

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

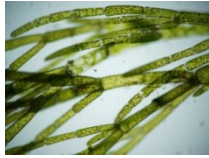
# Class: **Ulvophyceae**

Orders (+ current species number estimates)

Bryopsidales (cca 560)



Cladophorales (cca 480)



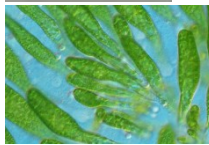
Dasycladales (cca 65)



Ignatiales (4)



Oltmannsiellopsidales (cca 10)



Scotinosphaerales (5)



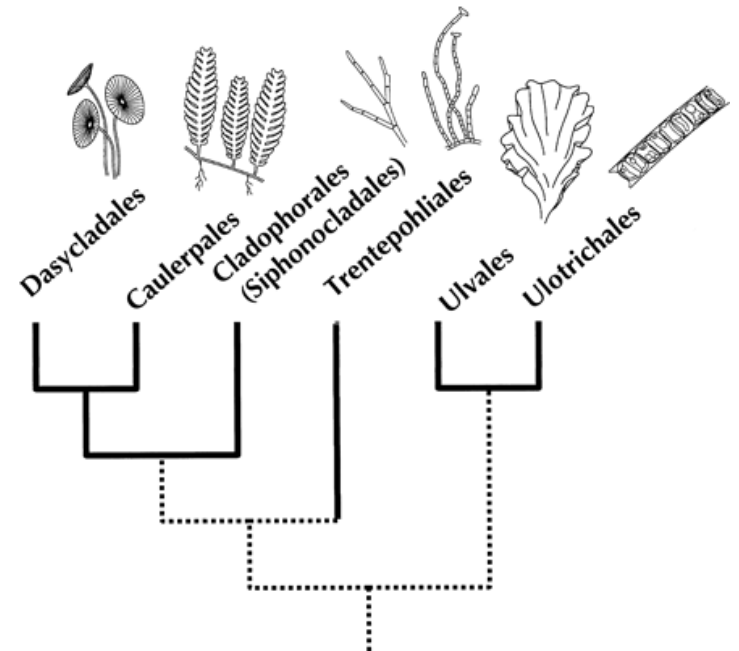
Trentepohliales (cca 120)



Ulotriconales (cca 180)



Ulvales (cca 320)



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

# early ulvophycean evolution - the case of *Proterocladus*

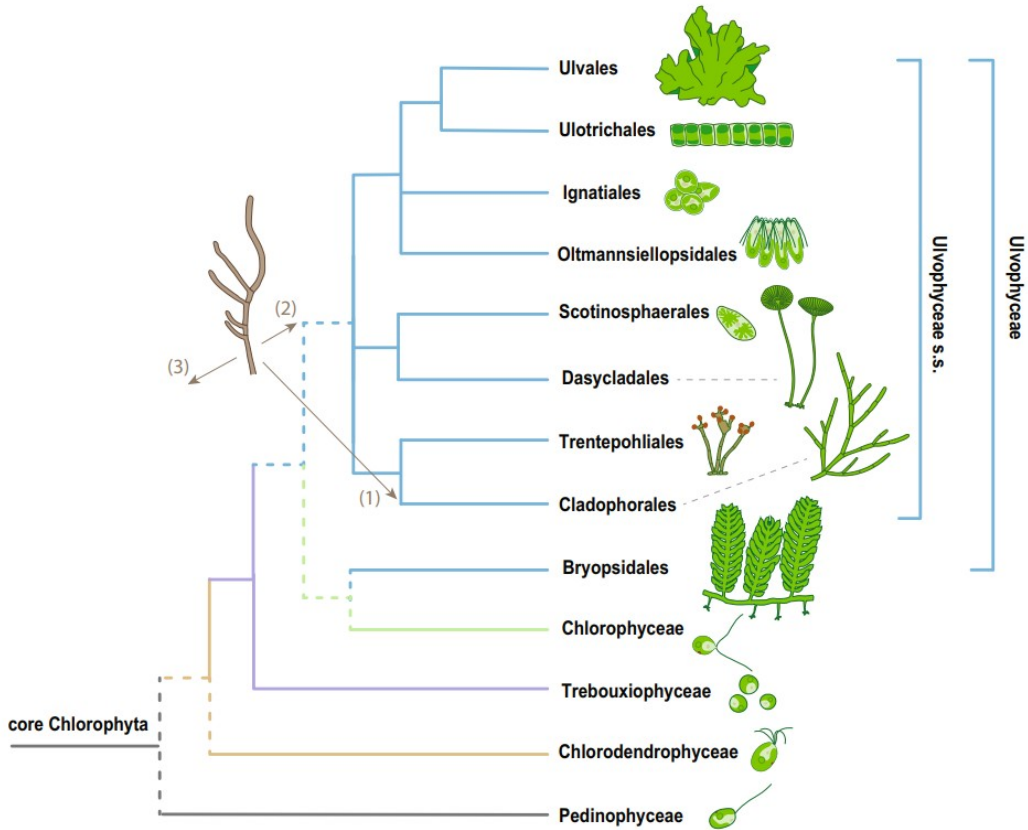
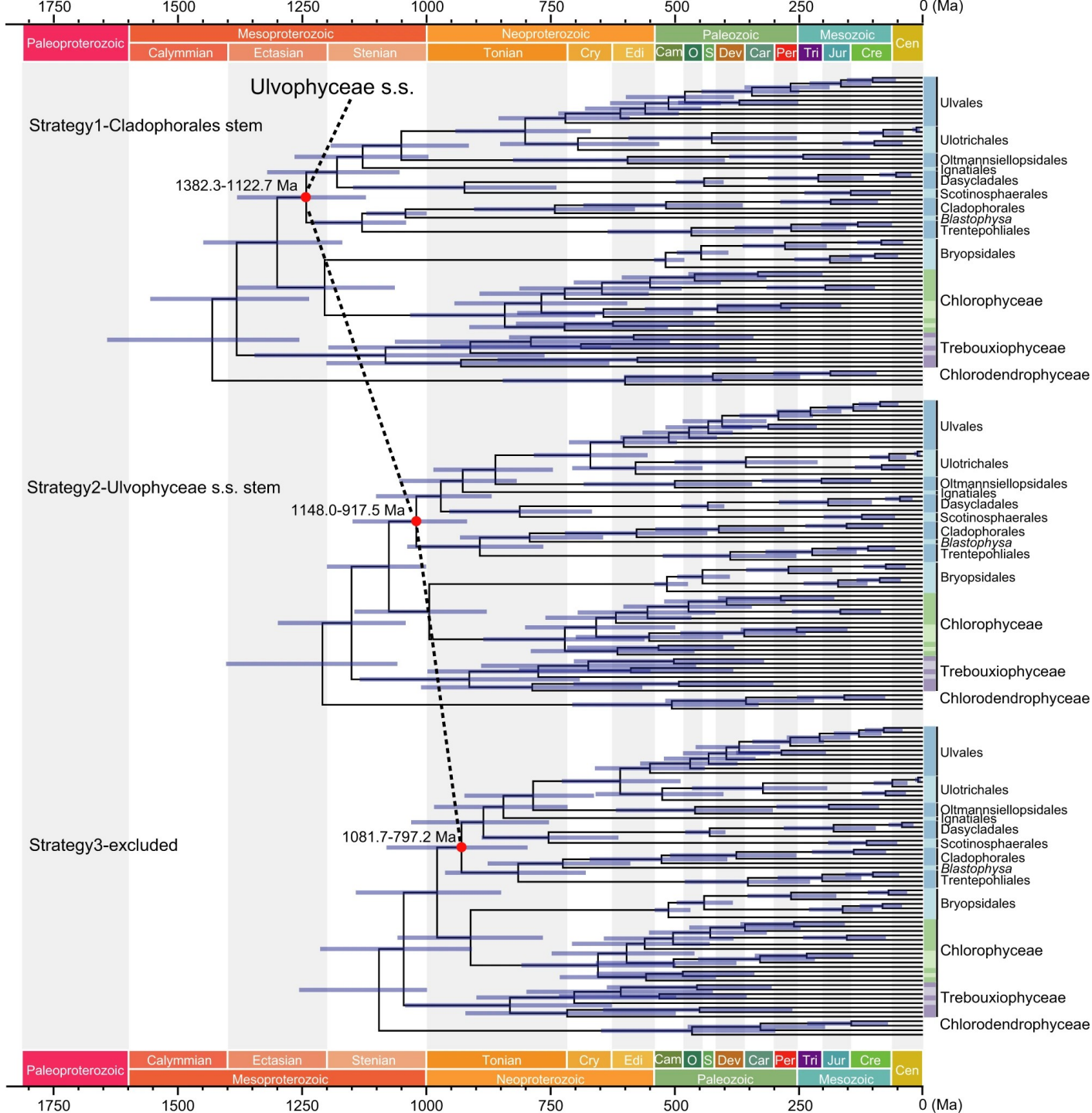


Fig. 1 Current knowledge of the phylogenetic relationships among the main lineages of the core Chlorophyta based on nuclear phylogenomic studies<sup>17,18,20</sup>. Uncertain phylogenetic relationships are indicated by polytomies or dashed lines. The three different interpretations of the *Proterocladus*

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

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

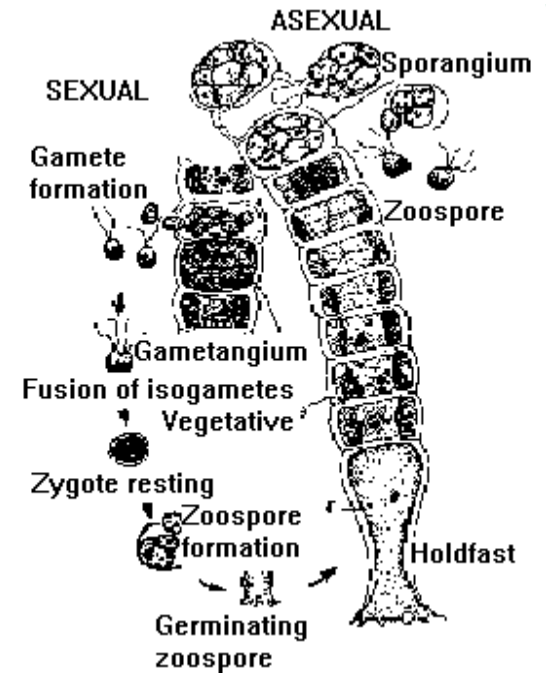
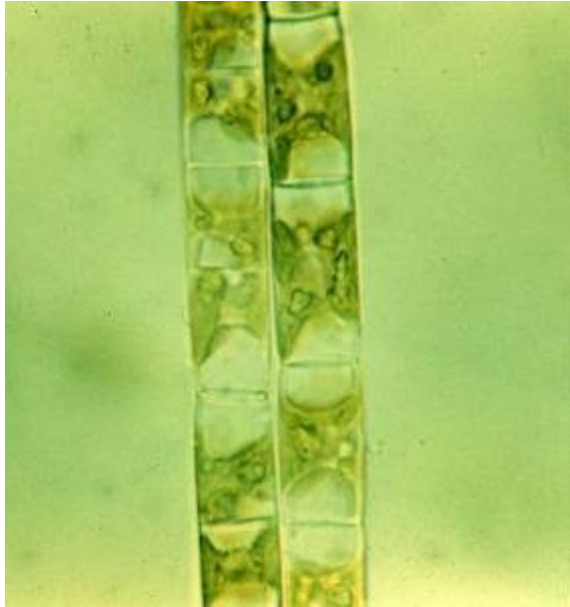


Hou et al., 2022,  
Nature Comm

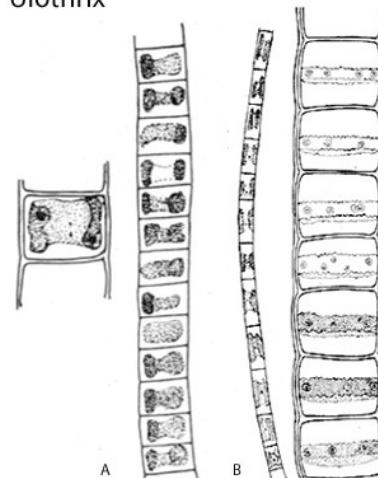
# Class: Ulvophyceae

## Order: Ulothrichales

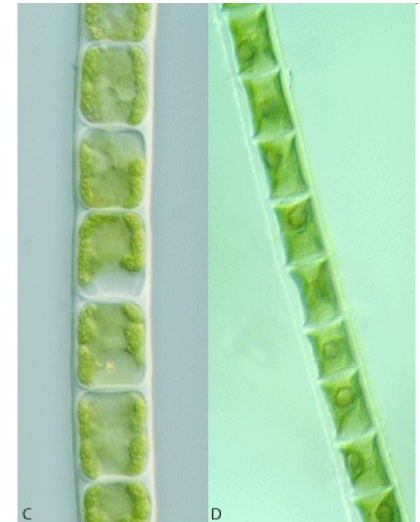
*Ulothrix* — frequent benthic algal of both marine and freshwater habitats



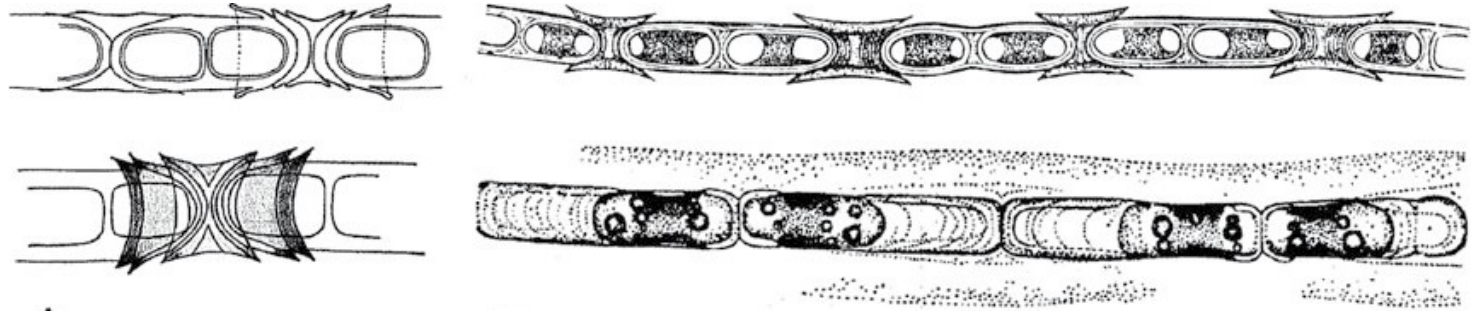
*Ulothrix*



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



# Binuclearia



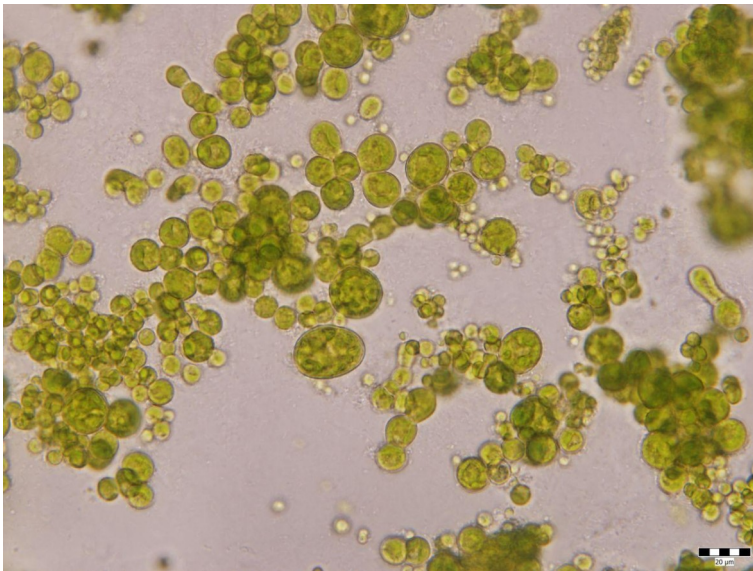
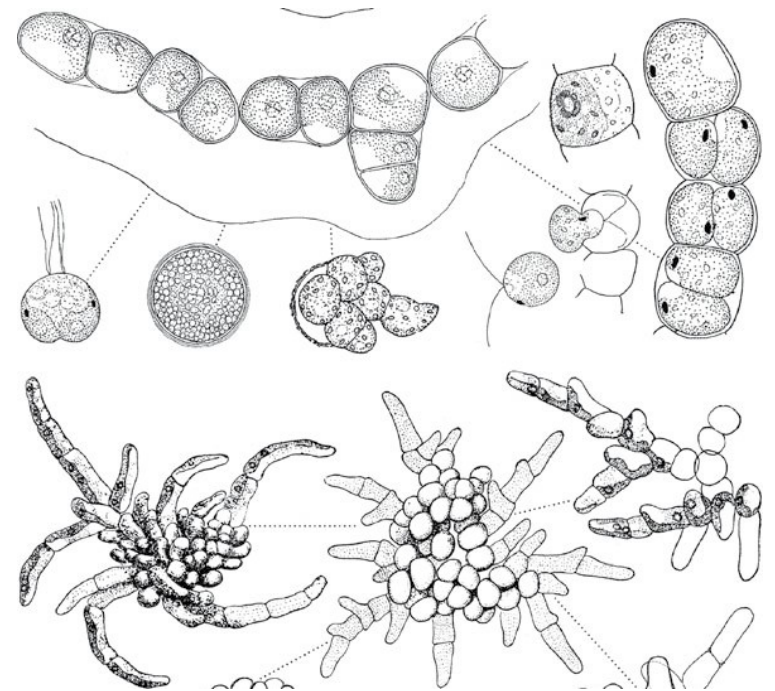
unbranched filaments, cellular pairs separated by thick cell wall parts

freshwater genus, phytobenthos

# Rhexinema

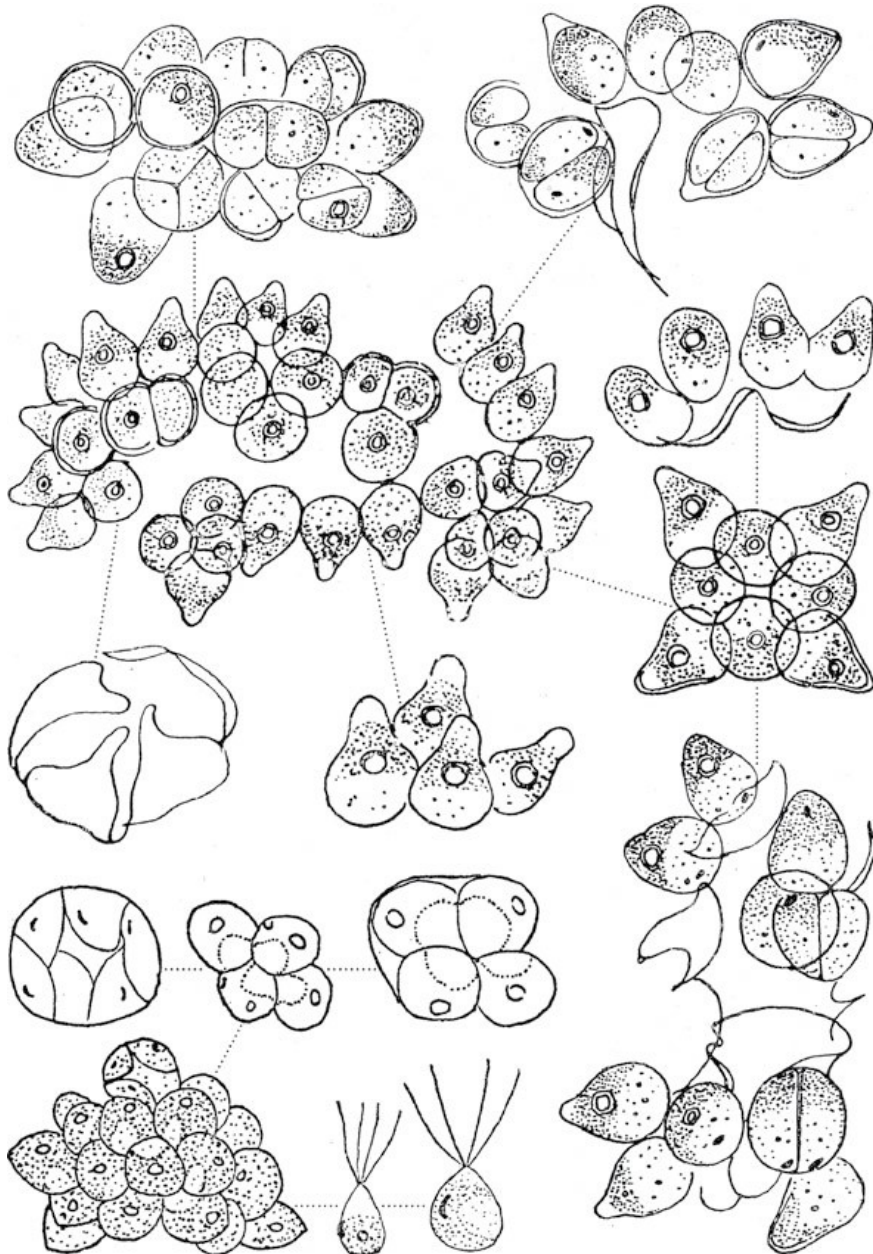


# Hazenia



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

# Fernandinella



# Planophila

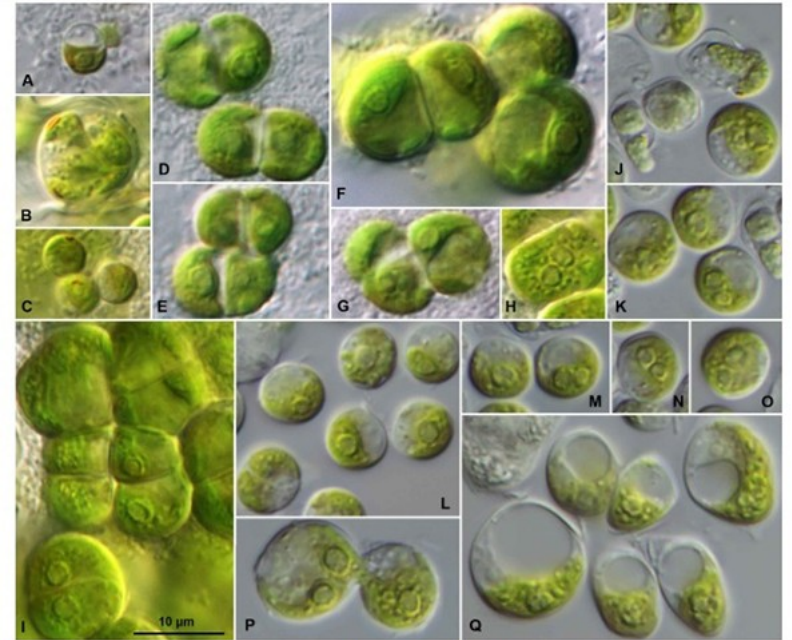
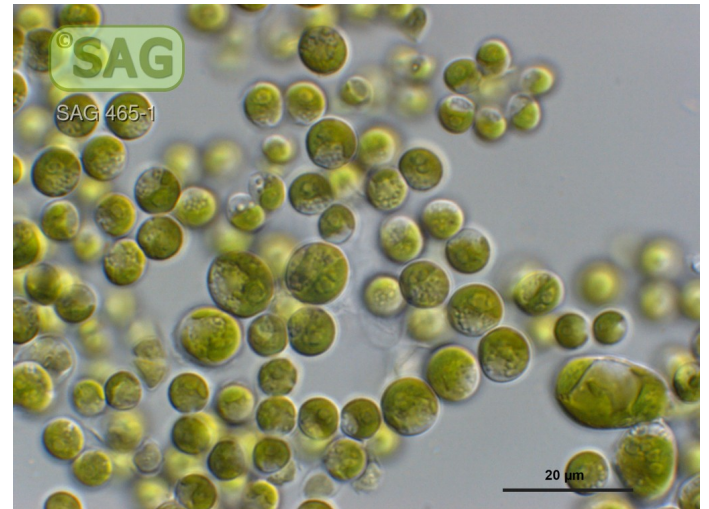


FIGURE 15. Morphology of *Planophila bipyrenoidosa* A-I. ULVO-1 and J-Q. ULVO-55 grown on 3NBBM medium. A-C. settled zoospores and sporangium, D-I. cell packets, J. settled zoospores, K-Q. variety of vegetative cells.

