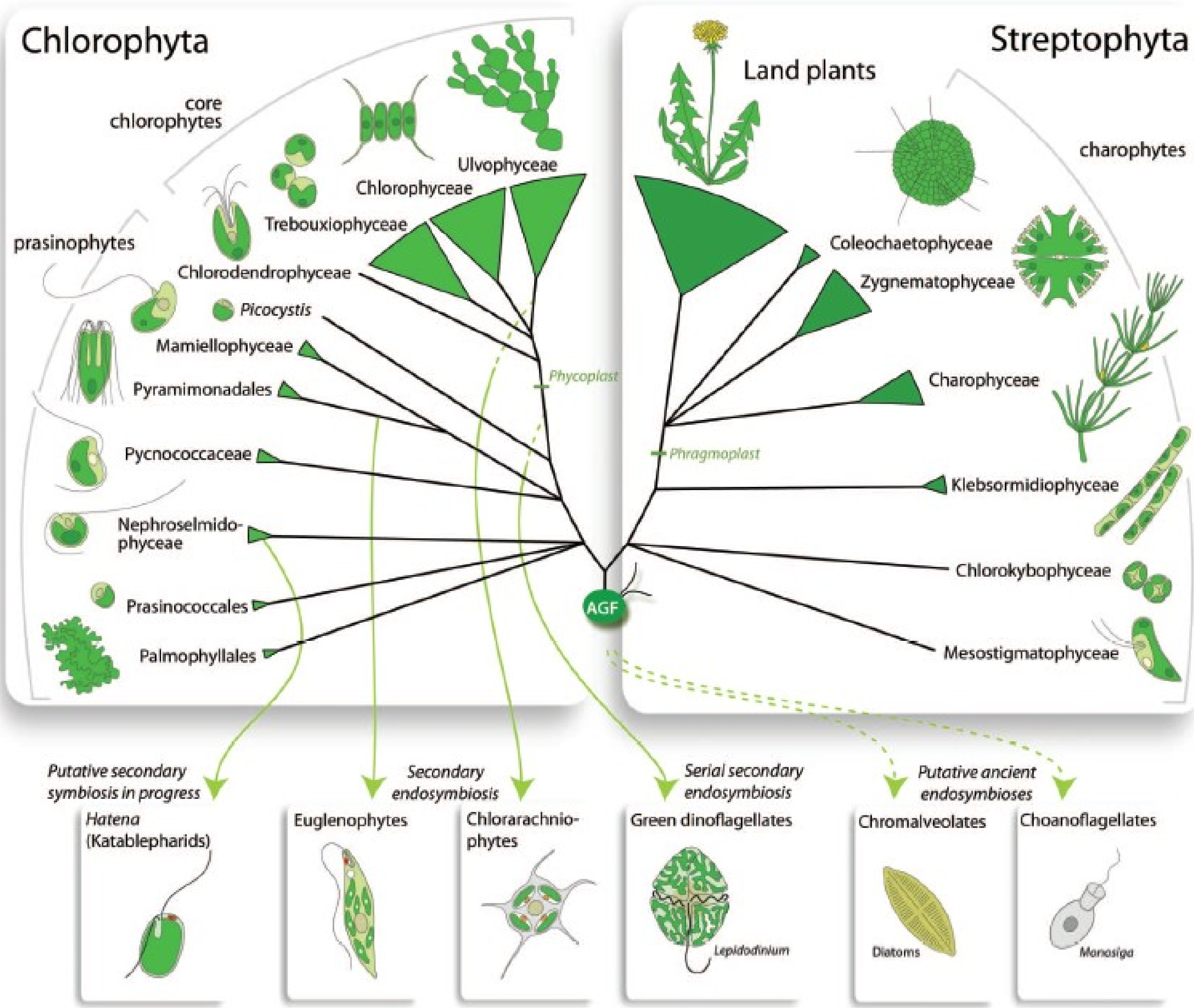


FIG. 2. Overview phylogeny of the green lineage (top) and spread of green genes in other eukaryotes (bottom). (Color figure available online.)

Leliaert et al., 2012, Crit. Rev. Pl. Sci. 31: 1-46

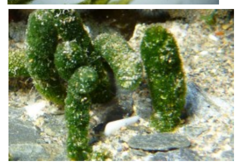
Class: **Ulvophyceae**

Orders *(+ current species number estimates)*

Bryopsidales (cca 560)

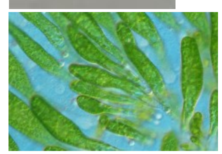
Cladophorales (cca 480)

Dasycladales (cca 65)



Ignatiales (4)

Oltmannsiellopsidales (cca 10)

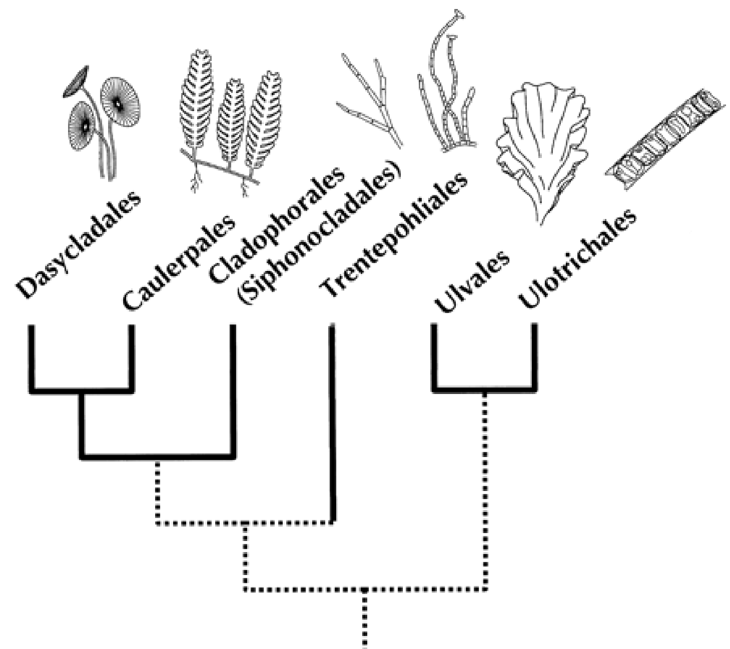


Scotinosphaerales (5)

Trentepohliales (cca 120)

Ulotrichales (cca 180)

Ulvales (cca 320)



Lewis & McCourt, 2004, Am. J. Bot.

early ulvophycean evolution - the case of *Proterocladus*

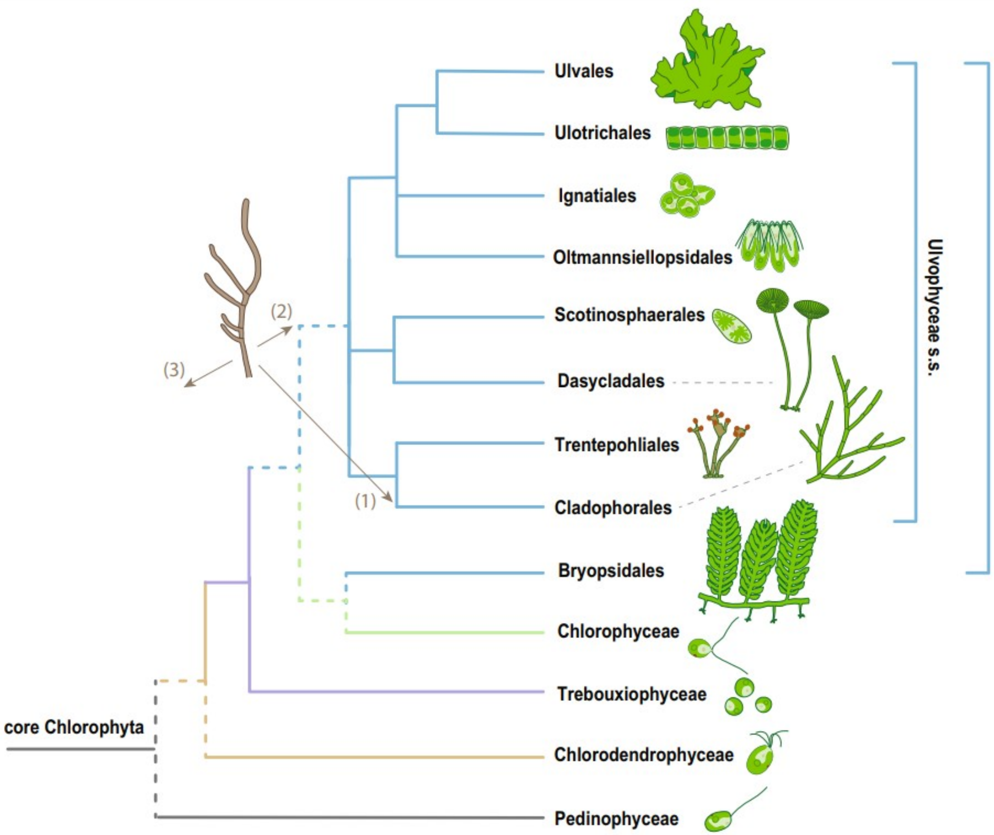
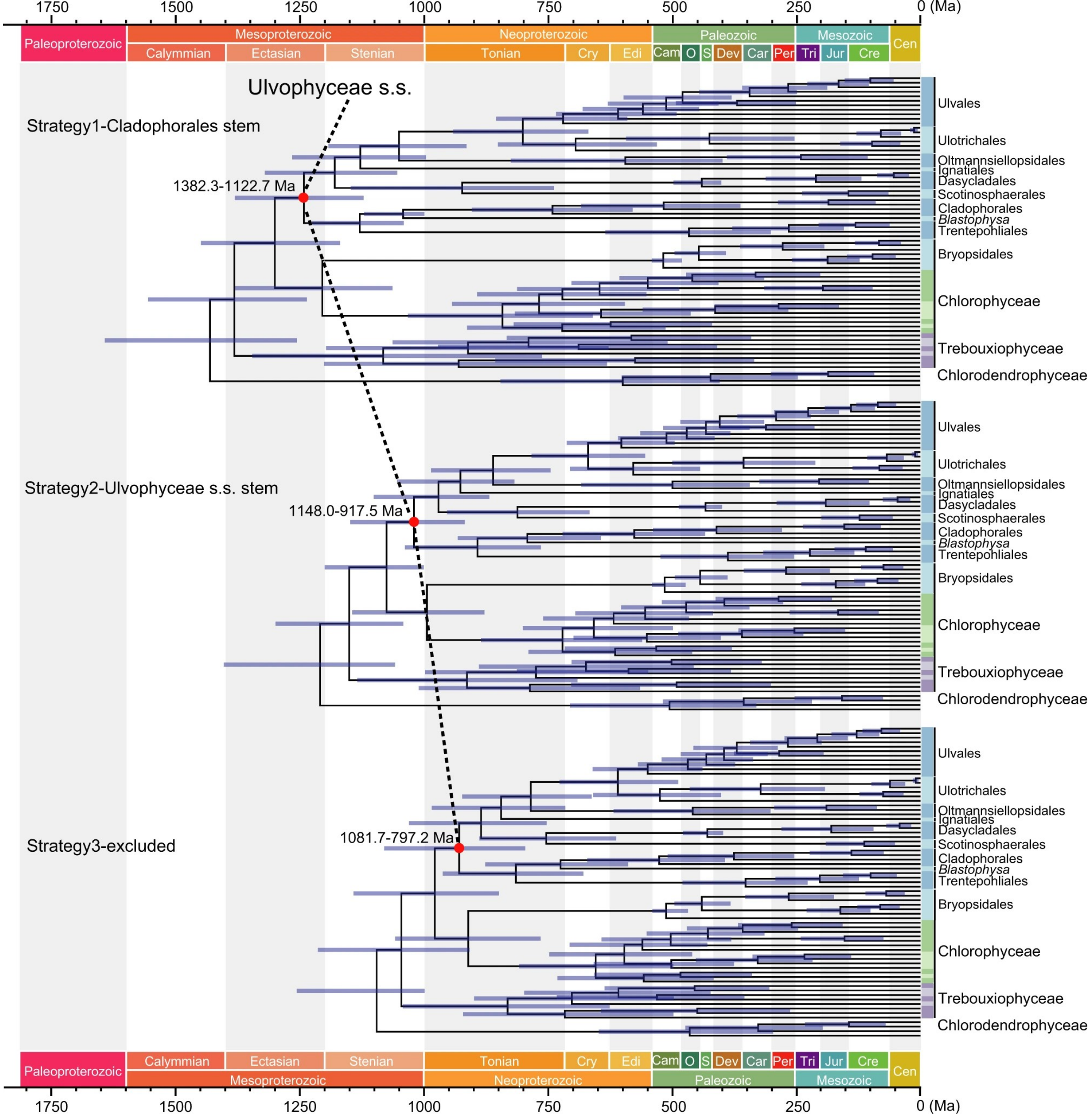


Fig. 1 Current knowledge of the phylogenetic relationships among the main lineages of the core Chlorophyta based on nuclear phylogenomic studies[17,18,20]. Uncertain phylogenetic relationships are indicated by polytomies or dashed lines. The three different interpretations of the *Protero*

Proterocladus - up to 1 bya
coenocytic cells,
branched filaments,
similar to recent
Cladophoraceae

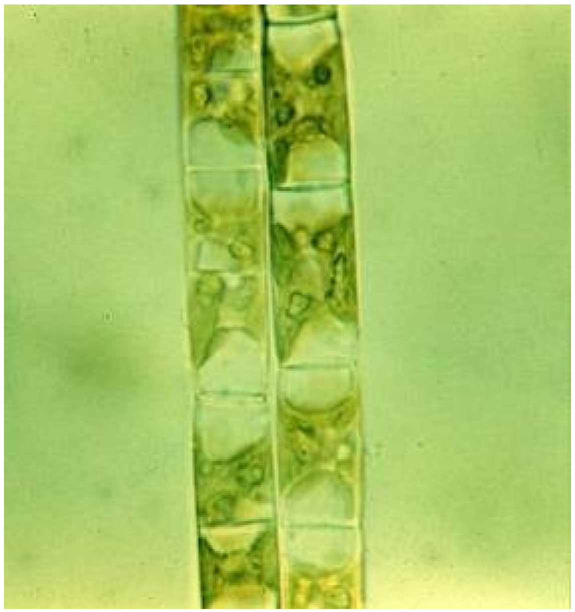
Tang et tal., 2020, Nat Ecol Evol
Hou et al., 2022, Nature Comm

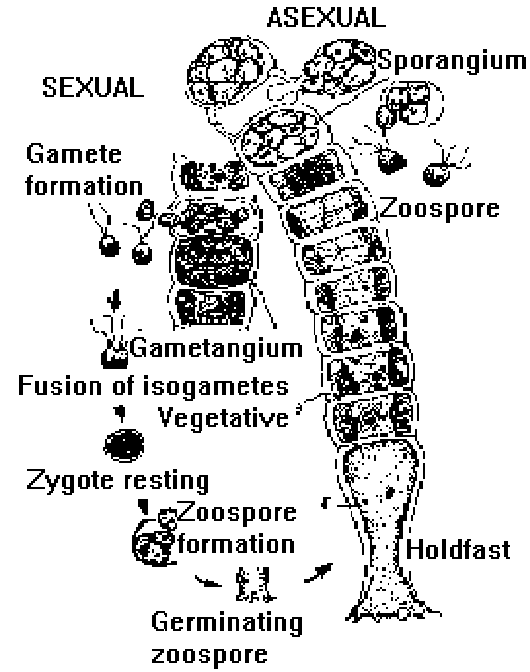


Hou et al., 2022, Nature Comm

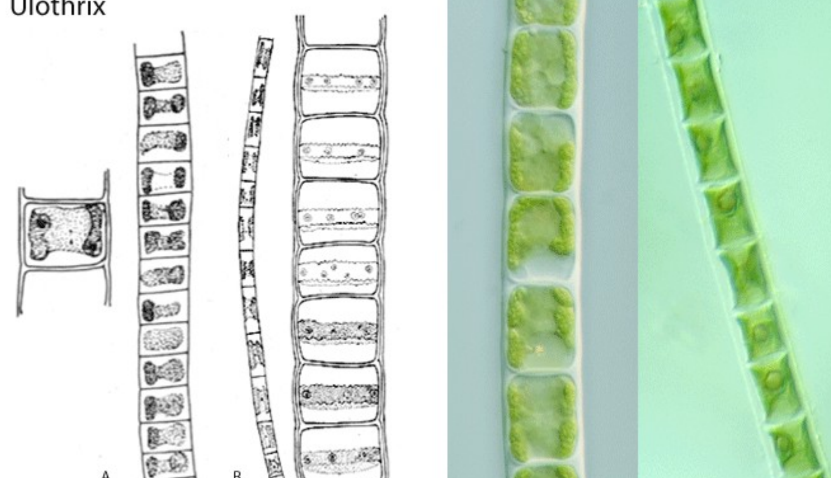
Class: Ulvophyceae
Order: Ulothrichales

Ulothrix – frequent benthic algal of both marine and freshwater habitats



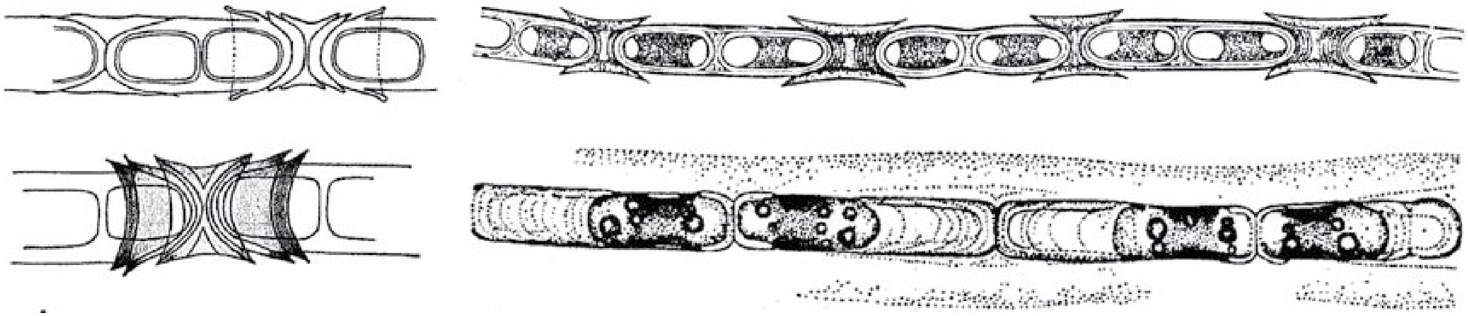


Ulothrix



A, B after Prescott (1951)
C, D after Entwisle et al. (1997)

Binuclearia

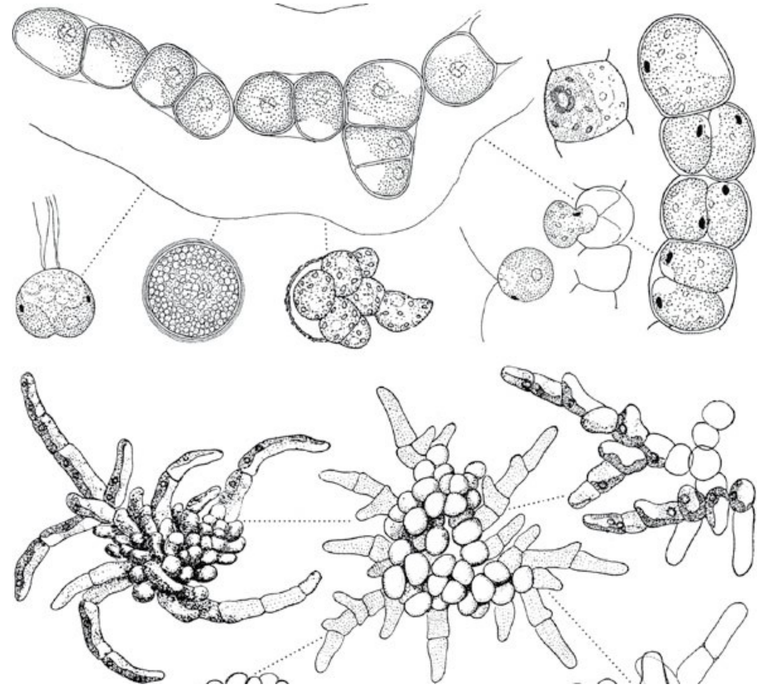


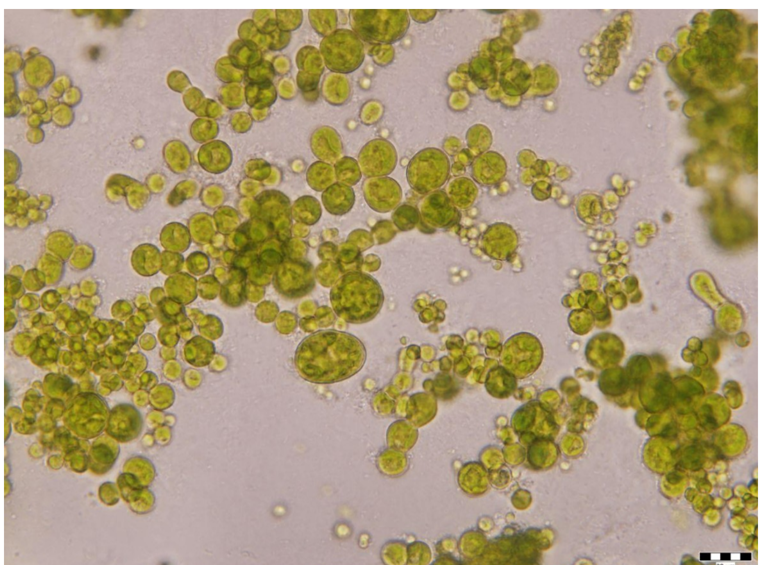
unbranched filaments, cellular pairs separated by thick cell wall parts

freshwater genus, phytobenthos

Rhexinema

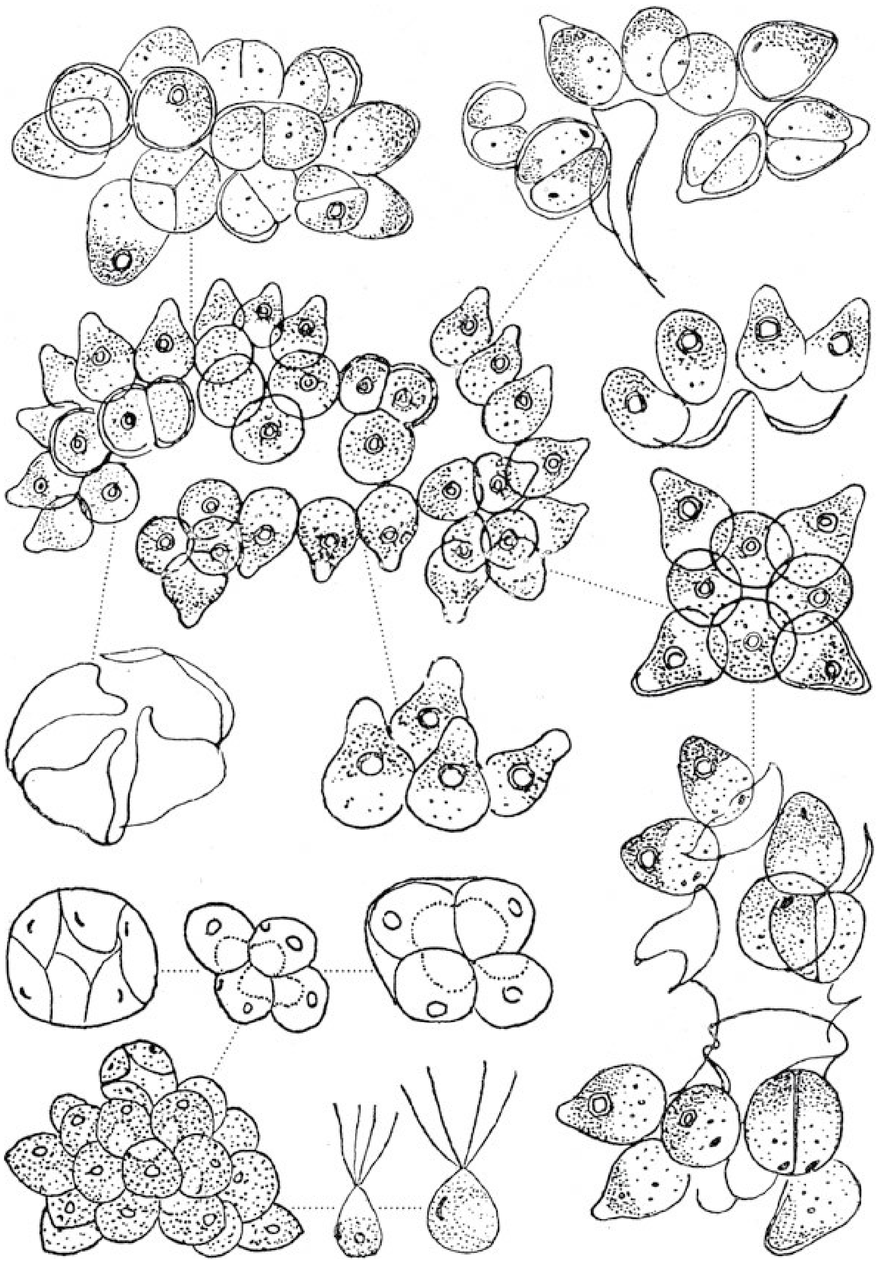
Hazenia





these taxa typically occur in wet soil, examples of extreme secondary simplification

Fernandinella



Planophila

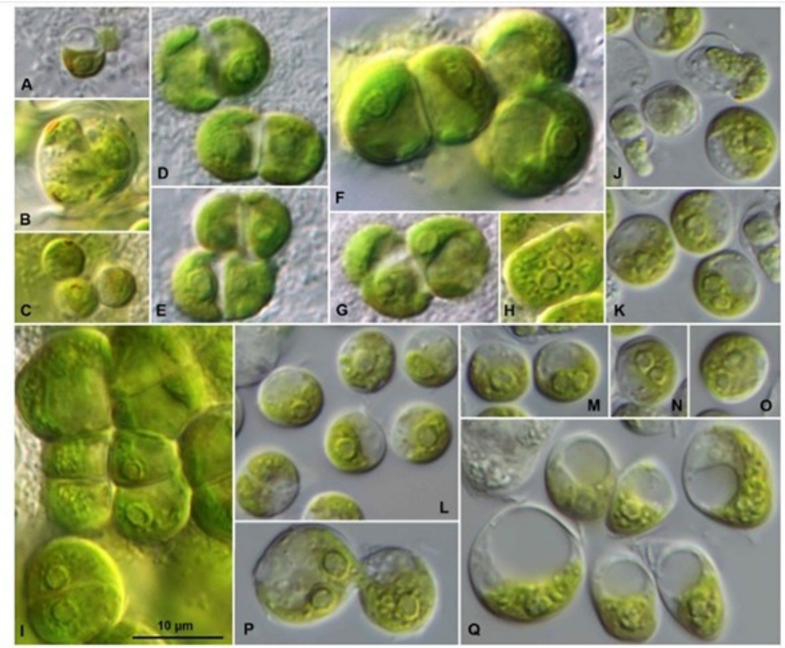
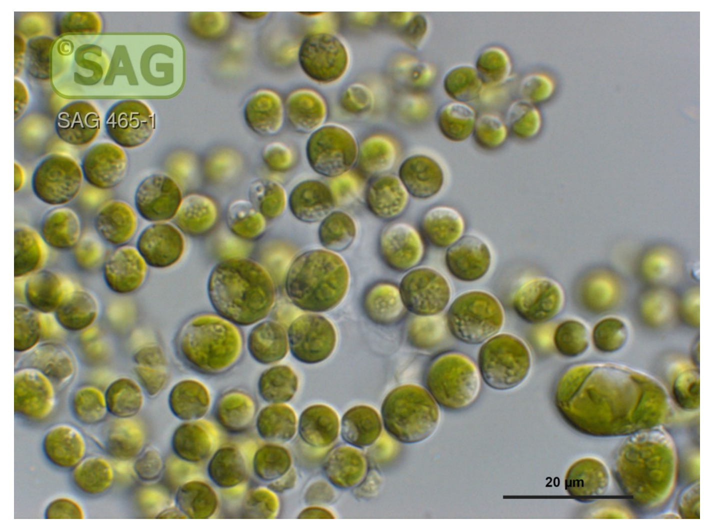


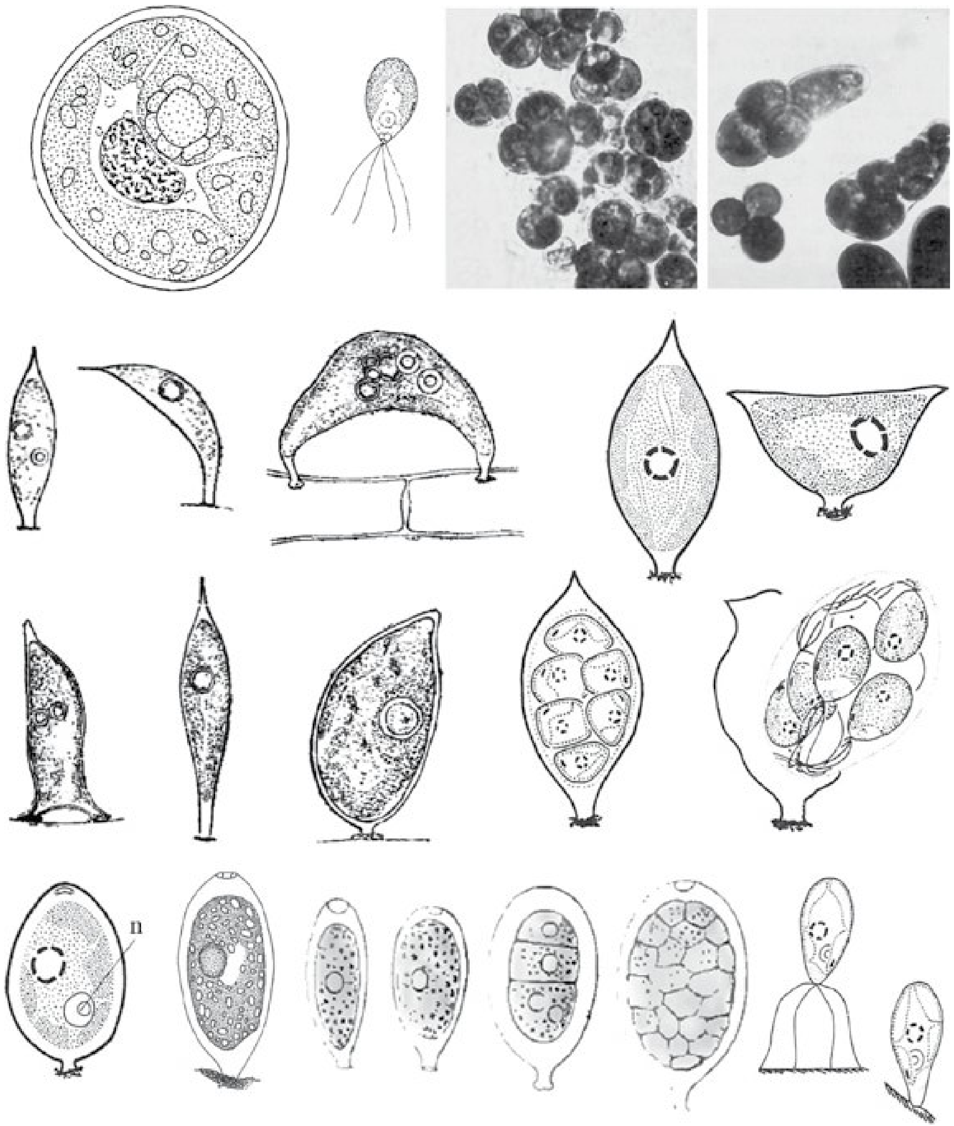
FIGURE 15. Morphology of *Planophila bipyrenoidosa* **A–I.** ULVO-1 and **J–Q.** ULVO-55 grown on 3NBBM medium. **A–C.** settled zoospores and sporangium, **D–I.** cell packets, **J.** settled zoospores, **K–Q.** variety of vegetative cells.

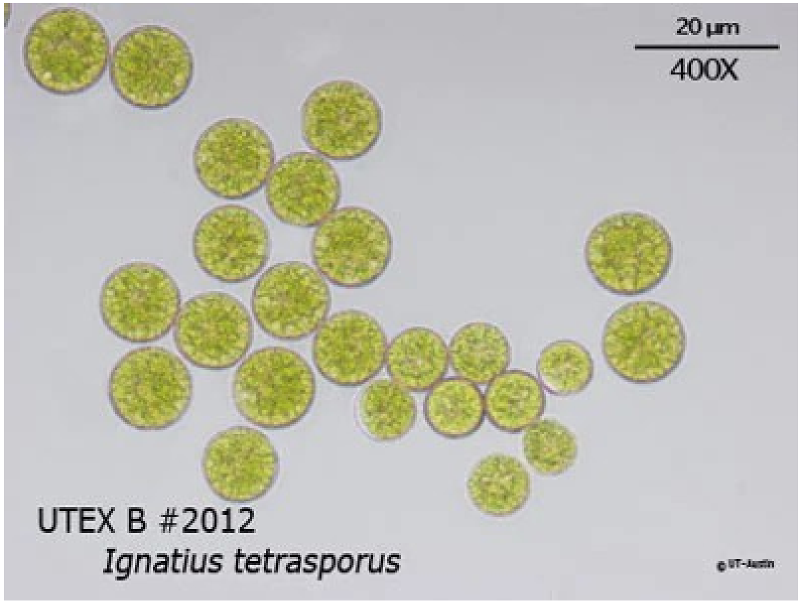


thallus simplification to unicells, terrestrial microhabitats

Ignatiales

two genera Ignatius and Pseudocharacium



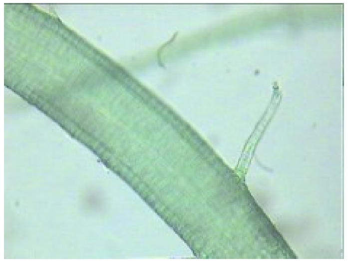


free-living and epiphytic unicells

tetraflagellate spores

Ulvales

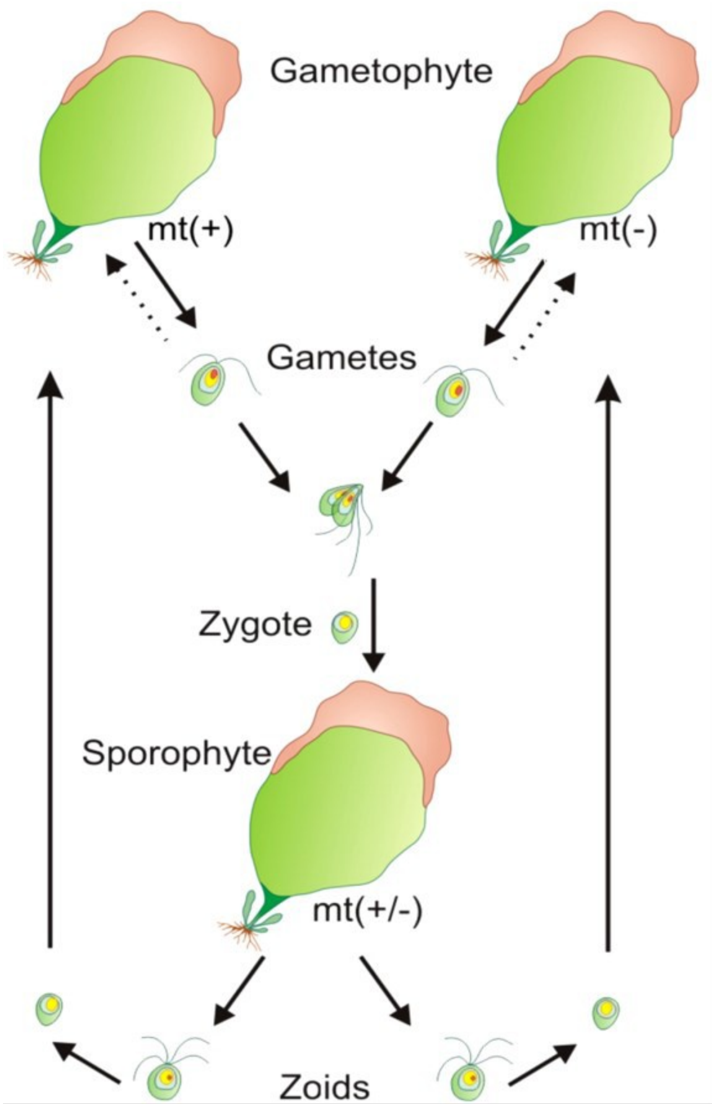
the genus Ulva – distromatic and tubular morphotypes (formerly *Enteromorpha*)



one of the most frequent genera in marine littoral

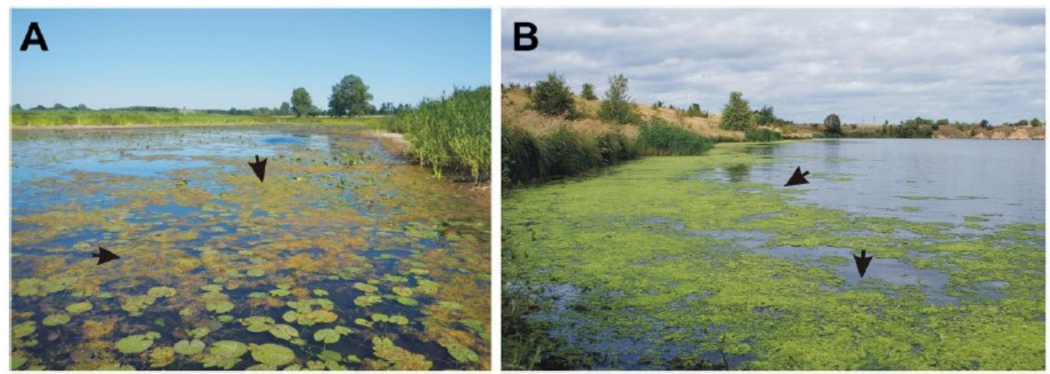
prefers eutrophicated conditions

several taxa also occur in the freshwater



Wichard, 2015, Front Pl Sci

Obr. č. 7: Mořské vodní květy rodu *Ulva* („green tides“): 1) vodní květ na pláži v Bretani, Francie, 2) největší vodní květ v zálivu Quingdao, Čína (Smetacek and Zingone, 2013).



Obr. č. 8: Sladkovodní květy druhu *U. flexuosa*: A) menší vodní květ v jezeře Białobrzeg v Polsku, B) Rozsáhlejší vodní květ na břehu rybníka Konin v Polsku (Rybak and Gąbka, 2018).

aonori

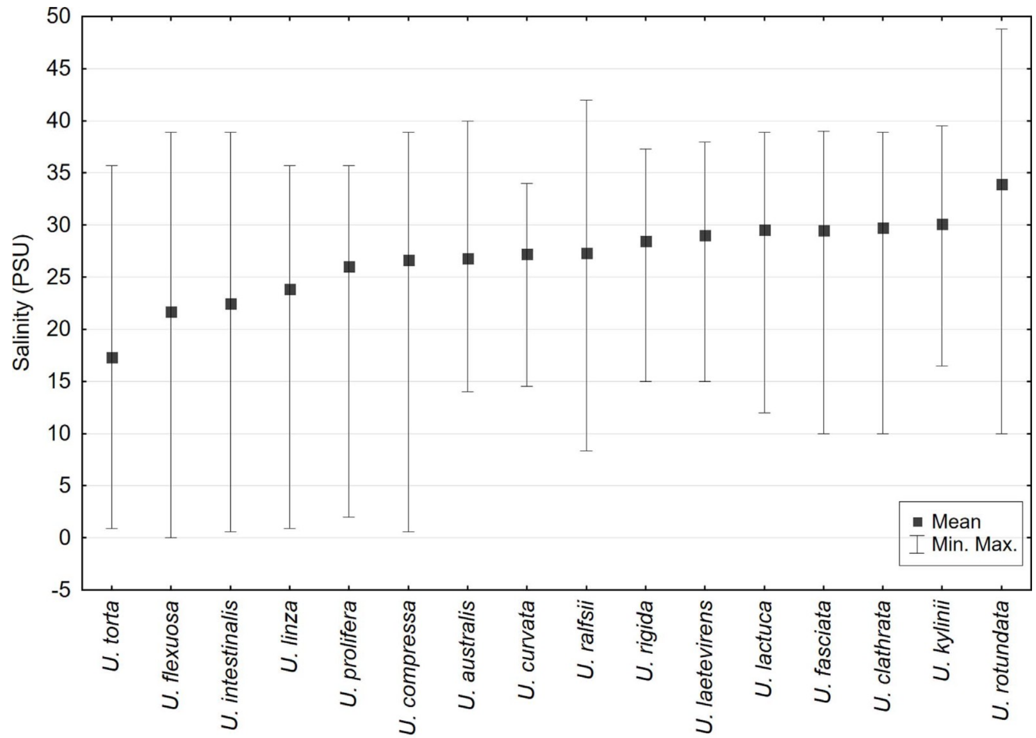
Hiraoka et al., 2011, Plos One

Ulva pilifera - the most frequent freshwater ulvoid species

eutrophicated habitats,
usually during warm-water season

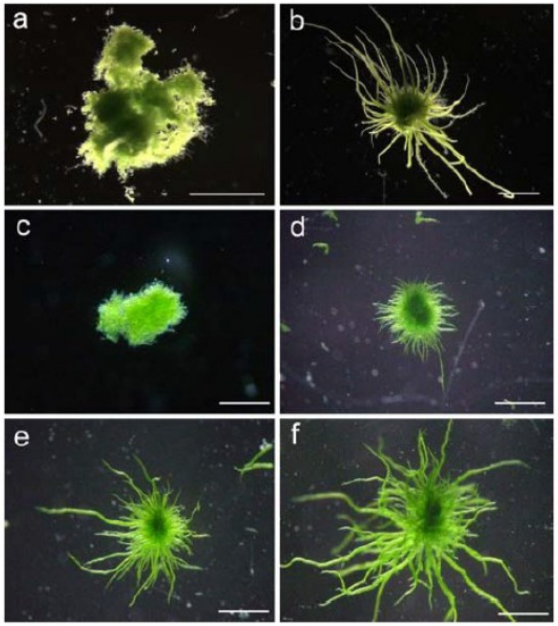
Rybak & Gabka, 2018, J. Appl. Phycol; Rybak & Messyasz, 2011

distribution of distromatic and tubular thalli of Ulva primarily depends on salinity

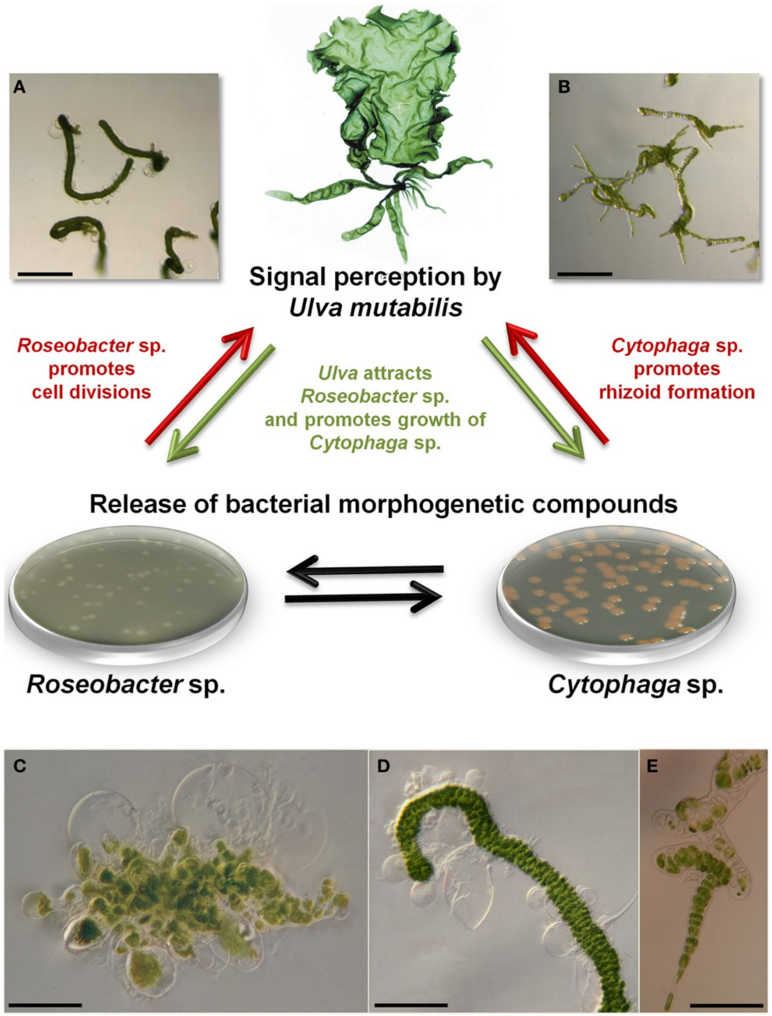


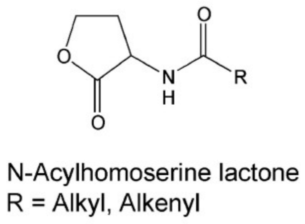
	Salinity zones						
Species of *Ulva*	freshwater (< 0.5 PSU)	oligohaline (0.5 – 5 PSU)	mesohaline (5 – 18 PSU)	polyhaline (18 – 30 PSU)	euhaline (30 – 40 PSU)	hyperhaline (40 – 50)	- (> 50)
U. flexuosa							
U. torta							
U. linza							
U. compressa							
U. intestinalis							
U. prolifera							
U. curvata							
U. clathrata							
U. fasciata							
U. rigida							
U. kylinii							
U. lactuca							
U. laetevirens							
U. australis							
U. ralfsii							
U. rotundata							
	freshwater	brackish			saline		brine
	Water salinity						

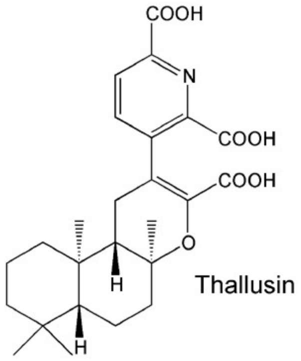
morphogenesis of ulvoid thalli depends on symbiotic relationships with bacterial communities



Obr.č.4: Morfologie druhu *U. linza*, kultivované z uvolněných zoospor: a) axenická kultura (bez přítomnosti bakterií), b) kultura s přítomností klasických bakterií vyvolá tvorbu typické tubulární morfologie, (a i b - po 6 týdenní kultivaci), c-f) řasy 28 dní po inokulaci bakteriálními kmeny: c) kontrola – bez bakterií, d) inokulace blíže neidentifikovaným kmenem mořské bakterie izolované z povrchu řas, e) Shewanella gaetbuli (γ-Proteobacteria), f) Cytophaga sp. (Bacteroidetes) (Marshall *et al.* 2006).





