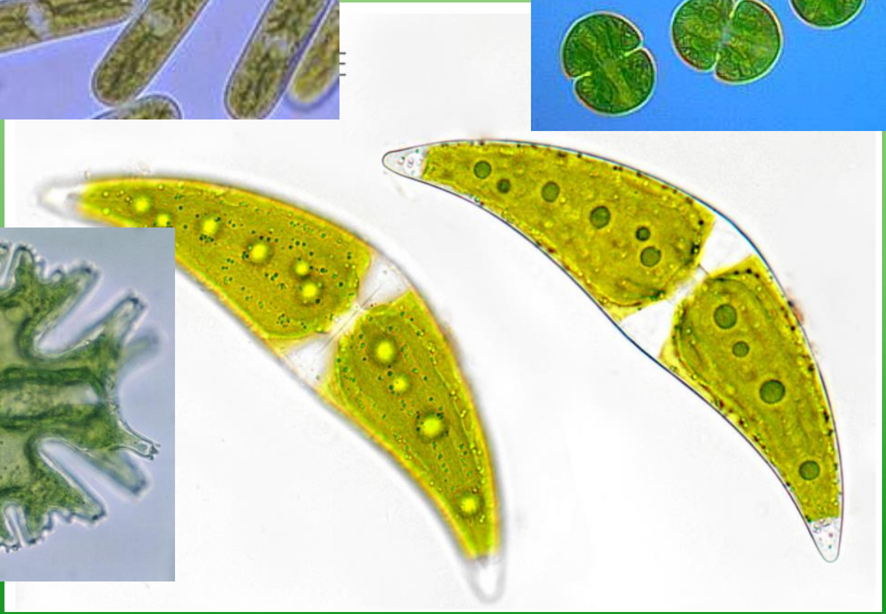
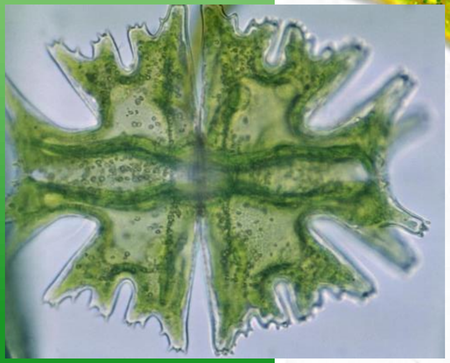


Leliaert et al. (2012)

Zygnematophyceae

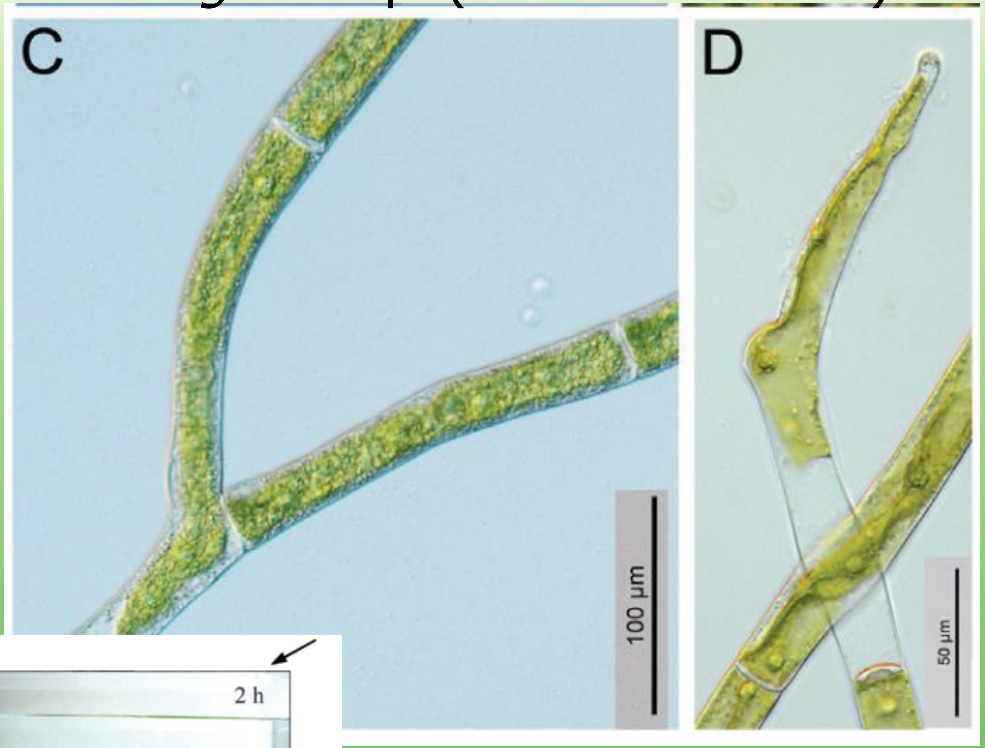





General characteristics

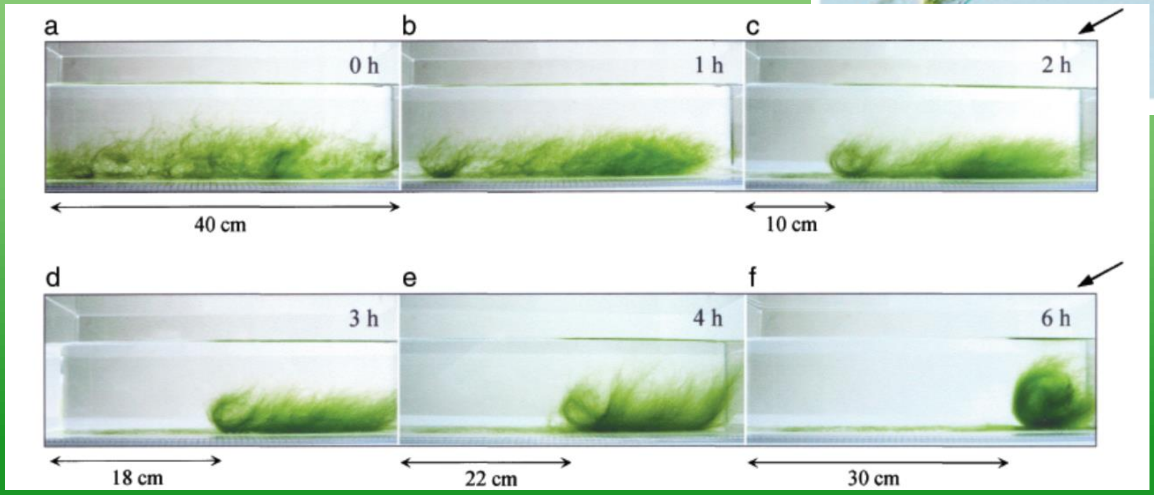
Mougeotia sp. (Buschmann 2020)



Coccoid or filamentous, no flagellate stages

BUT!

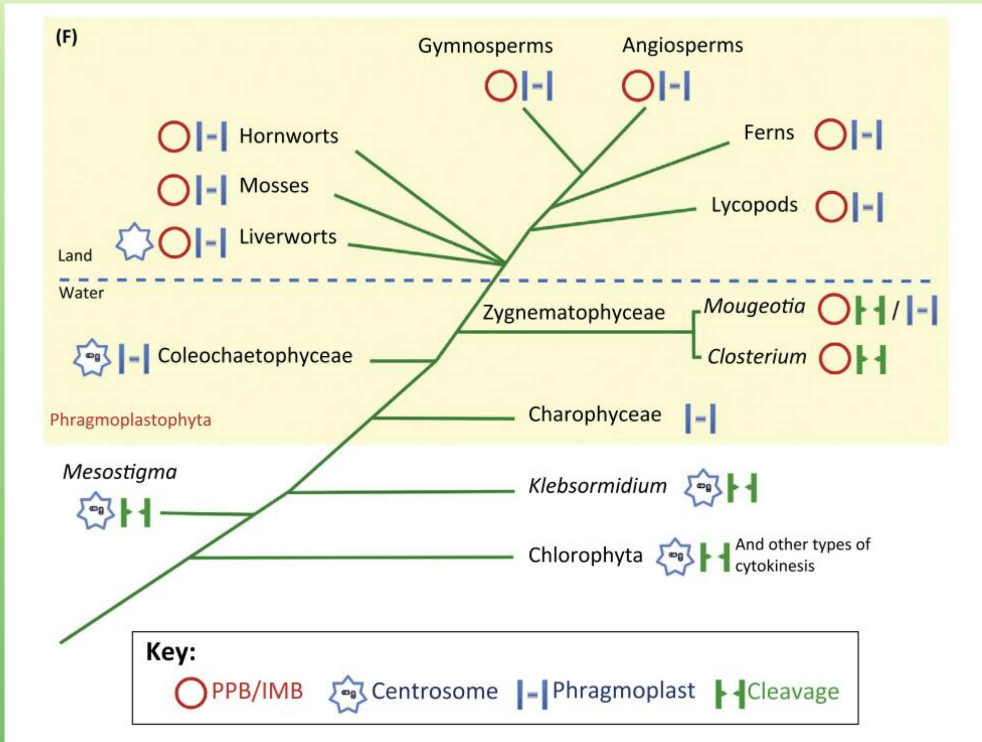
Rhizoids, branching, active movement



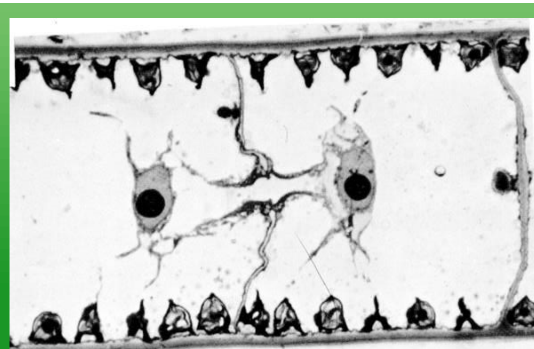
gliding and phototropic curvature Kim et al. (2005)

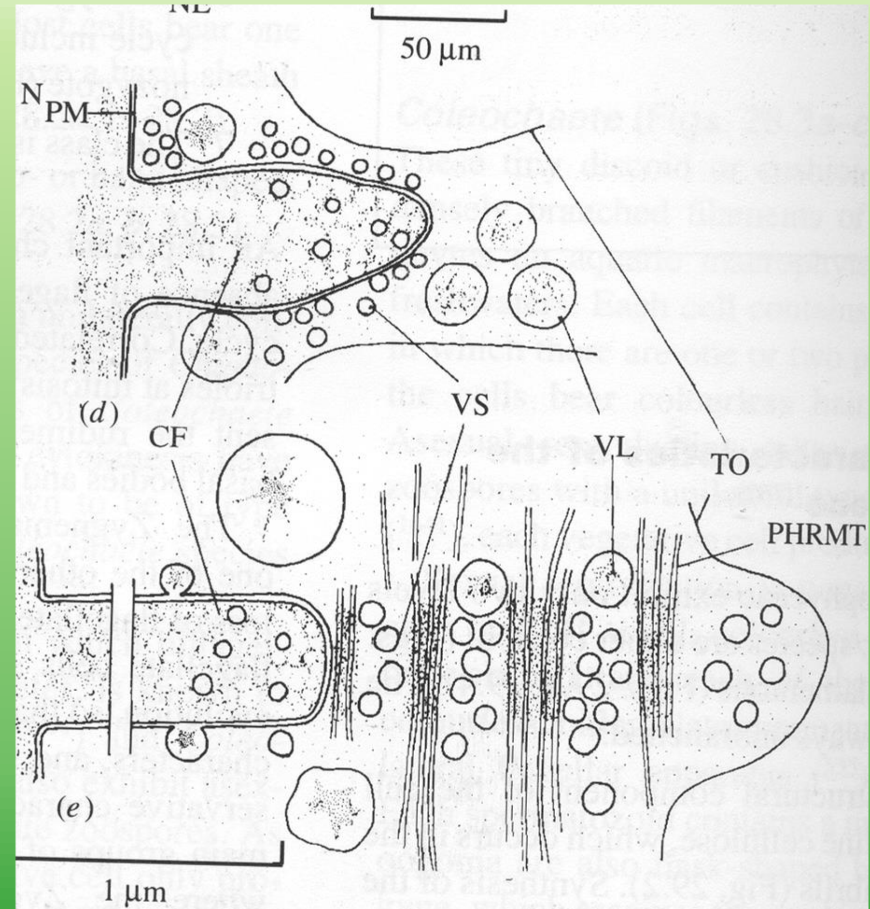
General characteristics

phragmoplast, cleavage furrow



Buschmann & Zachgo (2016)

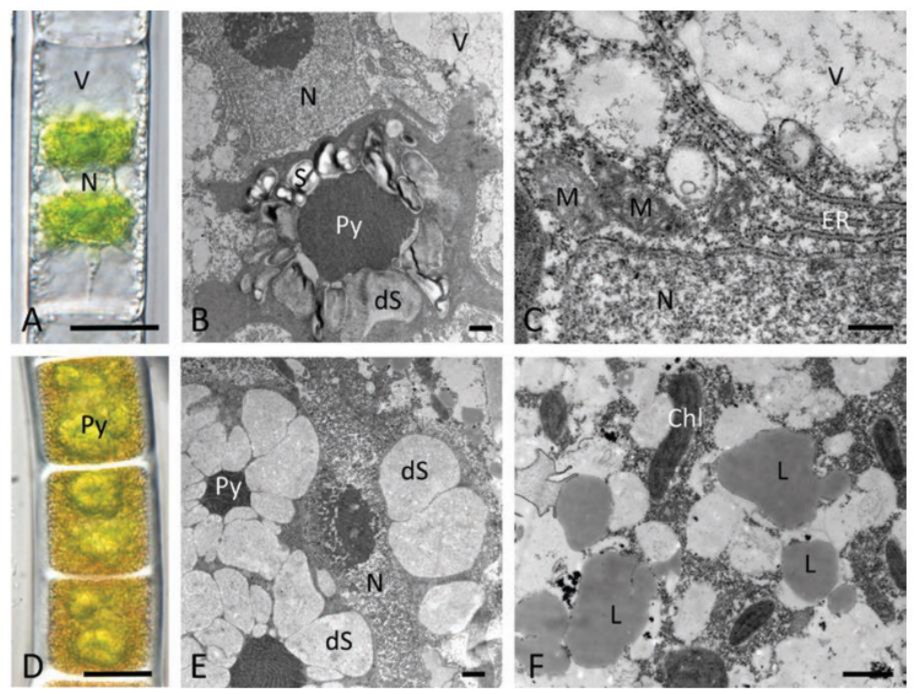




General characteristics

Plastids and pyrenoids

Zygnema



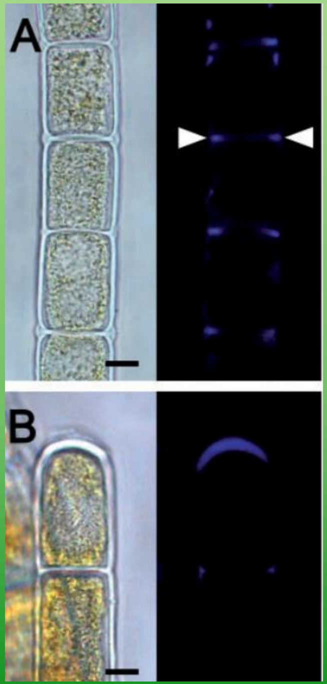
Arc et al. (2020)

Closterium moniliferum

General characteristics

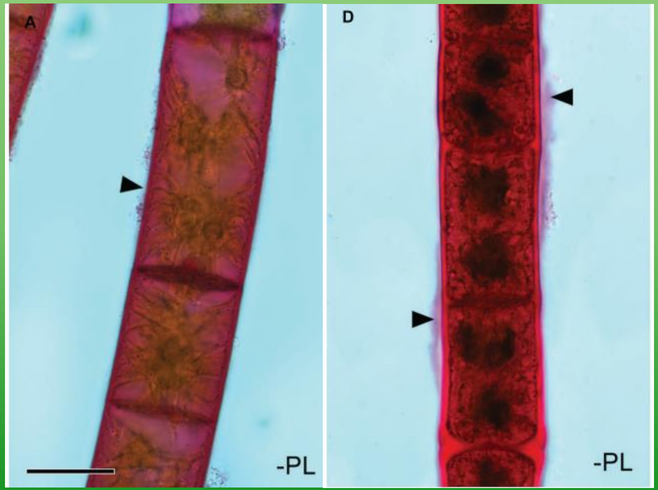
Cell wall – primary, secondary, outer amorphous layer (mucilage)

kalóza



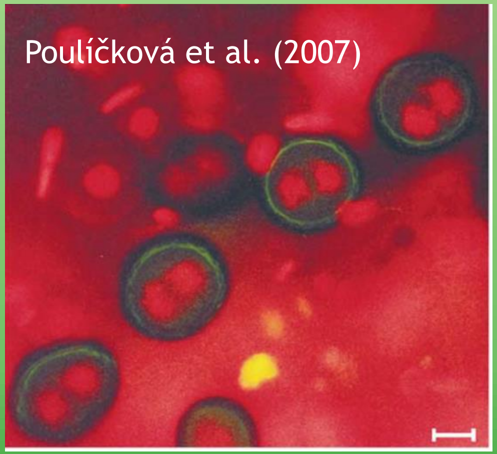
Herburger et al. (2015)

homogalacturonan



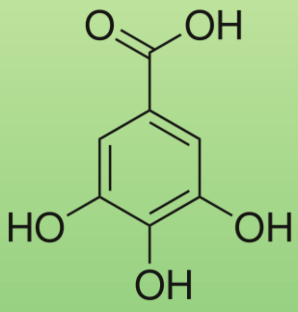
Herburger et al. (2019)

sporopollenin



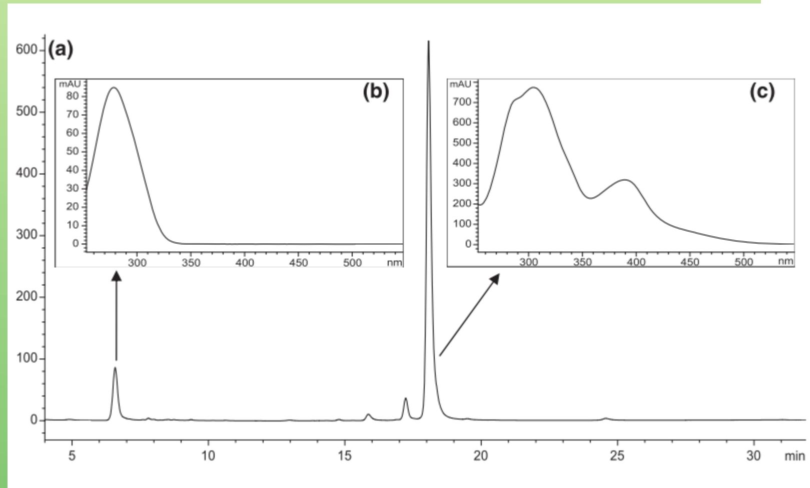
General characteristics

Phenolics



Gallic acid

Mesotaenium bergrgenii



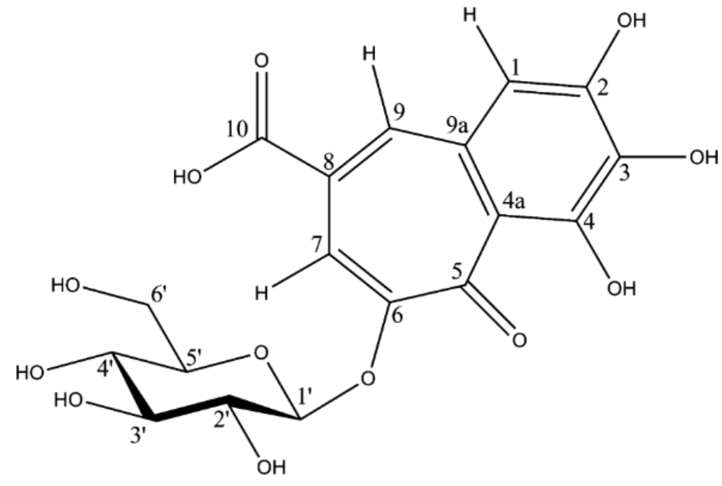
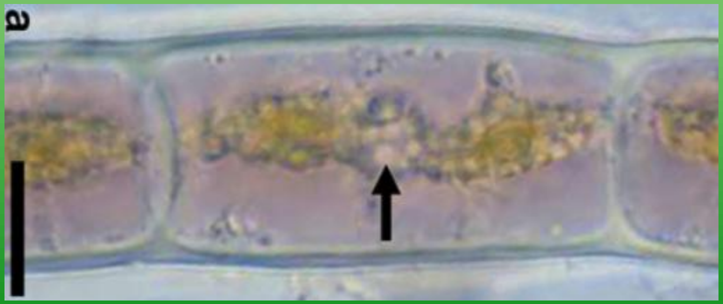
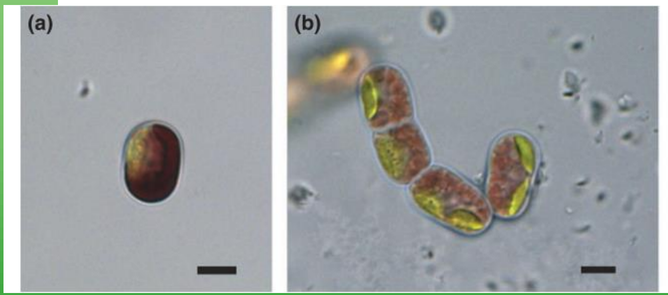


Fig. 4. Chemical structure of compound **3** (purpurogallin carboxylic acid-6-*O*-β-D-glucopyranoside) as identified by NMR in this work.

Zygogonium ericetorum



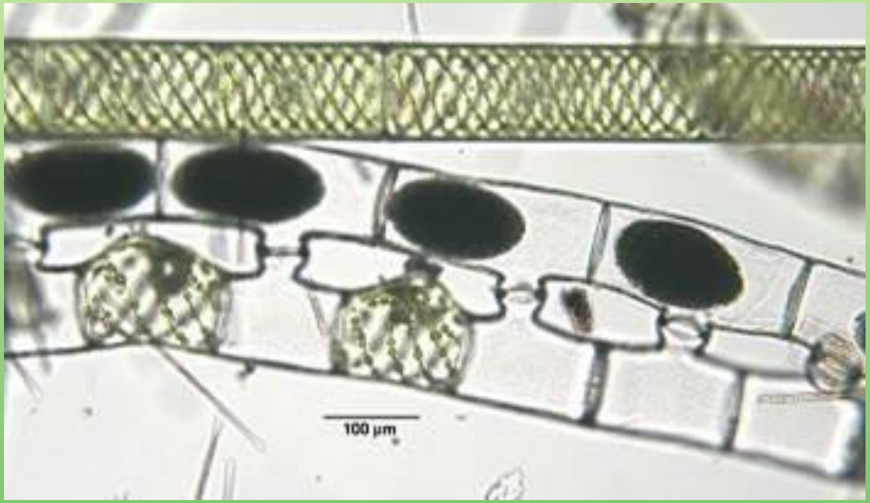
Holzinger et al. (2010)



Remias et al. (2012)

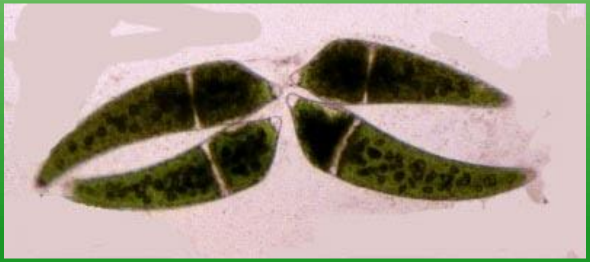
General characteristics

Sexual reproduction: isogamy – conjugation



Scalariform

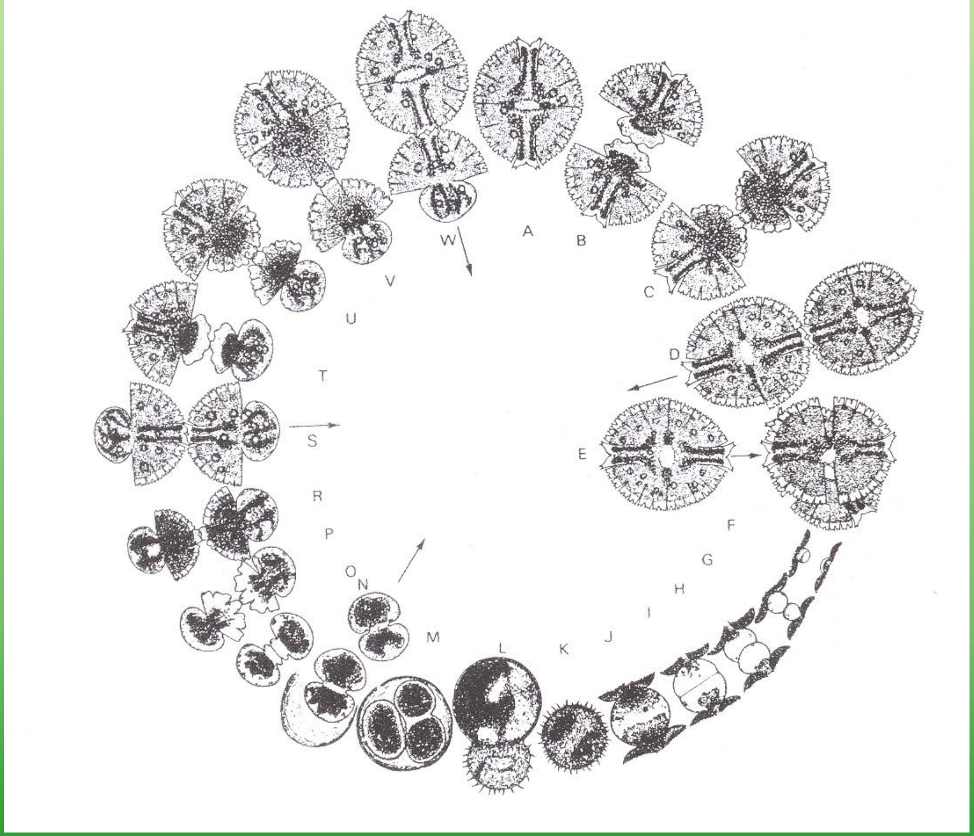
Lateral



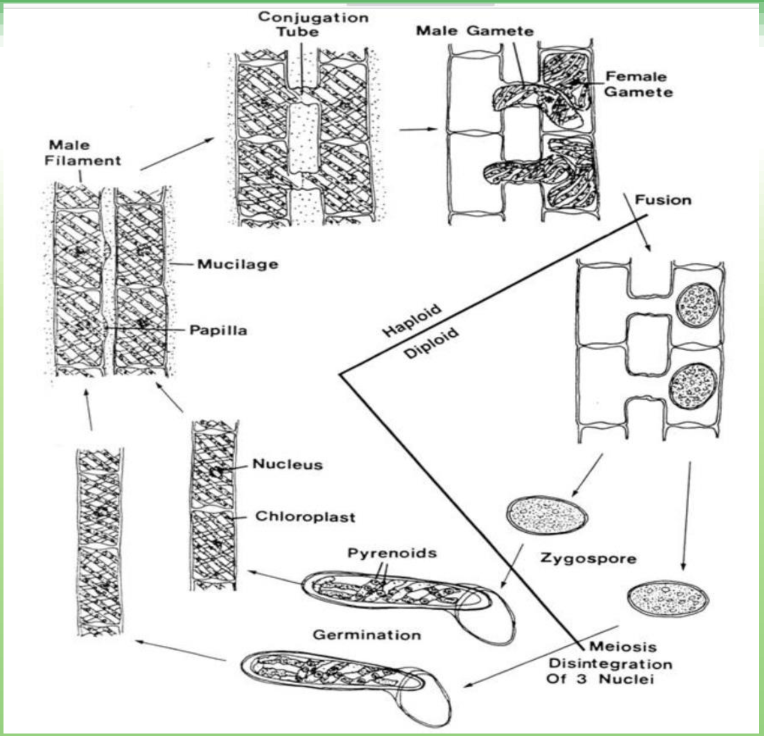
Homothalic and heterothalic species

General characteristics

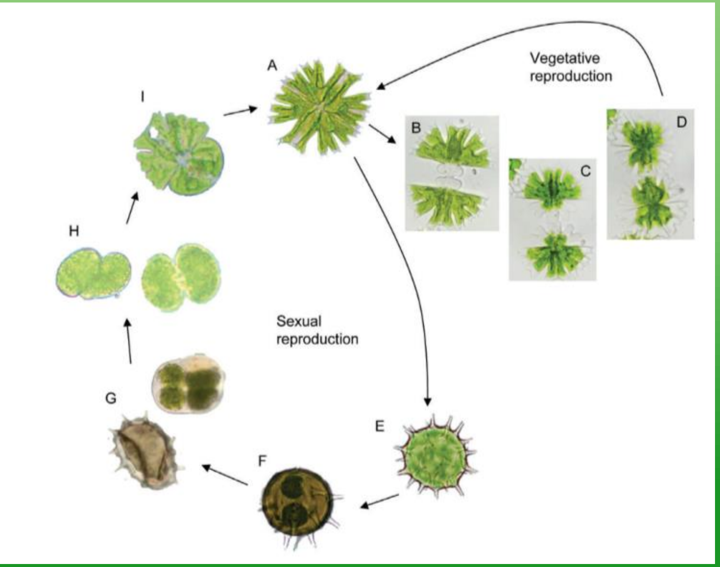
Life cycle



Lenzenweger (2002)



After Lee (1980)



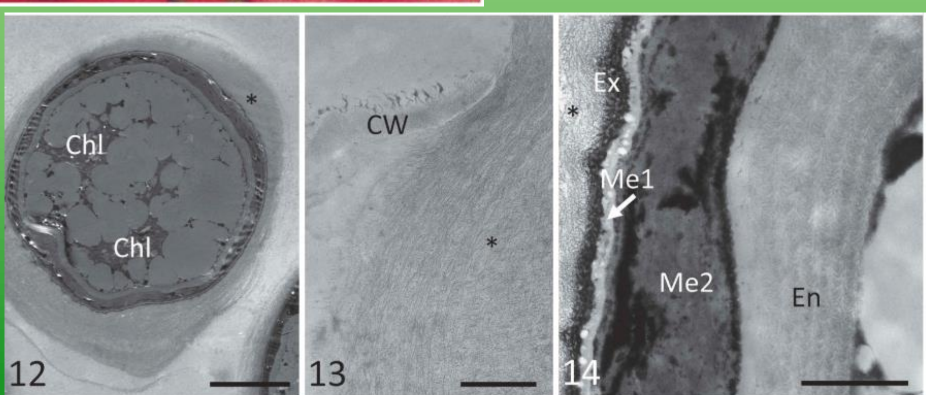
Zhou et al. (2020)

General characteristics

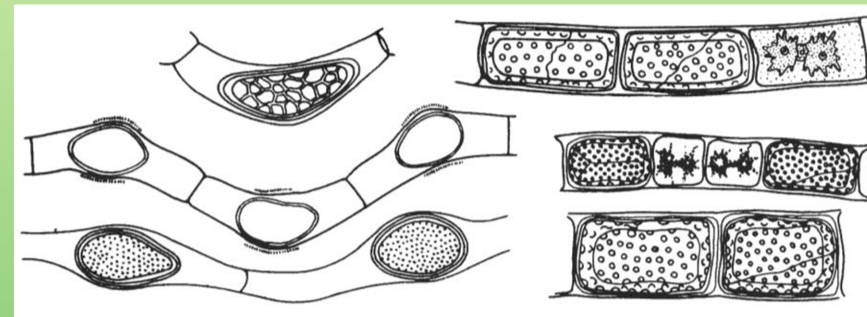
Specialized cells

Zygospores

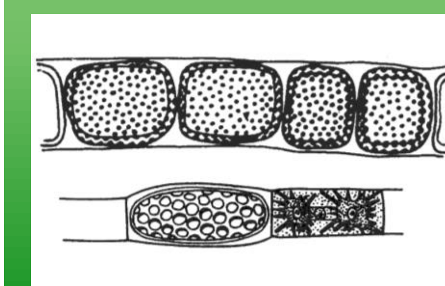
Poulíčková et al. (2007)