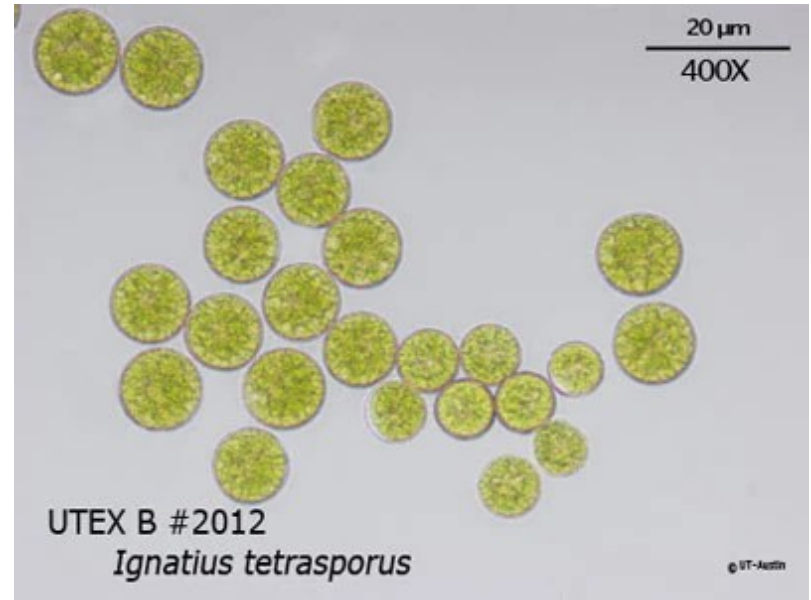
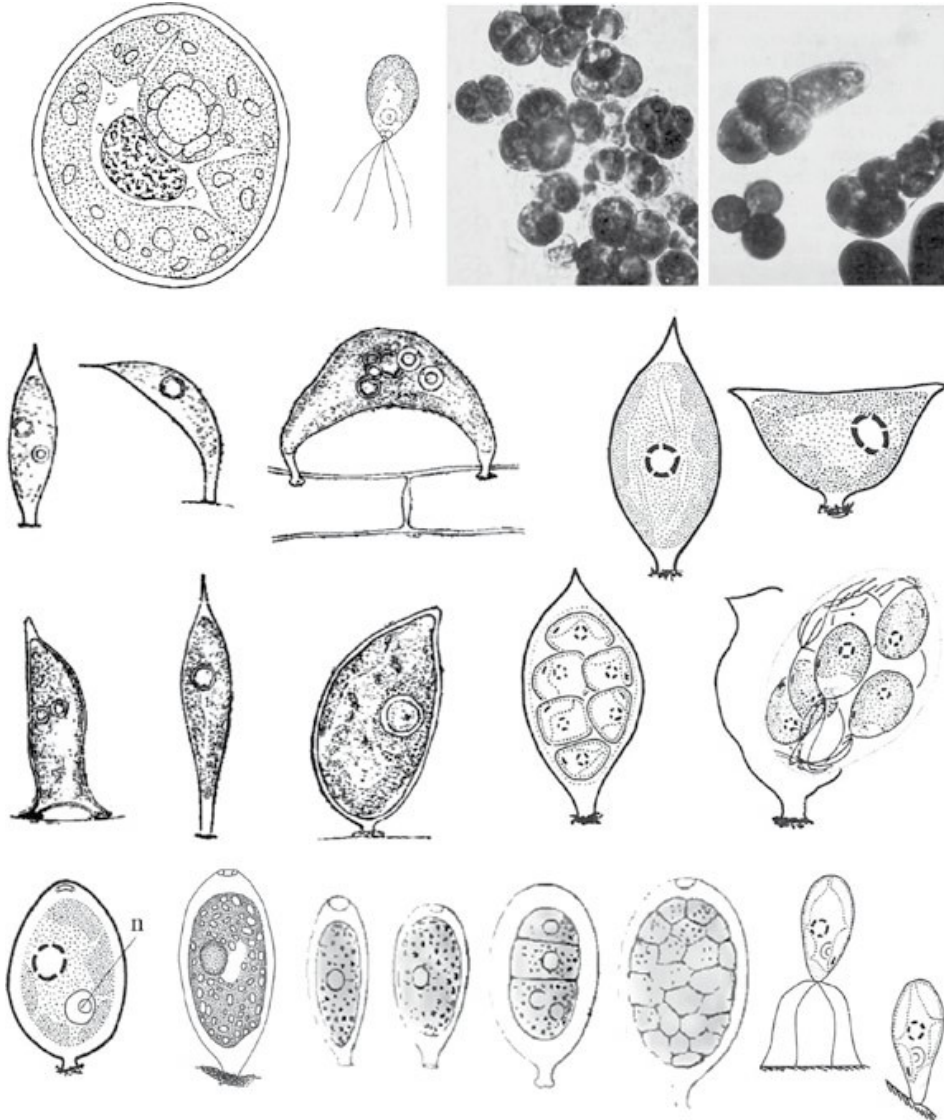


thallus simplification to unicells, terrestrial microhabitats



# Ignatiales

two genera *Ignatius* and *Pseudocharacium*



free-living and epiphytic unicells

tetraflagellate spores

# Ulvales

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

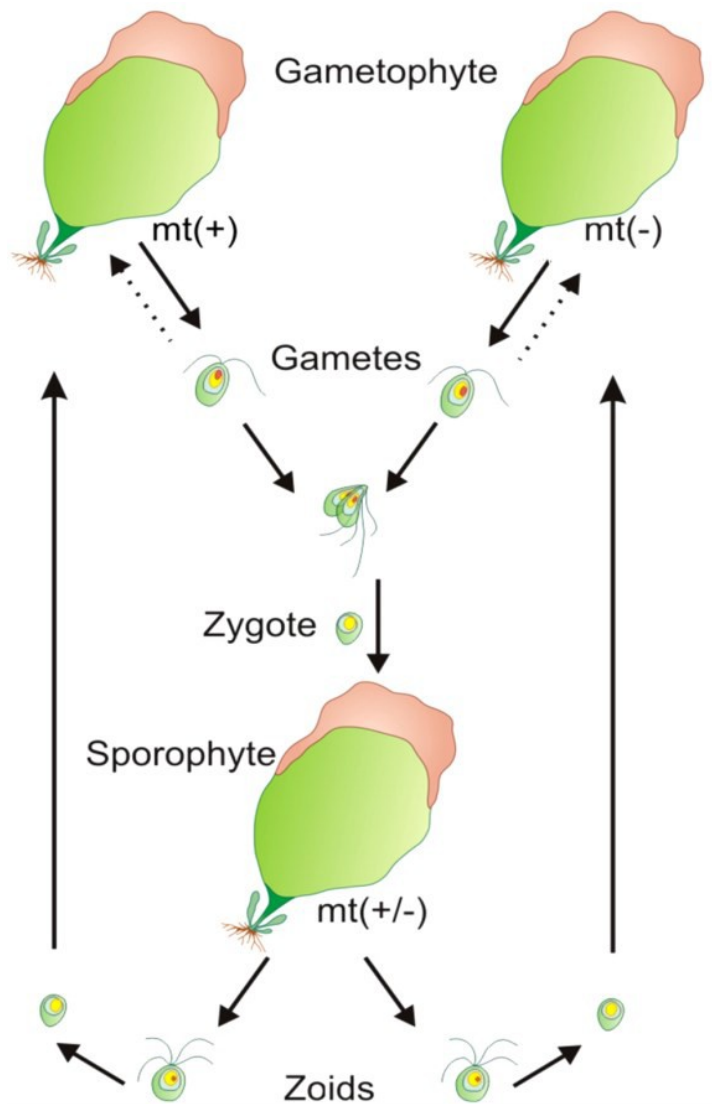


one of the most frequent genera in marine littoral

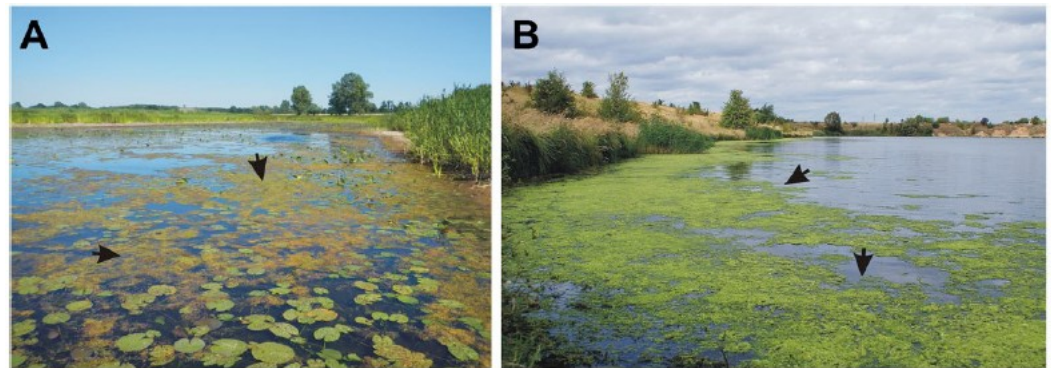
prefers eutrophicated conditions

several taxa also occur in the freshwater





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



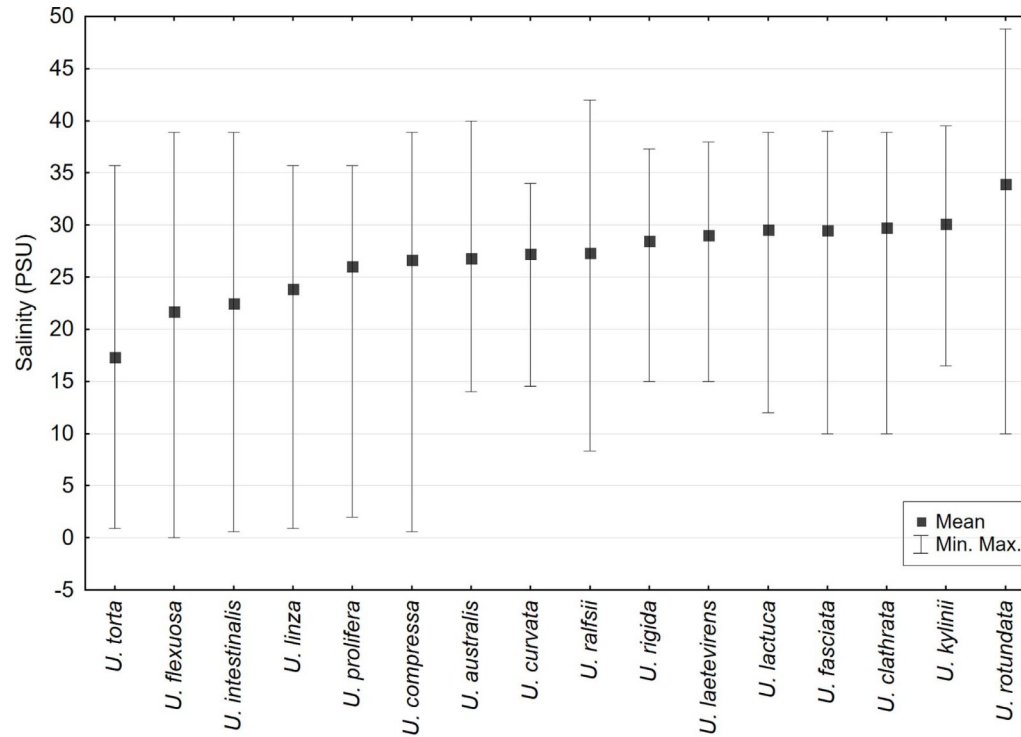
Hiraoka et al., 2011, Plos One

# *Ulva pilifera* - the most frequent freshwater ulvoid species



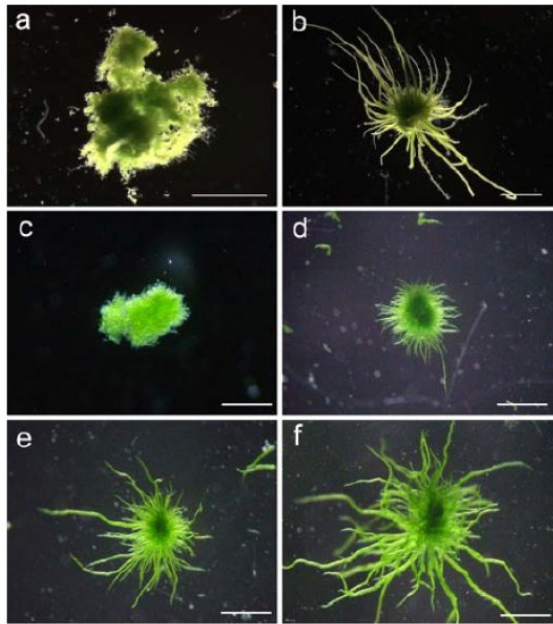
eutrophicated habitats,  
usually during warm-water season

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

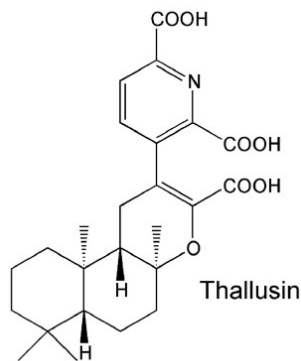
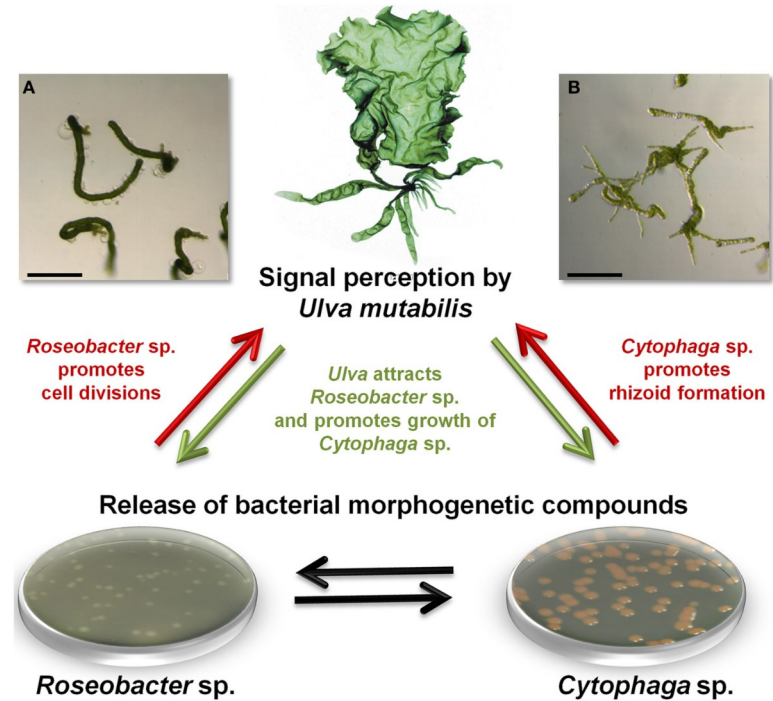


Species of <i>Ulva</i>	Salinity zones						
	freshwater (< 0.5 PSU)	oligohaline (0.5 – 5 PSU)	mesohaline (5 – 18 PSU)	polyhaline (18 – 30 PSU)	euhaline (30 – 40 PSU)	hyperhaline (40 – 50)	- (> 50)
<i>U. flexuosa</i>	Yellow	Yellow	Yellow	Yellow	Green	Red	Red
<i>U. torta</i>	Red	Green	Yellow	Green	Yellow	Red	Red
<i>U. linza</i>	Red	Yellow	Yellow	Green	Yellow	Red	Red
<i>U. compressa</i>	Red	Yellow	Yellow	Green	Green	Red	Red
<i>U. intestinalis</i>	Red	Yellow	Green	Green	Green	Red	Red
<i>U. prolifera</i>	Red	Yellow	Green	Green	Green	Red	Red
<i>U. curvata</i>	Red	Red	Green	Green	Green	Red	Red
<i>U. clathrata</i>	Red	Red	Yellow	Yellow	Green	Red	Red
<i>U. fasciata</i>	Red	Red	Yellow	Yellow	Green	Red	Red
<i>U. rigida</i>	Red	Red	Yellow	Yellow	Green	Red	Red
<i>U. kyllinii</i>	Red	Red	Yellow	Green	Green	Red	Red
<i>U. lactuca</i>	Red	Red	Yellow	Green	Green	Red	Red
<i>U. laetevirens</i>	Red	Red	Yellow	Green	Green	Red	Red
<i>U. australis</i>	Red	Red	Yellow	Green	Green	Yellow	Red
<i>U. ralfsii</i>	Red	Red	Yellow	Green	Green	Yellow	Red
<i>U. rotundata</i>	Red	Red	Yellow	Yellow	Green	Yellow	Red
	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* ( $\gamma$ -Proteobacteria), f) *Cytophaga* sp. (Bacteroidetes) (Marshall *et al.* 2006).

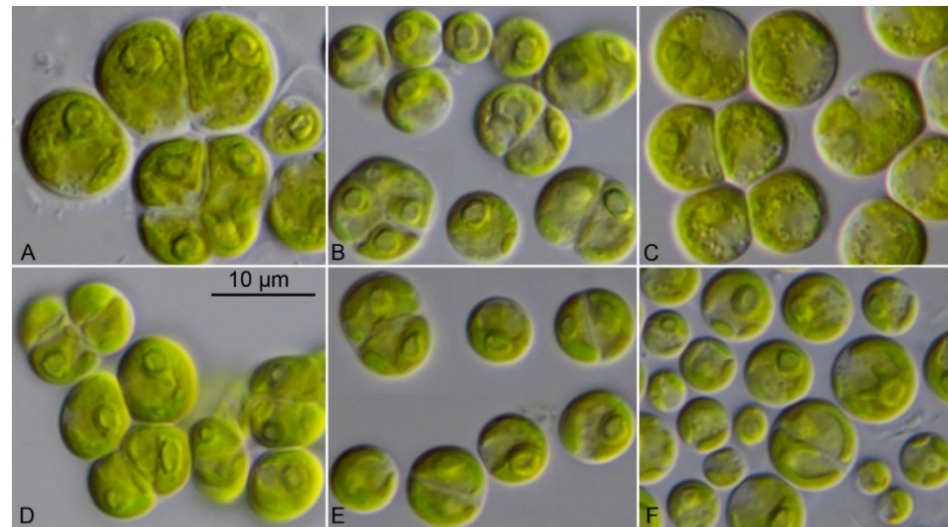


organické látky produkované bakteriemi, jež facilitují morfogenezi

## Percursaria



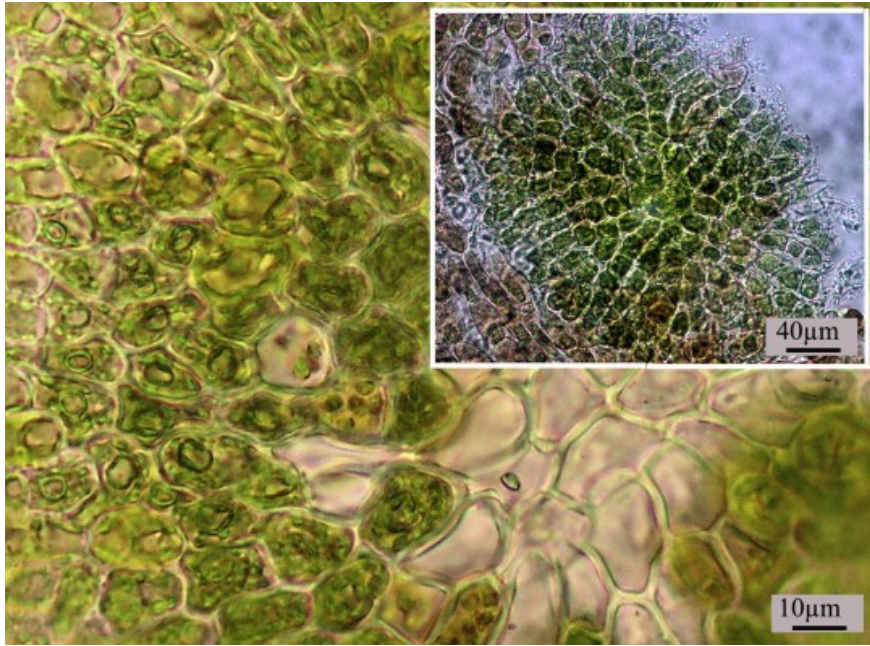
## Desmochloris



**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

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

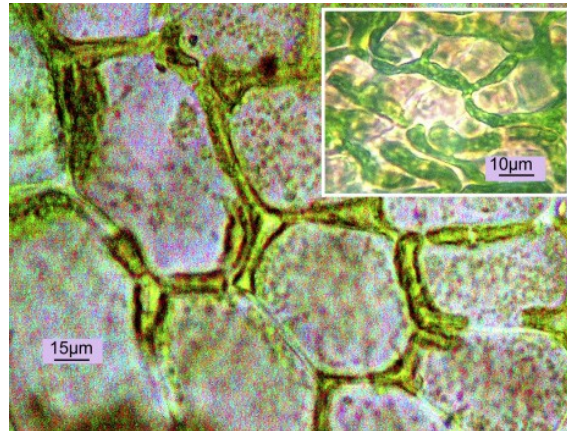


FIGURE 1. *Pseudoplexaura flagellosa* (Houttuyn) with algal nodules, depth 3 m, Bache Shoal, Florida. eys.

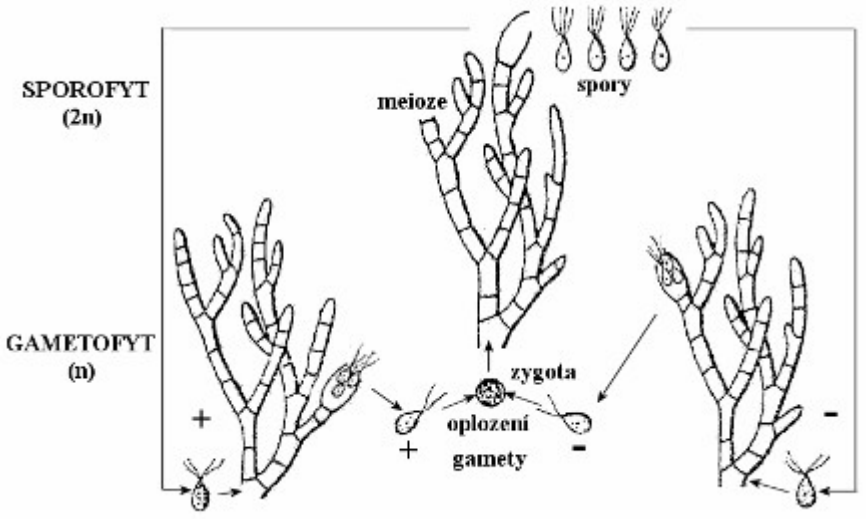
*U. geniculata* - endophyte of red algal genus *Hypnea*