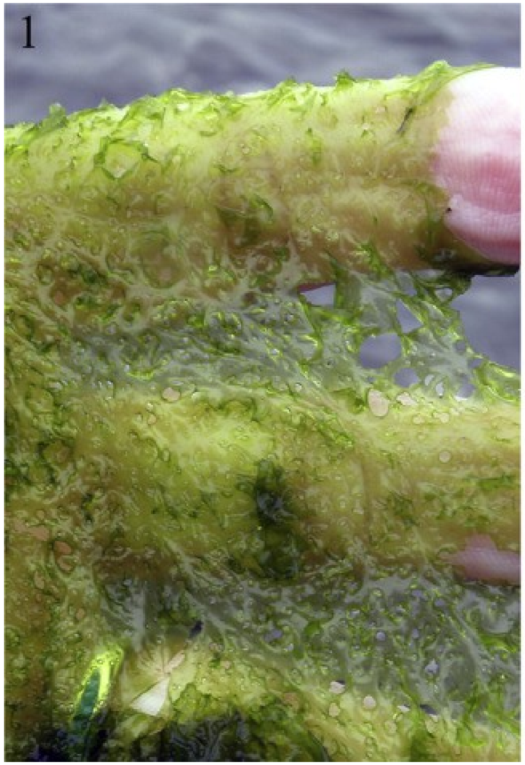


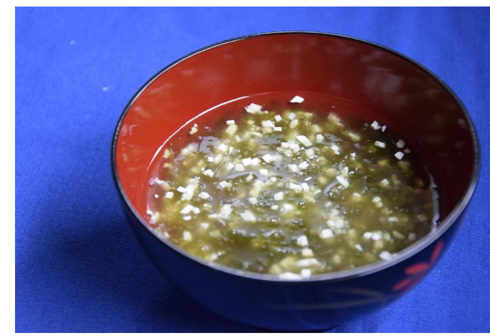
organické látky produkované bakteriemi, jež facilitují morfogenezi

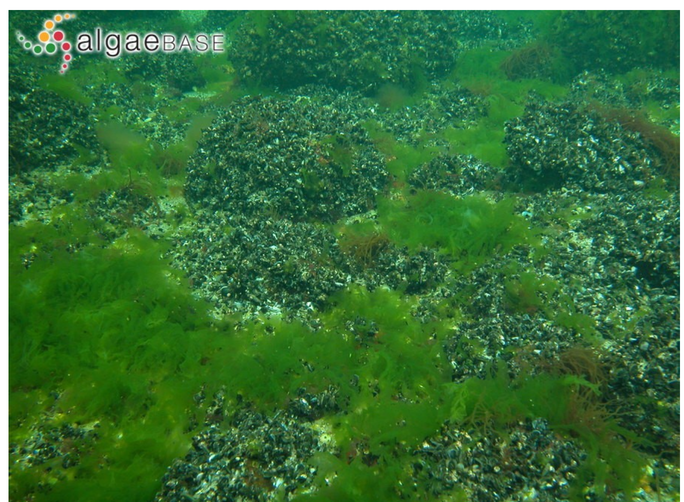
Kantnerová, 2018

Wichard, 2015, Front Pl Sci

Monostroma







M. kuroshiense
hitoegusa-nori

the most frequently green alga cultured for food

unclear boundaries to Ulva and other genera

Percursaria

Darienko et al., 2021

Desmochloris

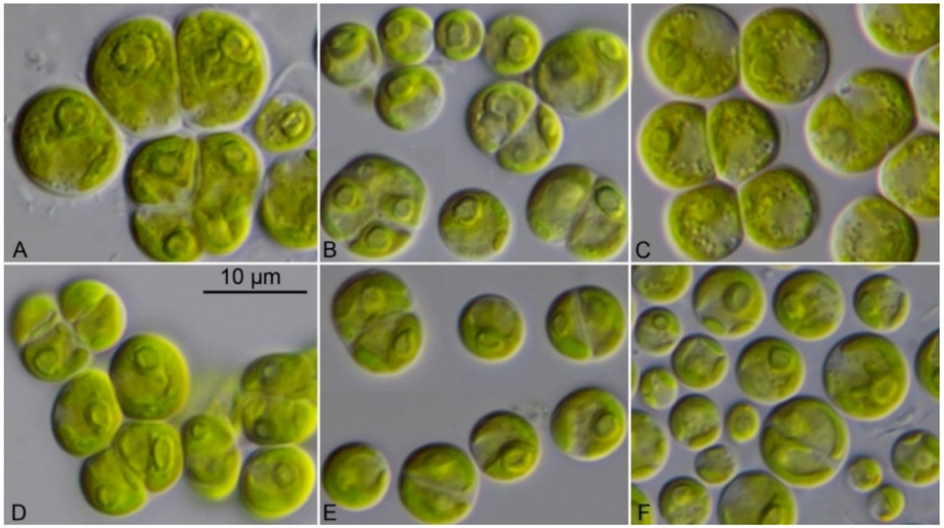
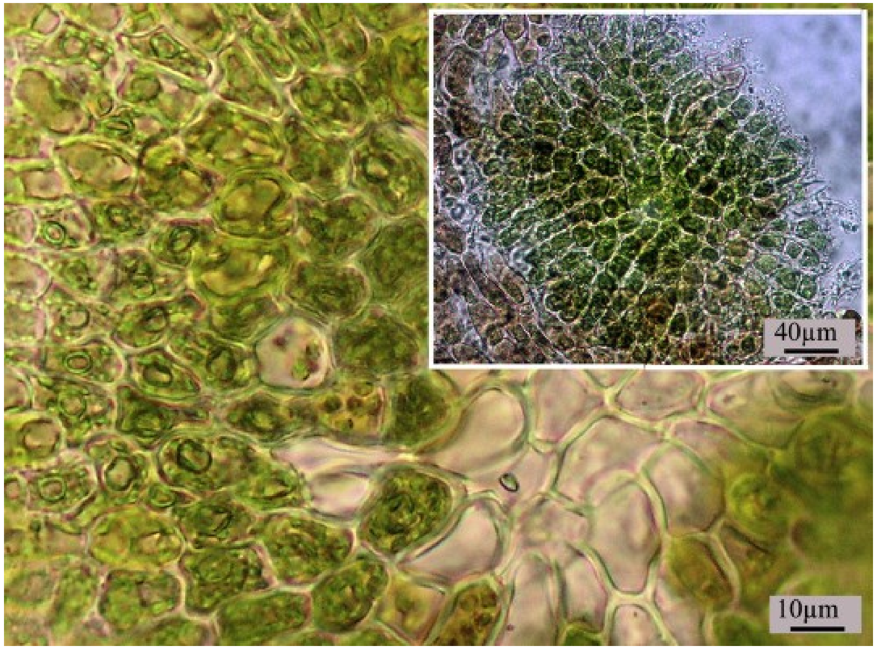


Figure 7. Morphology of the members belonging to the genus *Desmochloris*. (**A**) CCAP 6006/4 *D. halophila*, (**B**) CCAP 6006/5 *D. edaphica*, (**C**) CCAP 6006/6 *D. edaphica*, (**D**) CCAP 6006/7 *D. mollenhaueri*, (**E**) CCAP 6006/8 *D. mollenhaueri*, (**F**) CCAP 6006/9 *D. mollenhaueri*, scale bar for all pictures (**A**–**F**) = 10 µm.

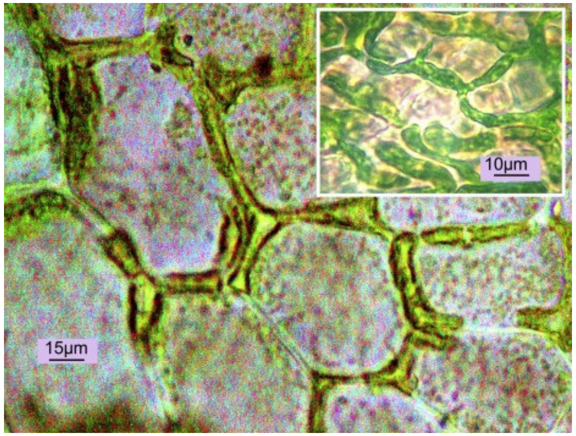
Ulvella, Entocladia



marine epiphytes and endophytes

FIGURE 1. *Pseudoplexaura flagellosa* (Houttuyn) with algal nodules, depth 3 m, Bache Shoal, Florida Keys.

E. endozoica lives as a parasite in corals (i.e. boring algae)

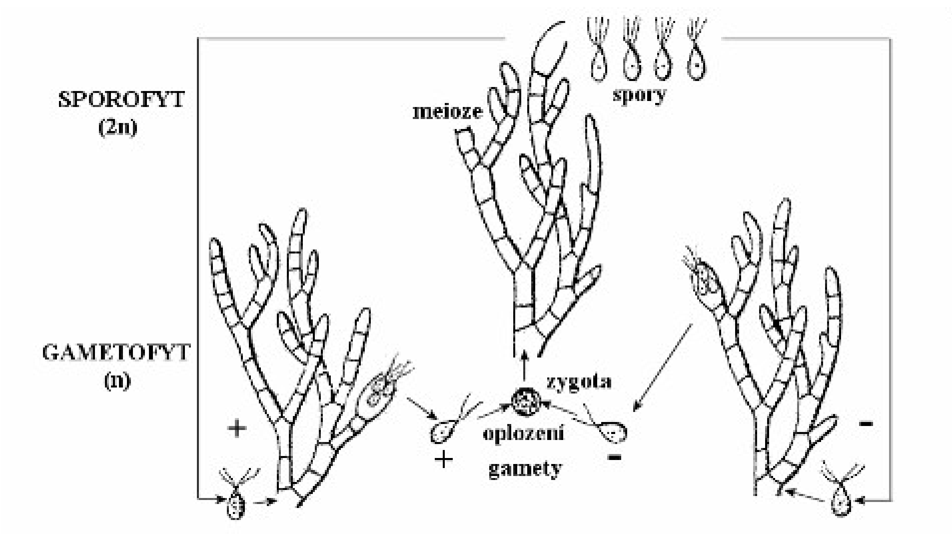


U. geniculata - endophyte of red algal genus *Hypnea*

Verbruggen, 2011; Goldberg et al., 1984
Titlyanov et al., 2017

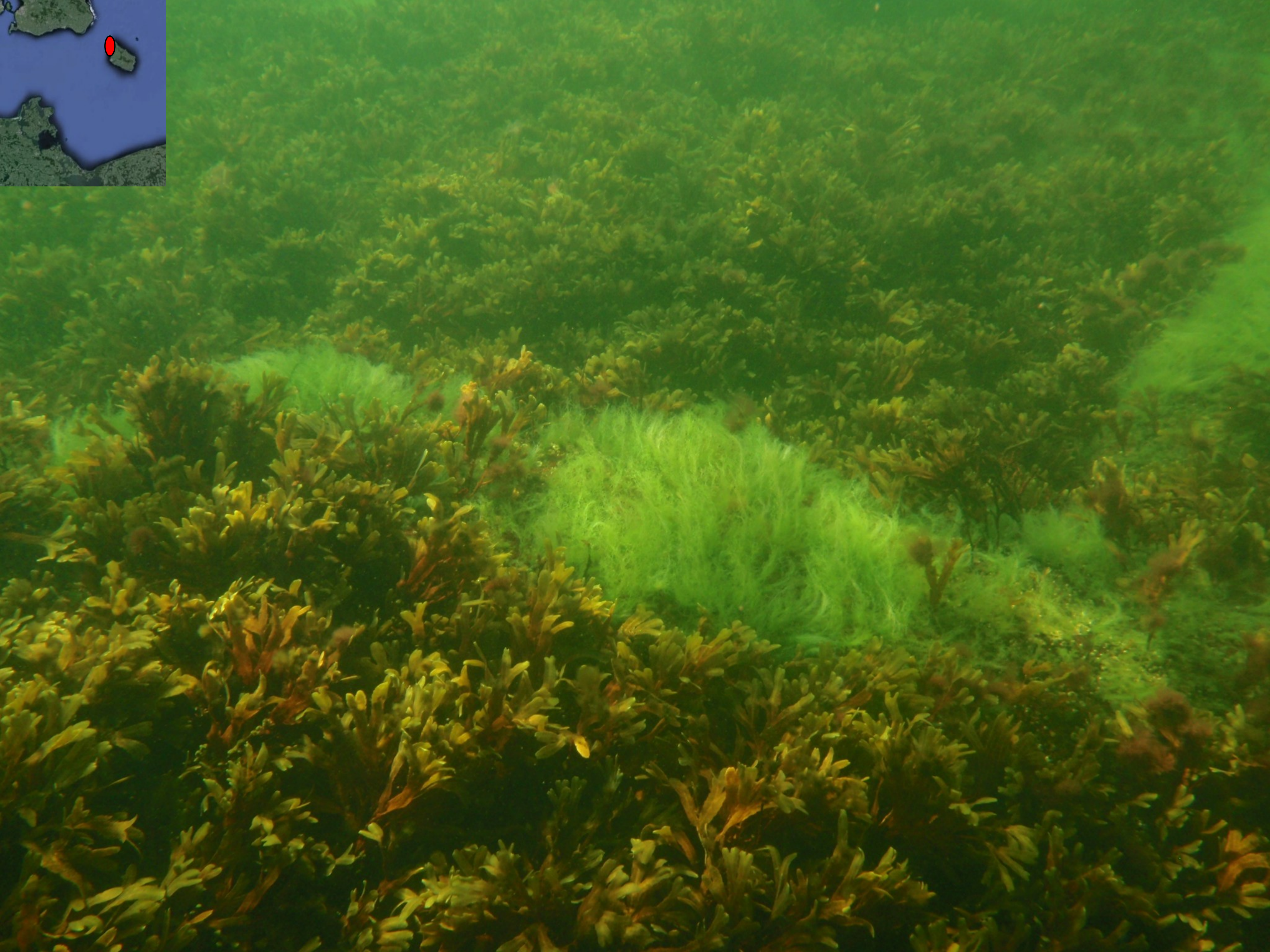
Order: **Cladophorales**

Cladophora



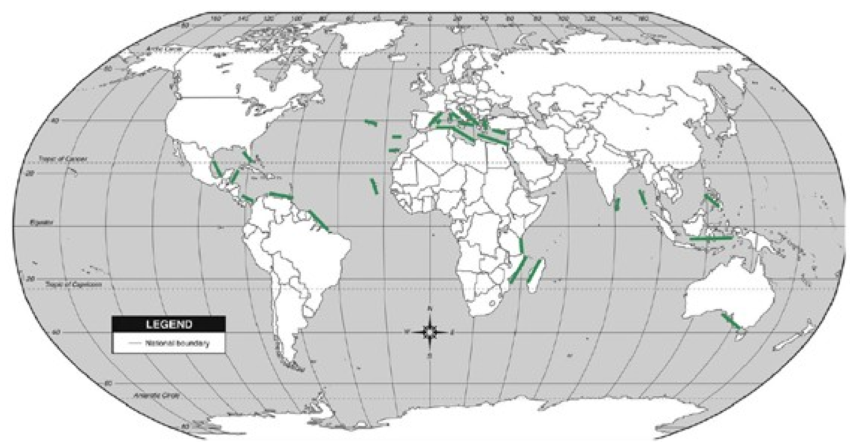
one of the most important bioindicators of eutrophic conditions

Cladophora glomerata -
one of the most frequent algae in Central European landscape



Anadyomene

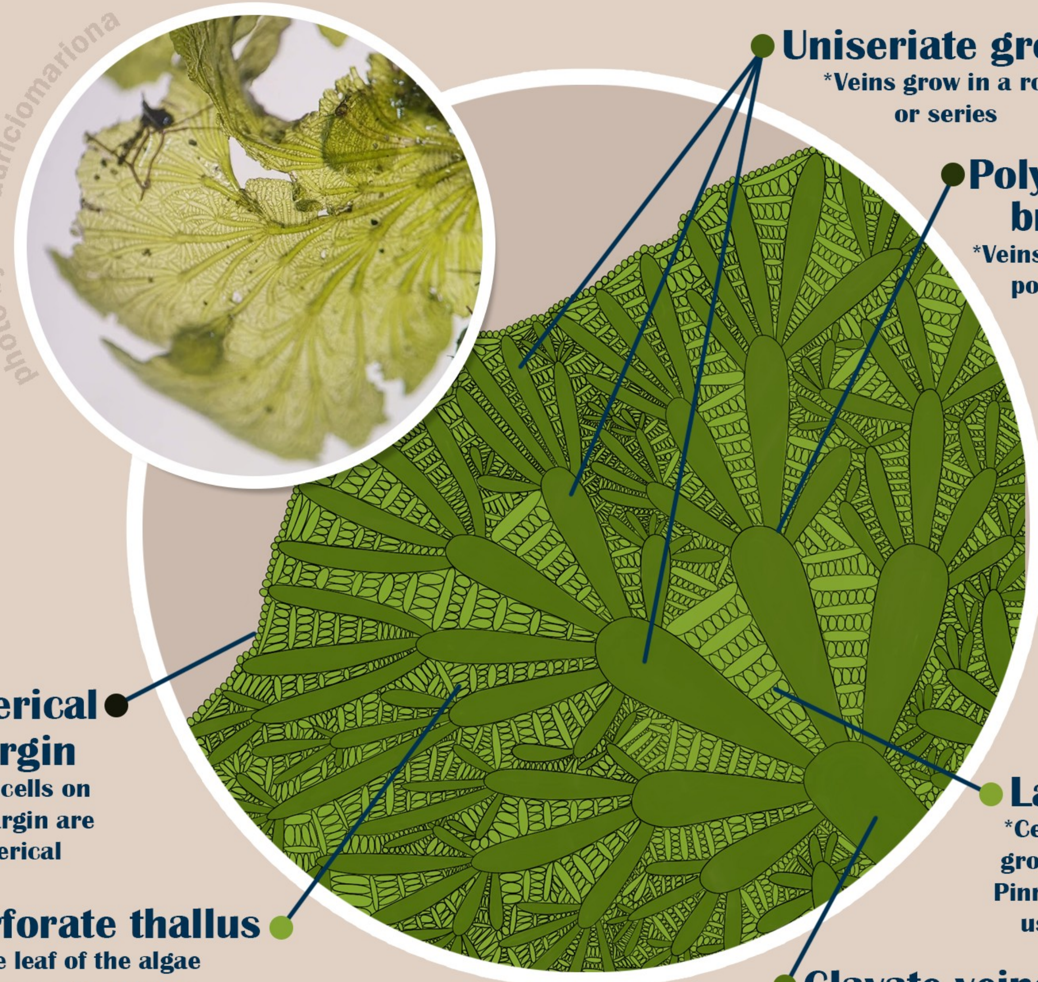
A. stellata

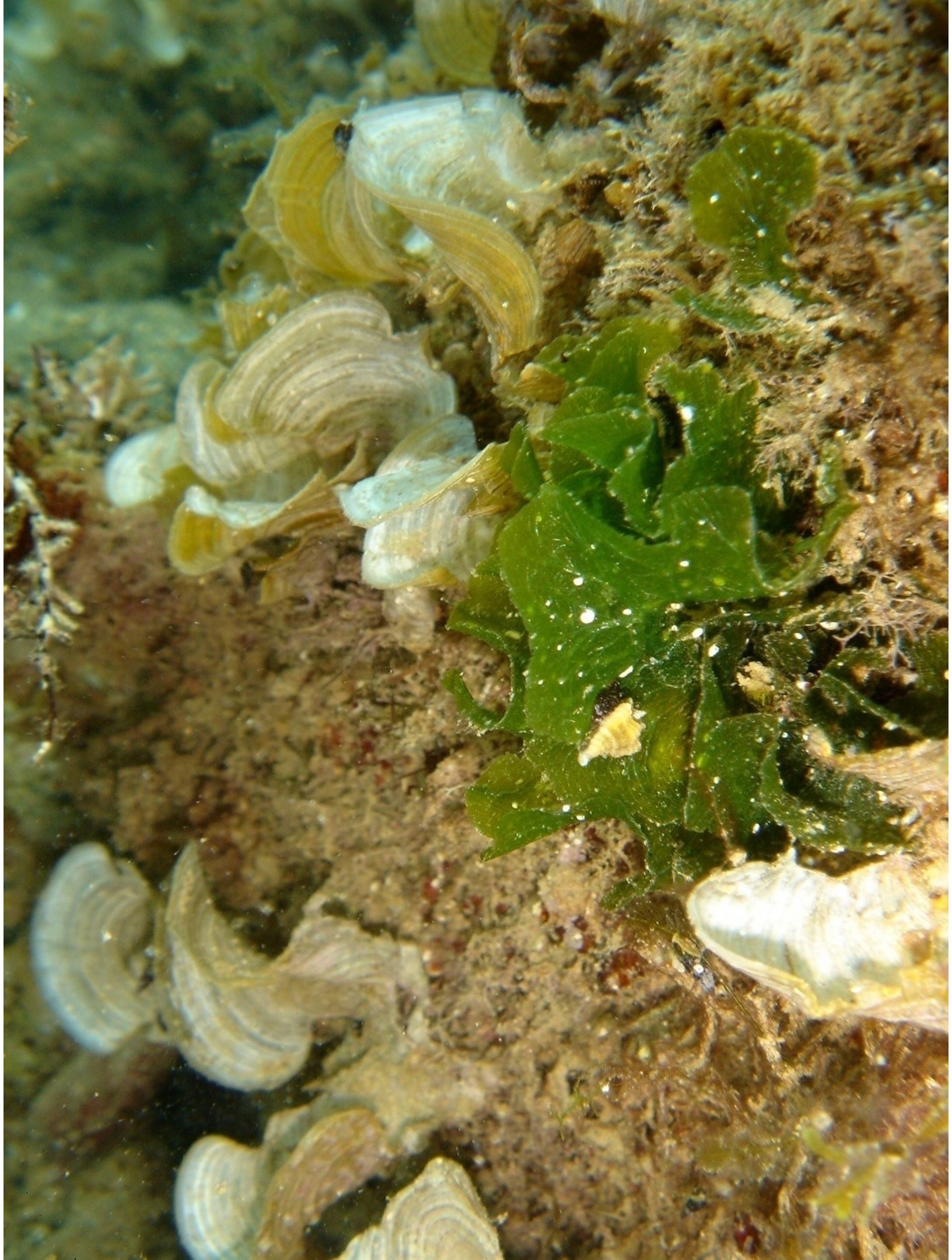


tropical species – SE Asia, Pacific, Carribean; single species in Europe

ANALYSIS

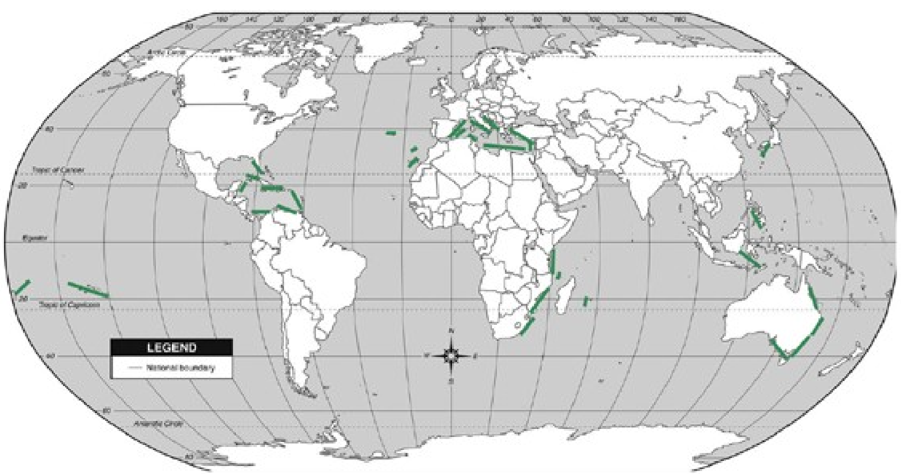
Anadyomene stellata





Valonia

V. utricularis

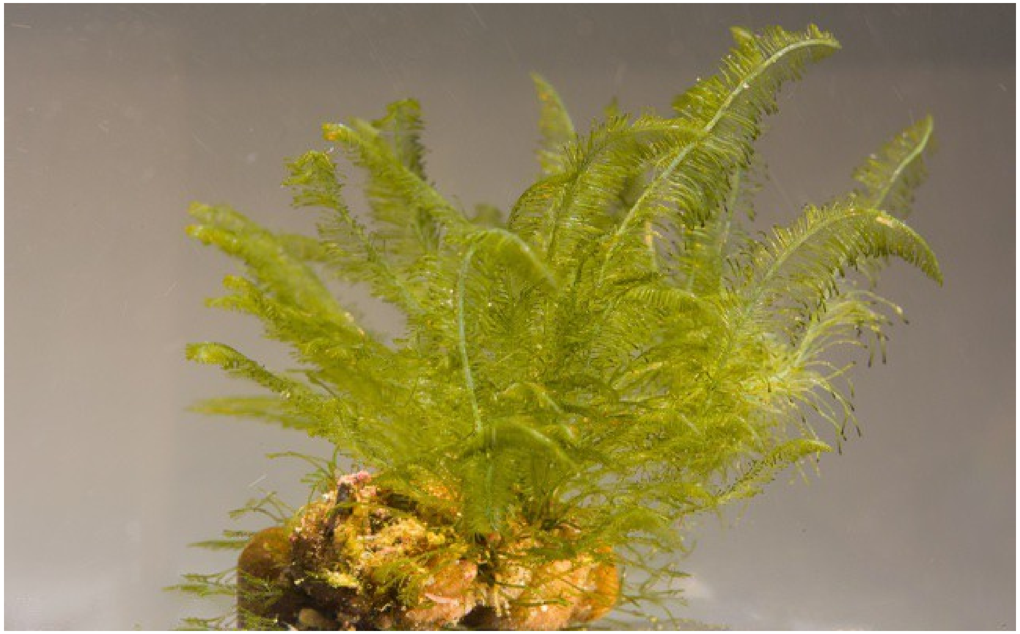


warm seas – tropics, subtropics

V. macrophysa

Bryopsidales

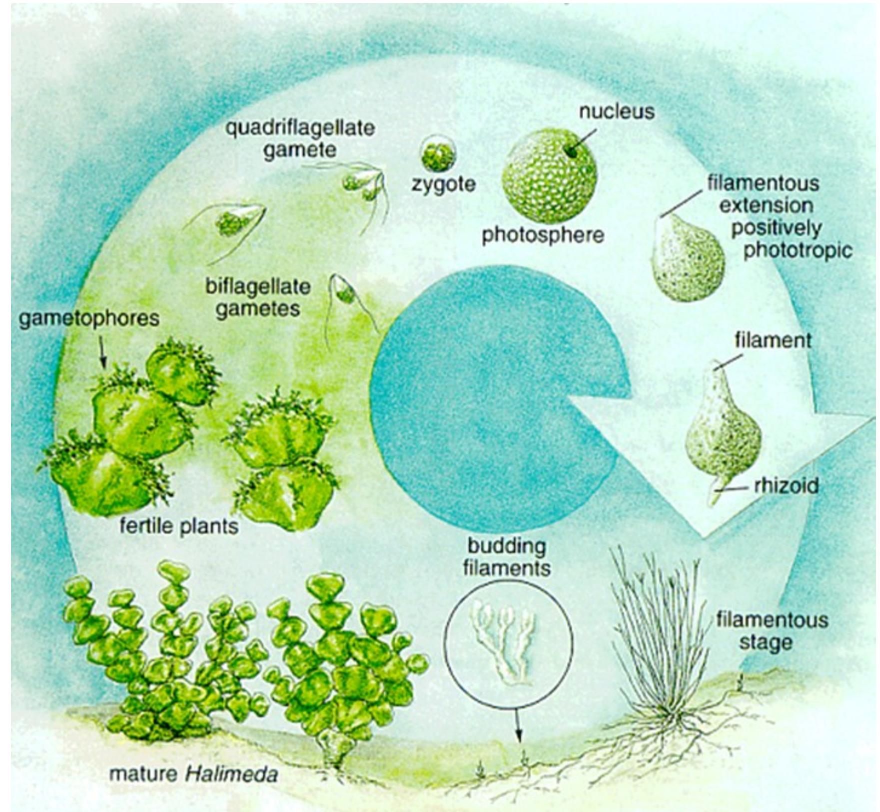
Bryopsis

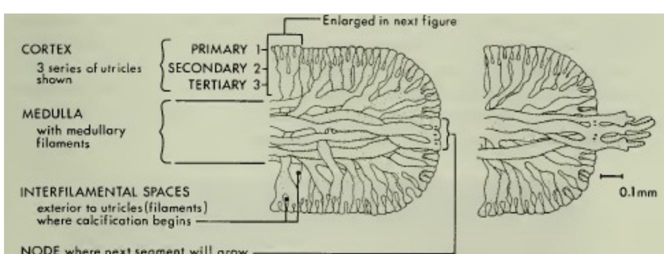


coenocytic thalli
(multinucleate)

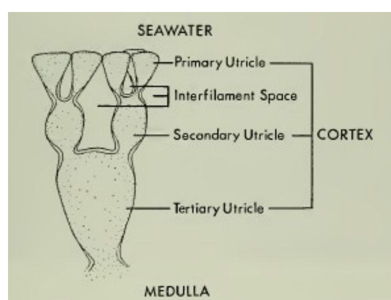
Halimeda – *a* key species in tropical habitats; coenocytic, macroscopic thalli
xylans in cell walls, aragonite crystals in interfilamentous spaces

calcified thalli producing about 30% of Neogene carbonate sediments





cross section through a segment



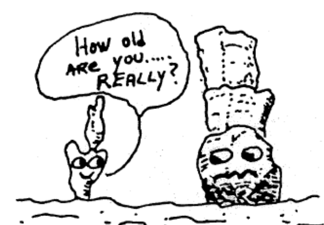
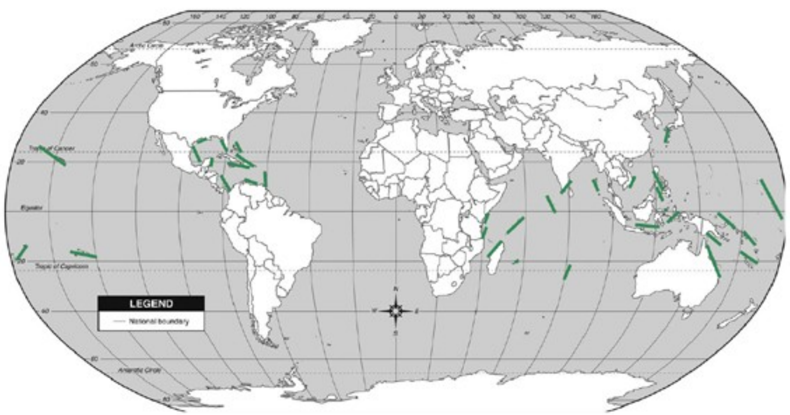


Figure 7. *Chemical defense.*

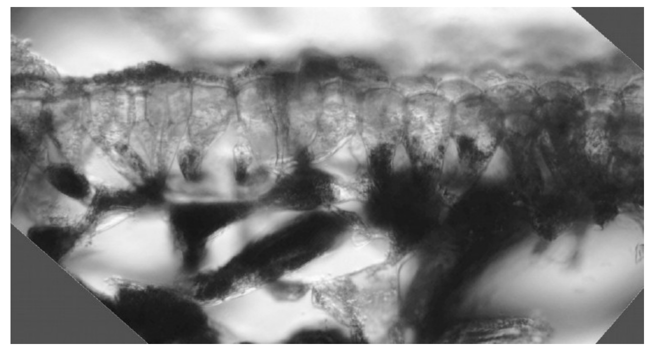
Multer & Clavijo, 2004, Halimeda Investigations: Progress and Problems

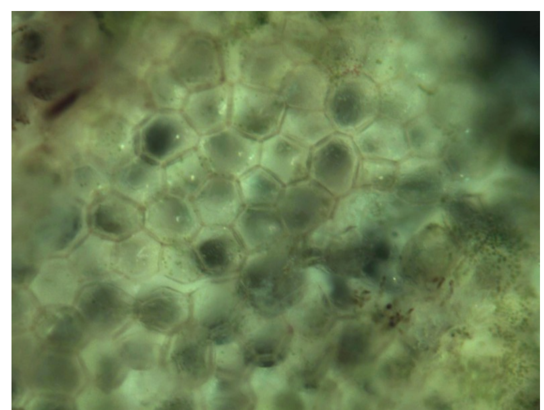
H. macroloba



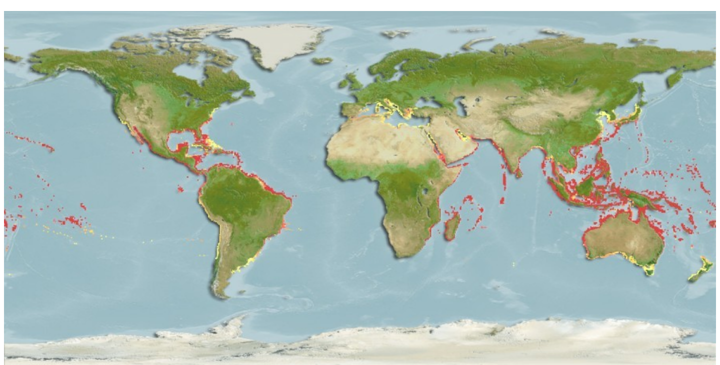
H. incrassata

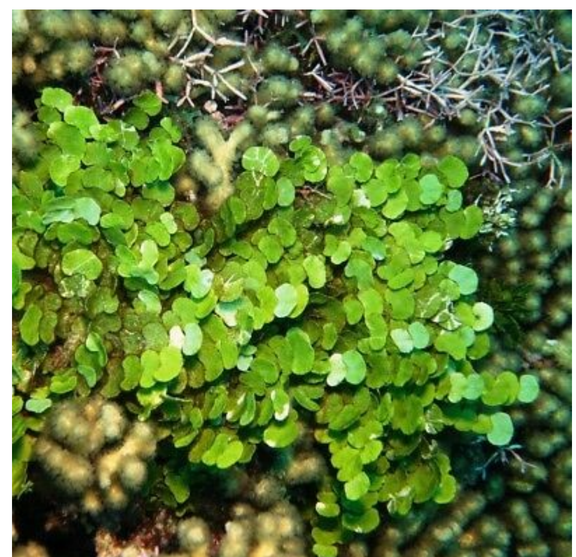
H. tuna





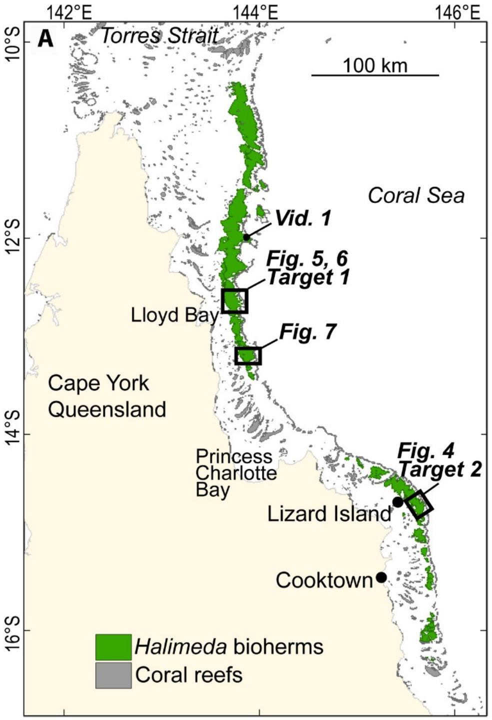
H. opuntia

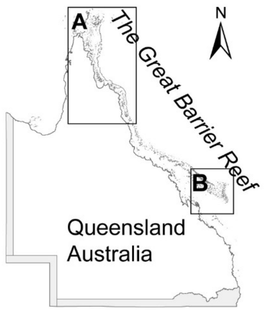


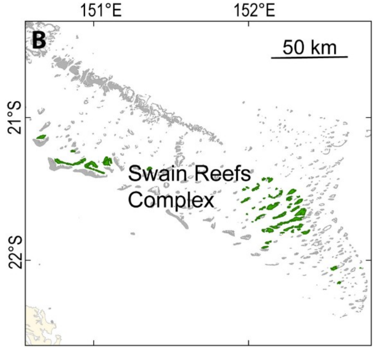


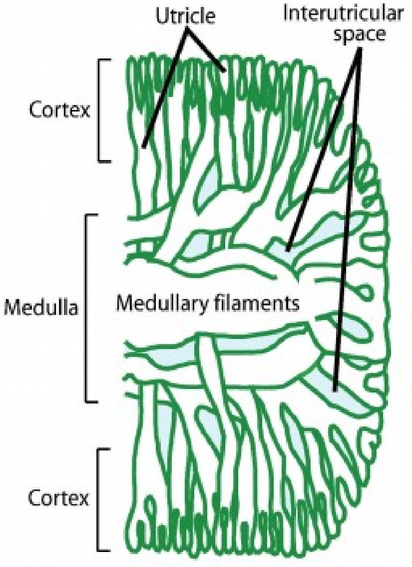
bioherms (organic reefs) – *Halimeda* reefs and meadows

key organisms to $CaCO_3$ in marine ecosystems (**benthic calcification**)









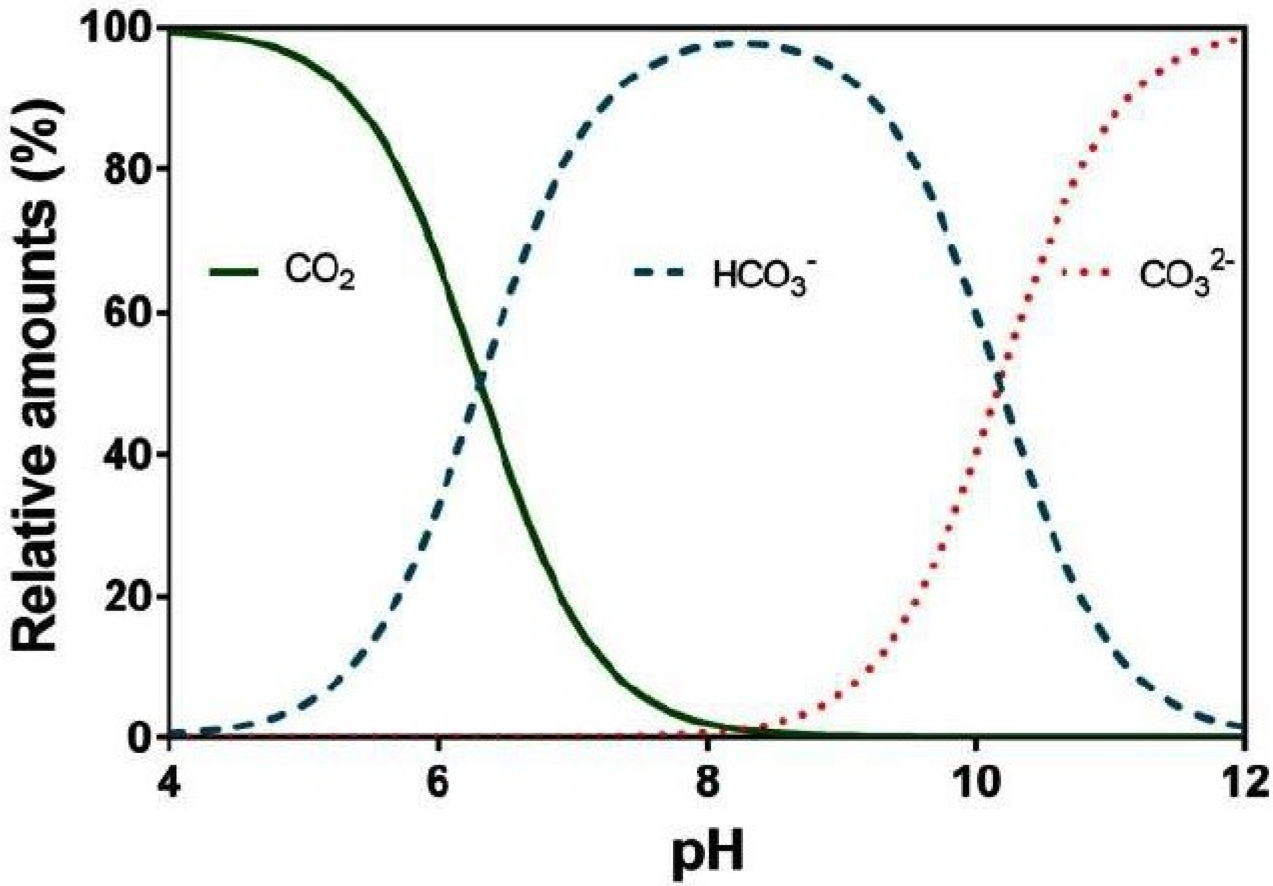
Rees et al., 2007, Coral Reefs 26: 177-188
McNeil et al, 2020.