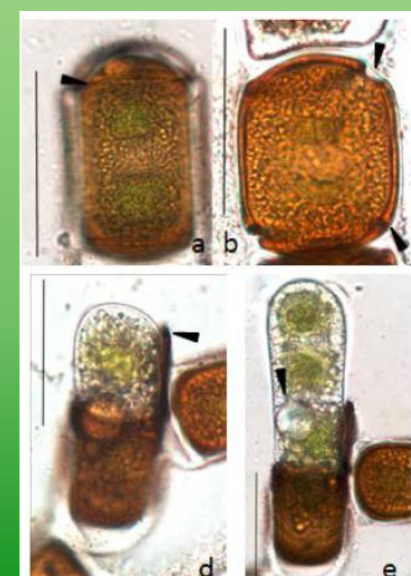
Pichrtová et al. (2018)



Parthenospores
Aplanospores
Akinetes



Kadlubowska (1984)



Fuller (2013)

General characteristics

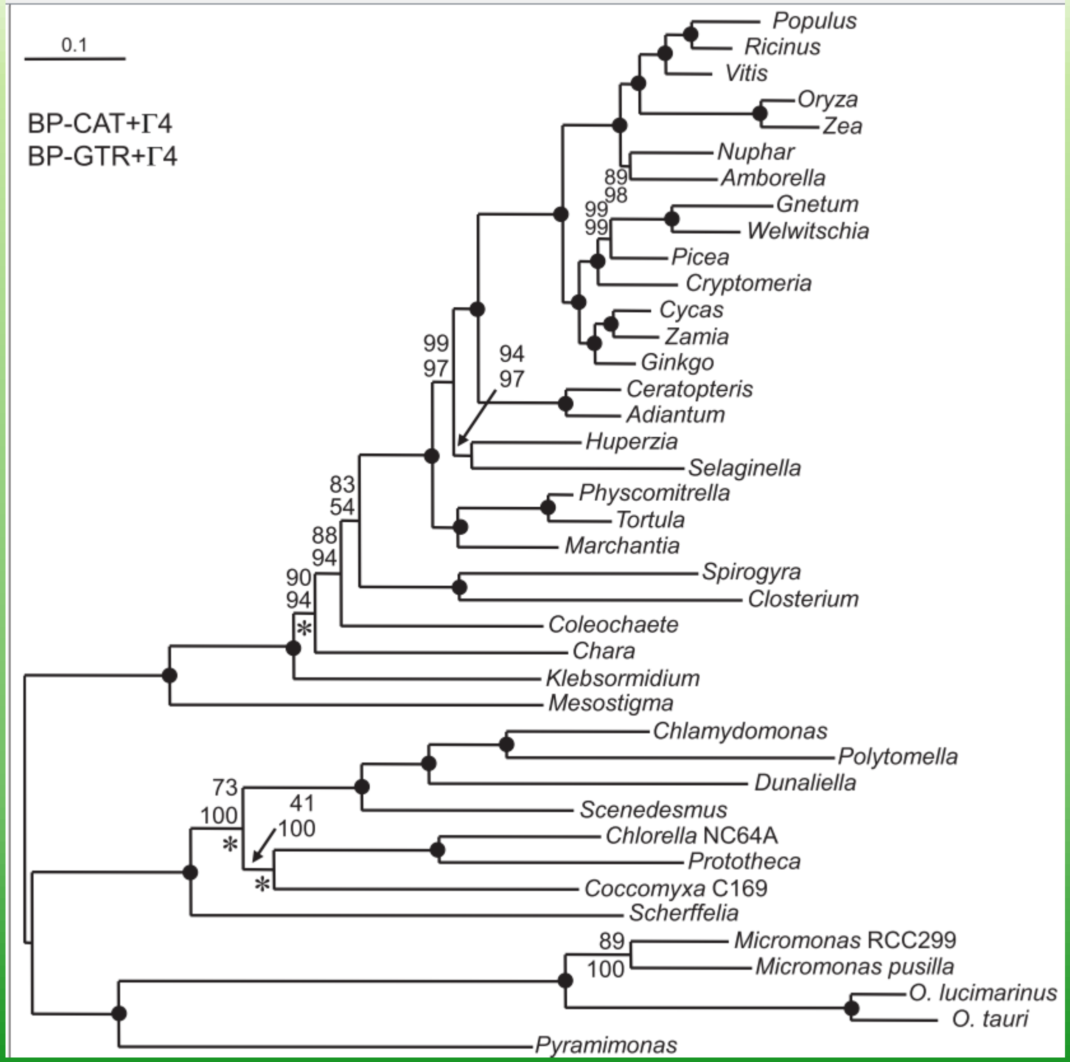
Occurrence

Ludmila Rodriguez

Coesel (2001)

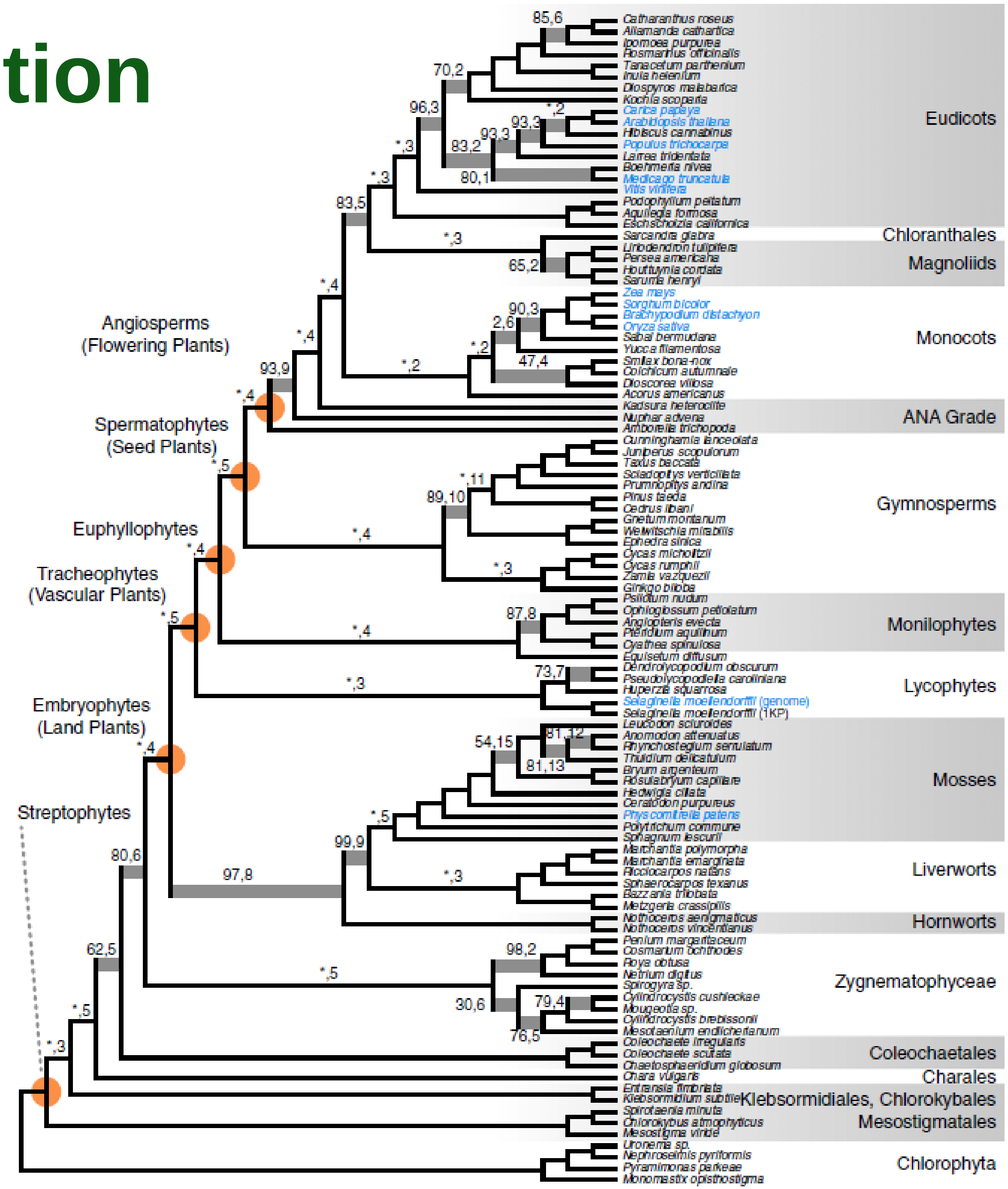
	Trophic state	Acidity	Life form	*r*	*m*	*r–1*
Micrasterias						
americana	meso	acido	benth-plankt	2	2	*
apiculata	meso-oligo	acido	benth	3	3	*
brachyptera	meso	acido	benth	2	3	*
crux-melitensis	meso	acido-neutr	benth-plankt	1	3	
denticulata	meso-oligo	acido	benth	2	–	
fimbriata	meso	acido	benth	2	3	*
furcata	meso-oligo	acido	benth-plankt	3	3	*
jenneri	oligo	acido	benth	3	3	*
mahabuleshwarensis	meso-oligo	acido	benth-plankt	3	–	
oscitans	oligo	acido	benth	3	3	*
papillifera	meso	acido	benth	2	3	*
pinnatifida	meso-oligo	acido	benth	3	3	*
radiosa	meso-oligo	acido	benth-plankt	3	3	*
rotata	meso	acido	benth	1	2	
thomasiana	meso-oligo	acido	benth	1	1	
truncata	oligo-meso	acido	benth	0	0	

Evolution



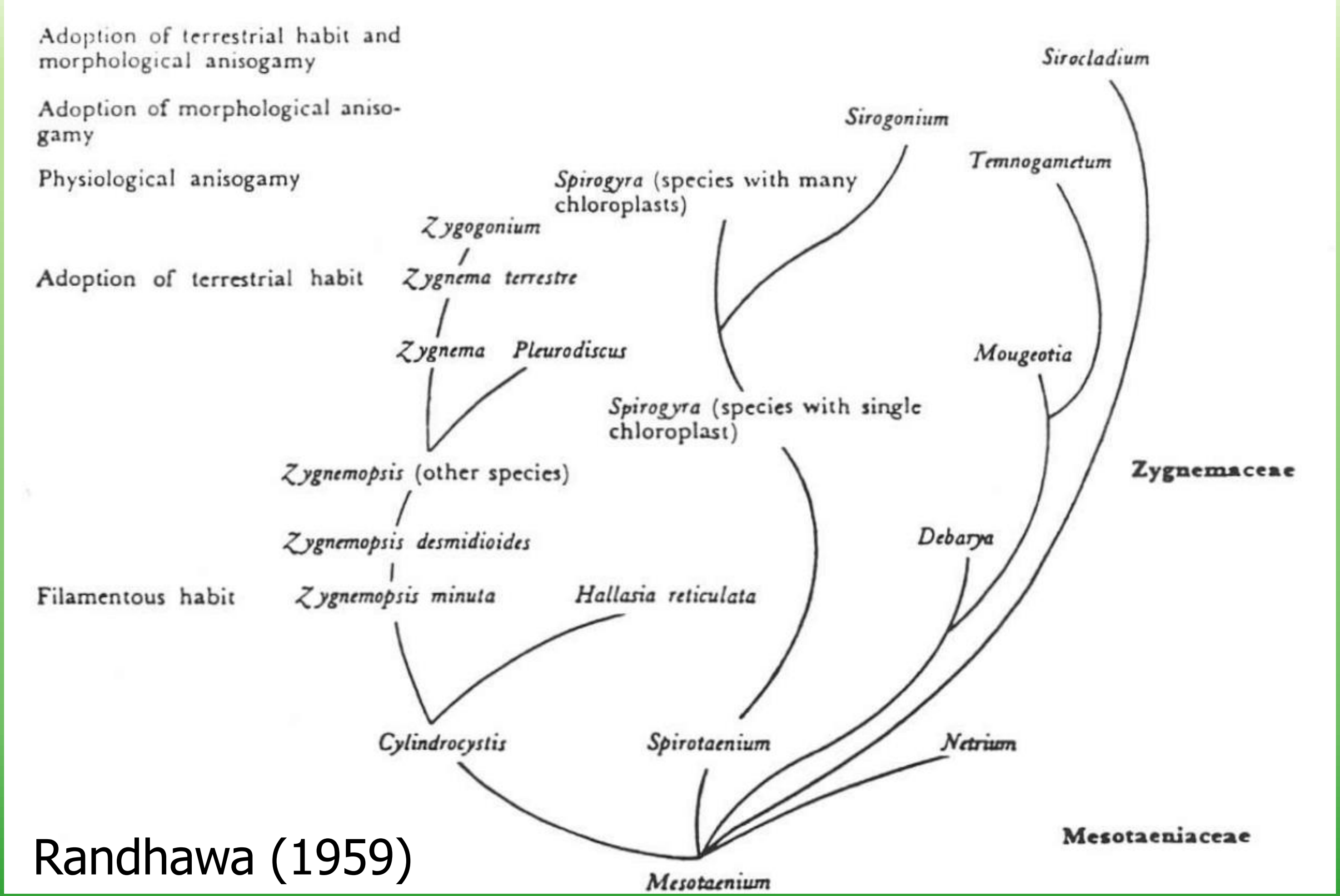
Wodniok et al. (2011)

Evolution



Wickett et al. (2014)

Systematics



Randhawa (1959)

Systematics

Hall et al. (2008)

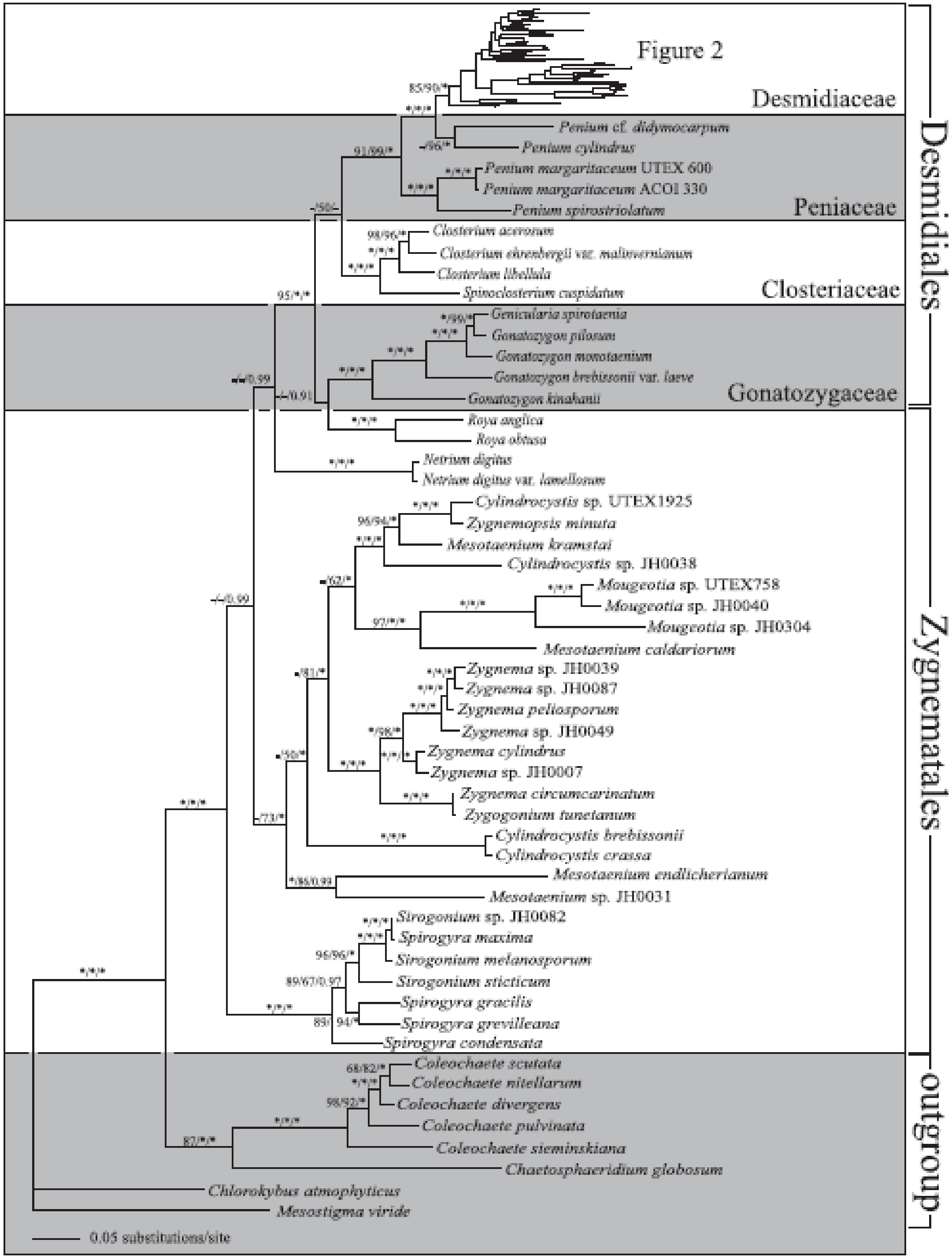
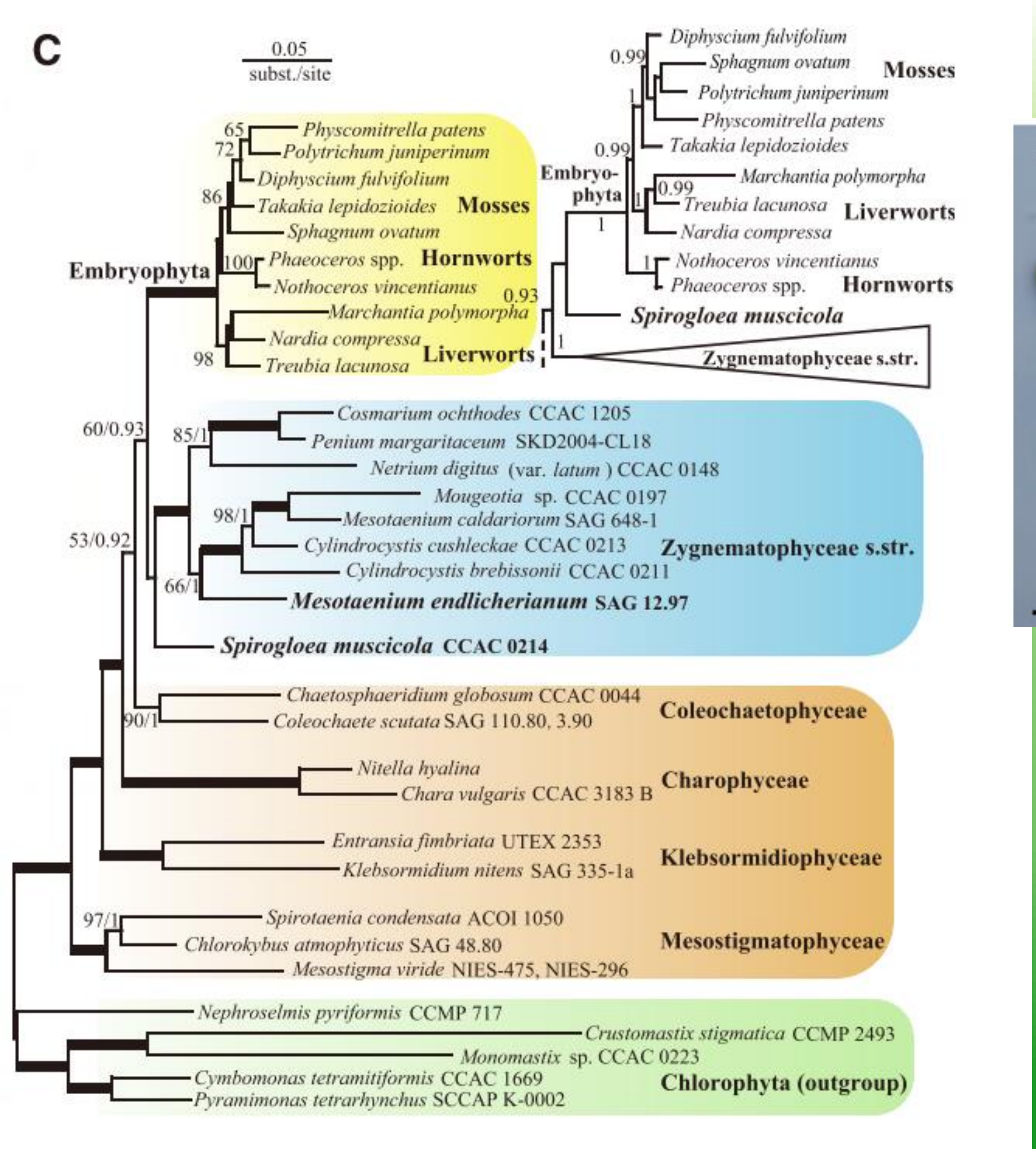
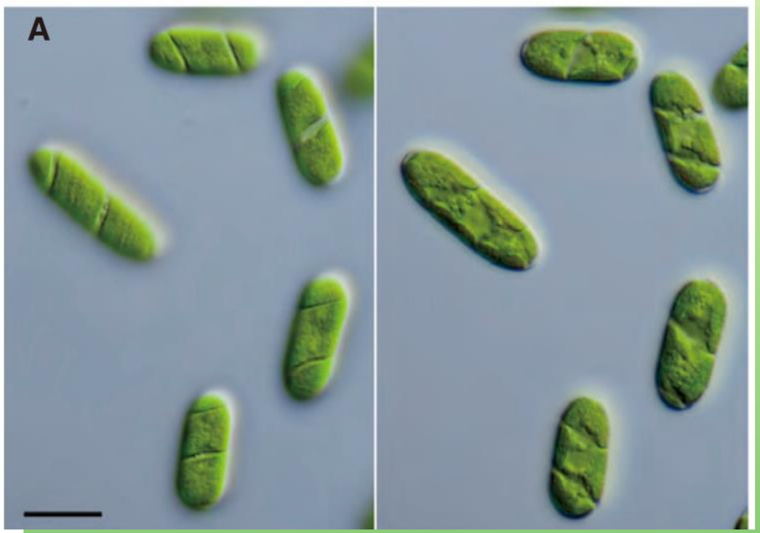


FIG. 1. Phylogeny of the *Zygnematophyceae*, *Zygnematales*, and Desmidiales based on the most likely tree when analyzing three genes with all codon positions included. Numbers above branches are ML and MP BS values and PP, respectively. Dashes indicate values <50% (BS) or 0.50 (PP). An asterisk indicates support values of 100 (BS) or 1.0 (PP). BS, bootstrap; ML, maximum likelihood; MP, maximum parsimony; PP, posterior probability.

Systematics



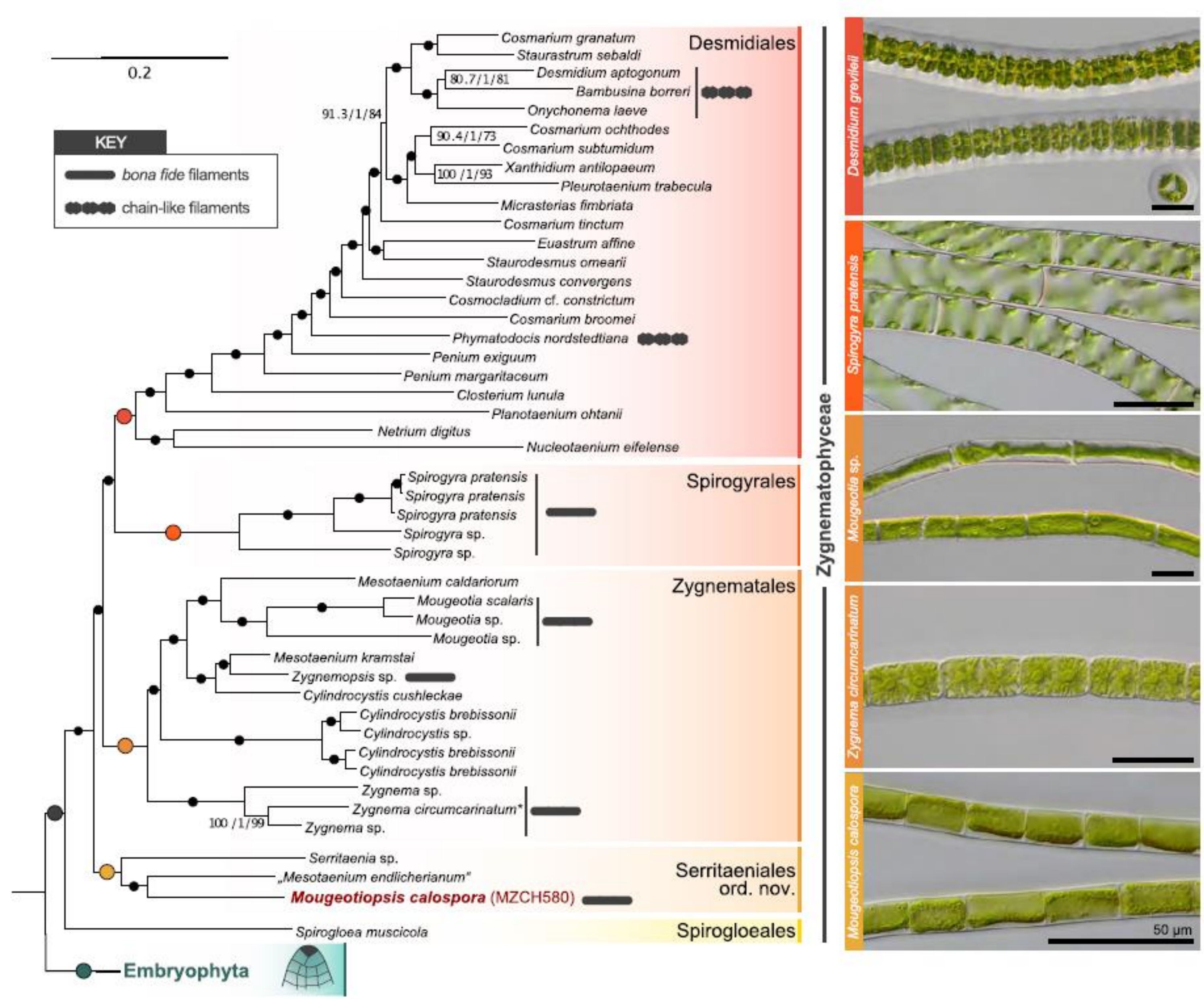


Spirogloea

Zygnematophycidae
Spirogloeophycidae

Cheng et al. (2019)

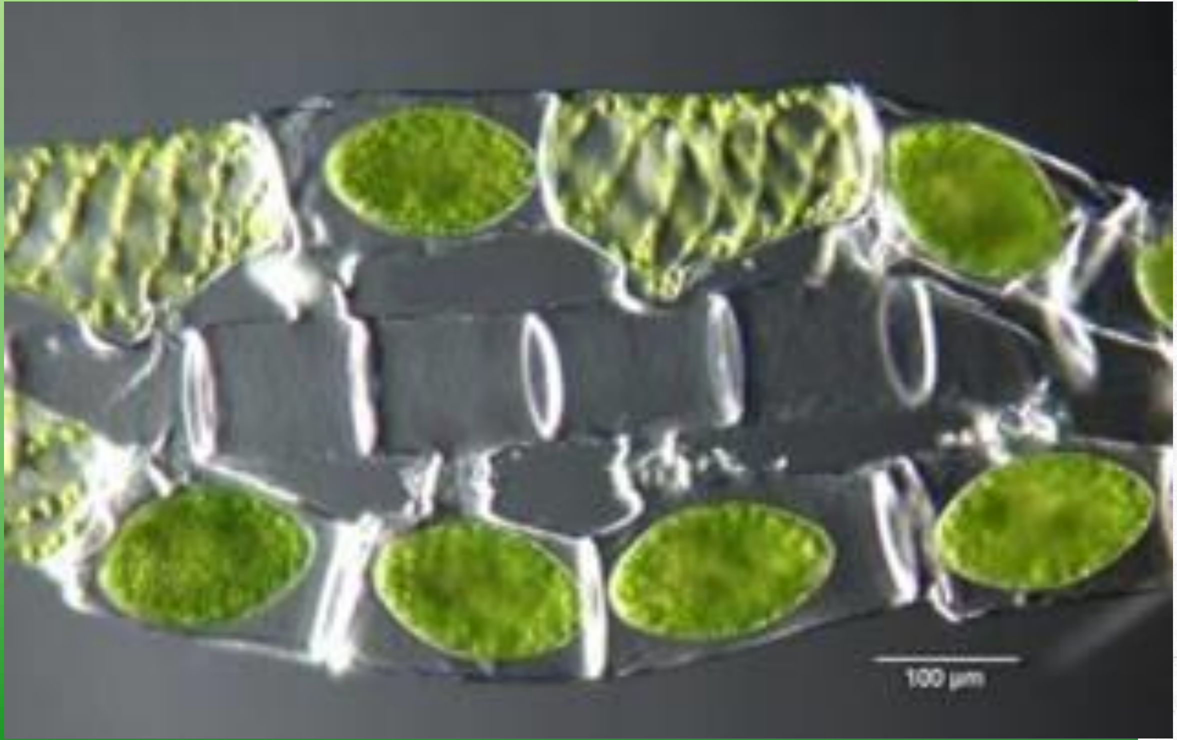
Systematics

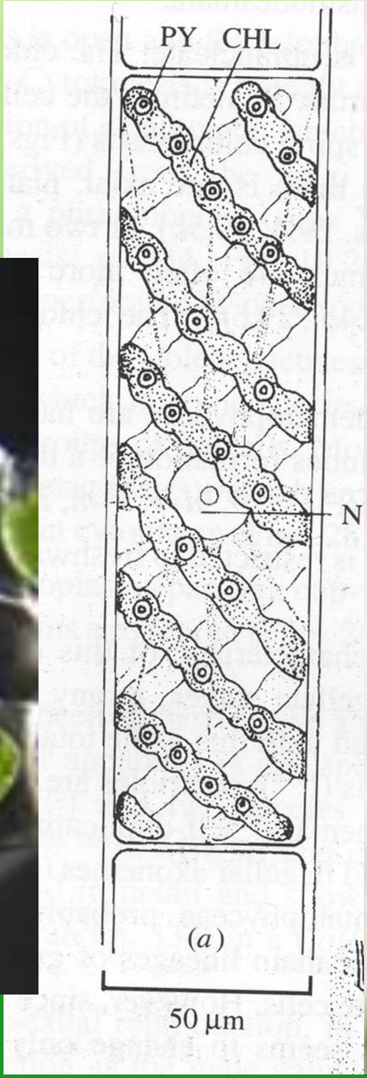


Hess et al. (2022)