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

# Order: **Cladophorales**

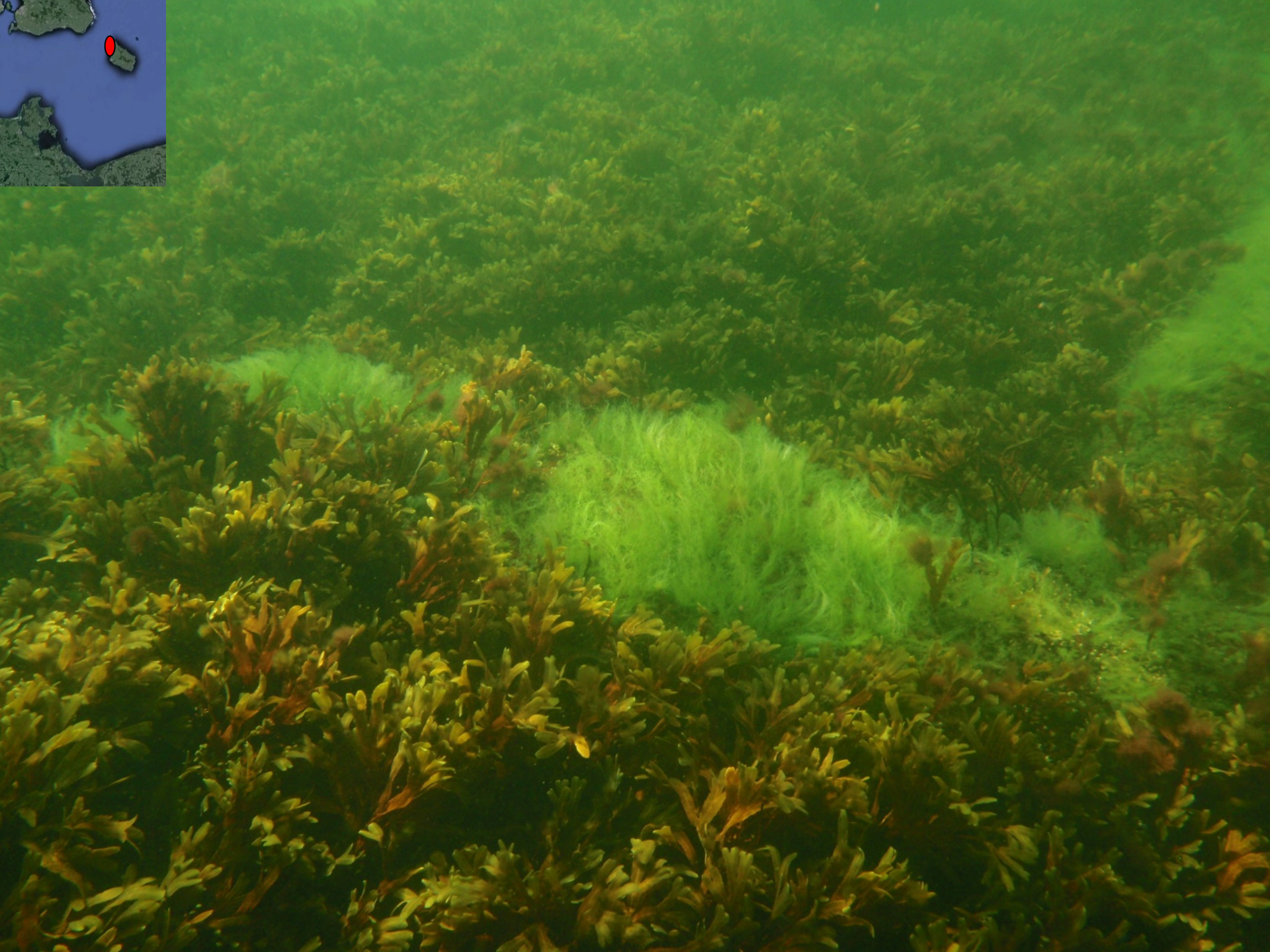


## *Cladophora*



one of the most important bioindicators of eutrophic conditions

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

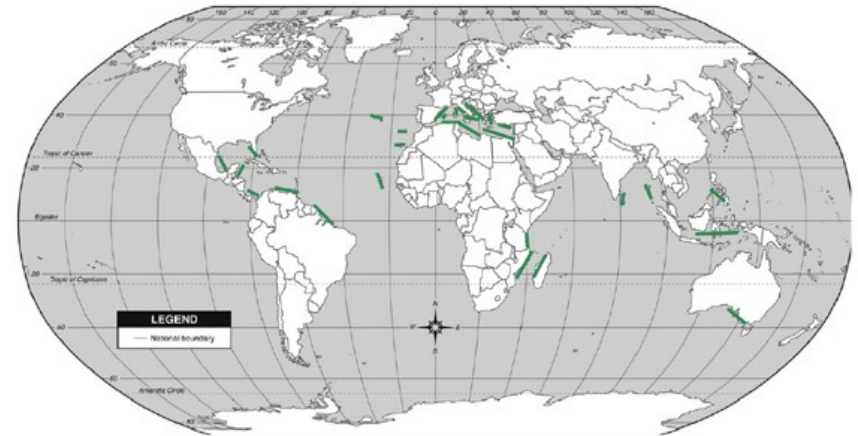




# Anadyomene



*A. stellata*



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



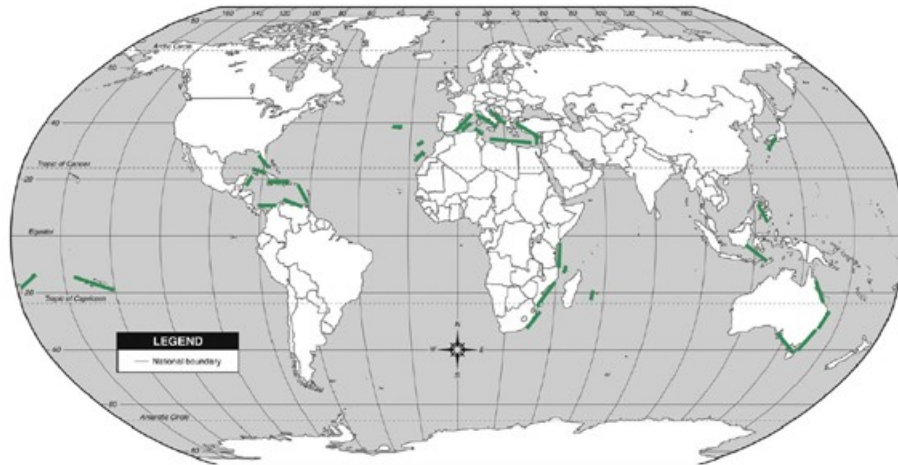


# Valonia

algaeBASE



*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

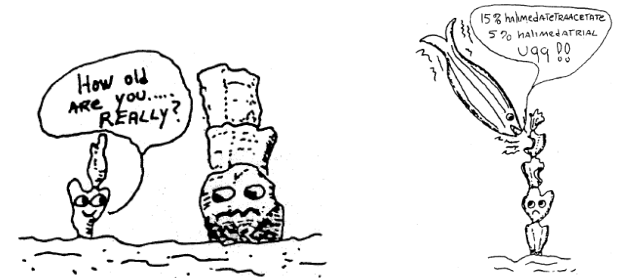
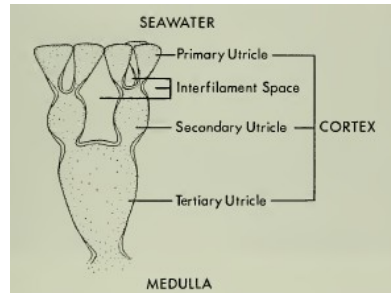
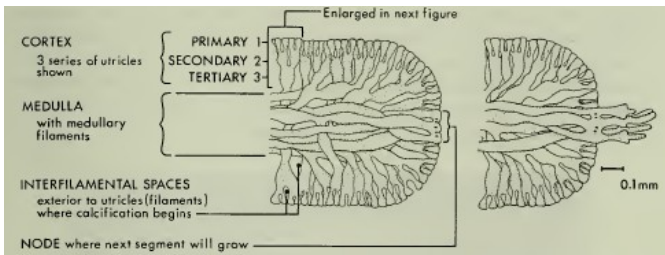
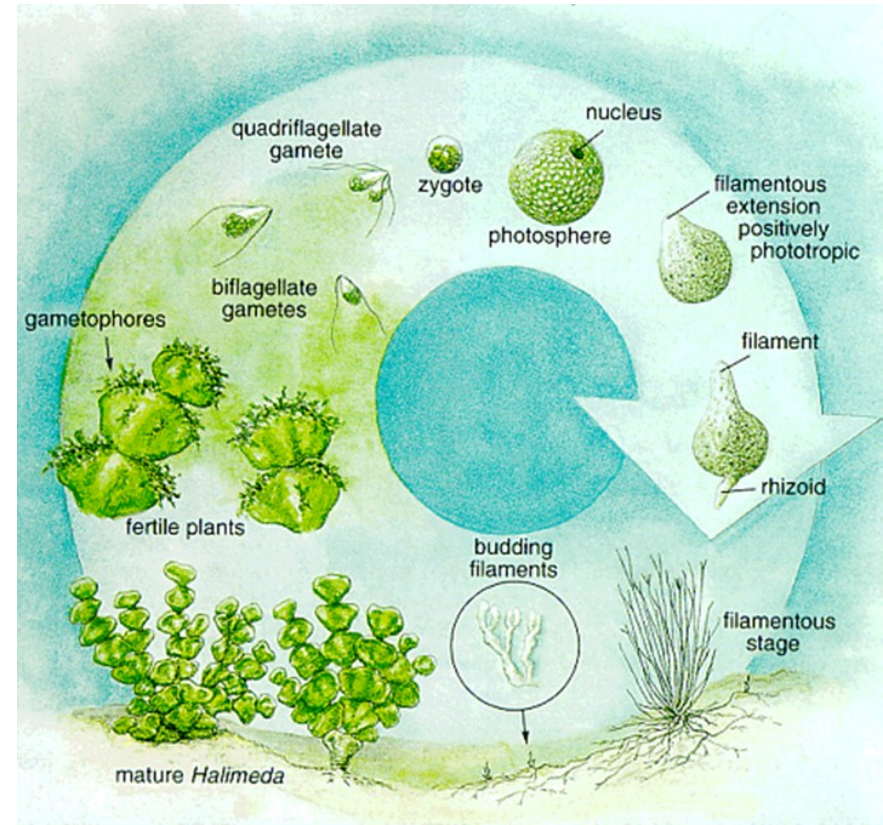


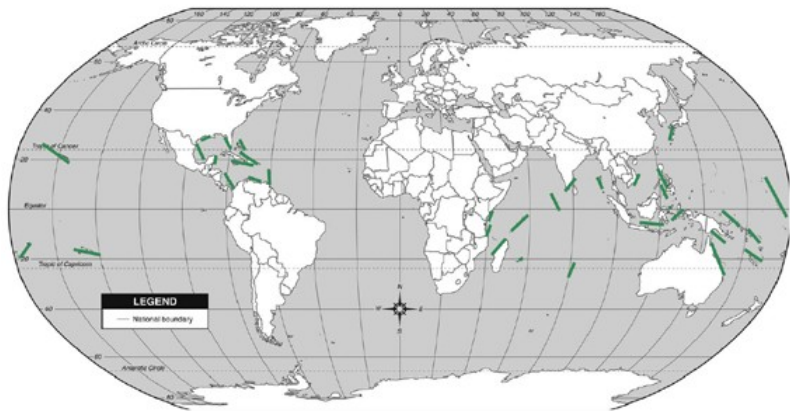
Figure 7. Chemical defense.

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

cross section through a segment



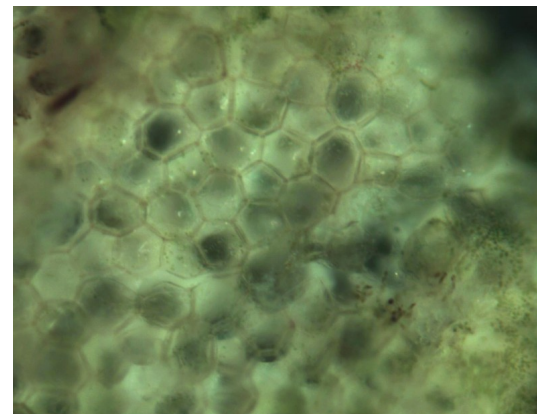
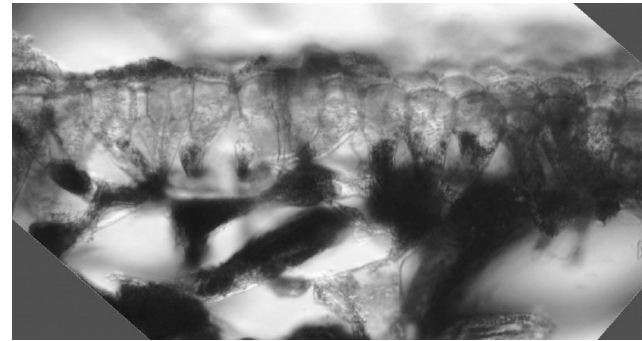
*H. macroloba*



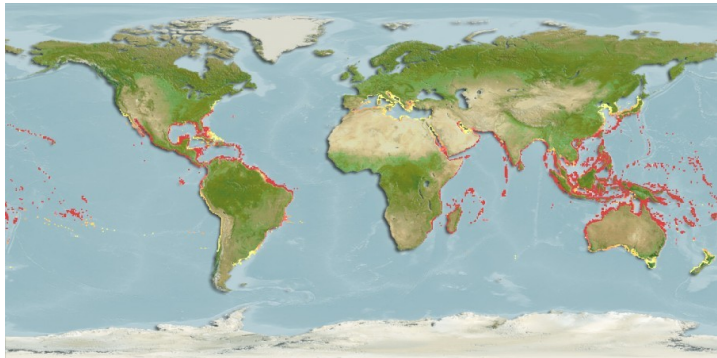
*H. incrassata*



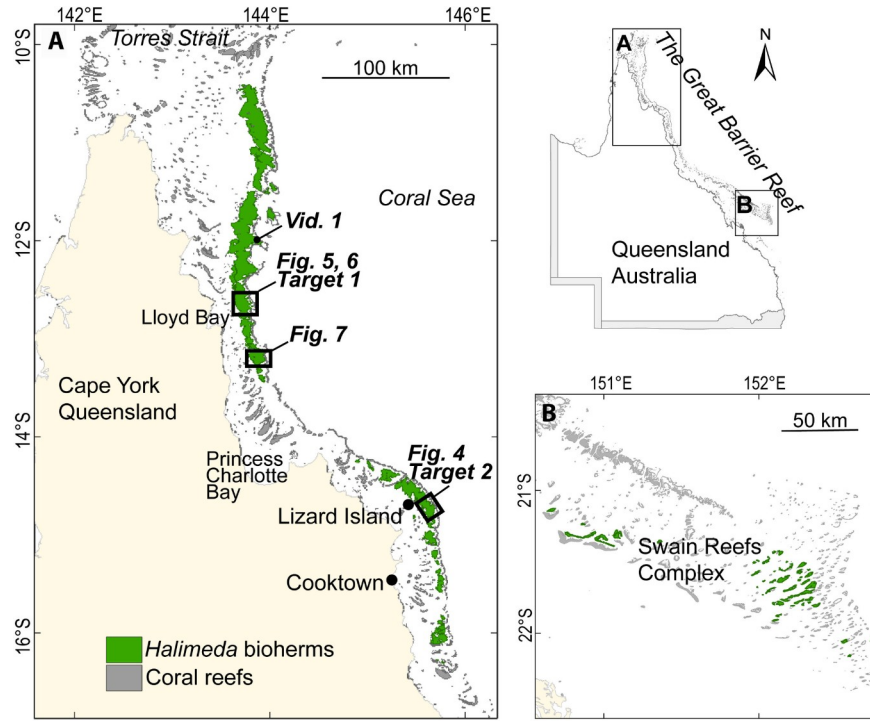
# H. tuna



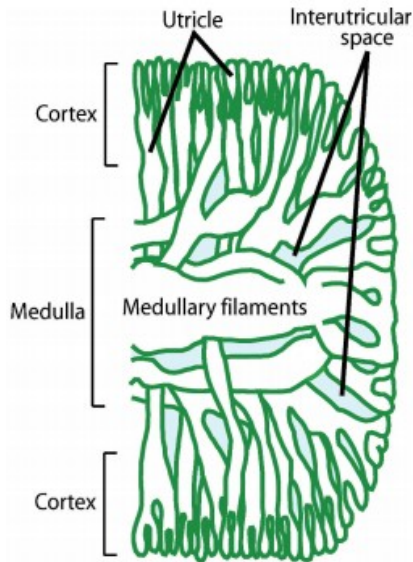
# H. opuntia



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



key organisms to  $\text{CaCO}_3$  in marine ecosystems  
(benthic calcification)



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



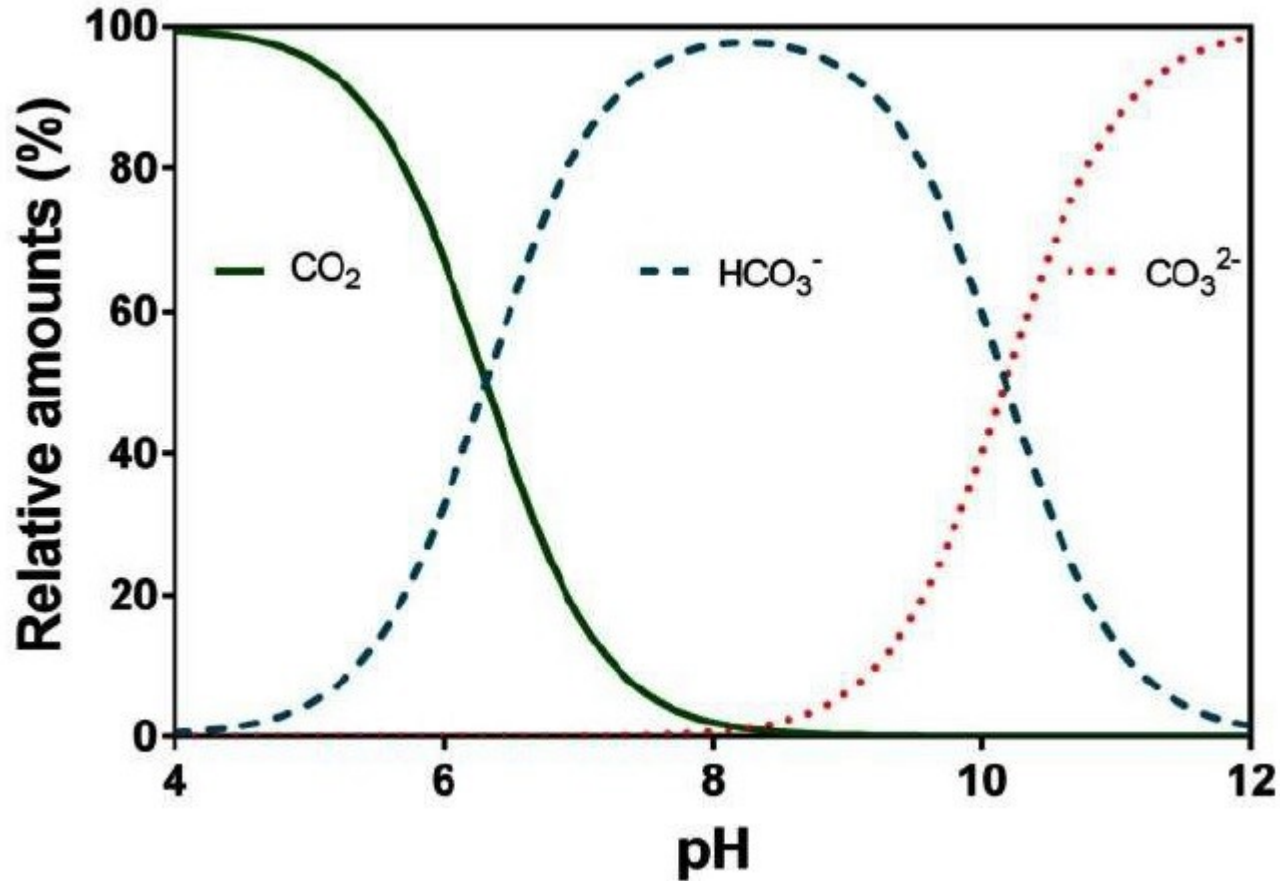
*Halimeda* meadows at GBR and close to Hawaii



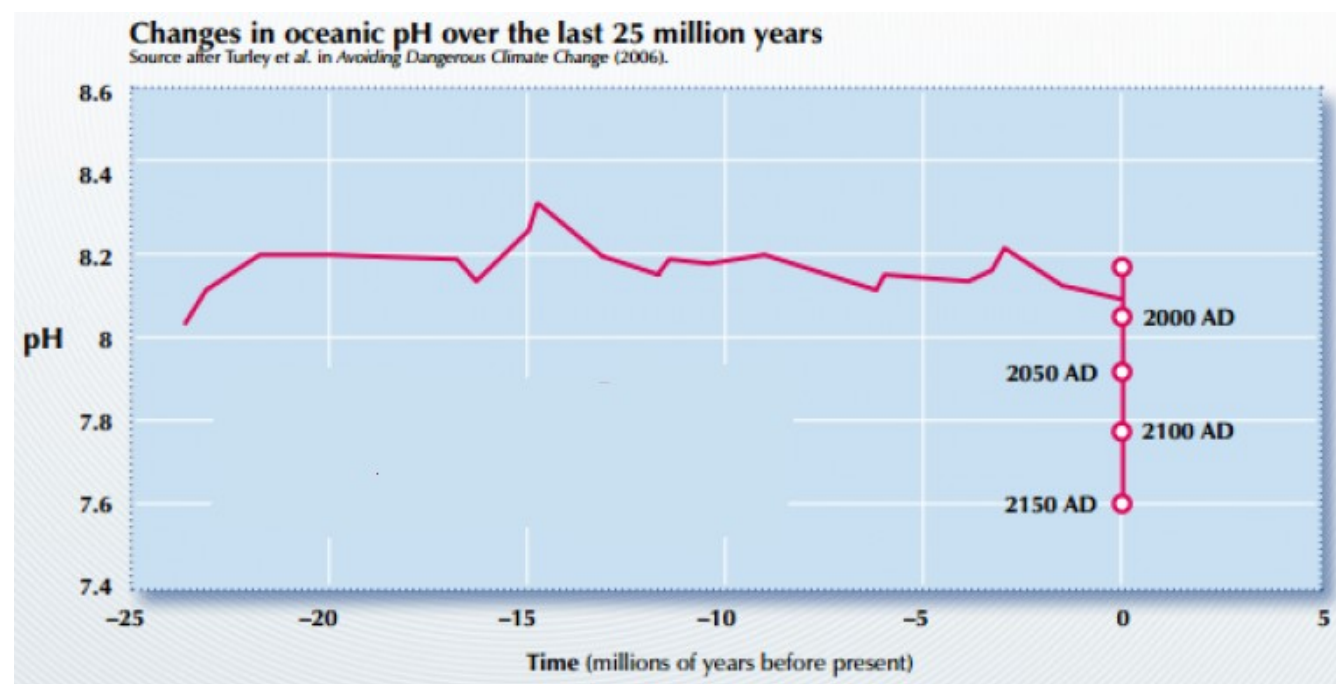
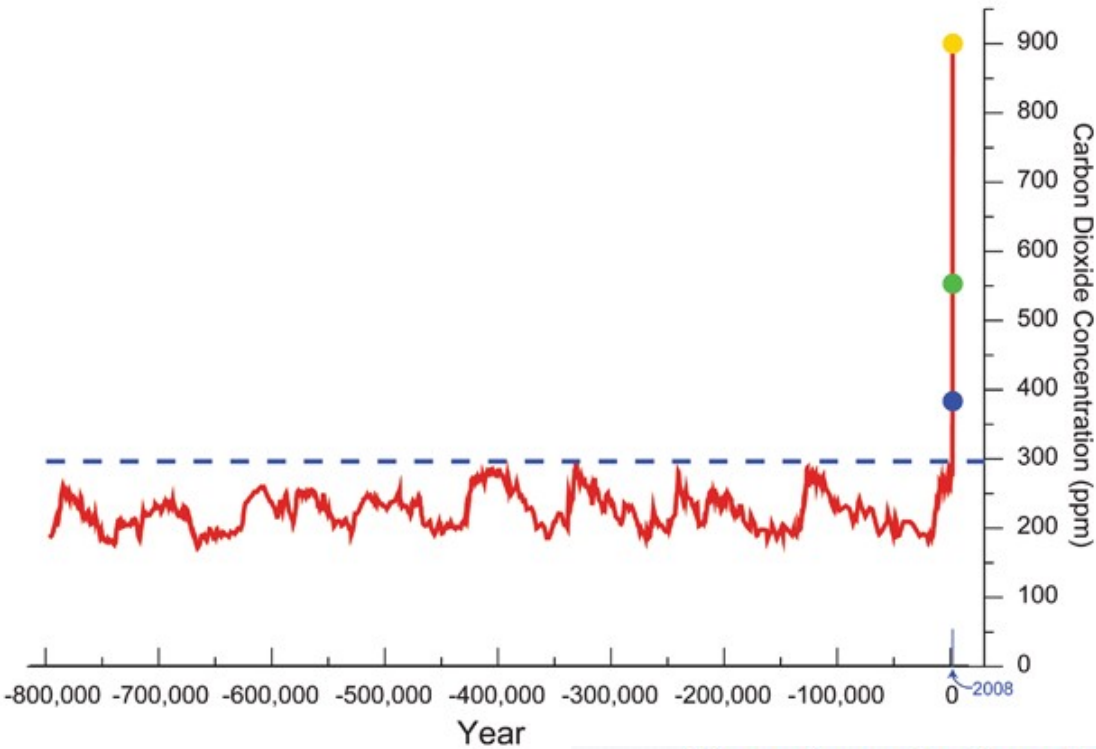
mesophotic *Halimeda* draperies



carbon dioxide – bicarbonate – carbonate equilibrium in water

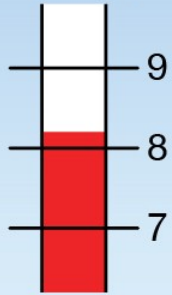






# Ocean acidification

seawater pH



late 1800s  
reduced acidity

lower concentration  
of atmospheric  $\text{CO}_2$



carbonate ions

$\text{H}_2\text{CO}_3$   
carbonic acid

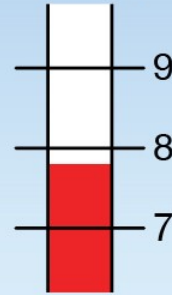
$\text{H}^+$   
free hydrogen ions

$\text{HCO}_3^-$   
bicarbonate



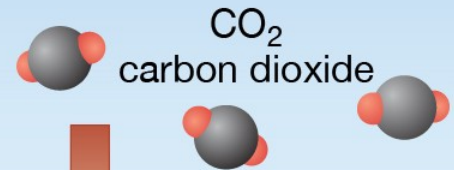
abundant healthy corals,  
mollusks, and other  
marine calcifiers

seawater pH



2100 (projected)  
increased acidity

higher concentration  
of atmospheric  $\text{CO}_2$



fewer  
carbonate ions

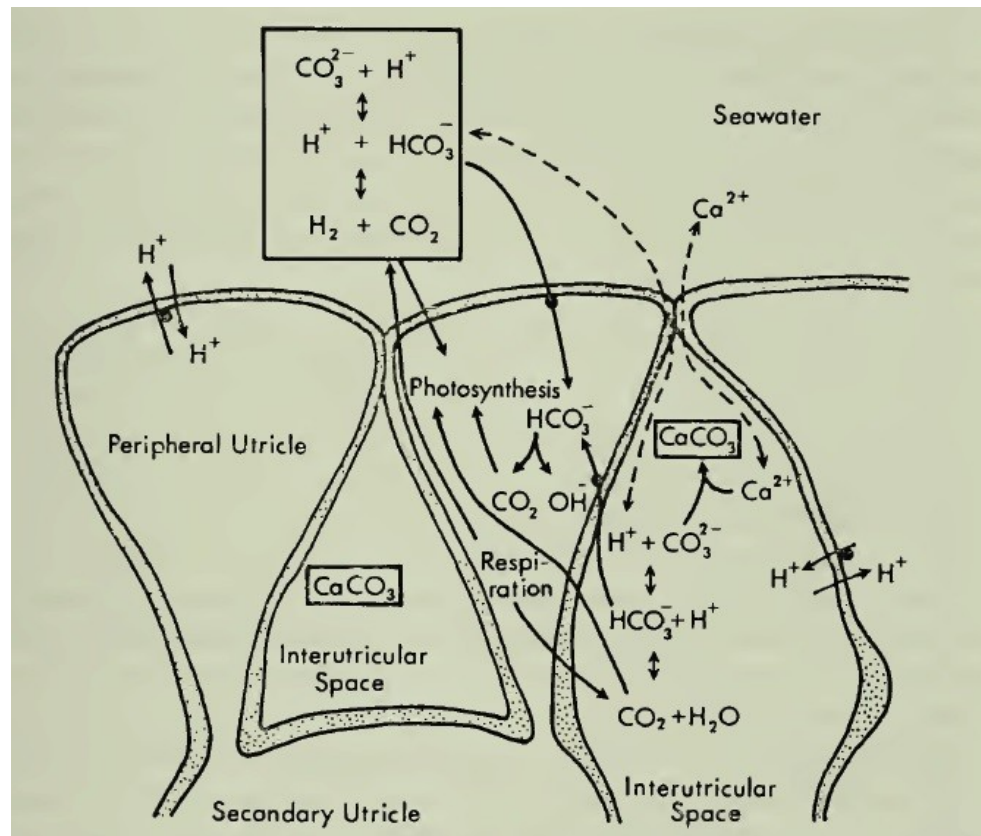
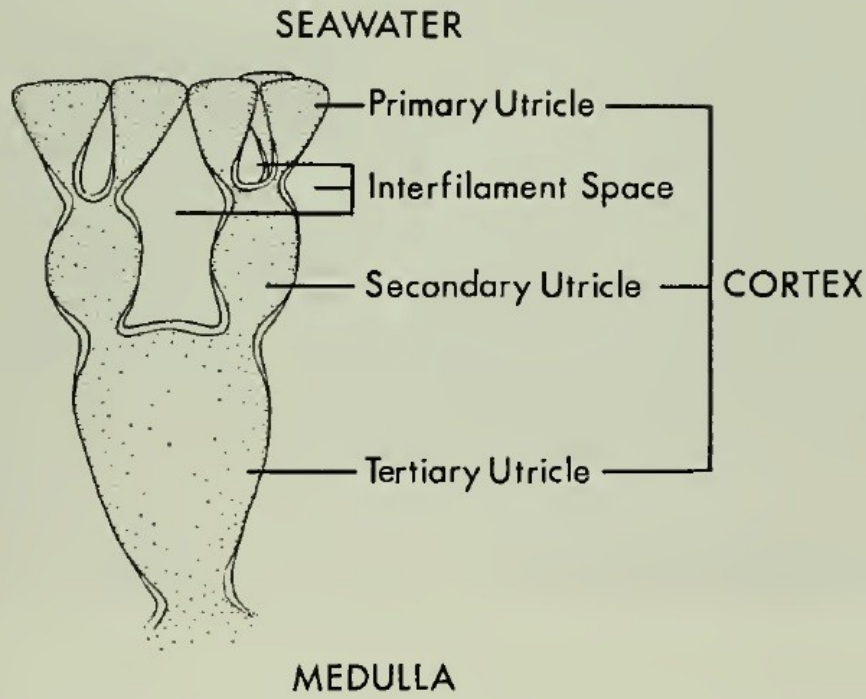
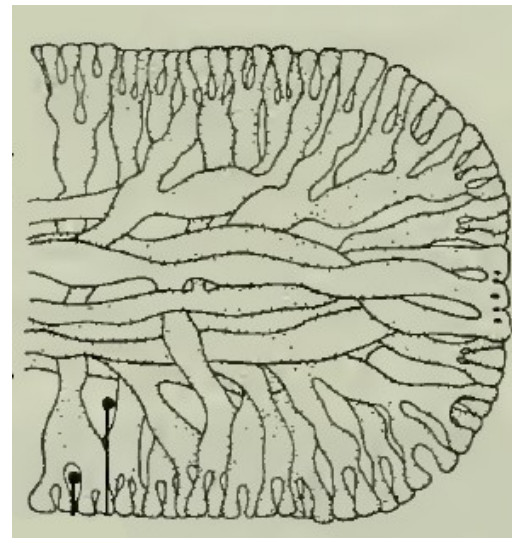
$\text{H}_2\text{CO}_3$   
carbonic acid