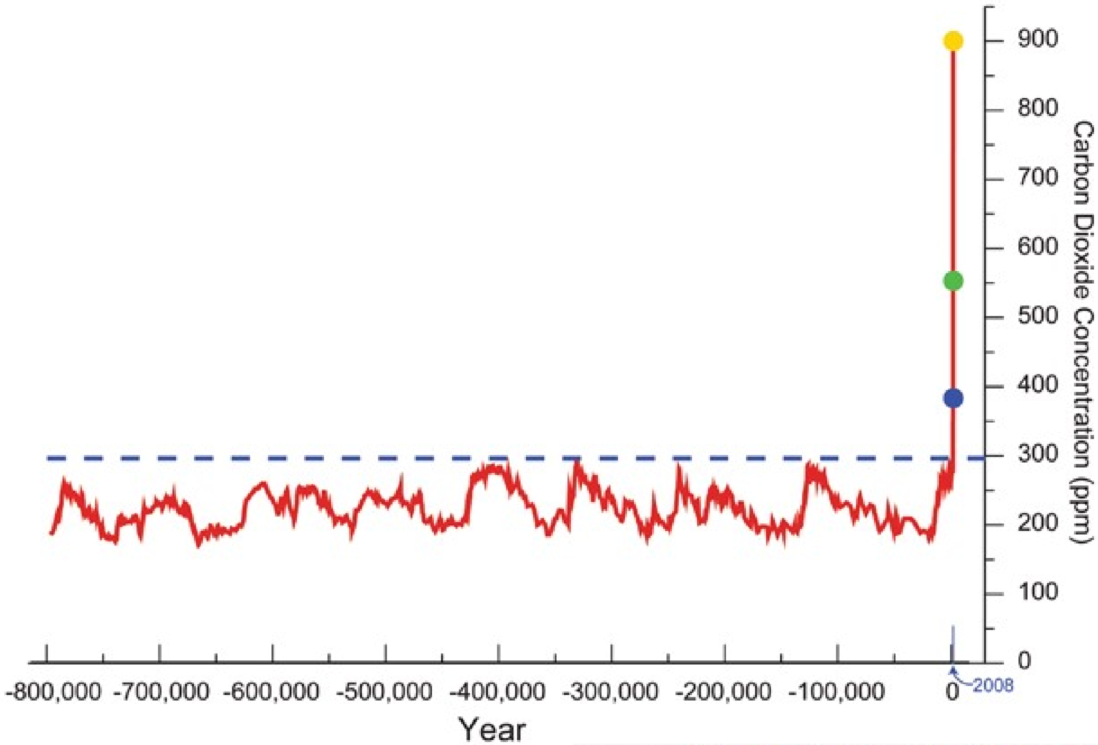
Halimeda meadows at GBR and close to Hawaii

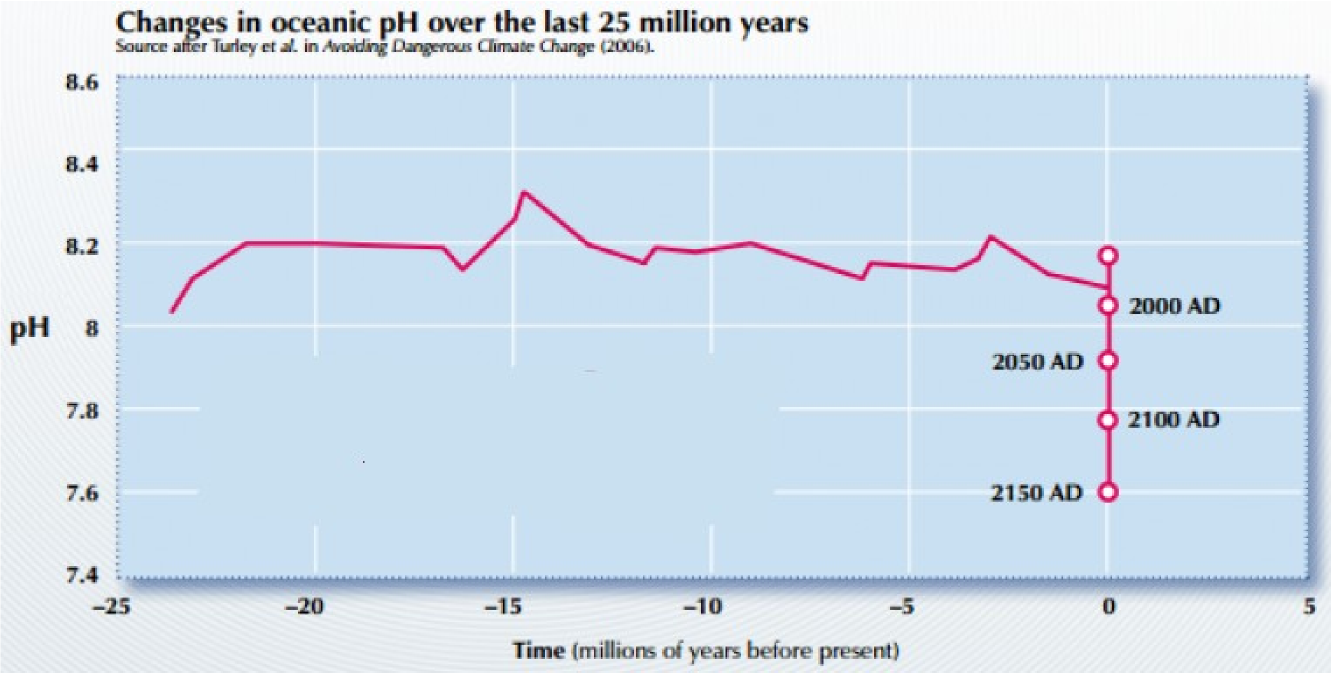
mesophotic *Halimeda* draperies

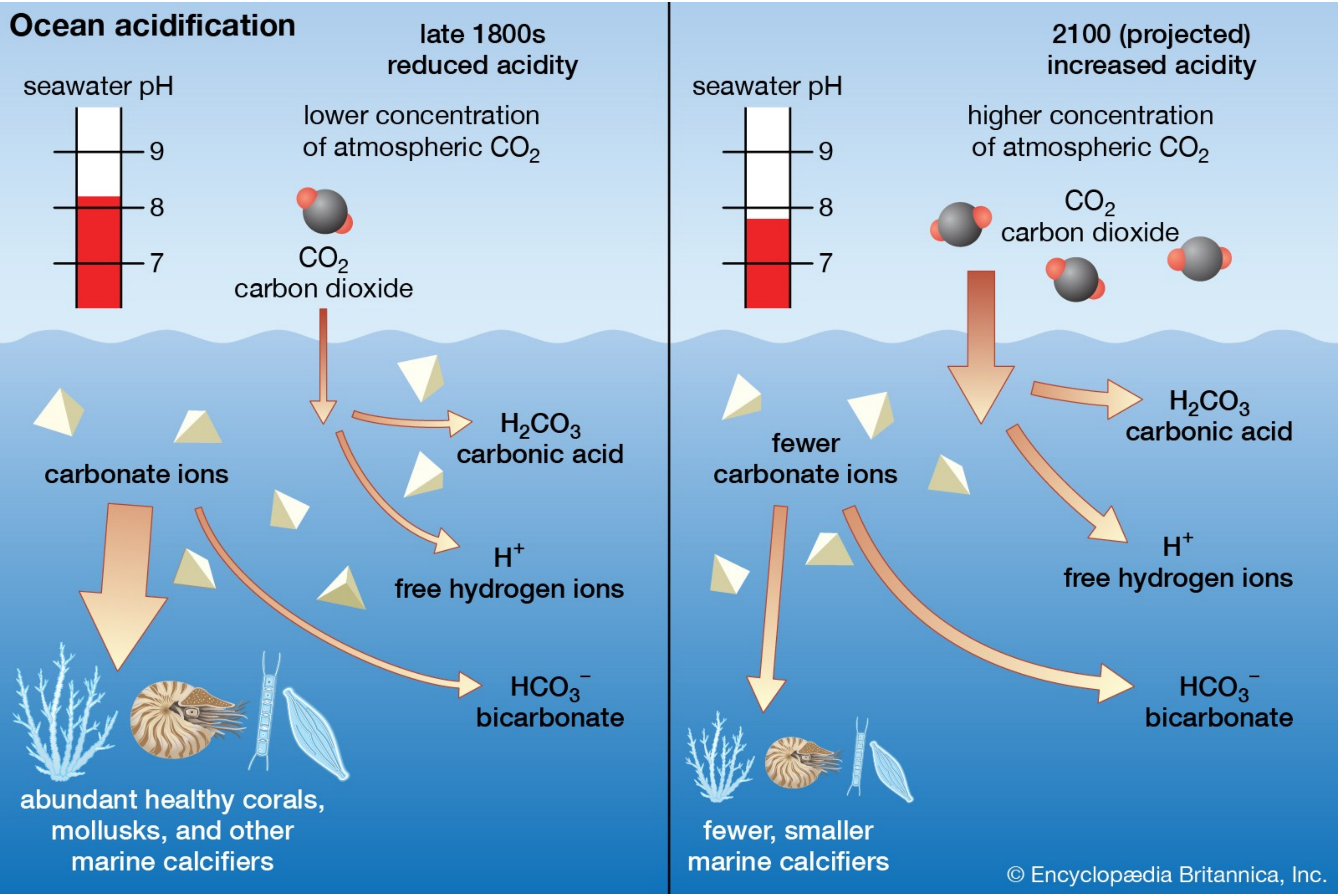
carbon dioxide – bicarbonate – carbonate equilibrium in water

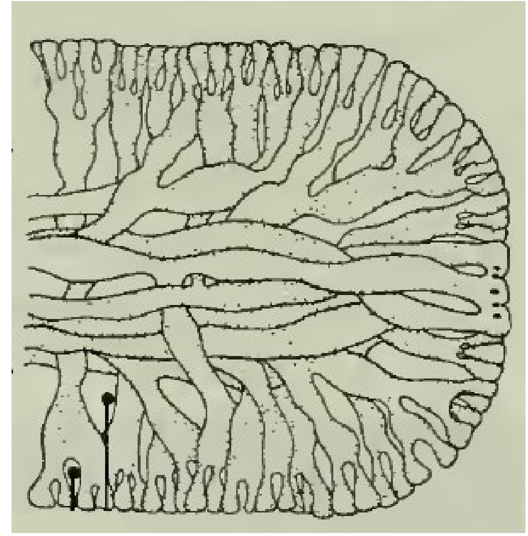
$$CO_2 + H_2O \Leftrightarrow H_2CO_3 \Leftrightarrow H^+ + HCO_3^- \Leftrightarrow 2H^+ + CO_3^{2-}$$

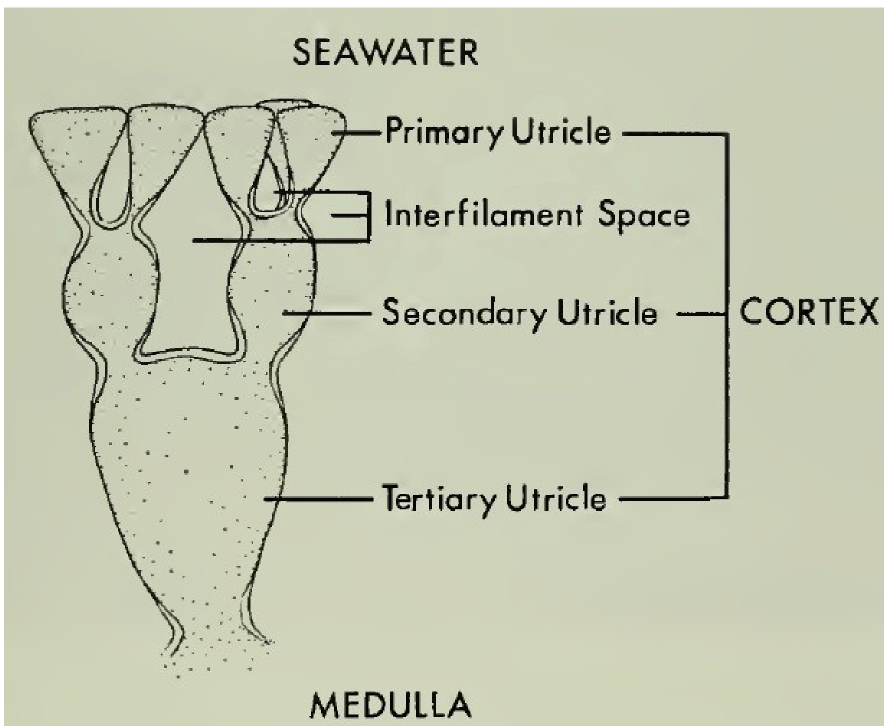


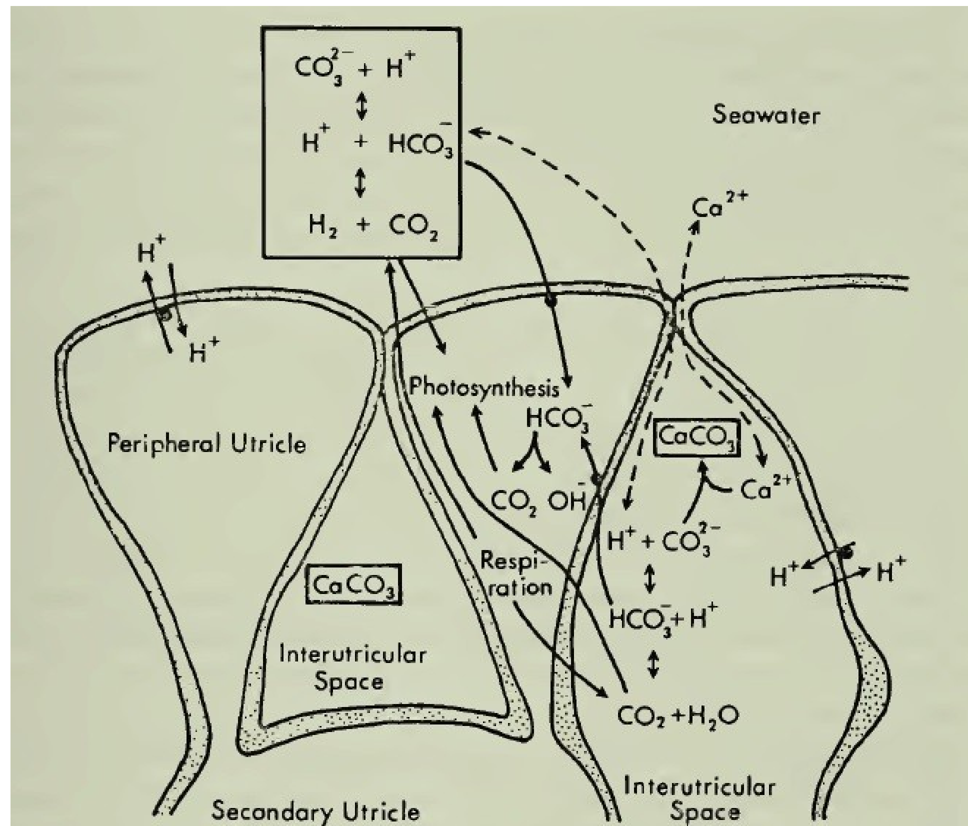

900
800
700
600
500
400
300
200
100
0
Carbon Dioxide Concentration (ppm)
-800,000
-700,000
-600,000
-500,000
-400,000
-300,000
-200,000
-100,000
0
2008
Year


Changes in oceanic pH over the last 25 million years
Source after Turley et al. in Avoiding Dangerous Climate Change (2006).
8.6
8.4
8.2
pH
8
7.8
7.6
7.4
2000 AD
2050 AD
2100 AD
2150 AD
−25
−20
−15
−10
−5
0
5
Time (millions of years before present)

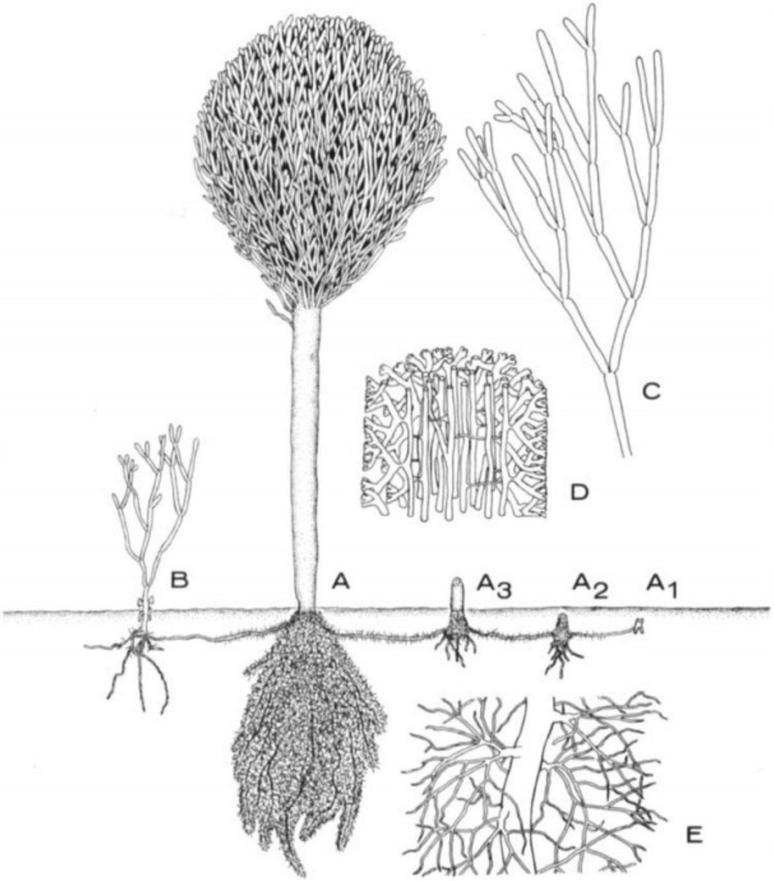

Ocean acidification
late 1800s
reduced acidity
seawater pH
9
8
7
lower concentration
of atmospheric CO_2
CO_2
carbon dioxide
H_2CO_3
carbonic acid
carbonate ions
H^+
free hydrogen ions
HCO_3^-
bicarbonate
abundant healthy corals,
mollusks, and other
marine calcifiers
2100 (projected)
increased acidity
seawater pH
9
8
7
higher concentration
of atmospheric CO_2
CO_2
carbon dioxide
H_2CO_3
carbonic acid
fewer
carbonate ions
H^+
free hydrogen ions
HCO_3^-
bicarbonate
fewer, smaller
marine calcifiers
© Encyclopædia Britannica, Inc.



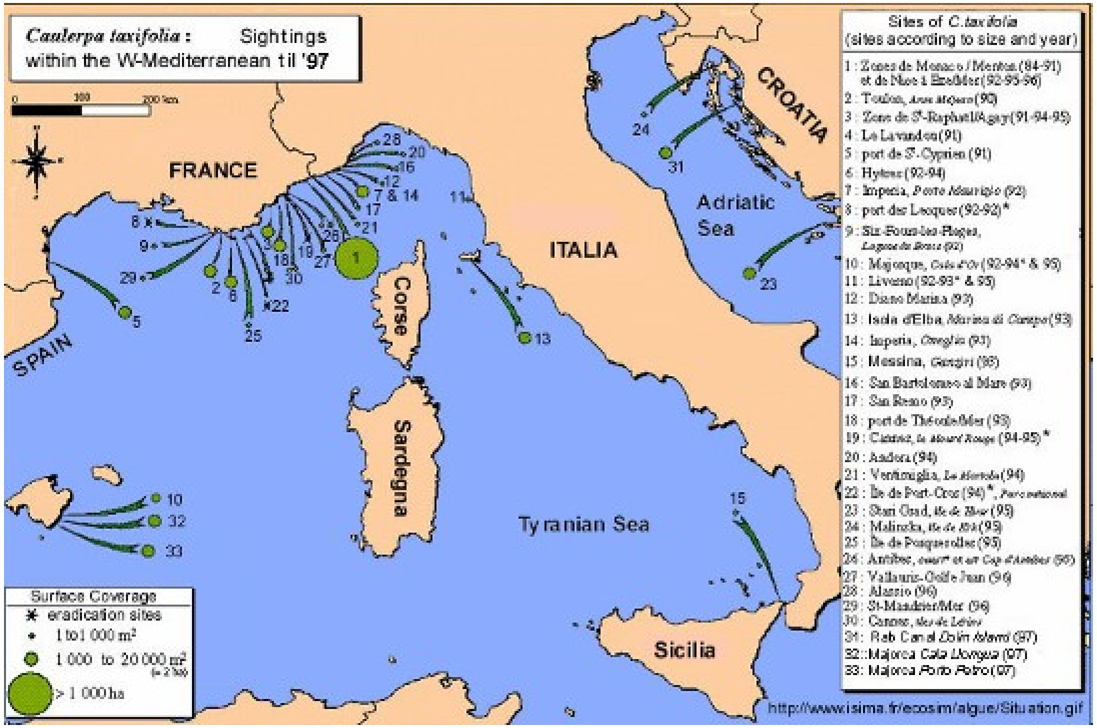

SEAWATER
Primary Utricle
Interfilament Space
Secondary Utricle
CORTEX
Tertiary Utricle
MEDULLA

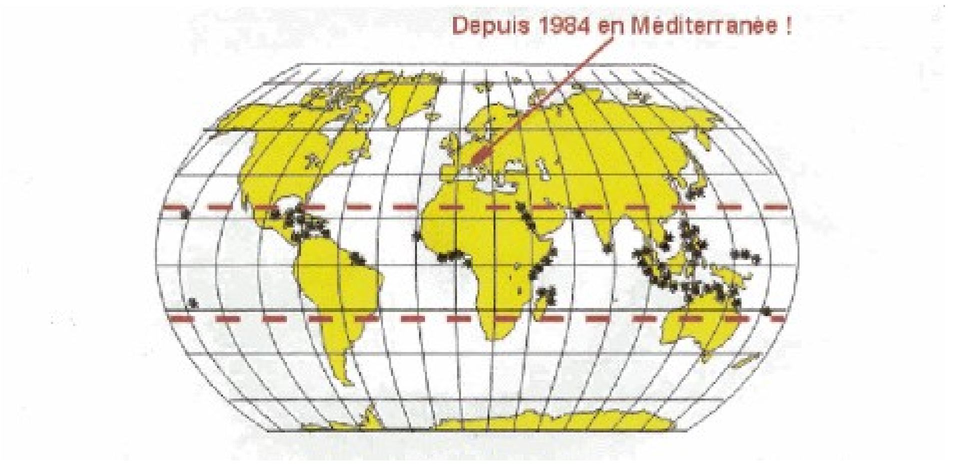

$CO_3^{2-} + H^+$
$H^+ + HCO_3^-$
$H_2 + CO_2$
Seawater
Ca^{2+}
H^+
H^+
Photosynthesis
HCO_3^-
CO_2 OH^-
$CaCO_3$
Ca^{2+}
Peripheral Utricle
$H^+ + CO_3^{2-}$
H^+
H^+
Respi-
ration
$HCO_3^- + H^+$
$CaCO_3$
Interutricular
Space
$CO_2 + H_2O$
Secondary Utricle
Interutricular
Space

Penicillus

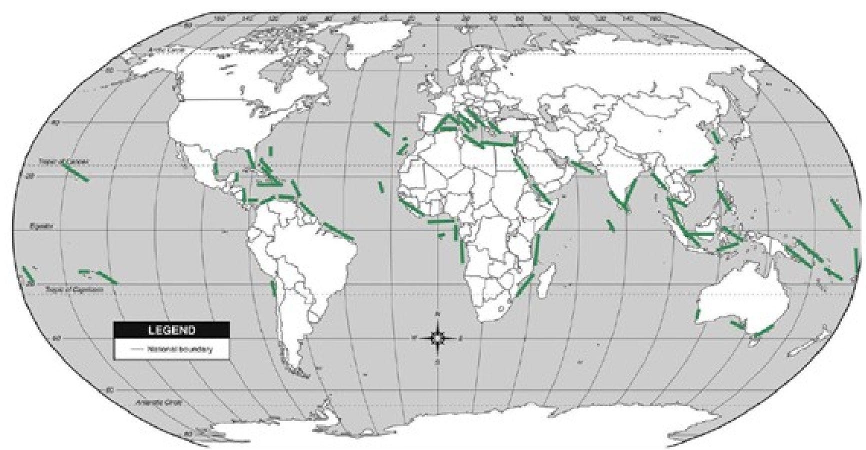


Caulerpa taxifolia



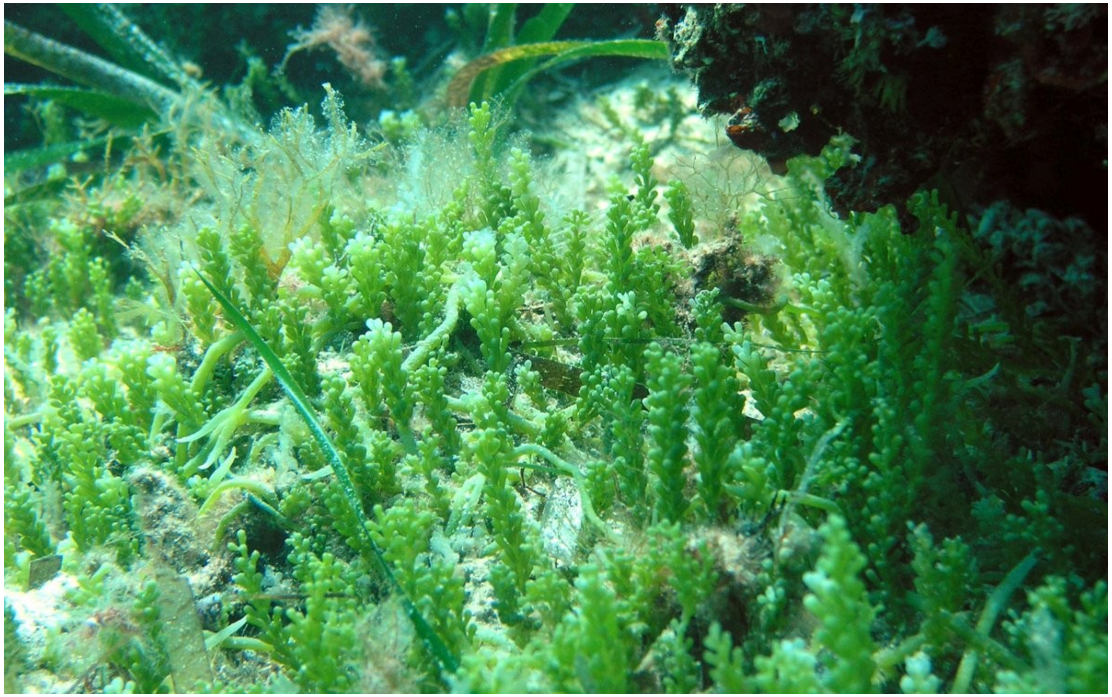


Caulerpa racemosa/cylindracea complex



Caulerpa cylindracea

the single most invasive macroalga in the Mediterranean Sea



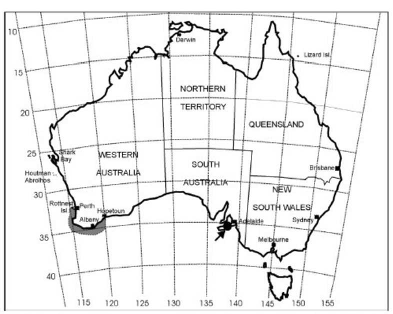
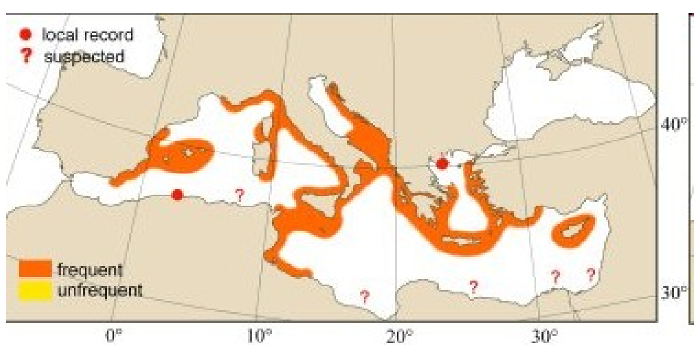


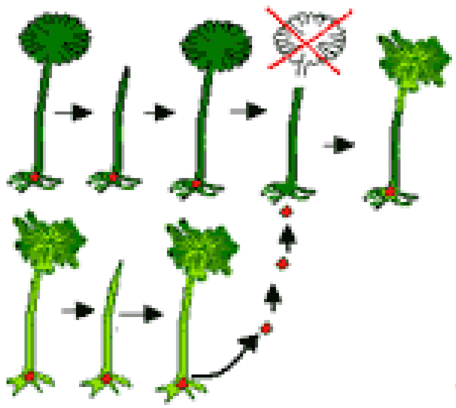
Fig. 2. Map indicating the native range of *Caulerpa racemosa* var. *cylindracea* in south-western Australia (grey surface) and its introduction in Adelaide (• + arrowhead) (from Verlaque et al., 2003; amended).

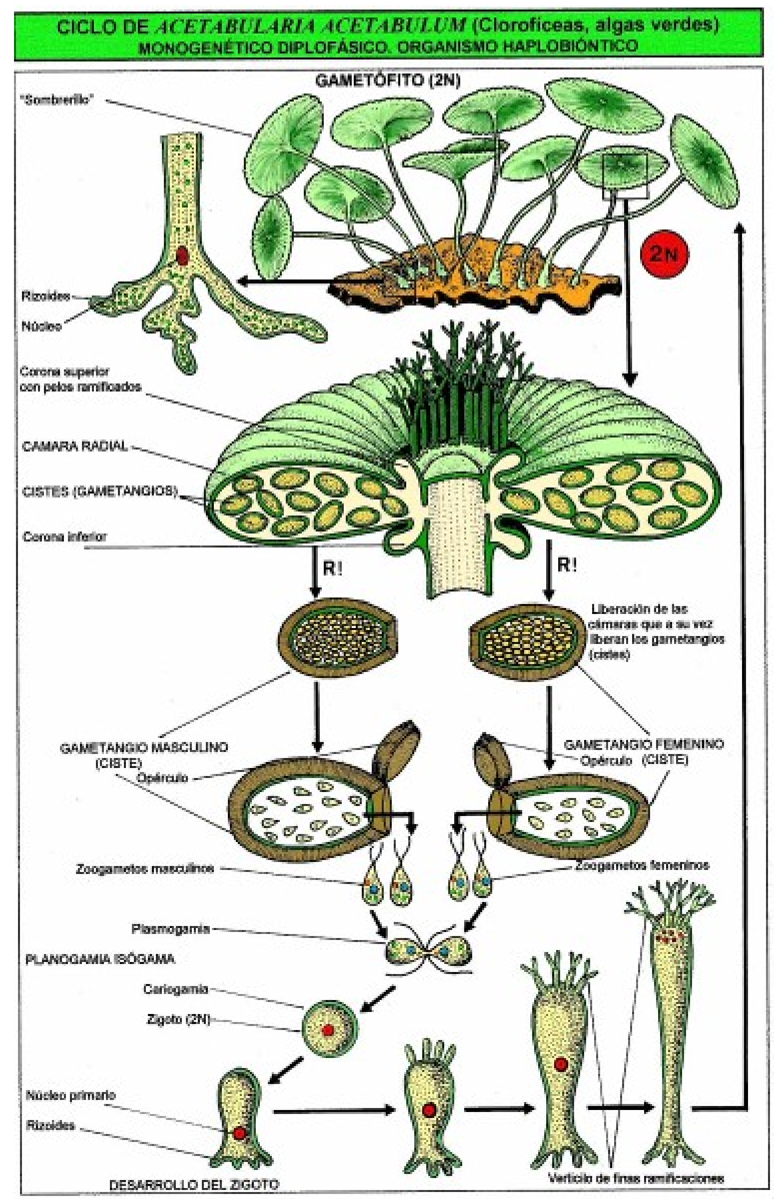


Verlaque & Klein, 2008, Mar. Poll. Bull.; Katsanevakis et al., 2020, Bioinvasions Rec.; Piazzi et al., 2016, Mar. Biol.

Dasycladales

Acetabularia and her giant nuclei

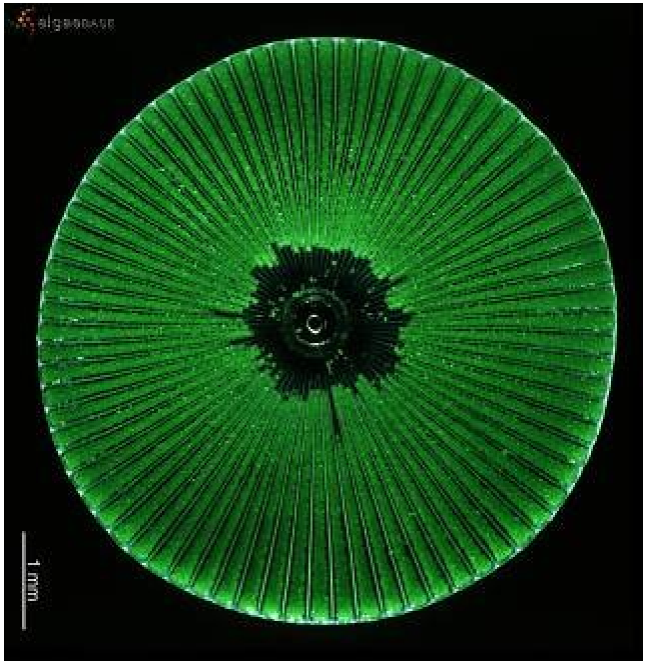


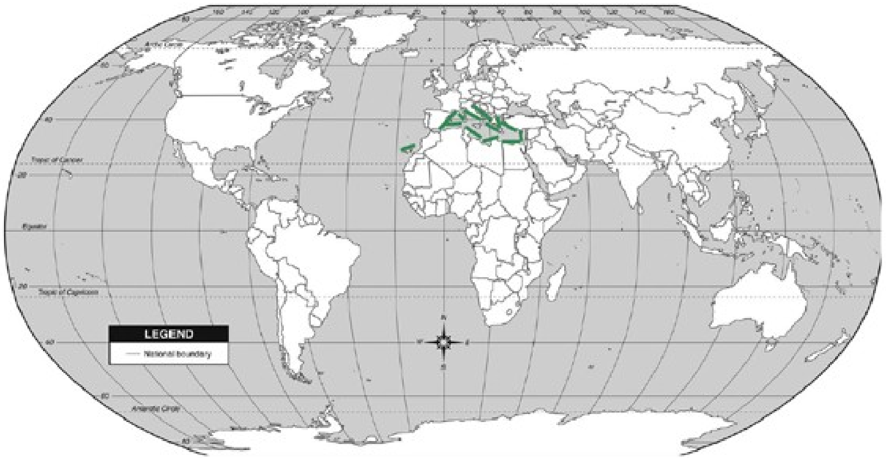


coenocytic thalli, mannans in cells walls

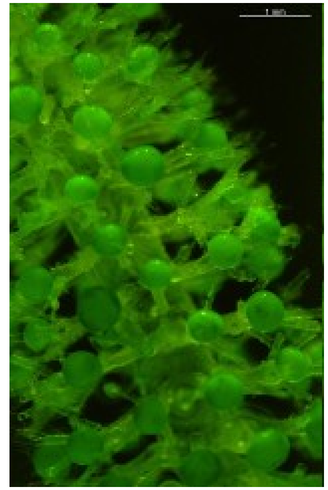
oldest findings in Cambrium (550 mya), Mesozoic radiation

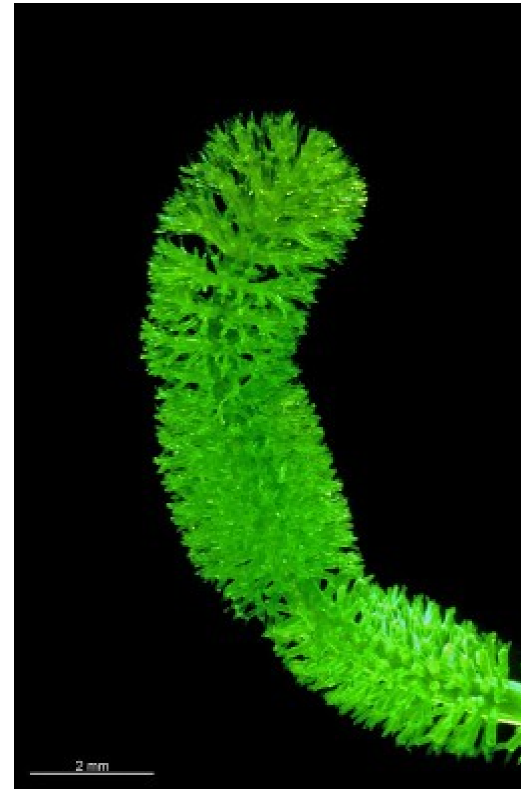
Acetabularia acetabulum

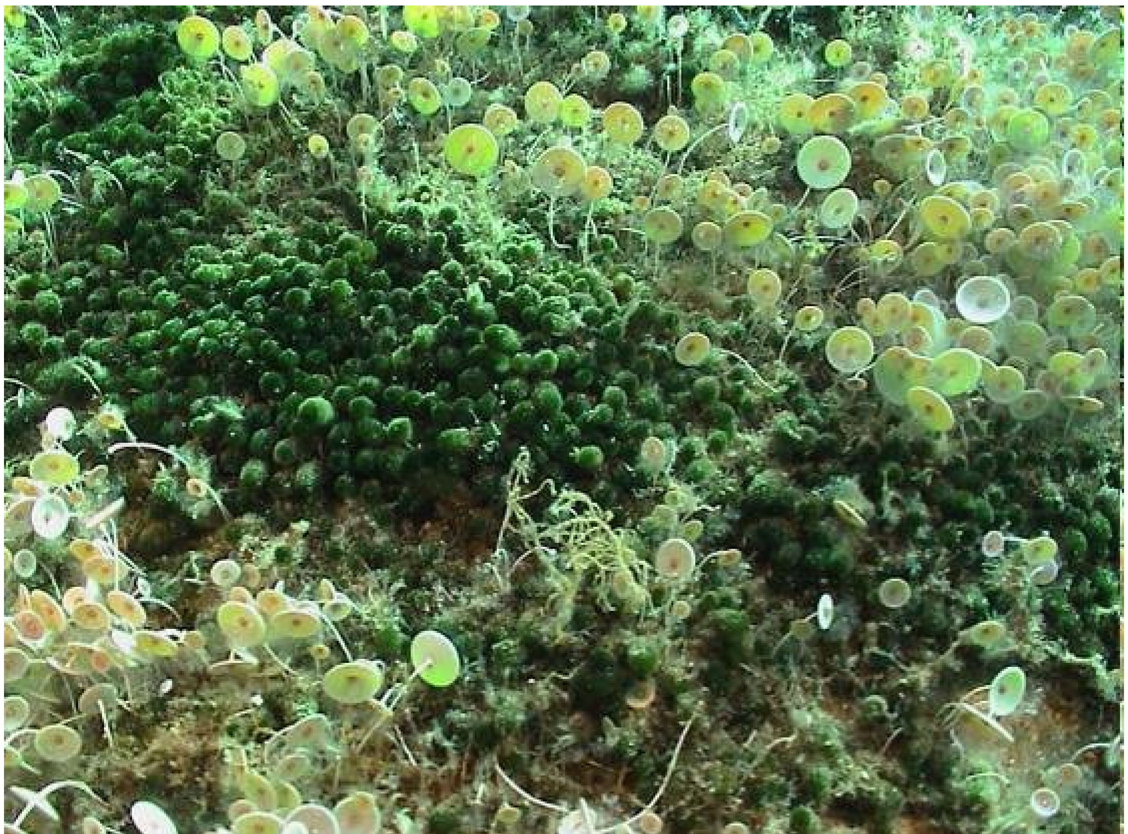


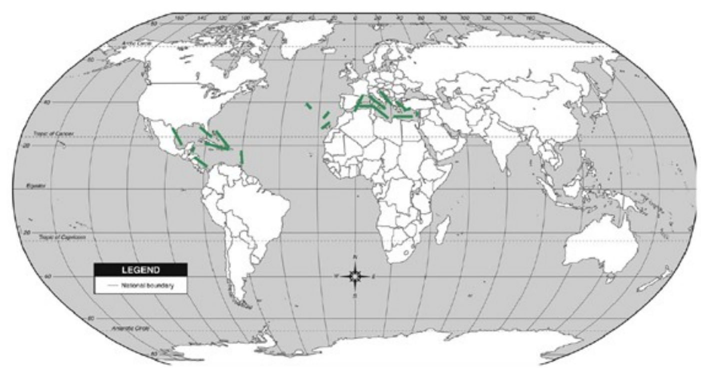


Dasycladus





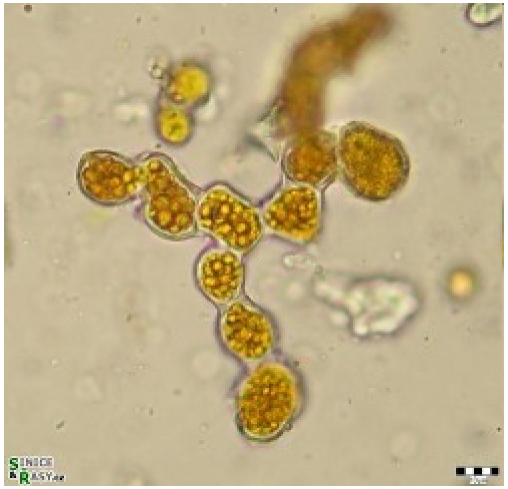


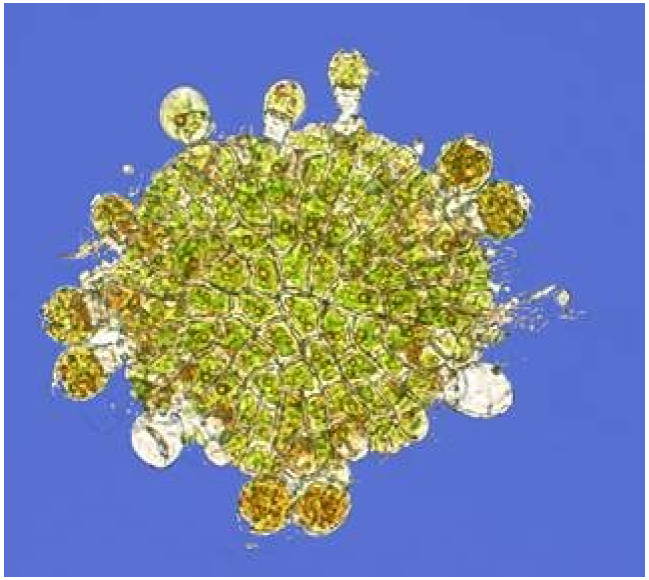


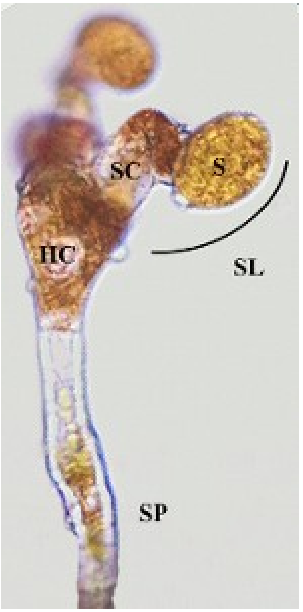
D. vermicularis

Order: **Trentepohliales**

Trentepohlia, Phycopeltis, Cephaleuros

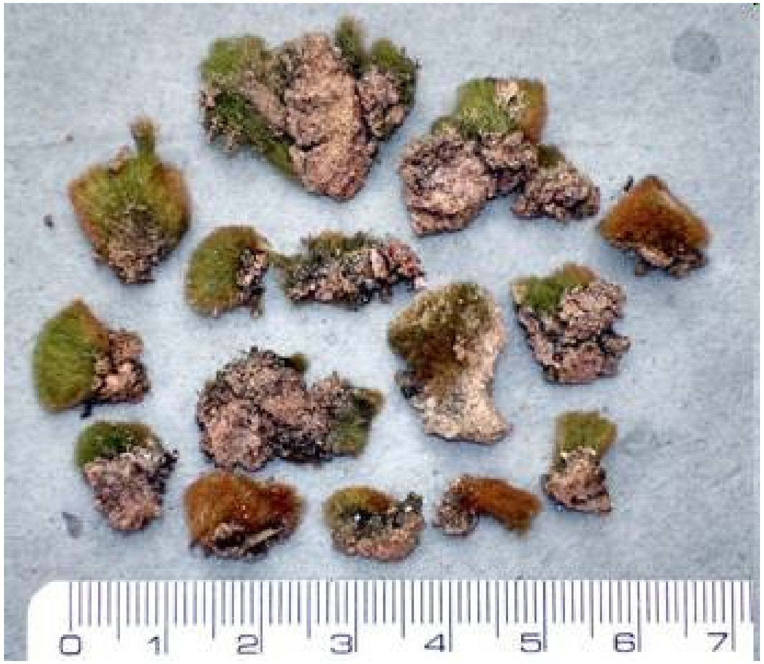




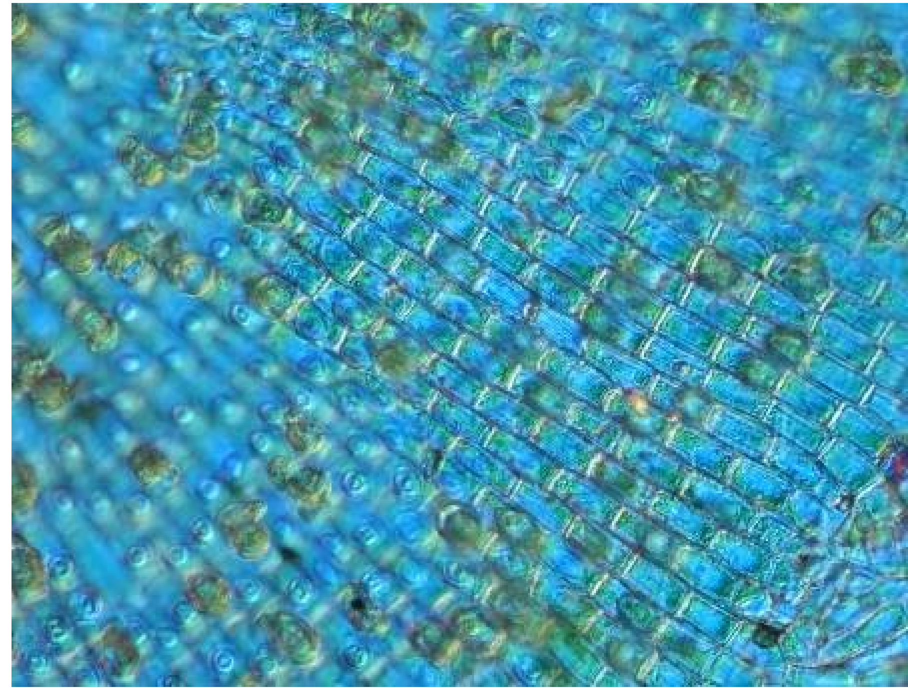


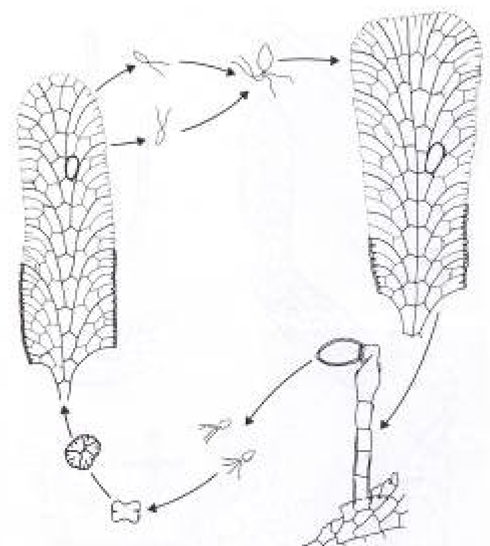
phragmoplast during cytokinesis; terrestrial specialists; parasites of vascular plants