Spirogyrales

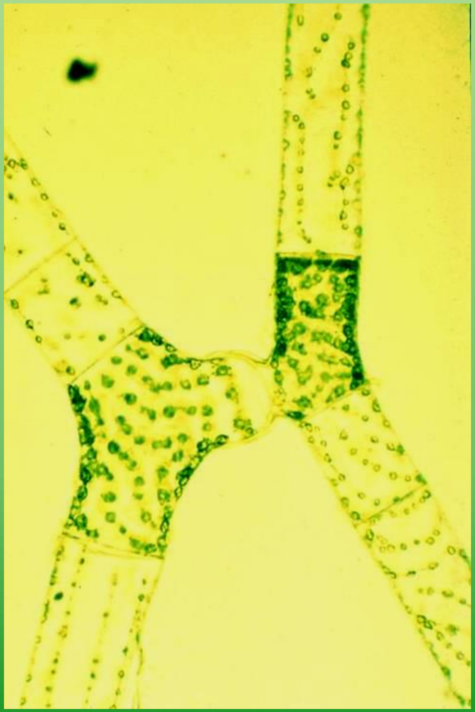
- ***Spirogyra***



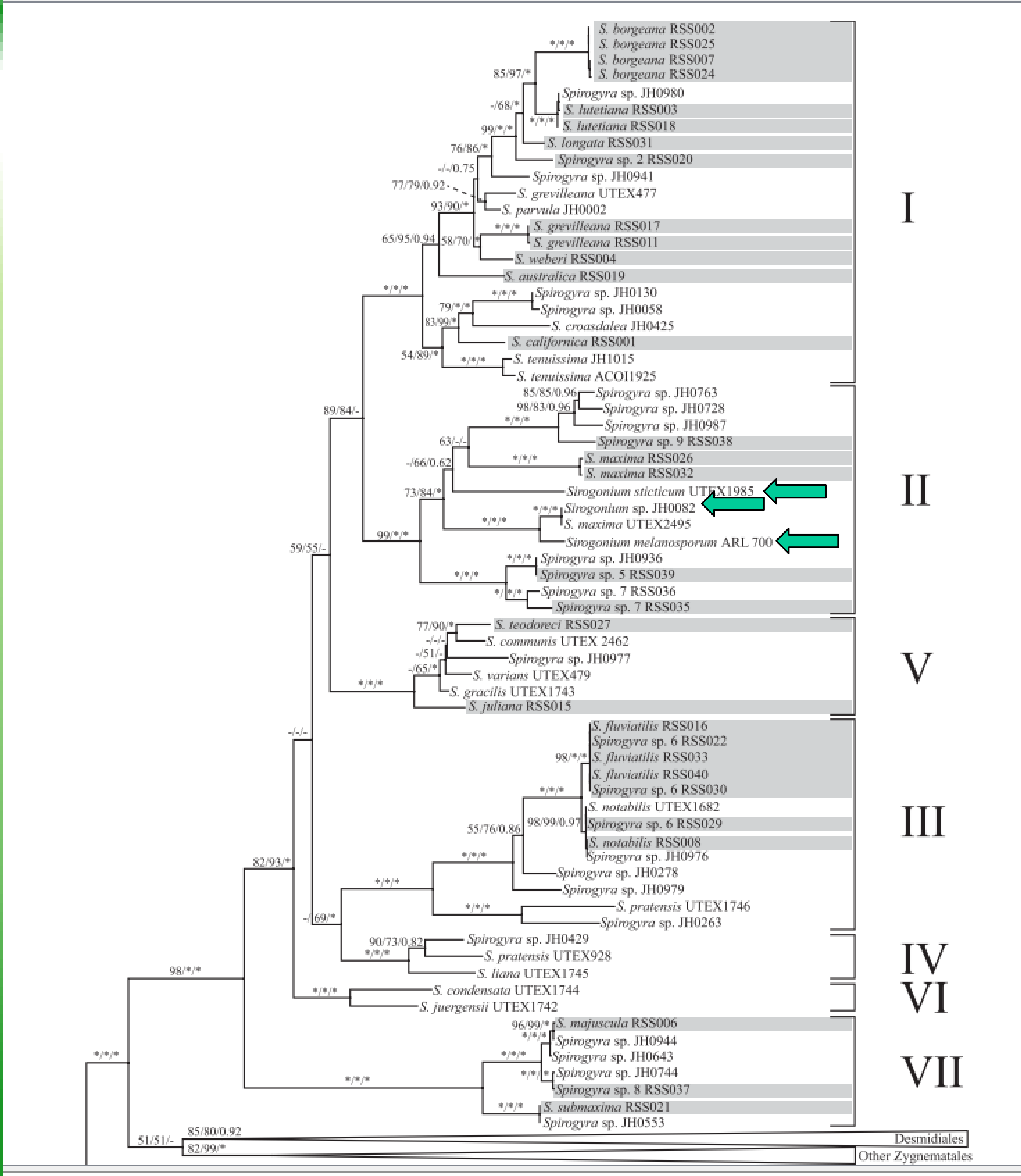


Přehled rodů - Spirogyrales

- ***Sirogonium***



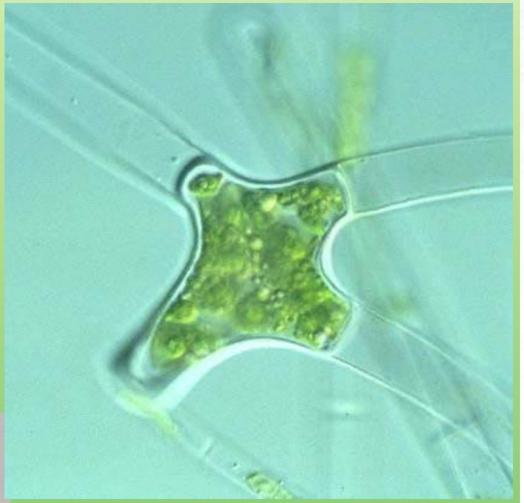
Spirogyra
and
Sirogonium

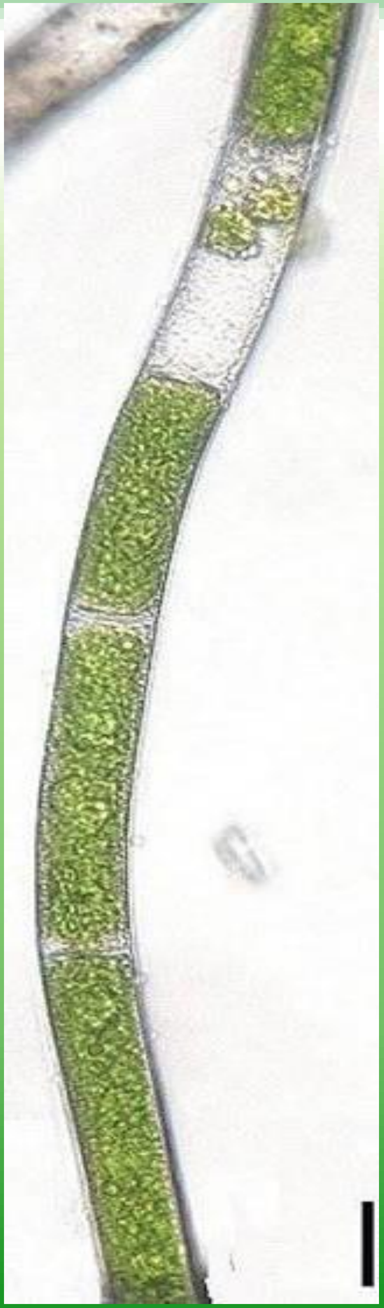


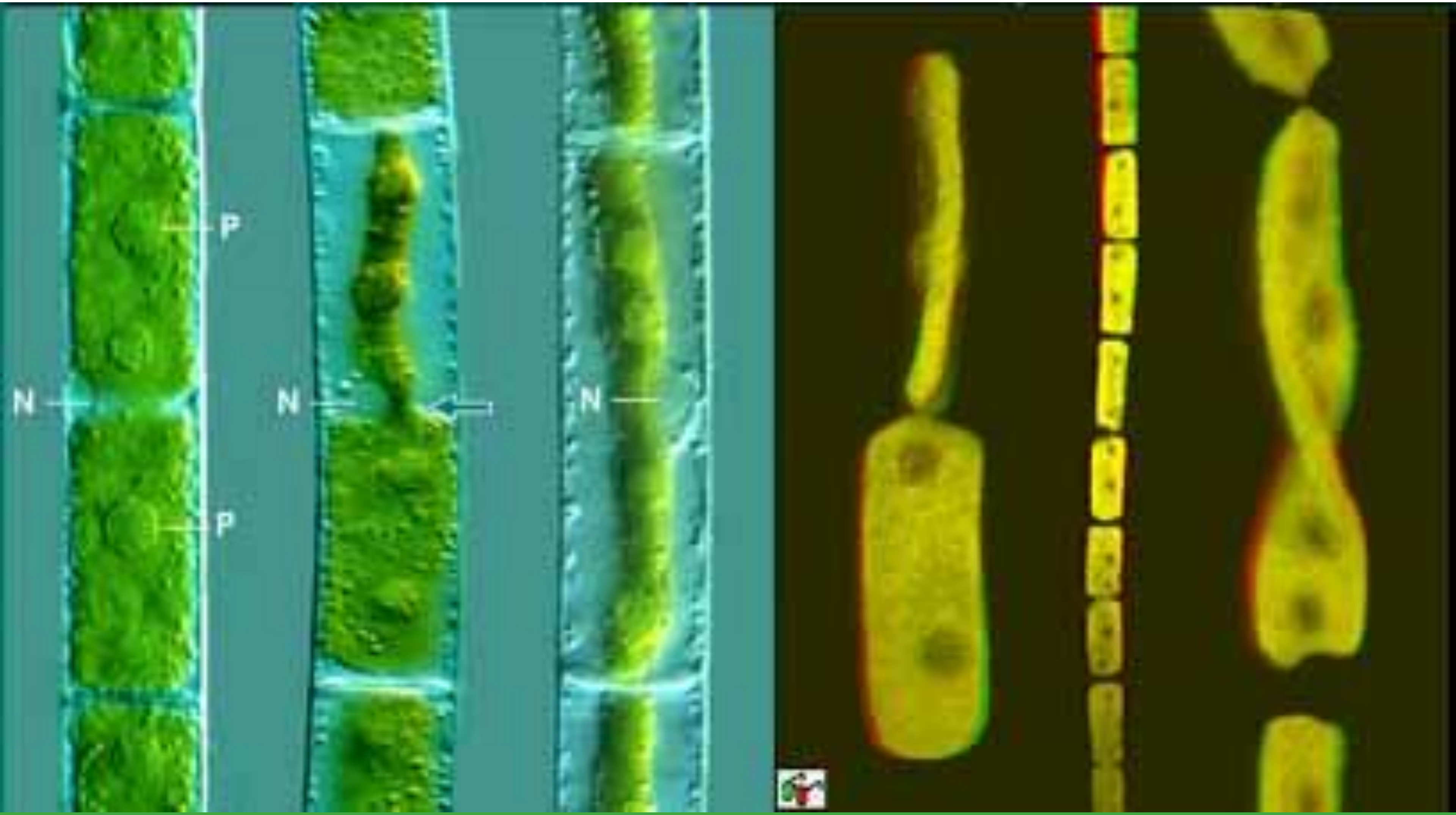
Stancheva et al. (2013)

Zygnematales

- ***Mougeotia***



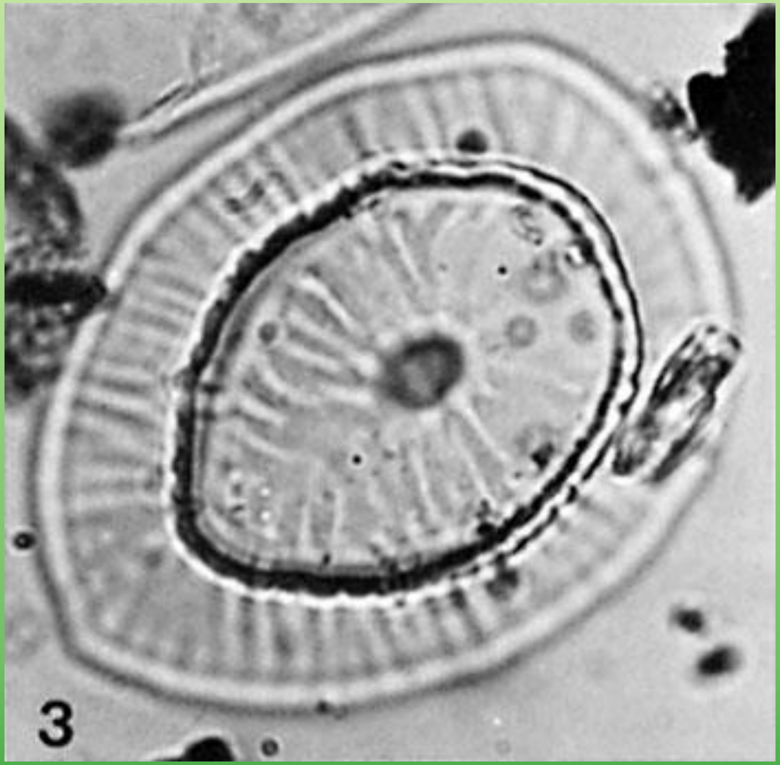




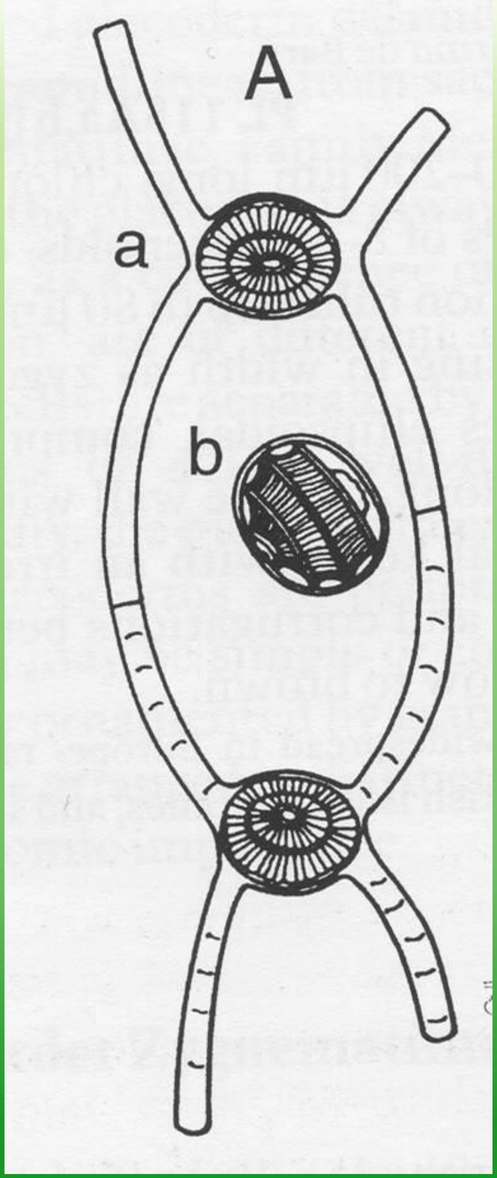
Mougeotia

Zygnematales

- ***Debarya***

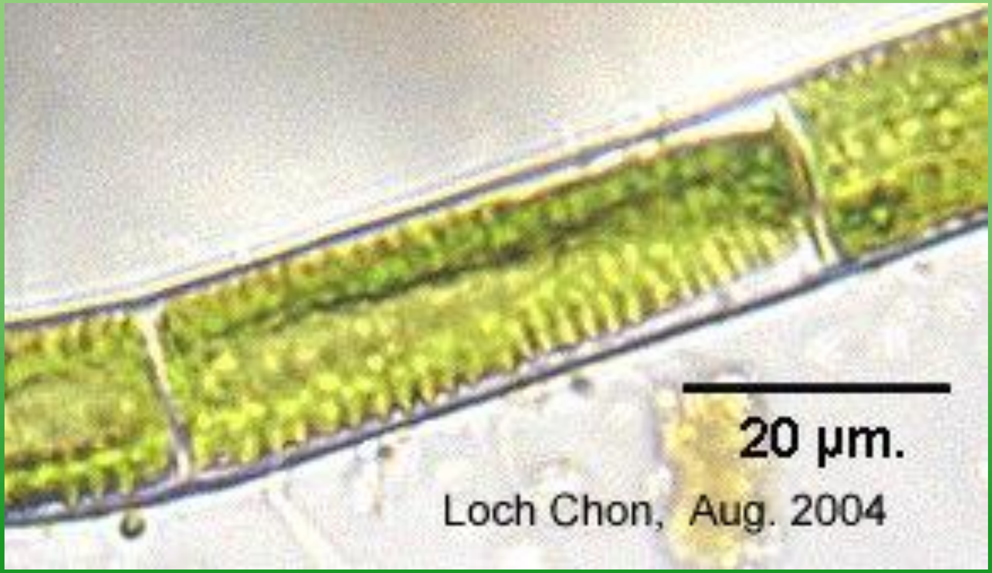


fossil zygospore



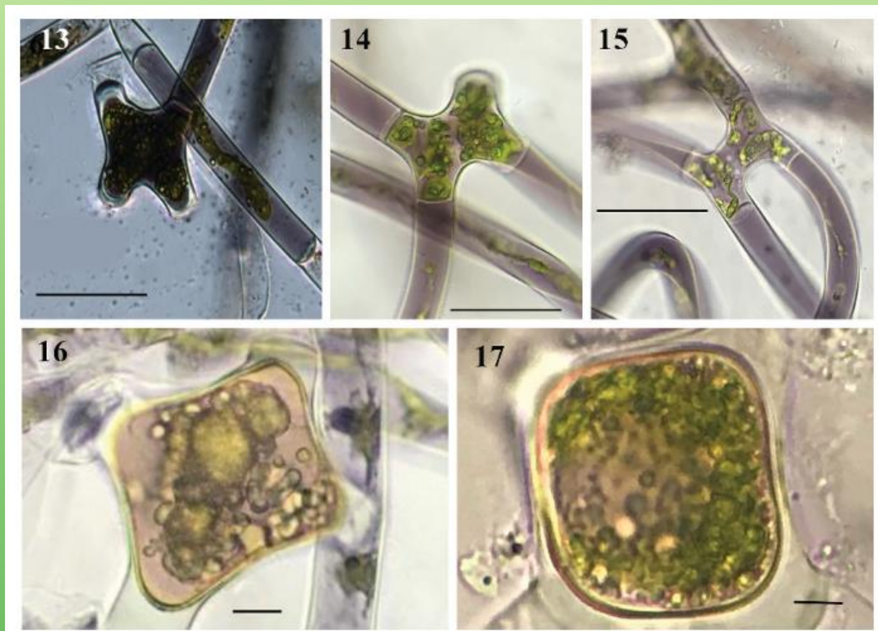
Zygnematales

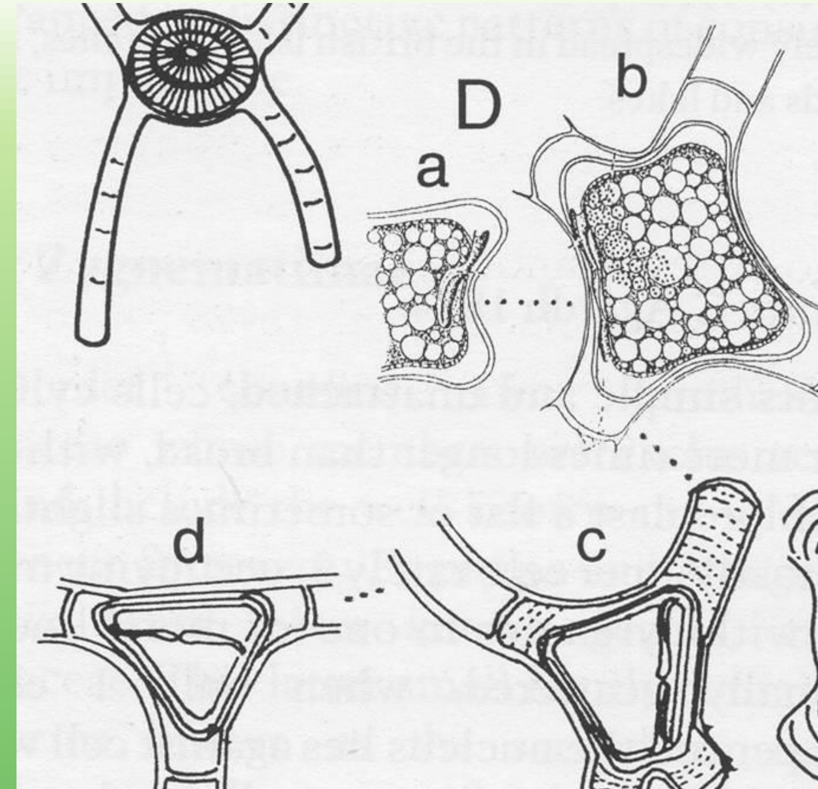
- ***Mougeotiopsis***



Zygnematales

- ***Temnogametum***

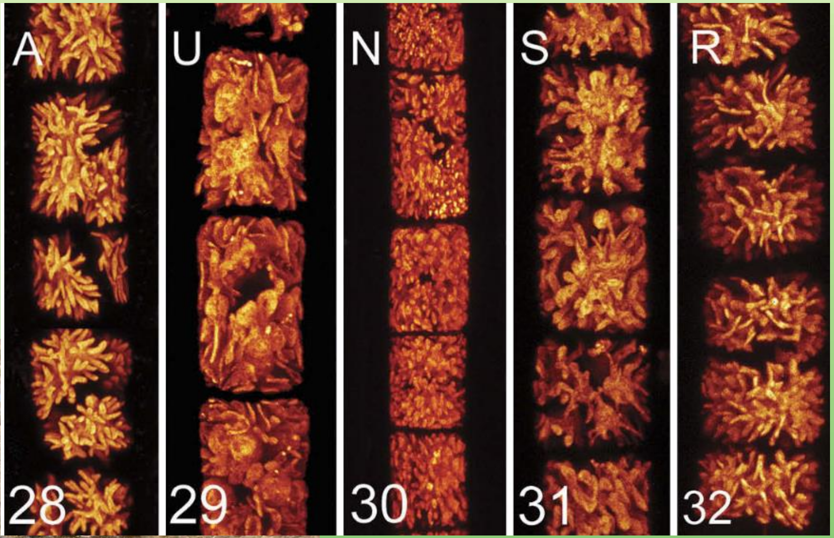




Garduño-Solórzano et al. (2020)

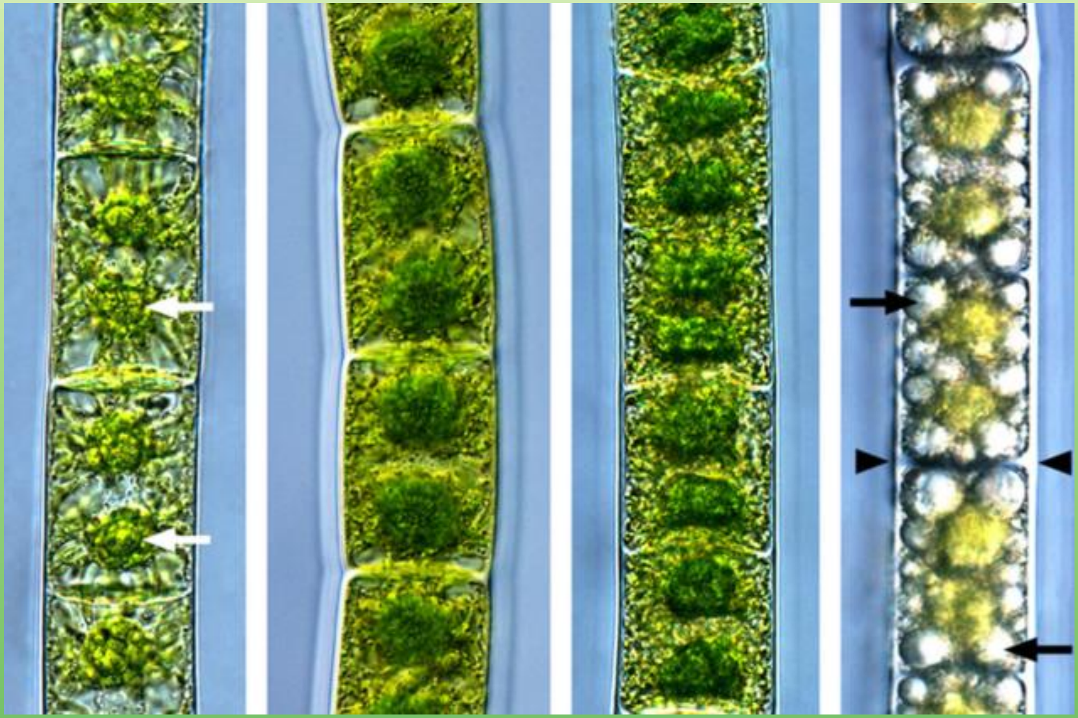
Zygnematales

- *Zygnema*

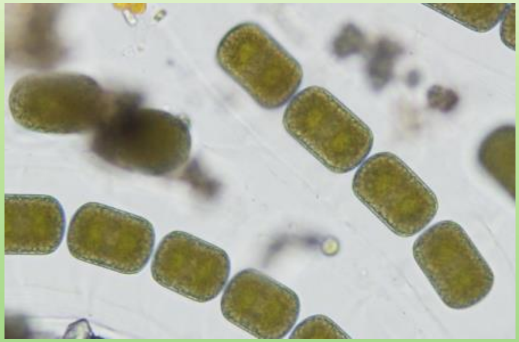


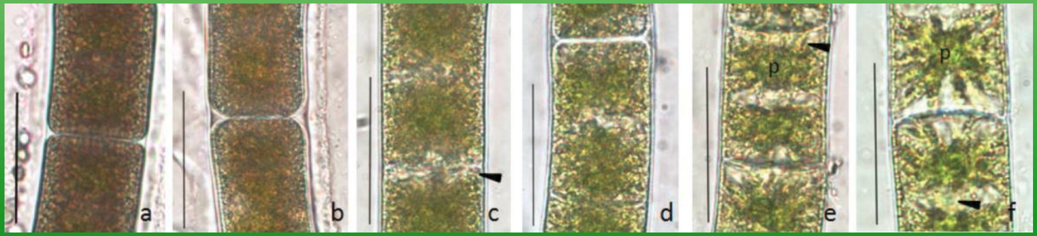
Zygnematales

Zygnema – pre-akinetes

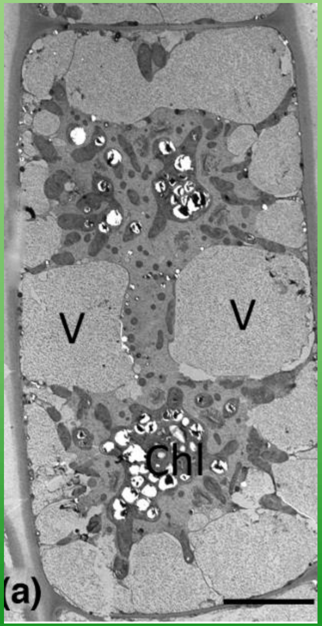


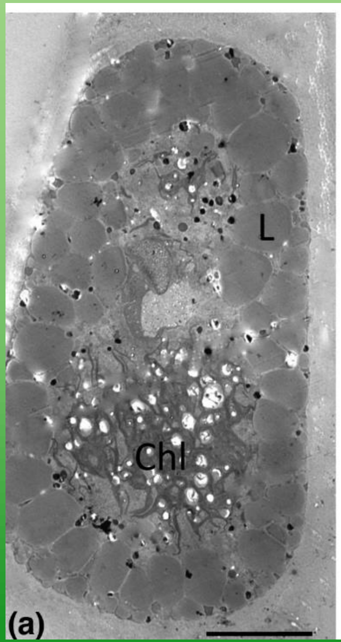
Herburger et al. (2014)





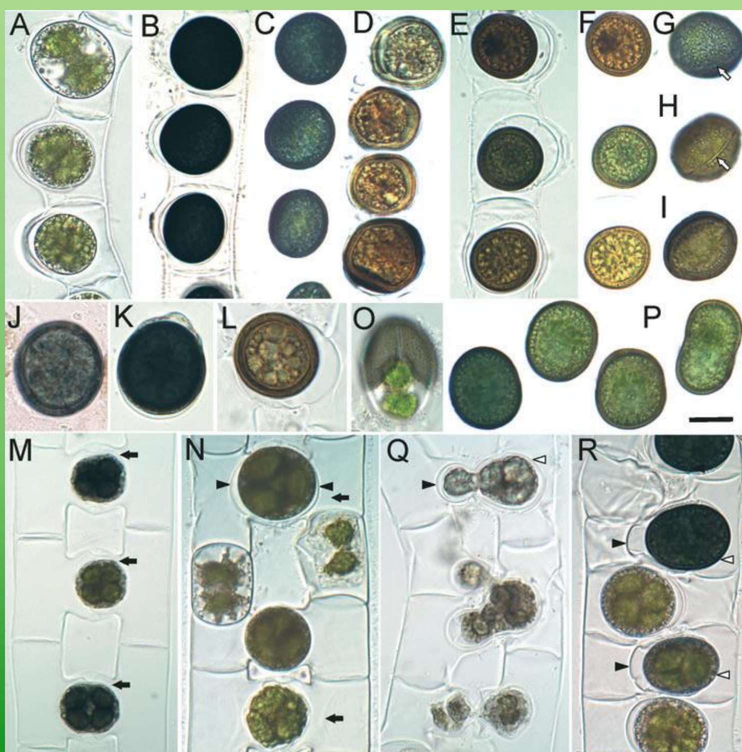
Fuller (2013)





Zygnematales

Mesospore colour



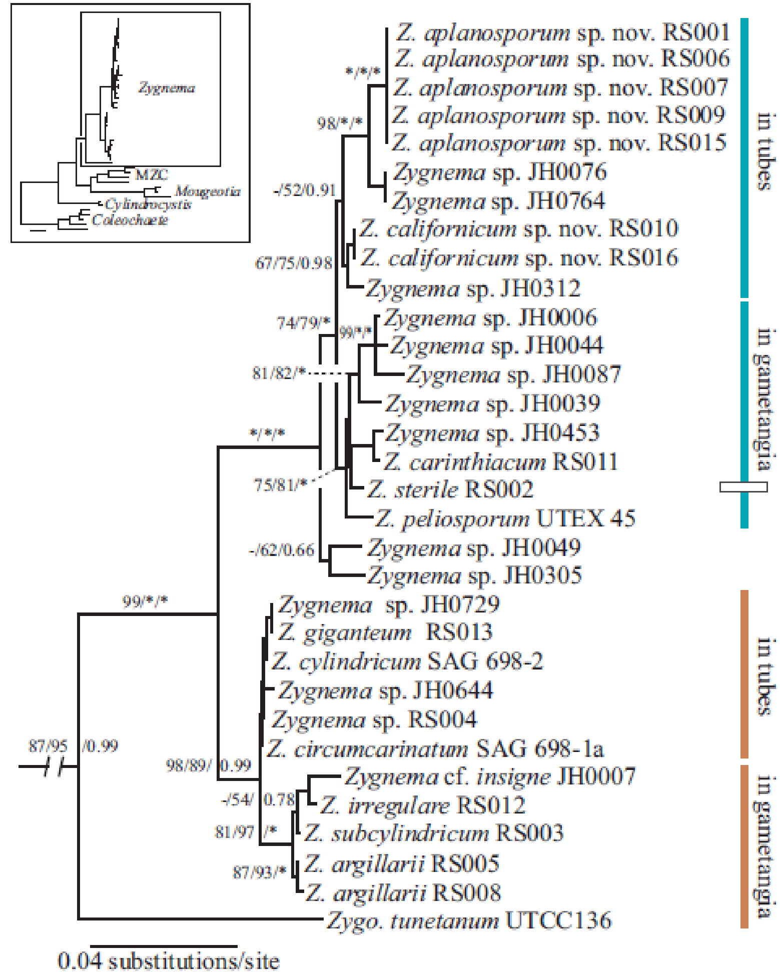
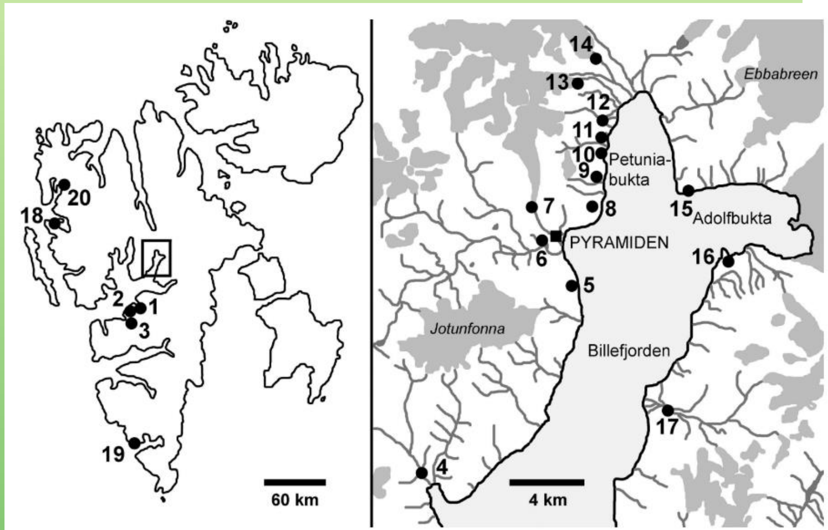


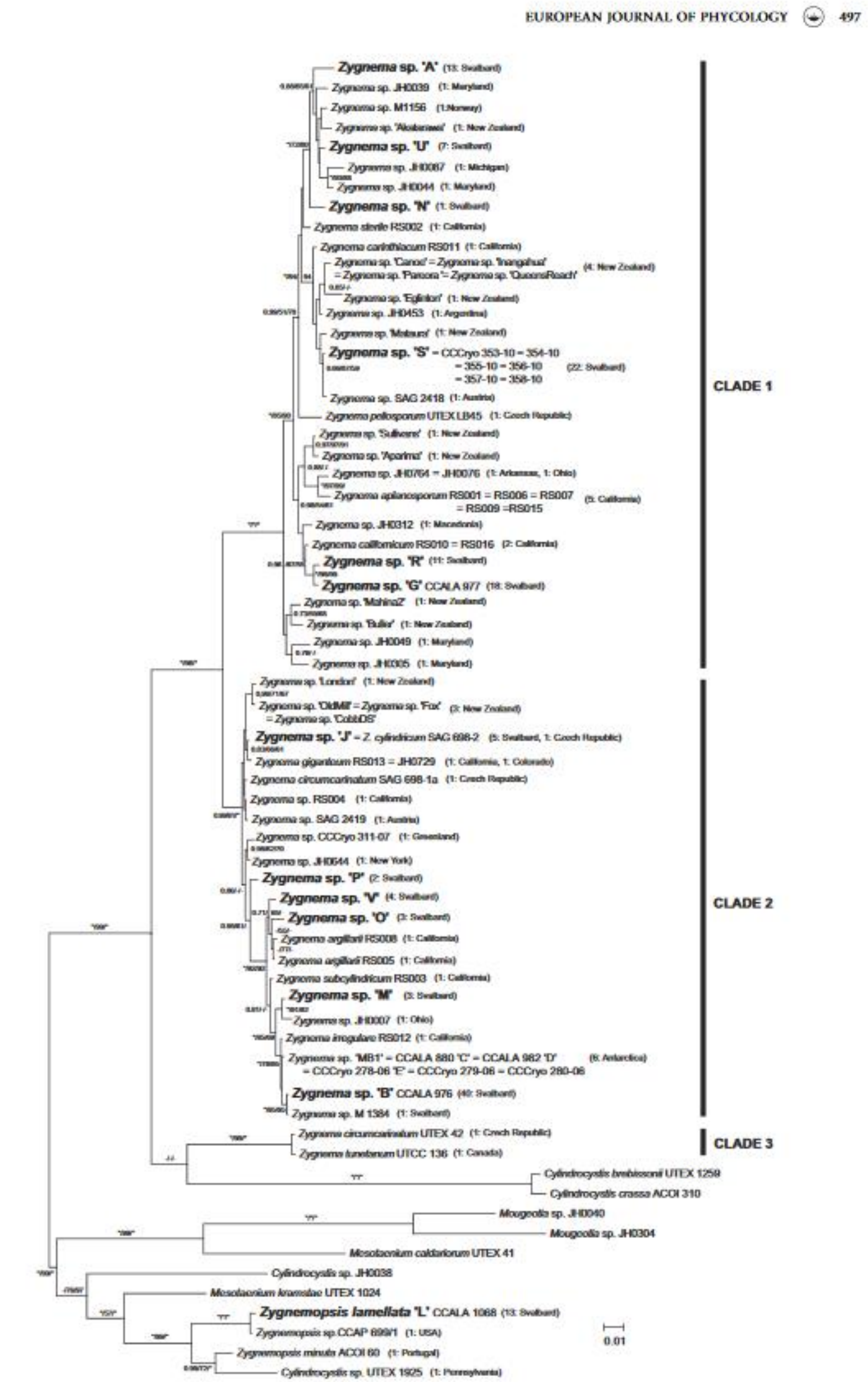
FIG. 5. Phylogeny of *Zygnema* and *Zygogonium* based on *rbcL* data. Maximum-likelihood tree found using the GTR + I + Γ model. Numbers above the branches are bootstrap values from Parsimony analysis, RAxML, and posterior probabilities from a Bayesian analysis, respectively. An asterisk indicates bootstrap support of 100 or a posterior probability of 1.0. A dash indicates bootstrap support of <50 or a posterior probability <0.5. Mesospore color is indicated by the color of the bar on the right.