$\text{H}^+$   
free hydrogen ions

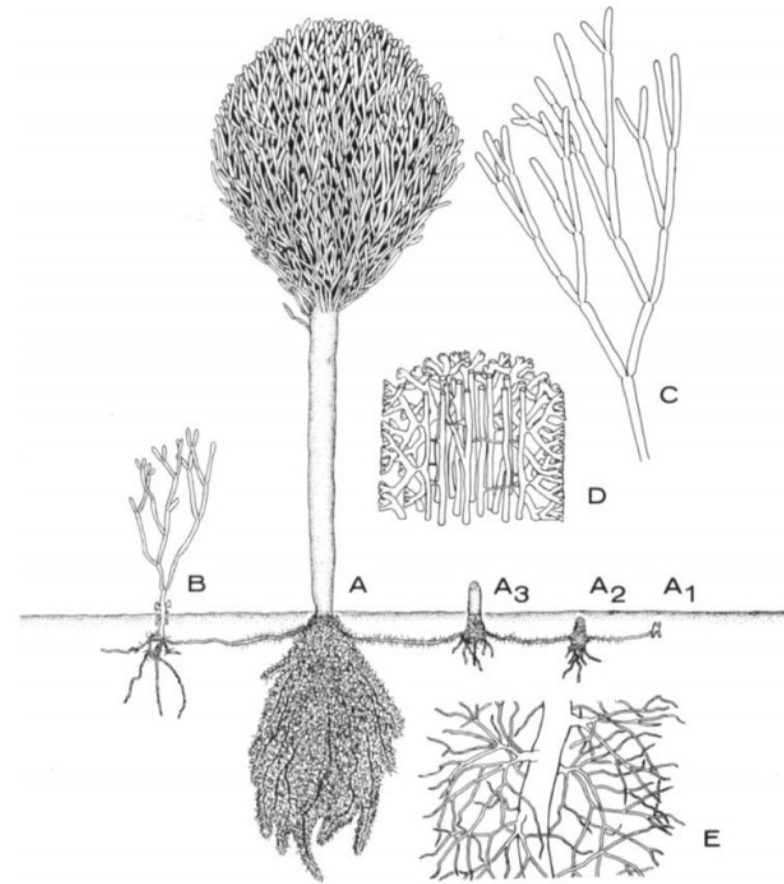
$\text{HCO}_3^-$   
bicarbonate



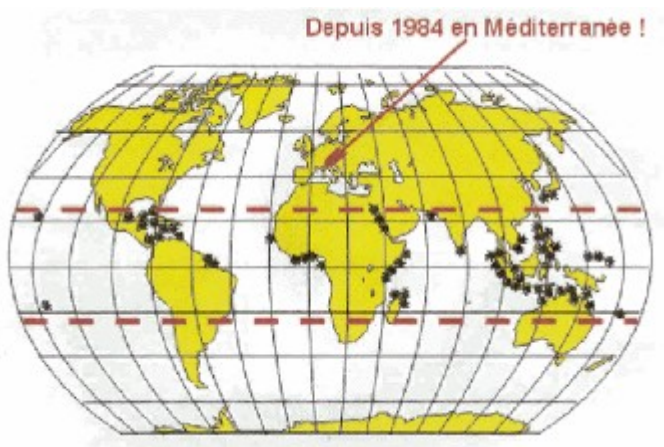
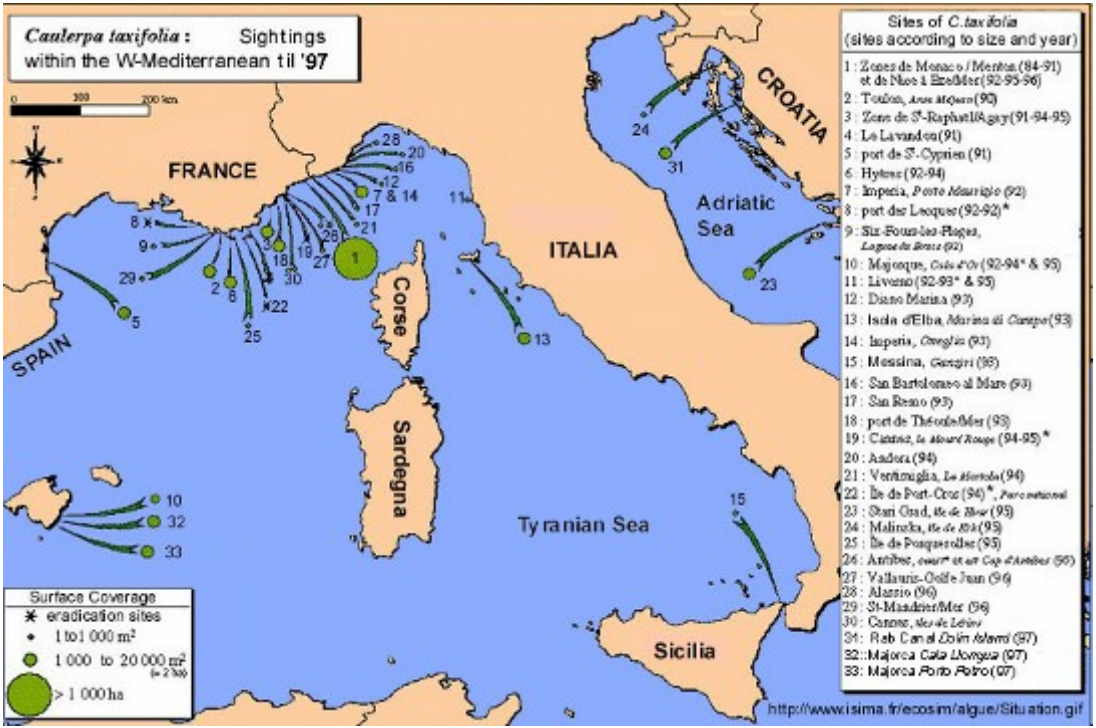
fewer, smaller  
marine calcifiers



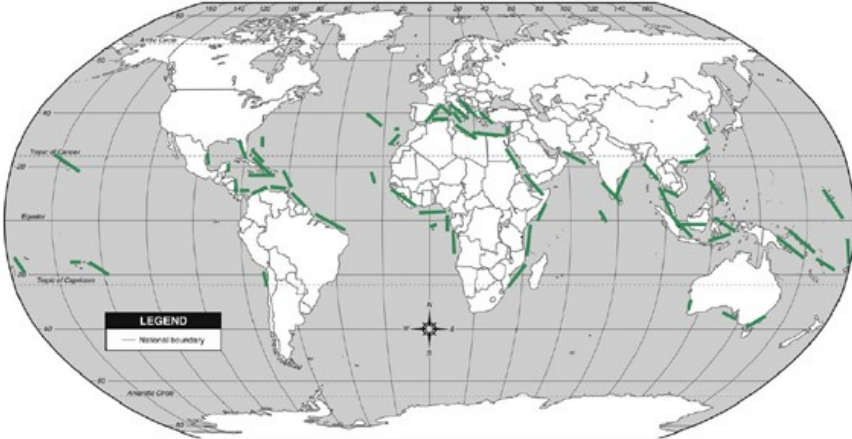
# Penicillium



# Caulerpa taxifolia



# *Caulerpa racemosa/cylindracea* complex



# *Caulerpa cylindracea*

the single most invasive macroalga in the Mediterranean Sea

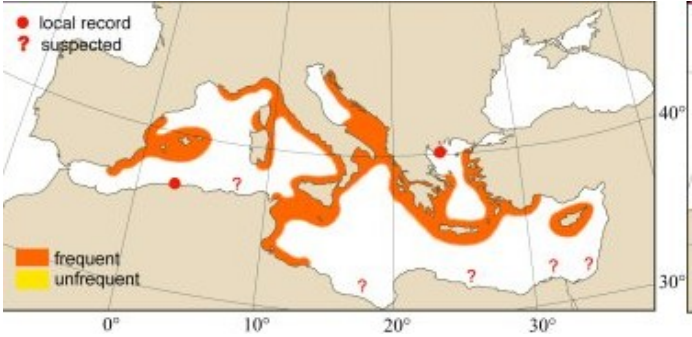
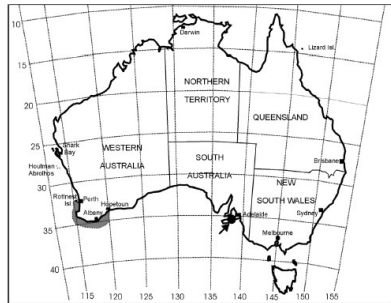
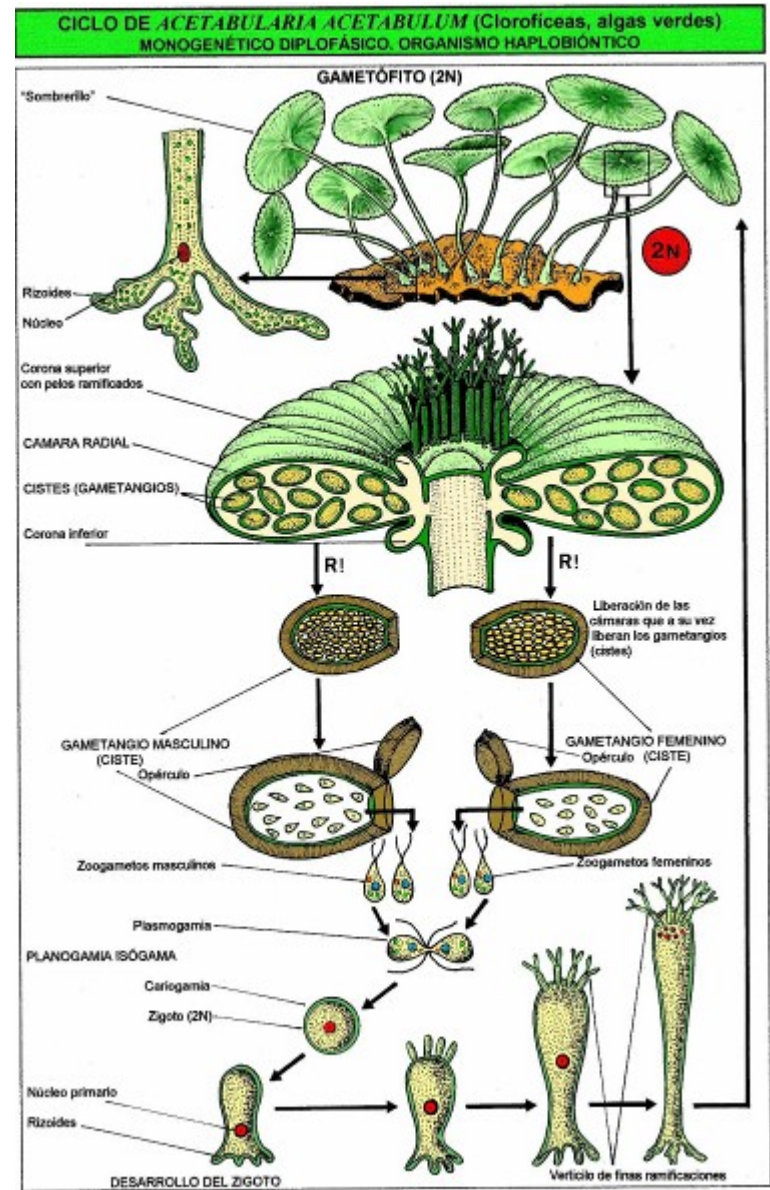
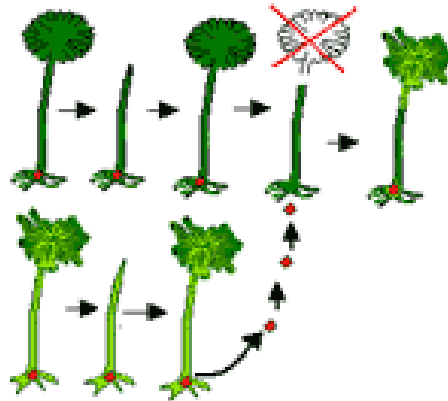


Fig. 2. Map indicating the native range of *Caulerpa racemosa* var. *cylindracea* in south-western Australia (grey surface) and its introduction in Adelaide (• + arrowhead) (from Verlaque et al., 2003, amended).

www.mer-littoral.org © Wilfried Bay-Nouailhat

# Dasycladales

## *Acetabularia* and her giant nuclei

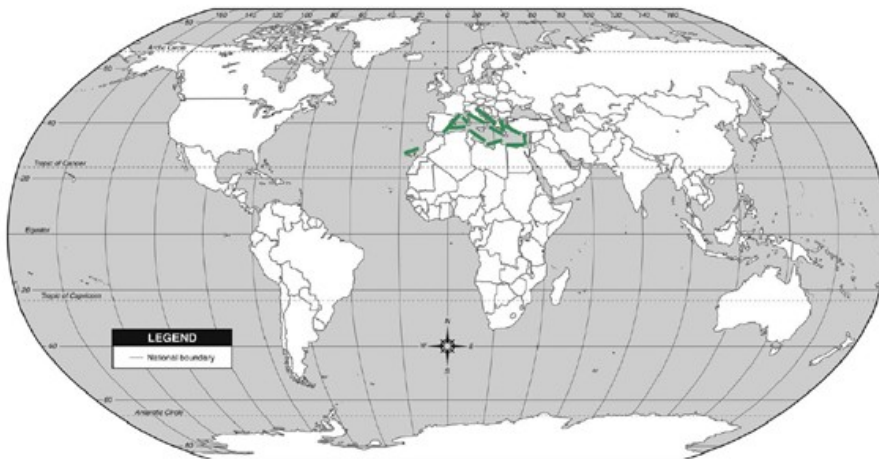
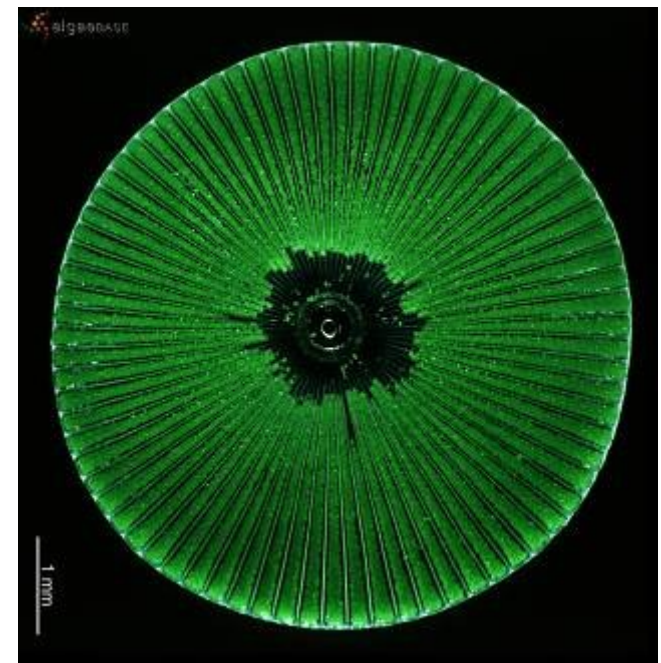


coenocytic thalli, mannans in cells walls

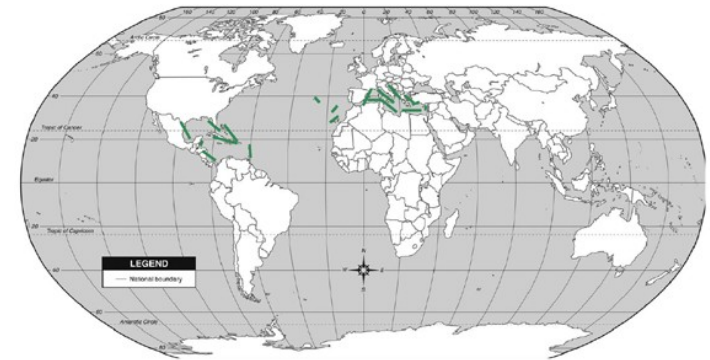
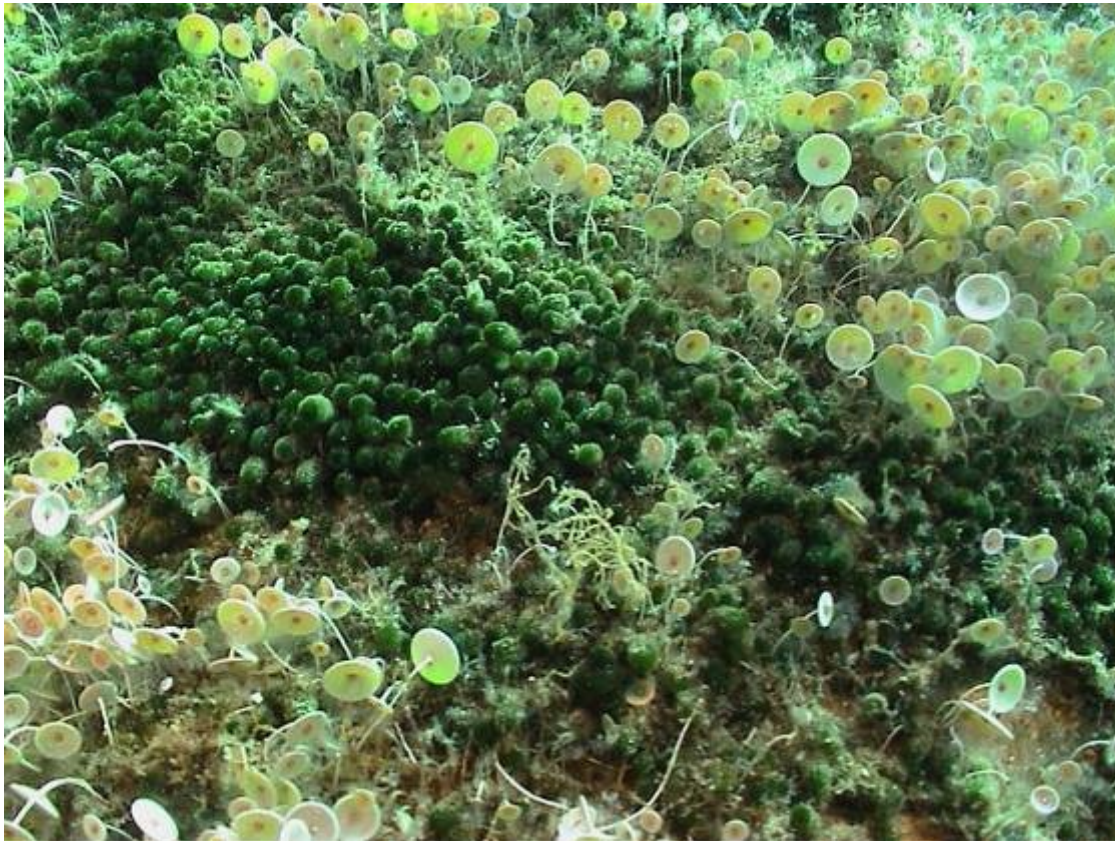
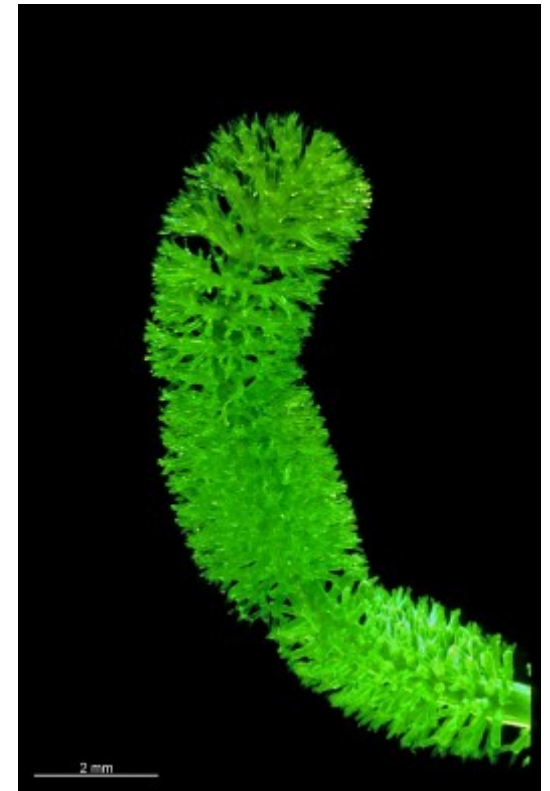
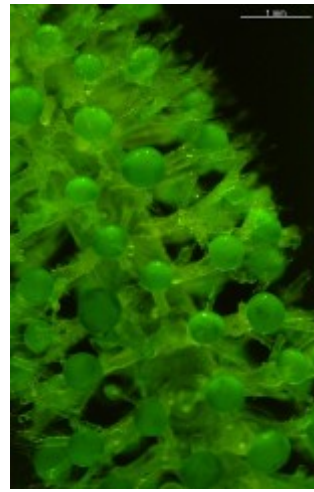
oldest findings in Cambrium (550 mya), Mesozoic radiation



# *Acetabularia acetabulum*



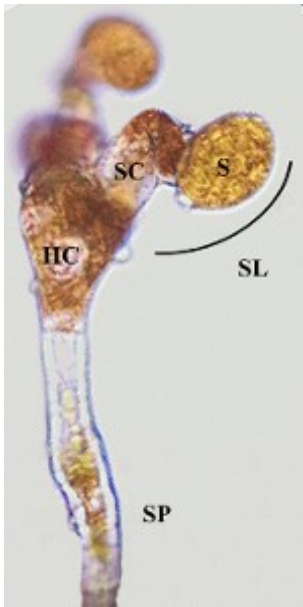
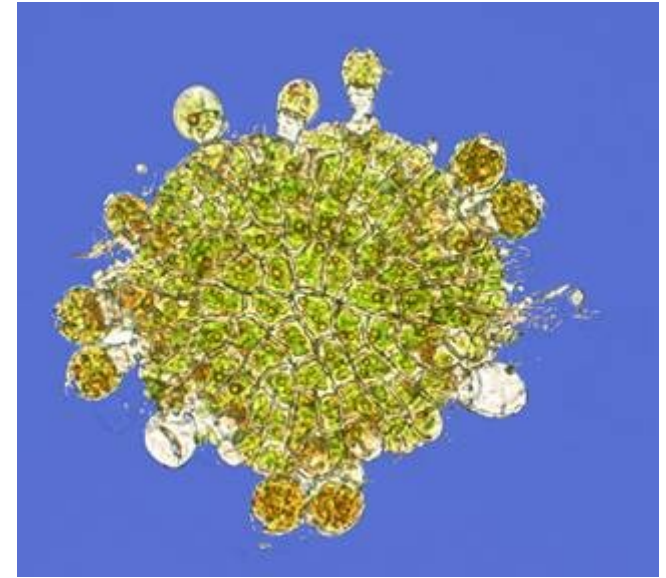
# *Dasycladus*