Trentepohlia



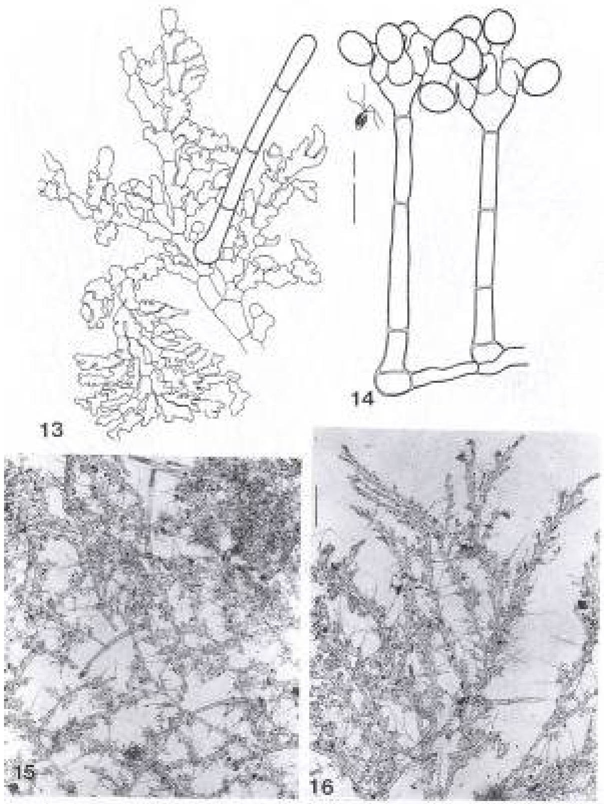
Phycopeltis

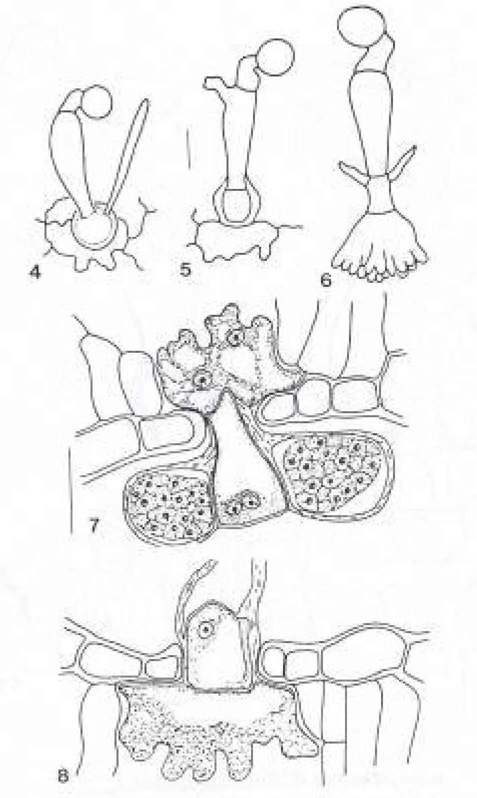


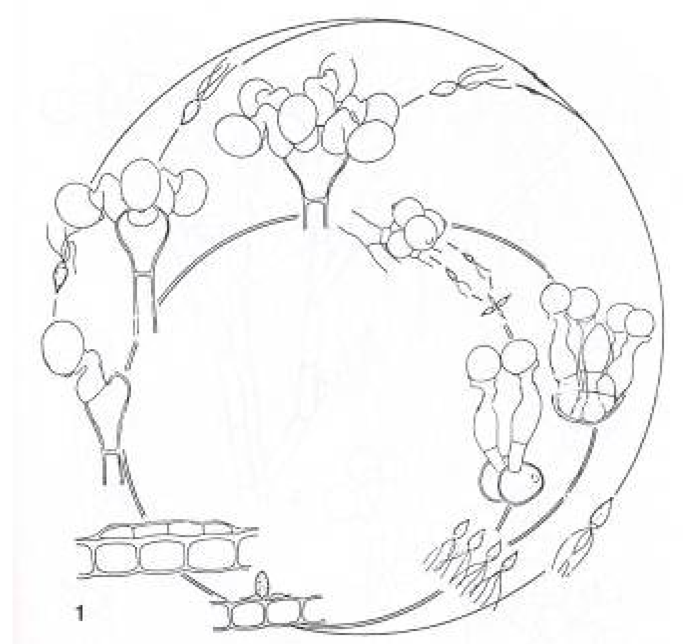


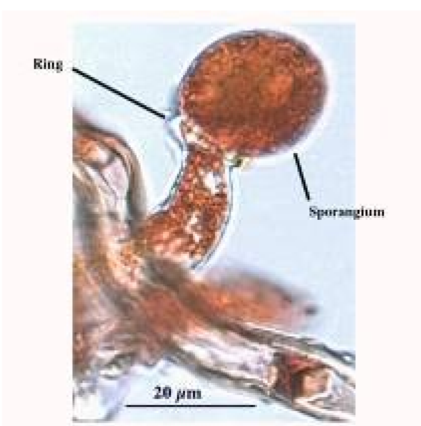
1

Cephaleuros and *Stomatochroon*









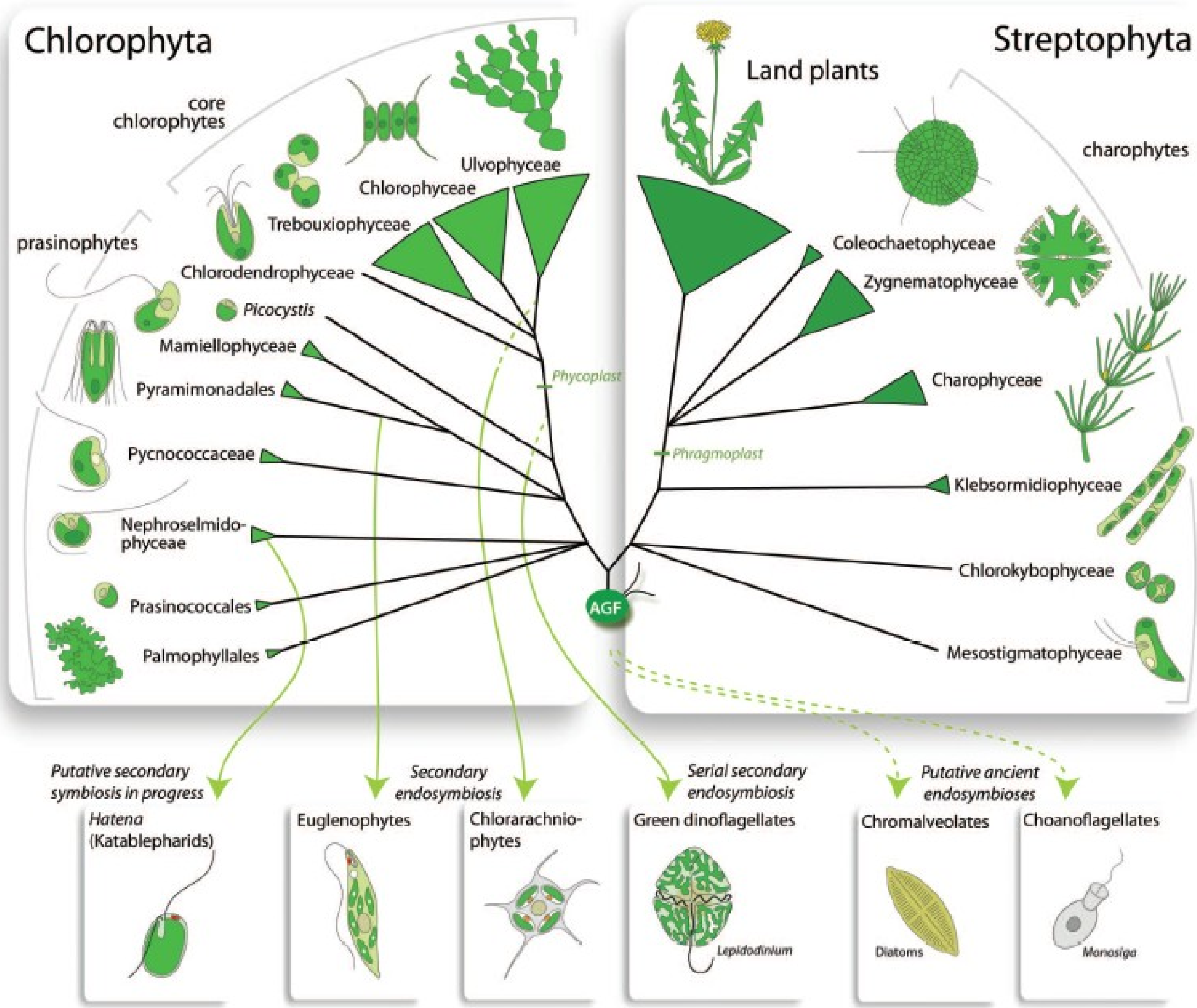


FIG. 2. Overview phylogeny of the green lineage (top) and spread of green genes in other eukaryotes (bottom). (Color figure available online.)

Leliaert et al., 2012, Crit. Rev. Pl. Sci. 31: 1-46

six algal classes of Streptophyta:

Mesostigmatophyceae (1 described species)

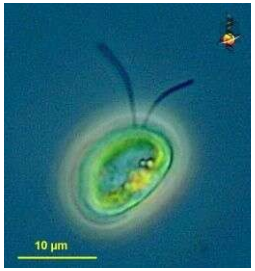
Chlorokybophyceae (5)

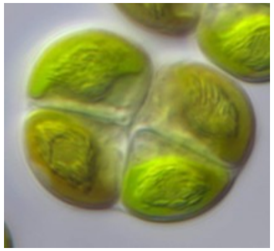
Klebsormidiophyceae (49)

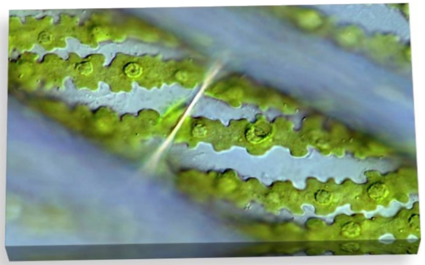
Coleochaetophyceae (36)

Charophyceae (ca 950)

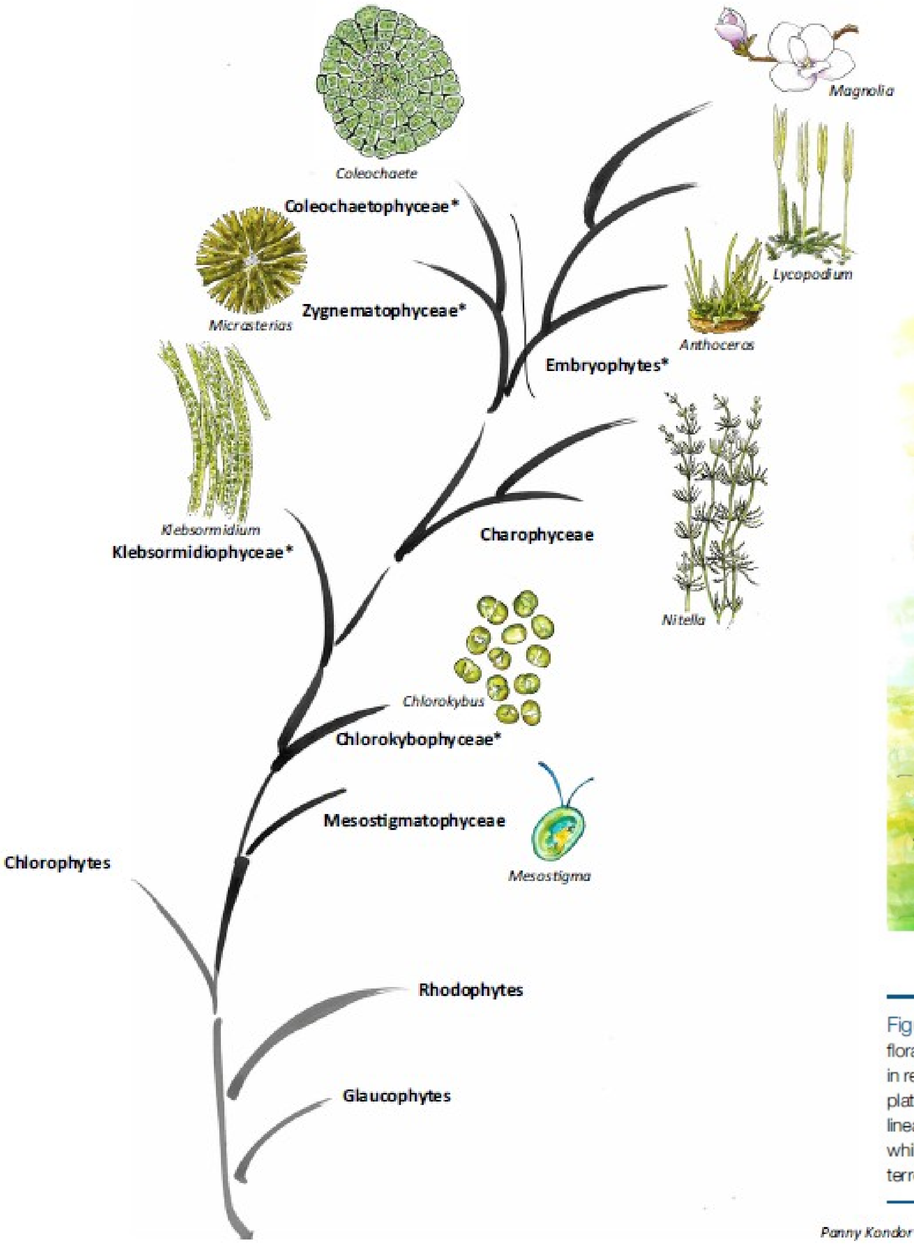
Zygnematophyceae (ca 4300)





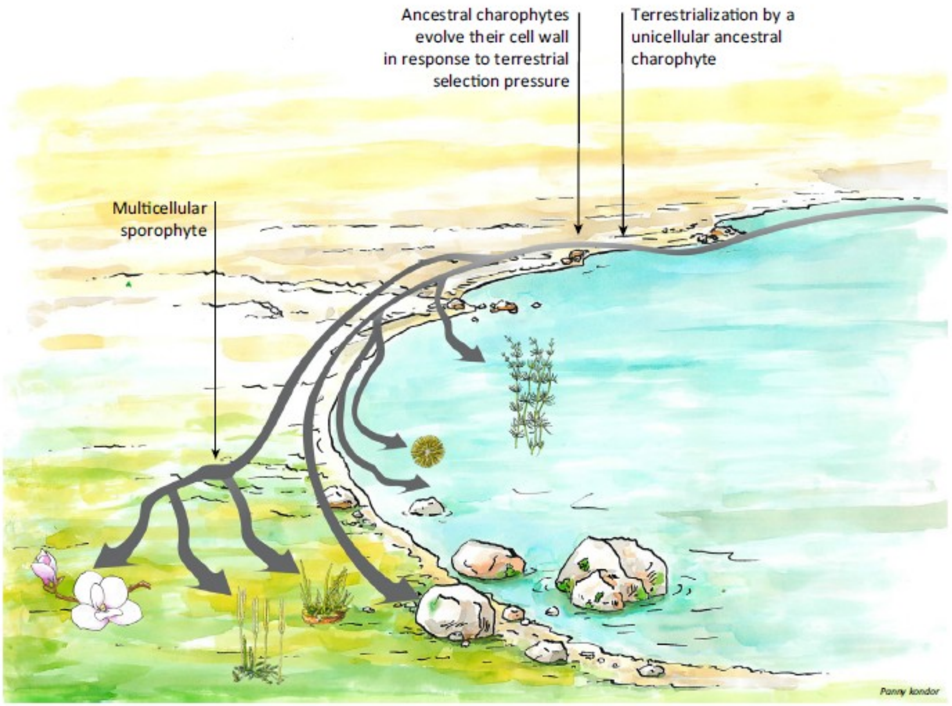


Early evolution of streptophytes



Trends in Plant Science

Figure I. Evolution of the Green Plant Lineage. Classes with terrestrial or facultative terrestrial species are indicated with an asterisk [21]. Modified from [1].



Trends in Plant Science

Figure 1. Evolution of land plants from algal ancestors that were already terrestrial. Key events in the establishment of a land flora were the primordial terrestrialization event by a unicellular ancestral charophyte followed by evolution of a novel cell wall in response to the new types of selection pressure. A particular successful lineage evolved the multicellular sporophyte as a platform for the development of complex body plans and vascularization, the latter facilitated by the new cell wall. Other lineages established themselves as extant terrestrial charophytes, here exemplified by *Klebsormidium* growing on a stone, while other taxa secondarily adopted an aquatic lifestyle yet retained the terrestrial traits in their cell wall as clues to their terrestrial ancestry.

Harholt et al., 2016, Trends Plant Sci.

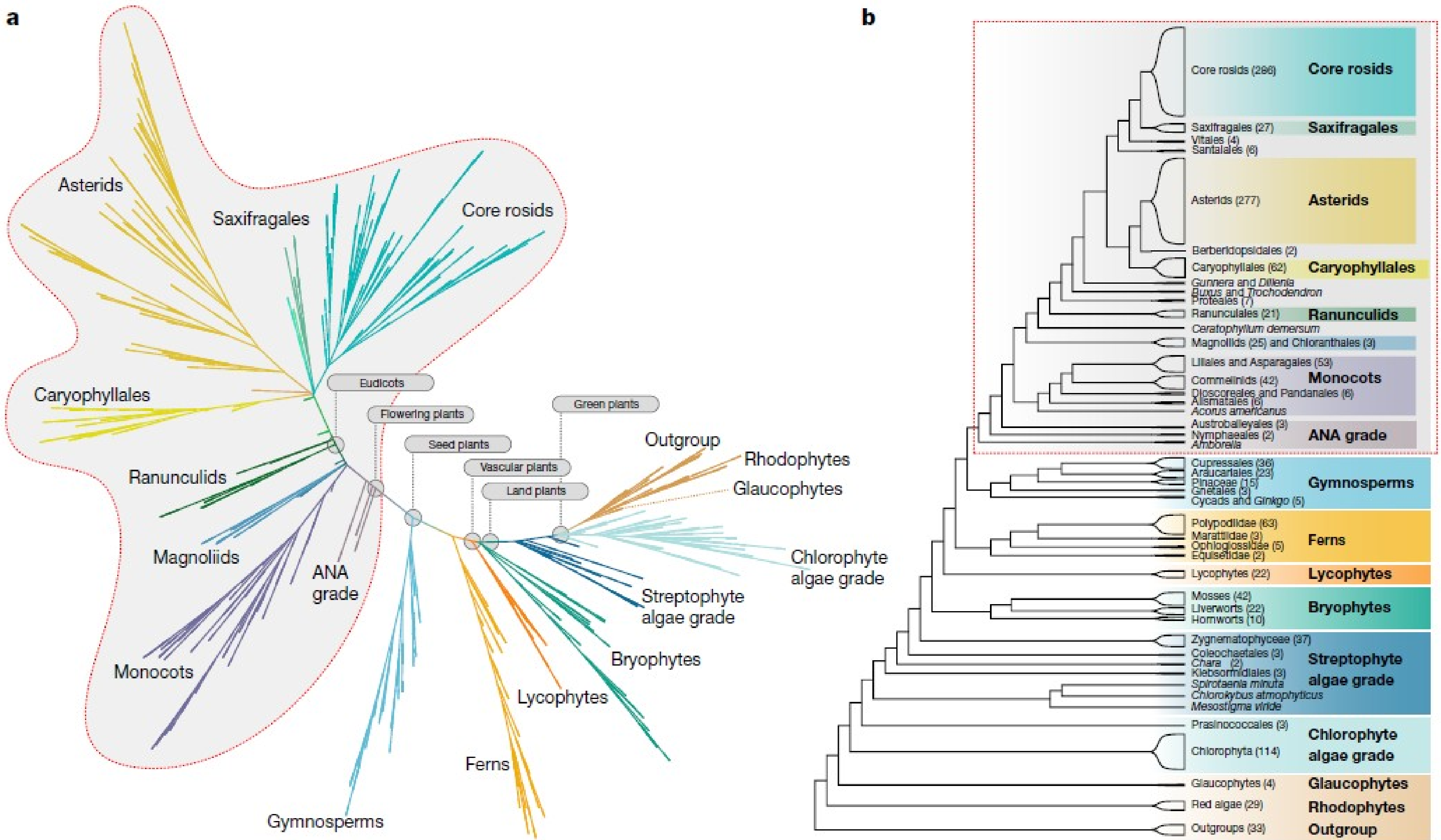
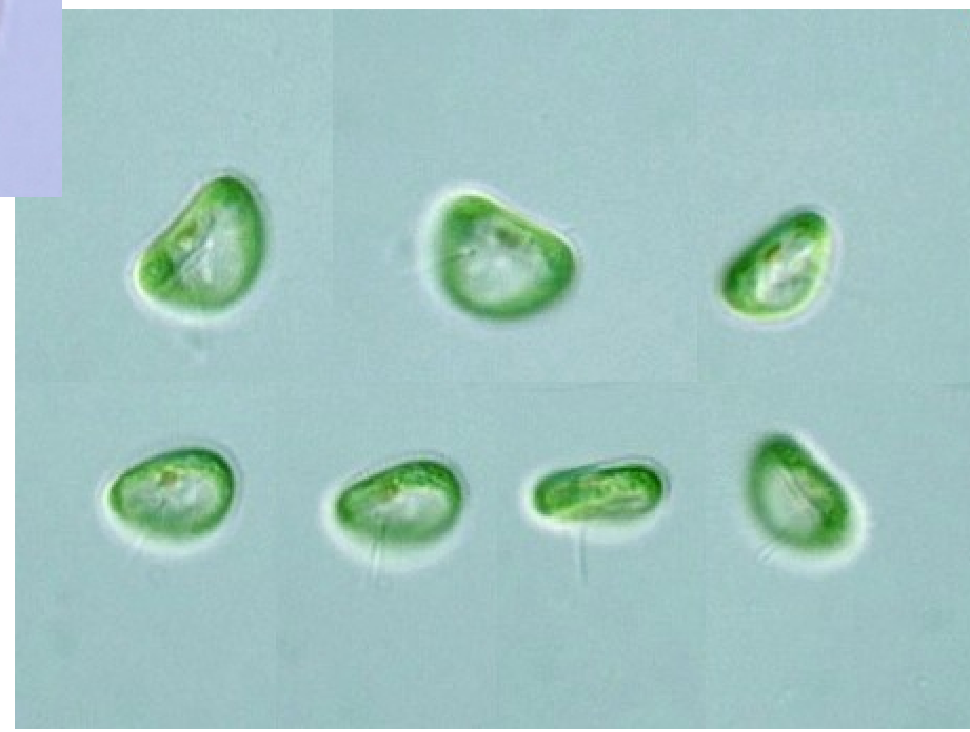


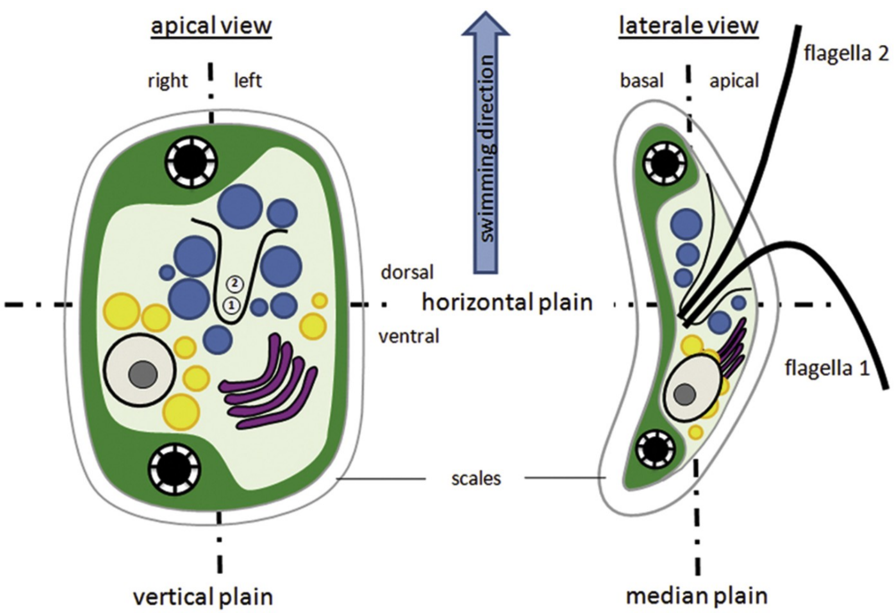
Fig. 2 | Phylogenetic inferences of major clades. Phylogenetic inferences were based on ASTRAL analysis of 410 single-copy nuclear gene families extracted from genome and transcriptome data from 1,153 species, including 1,090 green plant (Viridiplantae) species (Supplementary Table 1). **a**, Phylogram showing internal branch lengths proportional to coalescent units ($2N_e$ generations) between branching events, as estimated by ASTRAL-II[15] v.5.0.3. **b**, Relationships among major clades with red box outlining flowering plant clade. Species numbers are shown for each lineage. Most inferred relationships were robust across data types and analyses (Supplementary Figs. 1–3) with some exceptions (Supplementary Fig. 6). Data and analysis scripts are available at https://doi.org/10.5281/zenodo.3255100.

One Thousand Plant Transcriptomes, 2019, Nature

Mesostigmatophyceae (*Mesostigma viride*)

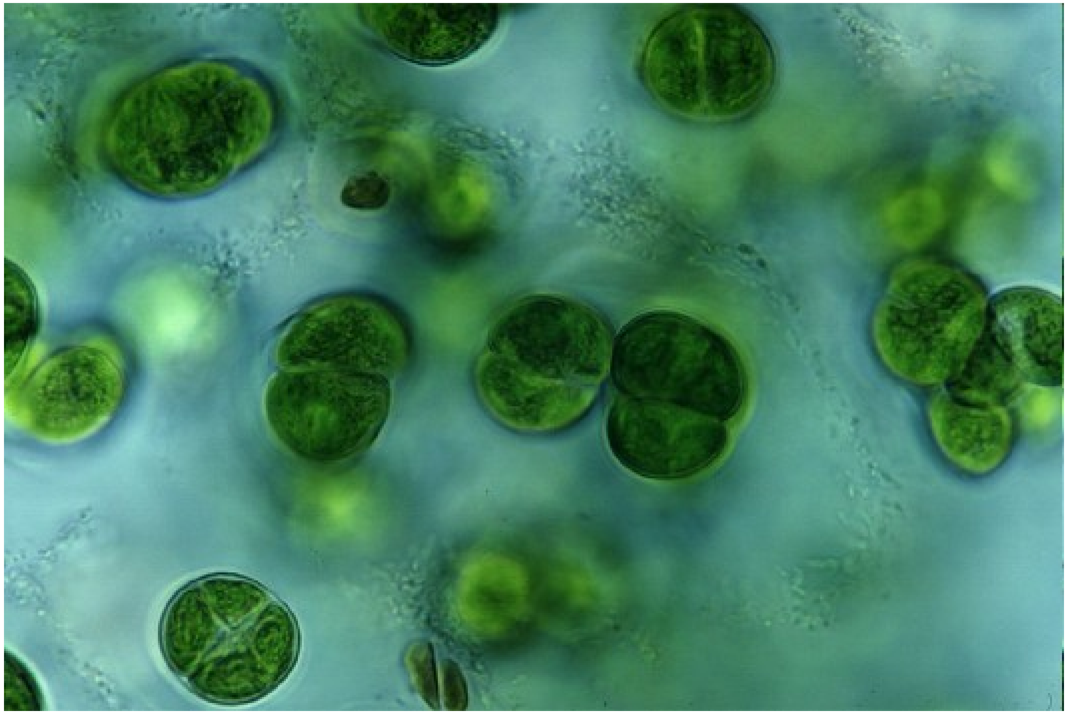
the only monadoid streptophyte „plant"



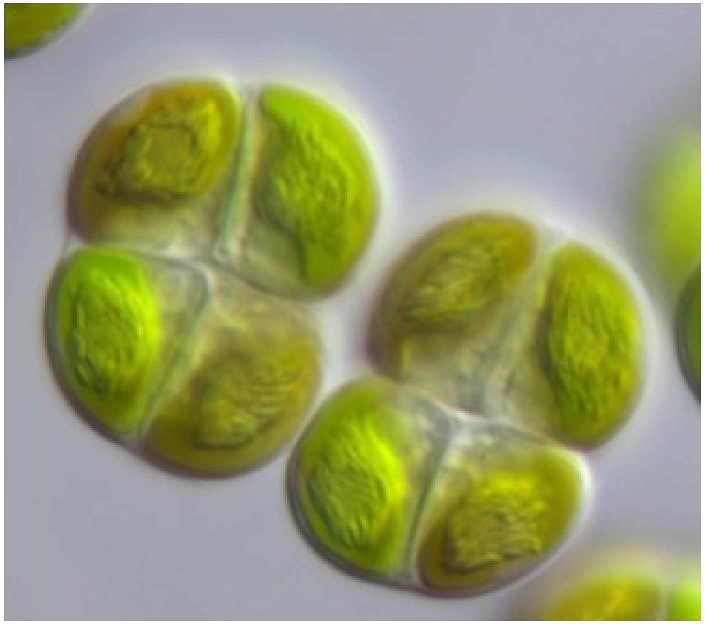


mesotrophic freshwater phytoplankton

Chlorokybophyceae



the earliest known streptophytan lineage adapted to the terrestrial way of life



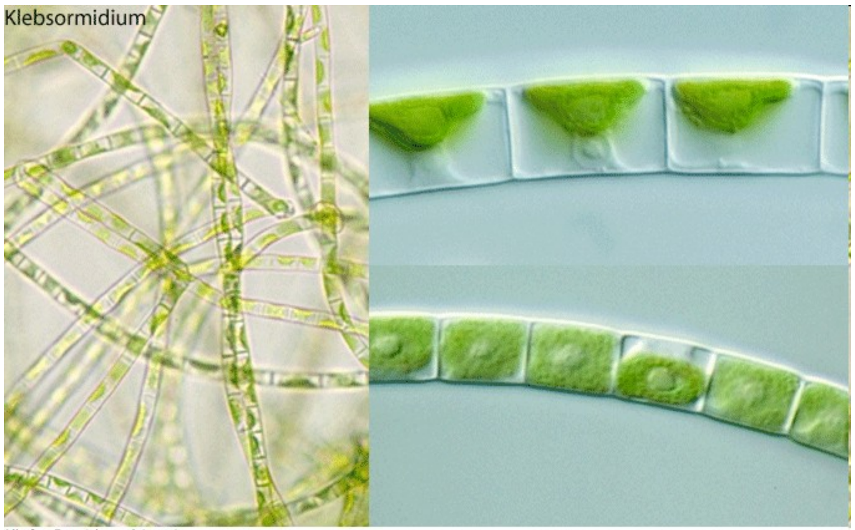
colonial coccoid microalgae

typically found in subaerial biofilms (soils, tree bark, rock surfaces)

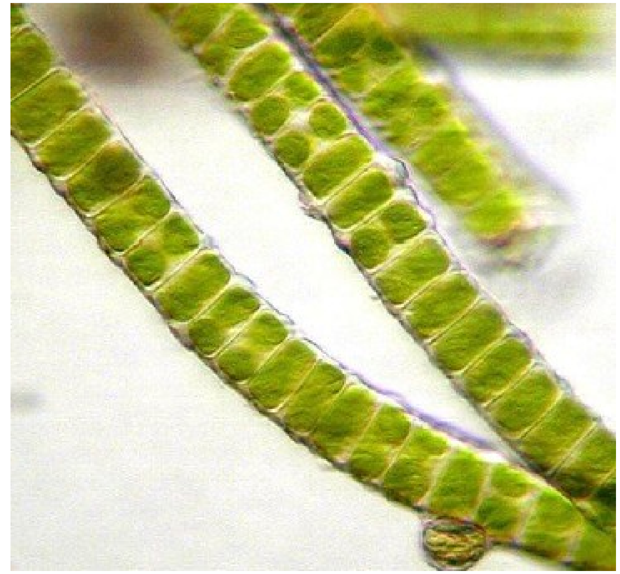
Klebsormidiophyceae

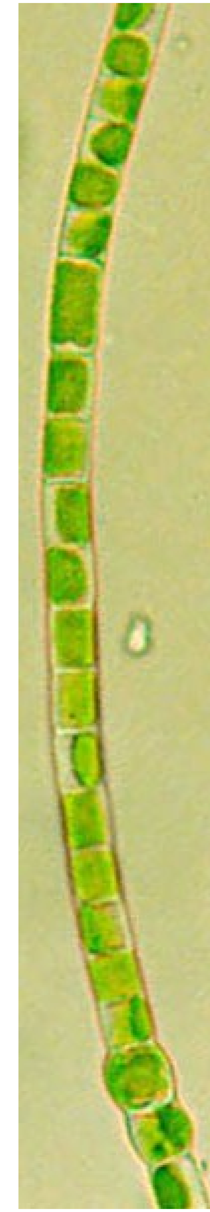
filamentous unbranched morphology

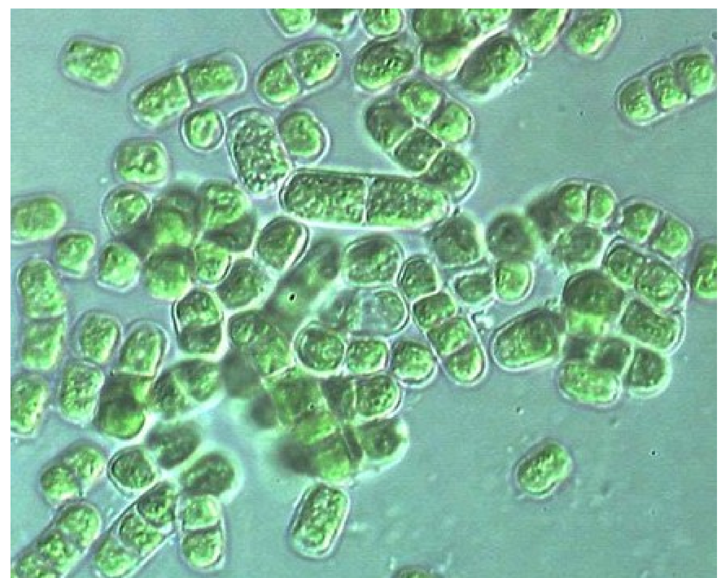
Klebsormidium



All after Entwisle et al. (1997)

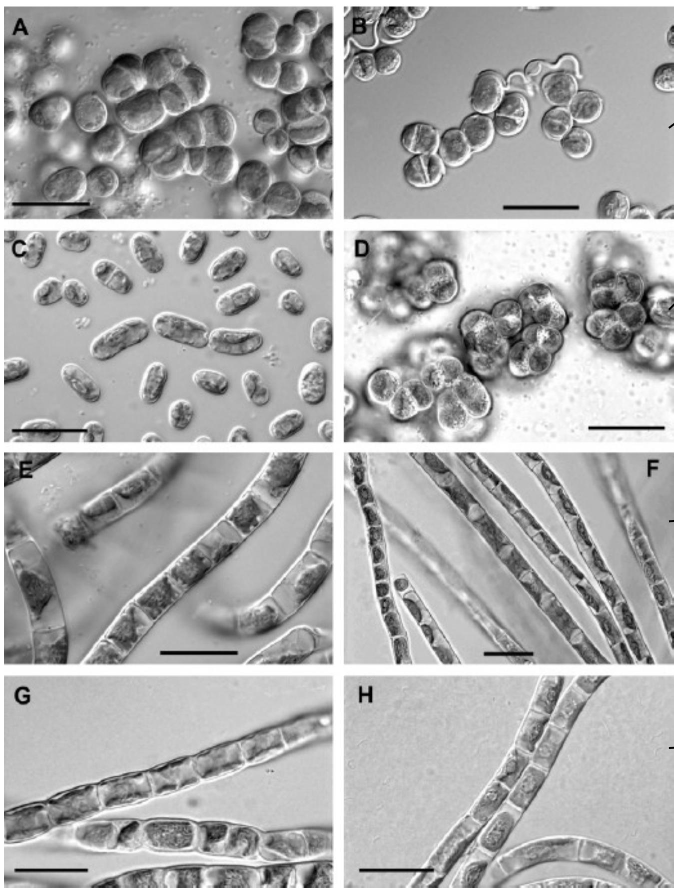


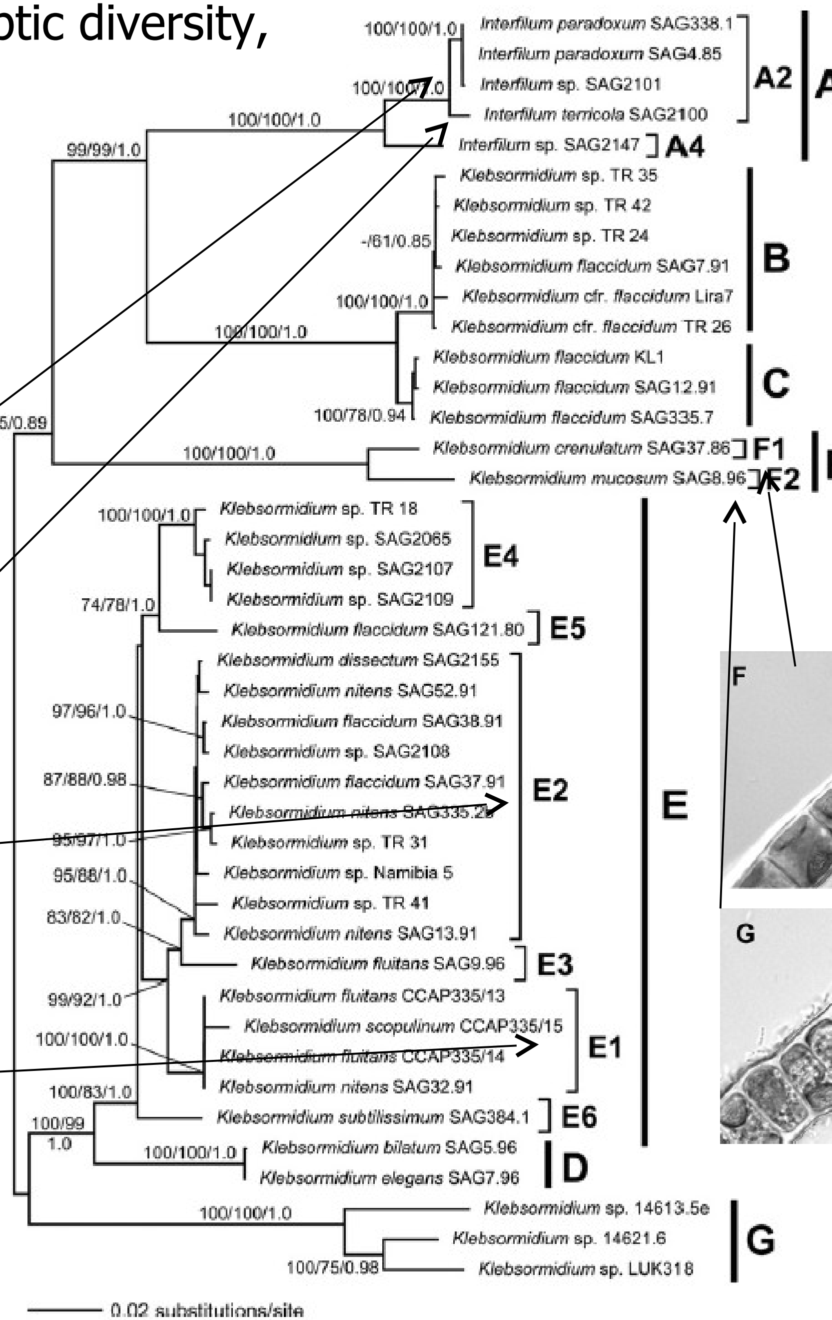


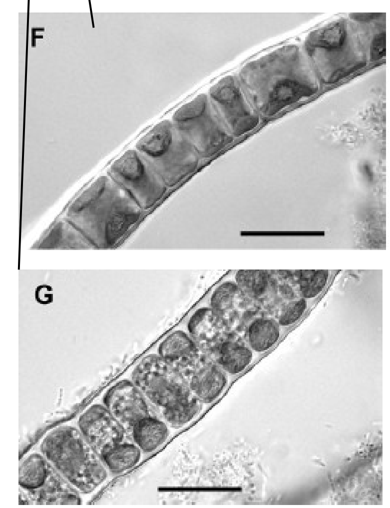


usually occurs in subaerial microhabitats

Klebsormidiophyceae – huge cryptic diversity, morphologically very similar taxa, ecologically differentiated (water x soil x bark)





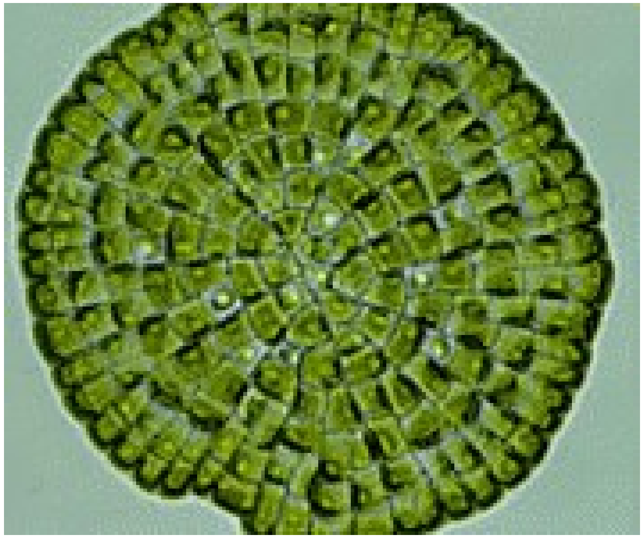


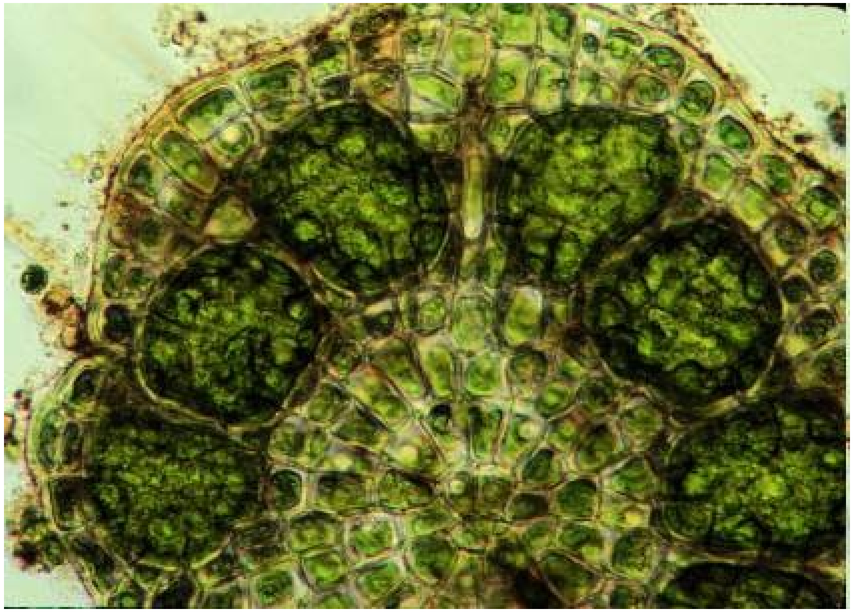
Rindi et al., 2011,
Mol Phyl Evol 58: 218-231.