Stancheva et al. (2012)

Zygnematales

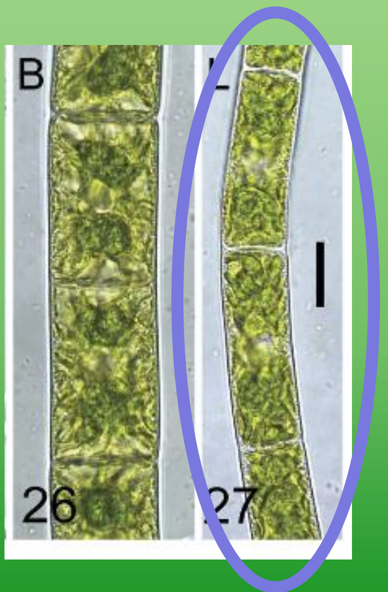


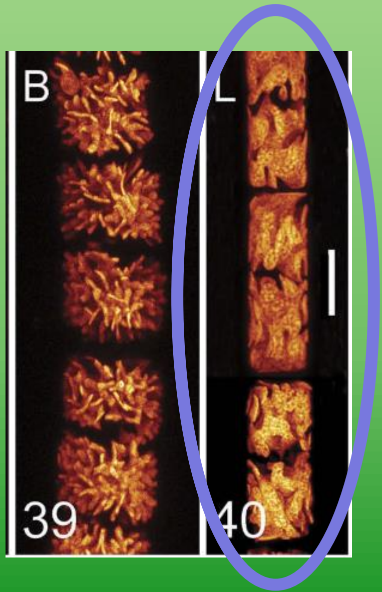
Pichrtová et al. (2018)

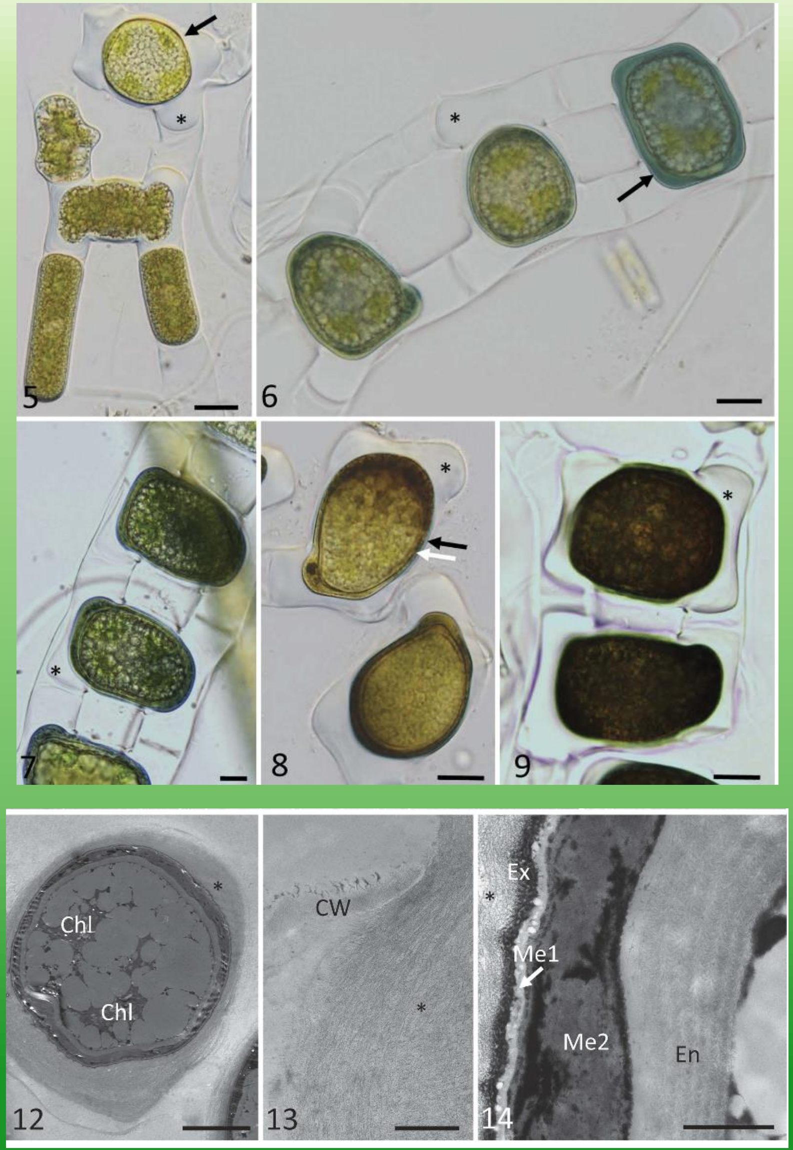


Zygnematales

- ***Zygnemopsis***



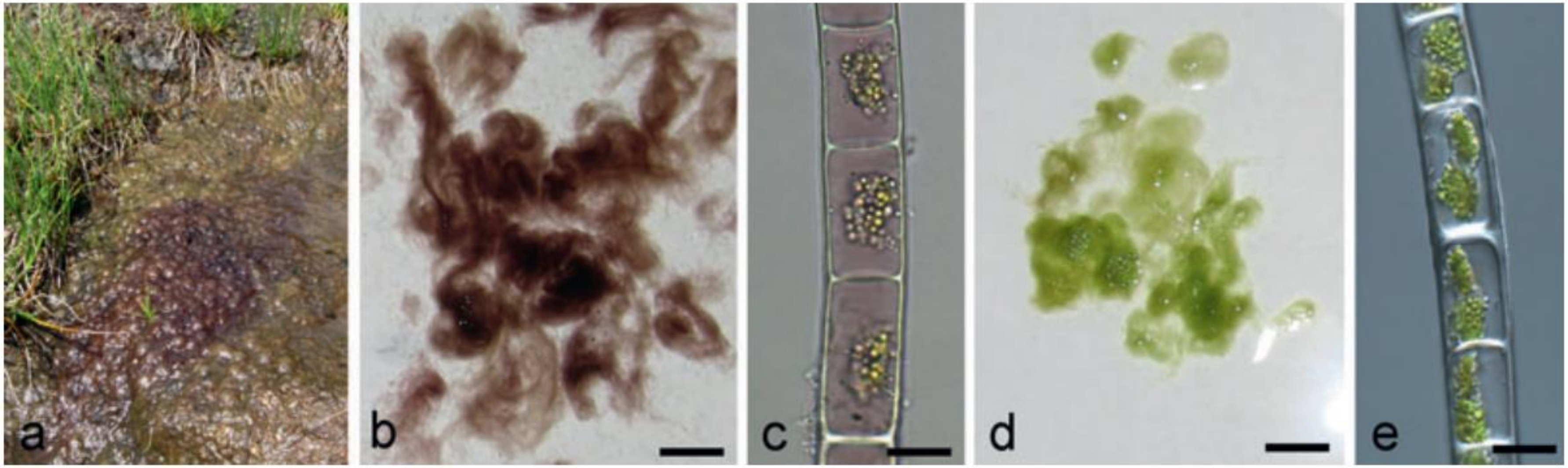




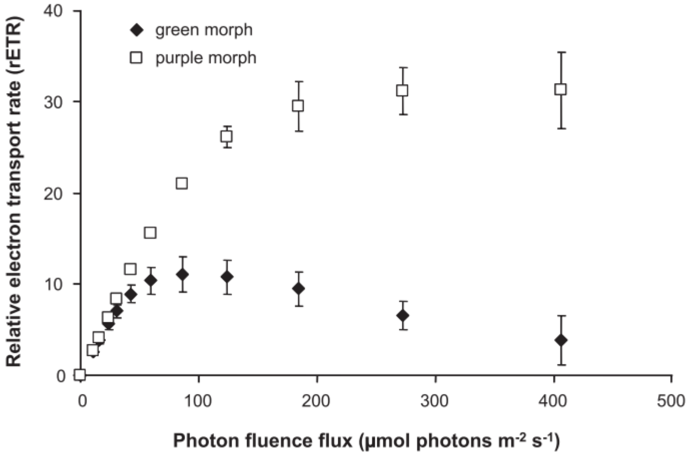
Přehled rodů - Zygnematales

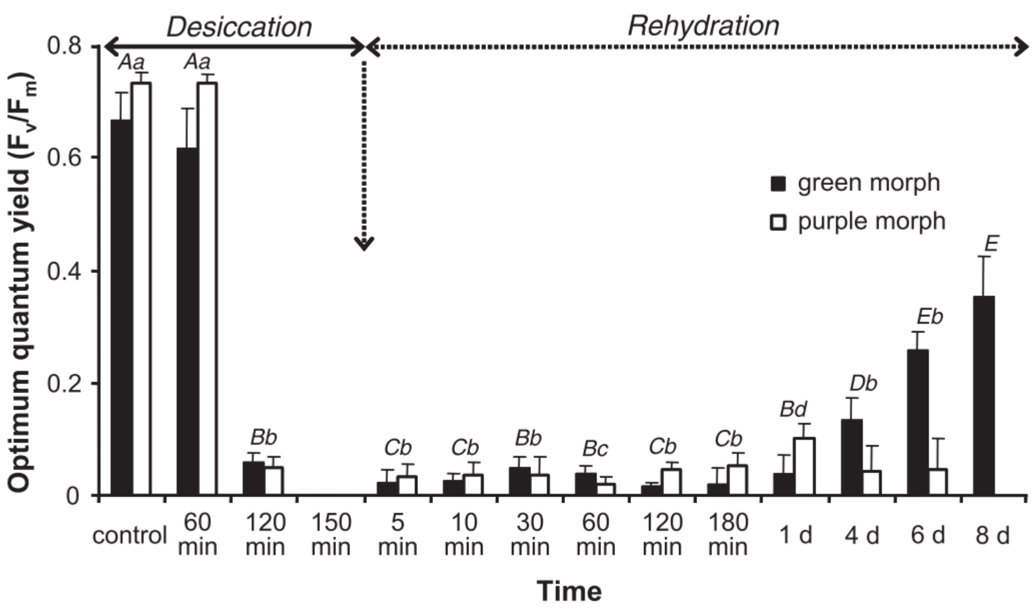
- ***Zygogonium***

Zygnematales



Aigner et al. (2013)





Zygnematales

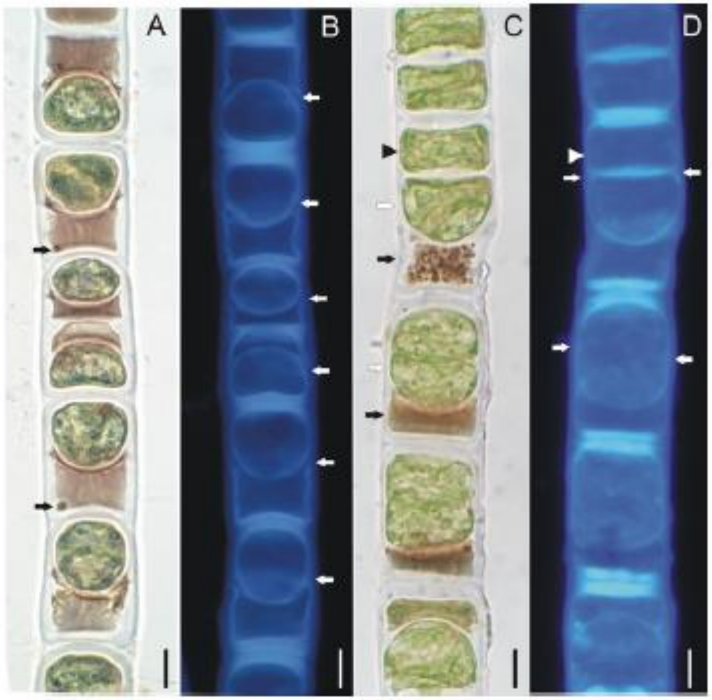


FIG. 5. Light (A, C) and fluorescence (B, D) microscopic images of aplanospores in *Zygogonium ericetorum*: (A) filament with completely developed aplanospores, note dark-purple vacuolated cytoplasmic residue with small dense granules (arrows), (B) CFW staining for cellulose, note the ring-like transverse rupture in the cellulose inner layer of vegetative cell wall above the equatorial region of the aplanospore (arrows), (C) Filament with two germinating aplanospores (white arrows) in different stages of cell division and resulting daughter cell (arrowhead), note dense brown cytoplasmic residue (black arrows), (D) CFW staining for cellulose, showing transverse cell wall formation in germinating aplanospores (arrows) and a daughter cell (arrowhead). Filaments CFW and 10% KOH treated. Scale bars: 10 µm.

Stancheva et al. (2014)

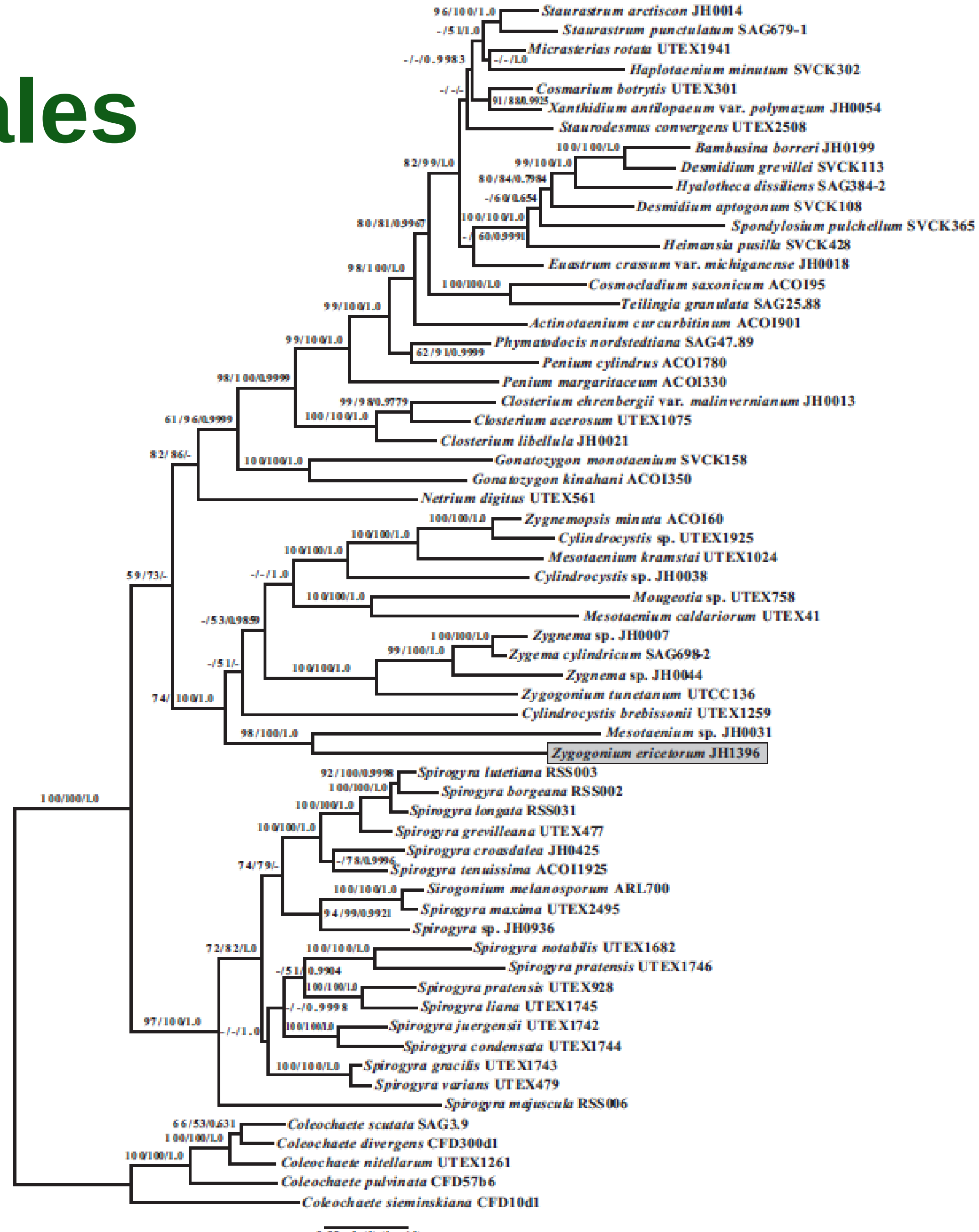
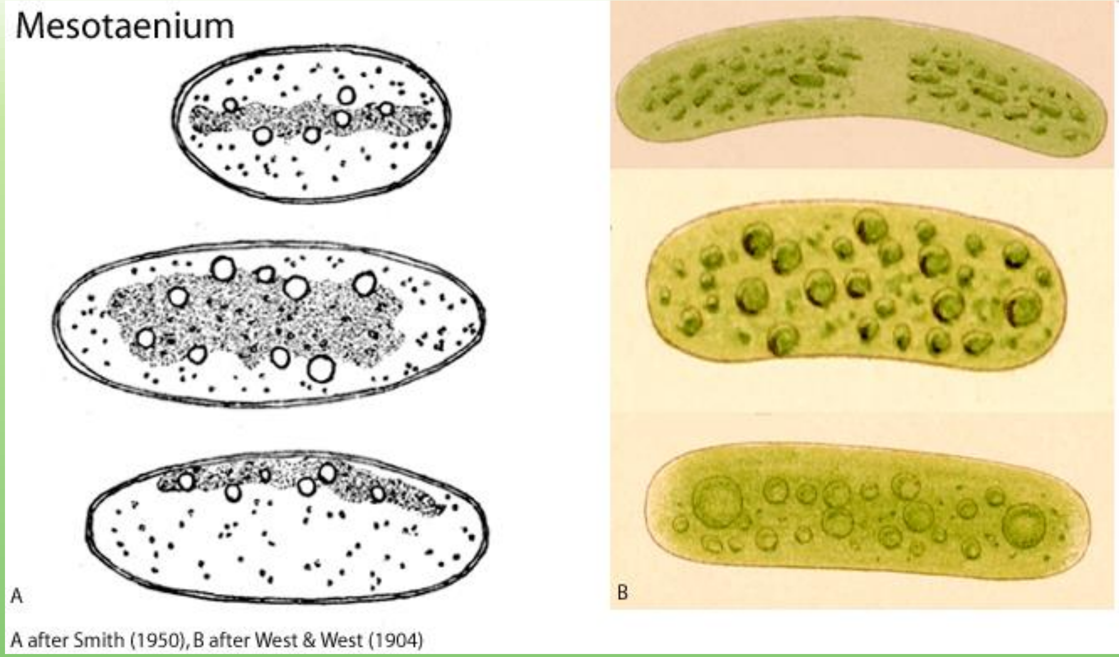


FIG. 1. Phylogeny of Zygnematophyceae based on a multigene RAxML analysis of the chloroplast genes *atpB*, *psbC* and *rbcL* analyzed as a single partition. *Zygogonium ericetorum* is highlighted in gray. Numbers above the branches represent bootstrap values from maximum parsimony and RAxML analyses and posterior probabilities from Bayesian inference, respectively. Bootstrap values less than 50 and posterior probabilities less than 0.5 are indicated with a dash.

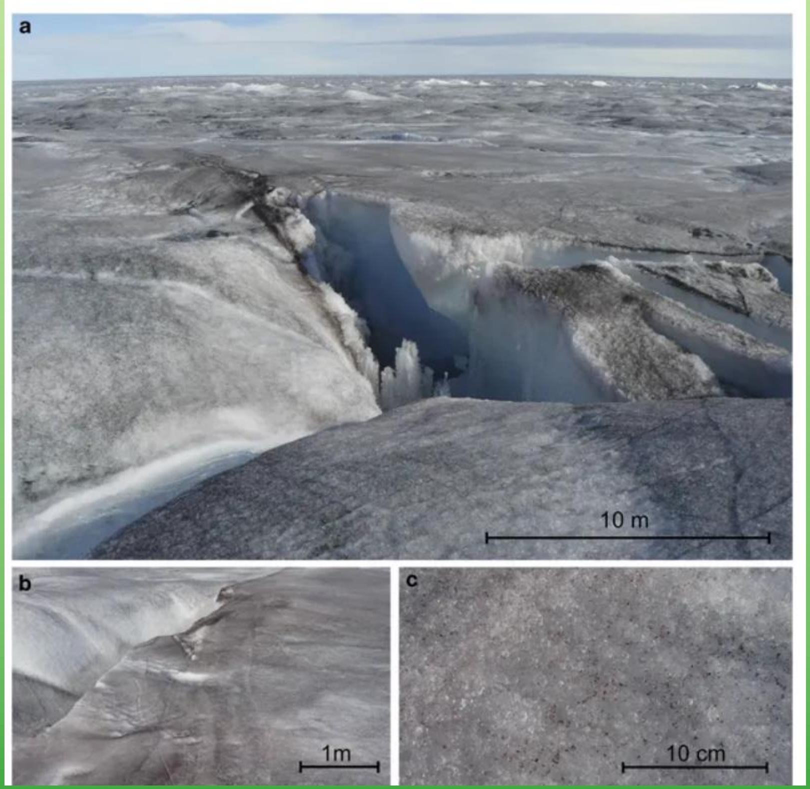
Zygnematales

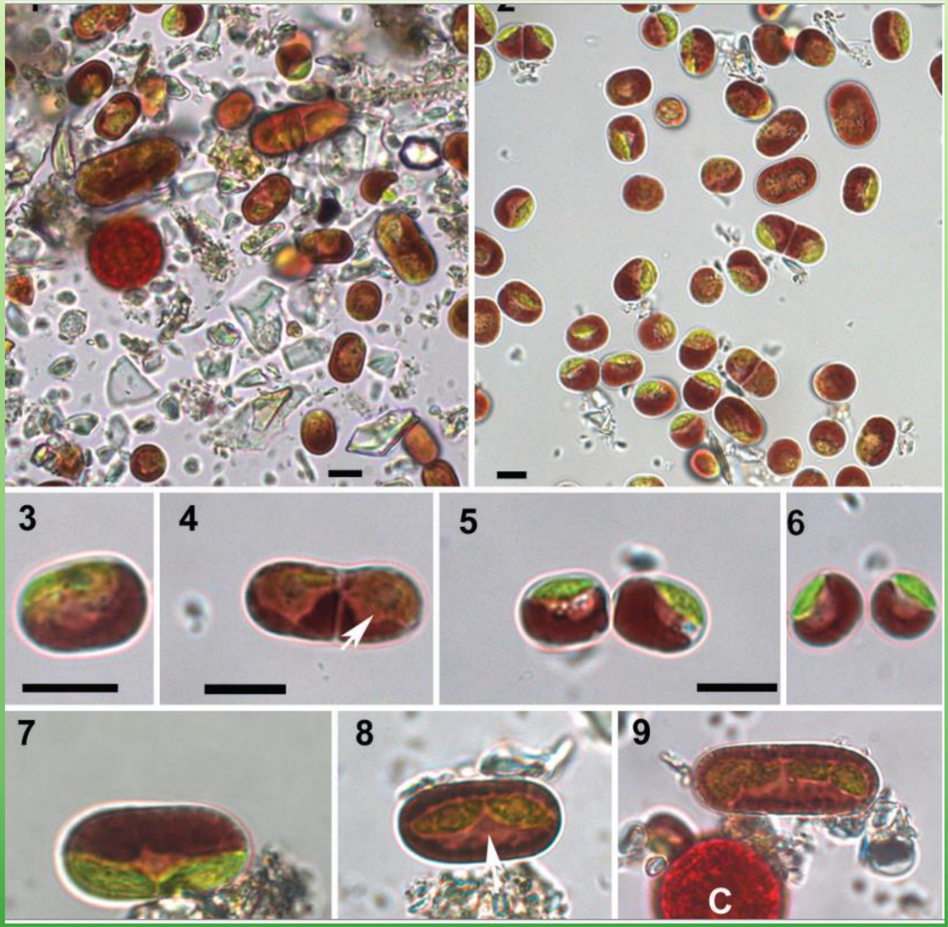
Mesotaenium



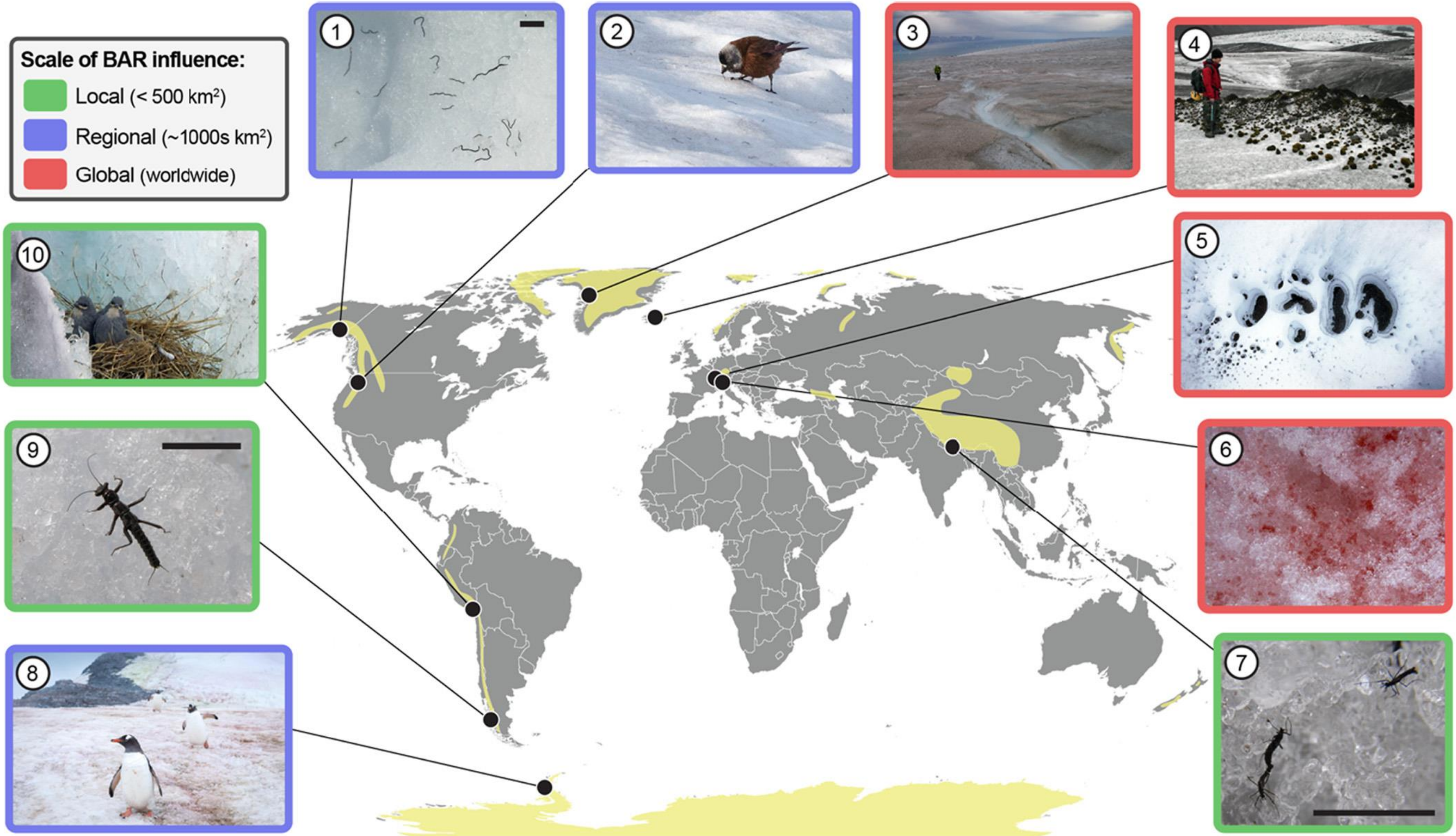
Zygnematales

Mesotaenium berggrenii





Yallop et al. (2012)



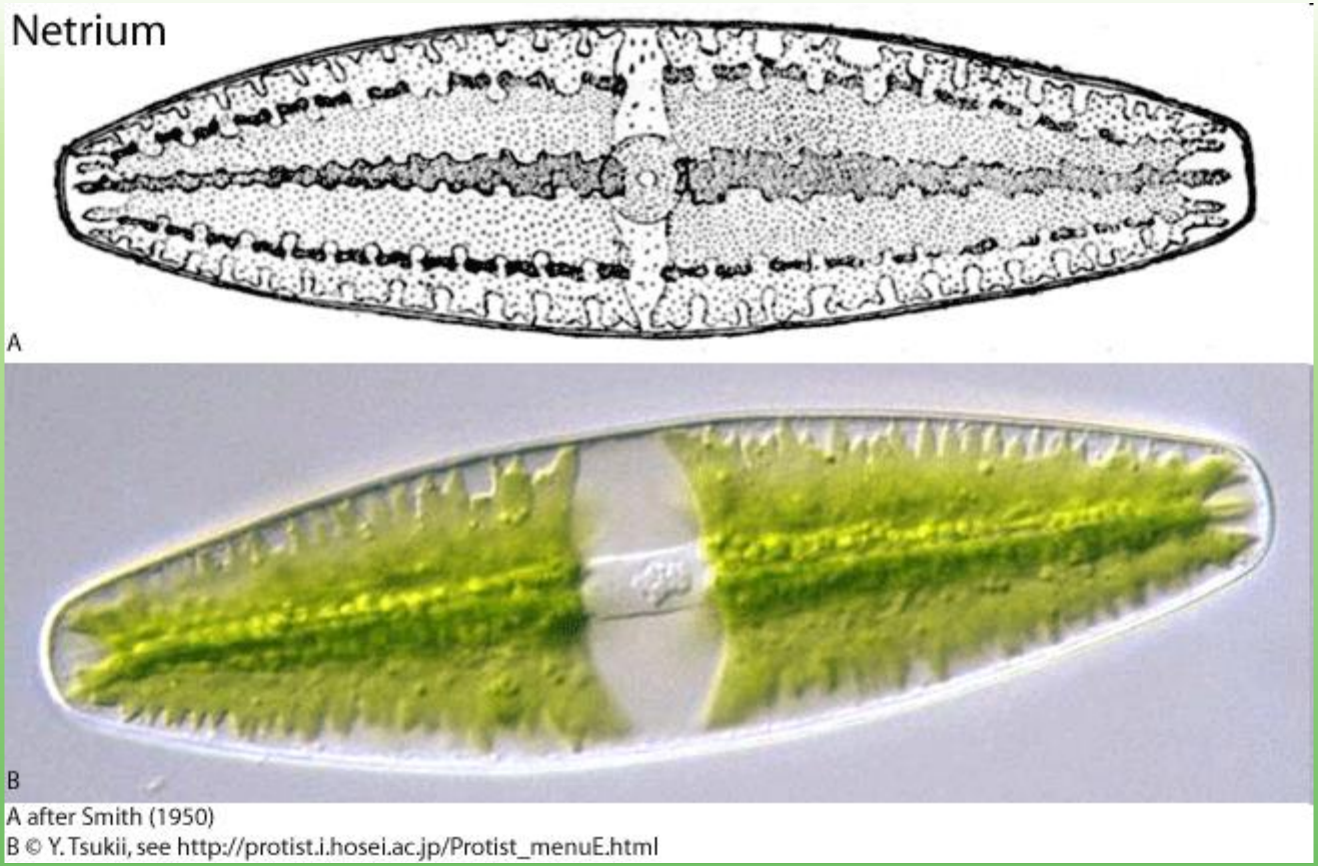
Known and potential drivers of biological albedo reduction (BAR) globally.