*D. vermicularis*

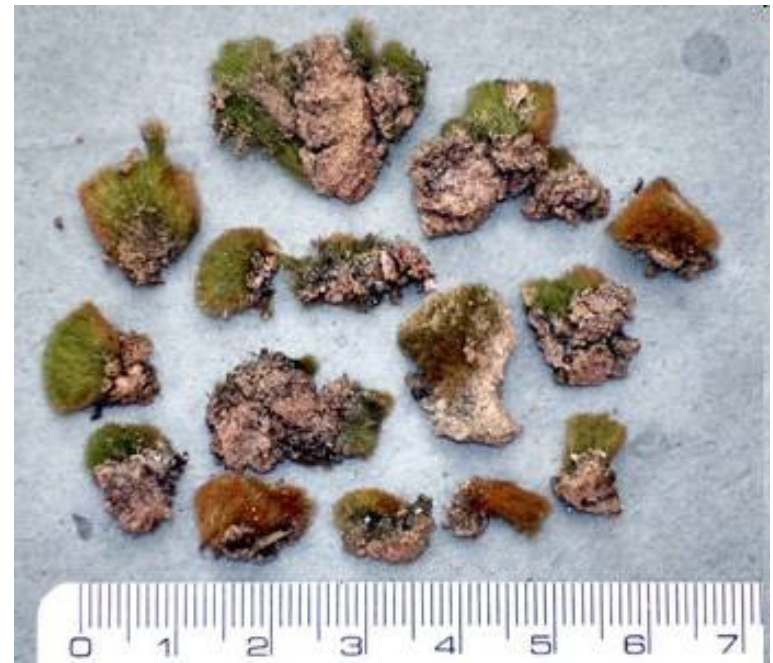
# Order: Trentepohliales

*Trentepohlia*, *Phycopeltis*, *Cephaleuros*



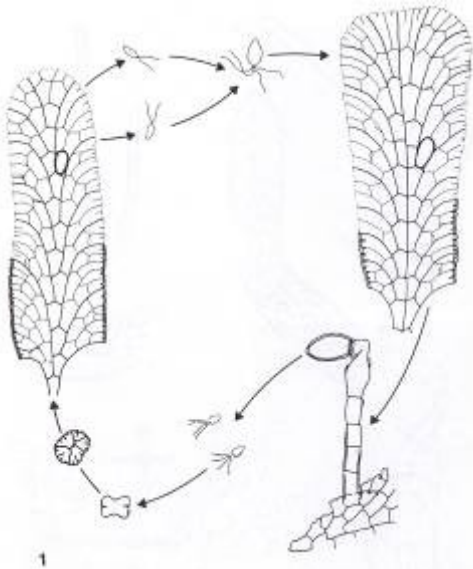
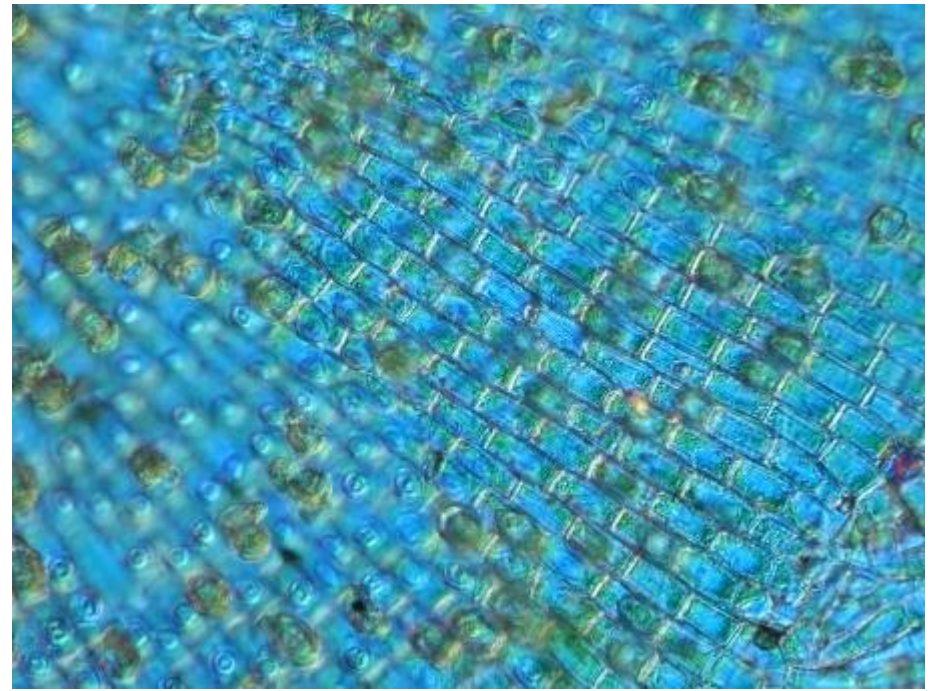
phragmoplast during cytokinesis; terrestrial specialists; parasites of vascular plants

# Trentepohlia

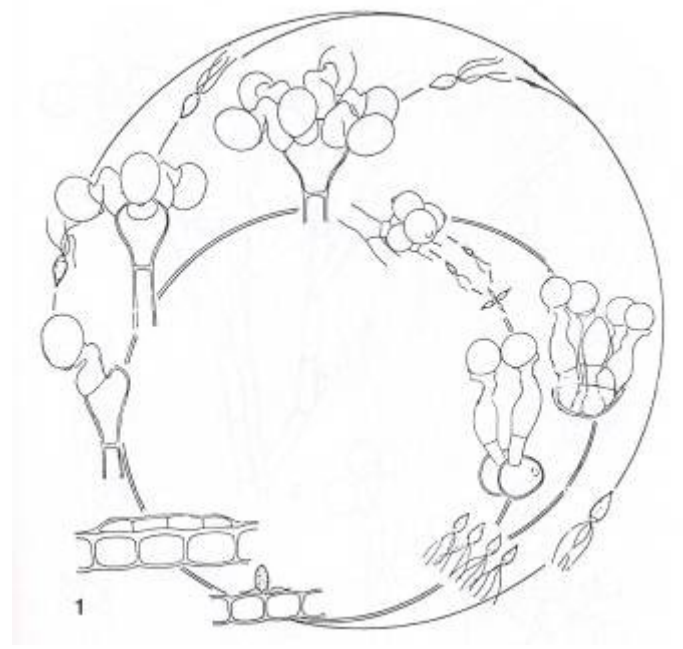
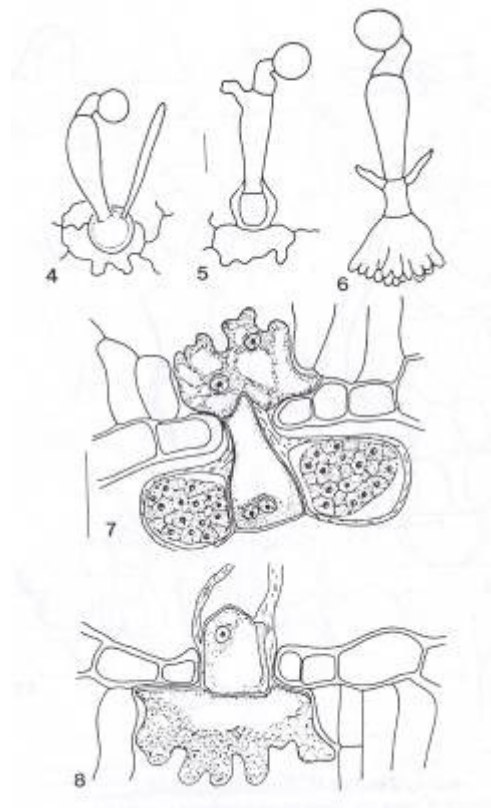
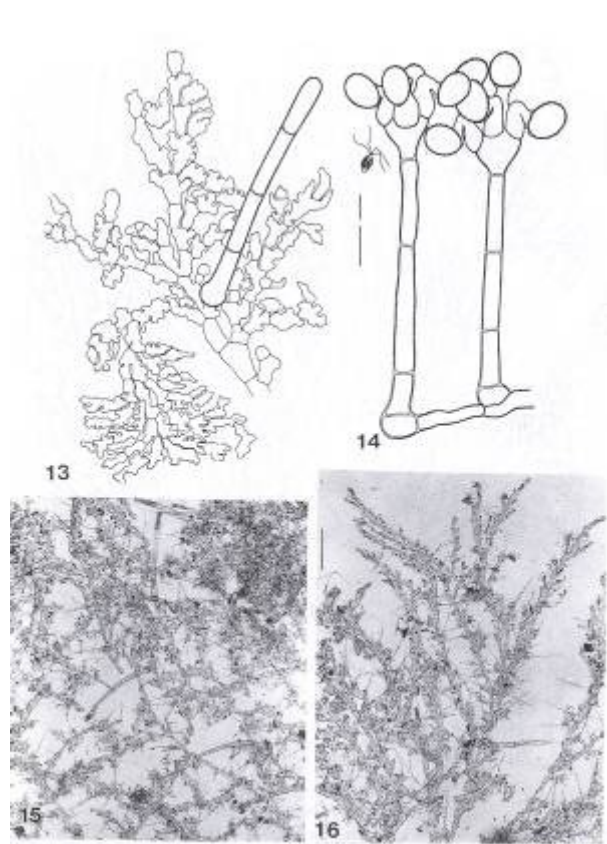




# Phycopeltis



# Cephaleuros and Stomatochroon



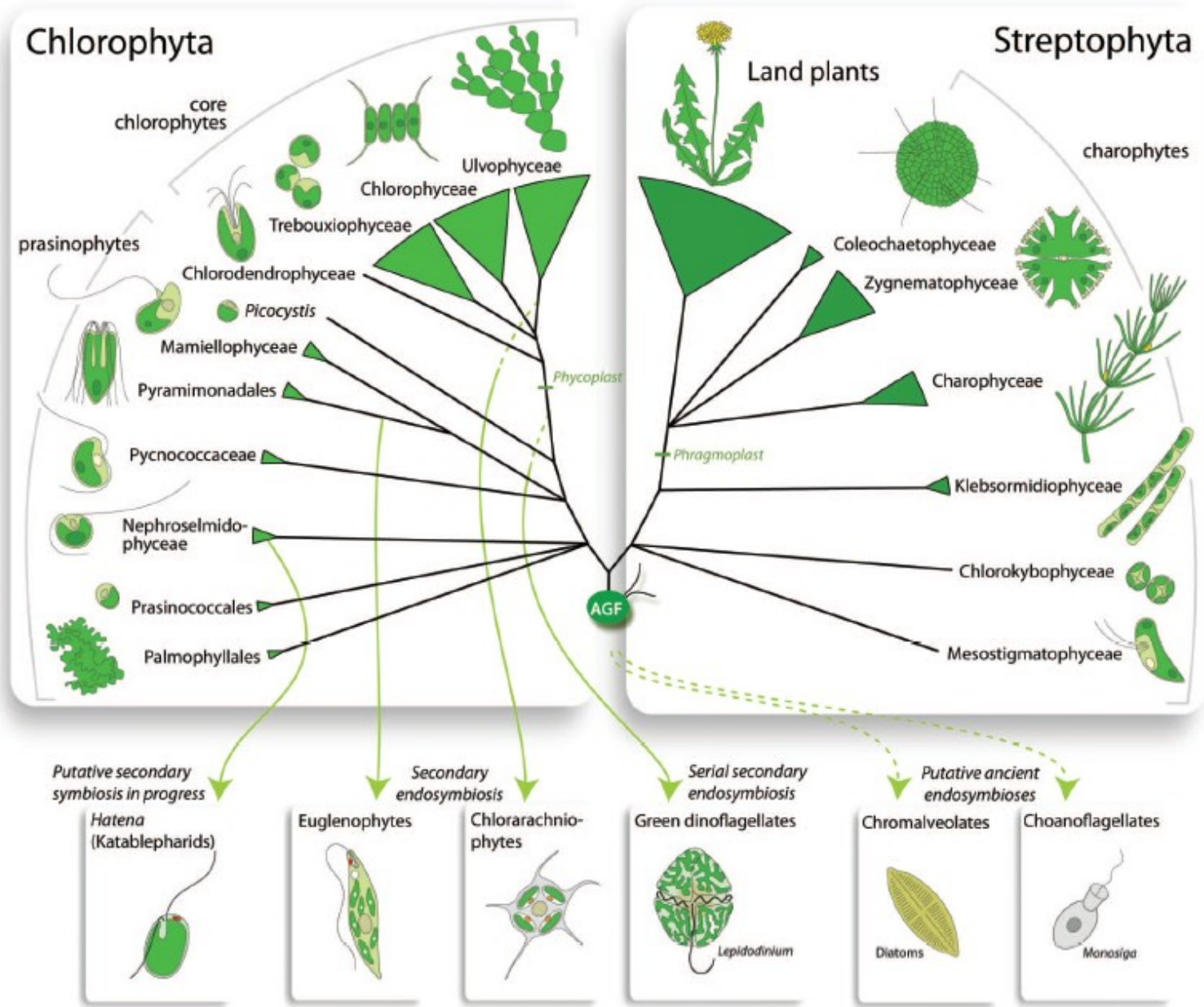


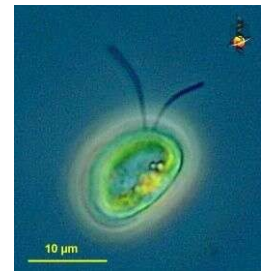
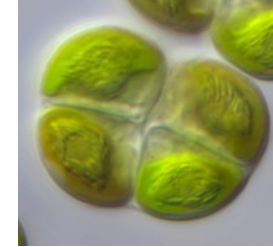
FIG. 2. Overview phylogeny of the green lineage (top) and spread of green genes in other eukaryotes (bottom). (Color figure available online.)



# six algal classes of Streptophyta:

**Mesostigmatophyceae**

(1 described species)



**Chlorokybophyceae**

(5)

**Klebsormidiophyceae**

(49)

**Coleochaetophyceae**

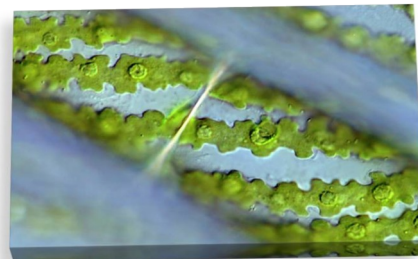
(36)

**Charophyceae**

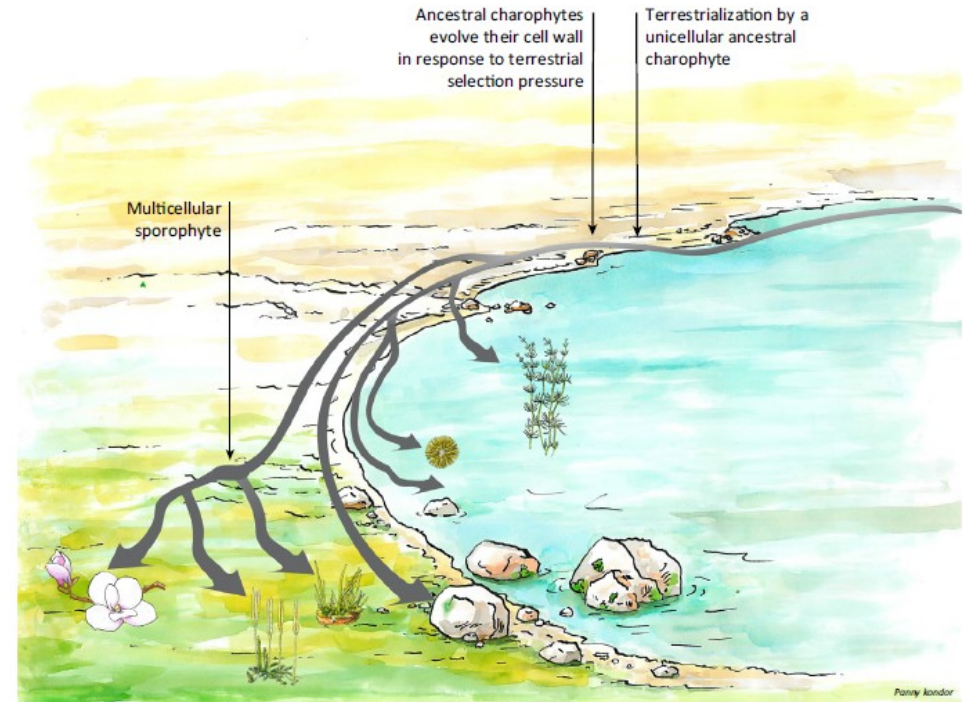
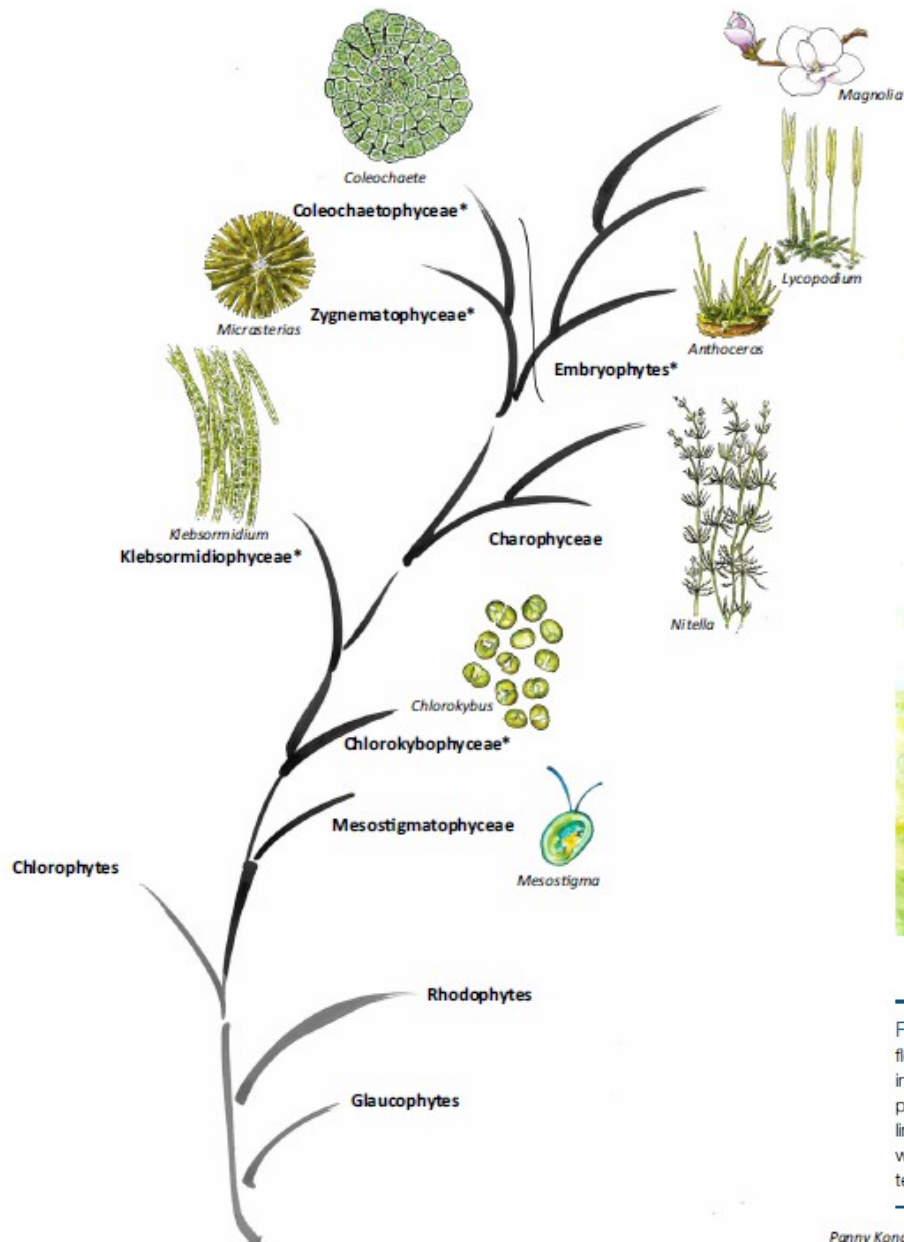
(ca 950)

**Zygnematophyceae**

(ca 4300)



# Early evolution of streptophytes



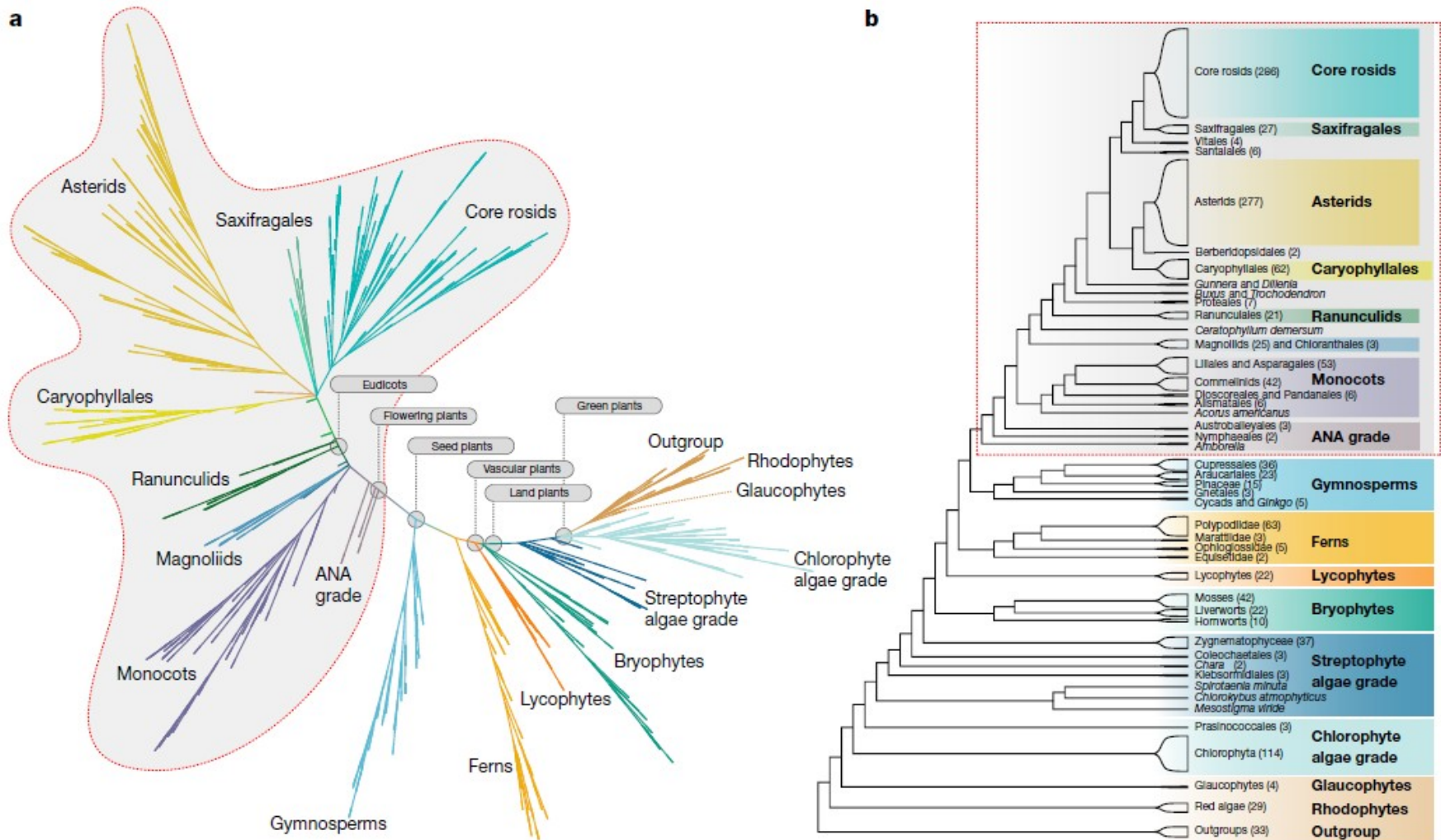
Trends in Plant Science

Figure 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.

Panny Kandor

Trends in Plant Science

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

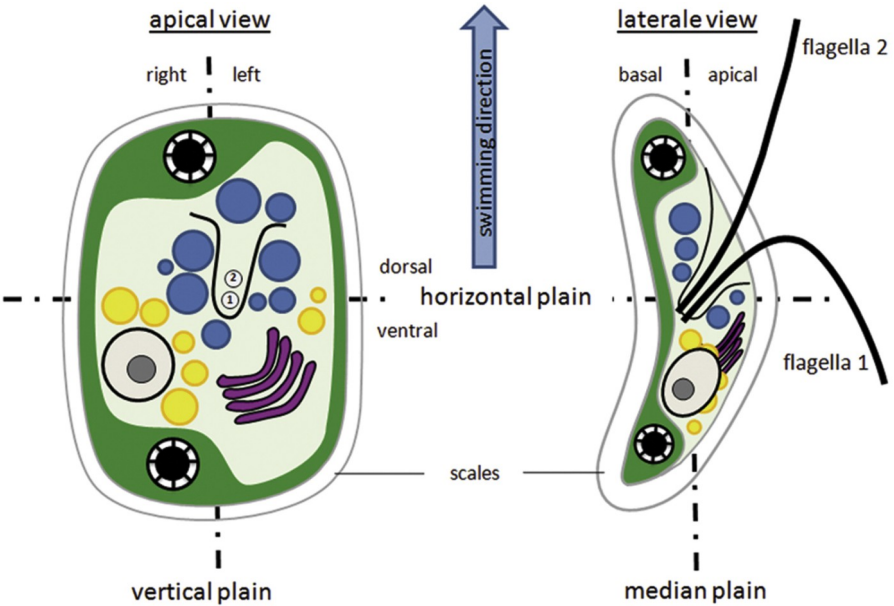
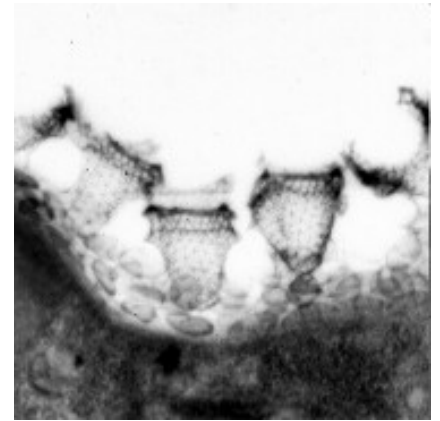
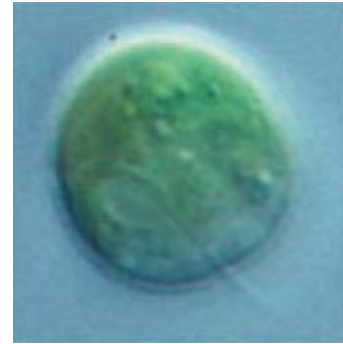


**Fig. 2 | Phylogenetic inferences of major clades.** Phylogenetic Inferences were based on ASTRAL analysis of 410 single-copy nuclear gene families extracted from genome and transcriptome data from 1,153 species, including 1,090 green plant (Viridiplantae) species (Supplementary Table 1). **a**, Phylogram showing internal branch lengths proportional to coalescent units ( $2N_e$  generations) between branching events, as estimated by ASTRAL-II<sup>15</sup> 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>.