Fig. 3. Phylogram inferred from Maximum-Likelihood analysis of the concatenated dataset *rbc*L-ITS rRNA in the Klebsormidiales, with bootstrap support (BP) and Bayesian Posterior Probabilities (PP) indicated at the nodes. From left to right and from top to bottom the support values correspond to Neighbor Joining BP, Maximum-Likelihood BP and Bayesian PP. BP values lower than 60% and PP lower than 0.8 are not reported.

Coleochaetophyceae

Coleochaete





discoid vs. heterotrichal taxa

ontogenetic cycle

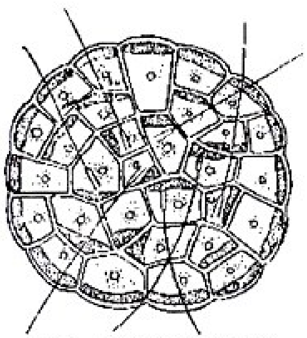


Fig. 1. *Coleochaete scutata* (discoid Rom)

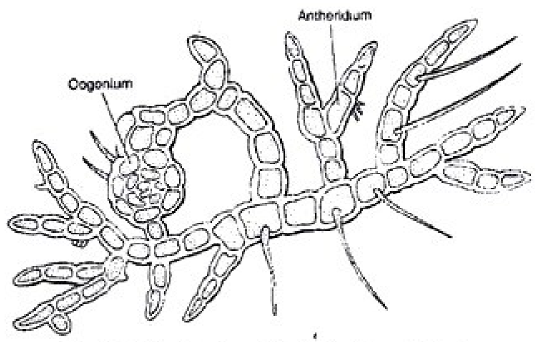


Fig. 2. *Coleochaete pulvinata* (cushioned form)

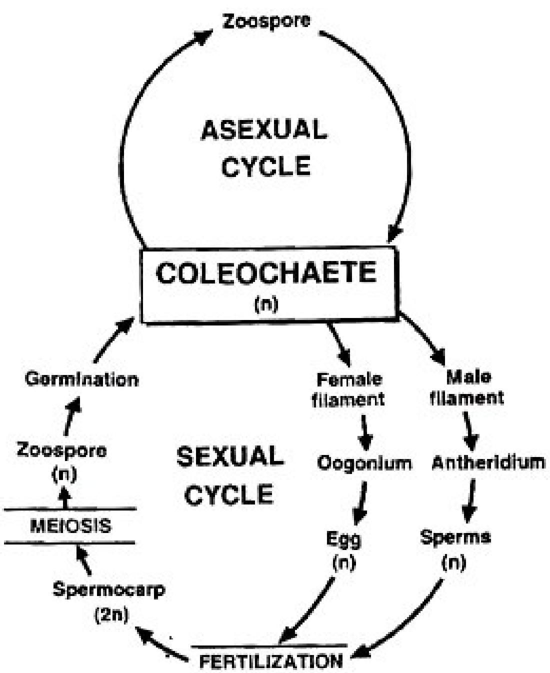


Fig. 6. *Coleochaete*. Graphic life Cycle

single flagellated cell is produced by an antheridium (or during asexual reproduction)

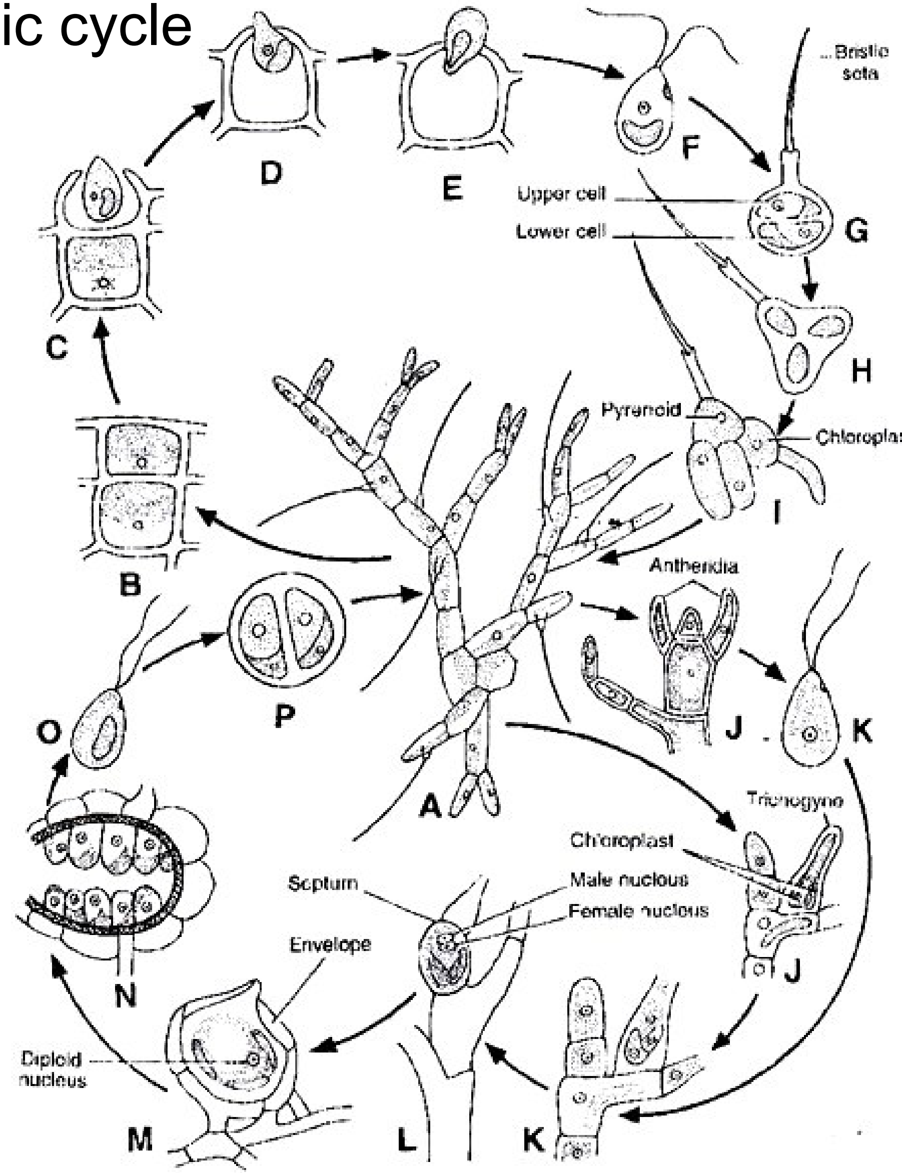
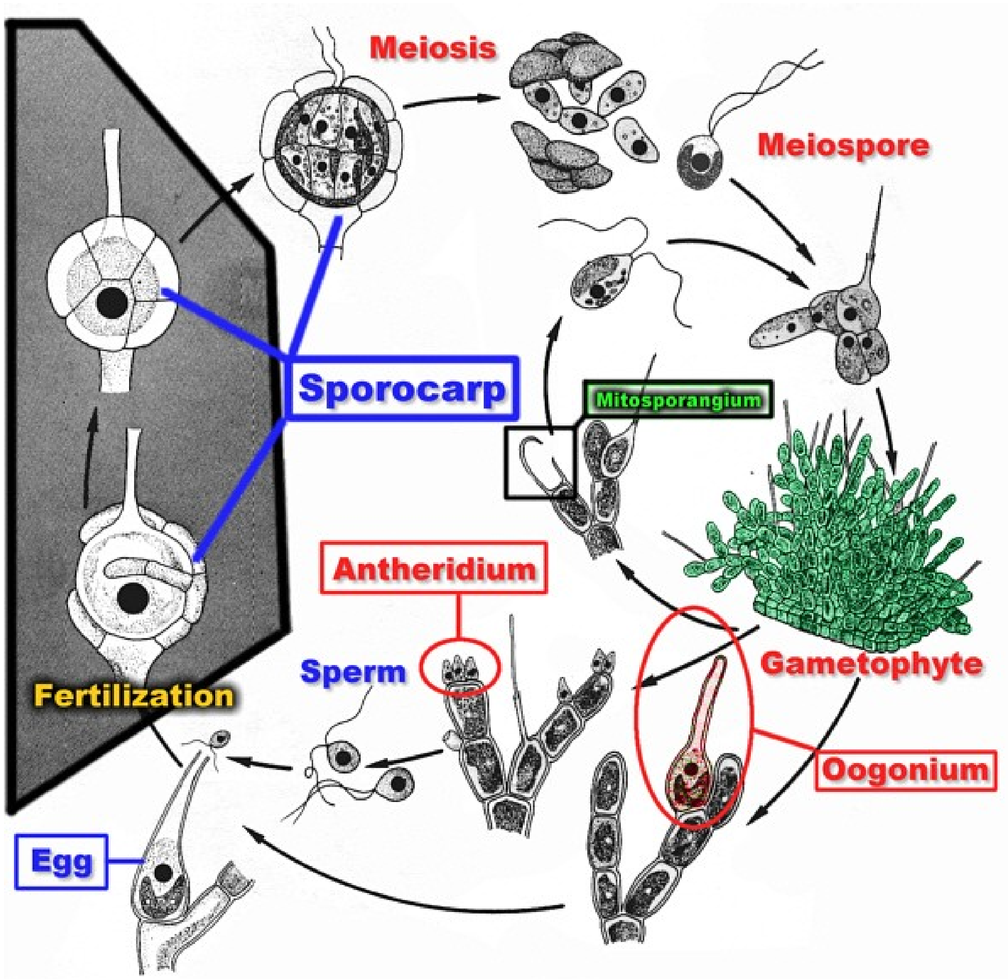


Fig. 5. *Coleochaete*. Diagrammatic life Cycle

vegetative plants are always haploid

sporocarp encases the zygote and nourishes it



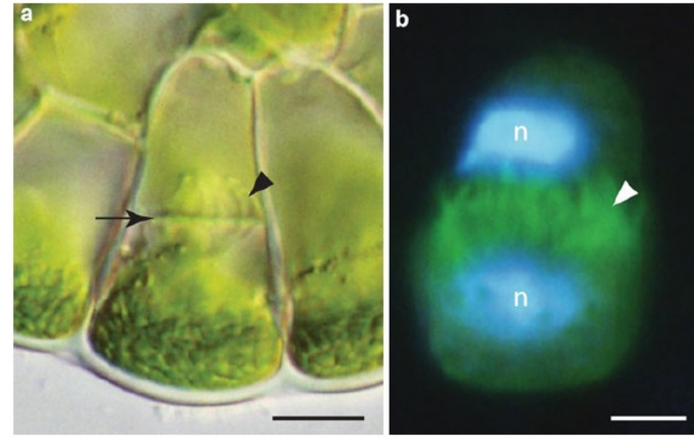


Fig. 2 Cell division involving a plantlike phragmoplast in *Coleochaete orbicularis*. (**a**) Differential interference contrast image with forming cell plate (*arrow*) in center of phragmoplast (*arrowhead*). Scale bar = 10 μm. (**b**) Immunofluorescence localization of tubulin in phragmoplast microtubules (*arrowhead*) between DAPI-stained telophase nuclei (*n*). Scale bar = 5 μm. Micrographs: (**a**) M.E. Cook; (**b**) K.F. Doty (From Graham et al. (2016) *Algae* 3rd edition, used with permission of LJLM Press)

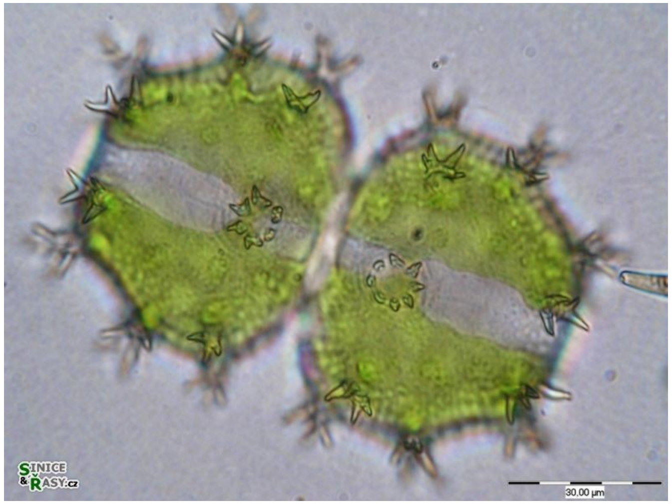
phragmoplast during cell division

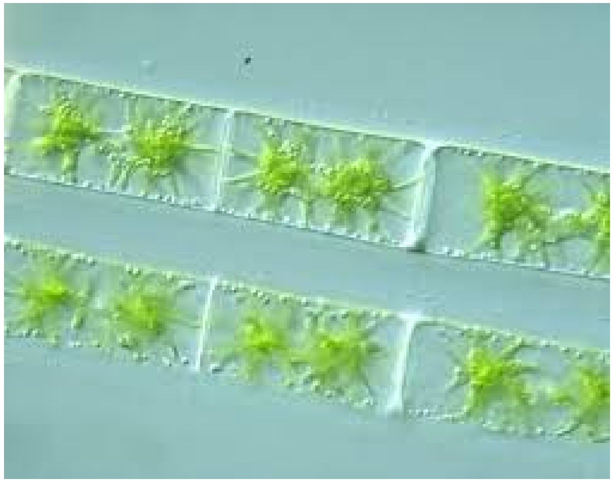
male gametes lacks any plastids (contrary to chlorophytan lineages)

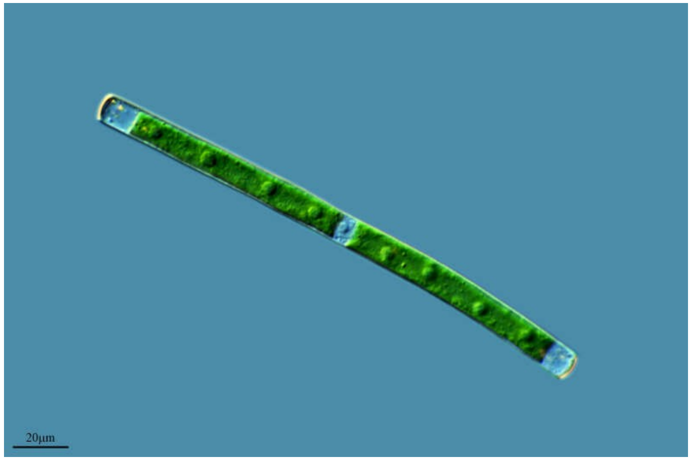
gametophytic cells overgrow the zygote and form the **sporocarp**
(similar structures in bryophytes, esp. liverworts)

Cook & Graham, 2017, in Handbook of Protists

Zygnematophyceae







unicellular or unbranched filamentous algae

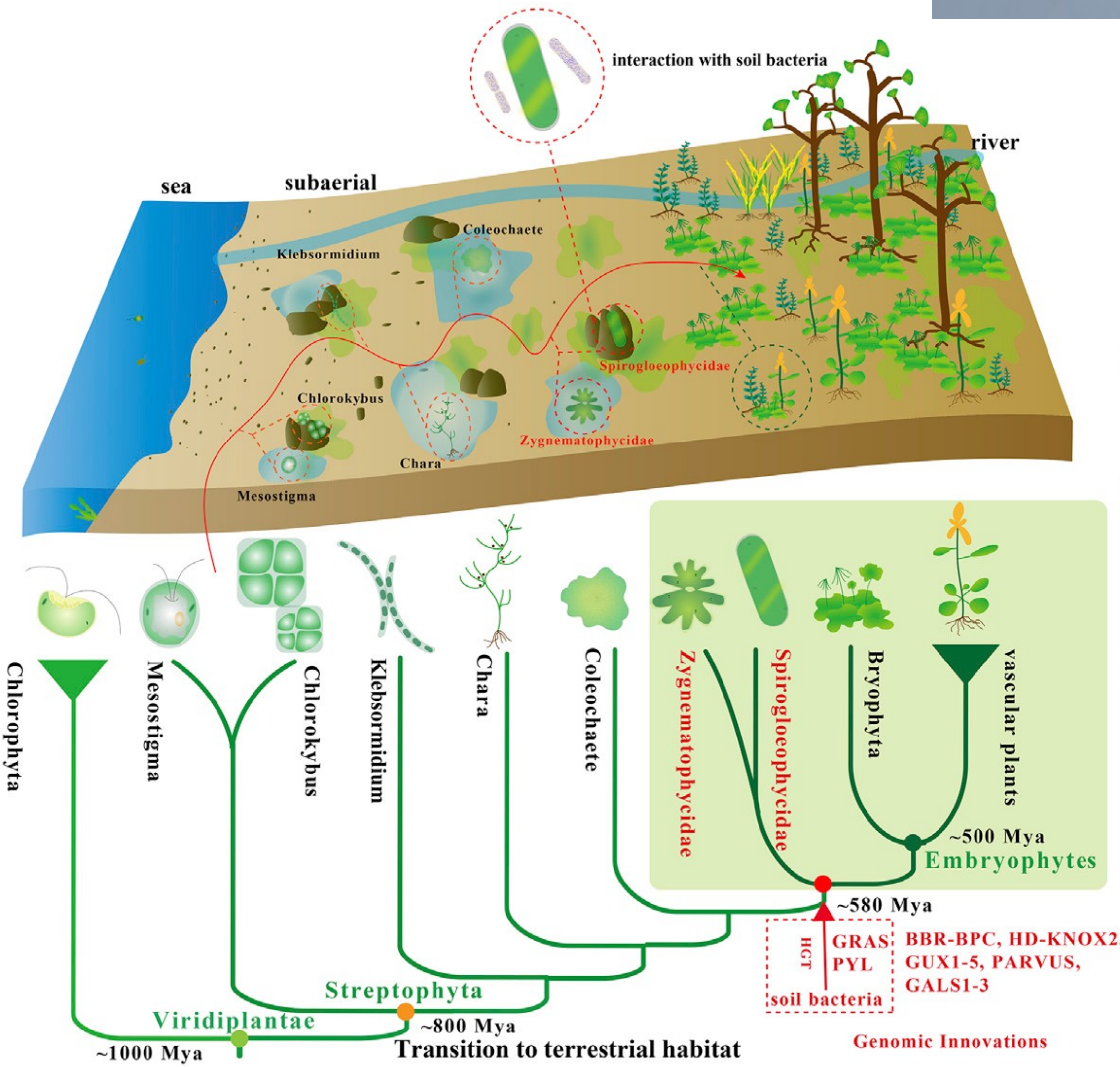
occuring solely in the freshwater (or in subaerial biofilms), often in acidic habitats

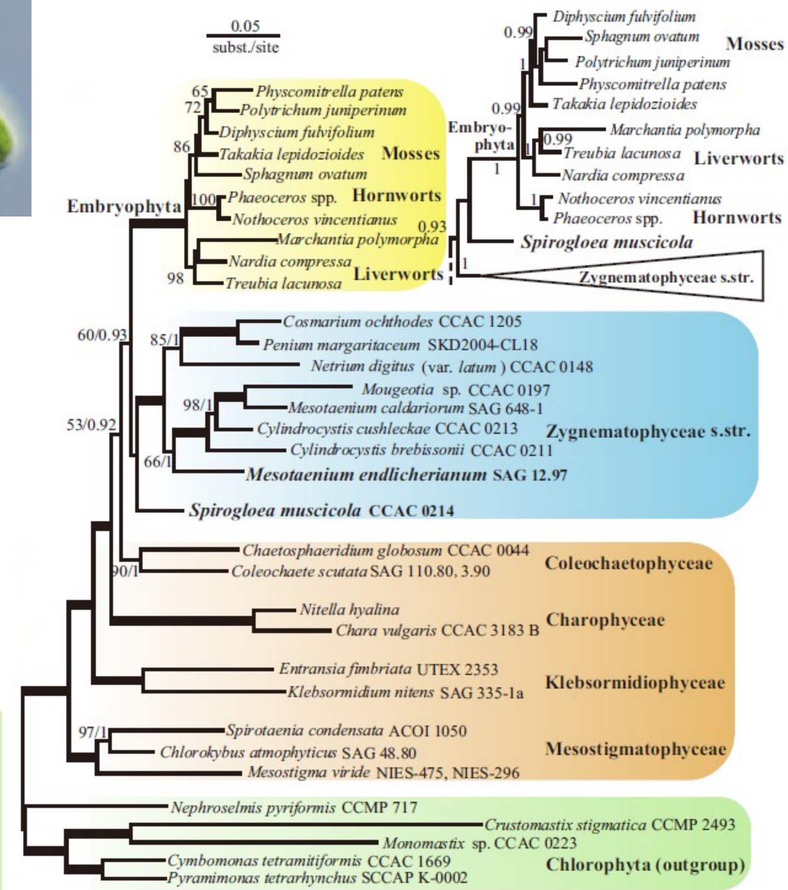
unique sexual reproduction - isogamic pattern, gametangiogamy, conjugation

absence of any flagellated cells

Spirogloeophycidae

Zygnematophycidae

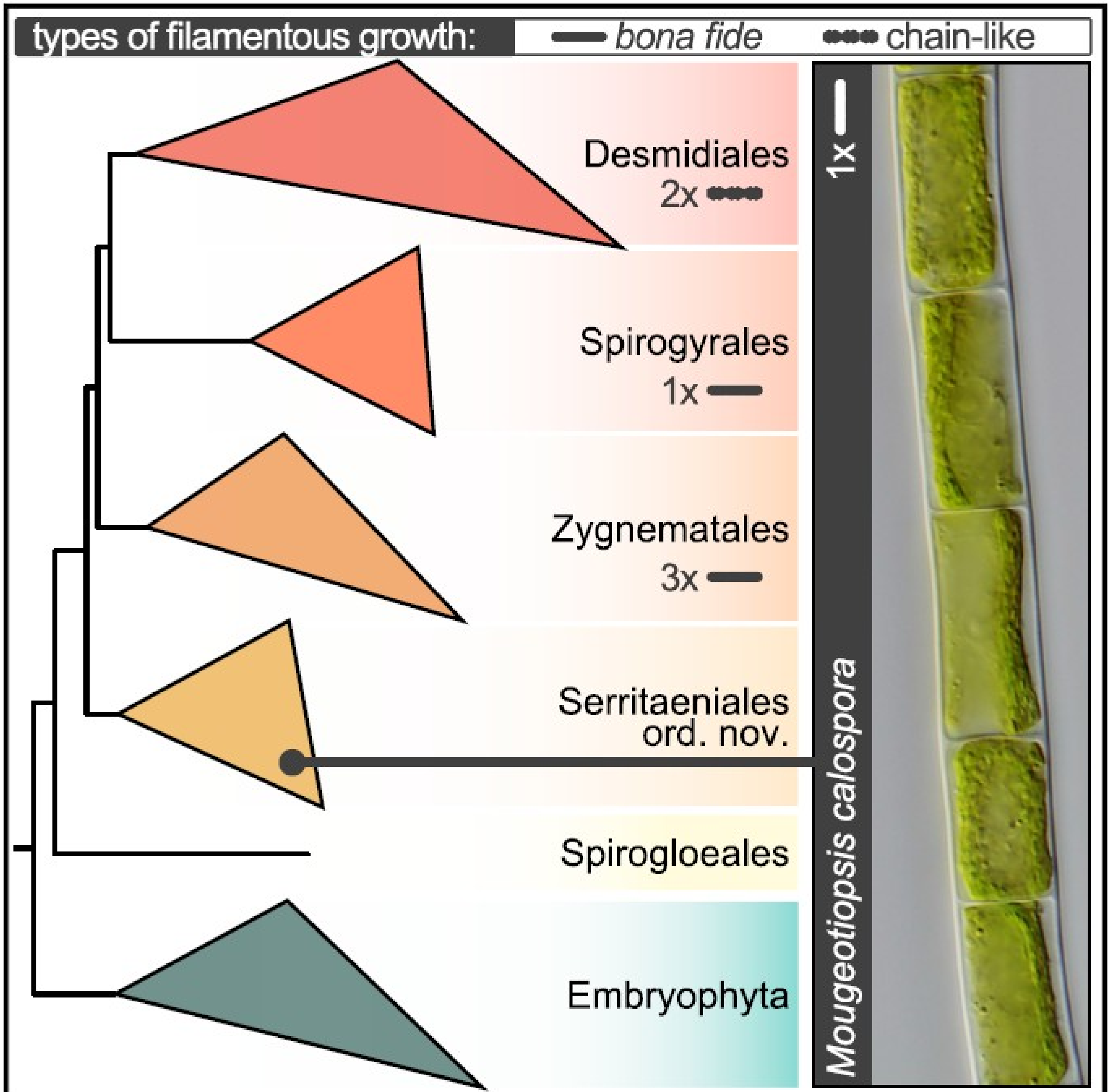




their common ancestor acquired genes thought to be important for resistance to desiccation by horizontal gene transfer from soil bacteria approximately 580 million years ago

Cheng et al., 2019, Cell 179

Zygnematophyceae



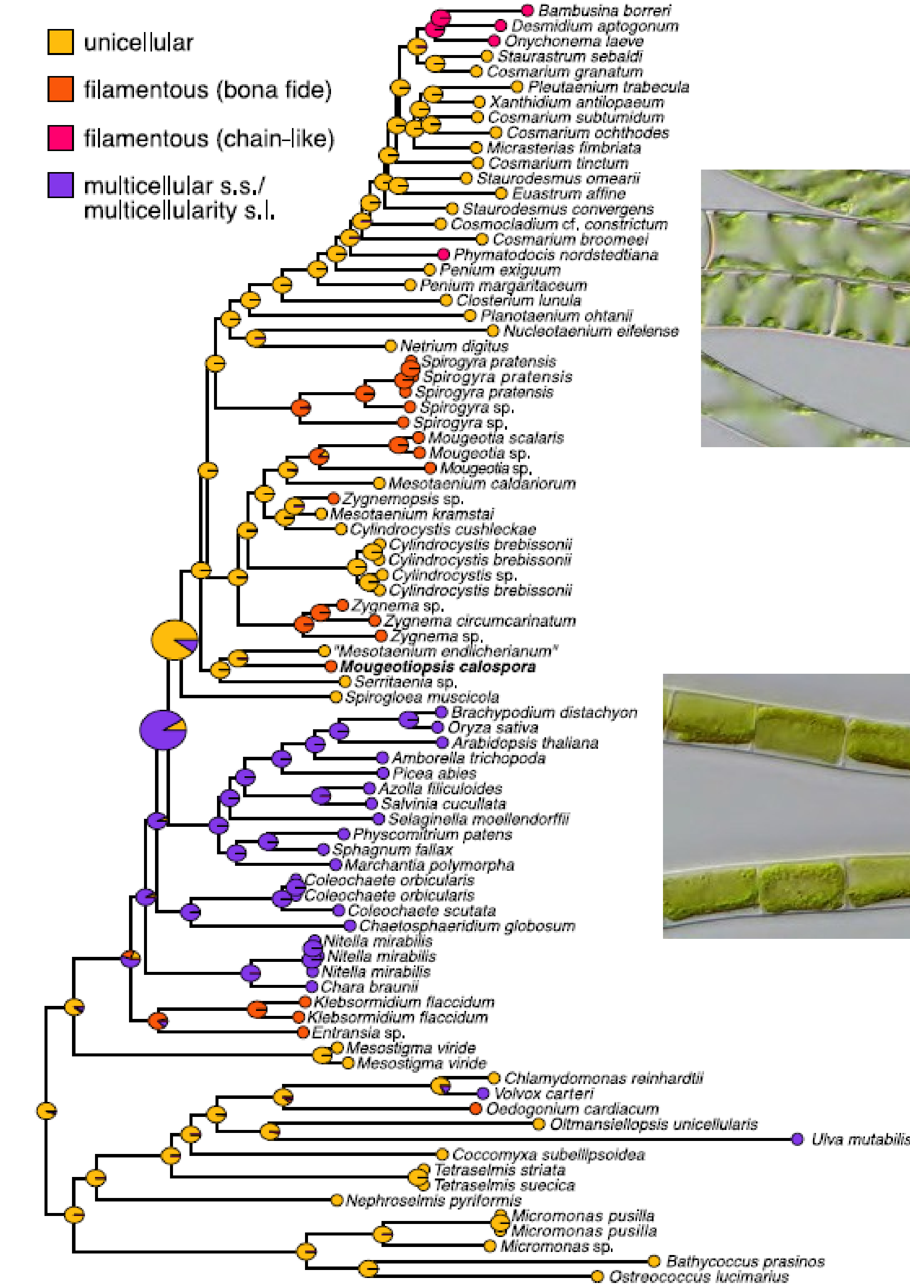
five orders (incl. Spirogloea)

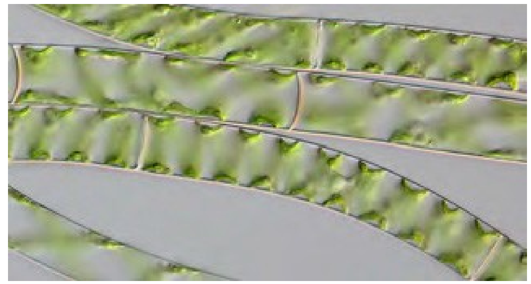
multiple evolution of filamentous morphology

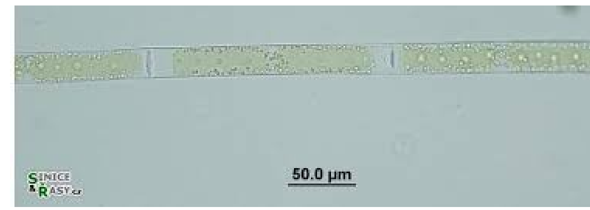
multiple transitions to terrestrial habitats

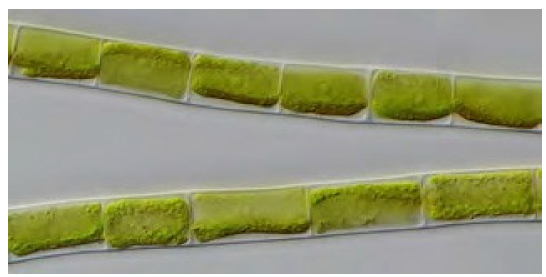
Hess et al., 2022, Curr Biol

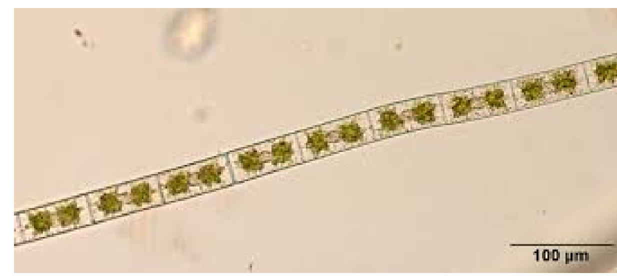
Zygnematophyceae





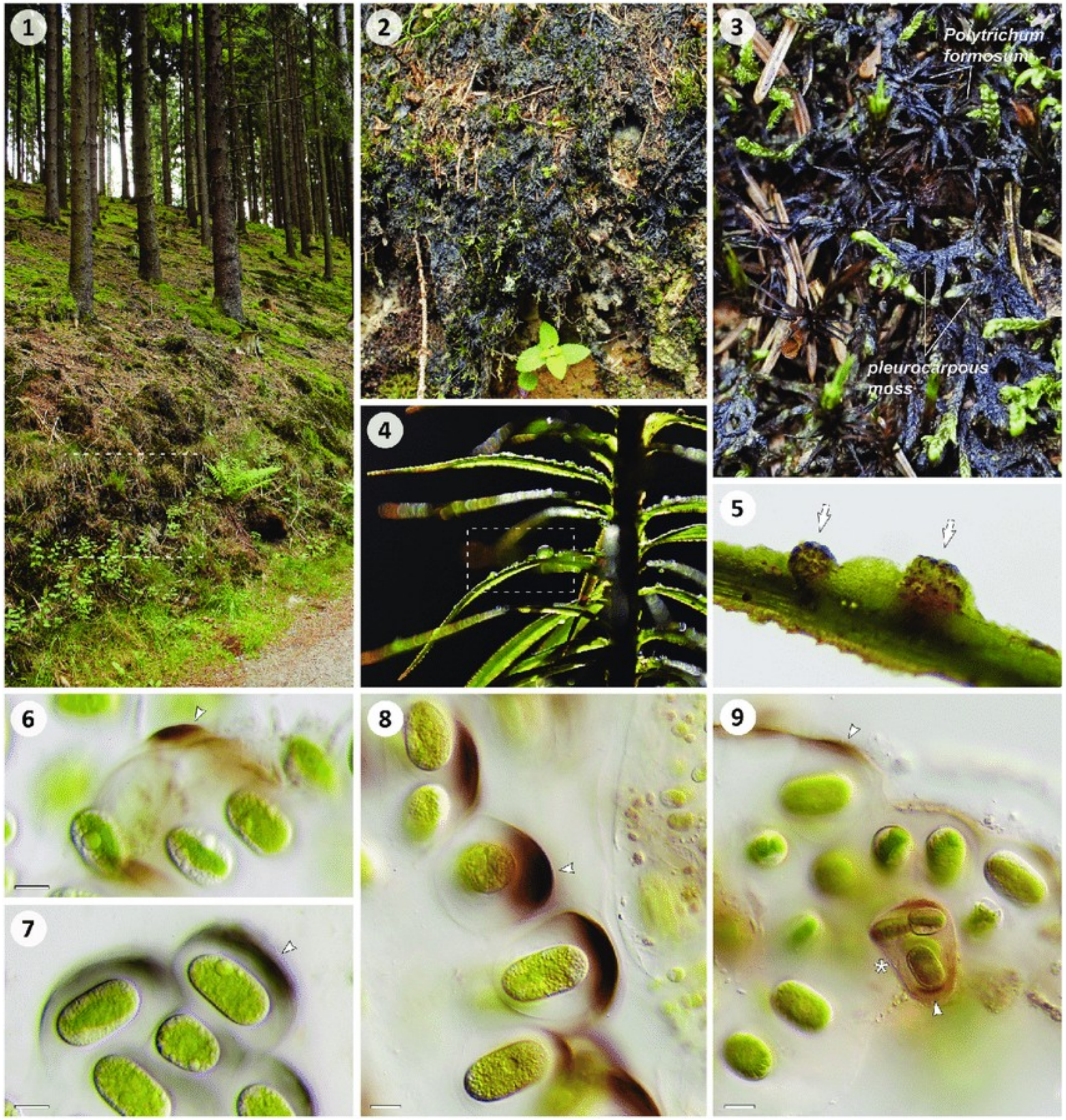






Hess et al., 2022, Curr Biol

Serritaeniales



Serritaenia - acidic subaerial habitats

Mesotaenium endlicherianum

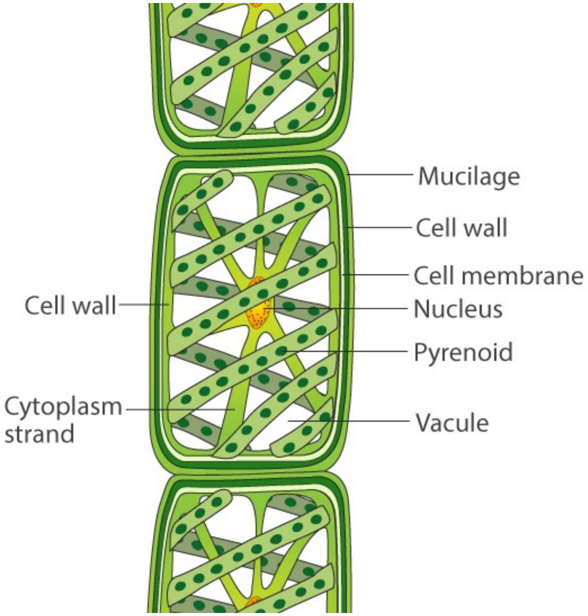
cryoseston, soil biofilms
alpine and polar habitats

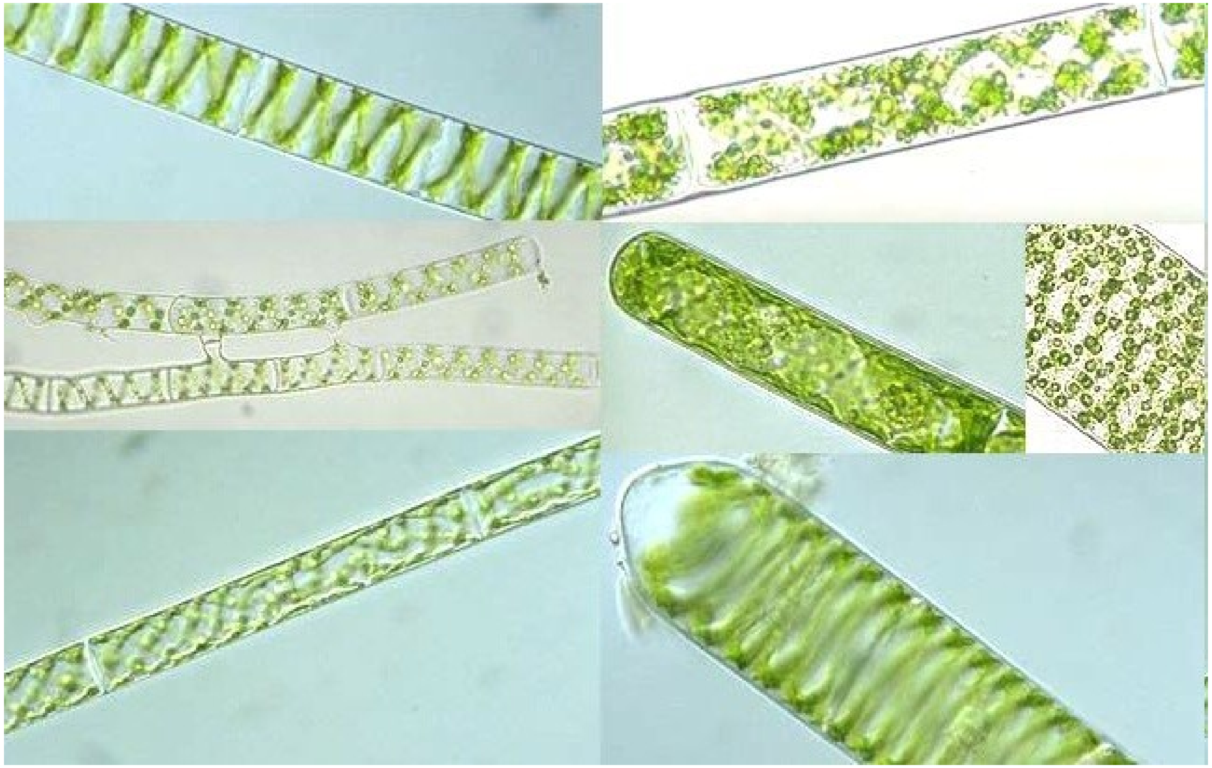
mucilage -
photoprotective adaptation

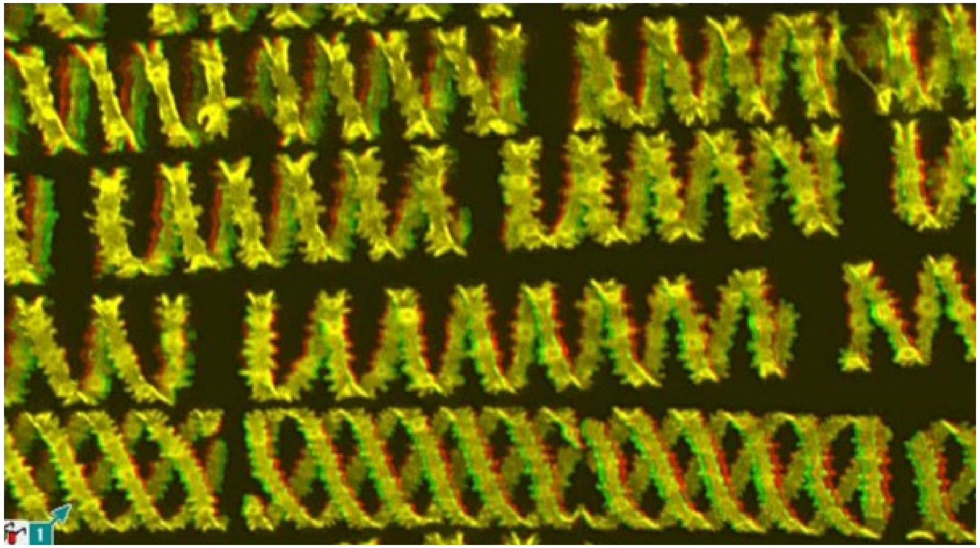
Busch et al., 2021, Eur J Phycol

Spirogyrales

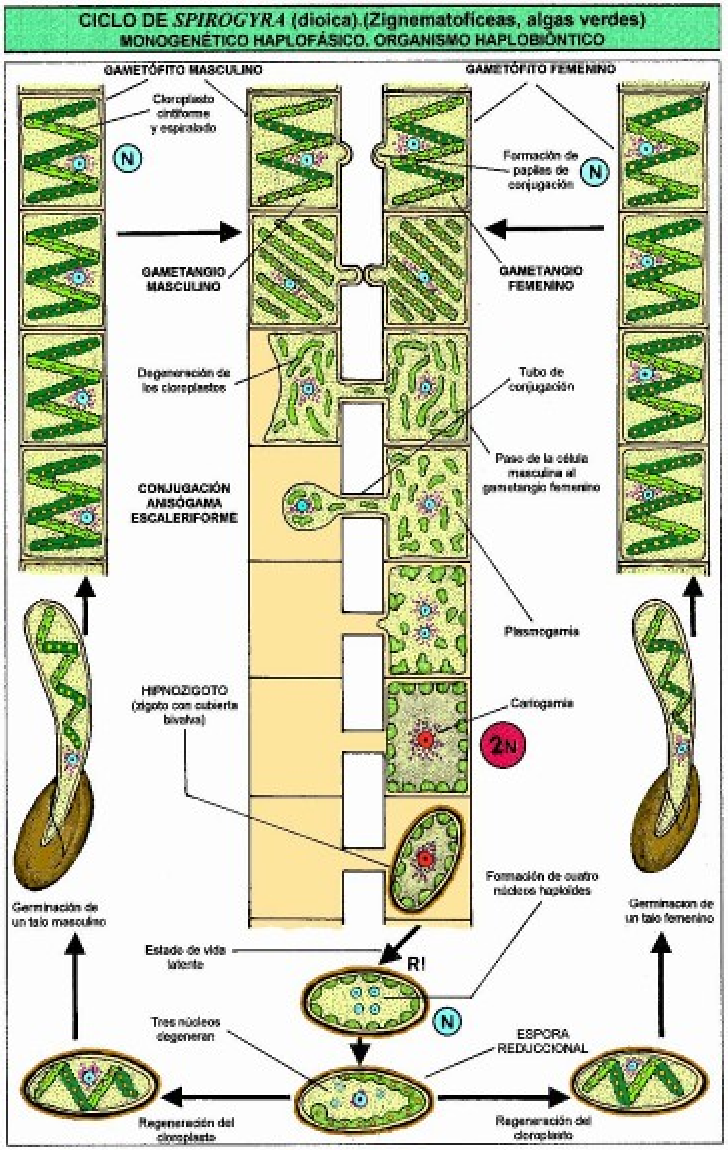
Spirogyra

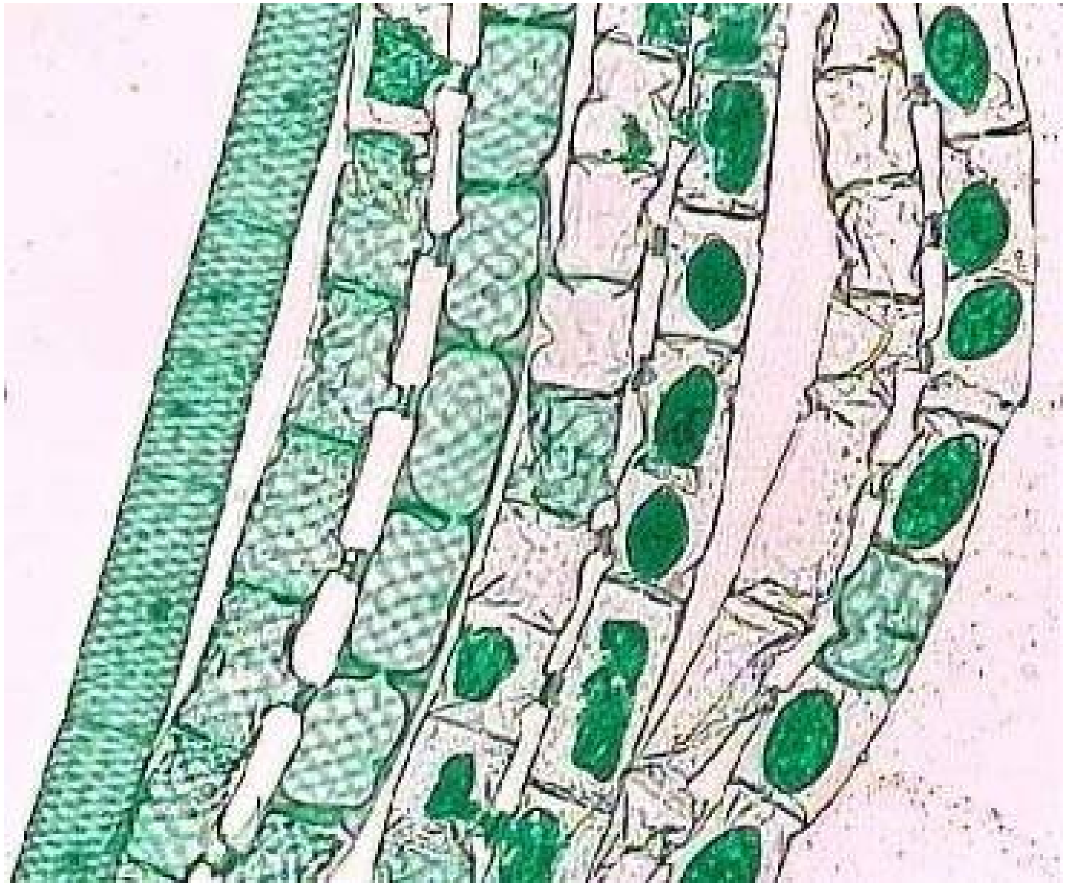


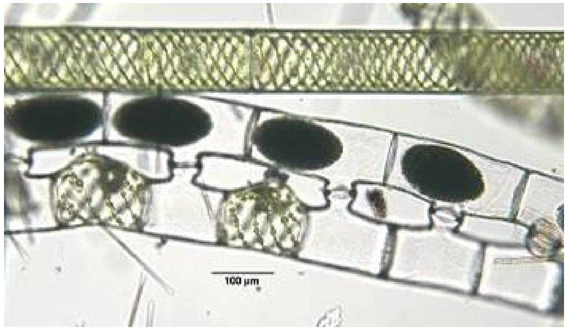




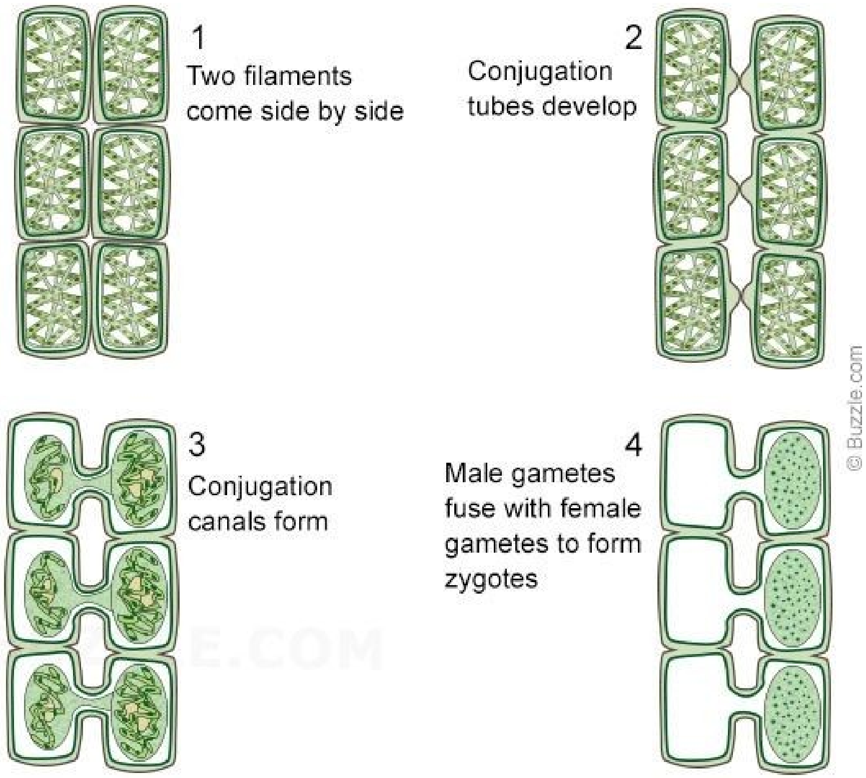
zygnematophycean life cycle and conjugation