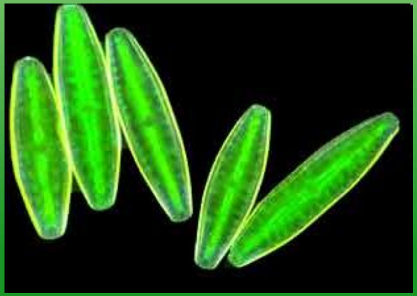
1. Ice worms are one of two annelids inhabiting mountain glaciers.
2. Gray-crowned rosy finches feed on ice worms.
3. Ice algae cover large areas of the Greenland Ice Sheet during melt.
4. Glacier moss balls occur idiosyncratically on a range of glaciers worldwide.
5. Cryoconite--conglomerations of dust and microbes--is a global driver of BAR.
6. Snow algae are a common global driver of BAR.
7. Himalayan midges are one of two midges that live on mountain glaciers.
8. Penguin input stimulates algal growth at southern latitudes.
9. Glacier-obligate stoneflies are endemic to Patagonian glaciers.
10. White-winged diuca finches nest on high Andean glaciers.

Zygnematales

Netrium

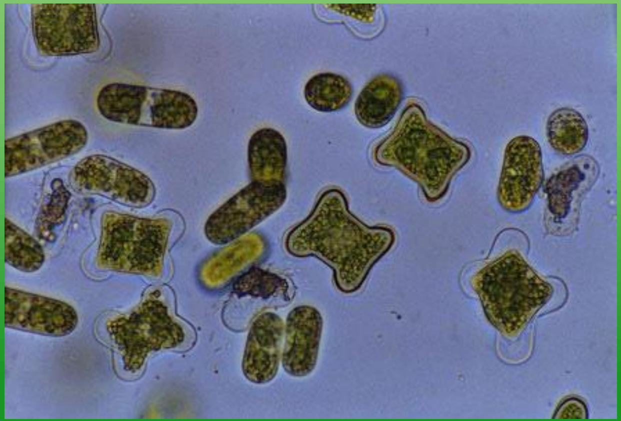
N. digitus





Zygnematales

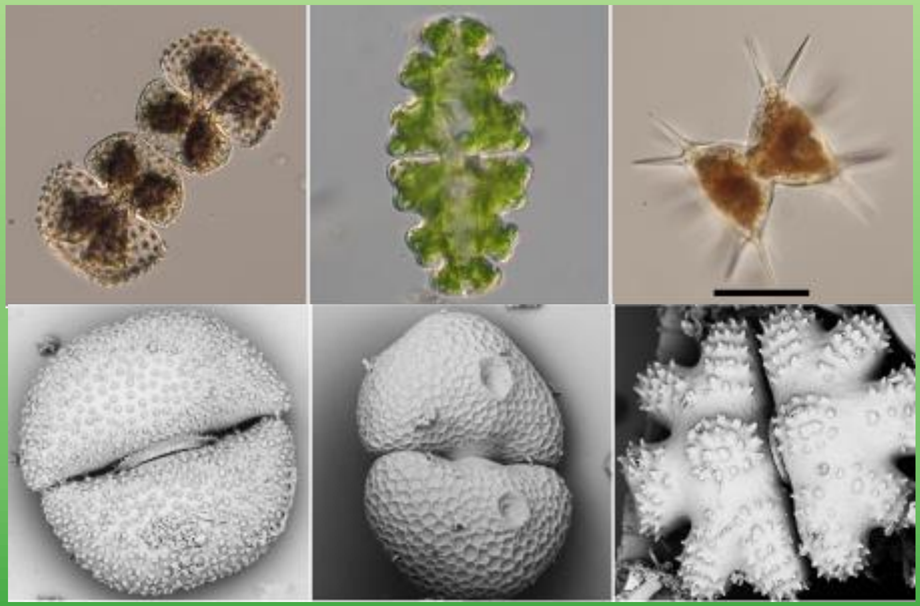
Cylindrocystis



Desmidiales - krásivky

Desmidiales

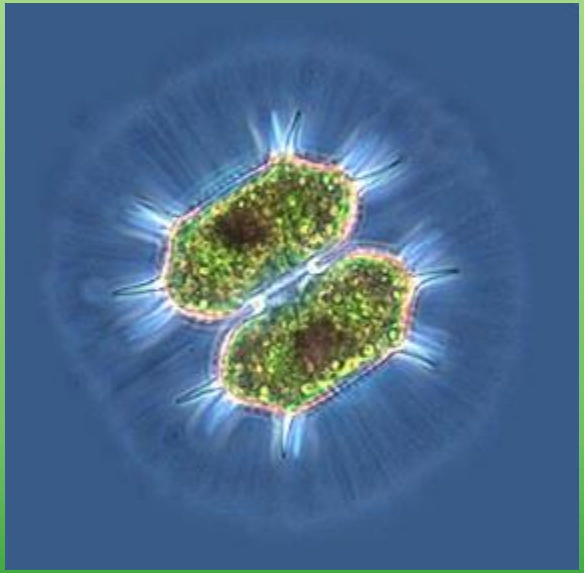
- isthmus, 2 semicells, sinus
- pores in cell walls
- Fossil records from Jurrasic and Cretaceous



Desmidiales

Mucilage

„mucilage vesicles"



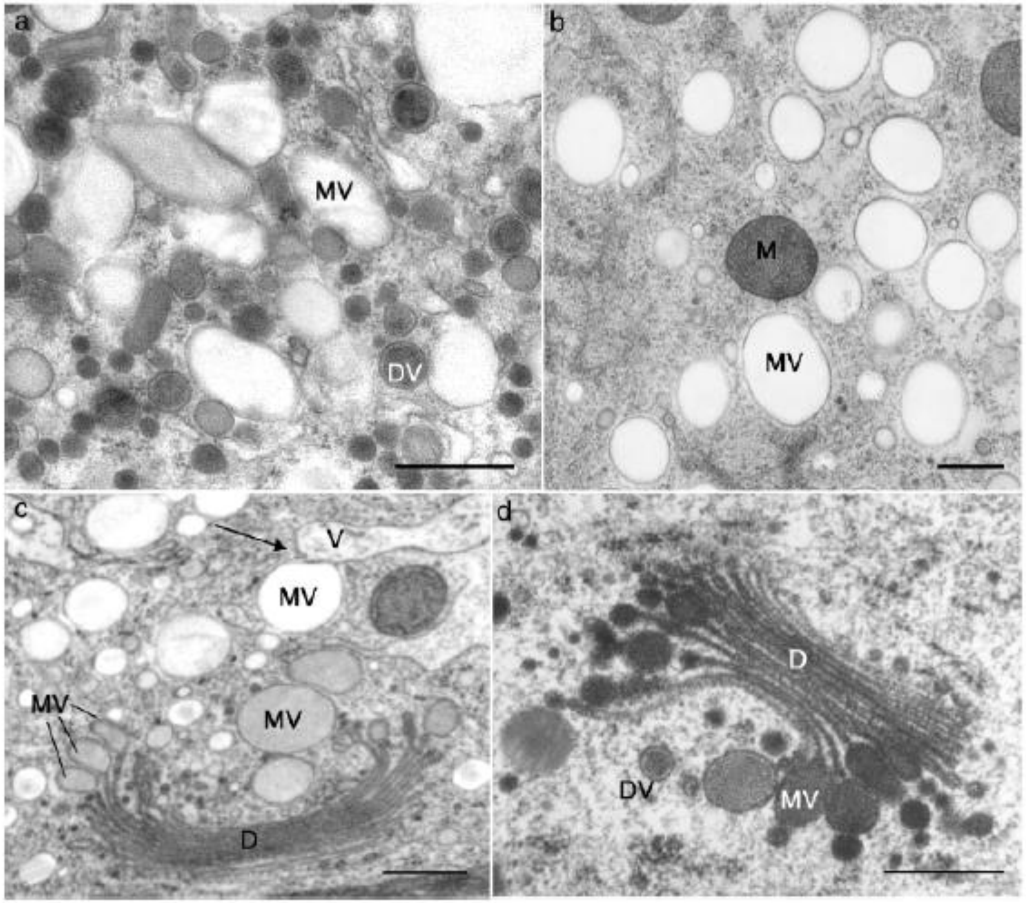


FIG. 2. Electron micrographs show mucilage vesicles (MV) in the cytoplasm and their maturation at the dictyosome (D) after different fixation methods. (a) MVs and primary wall forming dark vesicles (DV). Developing half cell after chemical fixation. (b) MVs in a high pressure-frozen and freeze-substituted interphase cell. (c) High contrast image of a high pressure-frozen interphase cell, production of MVs at a dictyosome, distribution in the cytoplasm, and fusion with a vacuole (arrow). (d) Dictyosome of a young developing half cell pinching off DVs and MVs, chemical fixation. M, mitochondrium. Scale bar, 0.5 μm.

Desmidiales

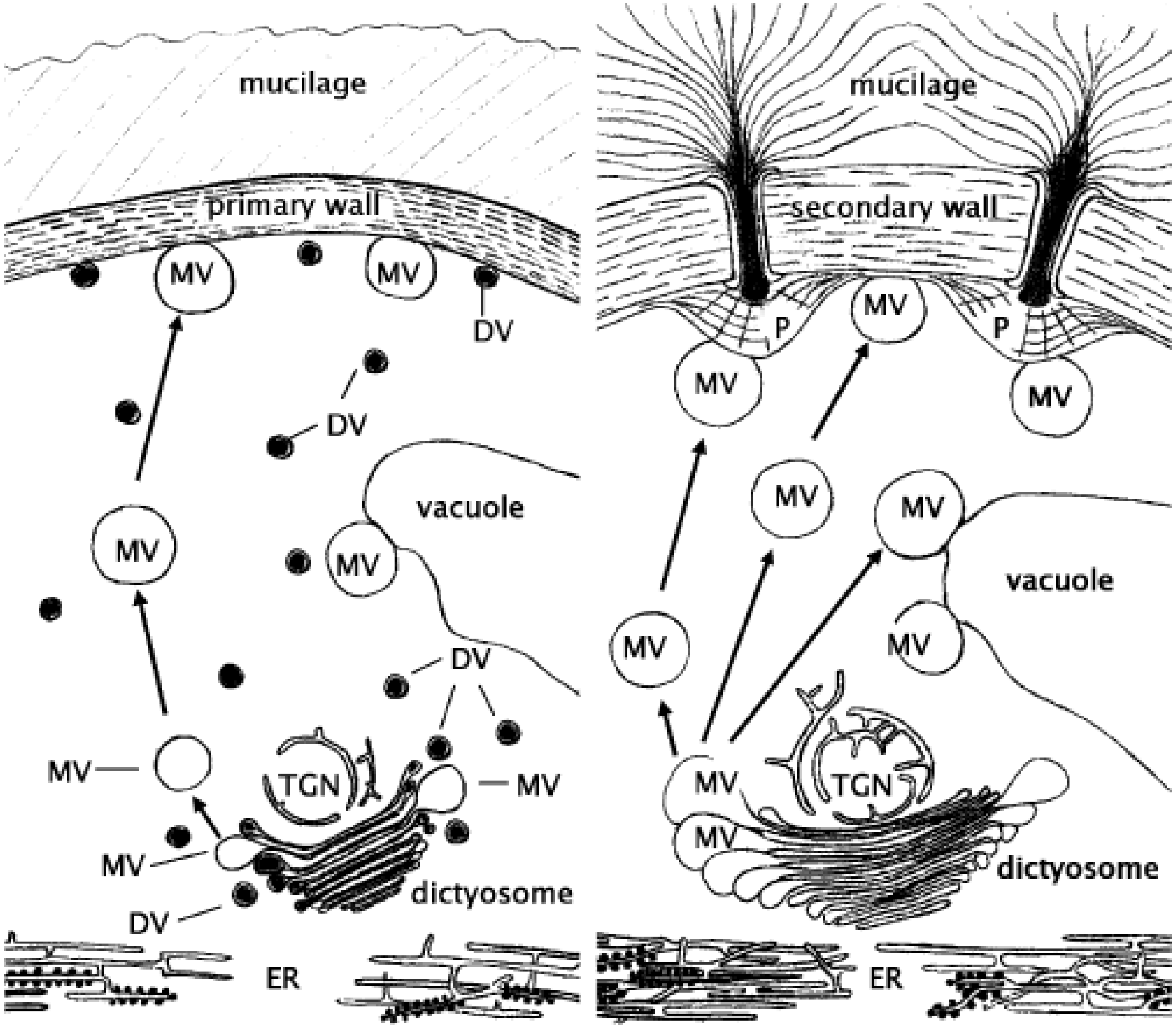


FIG. 6. Schematic drawing illustrating the secretory pathway of MVs in a growing (a) and a nongrowing *Micrasterias* cell (b). DV, dark vesicle; ER, endoplasmic reticulum; P, pore; TGN, trans-Golgi network.

Oertel et al. (2004)

Desmidiales

Mucilage

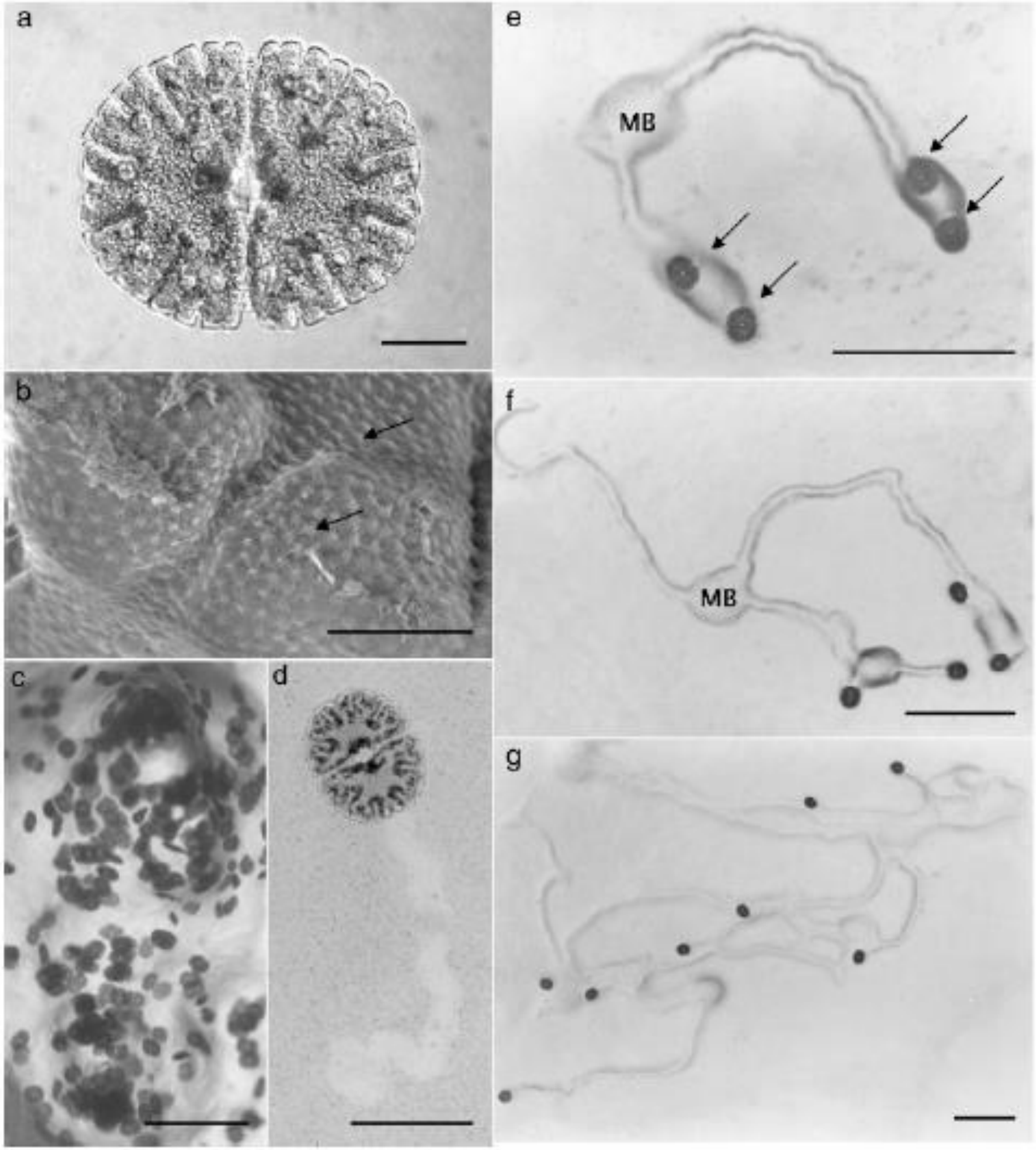
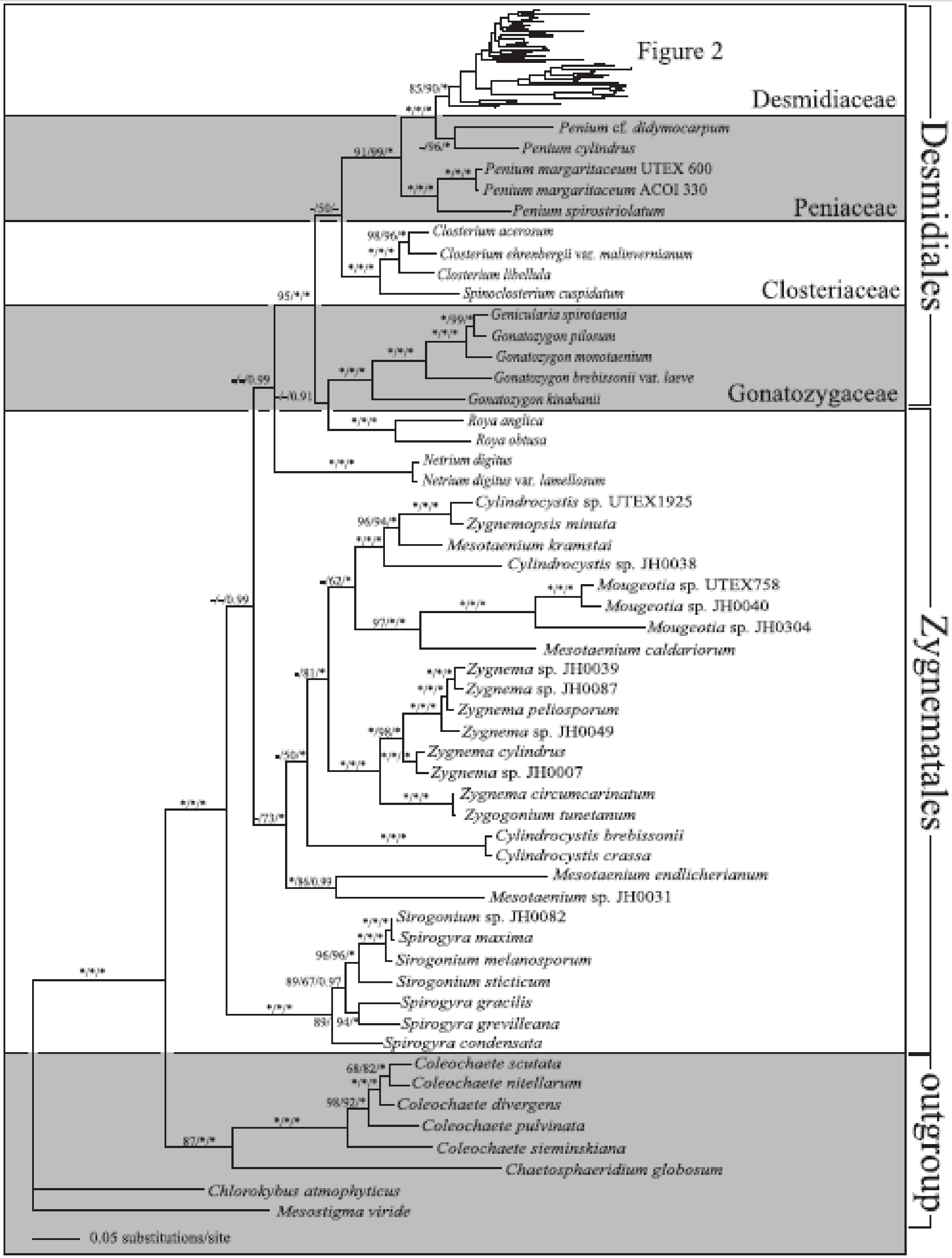


FIG. 1. (a) Interphase cell of *Micrasterias denticulata*. Scale bar, 50 µm. (b) Distribution of cell wall pores (arrows) at polar region and adjacent surface area, SEM micrograph. Scale bar, 10 µm. (c) Mucilage–algae accumulations on agar plates. Scale bar, 1 mm. (d) Mucilage track excreted from a polar lobe visualized by diluted Indian ink. Scale bar, 200 µm. (e–g) Mucilage tracks produced by algae in 2 weeks. (e) 1% agar, algae separating after mitosis and leaving mucilage bags (arrows). (f) 0.75% agar. (g) 0.5% agar. MB, mucilage bag. Scale bar, 1 mm.

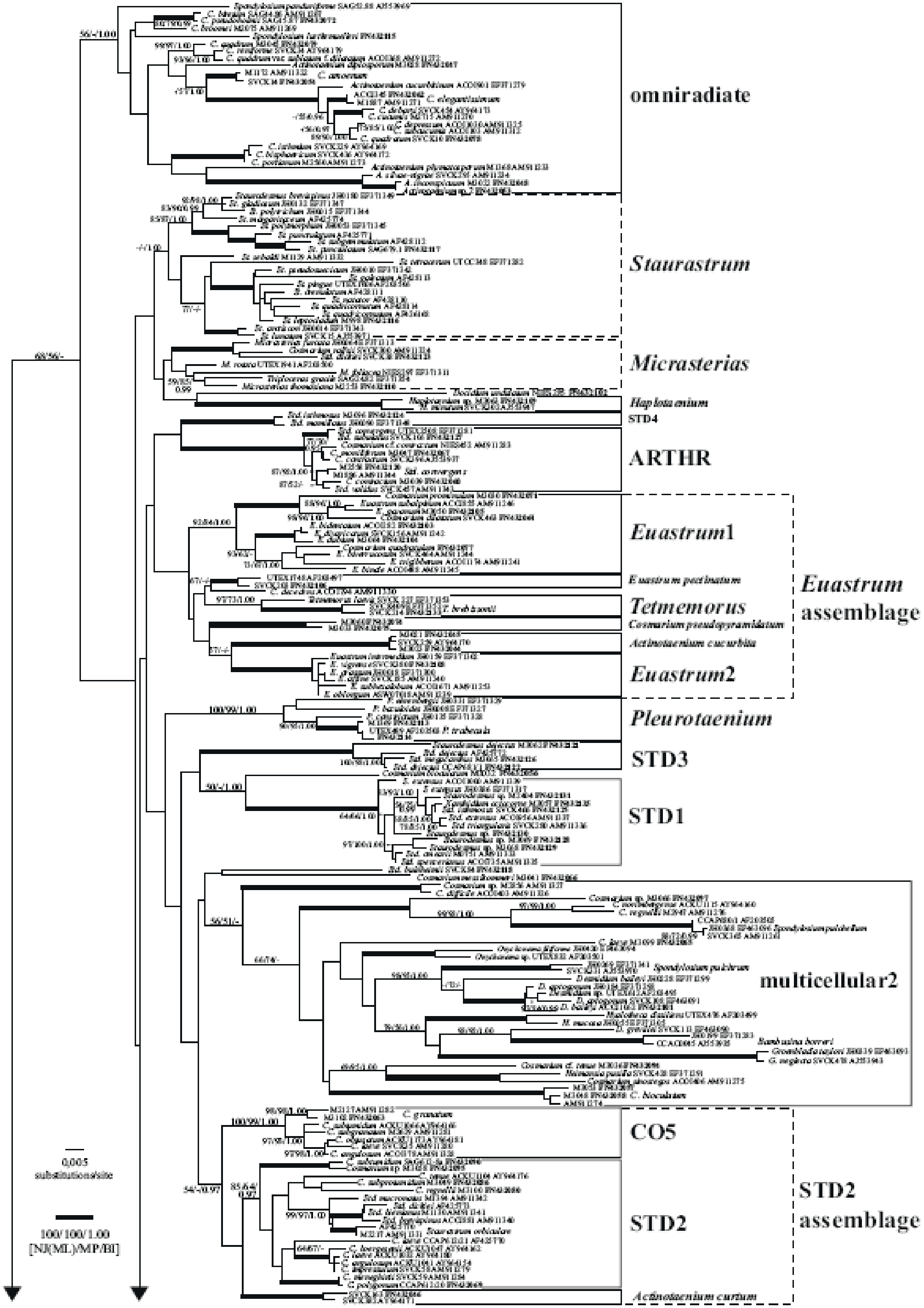
Oertel et al. (2004)



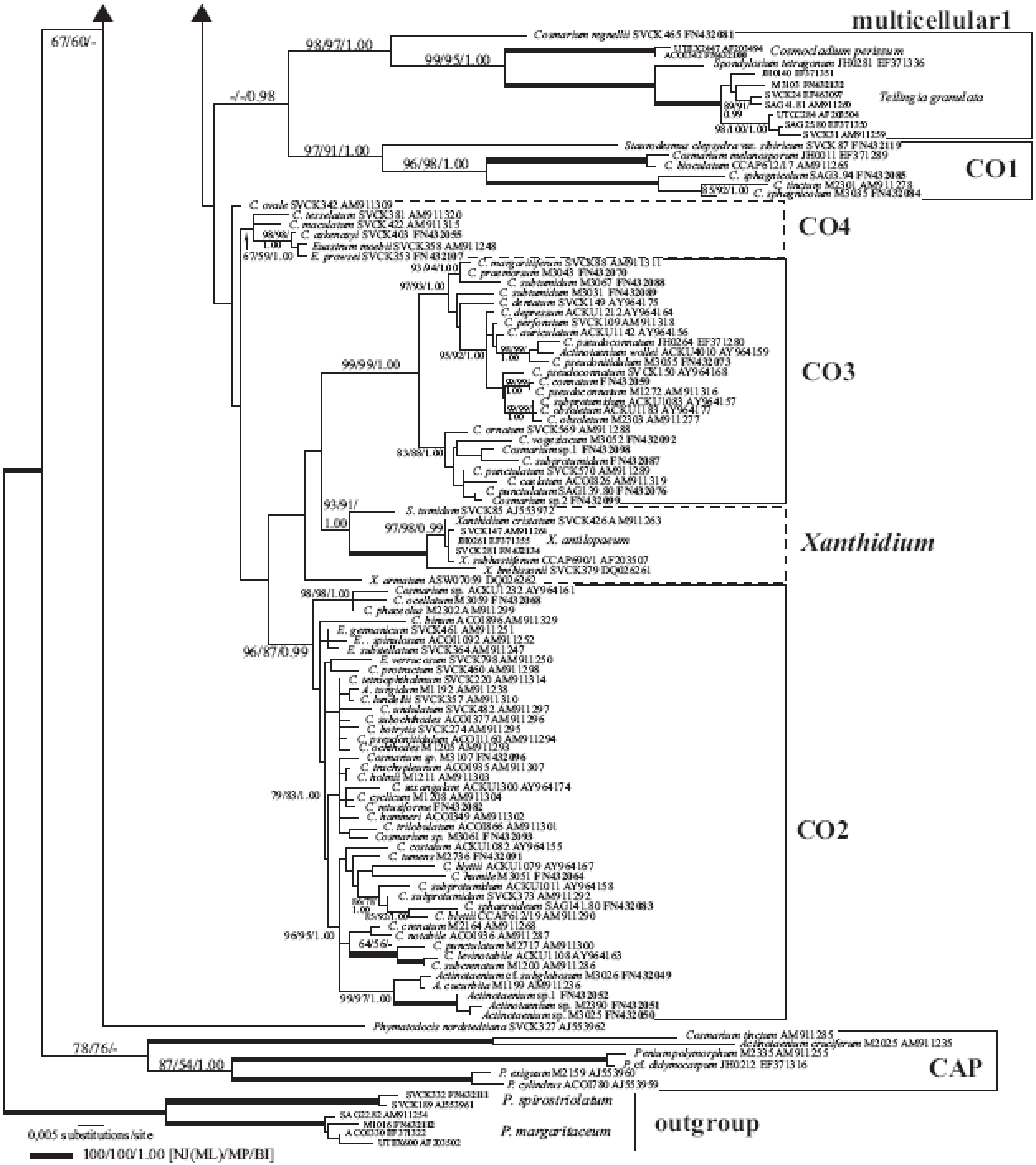
Desmidiales

Hall et al. (2008)

Desmidiales



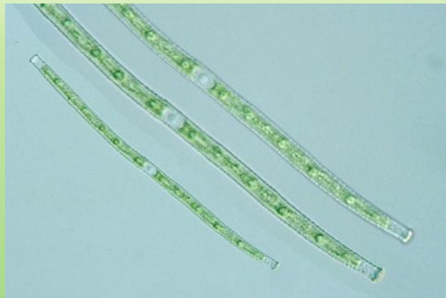
Gontcharov & Melkonian (2011)