# Mesostigmatophyceae (*Mesostigma viride*)

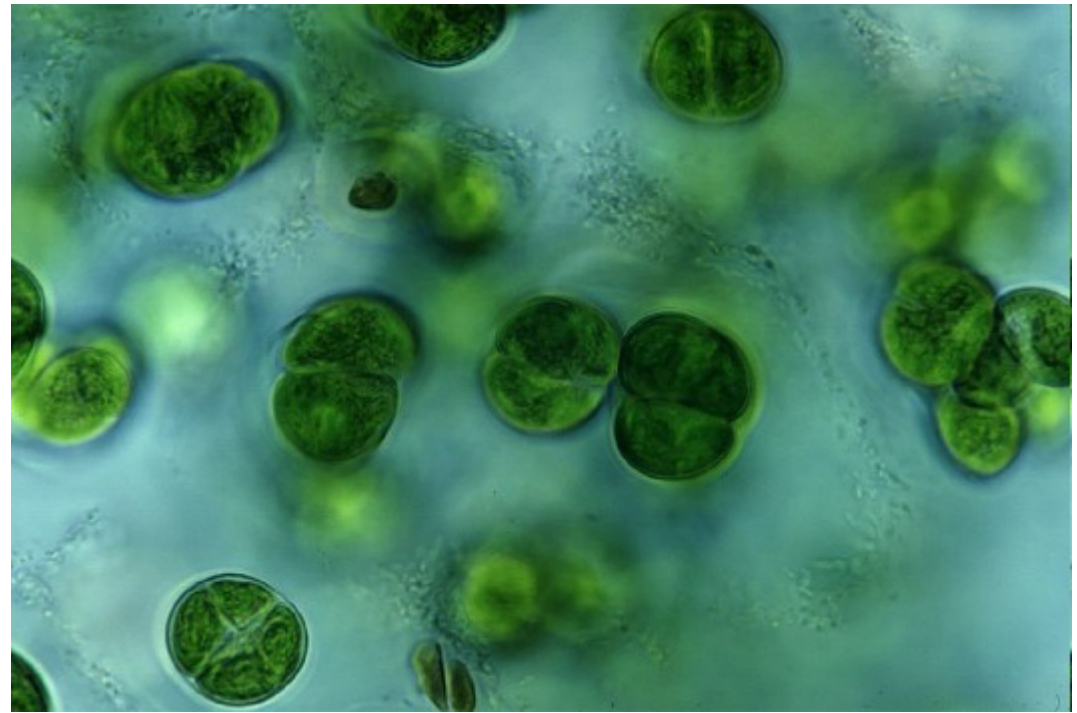
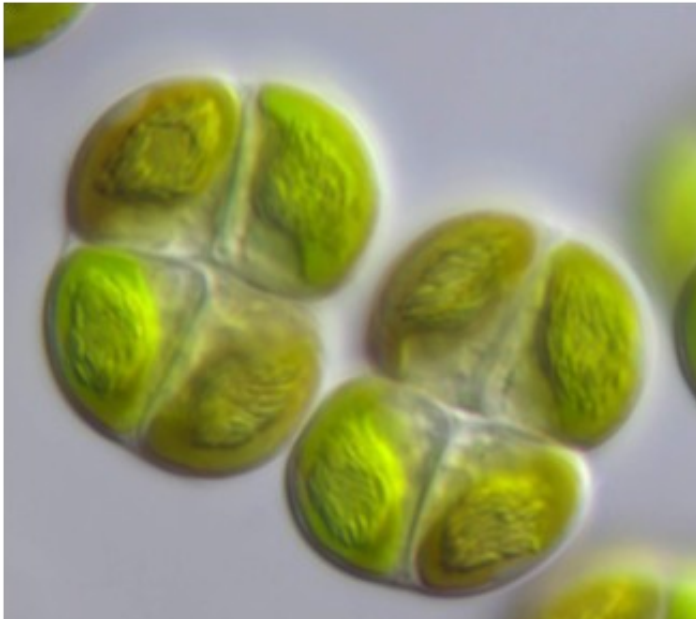
the only monadoid streptophyte „plant“



mesotrophic freshwater phytoplankton

# Chlorokybophyceae

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



colonial coccoid microalgae

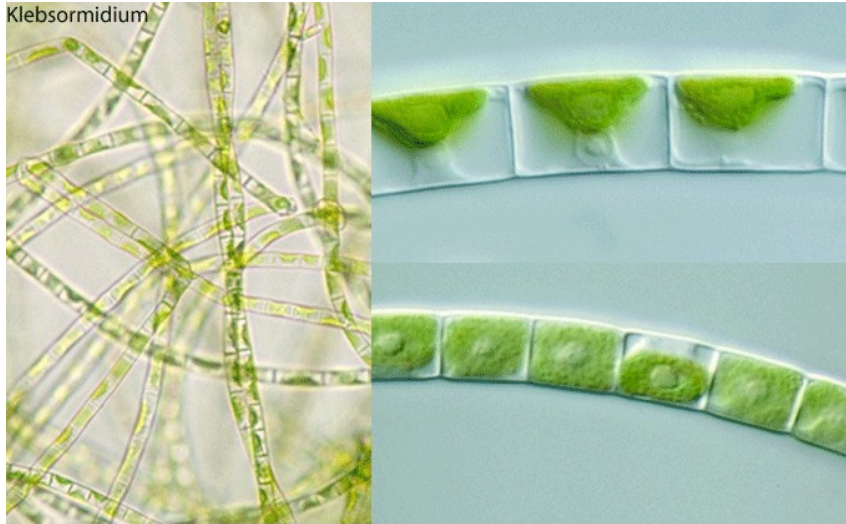
typically found in subaerial biofilms  
(soils, tree bark, rock surfaces)



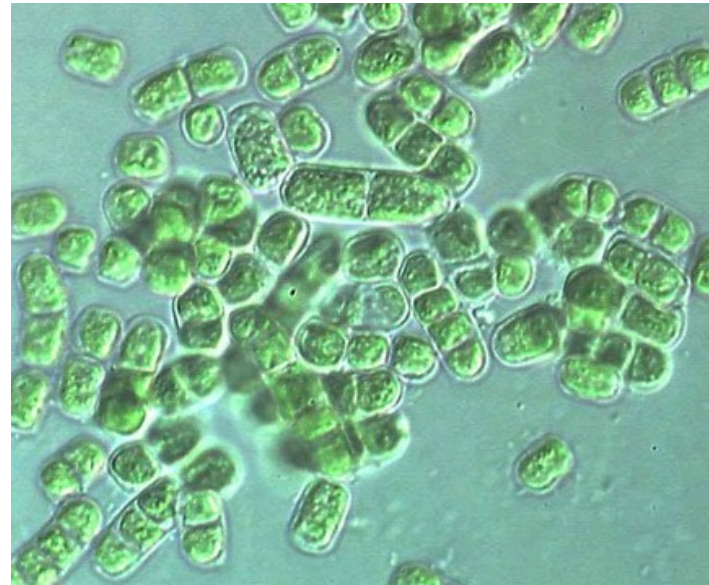
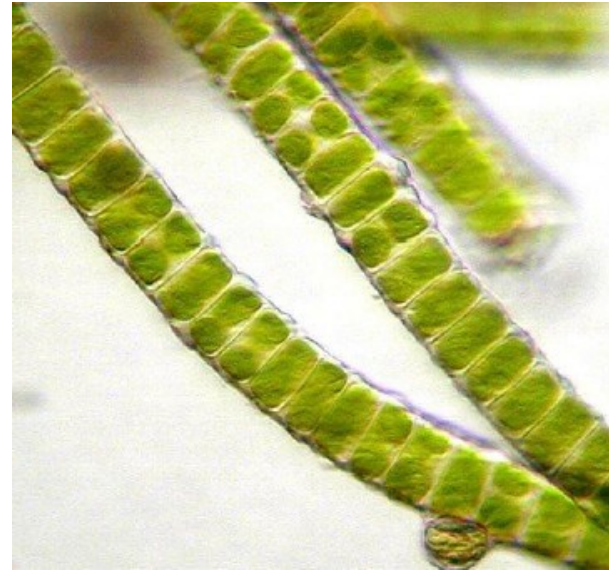
# Klebsormidiophyceae

filamentous unbranched morphology

## *Klebsormidium*

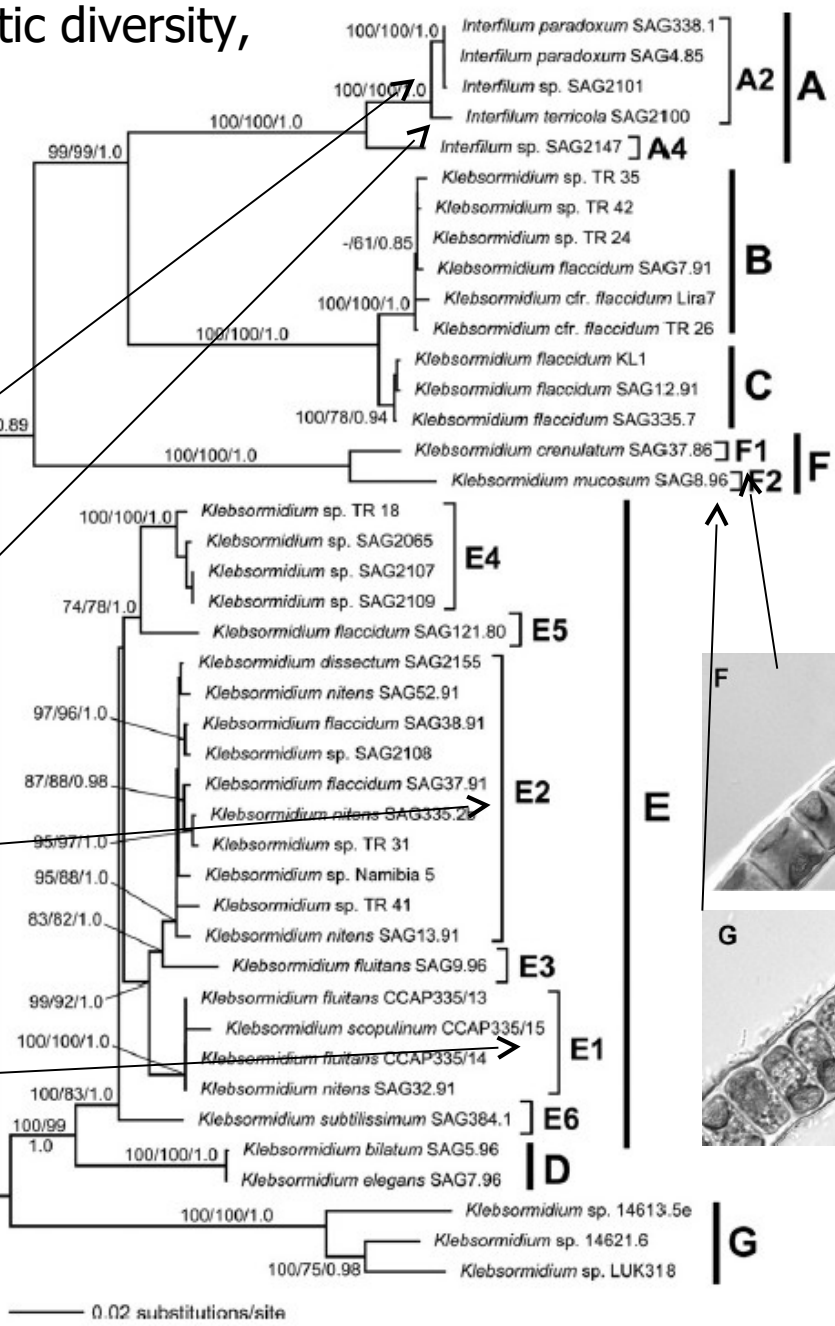
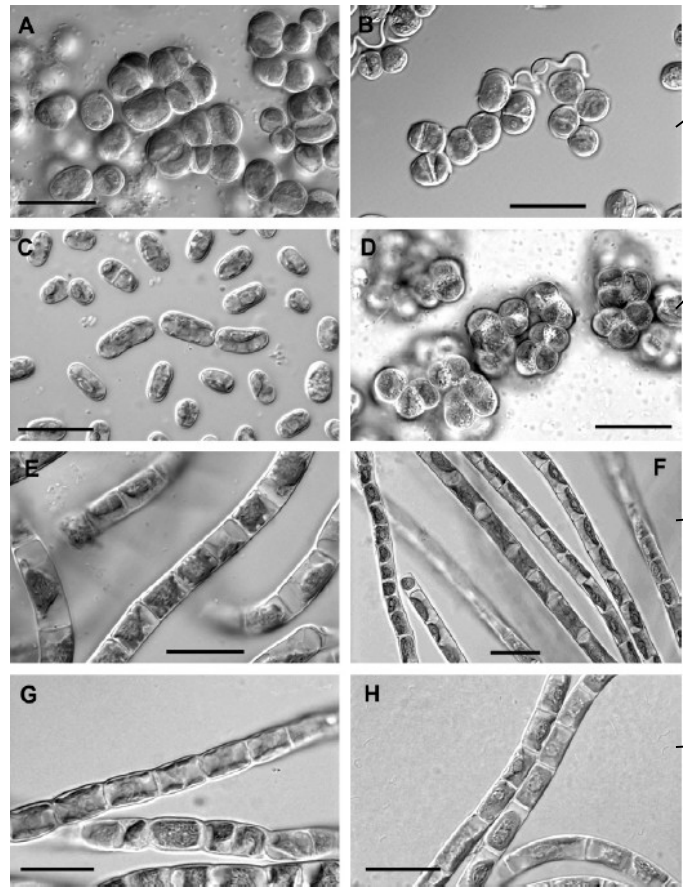


All after Entwisle et al. (1997)



usually occurs in subaerial microhabitats

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

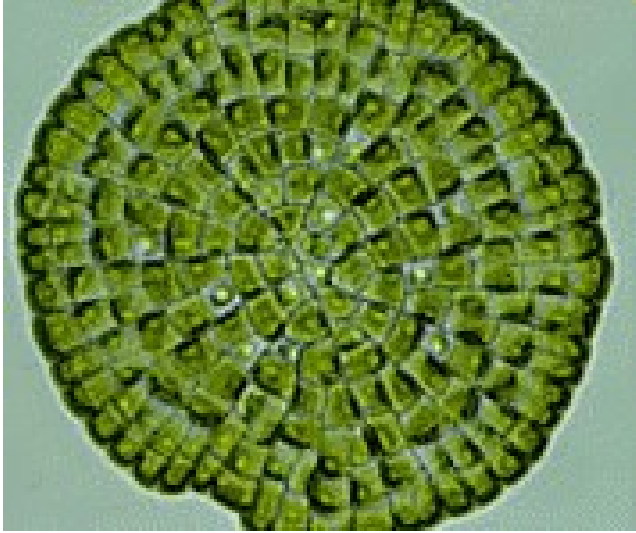


Rindi et al., 2011,  
 Mol Phy Evol 58: 218-231.

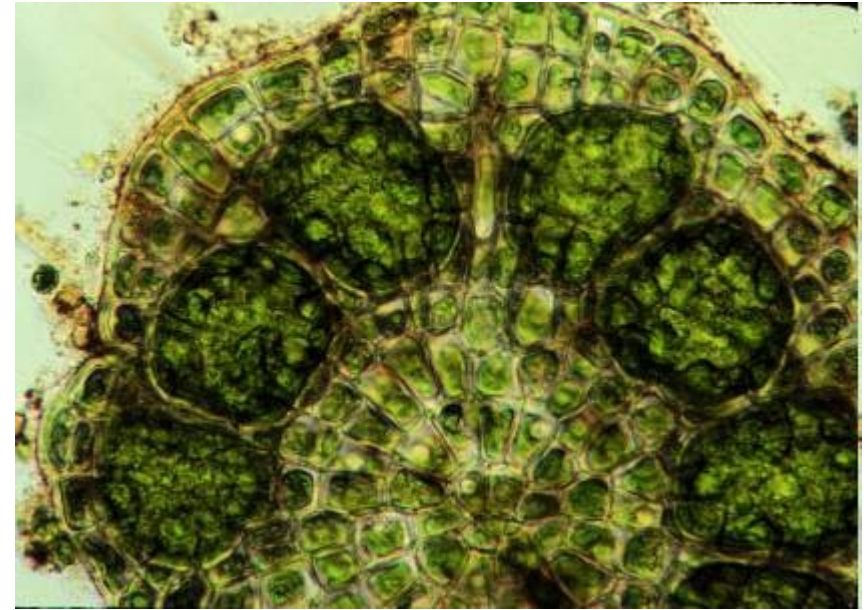
Fig. 3. Phylogram inferred from Maximum-Likelihood analysis of the concatenated dataset *rbcl*-ITS rRNA in the Klebsormidiales, with bootstrap support (BP) and Bayesian Posterior Probabilities (PP) indicated at the nodes. From left to right and from top to bottom the support values correspond to Neighbor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

# Coleochaetophyceae

## *Coleochaete*



Coleochaete growing on edge of Elodea leaf





discoid vs. heterotrachelal taxa

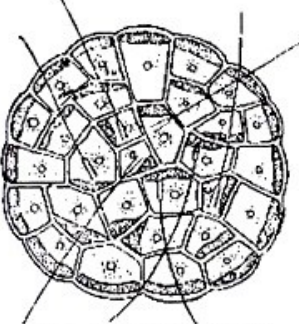


Fig. 1. *Coleochaete scutata* (discoid Rom)

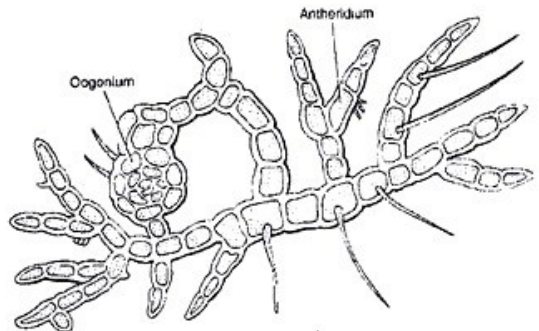


Fig. 2. *Coleochaete pulvinata* (cushioned form)

ontogenetic cycle

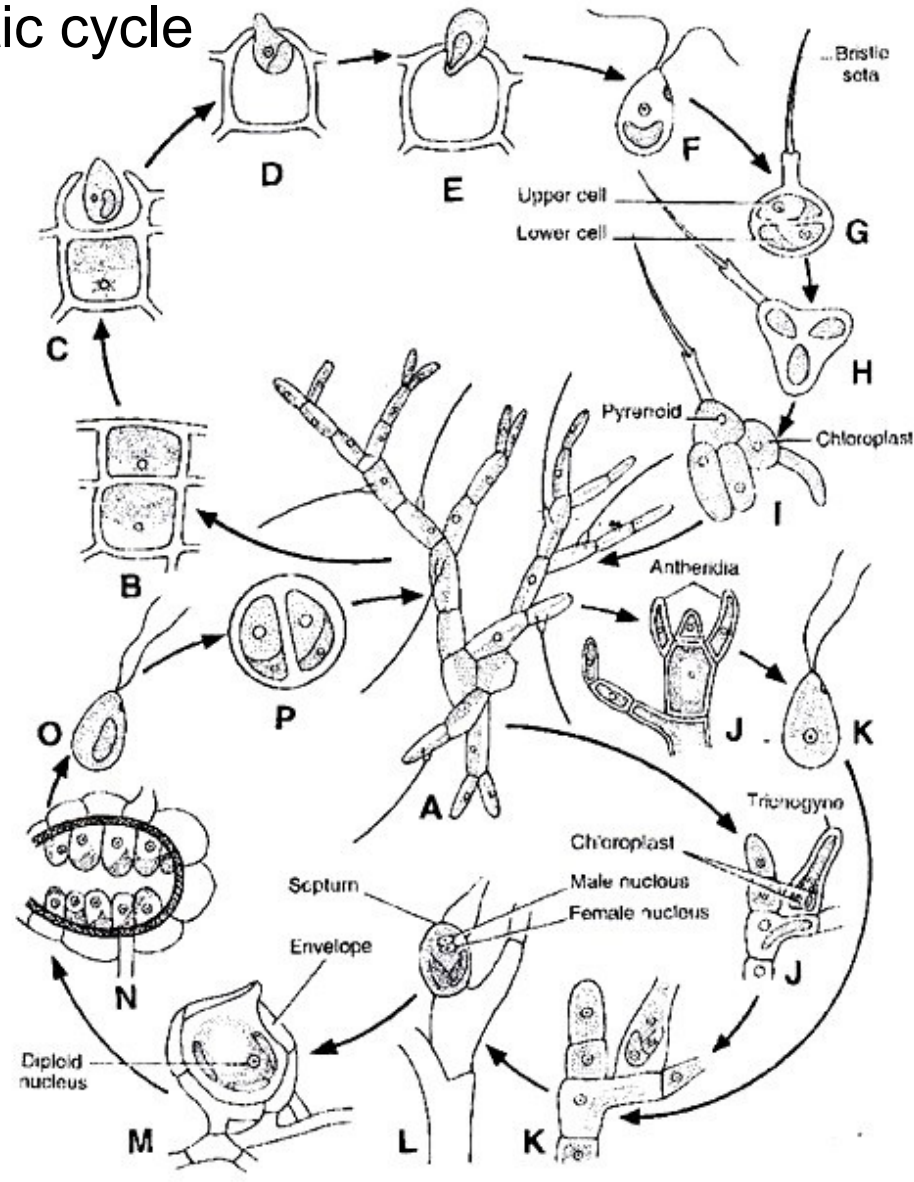


Fig. 5. *Coleochaete*. Diagrammatic life Cycle

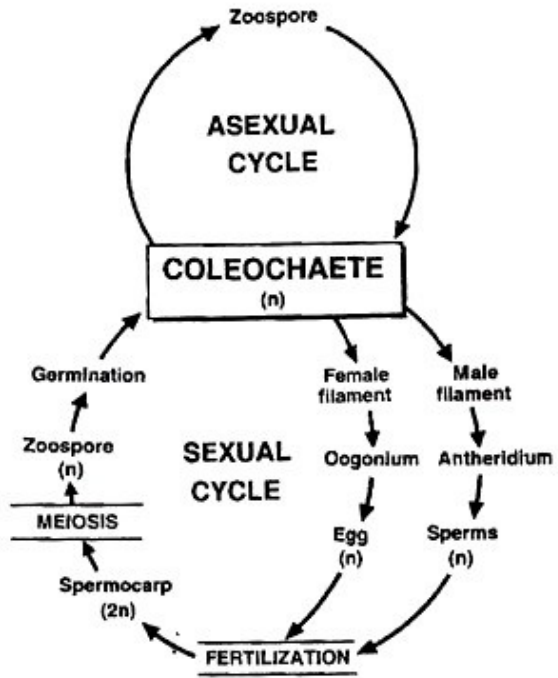
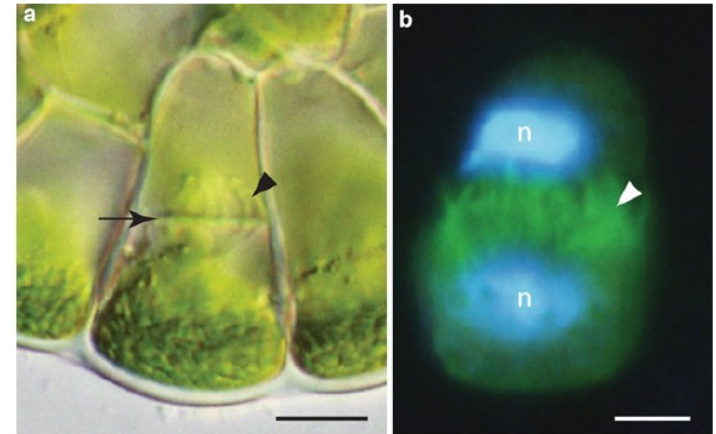
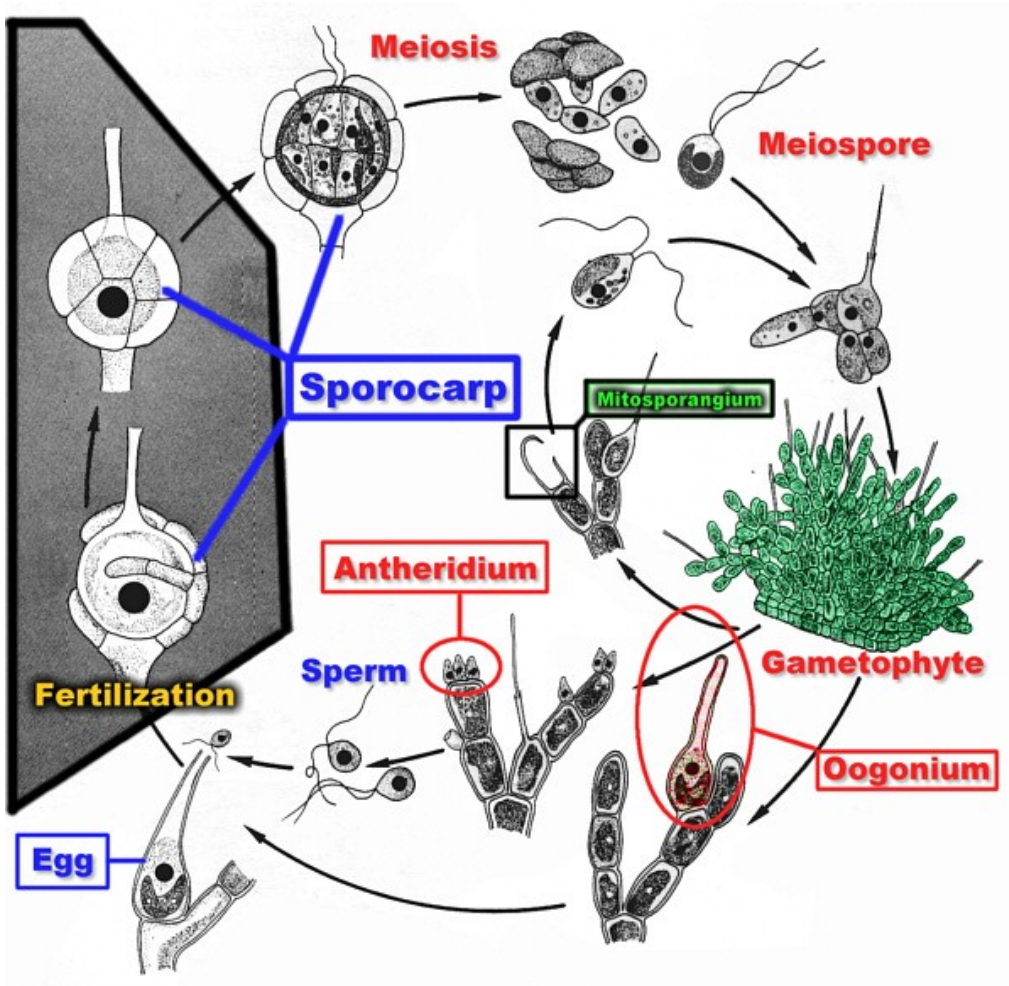