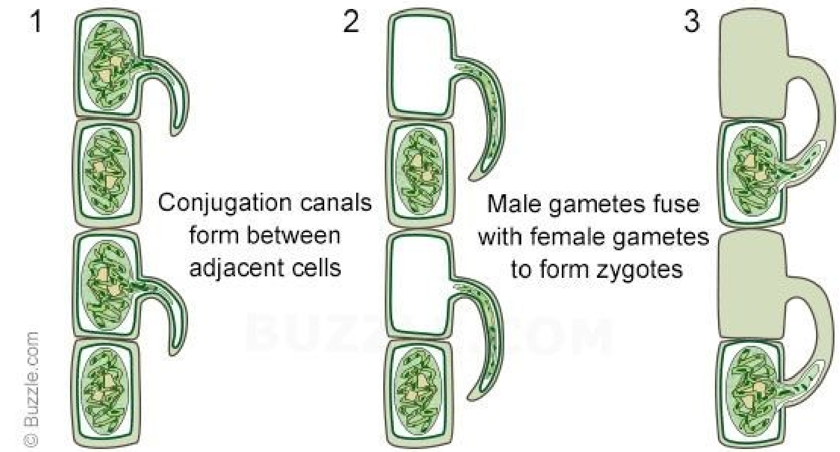


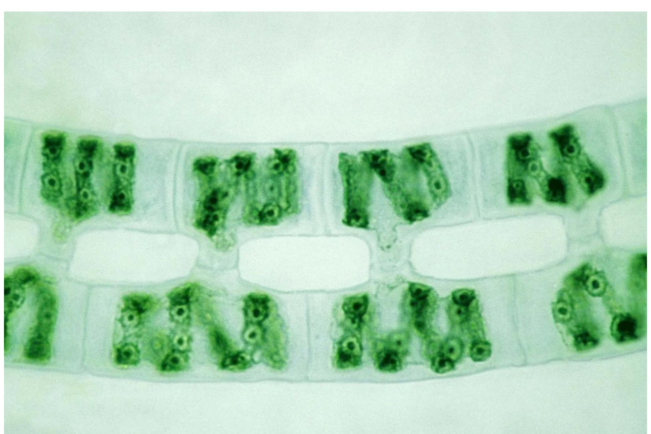




scalariform and lateral conjugation

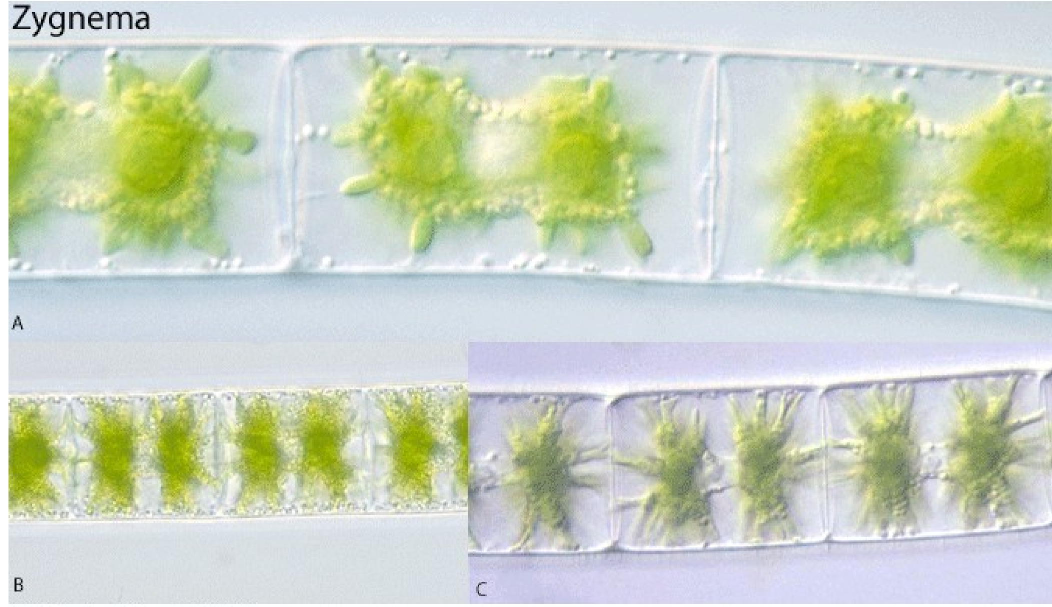






Zygnematales

Zygnema

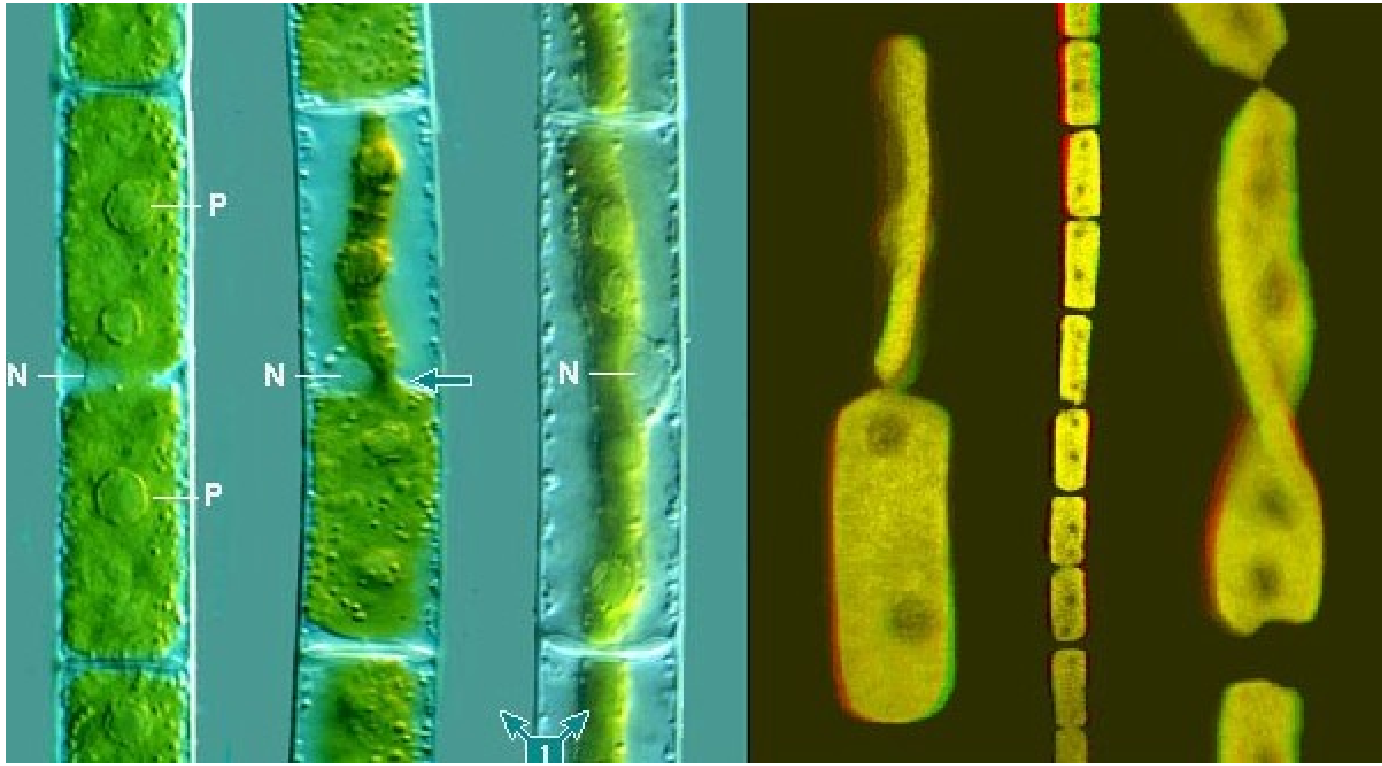


A, B after Entwisle et al. (1997)
C © Y. Tsukii, see http://protist.i.hosei.ac.jp/Protist_menuE.html

scalariform conjugation

Zygnematales

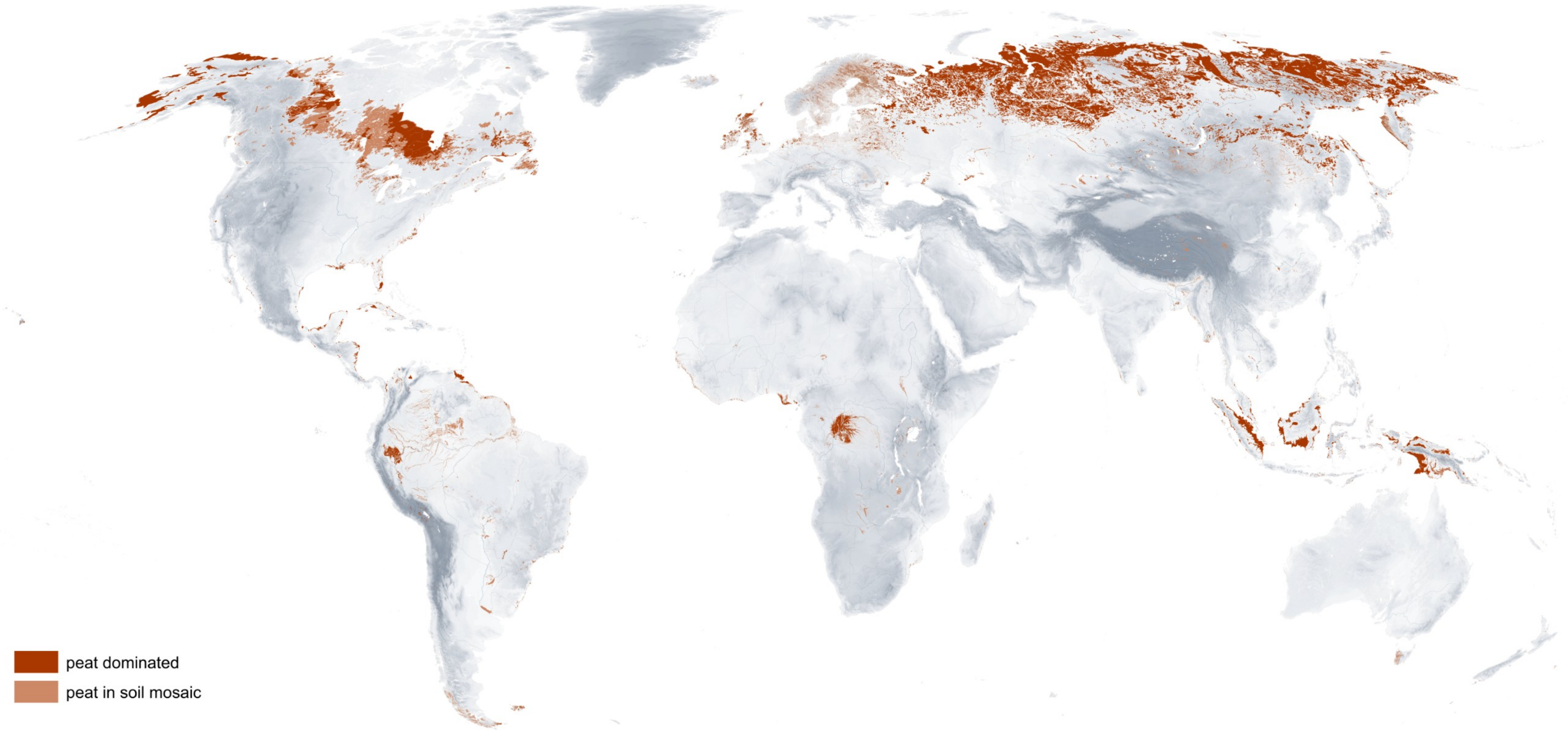
Mougeotia



Cylindrocystis

acidic peatlands
phytobenthos

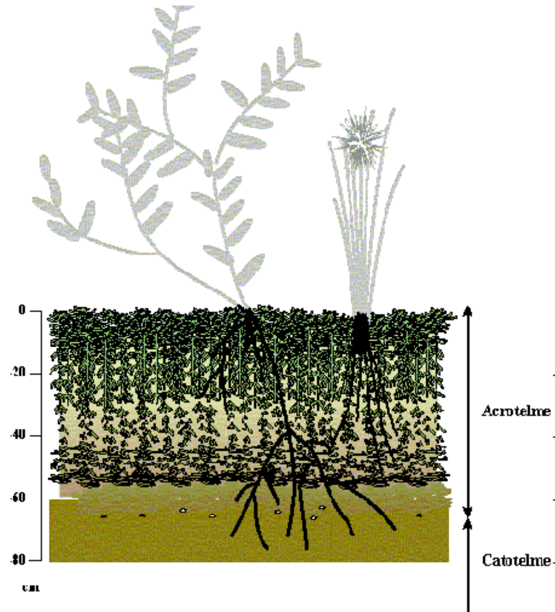

zygnematophycean algae in peatland habitats



Sphagnum-dominated boreal peatlands

acrotelm vs. catotelm (anaerobic, permanently humid)

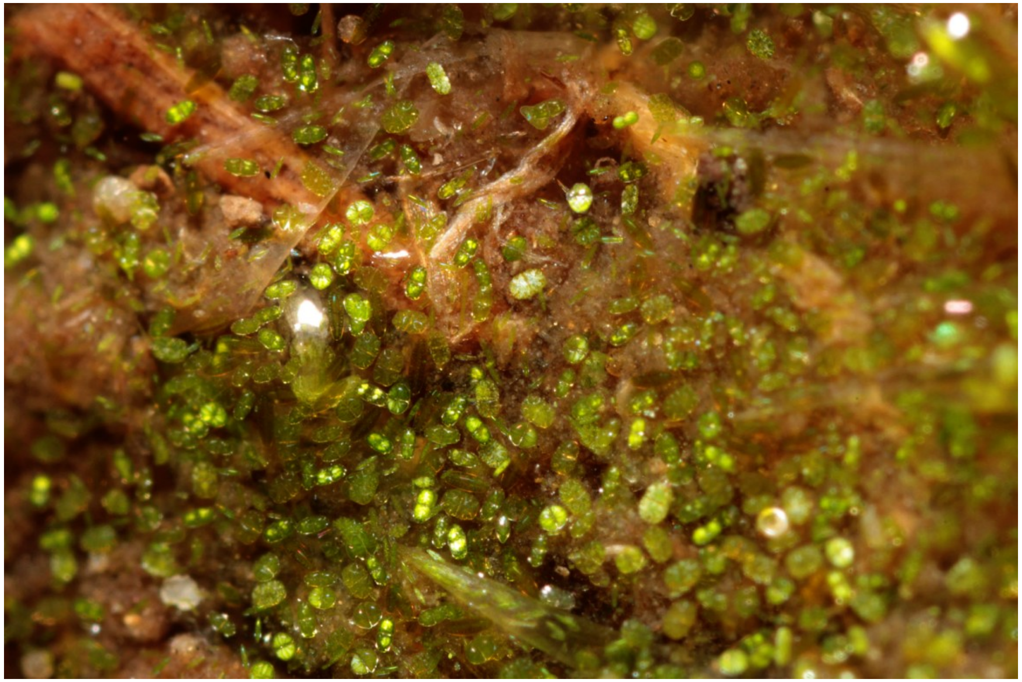
acidity caused by dissociation of humic acids

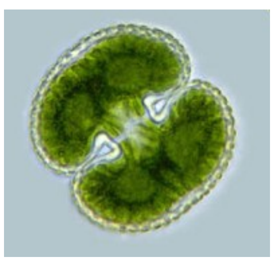


Wieder & Witt (eds.), Boreal peatland ecosystems, 2006
Int. Peatland Soc., 2021

bogs, transient bogs, fens ⟷ ombrothophic, minerotrophic ⟷ catotelm, acrotelm

Desmidiales





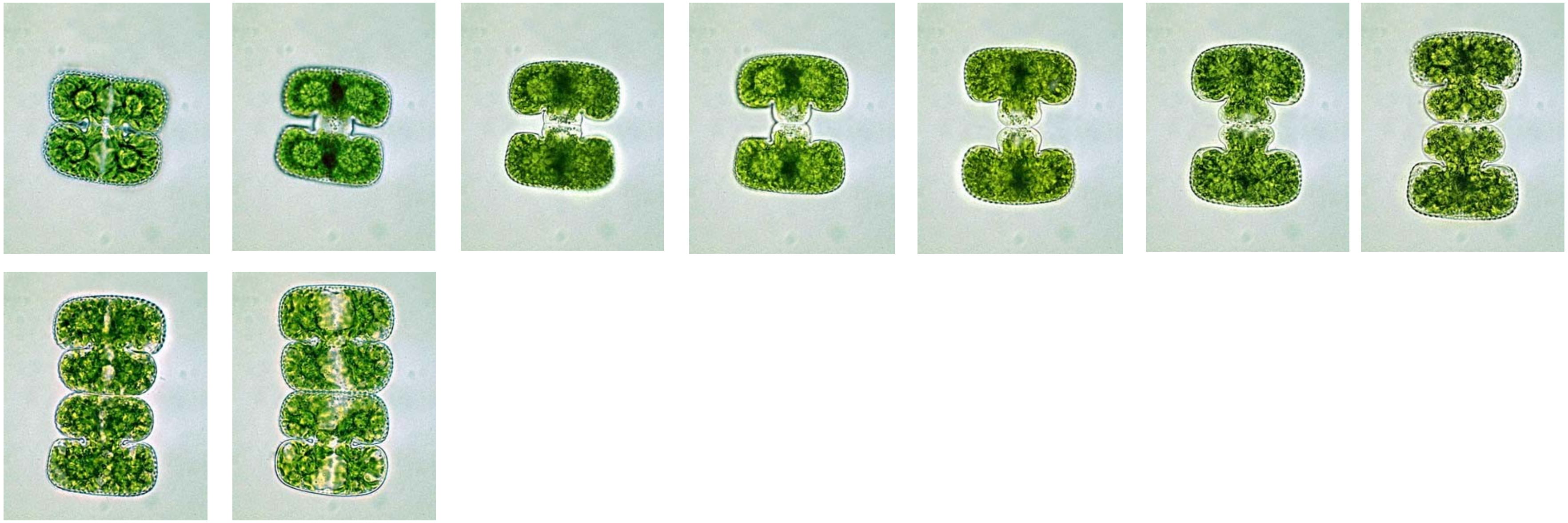
unicellular or chain-like filamentous taxa

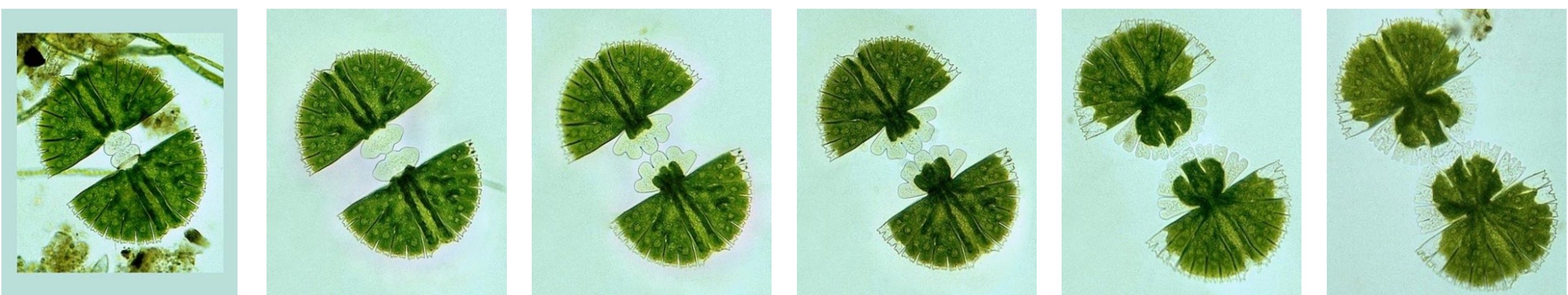
cells formed by two opposite semicells mirroring each other (Desmidiaceae)

pores in the cell wall (mostly Desmidiaceae)

includes taxa with most complex morphologies in plant kingdoms, exceptional morphological radiation

asexual reproduction

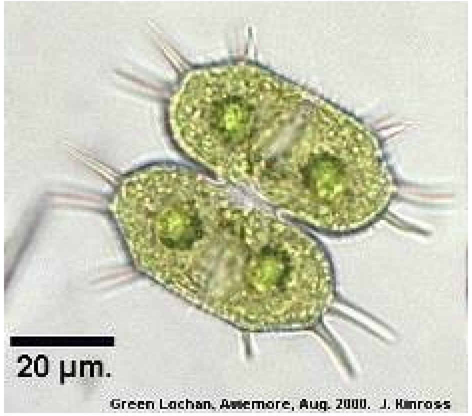


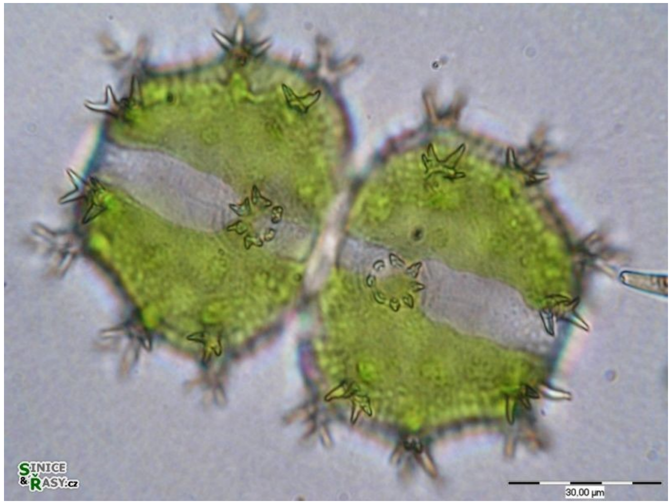


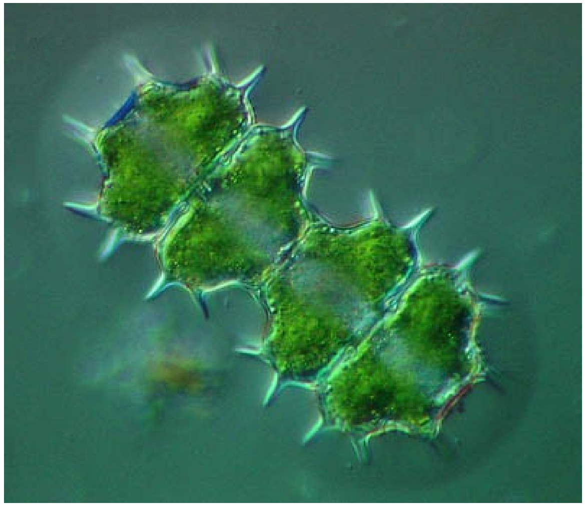
results in cells composed of two unequally old semicells

Closterium

Xanthidium

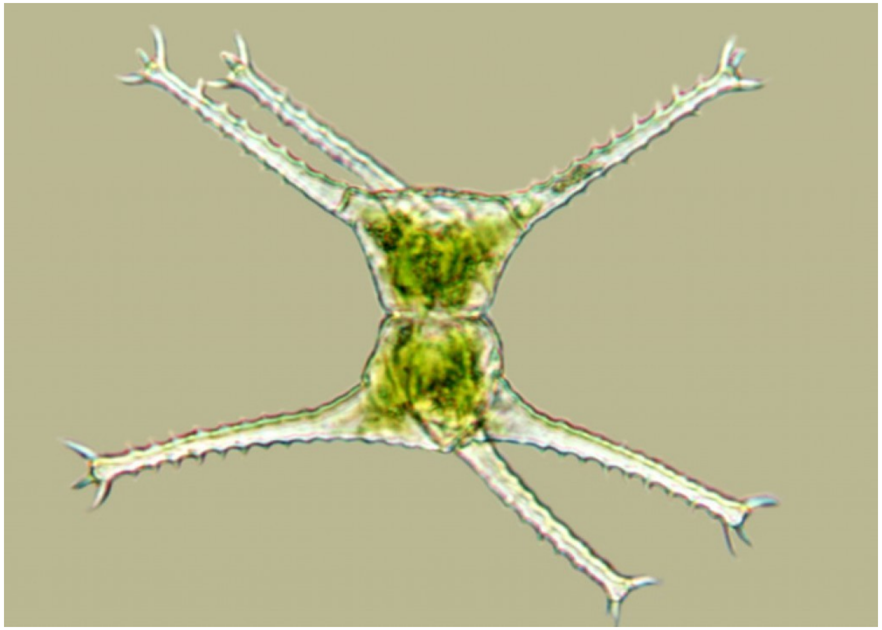


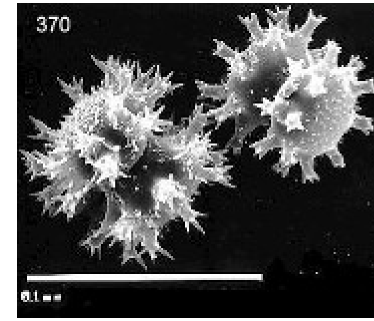


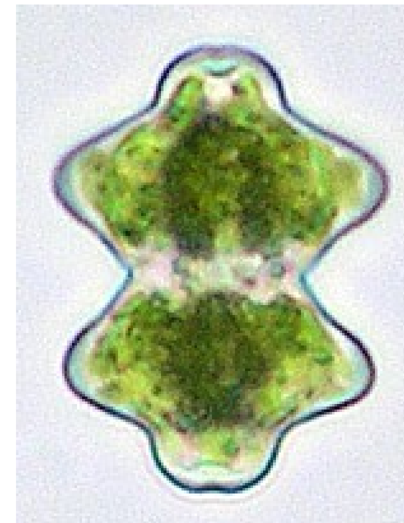


digicodes.info, desmids.nl

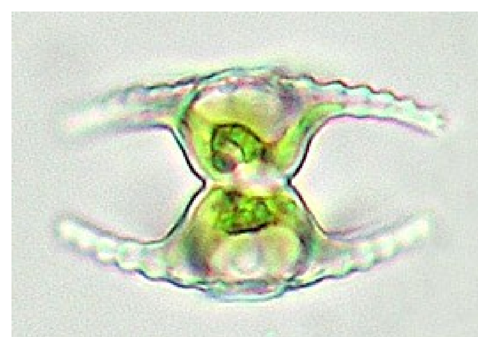
Staurastrum

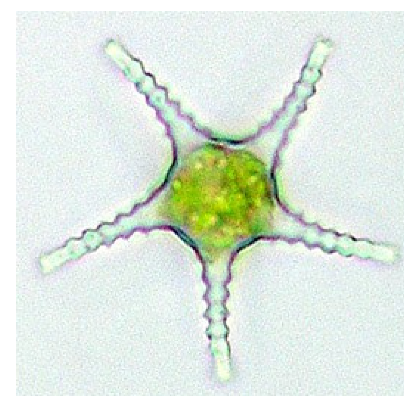




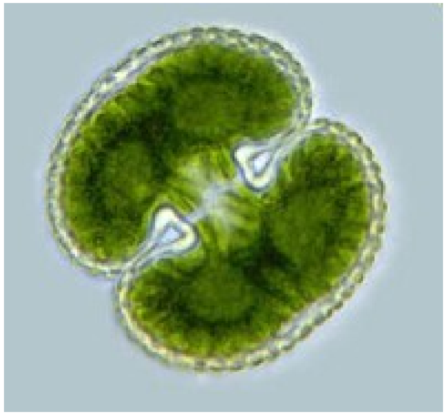


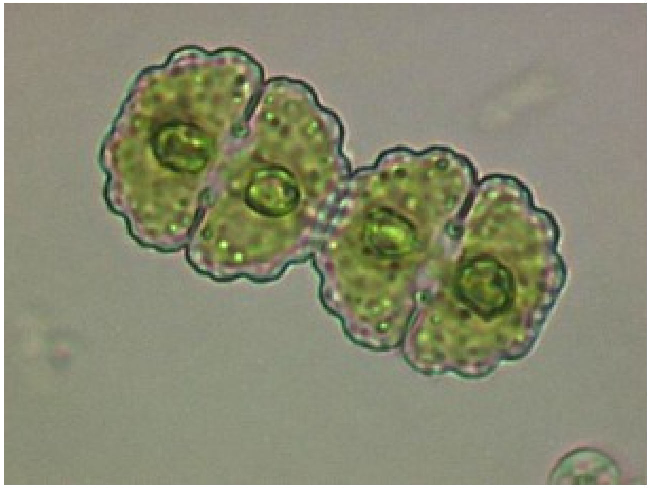
semicells with more than two radially symmetric parts

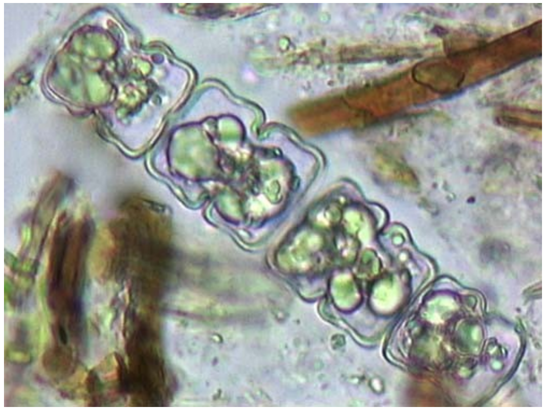




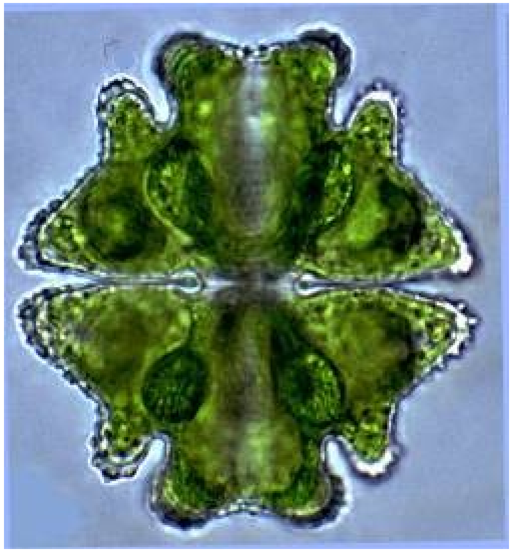
Cosmarium

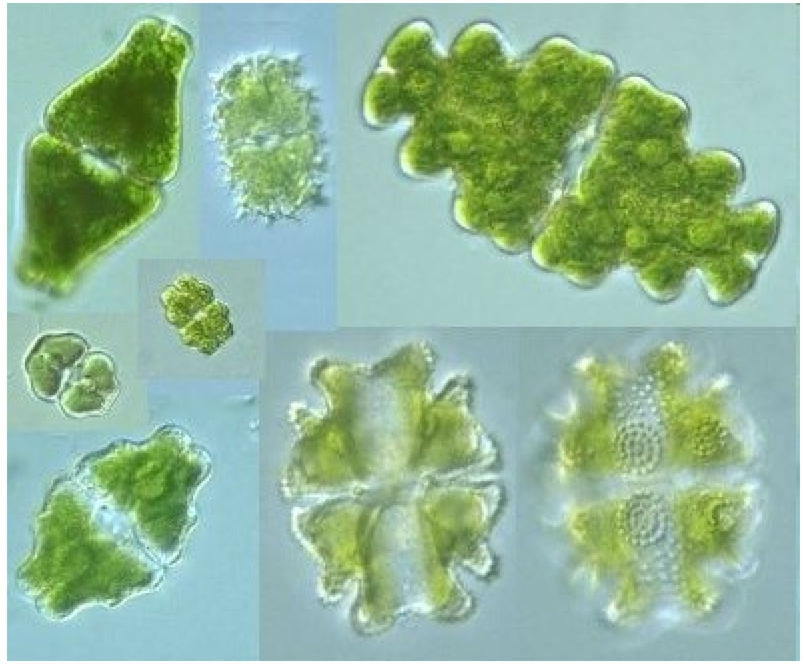


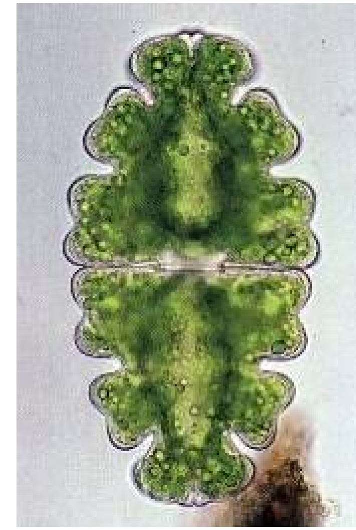


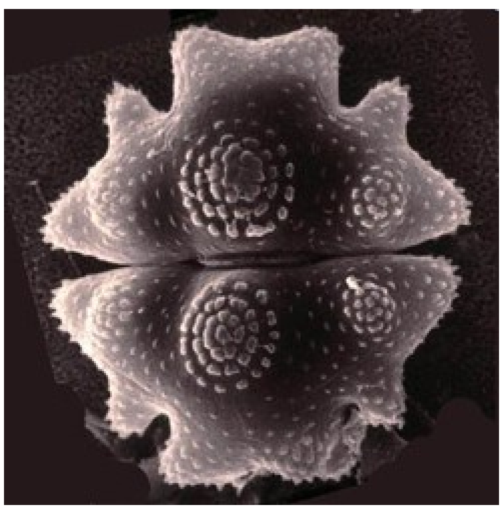


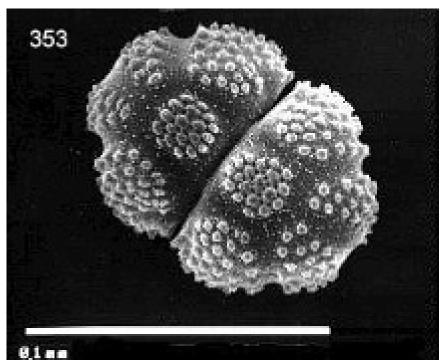
Euastrum

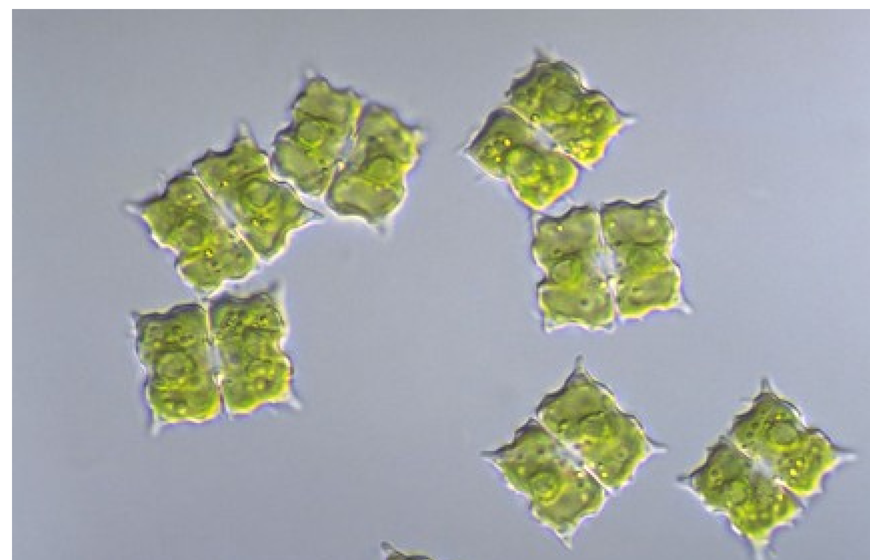




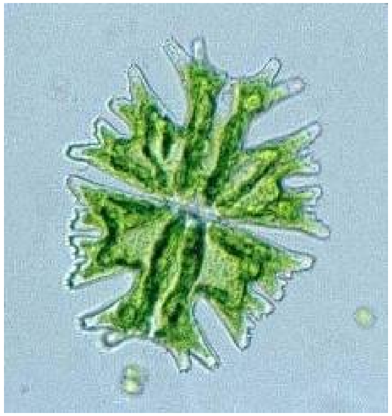


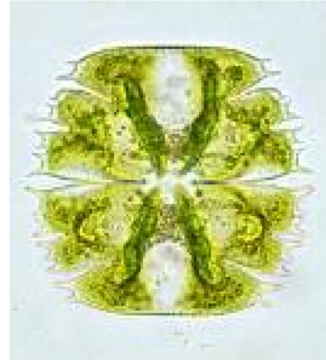


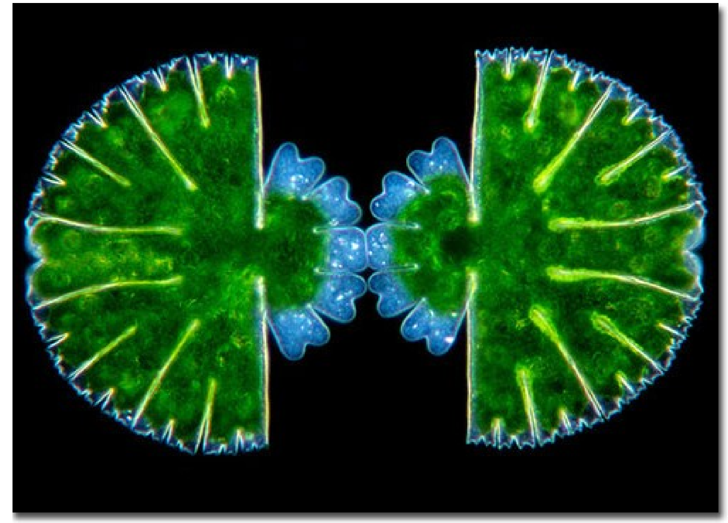


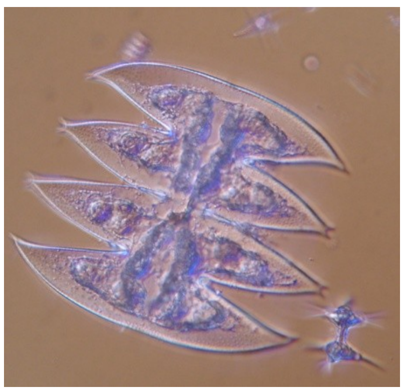


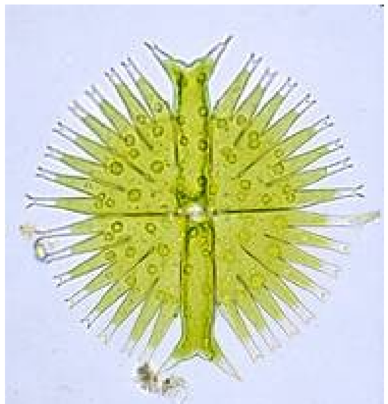
Micrasterias

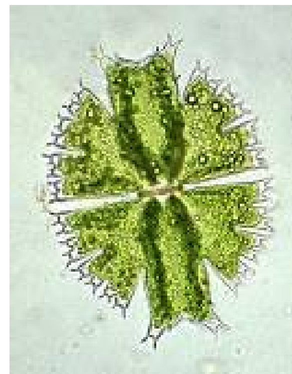


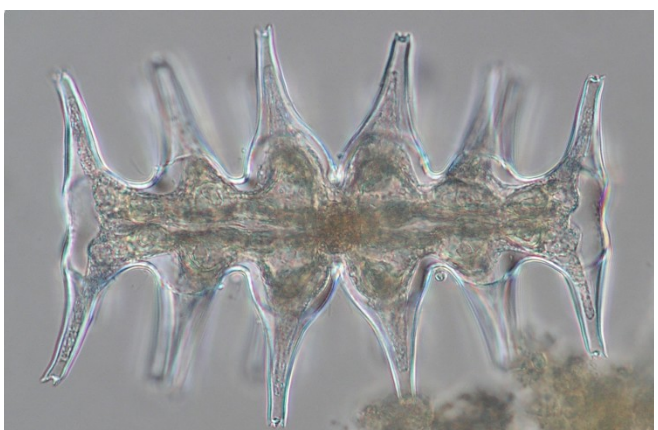


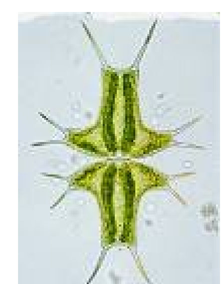












lobe patterning in developing turgor-reduced cells

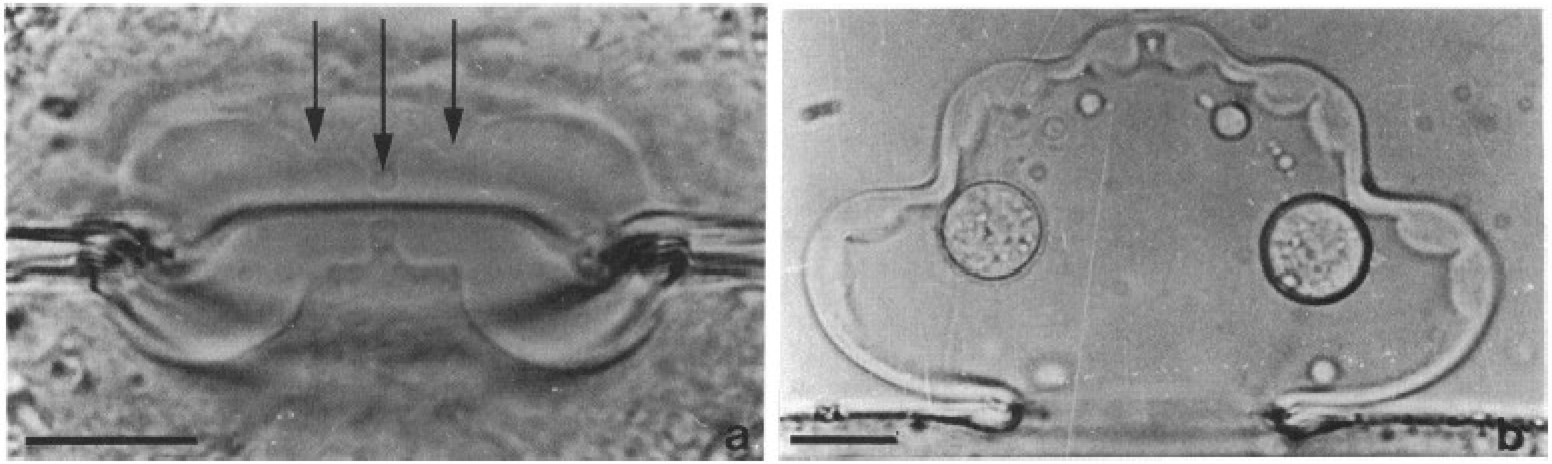


FIG. 11. (a) Septum initial pattern developed in 0.22 M glucose. At both sides of the septum, one central (arrow) and two lateral (arrows) minimum zones are visible. Bar, 20 μm. Reprinted from reference 28 with permission. (b) Accumulation pattern of primary-wall material resulting from turgor reduction in 0.12 M polyethylene glycol 400. Bar, 20 μm. Reprinted from reference 27 with permission.