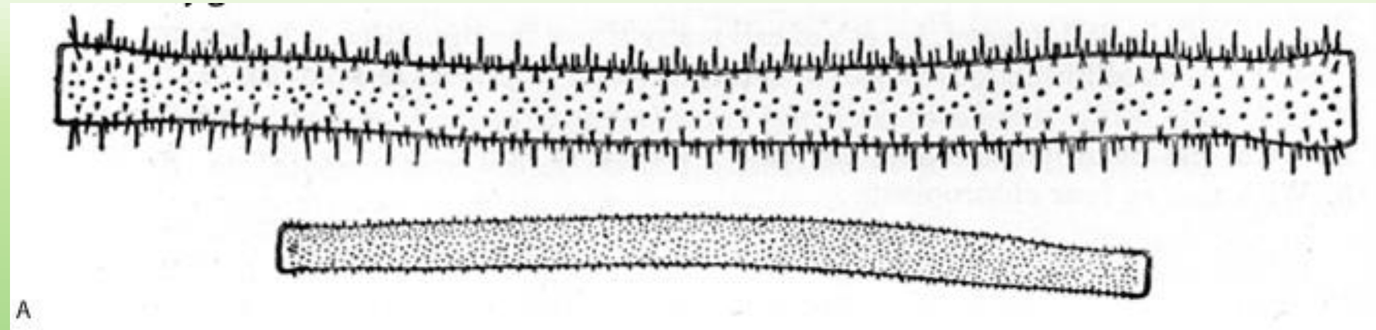


multicellular1
CO1
CO4
CO3
Xanthidium
CO2
CAP
outgroup
Cosmocladium perissum
Teilingia granulata
X. antilopaeum
P. spirostriolatum
P. margaritaceum
67/60/-
98/97/1.00
99/95/1.00
-/-/0.98
97/91/1.00
96/98/1.00
99/99/1.00
93/91/
1.00
97/98/0.99
96/87/0.99
78/76/-
87/54/1.00
0,005 substitutions/site
100/100/1.00 [NJ(ML)/MP/BI]

Family: Gonatozygaceae

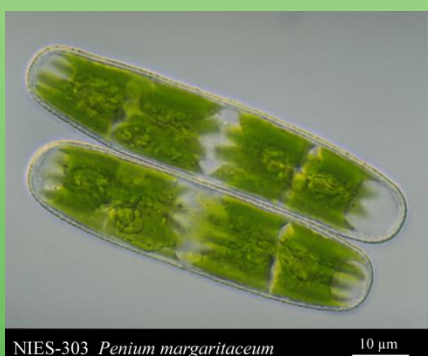
Gonatozygon

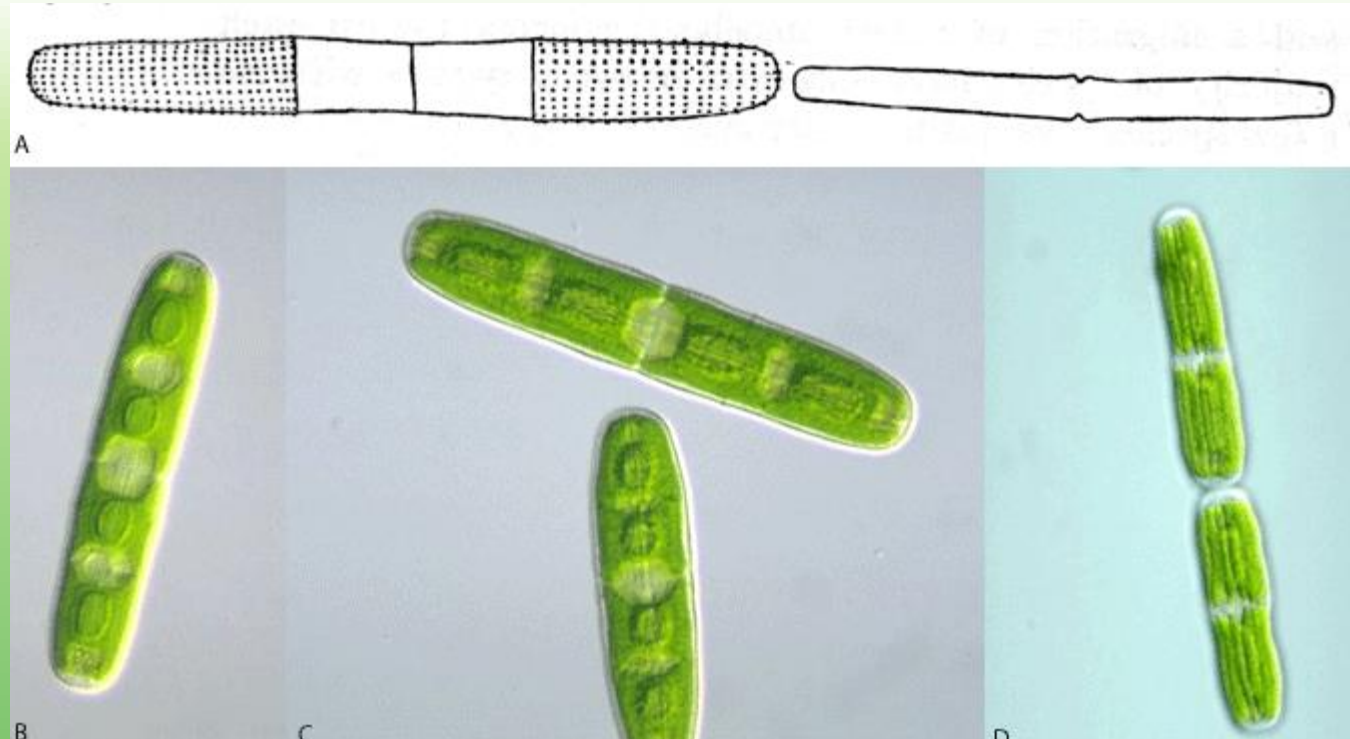


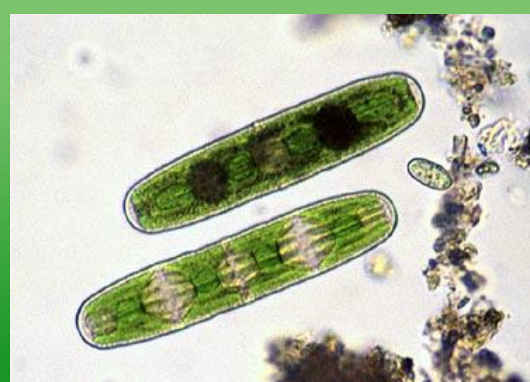


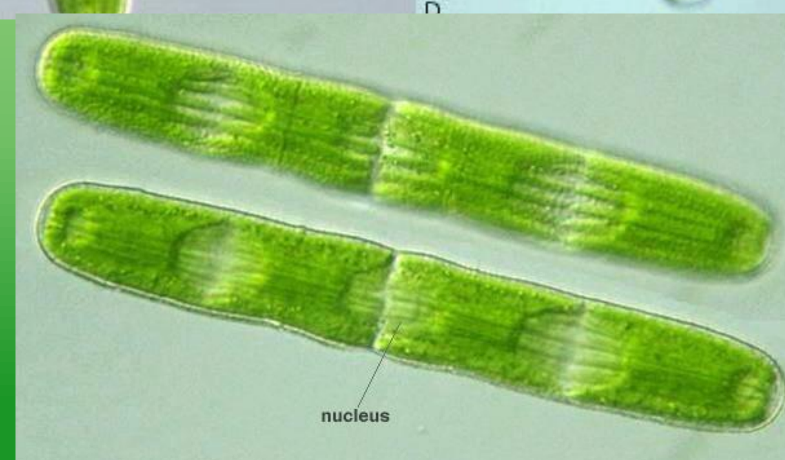
Family: Peniaceae

Penium



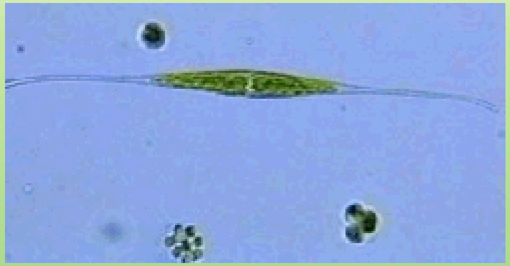


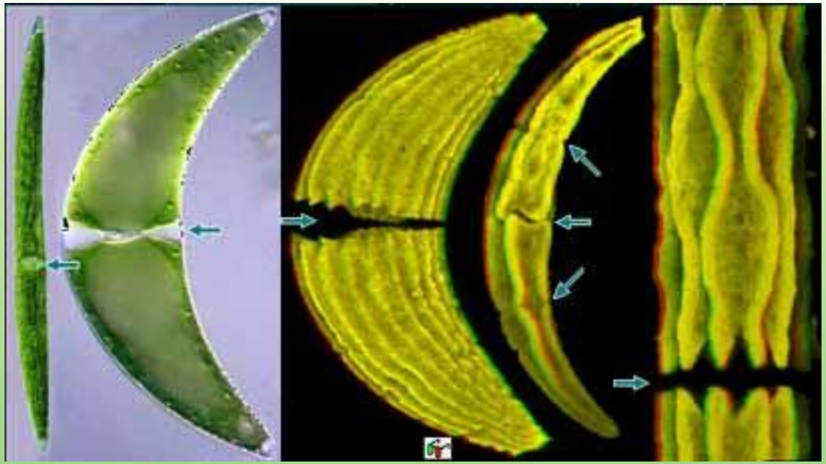




Family: Closteriaceae

Closterium





Closterium

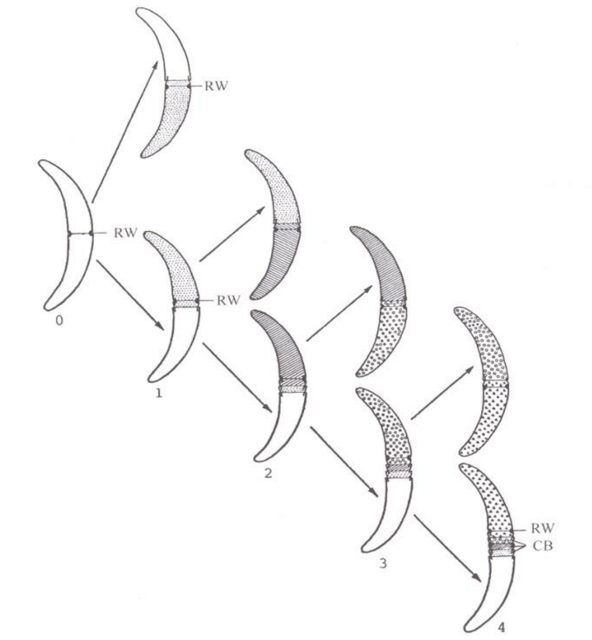


Fig. 9. Cell division in a *Closterium* species without girdle bands (schematically): 0 = germling cell; 1 = daughter cells; 2-4 = three subsequent generations; RW = ring-wall; CB = cross-band (breadth of cross-band largely exaggerated). After Rieth, 1961.

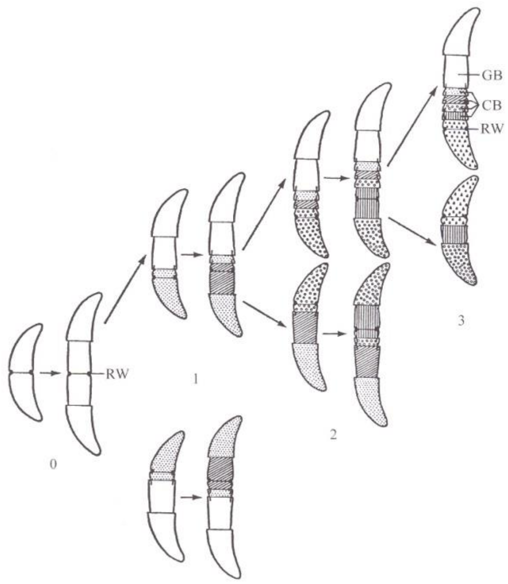


Fig. 10. Cell division in a *Closterium* species with girdle bands (schematically): 0 = germling cell; 1 = daughter cells; 2-3 = two subsequent generations; RW = ring-wall; CB = cross-band (breadth of cross-band largely exaggerated); GB = girdle band. After Rieth, 1961.

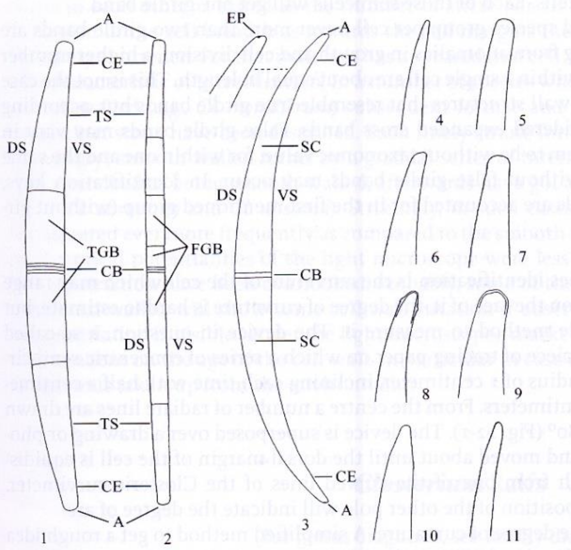


Fig. 11. Morphology terminology in *Closterium*:
1-3: Cell wall segmentation.
1 = cell with true girdle bands;
2 = cell with false girdle bands;
3 = cell without girdle bands.
A = apex (top); CB = cross-band;
CE = cell end; DS = dorsal side;
EP = end-pore; FGB = false girdle band;
SC = semicell (half-cell);
TGB = true girdle band;
TS = top segment (terminal segment);
VS = ventral side.
4-11: Apex shapes.
4 = narrowly rounded;
5 = broadly rounded;
6 = truncate;
7 = capitate;
8 = lanceolate;
9 = cowl-shaped;
10 = conical;
11 = recurved.
Modified after Růžička, 1977.

Closteriaceae

Sexual feromones

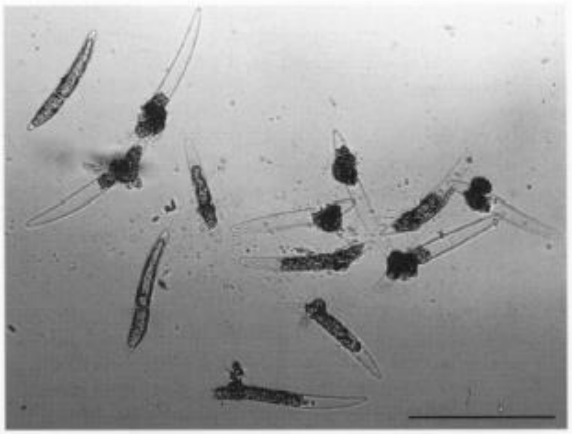
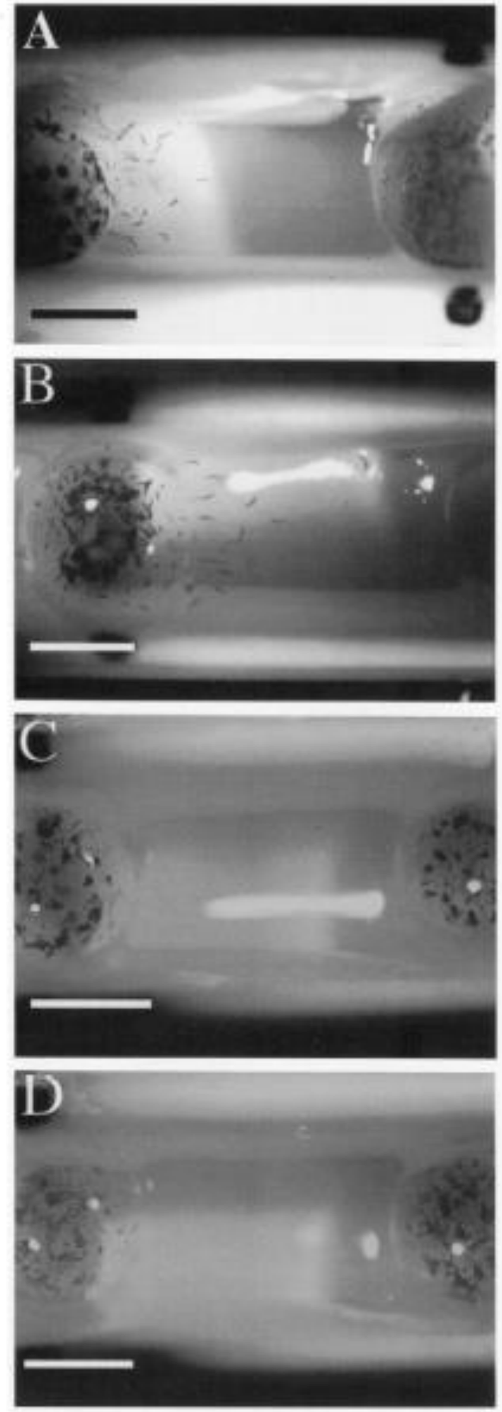


Fig. 2. Effect of culture medium on the release of protoplasts from mt⁻ cells of *Closterium p-s-l* complex. Mt⁻ cells were incubated in MI medium in which mt⁺ and mt⁻ cells had been cultured together. Most of them are in the process of releasing protoplasts (formation of papillae, condensing of cytoplasm, release of protoplasts) without paring. Scale bar=100 μm.

Table 1. Comparison of two sex pheromones isolated from *Closterium peracerosum-strigosum-littorale* complex.

	PR-IP	PR-IP inducer
Producer	mt⁺ cells	mt⁻ cells
Receiver	mt⁻ cells	mt⁺ cells
Activity	Induction of protoplast-release	Induction of production of PR-IP
Receptor	Binding 19-kDa subunit ; appeared under low cell density culture conditions in light	NA
Molecular state	Hetero-tetramer of two 42-kDa and two 19-kDa glycopolypeptides	Monomer of 18.7-kDa glycopolypeptide
Gene expression	Transiently induced in the presence of the inducer and light	Induced in the nitrogen-depleted medium and light

NA ; not analyzed



+ and **–** cells

+ cells and medium from **–** cells

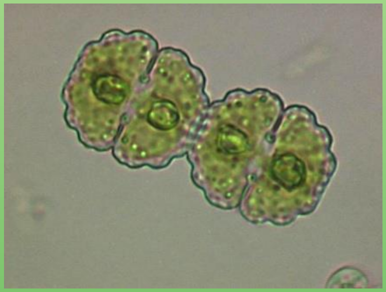
+ and **+** cells

- and - cells

Sekimoto (2000)

Family: Desmidiaceae

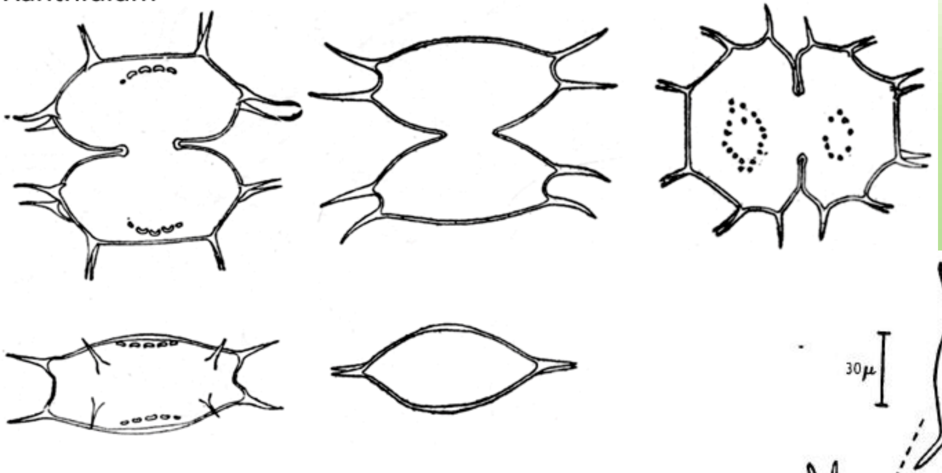
Cosmarium



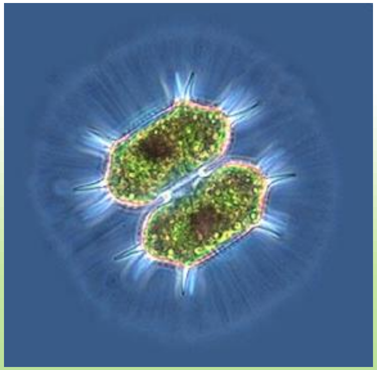
Desmidiaceae

Xanthidium

Xanthidium



All illustrations after Smith (1950)
B after Entwisle et al. (1997)



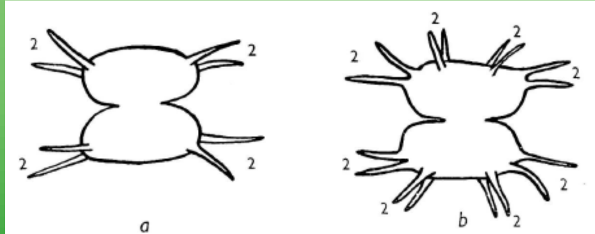


Fig. 1. Diagrams of two types of *Xanthidium* cells with the formulæ (*a*) 22/22, (*b*) 2222/2222.

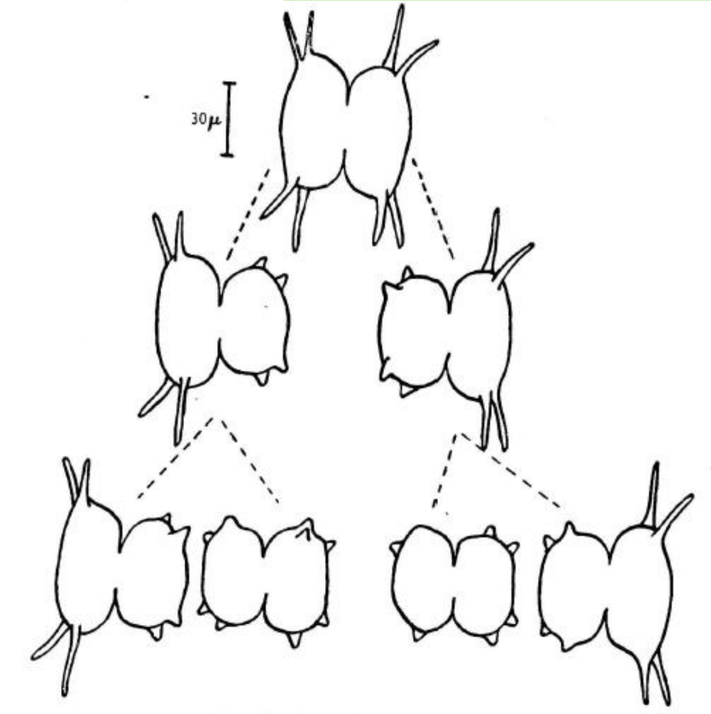
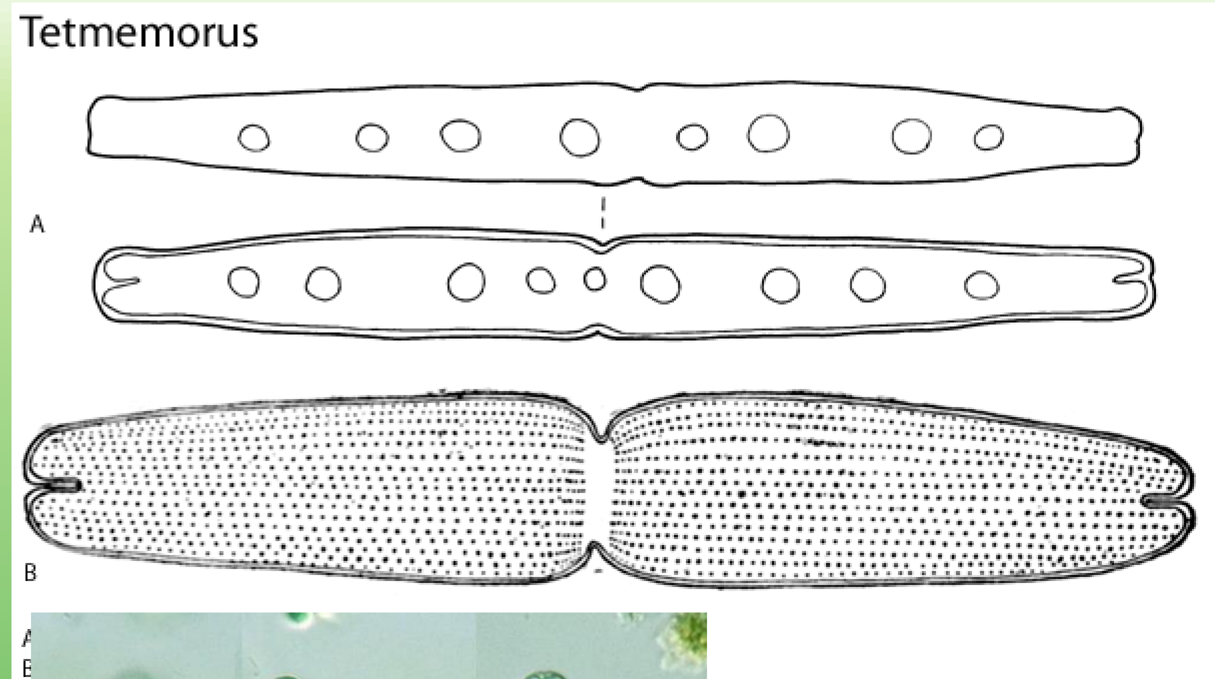


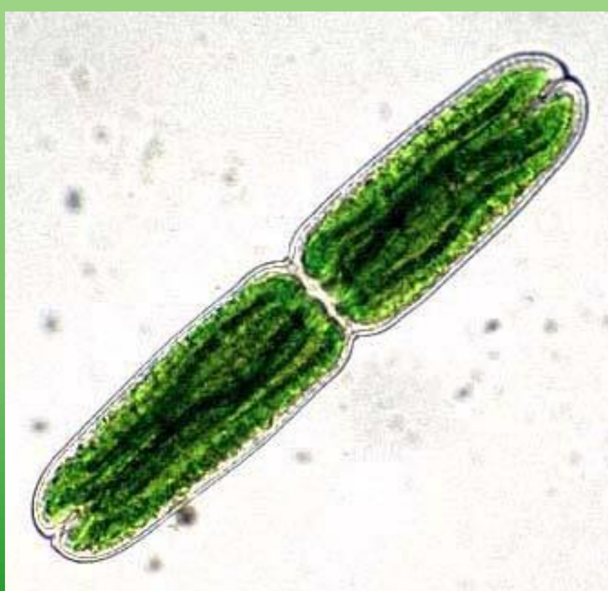
Fig. 3. *Xanthidium subhastiferum*. Cell types arising from two successive divisions starting with a 22/22 cell, on agar.

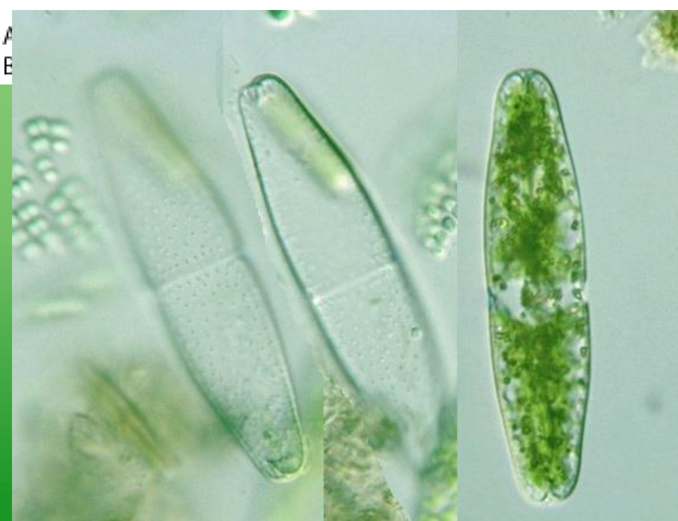
Rosenberg (1944)