Fig. 6. *Coleochaete*. Graphic life Cycle

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

sporocarp encases the zygote and nourishes it

vegetative plants are always haploid



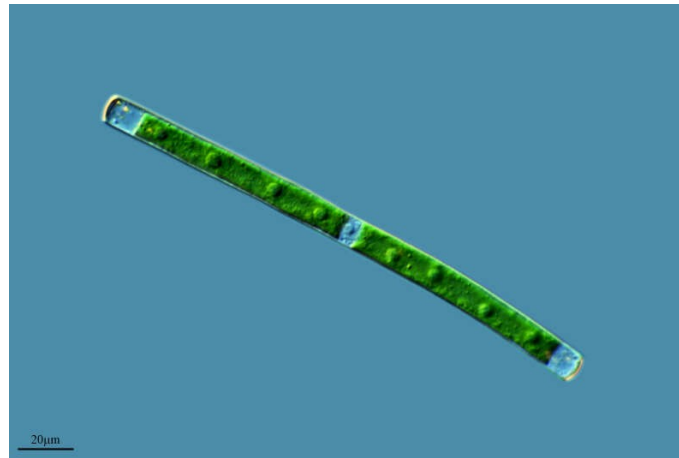
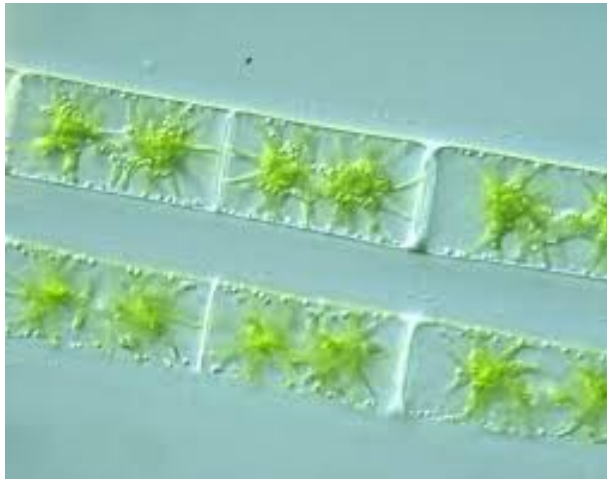
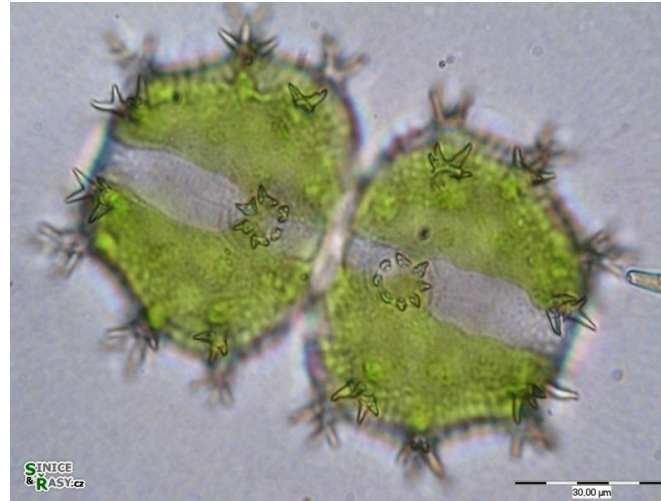
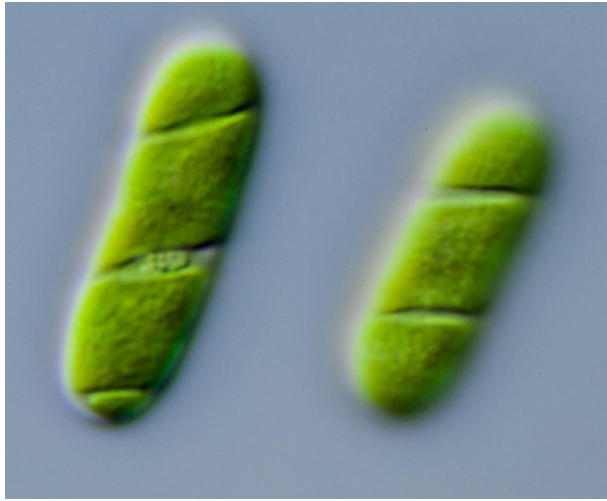
**Fig. 2** Cell division involving a plantlike phragmoplast in *Coleochaete orbicularis*. (a) Differential interference contrast image with forming cell plate (arrow) in center of phragmoplast (arrowhead). Scale bar = 10  $\mu$ m. (b) Immunofluorescence localization of tubulin in phragmoplast microtubules (arrowhead) between DAPI-stained telophase nuclei (n). Scale bar = 5  $\mu$ m. 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 chlorophyten lineages)

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

# Zygnematophyceae



unicellular or unbranched filamentous algae

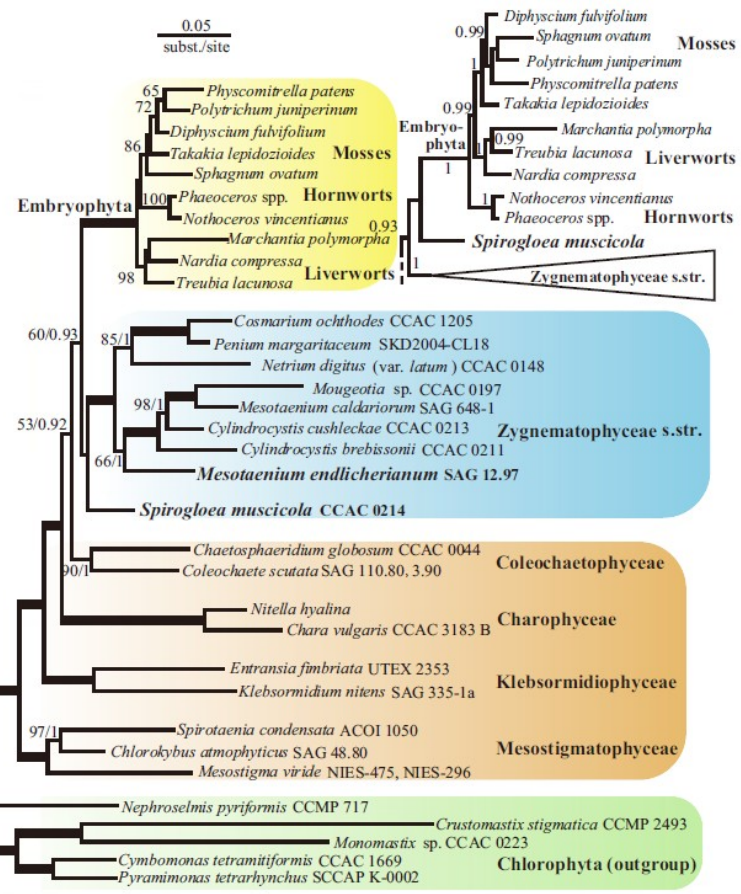
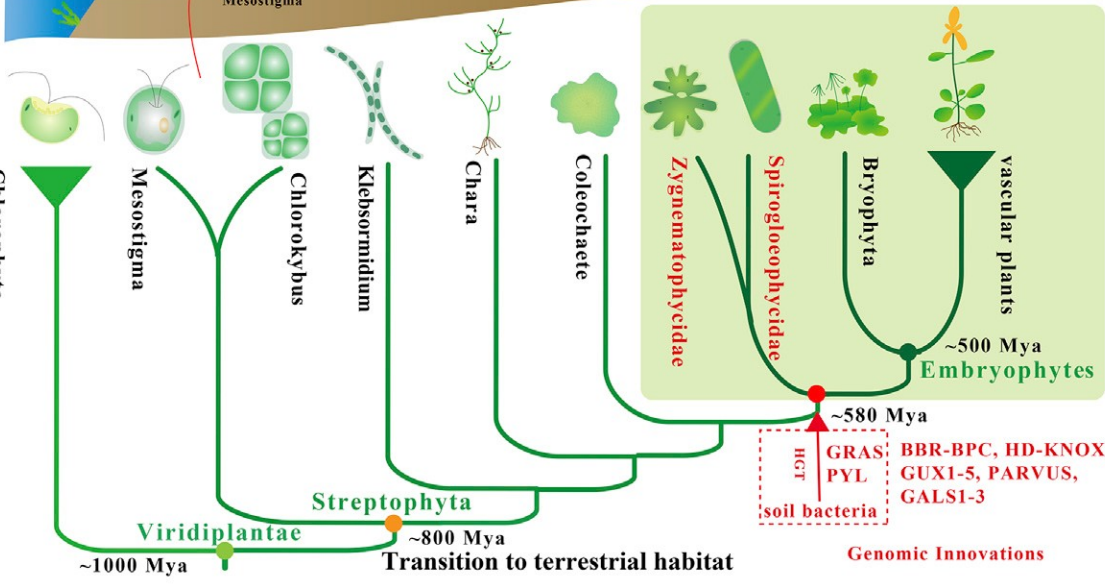
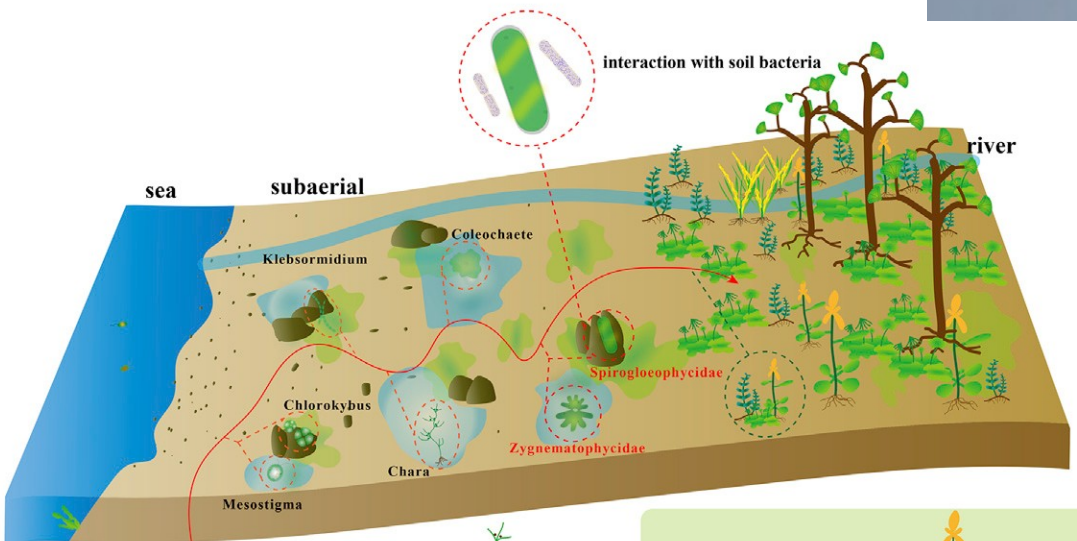
occurring solely in the freshwater (or in subaerial biofilms), often in acidic habitats

unique sexual reproduction - isogamic pattern, gametangiogamy, conjugation

absence of any flagellated cells

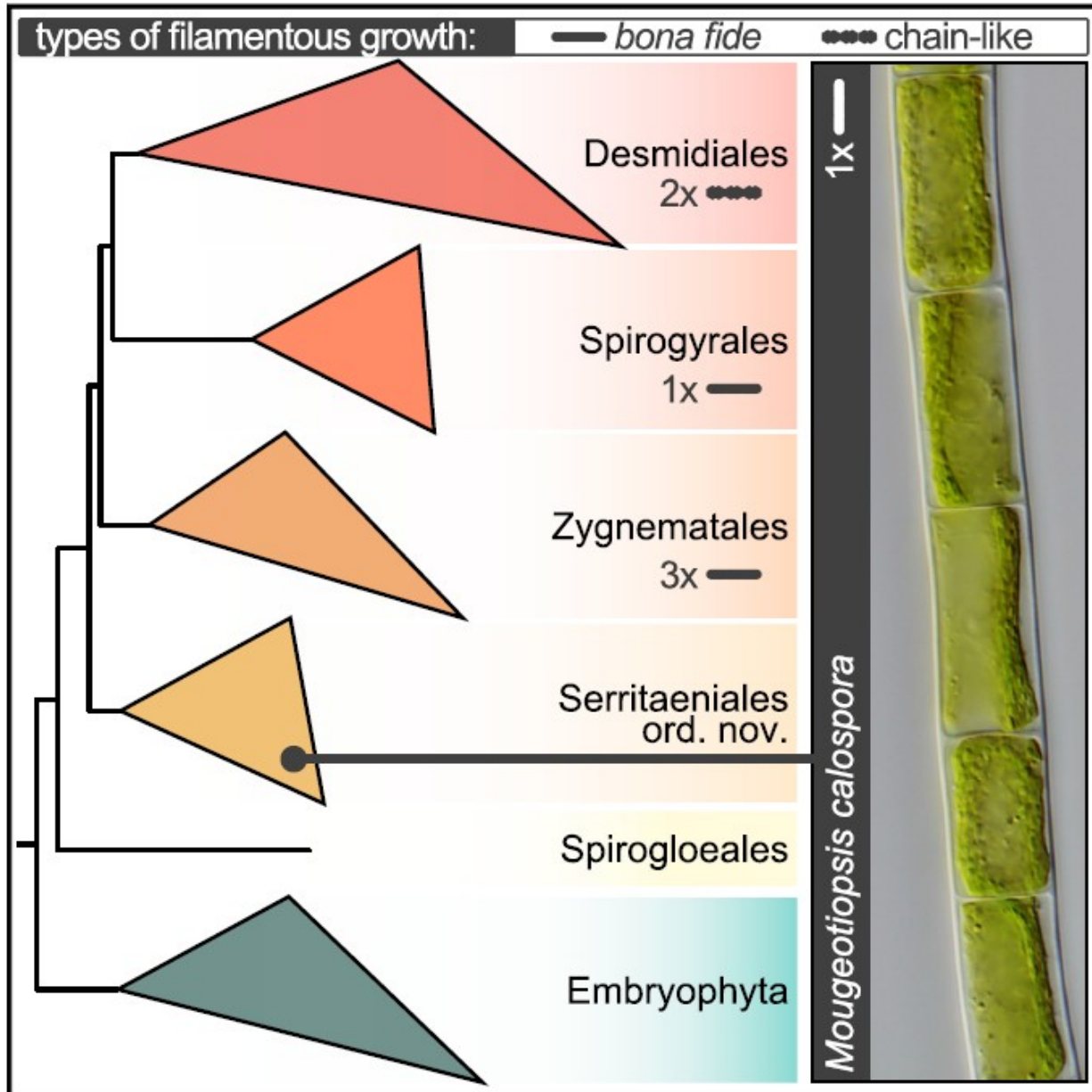
# Spirogloeoophycidae

# 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

# Zygnematophyceae

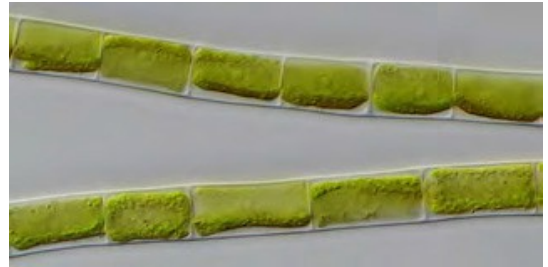
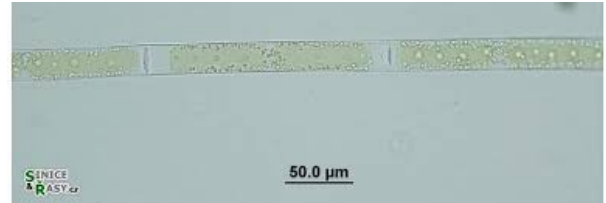
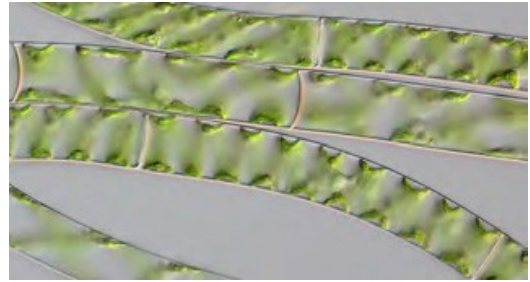
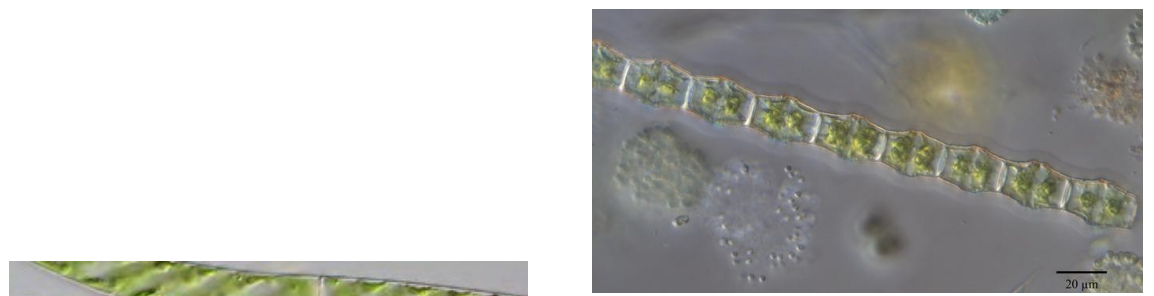
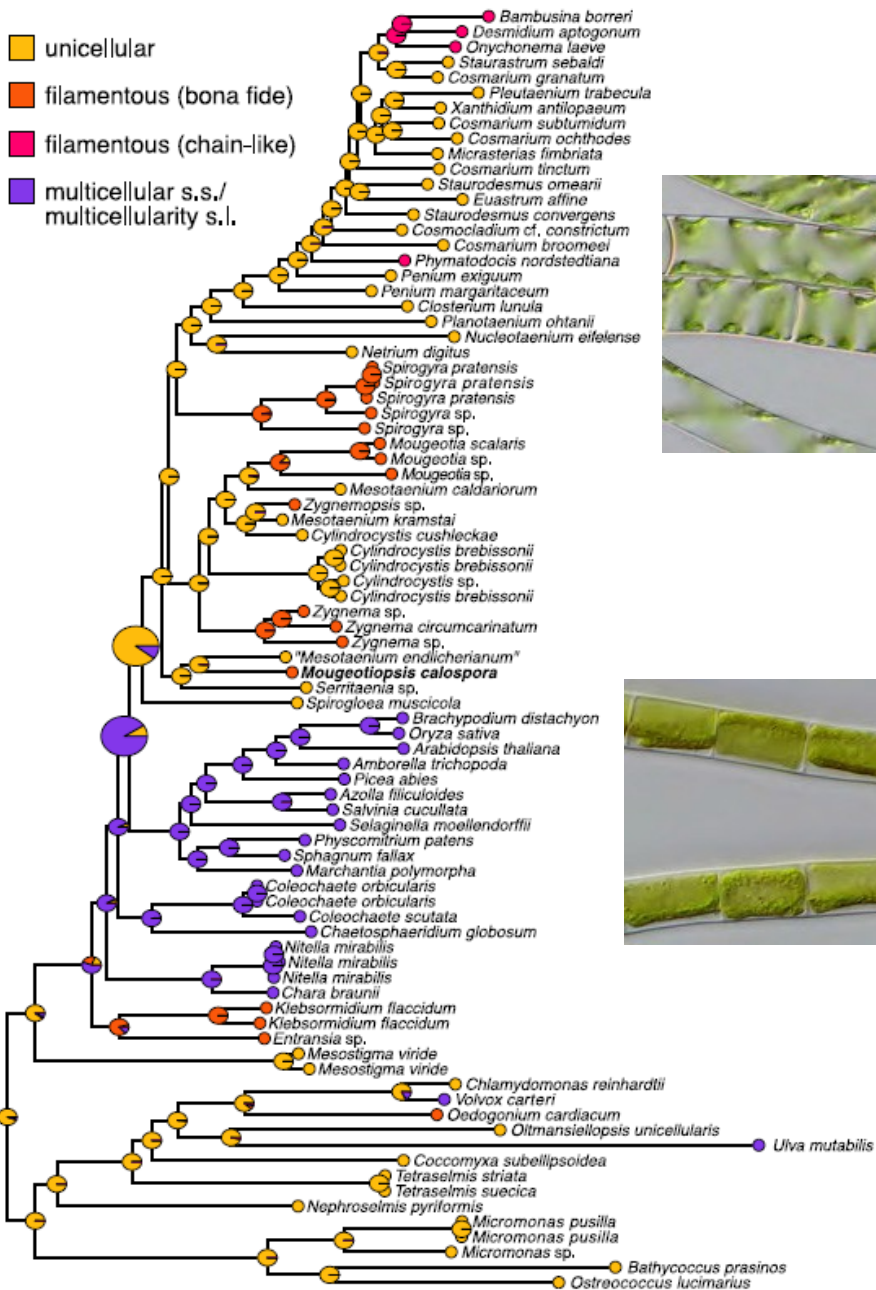


five orders (incl. Spirogløea)