concept of the morphogenetic plasmatic templates

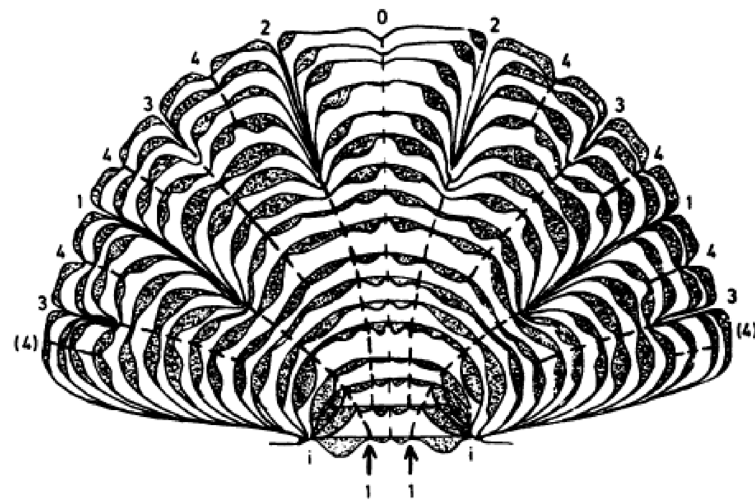
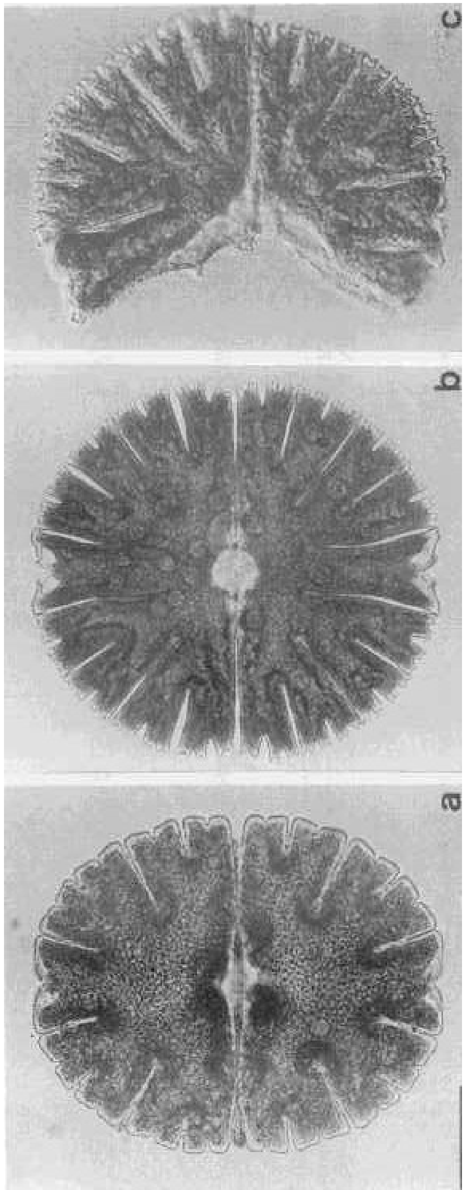
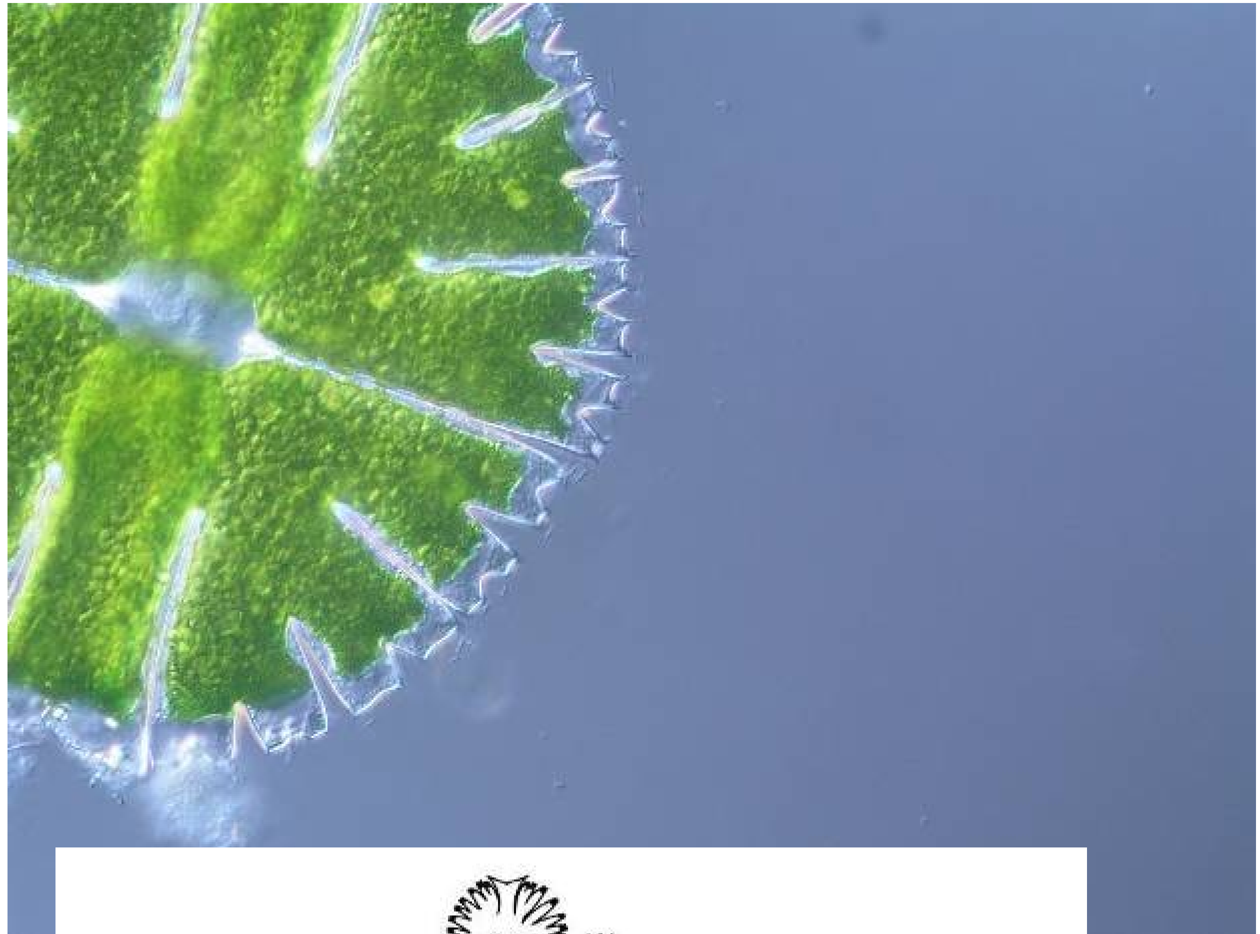


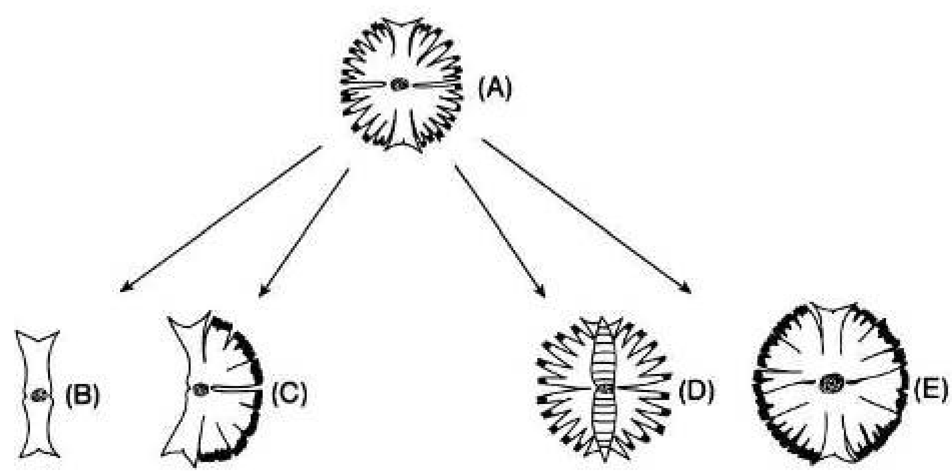
FIG. 12. Pattern of wall material accumulation under turgor reduction and schematic representation of the developmental steps in *M. denticulata*. The minimum zones visualized by turgor reduction correspond to the indentations forming later in cell development. The numbers indicate the lobe indentations corresponding to the sequence of their formation. Reprinted from reference 27 with permission.

Kiermayer, 1964, Protoplasma
Lütz-Meindl, 2016, Front. Pl. Sci.

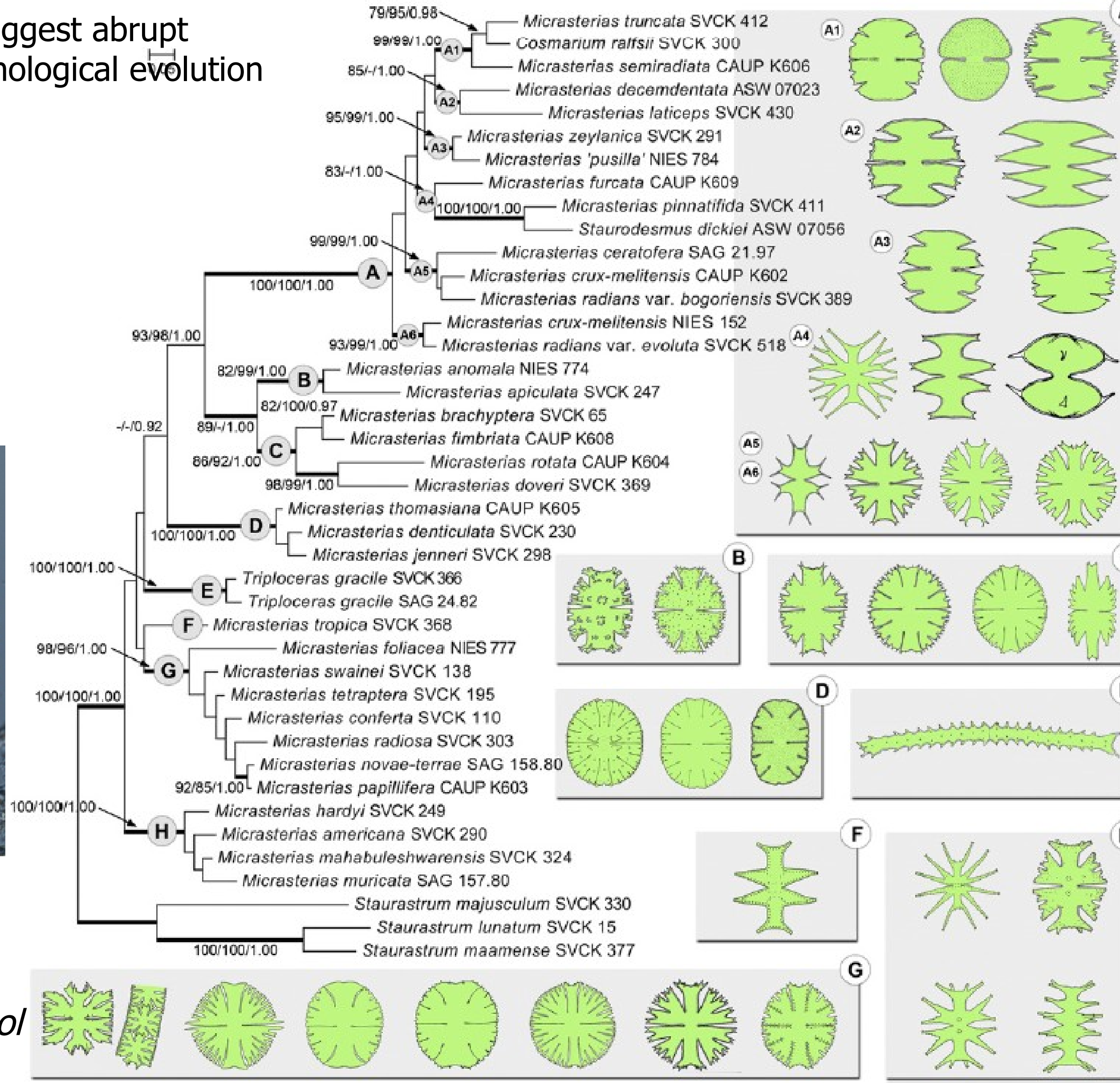
modular morphogenesis







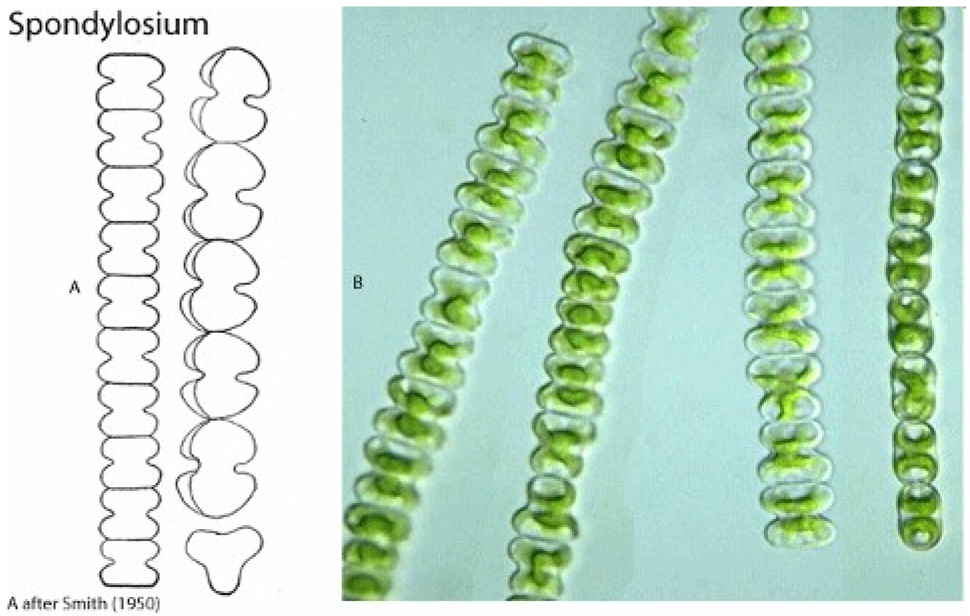
Micrasterias phylogeny suggest abrupt changes in rates of morphological evolution



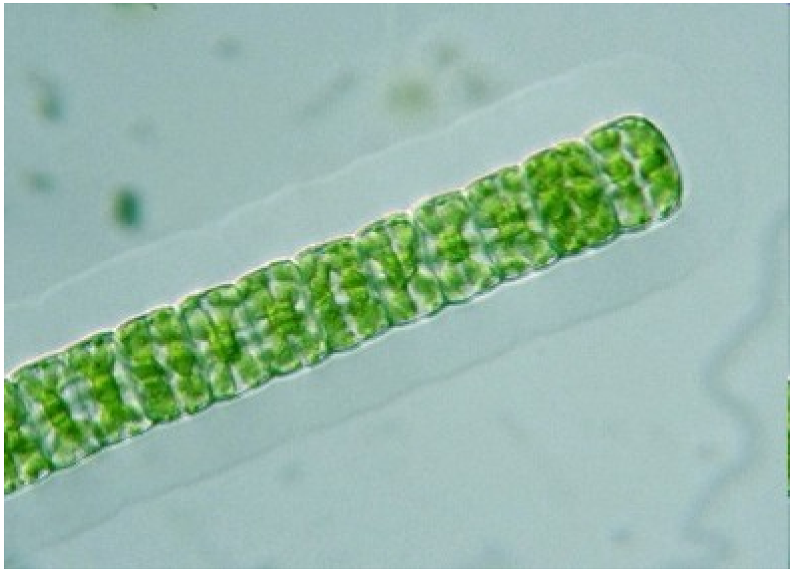
Škaloud et al., 2011, Mol Phyl Evol 61: 933-943.

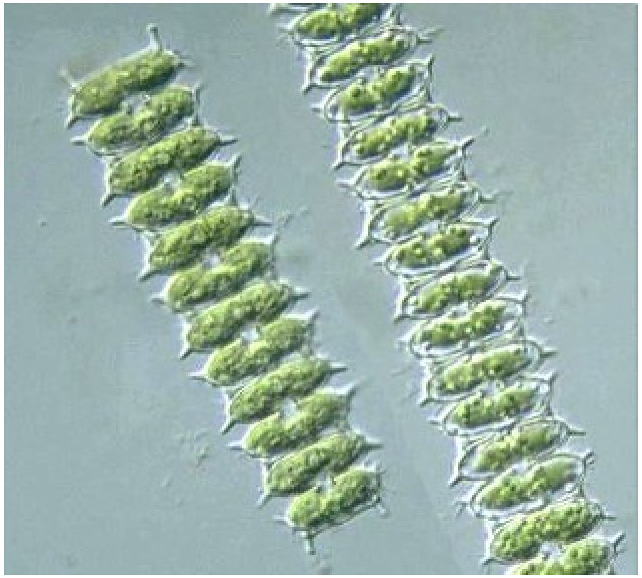
Fig. 3. Bayesian analysis based on the combined and partitioned SSU rDNA, *psa*A, and *cox*III dataset using a GTR + Γ model for SSU rDNA region and 3rd codon position of *psa*A gene, F81 + Γ model for 1st and 2nd codon position of *psa*A and *cox*III genes, and HKY model for 3rd codon position of *cox*III gene. The doublet model is applied for the stem regions in the SSU rDNA region. Values at the nodes indicate statistical support estimated by three methods – maximum likelihood bootstrap (left), maximum parsimony bootstrap (in the middle) and MrBayes posterior node probability (right). Thick branches represent nodes receiving the highest PP support (1.00). Species affiliation to eight clades (A–H; including six sub-clades A1–A6) is indicated. Morphology of investigated strains is given in the boxes next to the tree, according to their affiliation to the particular clades. The order of the species in the tree (from above to down) corresponds to the order of the cells illustrated in the boxes (from left to right). Scale bar – estimated number of substitutions per site.

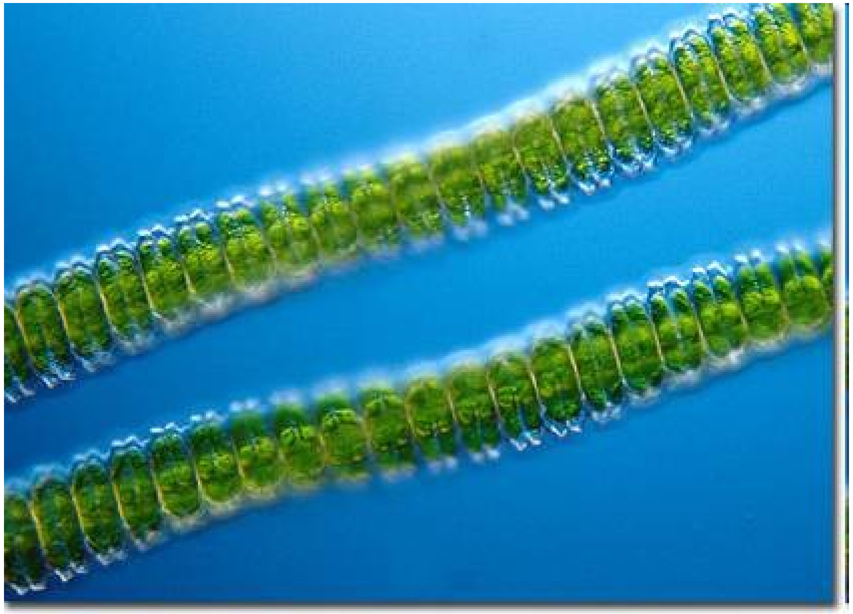
filamentous genera: Desmidium, Hyalotheca, Spondylosium



A after Smith (1950)
B © Y. Tsukii, see http://protist.i.hosei.ac.jp/Protist_menuE.html

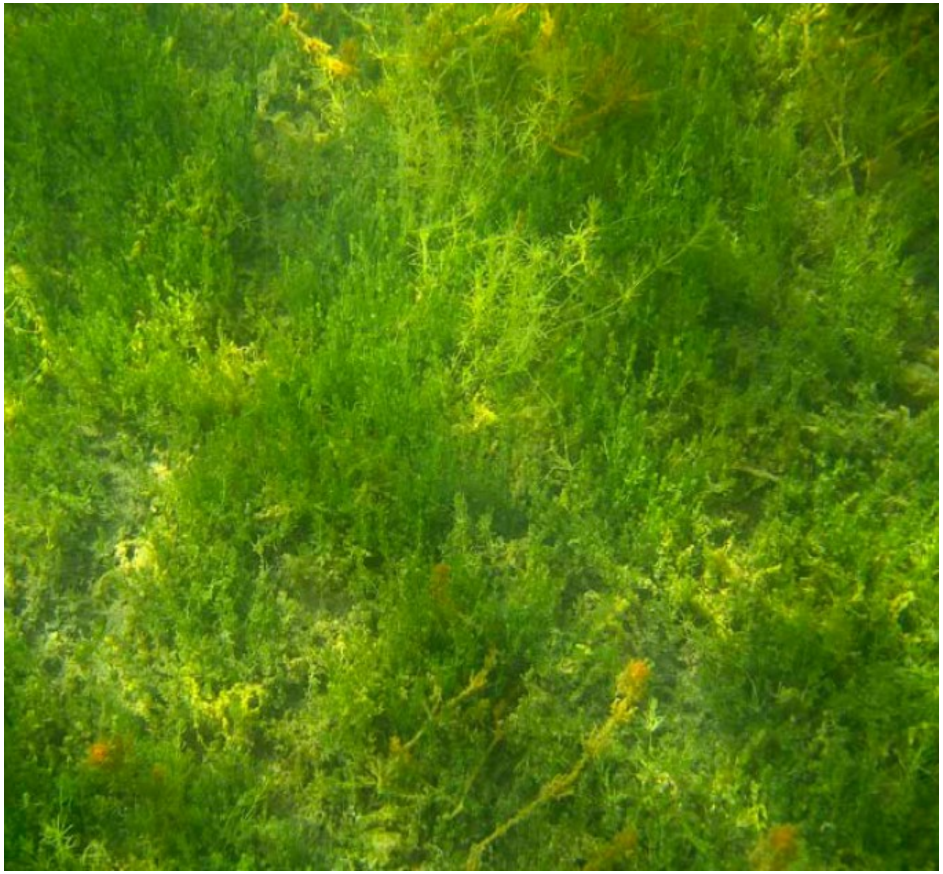




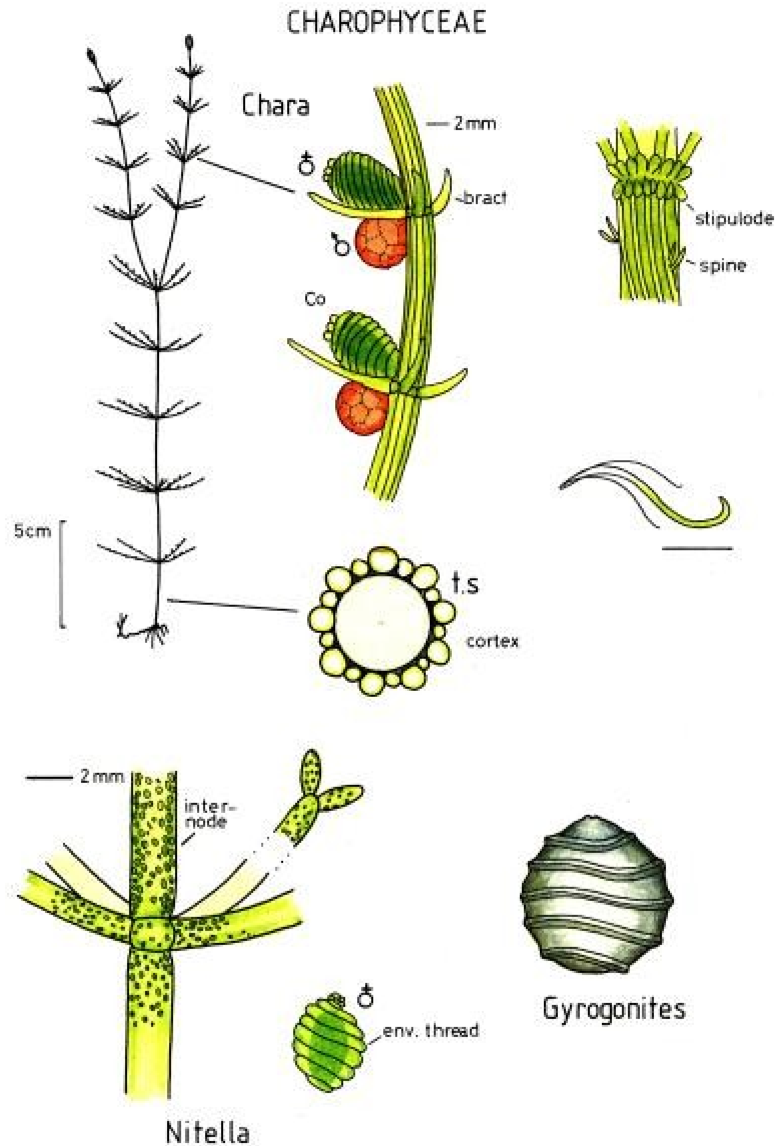


Charophyceae

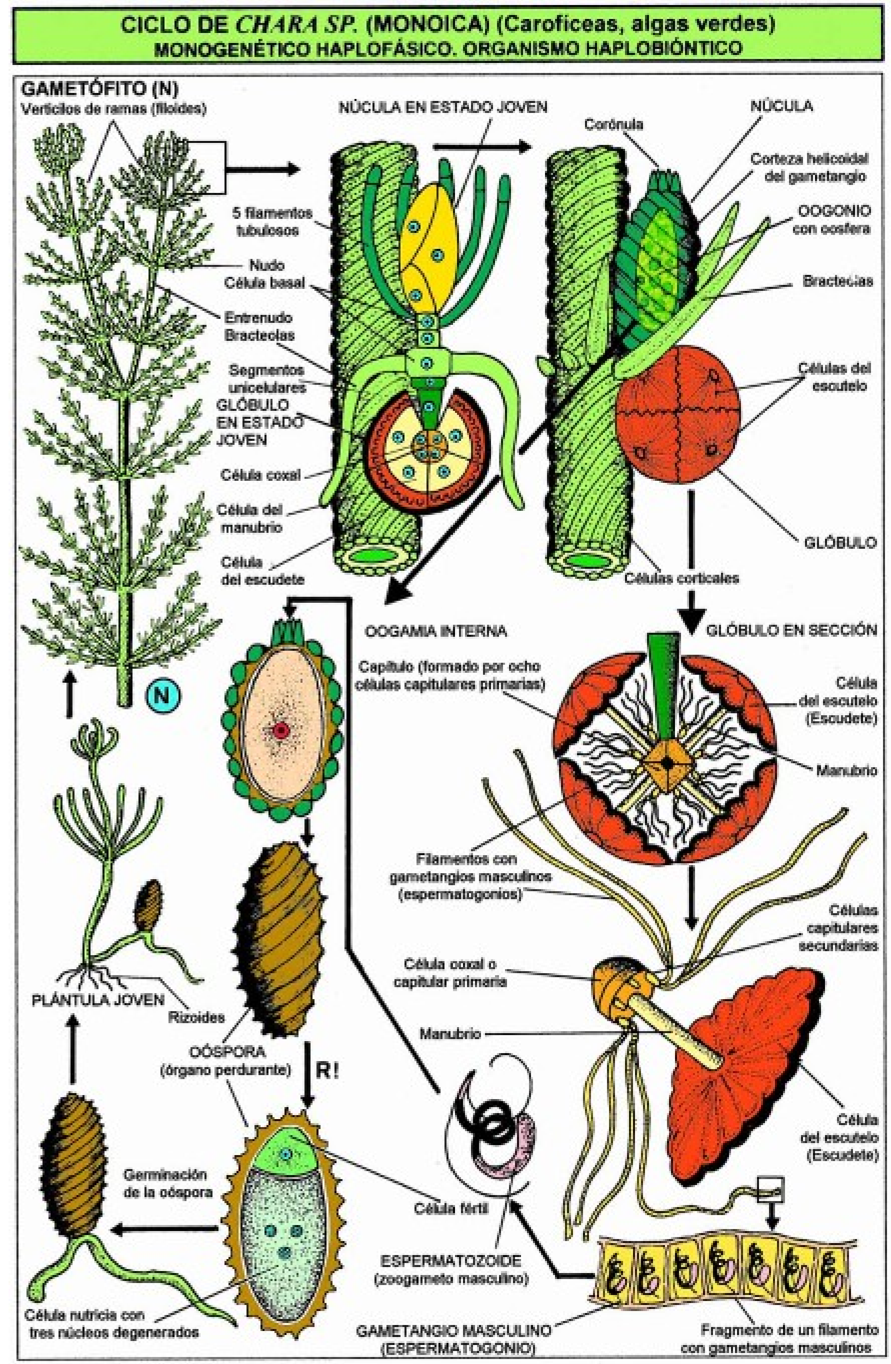
(stoneworts, parožnatky)



sinicearasy.cz



freshwaterlife.org



gyrogonity – nejstarší fosílie 400 miliónů let

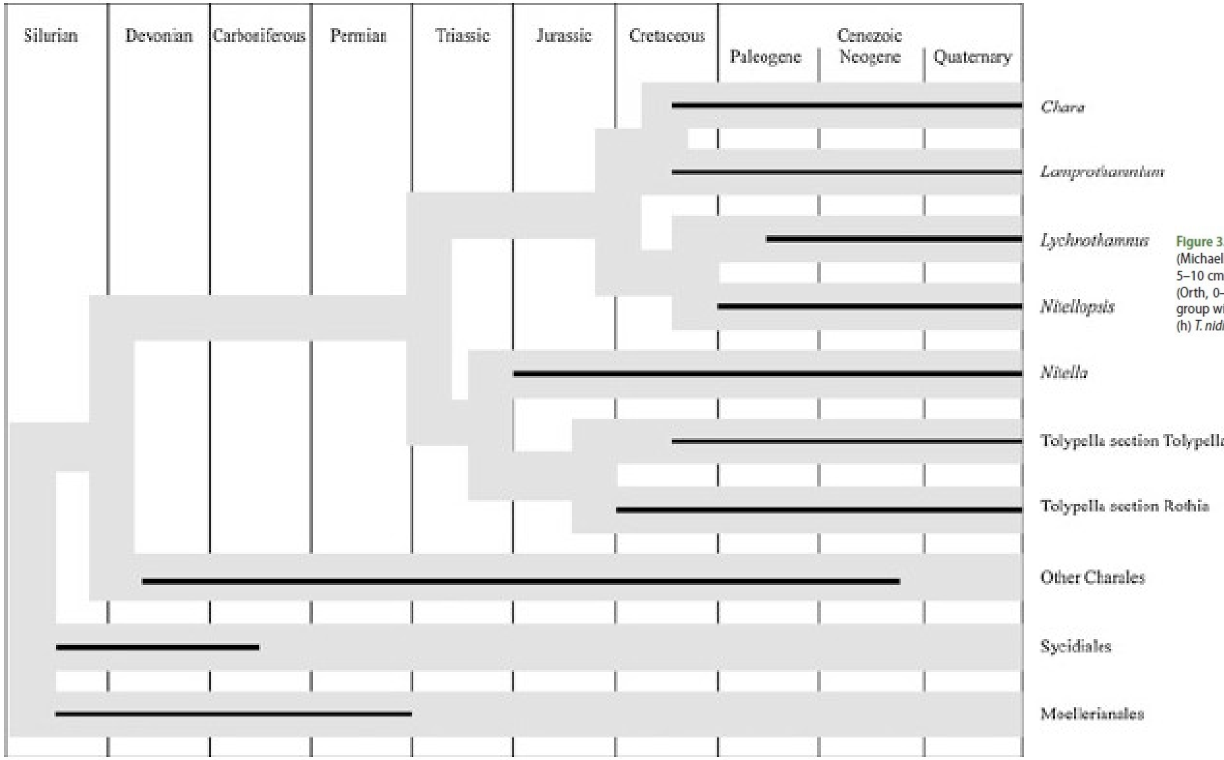


Fig. 6 Phylogenetic relationships of genera in the Charales, and ranges of fossil ages of extant genera and several extinct taxa. The black bars indicate the ages of the earliest known fossils for taxa, as well as fossil ages for extinct taxa in the Charales and the extinct Orders Sycidiales and Moellerinales. Relationships of extant taxa based on molecular phylogenetic studies (McCourt et al. 1999; Meiers et al. 1999; Karol et al. 2001). Fossil ages and phylogenetic relationships of fossil taxa based on Feist et al. (2005). (R. M. McCourt and J. D. Hall)

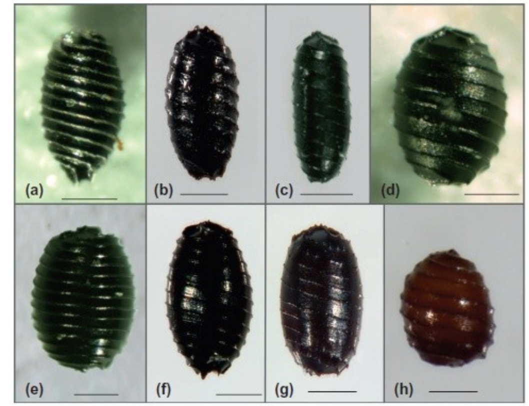


Figure 3. Lateral view of the oospores of the charophytes (scale bars = 200 µm). (a) *C. aspera* with prominent ridges and basal cage (Michaelsdorf, 0–5 cm sediment depth); (b) intermediate form of the *C. canescens/C. aspera* group without basal cage (Michaelsdorf, 5–10 cm sediment depth); (c) *C. canescens*, elongated form (Breitling/Stove, 0–5 cm sediment depth); (d) *C. canescens*, ovoid form (Orth, 0–5 cm sediment depth); (e) *C. baltica/C. horrida* group (Rügen/Vilm, 0–5 cm sediment depth); (f) *C. globularis/C. virgata* group with a apical rosette (Breitling/Stove, 0–5 cm sediment depth); (g) *L. papulosum* (Lehmkenhafen, 5–10 cm sediment depth); (h) *T. nidifica* (Breitling/Stove, 0–5 cm sediment depth).

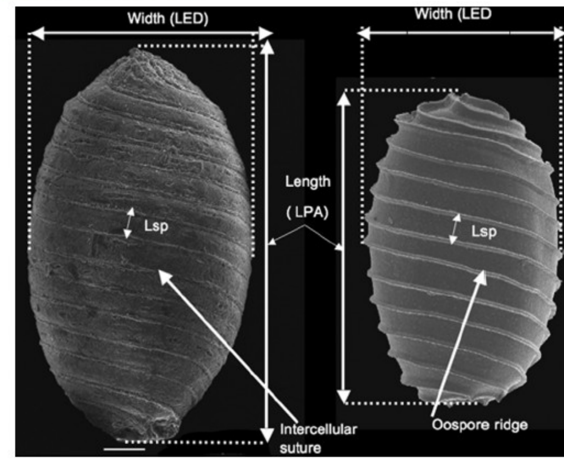
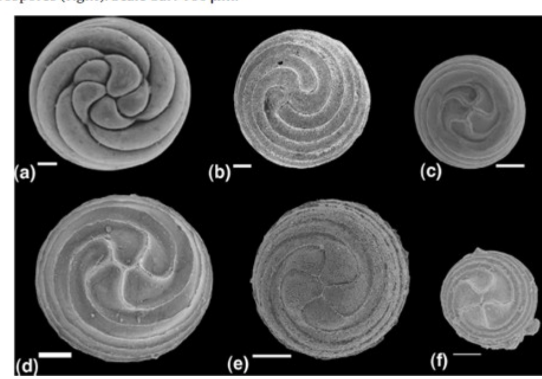


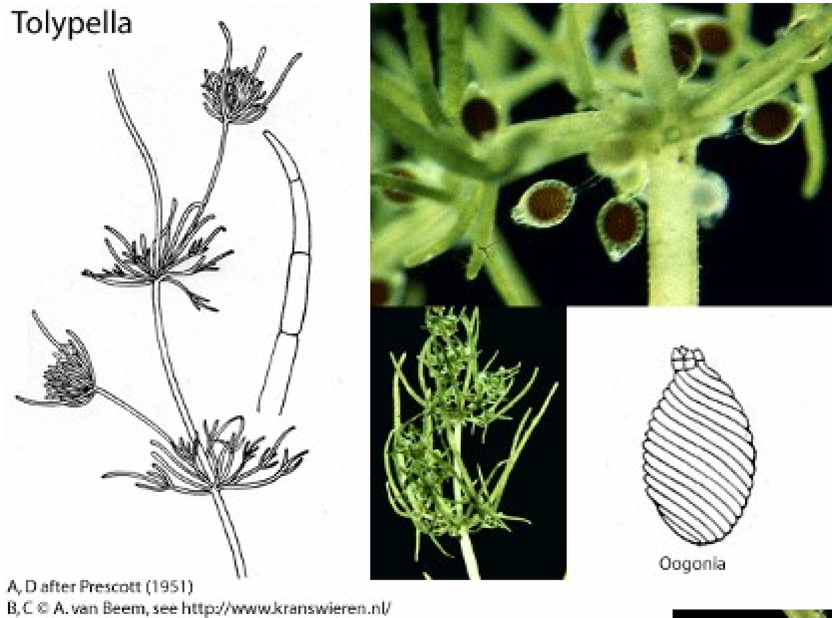
Fig. 9. Parameters for measurements and description of gyrogonites (left) and oospores (right). Scale bar: 100 µm.

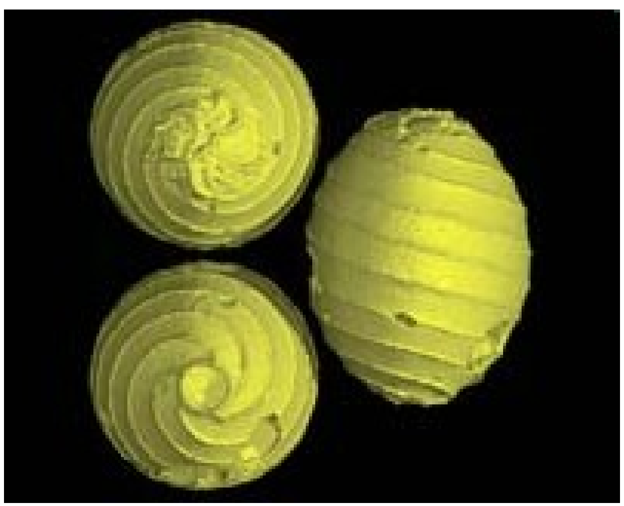


McCourt et al., 2017, in Handbook of Protists
Souillé-Märsche & García, 2015, Aquat. Bot.
Nowak et al., 2018, Bot. Letters

Tolypella

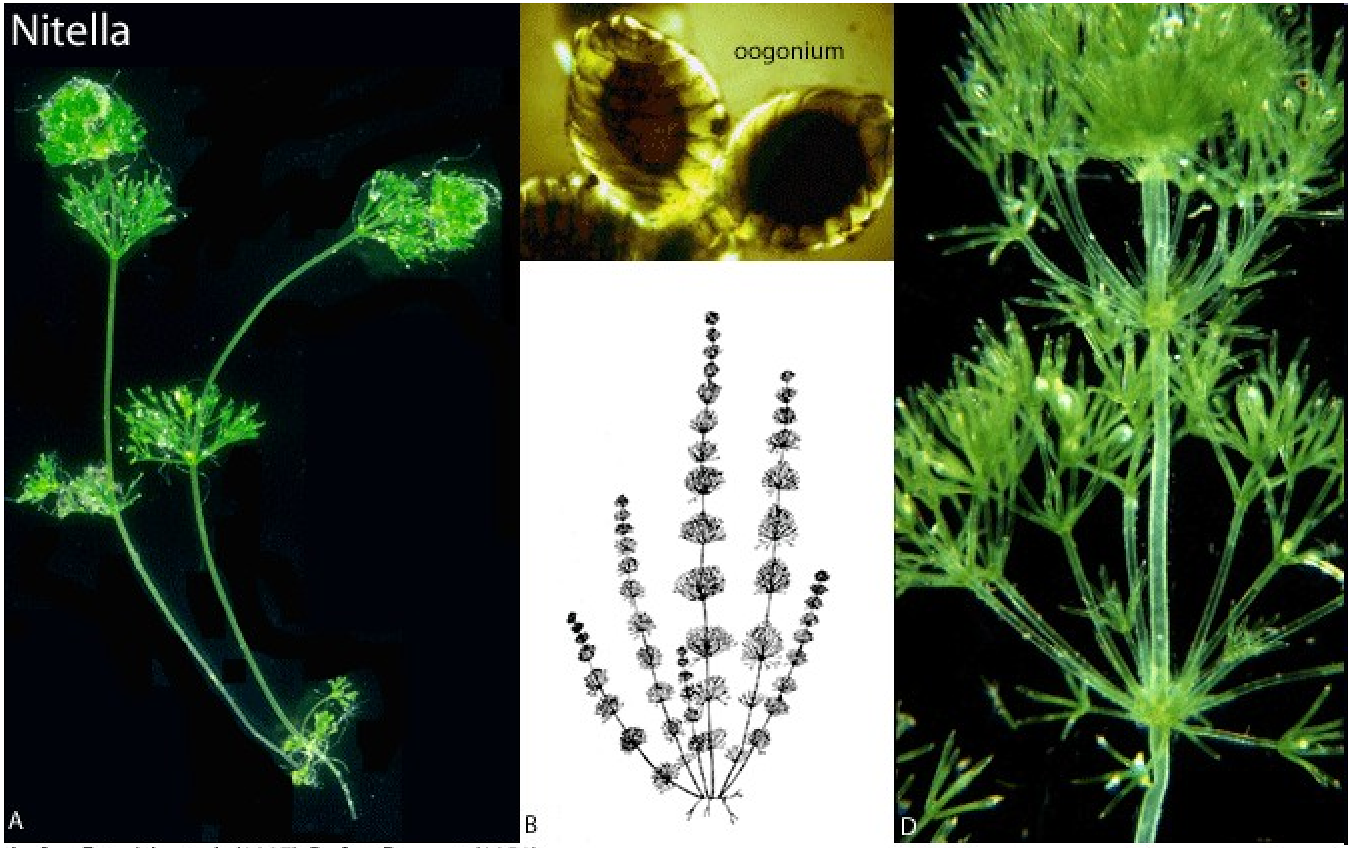
Chara





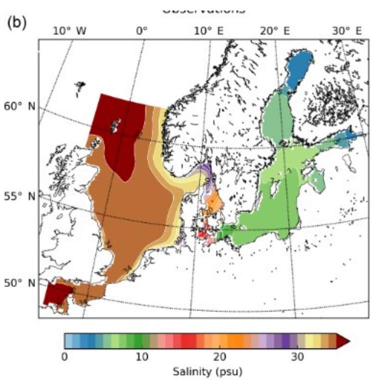
fossilized zygotes (gyrogonites)

Nitella



... al. (1997), B after Prescott (1951)
..., see http://www.kranswieren.nl/

distribution and ecology of stoneworts



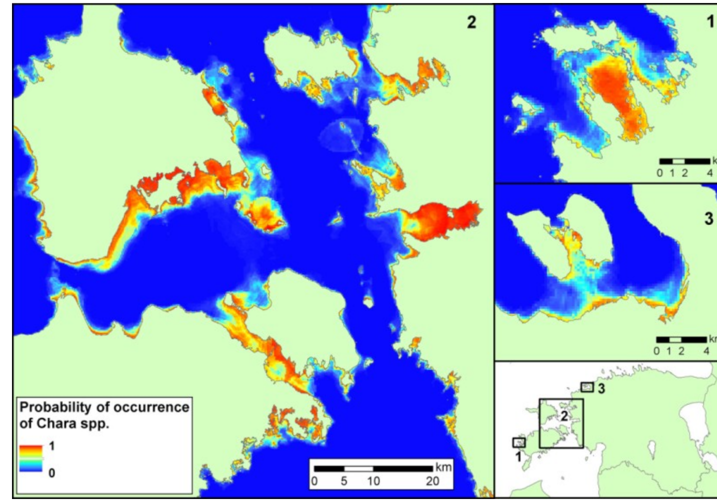


Fig. 3. Probability of occurrence of charophytes as predicted by the BRT model. The full spatial extent of the modelled prediction is not shown as the zoom level for the full display would render the map hard to read. Instead of the full extent, three areas of higher probability of *Chara* spp. are shown. The full extent of the prediction can be found in the online appendix.