Desmidiaceae

Tetmemorus

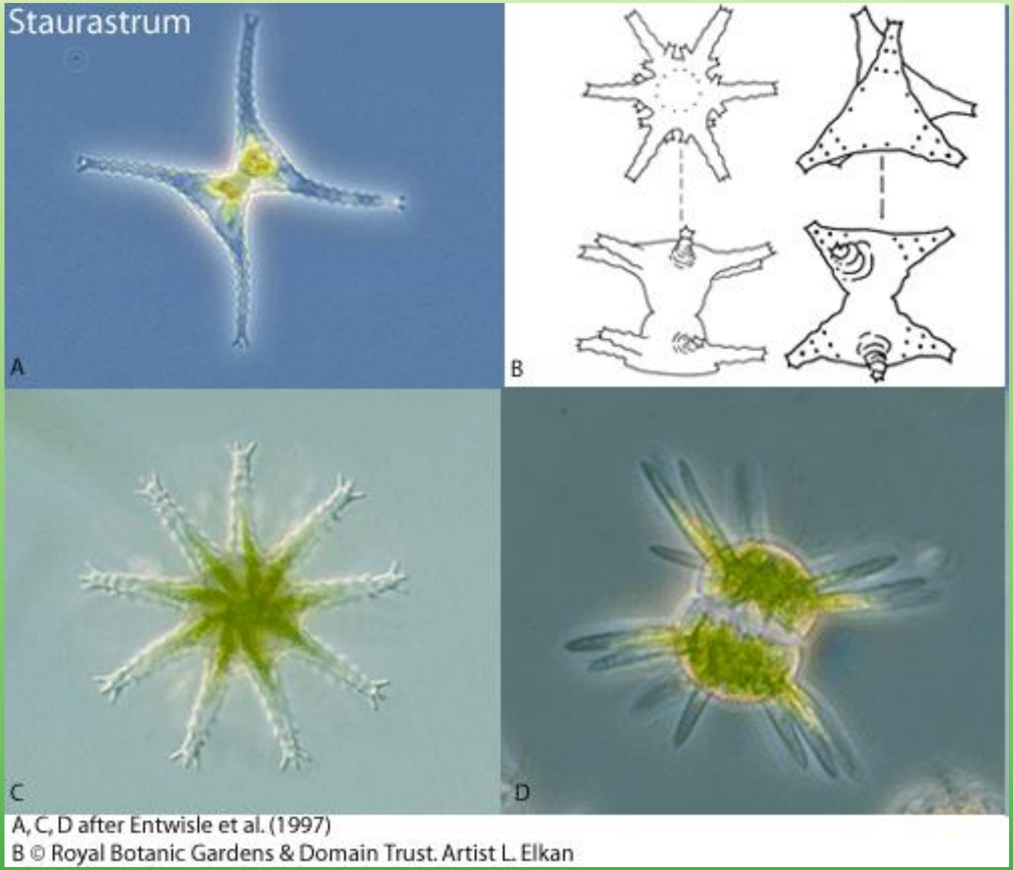


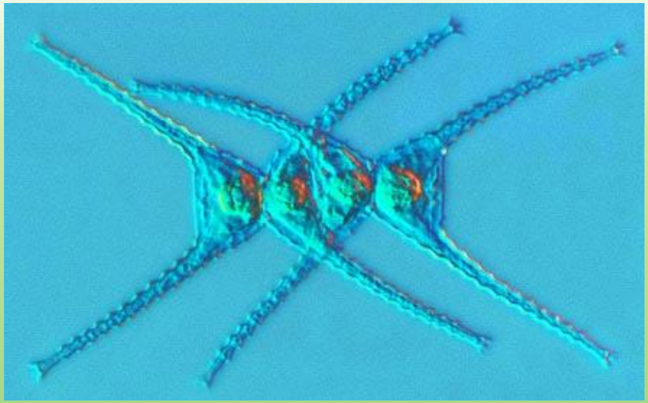




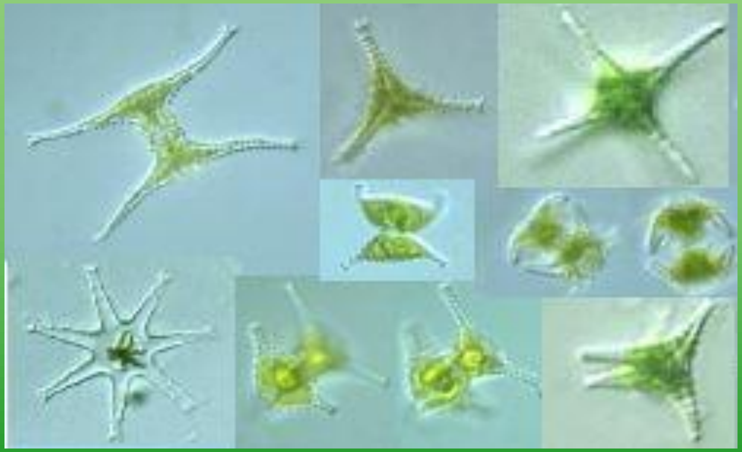
Desmidiaceae

Staurastrum





S. chaetoceras



Staurastrum

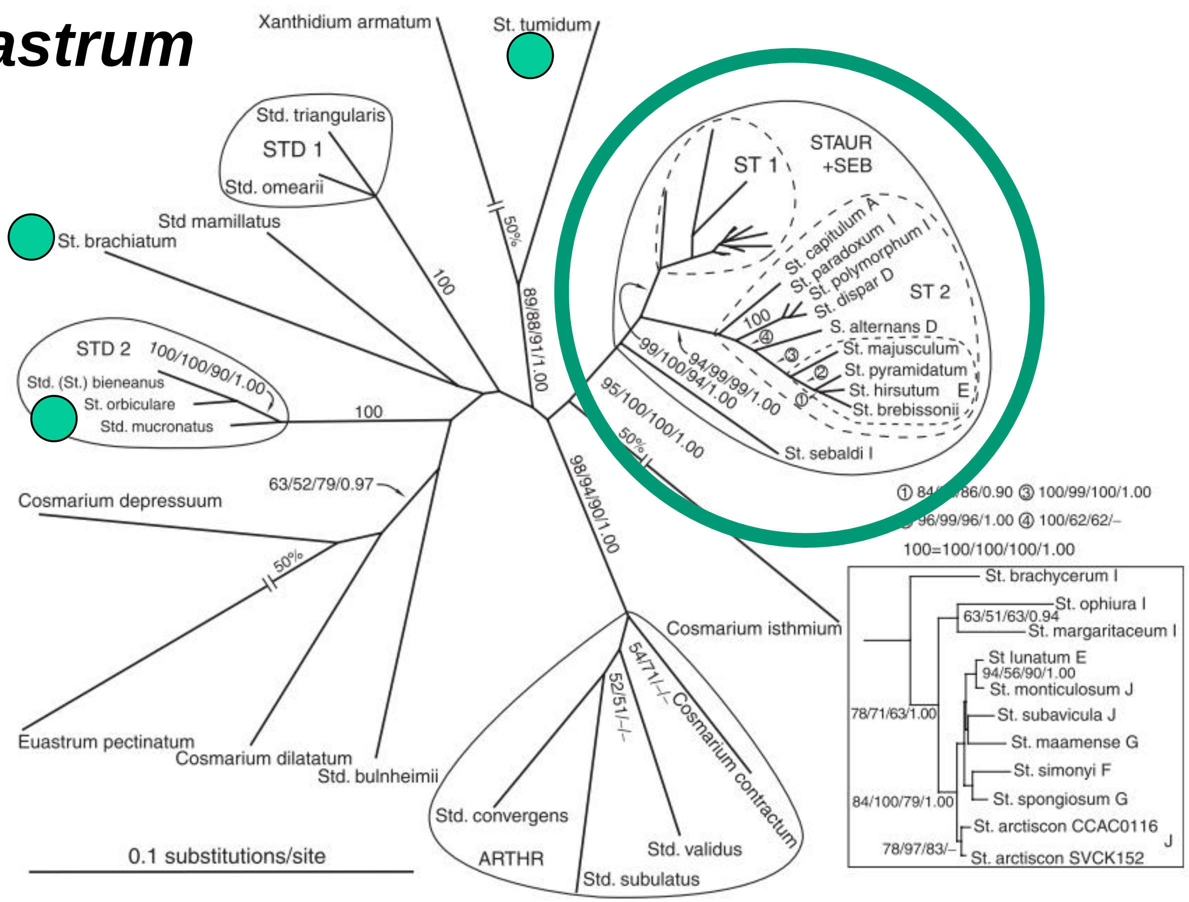
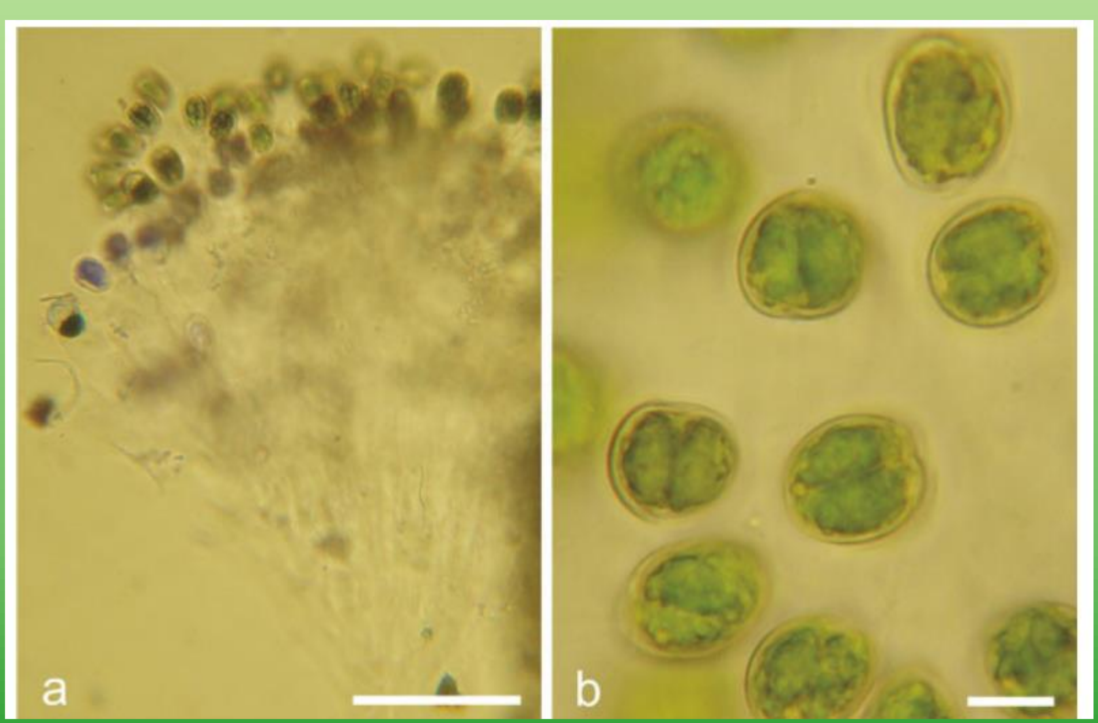


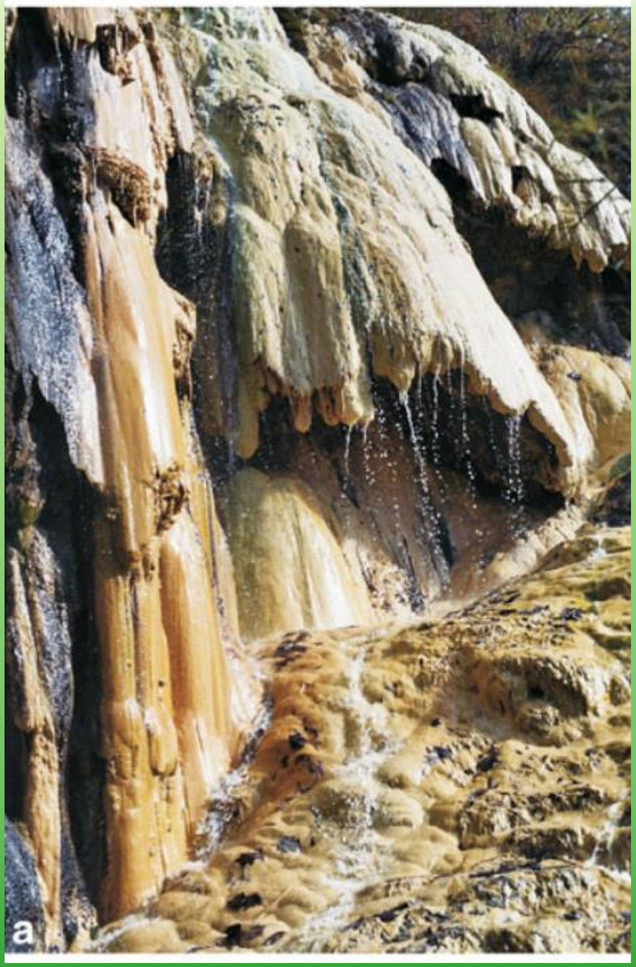
FIG. 5. Unrooted phylogenetic tree of 39 strains (38 species) representing five traditional desmid (Desmidiaceae, Zygnematophyceae) genera based on comparisons of concatenated coding (SSU rDNA and 5.8S) and noncoding (1506 group I intron, ITS1, and ITS2) rDNA sequences (2633 aligned positions). The tree shown was constructed with ML (TrN + I + Γ, for model parameters, see Table 2). BP ≥ 50% for ML/NJ (TrN + I + Γ)/MP and PP ≥ 0.9 (Bayesian inference) values are given for the nodes; long branches are graphically reduced to 50%. For abbreviation of clade names, see Results. Sections of *Staurastrum* (STAUR + SEB) according to West and West (1912) are labeled by capital letters (A, D, E, F, G, I, and J).

Gontcharov & Melkonian (2005)

Desmidiaceae

Oocardium

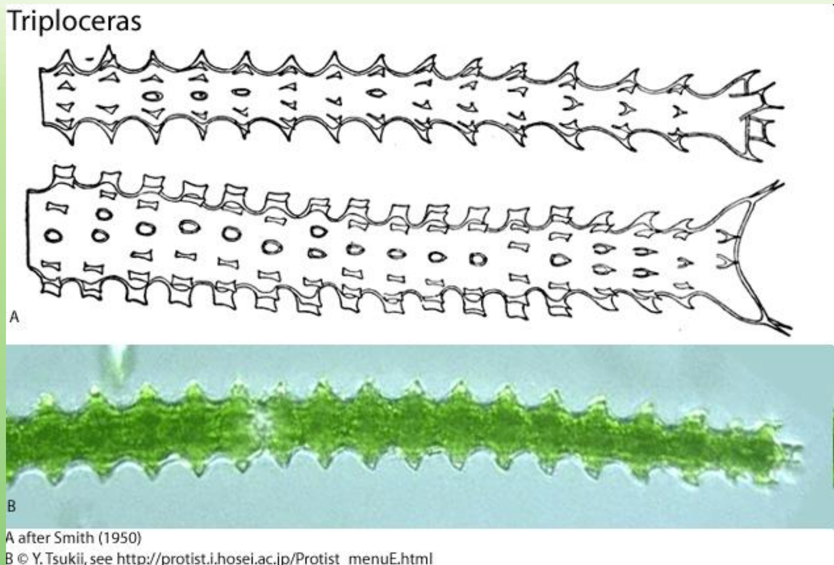




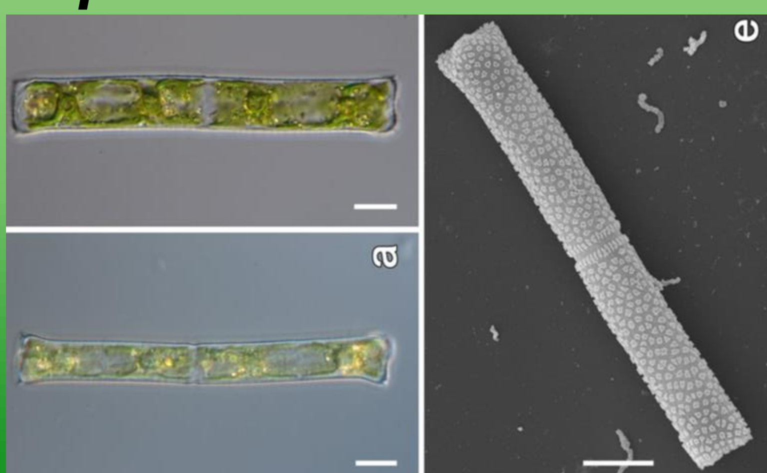
Rott et al. (2010)

Desmidiaceae

Triploceras



Triplastrum



Škaloud et al. (2012)

Rod-shaped genera

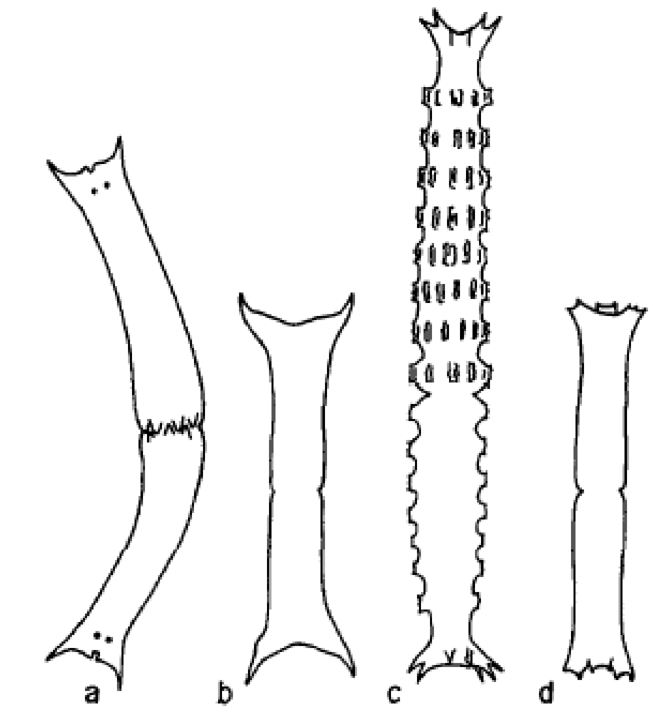
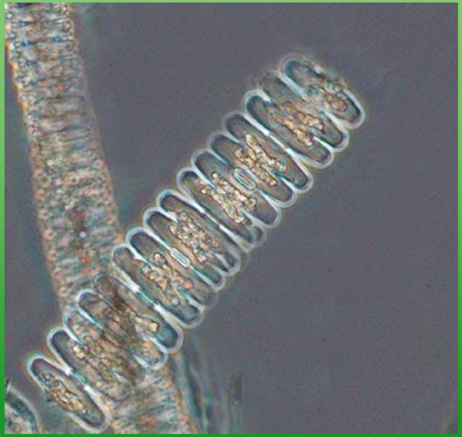
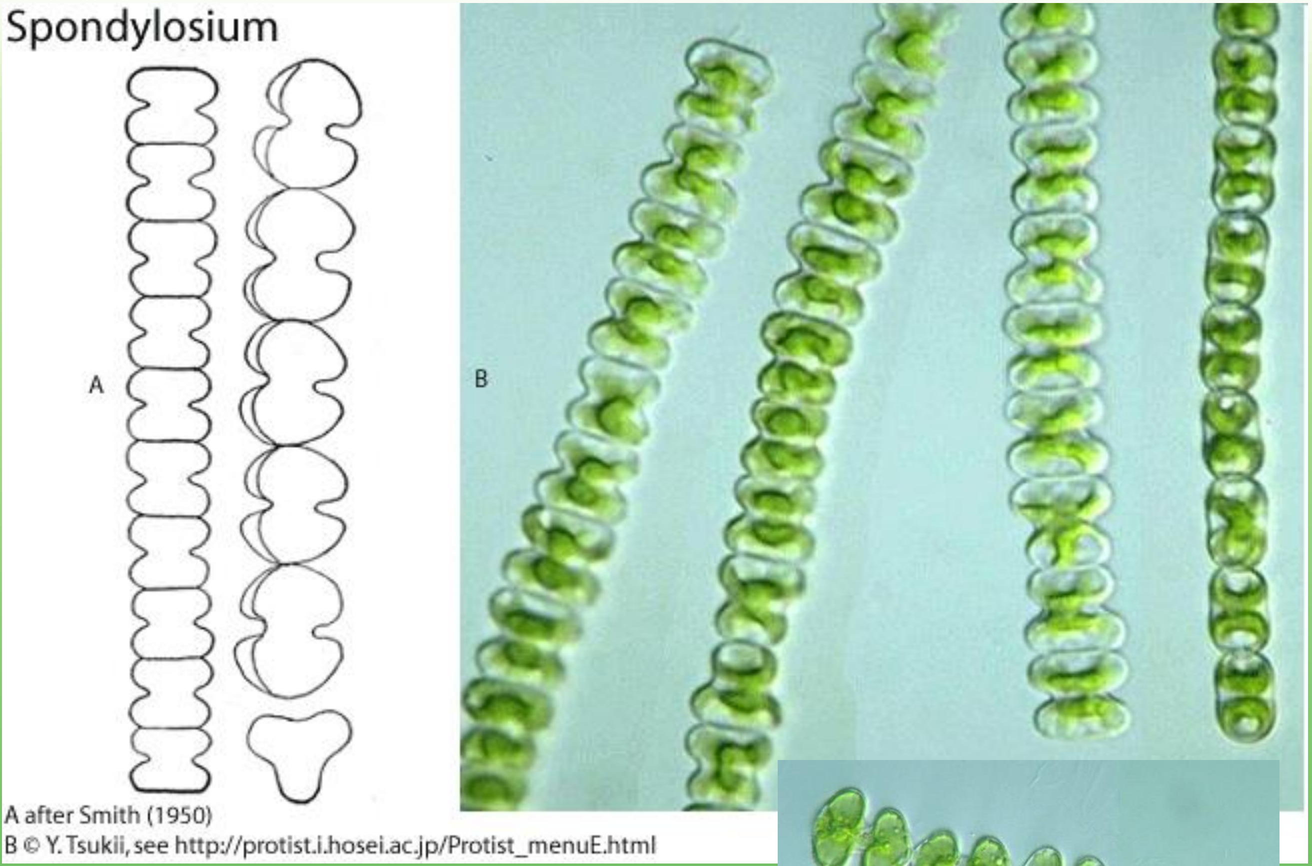


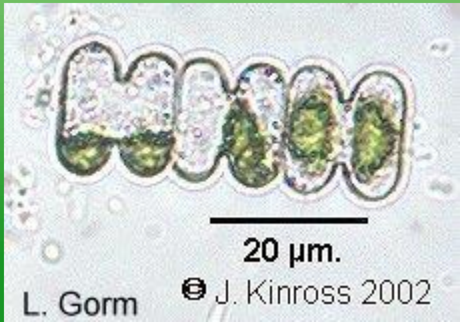
Figure 8. Four genera with a mainly tropical distribution, radiating to different extent into colder climatic regions. a. *Ichthyodontum (I. sachlanii)*, b. *Ichthyocercus (I. longispinus)*, c. *Triploceras (T. verticillatum* var. *minor)*, d. *Triplastrum (T. spinulosum* var. *africanum)* (a. after Scott & Prescott, 1956; b–d. after Gauthier-Lièvre, 1960).

Desmidiaceae

Spondylosium

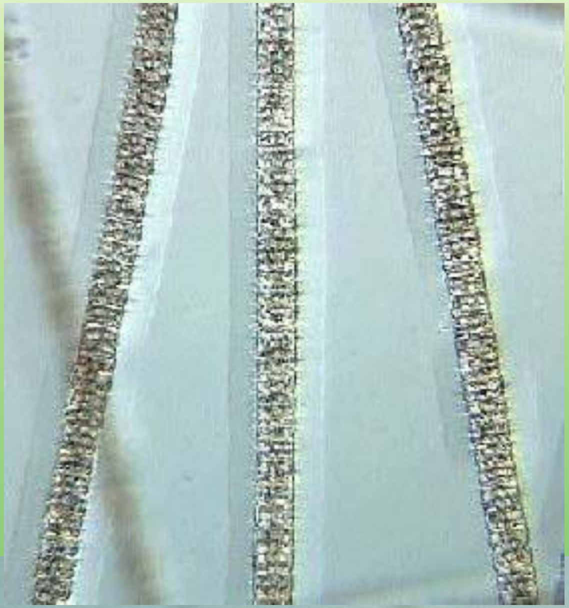


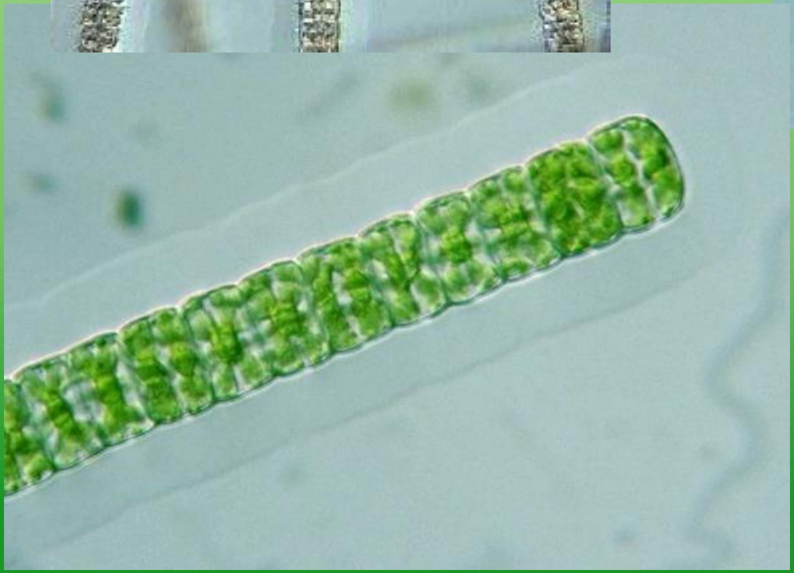


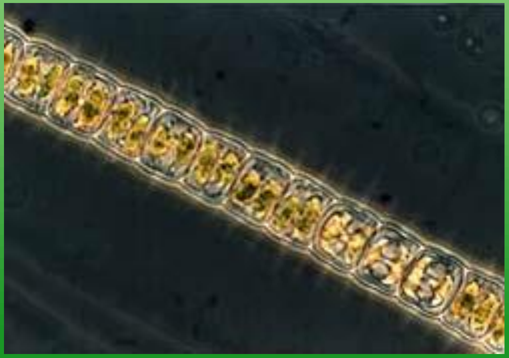


Desmidiaceae

Hyalotheca

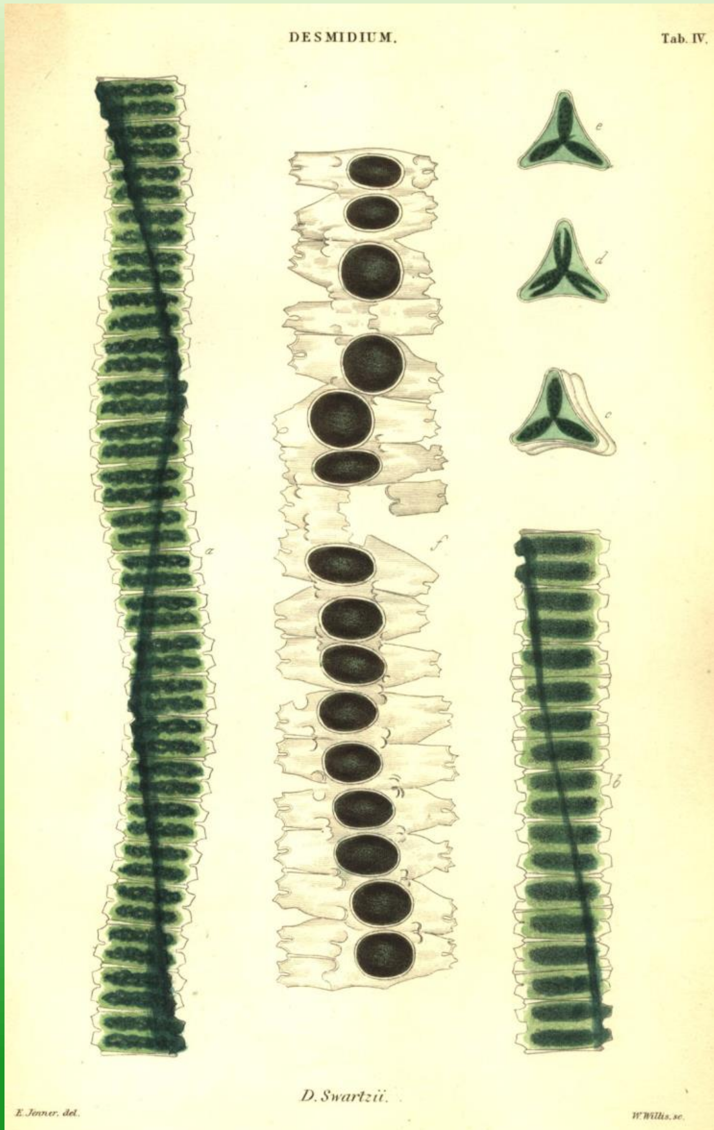


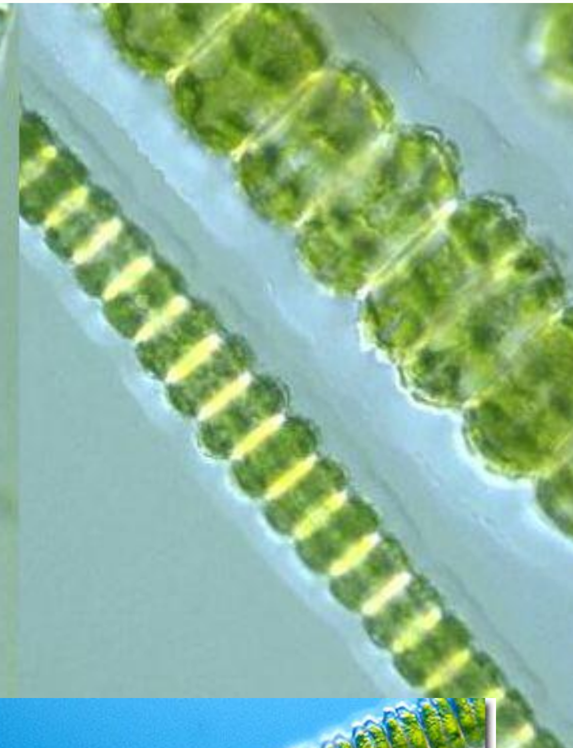




Desmidiaceae

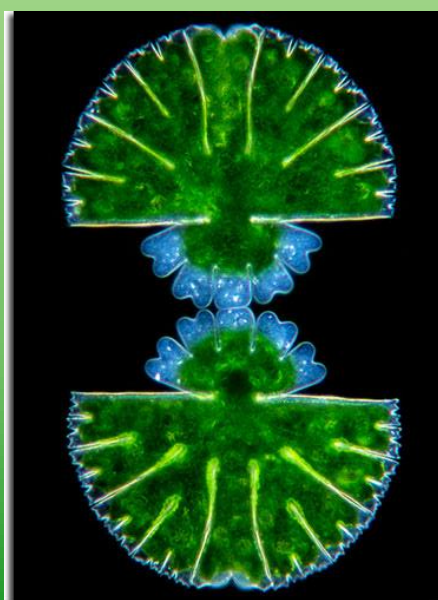
Desmidium

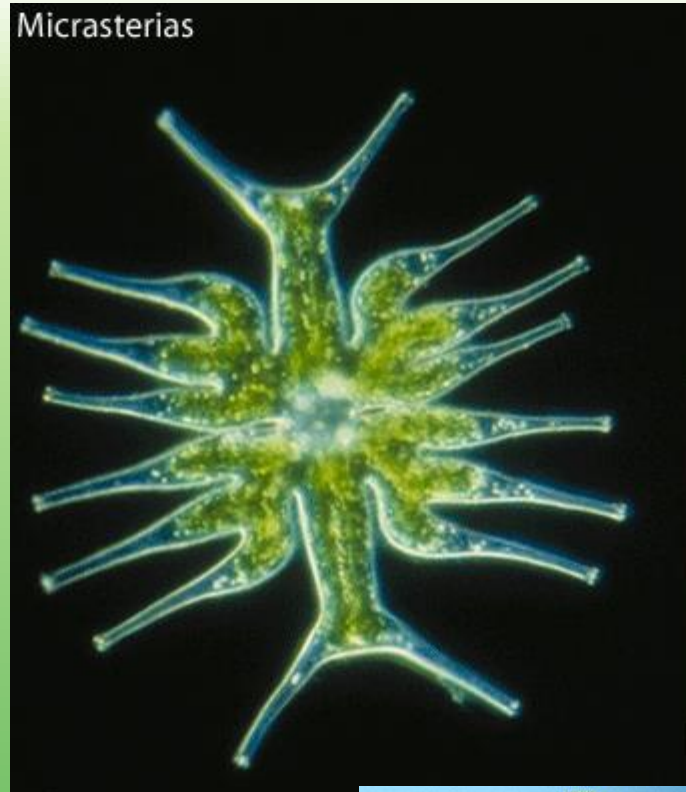


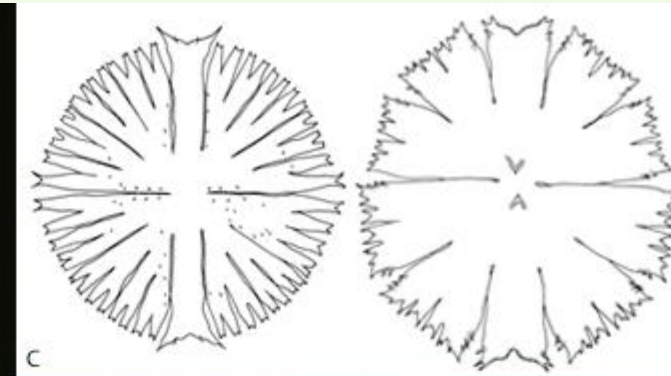


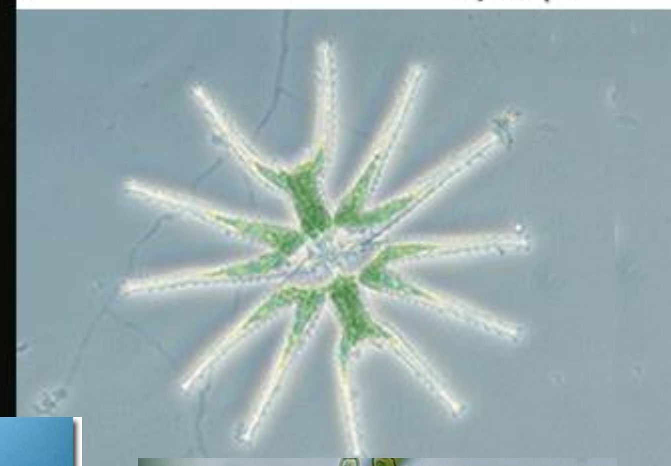
Desmidiaceae

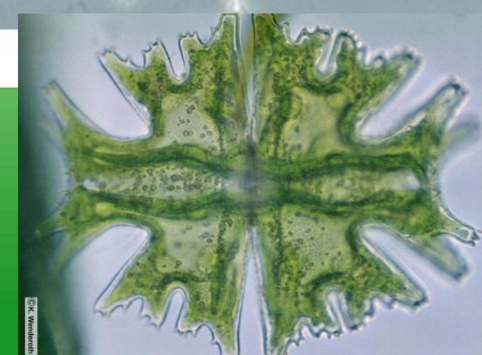
Micrasterias





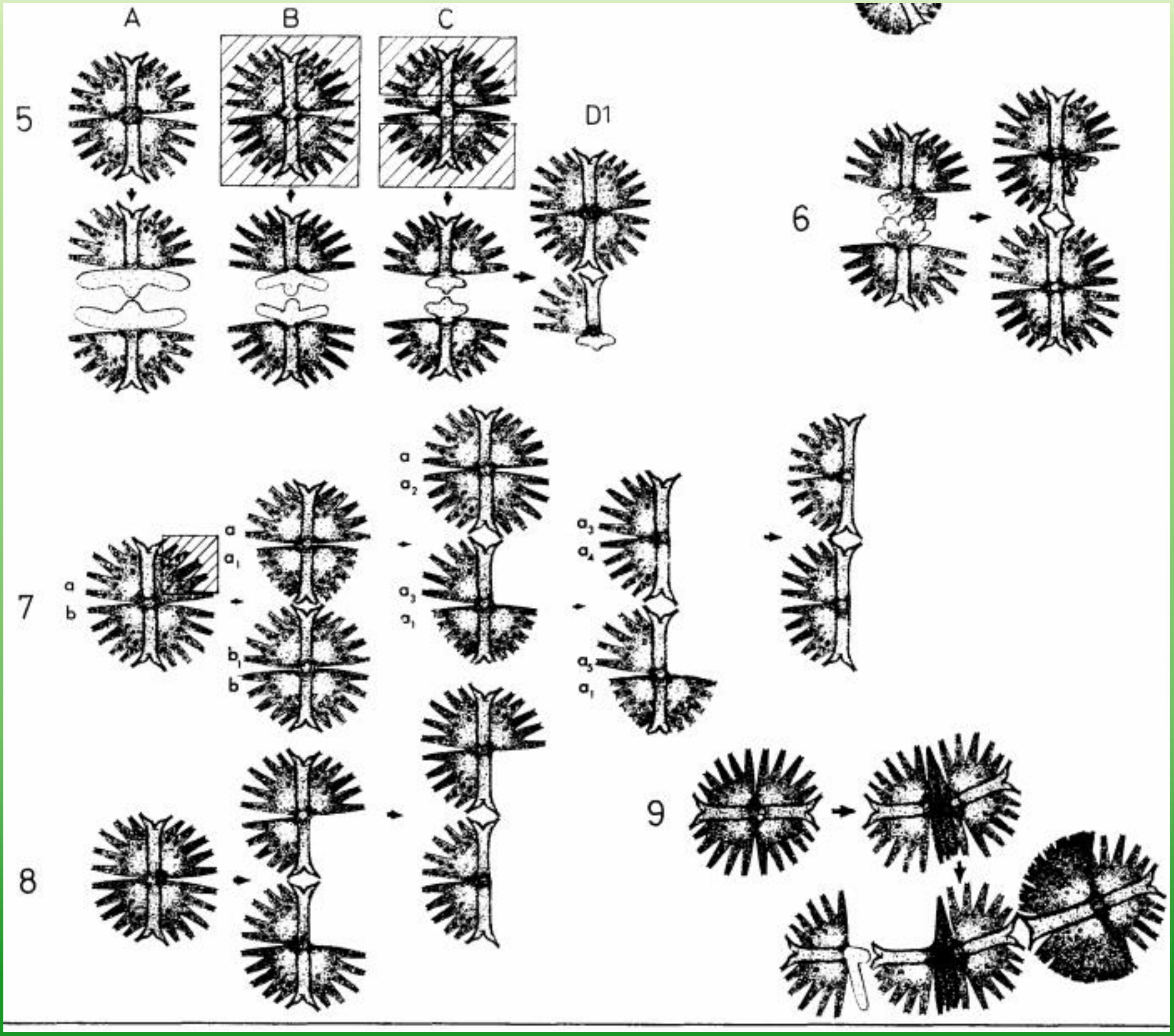






Čeleď: Desmidiaceae

Micrasterias



Kallio & Lehtonen (1973)

Fig. 1.5. The nucleus (A), the whole cell (B) and the cell except the nuclear region (C) have been irradiated at mitosis.