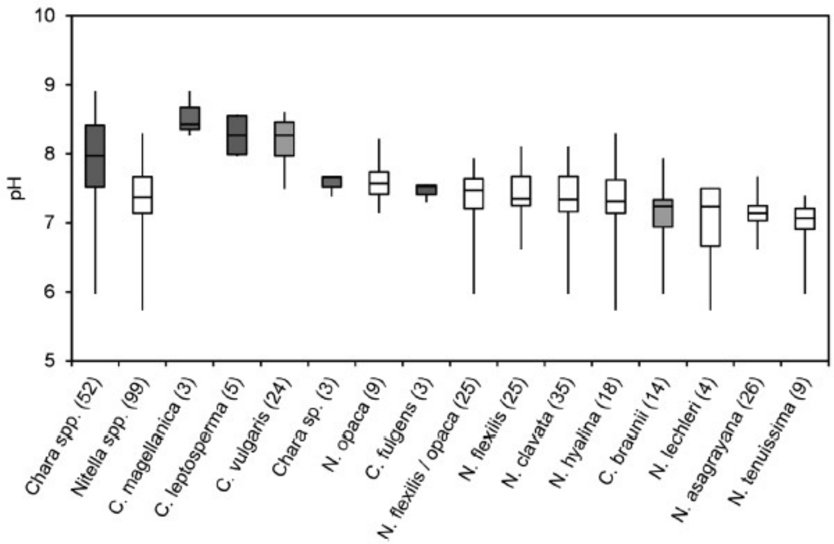


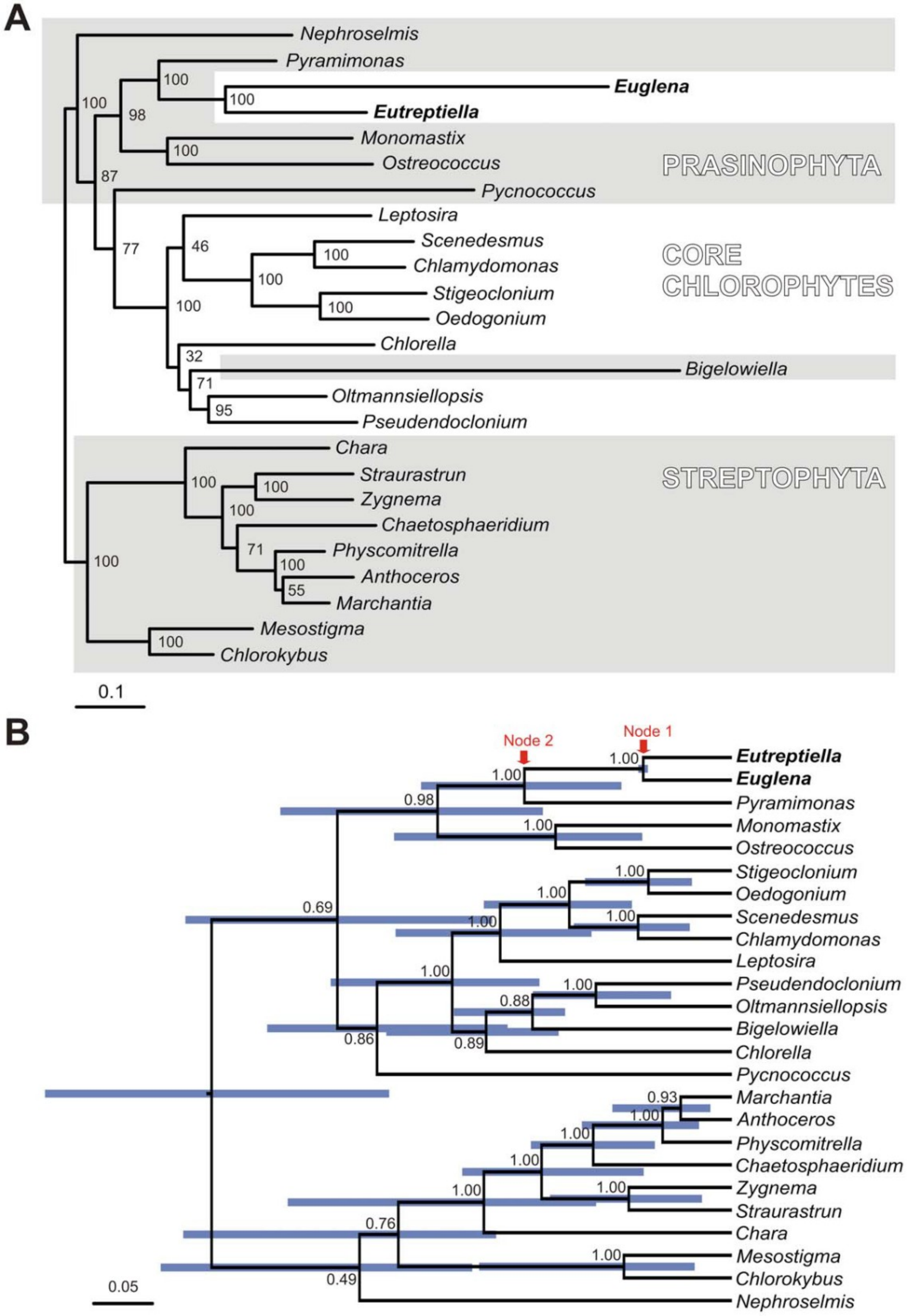
Figure 2. Box-Whisker plot of pH values for taxa with at least 3 values in the water chemistry dataset. Minimum, maximum and median pH are given as well as 50% and 75% quartiles (boxes). Number of values are given in brackets; *Chara* spp. marked in grey.

vast majority of charaleans needs **neutral to alkaline pH**

calcification in charophytes takes place as precipitation of calcium carbonate (aragonite) in alkaline pH at the surface of the cell wall of the cortical cells

Schubert et al., 2018, Bot. Letters
Torn et al., 2014, Aquat. Bot.

Phylogenetic history of secondary chloroplasts

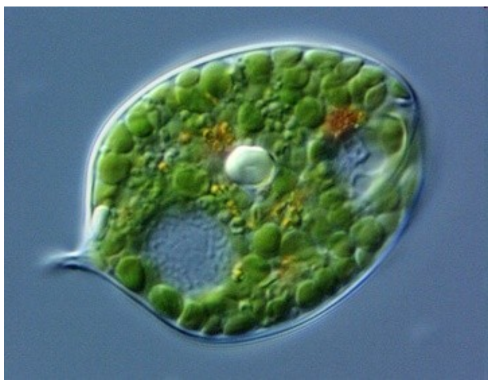


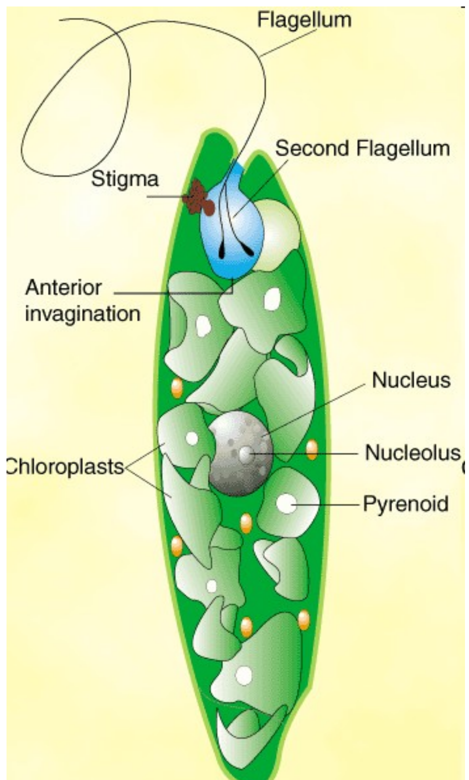
Hrdá et al, 2012, PlosOne

Euglenophyta (Euglenozoa, Euglenida)

skupina sladkovodních bičíkovců
patří do superskupiny Excavata;
mají sekundární **chloro**plasty

zde pouze (primárně ekologický) přehled zástupců
fylogeneze skupiny ⟶ přednáška Protistologie





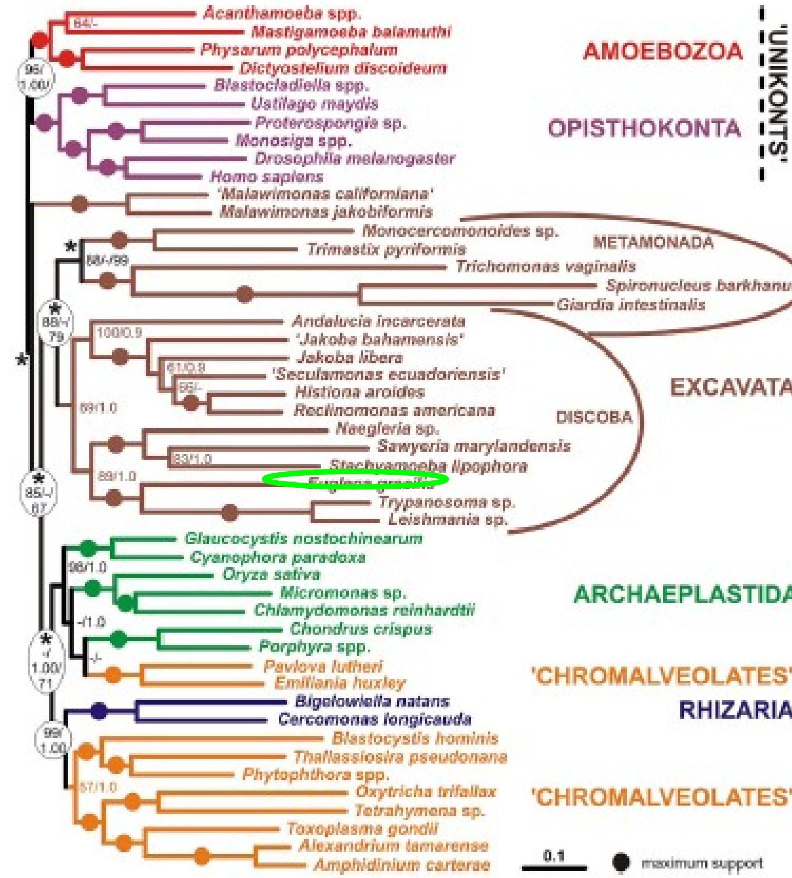


Fig. 1. The phylogenetic tree estimated from the main dataset. This topology received the highest likelihood in the exhaustive search of unconstrained nodes using the WAG+ Γ model; branch-lengths were calculated in RAxML using the WAG+ Γ model. The representatives of the 6 supergroups are color-coded. Asterisks indicate the nodes that were not constrained during the exhaustive search. The numbers at the nodes indicate bootstrap support calculated by RAxML bootstrapping/PhyloBayes posterior probability. At nodes that were not constrained during the exhaustive search in the separate analysis (asterisks), the third number indicates the RELL bootstrap value. Branches that received maximum possible support by all methods are indicated by full circles. Dashes indicate bootstrap values <50%, or posterior probabilities <0.5. Although the analyses did not assume a root, the tree is displayed with the basal split between "unikonts" and bikonts as suggested in ref. 37.

Hampl et al., 2009, P.N.A.S. 106: 3859–3864

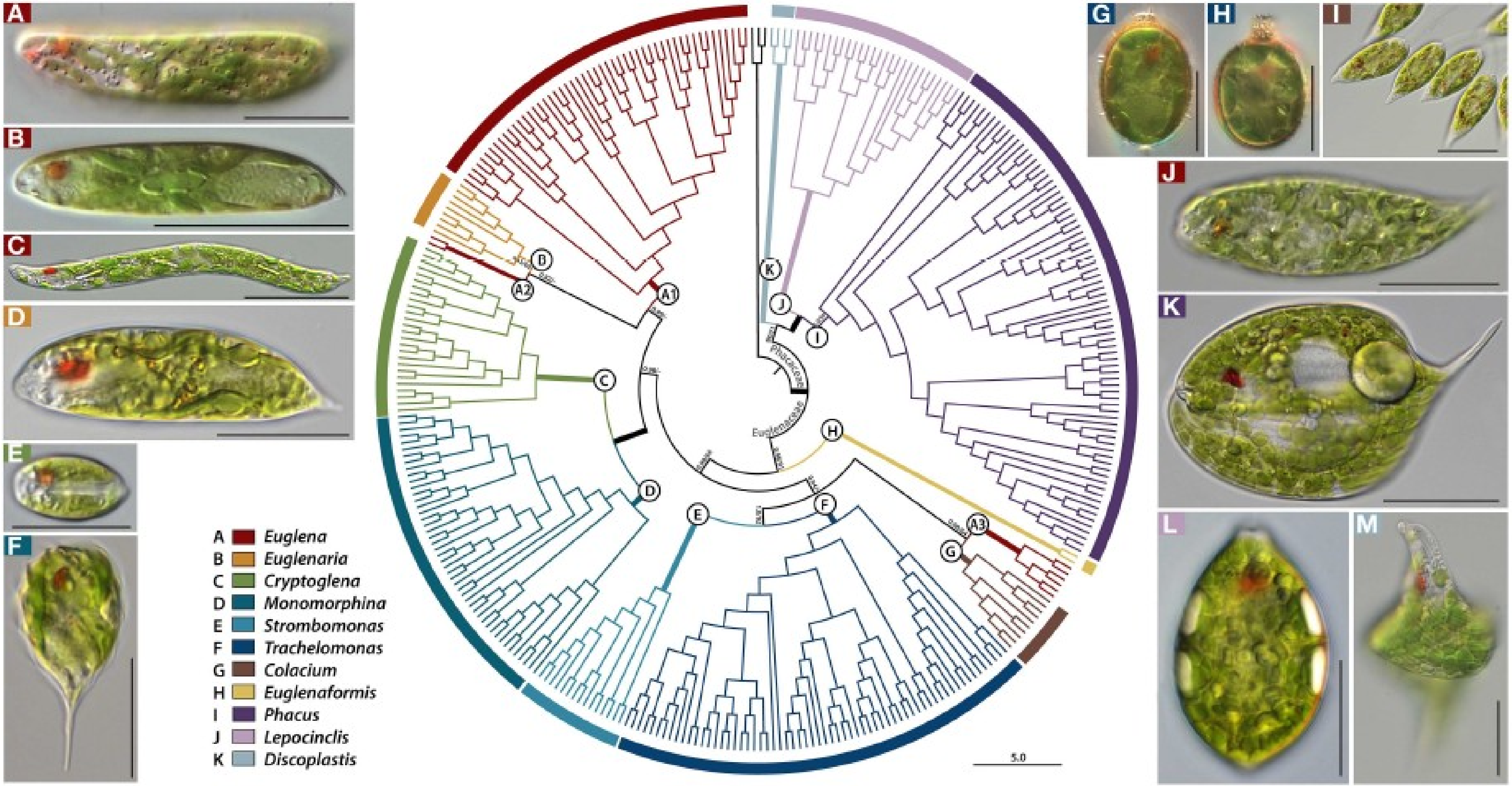


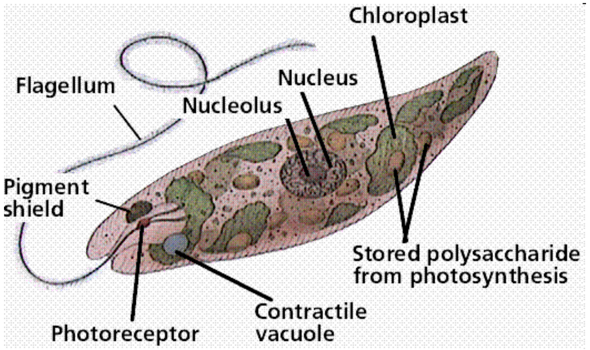
FIGURE 1 | A rooted Bayesian tree for the Euglenales based on a four-gene dataset. The order is divided into two major families, represented by many lineages within the family Euglenaceae and Phacaceae, each of which is further split into subclades **(A–K)**. Names of pictured taxa are the following: **(A)**, *Euglena laciniata* with diplopyrenoid in net-like chloroplast; **(B)**, *Euglena stellata* with pyrenoid center in stellate chloroplast; **(C)**, *Euglena deses* with naked pyrenoid in chloroplast; **(D)** *Euglenaria caudata* with diplopyrenoid in lobed, larger discoid chloroplast; **(E)** *Cryptoglena pigra* with U-shaped chloroplast; **(F)** *Monomorphina pyrum* with larger discoid chloroplast; **(G)** *Trachelomonas* sp. with diplopyrenoid in larger discoid chloroplast; **(H)** *Trachelomonas* sp. with haplopyrenoid in larger discoid chloroplast; **(I)** *Colacium* sp. Songjanggol033107B with haplopyrenoid in larger discoid chloroplast; **(J)** *Euglena* cf. *velata* with diplopyrenoid in deeply lobed chloroplast; **(K)** *Phacus orbicularis* with small discoid chloroplasts; **(L)** *Lepocinclis ovum* with small discoid chloroplast; **(M)** *Discoplastis spathirhyncha* with small discoid chloroplast. The numbers on each node represents posterior probabilities (left) and bootstrapping values (right). The bold branches indicate strongly supported values (pp = 1.00 and ML = 100%). Scale bars in pictures, 20 µm.

Kim et al., 2015, Frontiers Ecol. Evol.

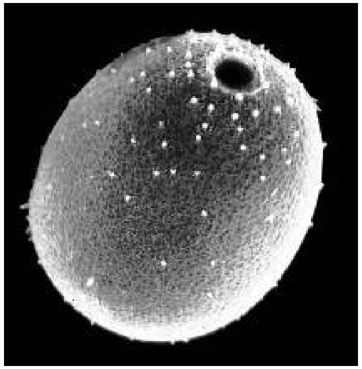
Euglena

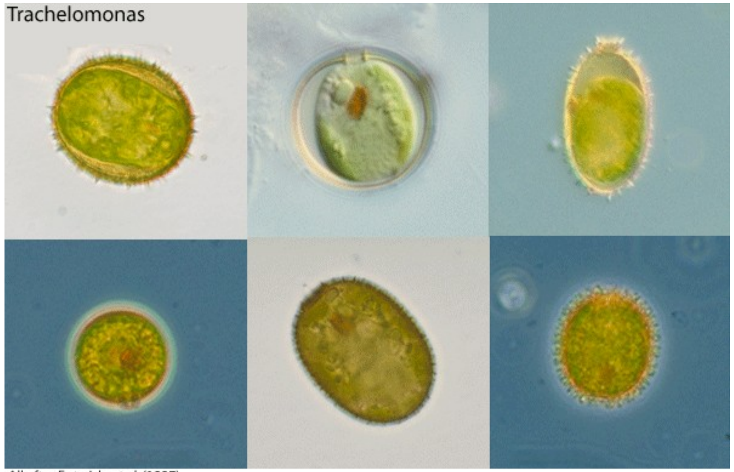
- hojný rod ve sladkovodním fytoplanktonu a fytobentosu
- více než 80 druhů
- výzkyt: přes extrémně kyselé tůňky až po eutrofní plankton

All after Entwisle et al. (1997)

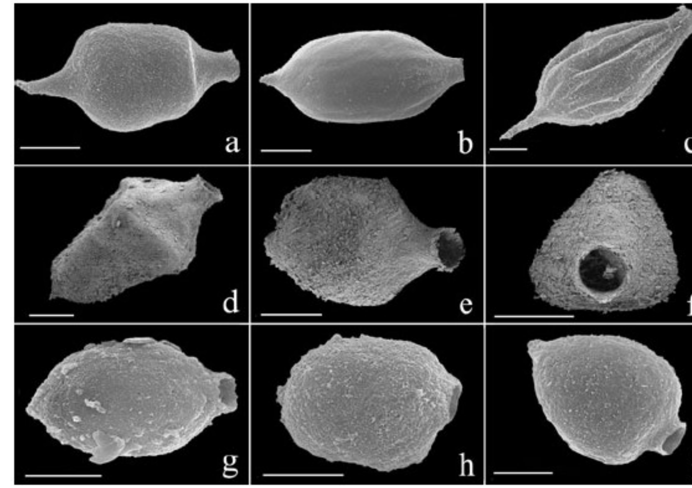


Trachelomonas a Strombomonas - polysacharidové loriky; Fe^{2+}, [Mn^{2+}]





All after Entwisle et al. (1997)



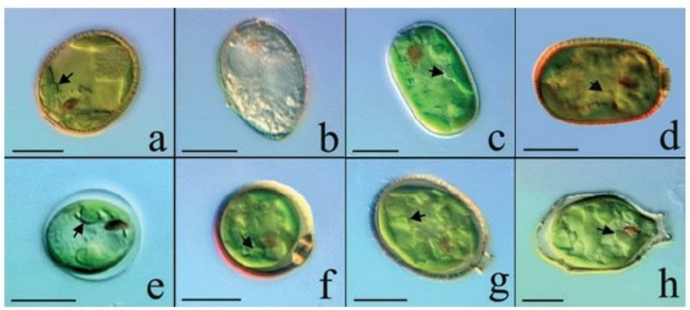
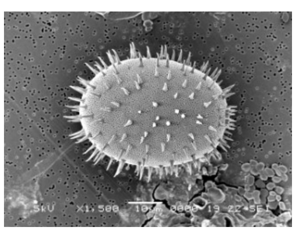
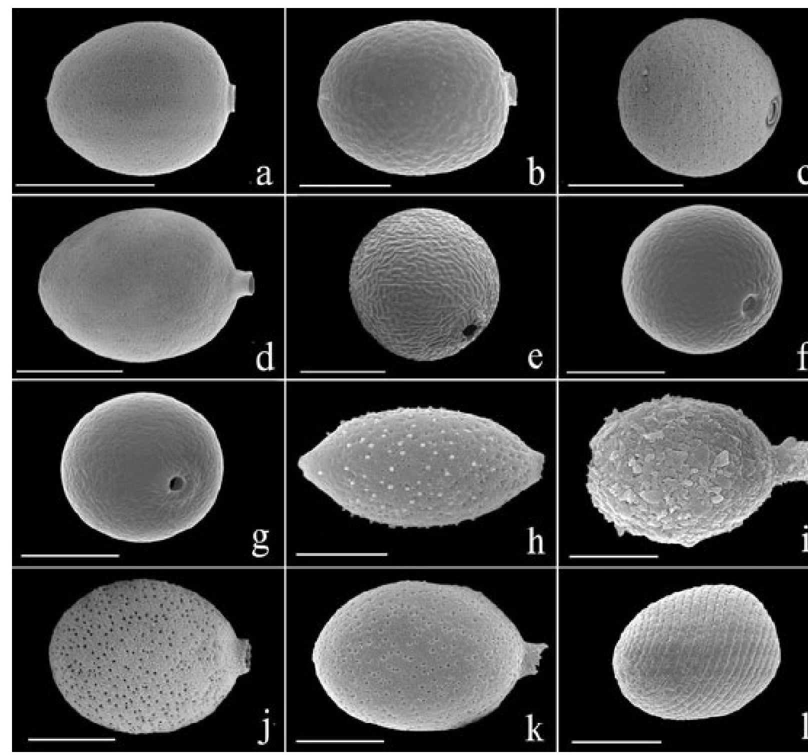


FIG. 5. Light micrographs of *Trachelomonas* (a–g) and *Strombomonas* (h) taxa demonstrating chloroplast number and pyrenoid structure. (a) *Trachelomonas* strain T201. (b) *T. reticulata*. (c) *T. ellipsoidalis*. (d) *T. abrupta*. (e) *T. oblonga*. (f) *T. volvocinopsis*. (g) *T. lefevrei*. (h) *S. triquetra*.

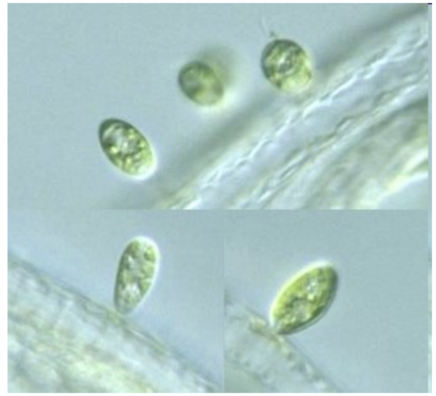




Ciugulea et al., 2008, J. Phycol. 44, 406–418.

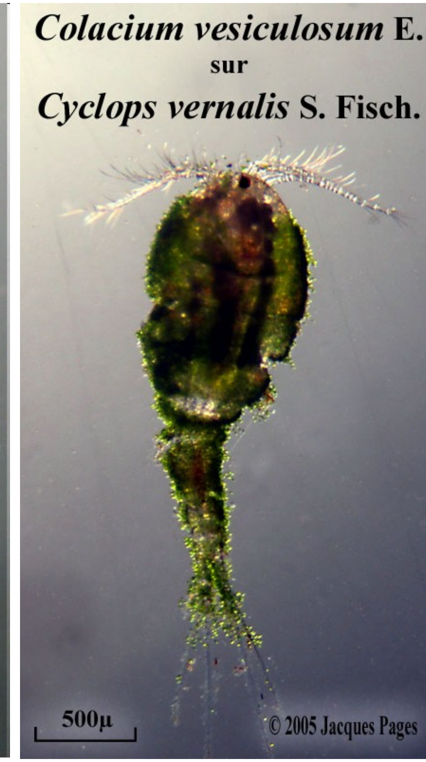
druhově nejbohatší rody (zejména Trachelomonas)
mnoho druhů je ale nejistých
žijí ve fytoplanktonu

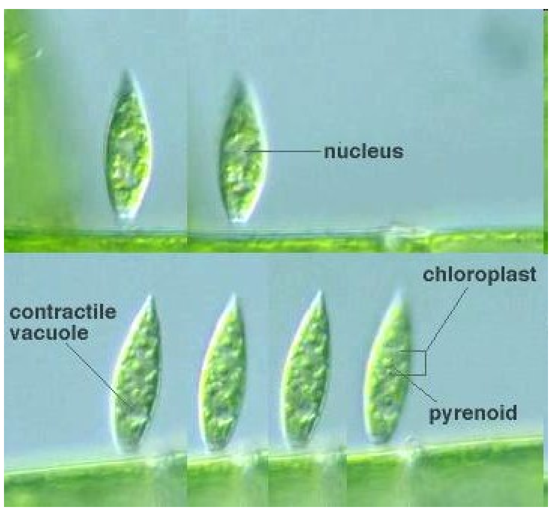
Colacium



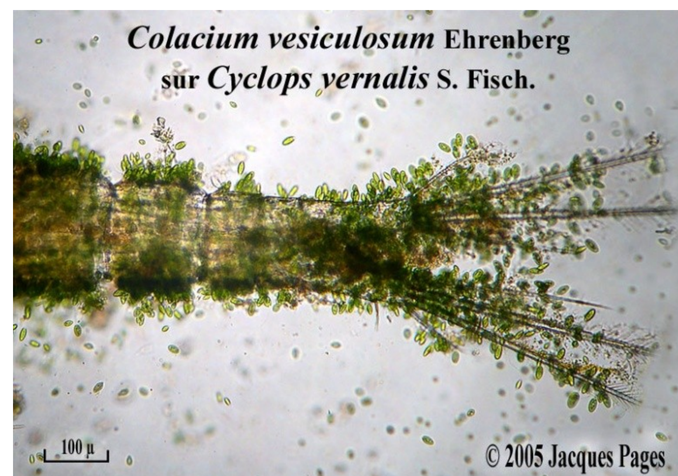
C. cyclopicola

C. cyclopicola - epizoický způsob života
na planktonních korýších
jiné druhy - epifytické



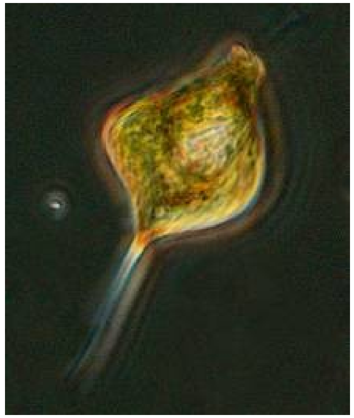


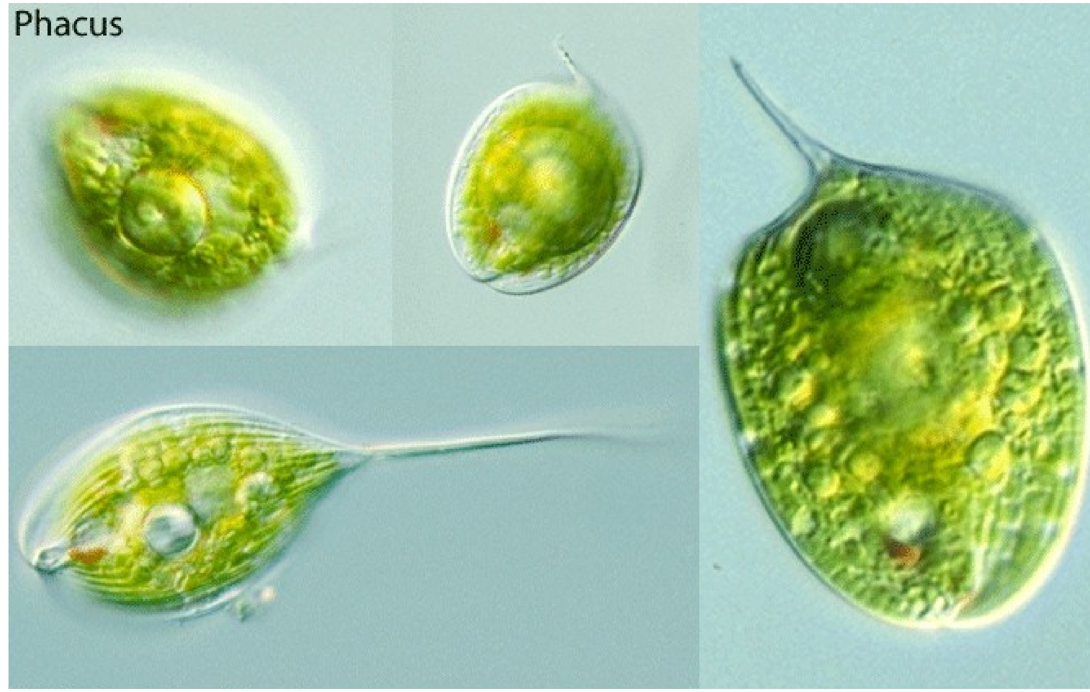
C. mucronatum



http://aelmh.free.fr/Colacium_vesiculosum.htm

Phacus

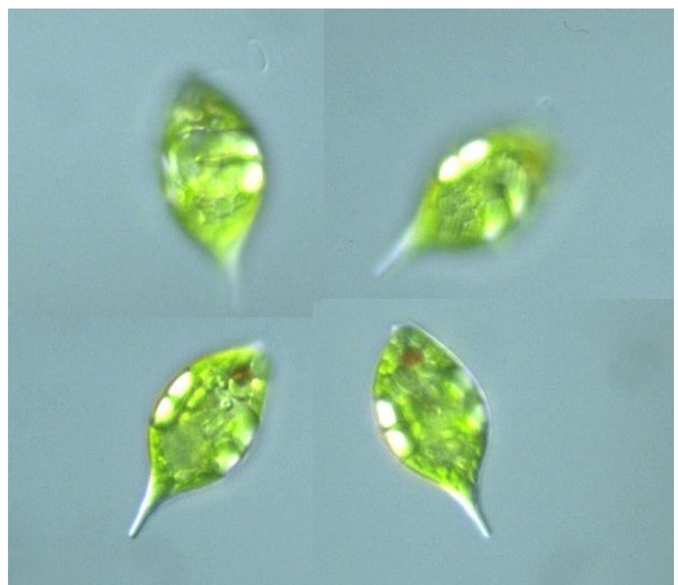


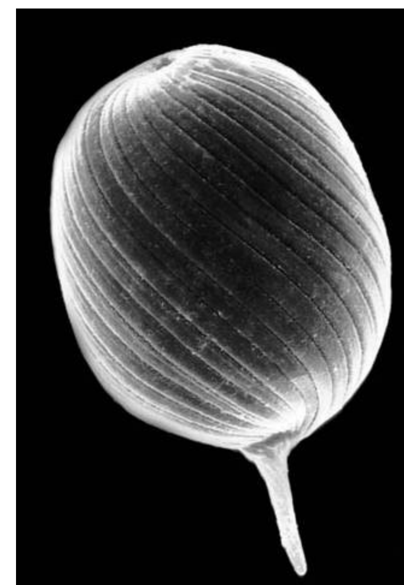


All after Entwisle et al. (1997)

řada druhů má spirální tvar

Lepocinclis

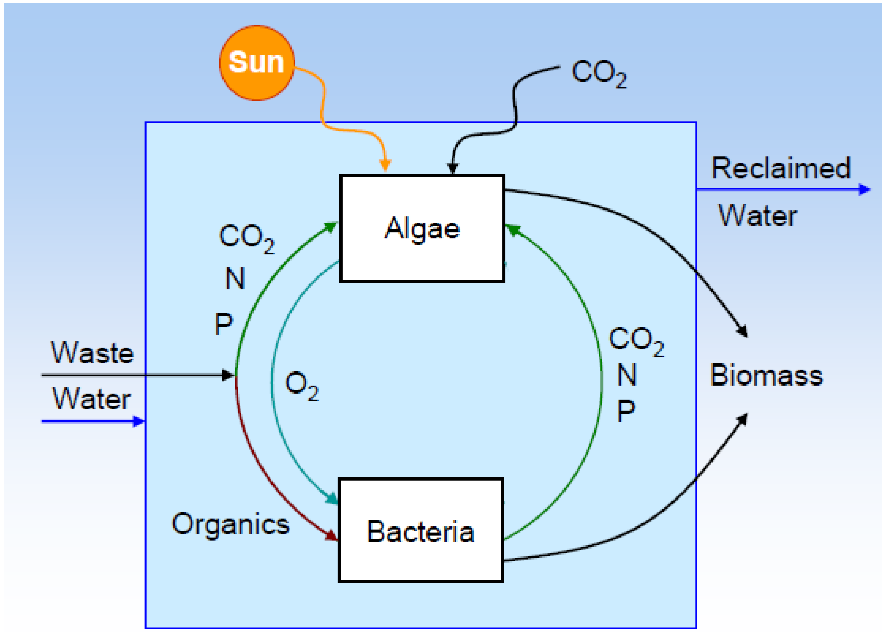




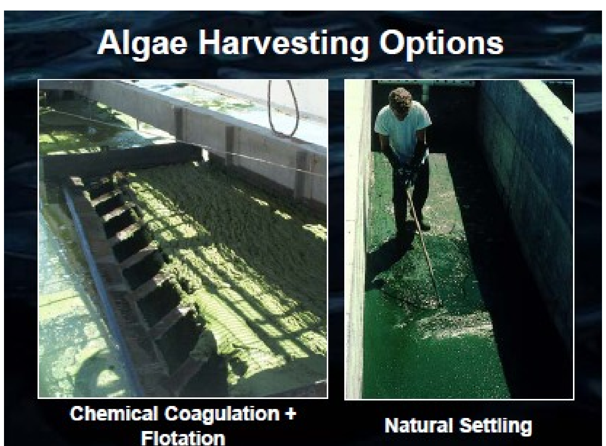
pevná pelikula

euglenoidní bičíkovci patří mezi důležité organismy v procesu čištění odpadních vod

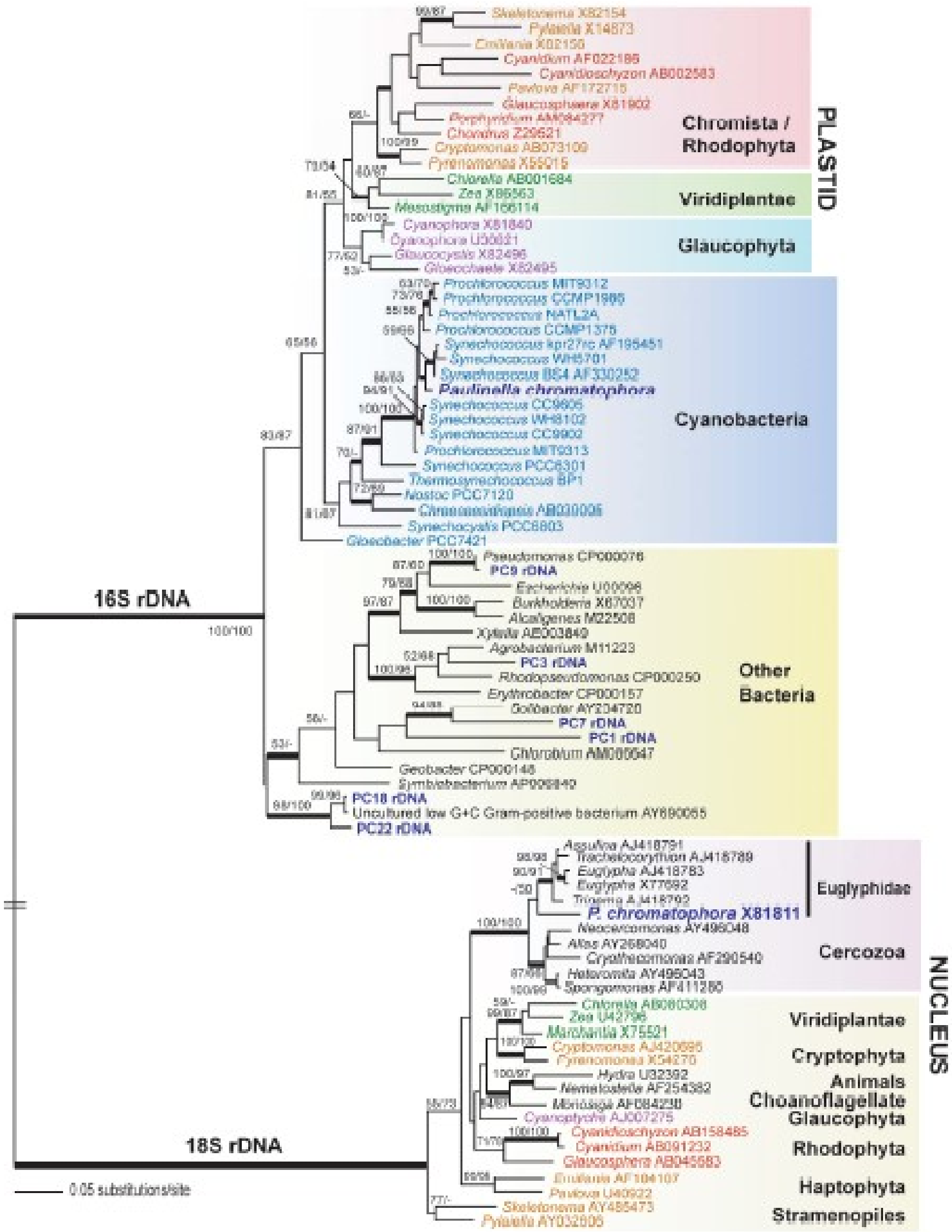
Algae-Based Wastewater Treatment

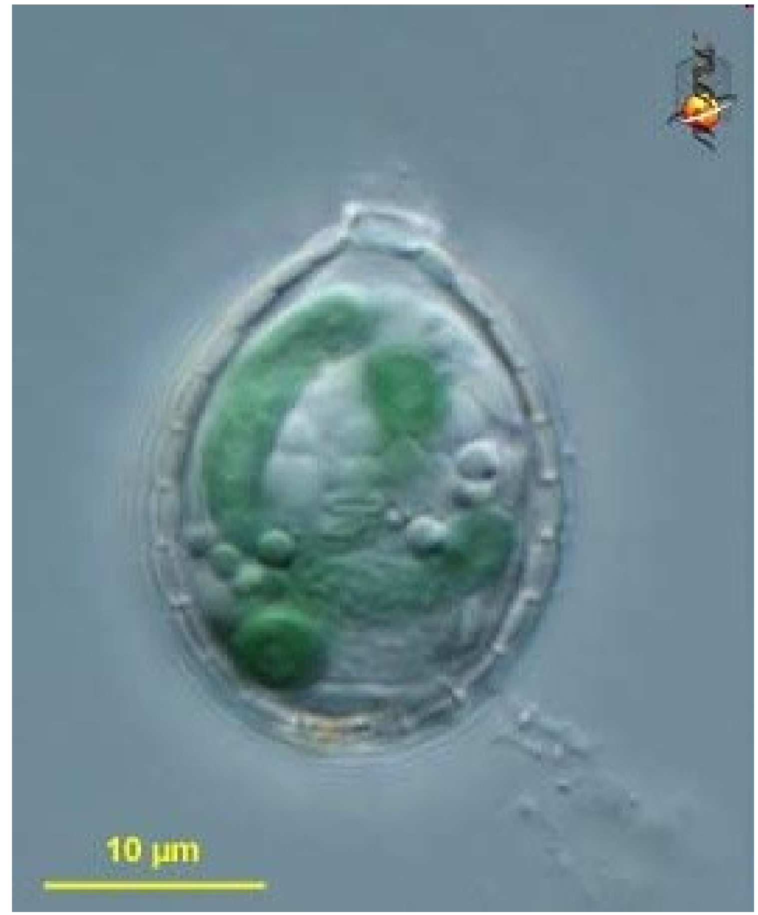


tradiční technologie - usazovací nádrže



Paulinella chromatophora – výjimka na závěr…





Yoon et al., 2006, Curr. Biol. 16