Fig. 1.6. One wing of the new semicell has been irradiated.

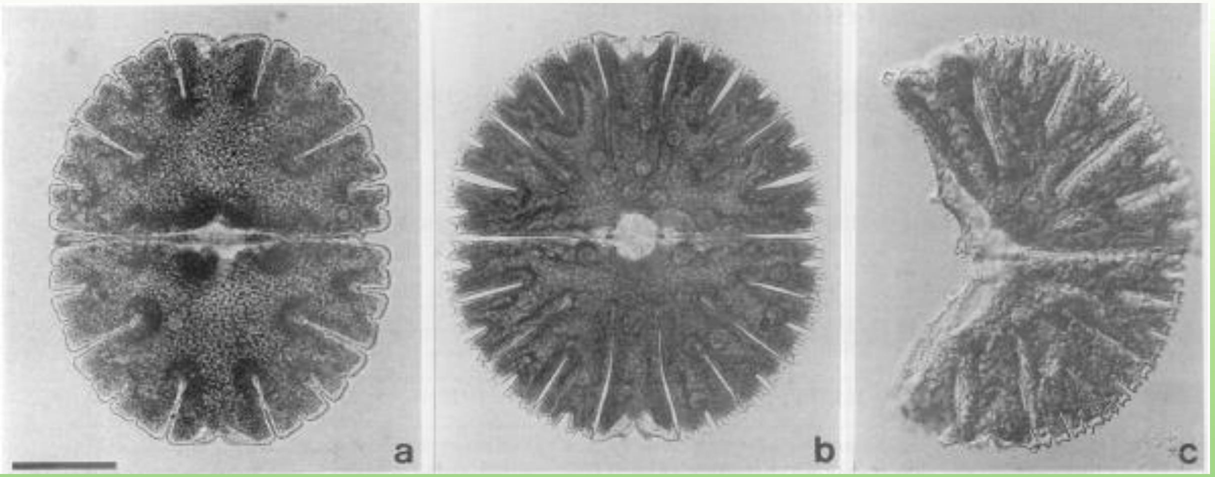
Fig. 1.7. One wing has been irradiated at the time of septum formation and the four following divisions are shown. As a result a one-winged clone has arisen.

Fig. 1.8. One side of the isthmus and a part of the nucleus have been irradiated; the first and the second generation are shown.

Fig. 1.9. The cell has been first centrifuged and the nuclei displaced from the normal site, and the upper half of isthmus irradiated without affecting the nucleus (at telophase). A double cell has arisen. The first division of the double cell is also shown.

Čeleď: Desmidiaceae

Micrasterias



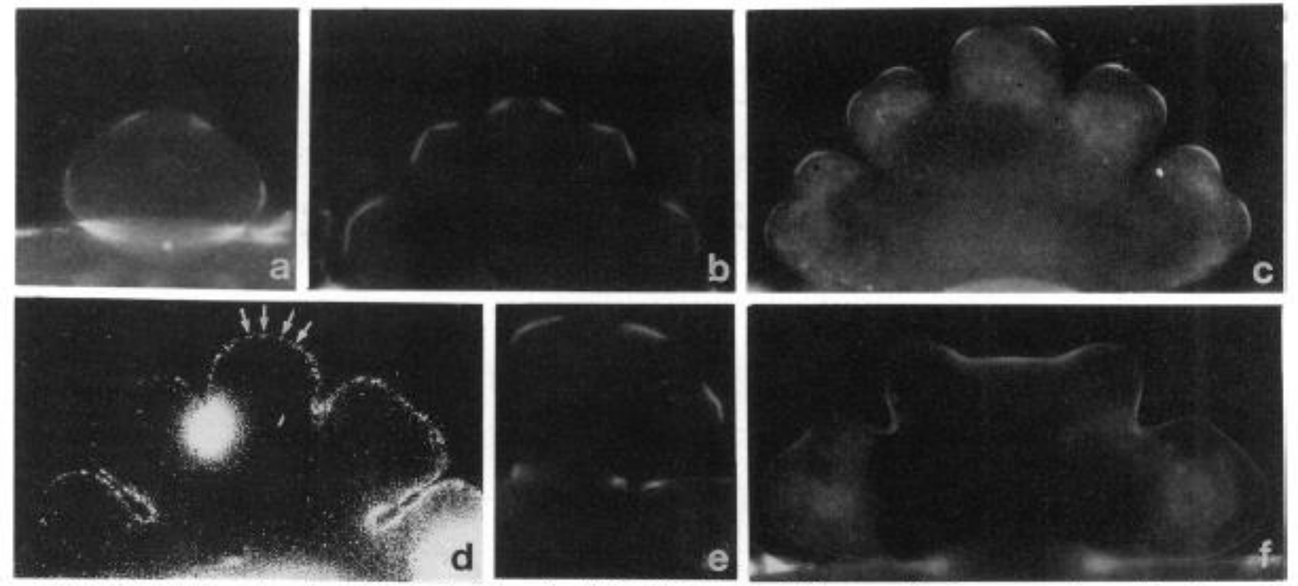


FIG. 13. Distribution of membrane-associated calcium visualized with the help of chlortetracycline fluorescence. (a to c) Developmental sequence of *M. denticulata* with splitting of the fluorescent areas corresponding to the cell pattern. (d) *M. denticulata* at the stage of pore formation. Fluorescent dots corresponding to the distribution pattern of the cell wall pores are visible (arrows). (e) Young developmental stage of *M. thomasiana* f. *uniradiata*, with fluorescent areas only at the side which develops a normal cell pattern. (f) Developmental stage of *M. denticulata* grown at 35°C. Fluorescence is visible only between the outgrowing lobes. Reprinted from references 49 (a to c), 50 (d), 55 (e), and 57 (f) with permission.

Meindl (1993)
Ca gradient under the plasmatic membrane of developing semicells

Terrestrialization and origin of land plants

Becker & Marin (2009)

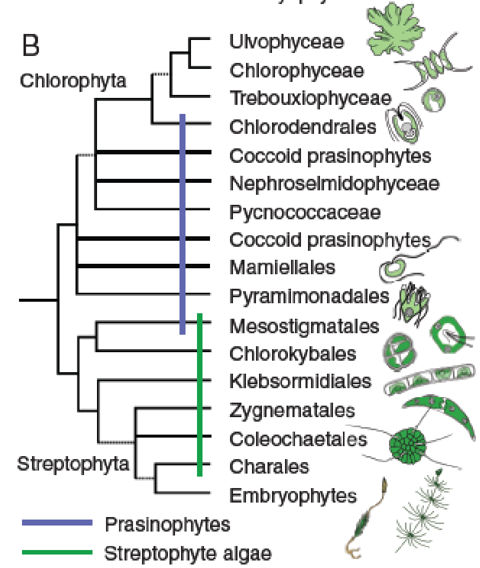
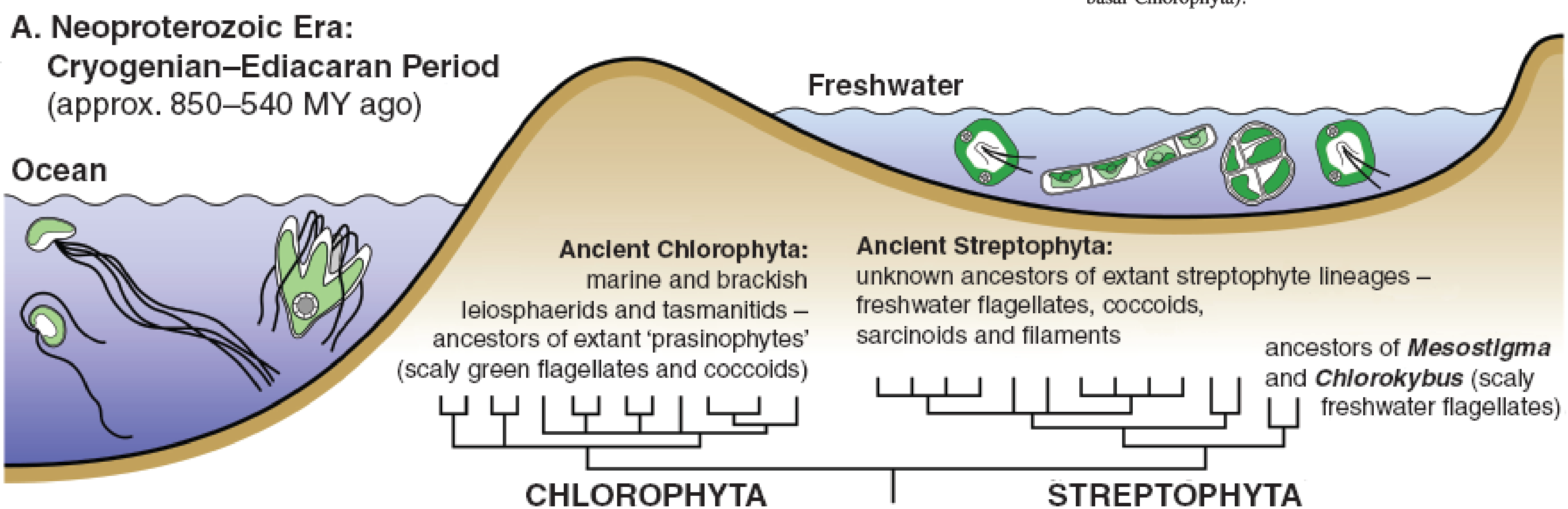
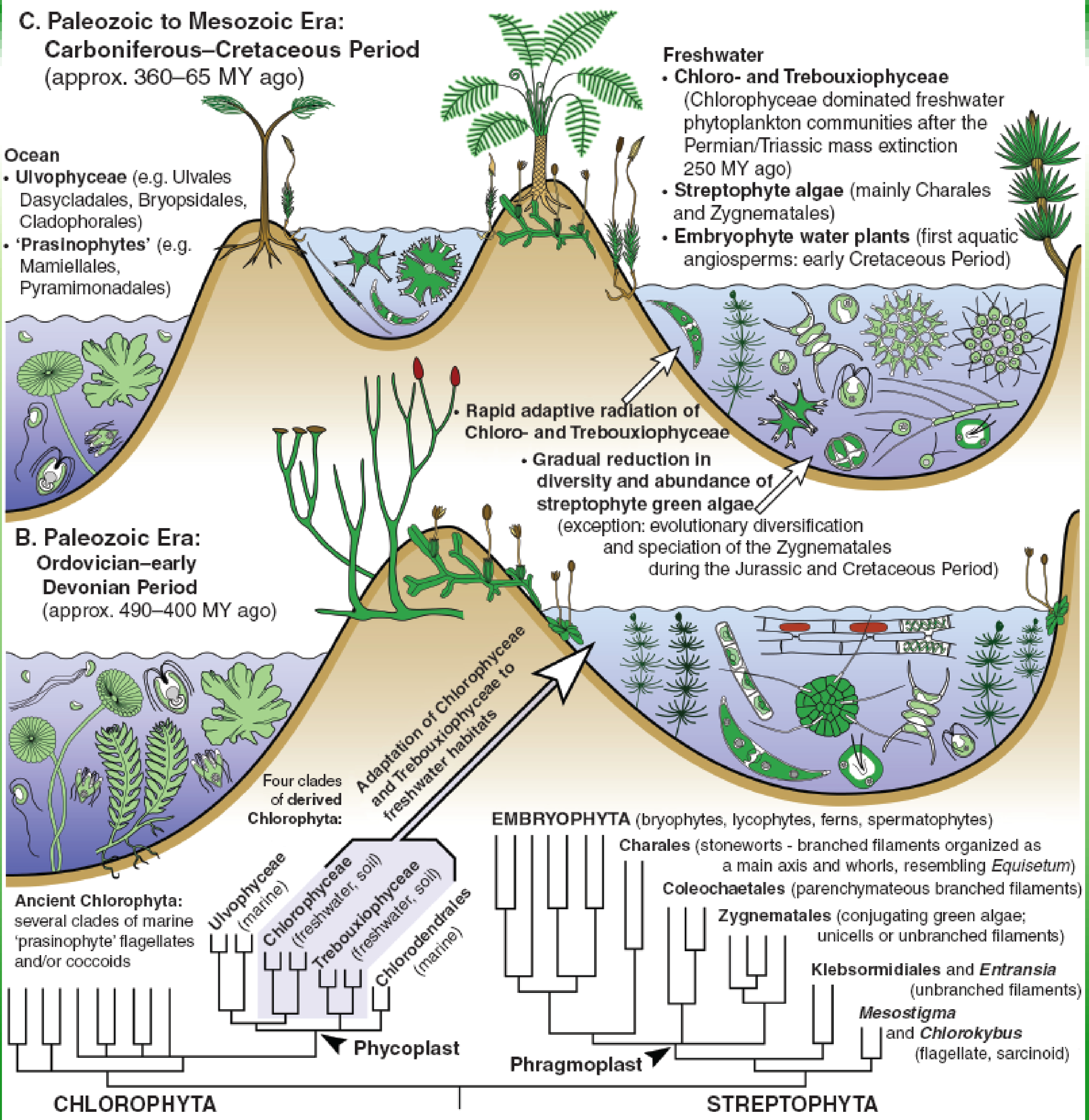
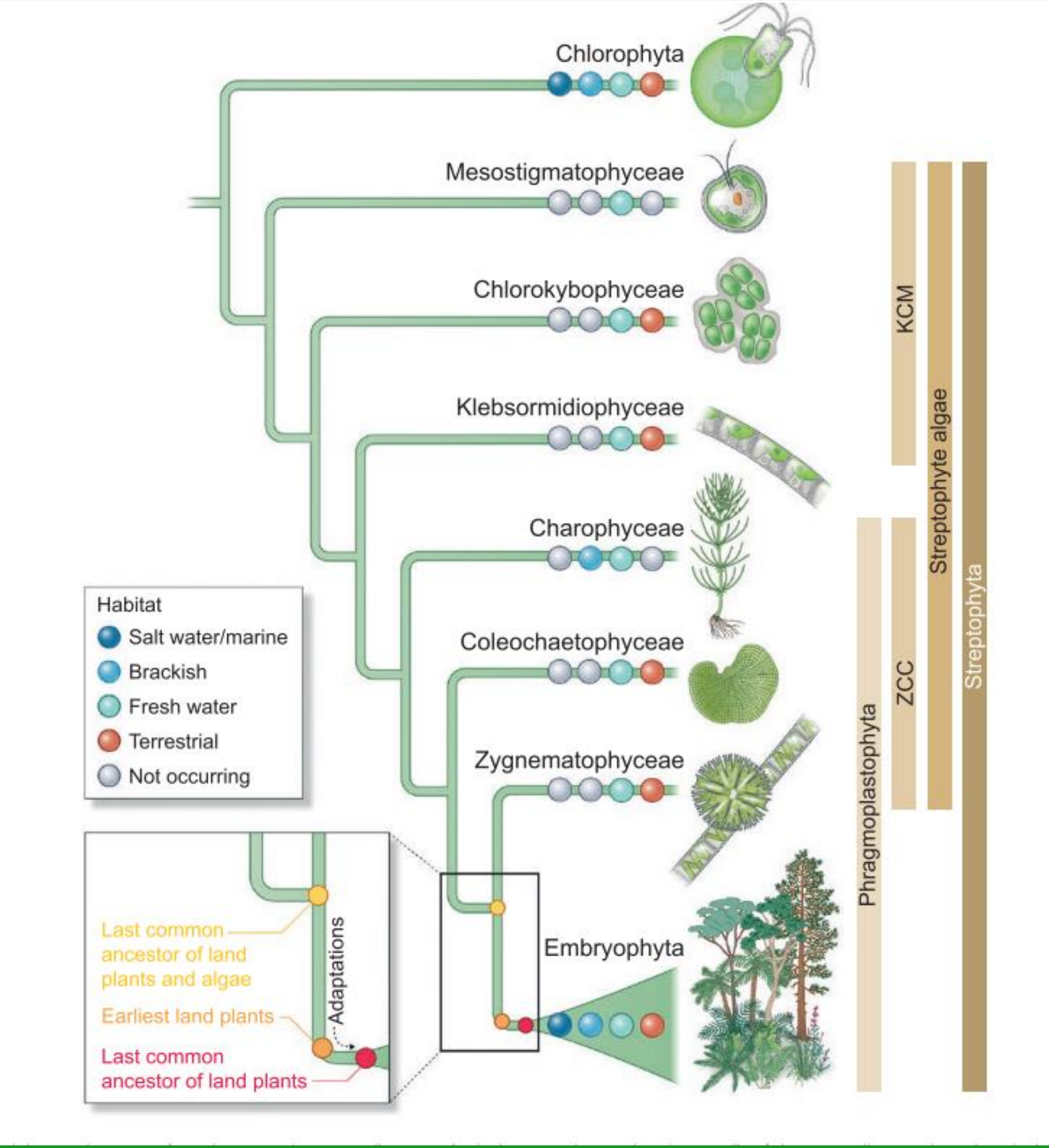


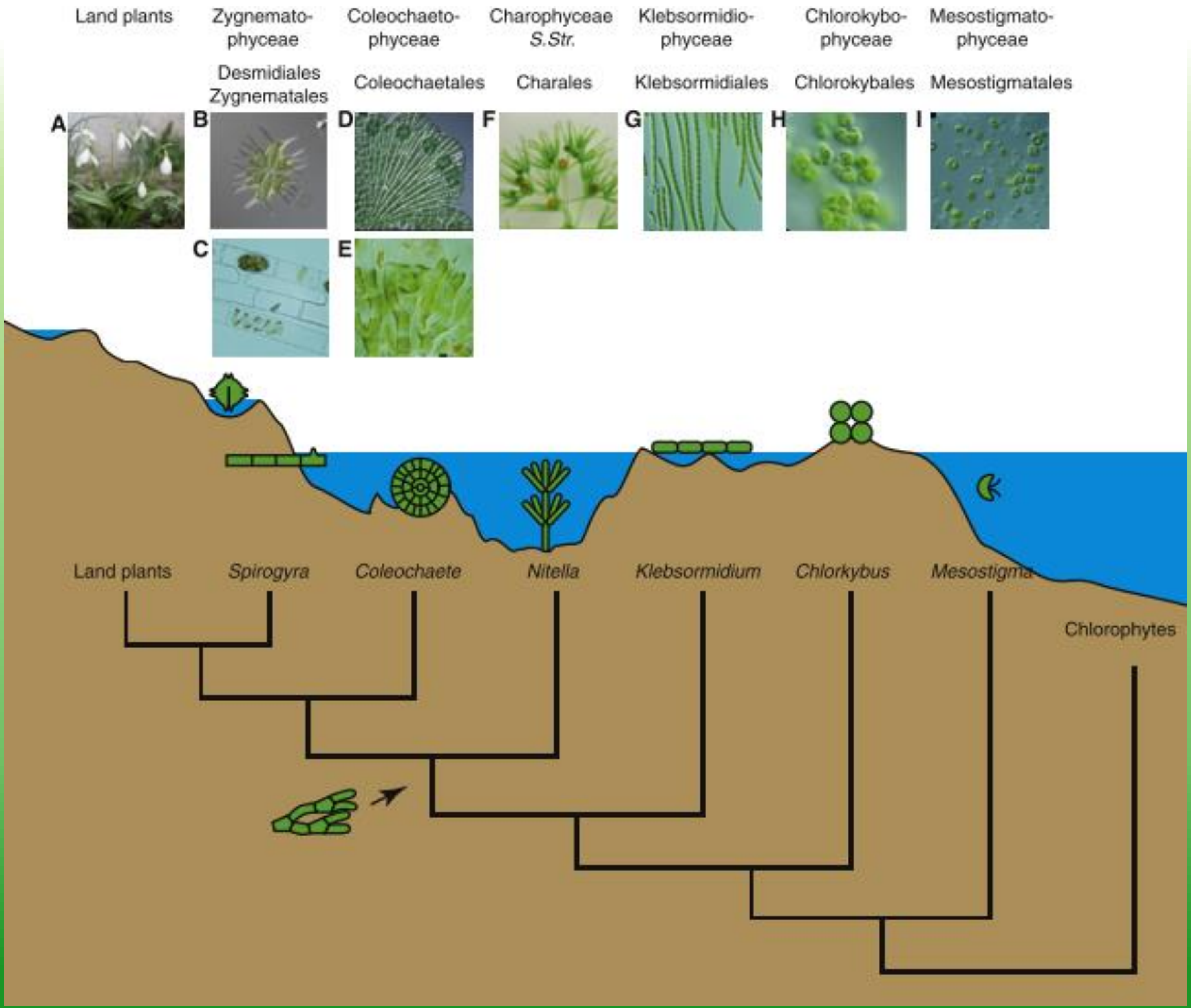
FIG. 1. Phylogenetic relationships among the major lineages of the Viridiplantae. Branches indicated by dotted lines are not well supported. (A) According to Lewis and McCourt (2004), and (B) based on unpublished, ongoing work by the authors. Some of the class names used by Lewis and McCourt (2004) have 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).



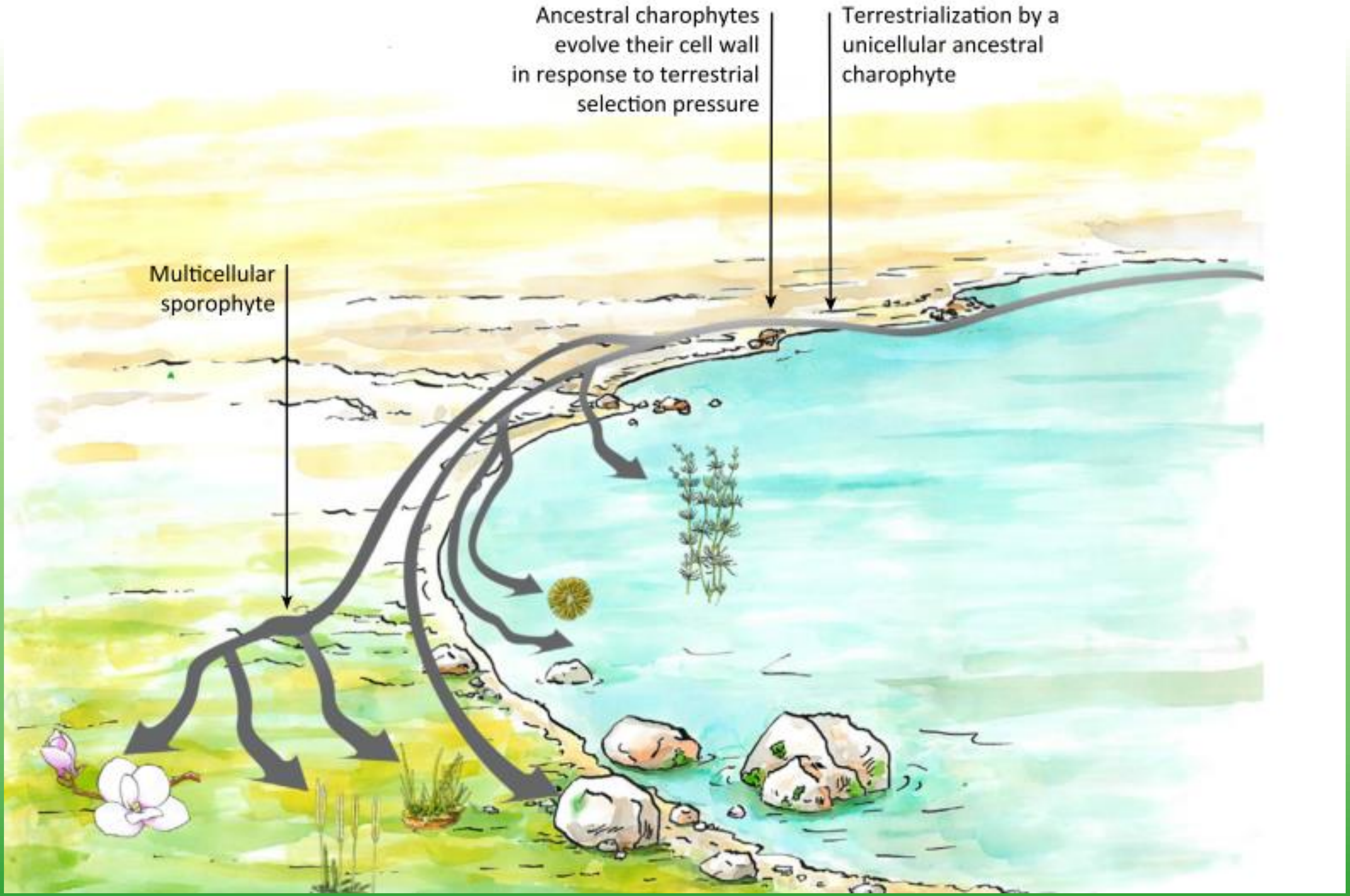

C. Paleozoic to Mesozoic Era:
Carboniferous–Cretaceous Period
(approx. 360–65 MY ago)
Ocean
• Ulvophyceae (e.g. Ulvales Dasycladales, Bryopsidales, Cladophorales)
• 'Prasinophytes' (e.g. Mamiellales, Pyramimonadales)
Freshwater
• Chloro- and Trebouxiophyceae (Chlorophyceae dominated freshwater phytoplankton 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:
Ancient Chlorophyta: several clades of marine 'prasinophyte' flagellates and/or coccoids
Ulvophyceae (marine)
Chlorophyceae (freshwater, soil)
Trebouxiophyceae (freshwater, soil)
Chlorodendrales (marine)
Phycoplast
CHLOROPHYTA
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
STREPTOPHYTA



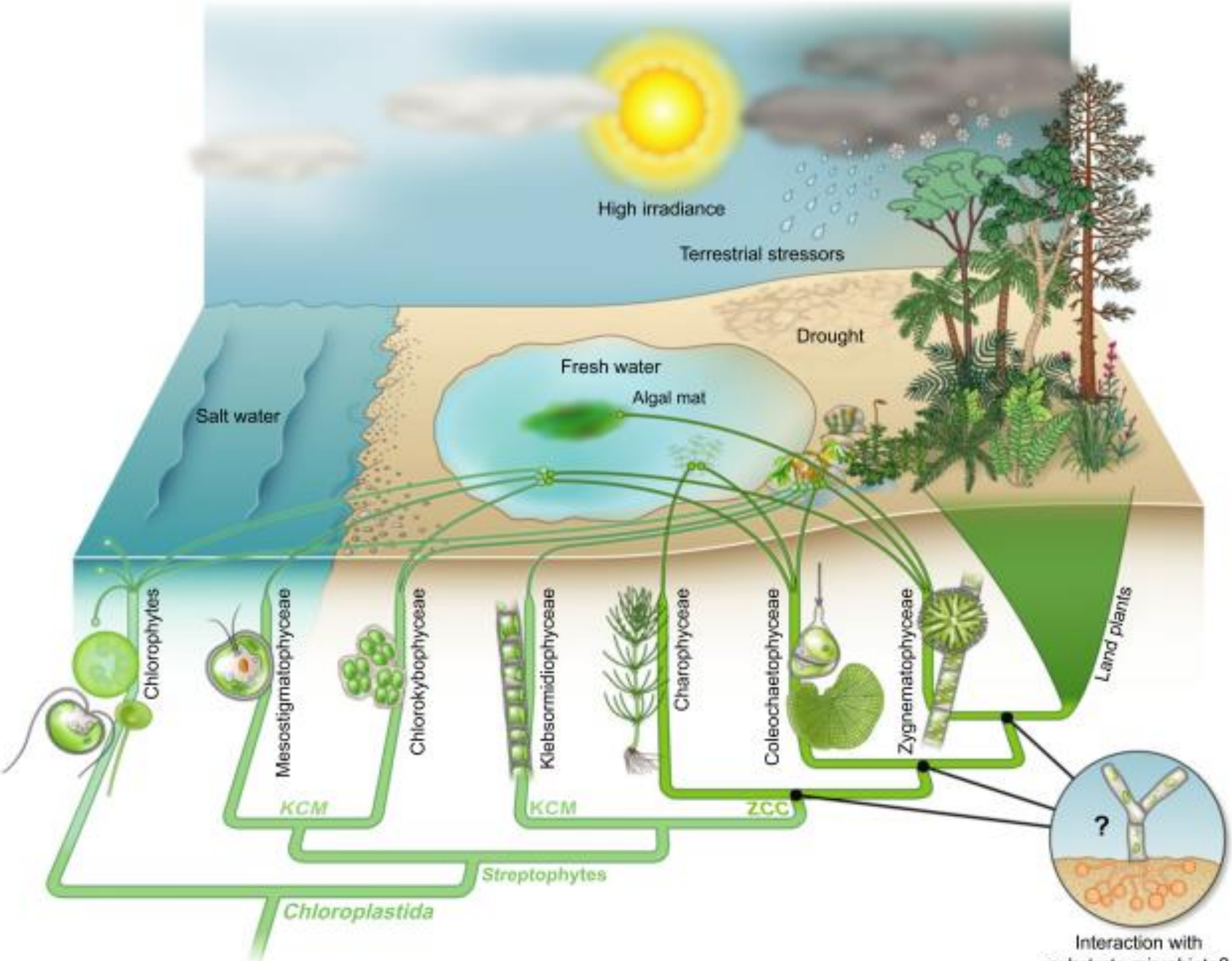
Fürst-Jansen et al. 2020



Delwiche & Cooper (2015)



Harholt et al. (2015)



deVries & Archibald (2018)