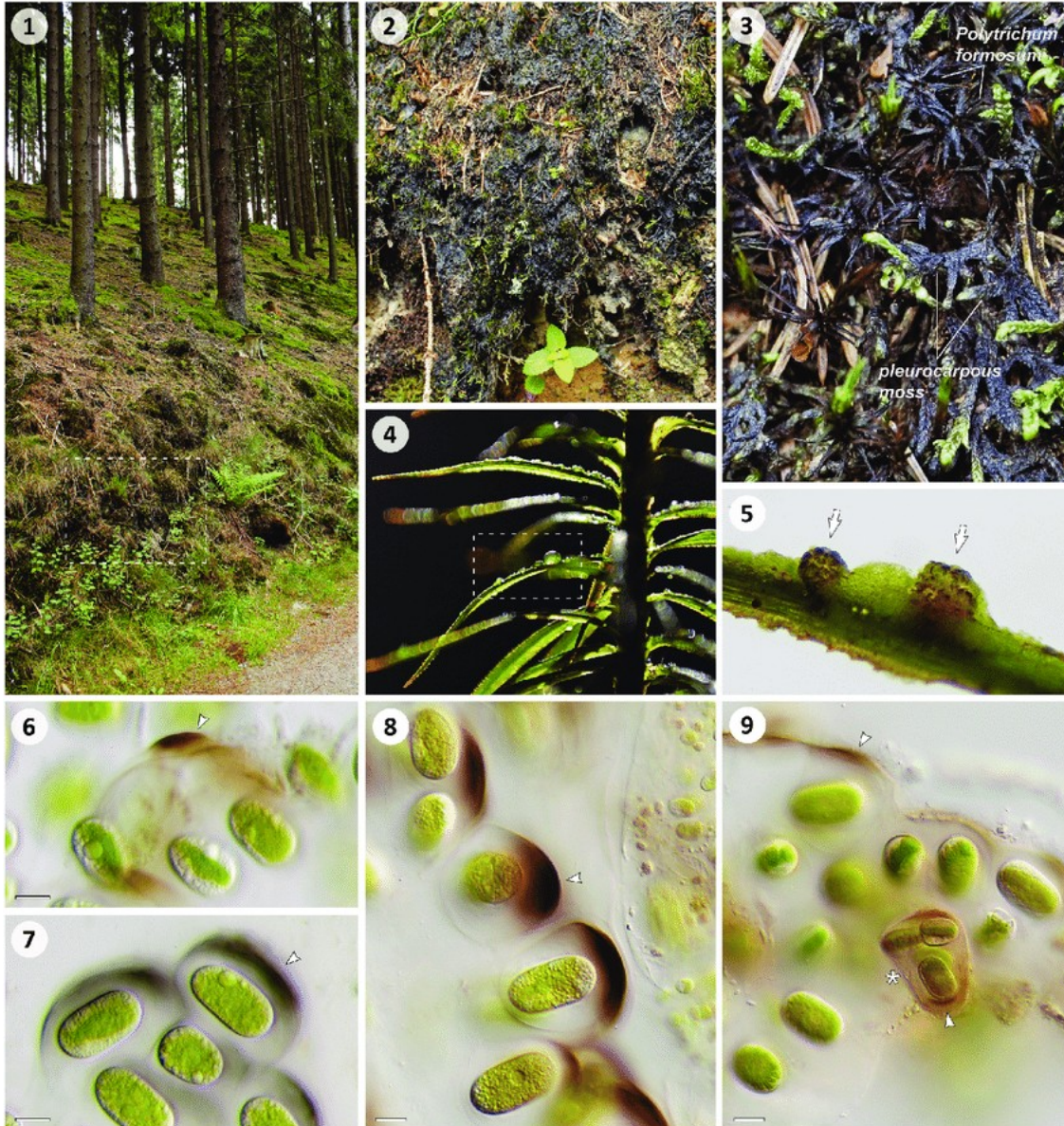
multiple evolution of  
filamentous morphology

multiple transitions to  
terrestrial habitats

# Zygnematophyceae



# Serritaeniales



*Mesotaenium endlicherianum*



cryoseston, soil biofilms  
alpine and polar habitats

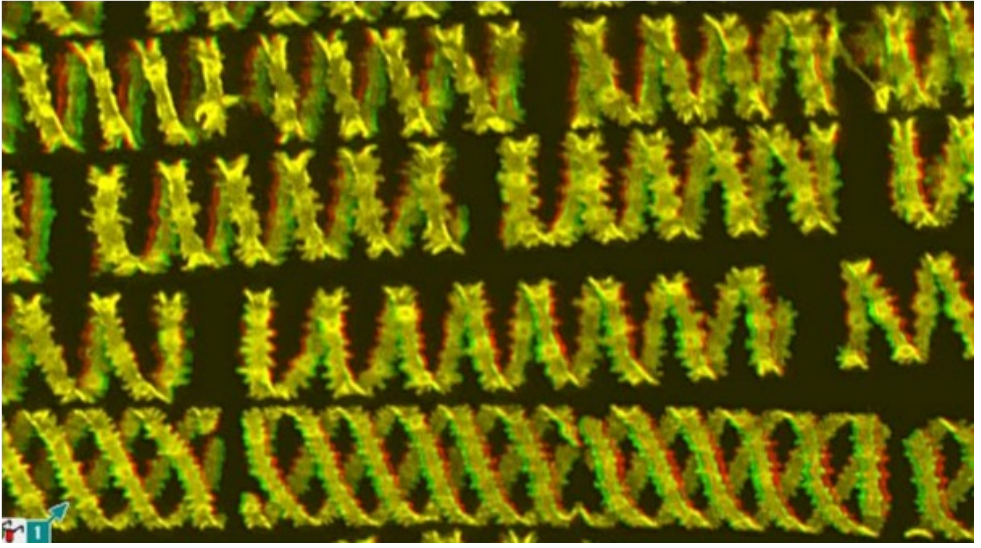
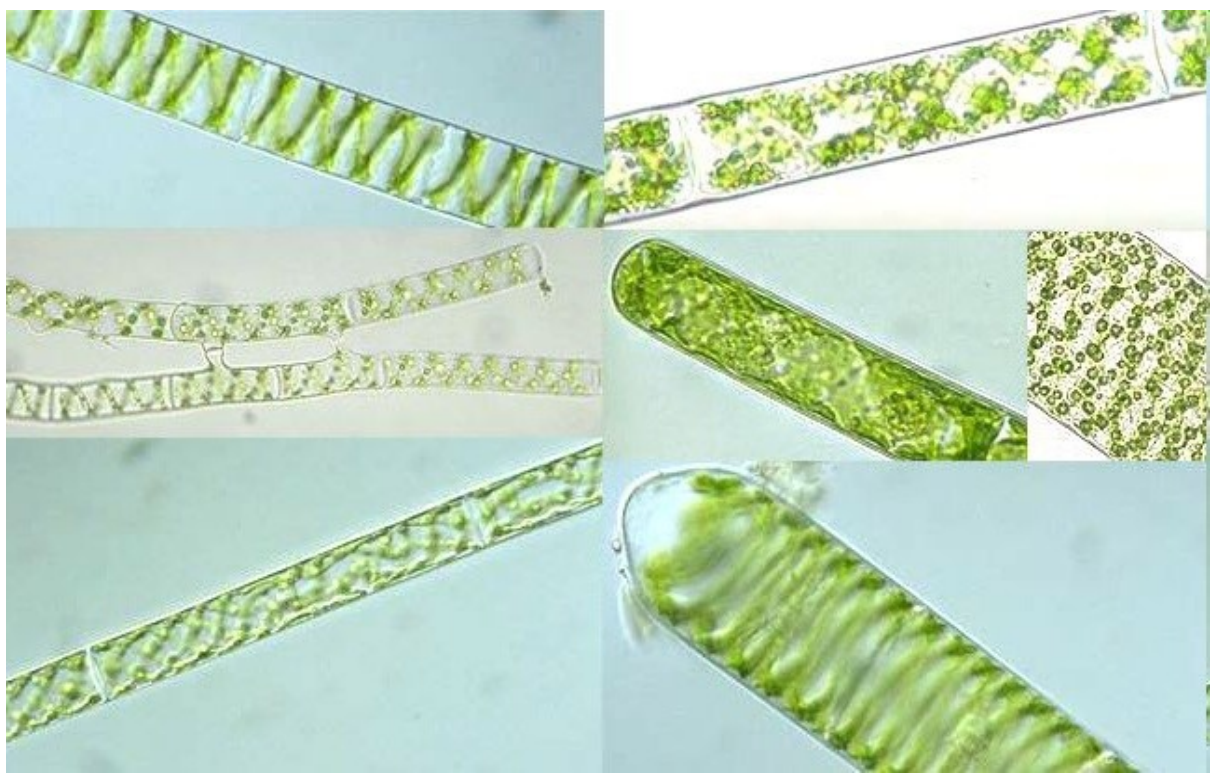
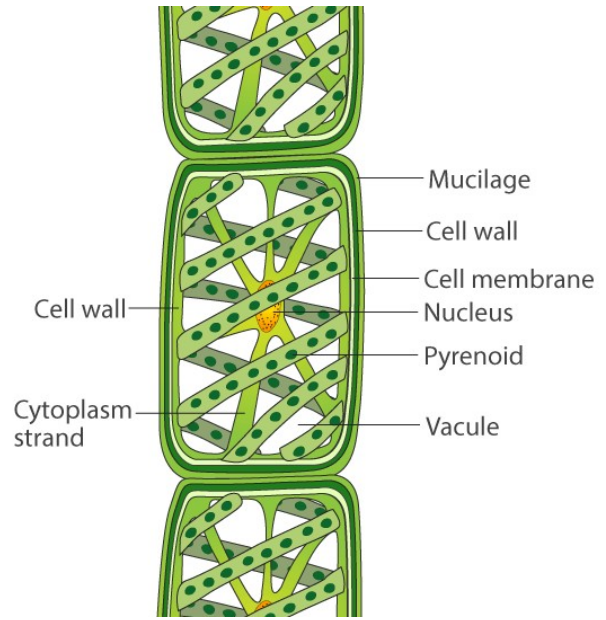
mucilage -  
photoprotective adaptation

*Serritaenia* - acidic subaerial habitats

*Busch et al., 2021, Eur J Phycol*

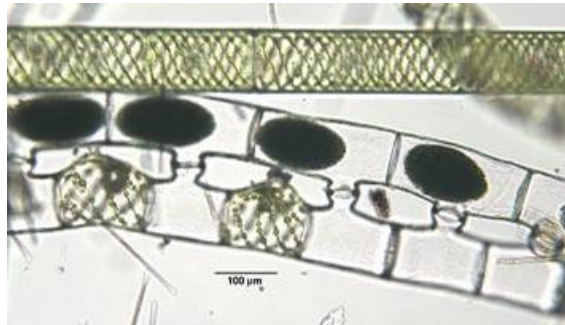
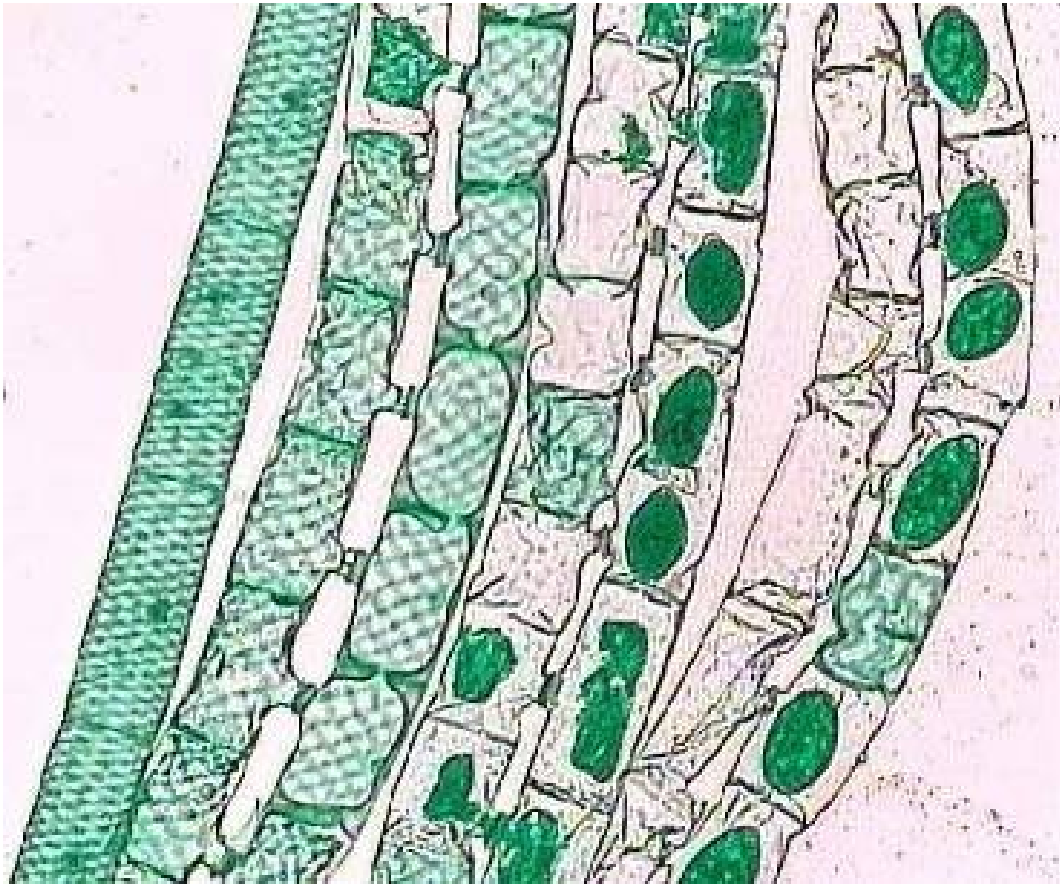
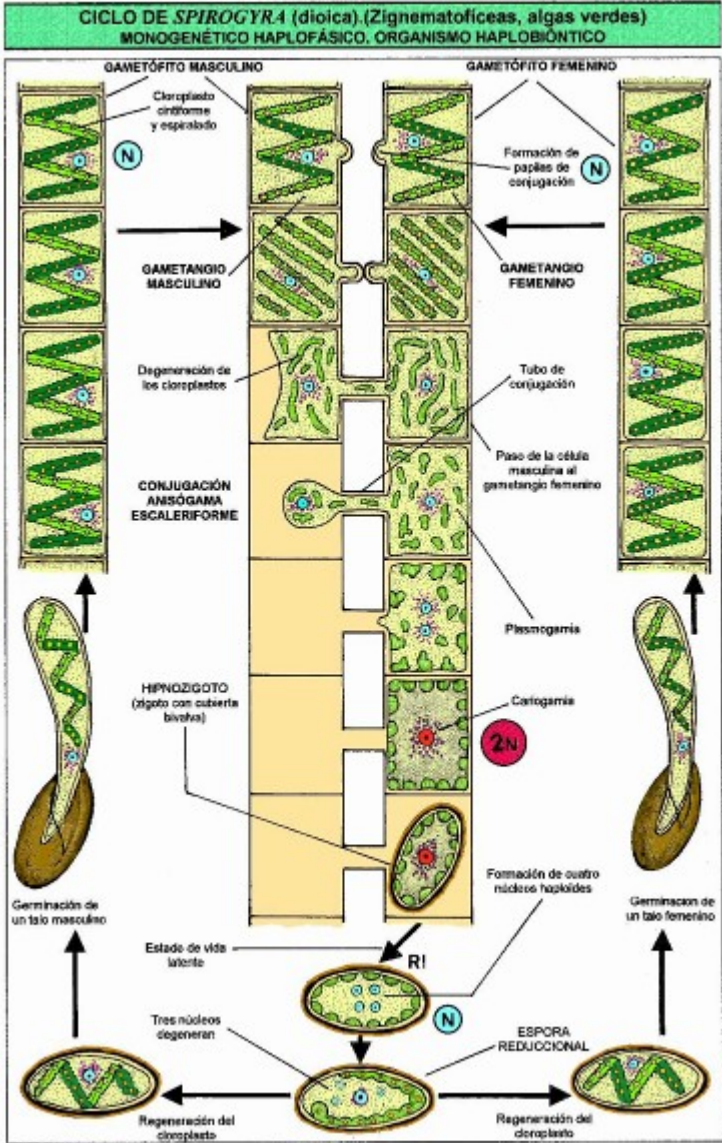
# Spirogyrales

## Spirogyra

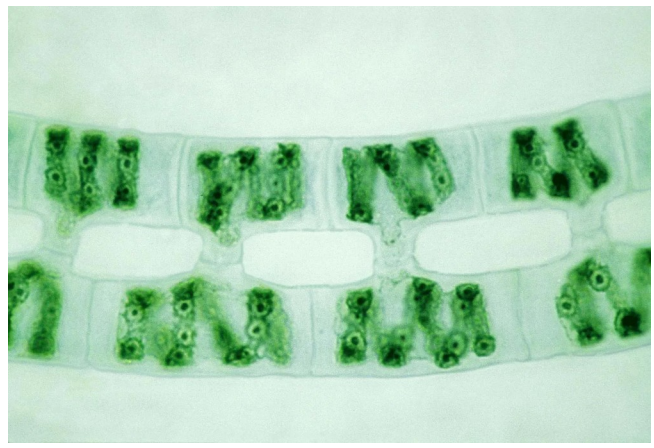
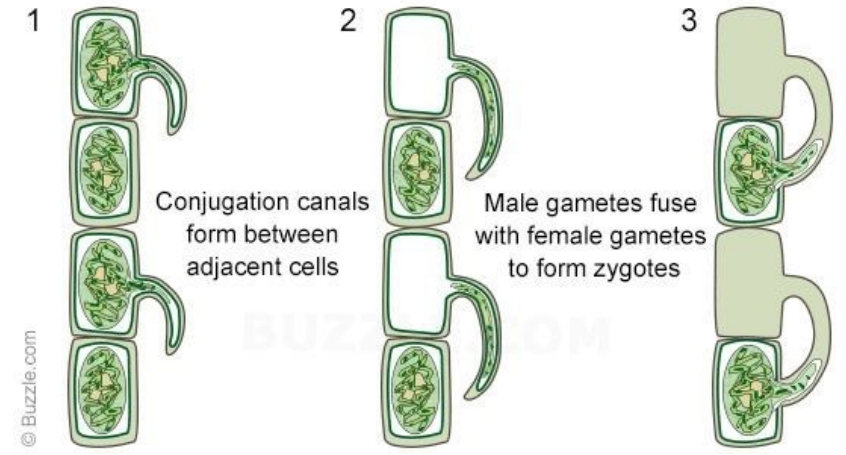
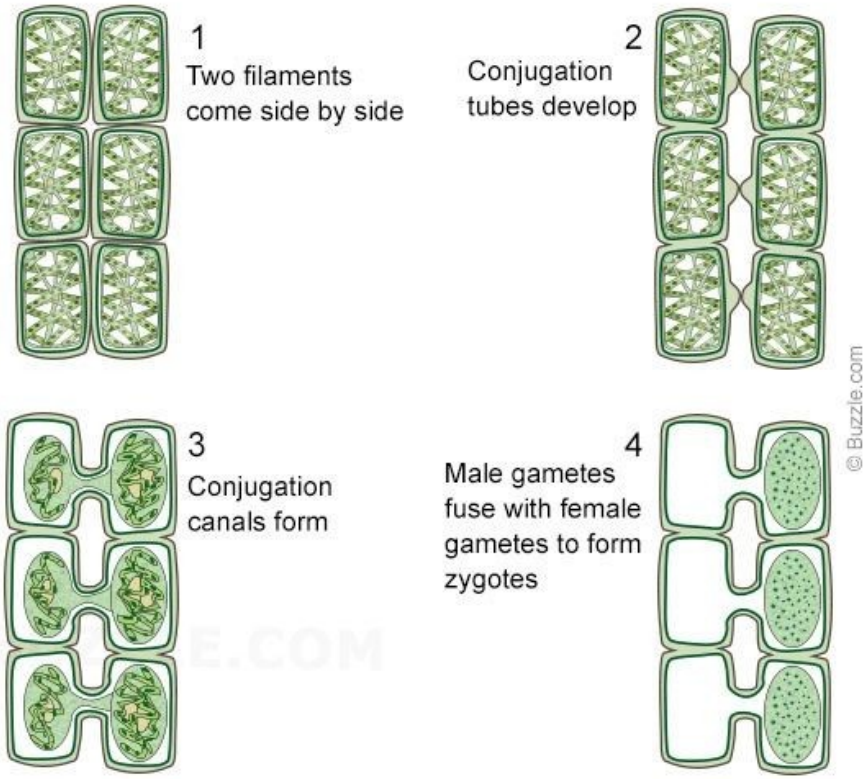




# zygnematophycean life cycle and conjugation

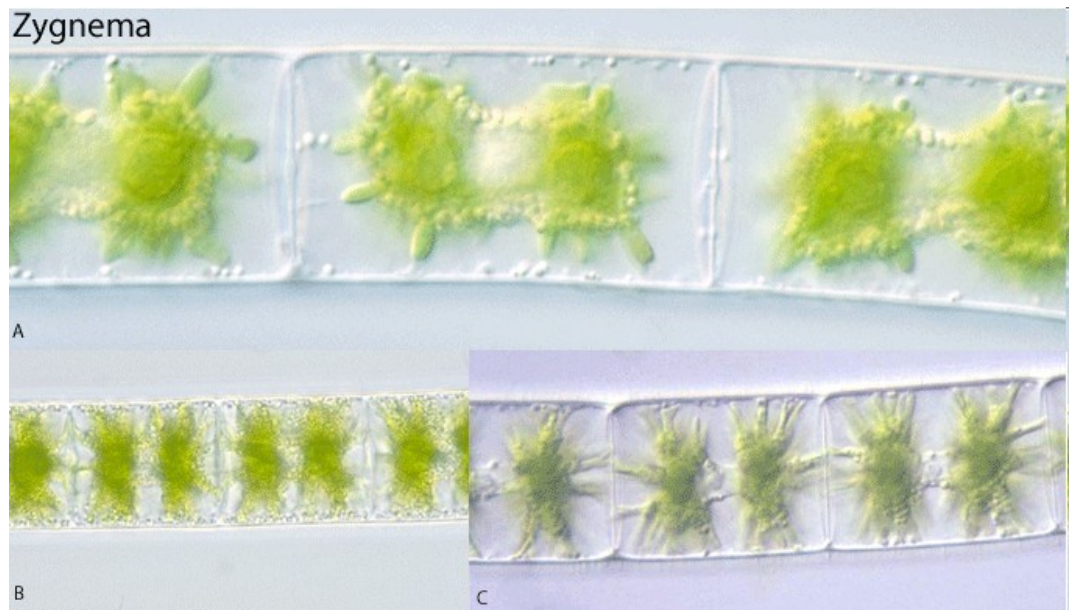


# scalariform and lateral conjugation



# Zygnematales

## Zygnema



A, B after Entwisle et al. (1997)

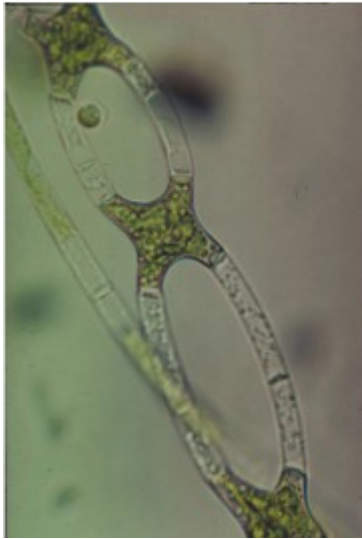
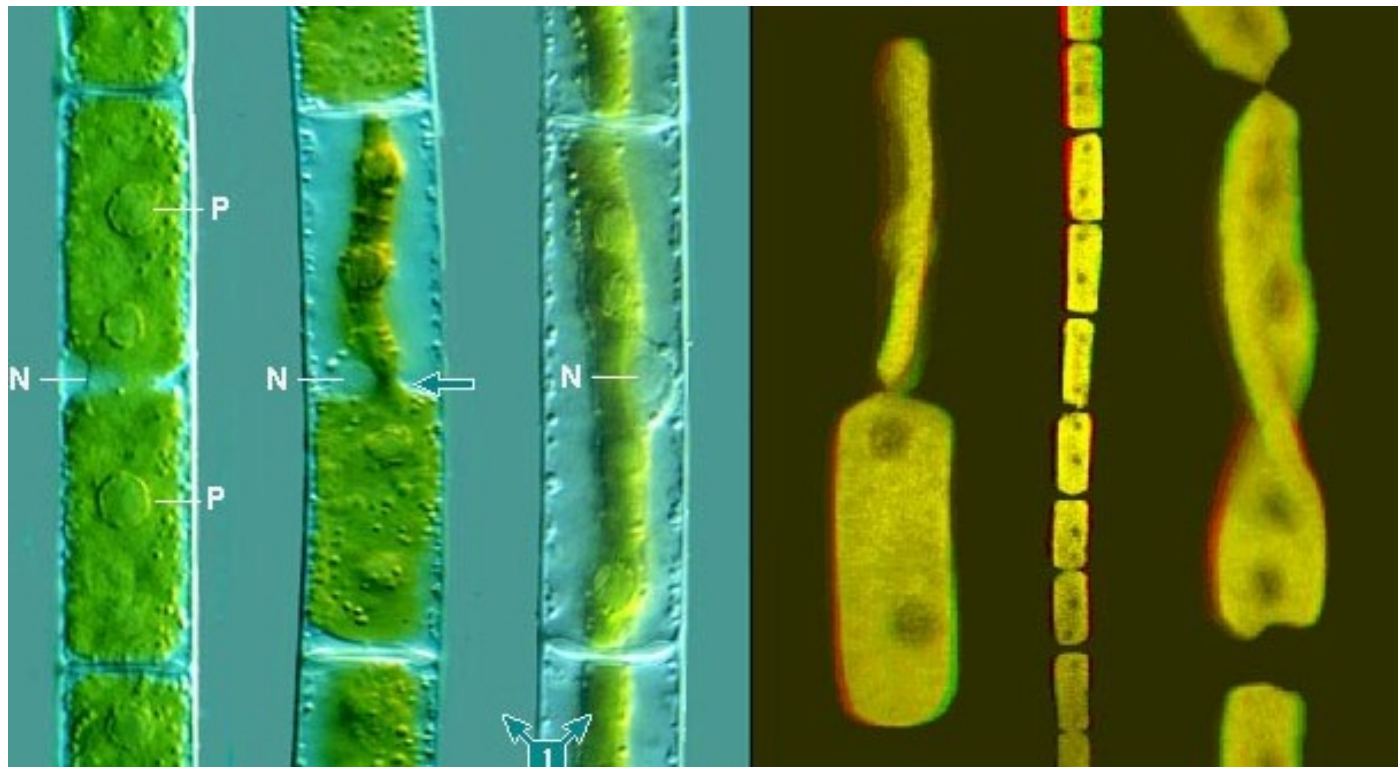
C © Y. Tsukii, see [http://protist.i.hosei.ac.jp/Protist\\_menuE.html](http://protist.i.hosei.ac.jp/Protist_menuE.html)



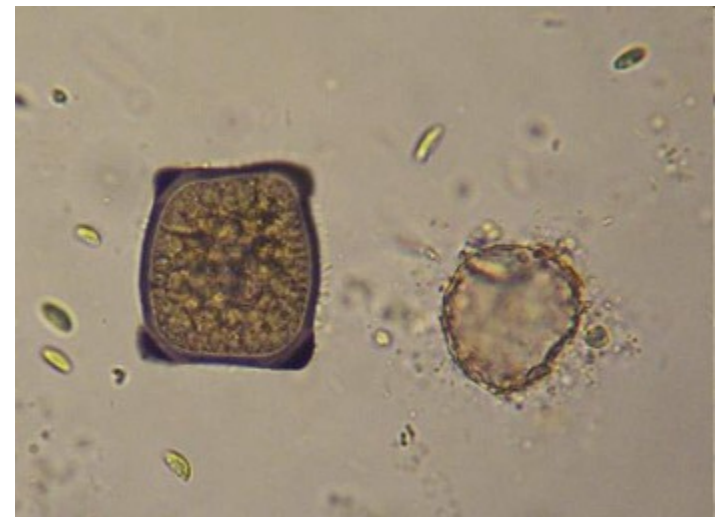
scalariform conjugation

# Zygnematales

## Mougeotia



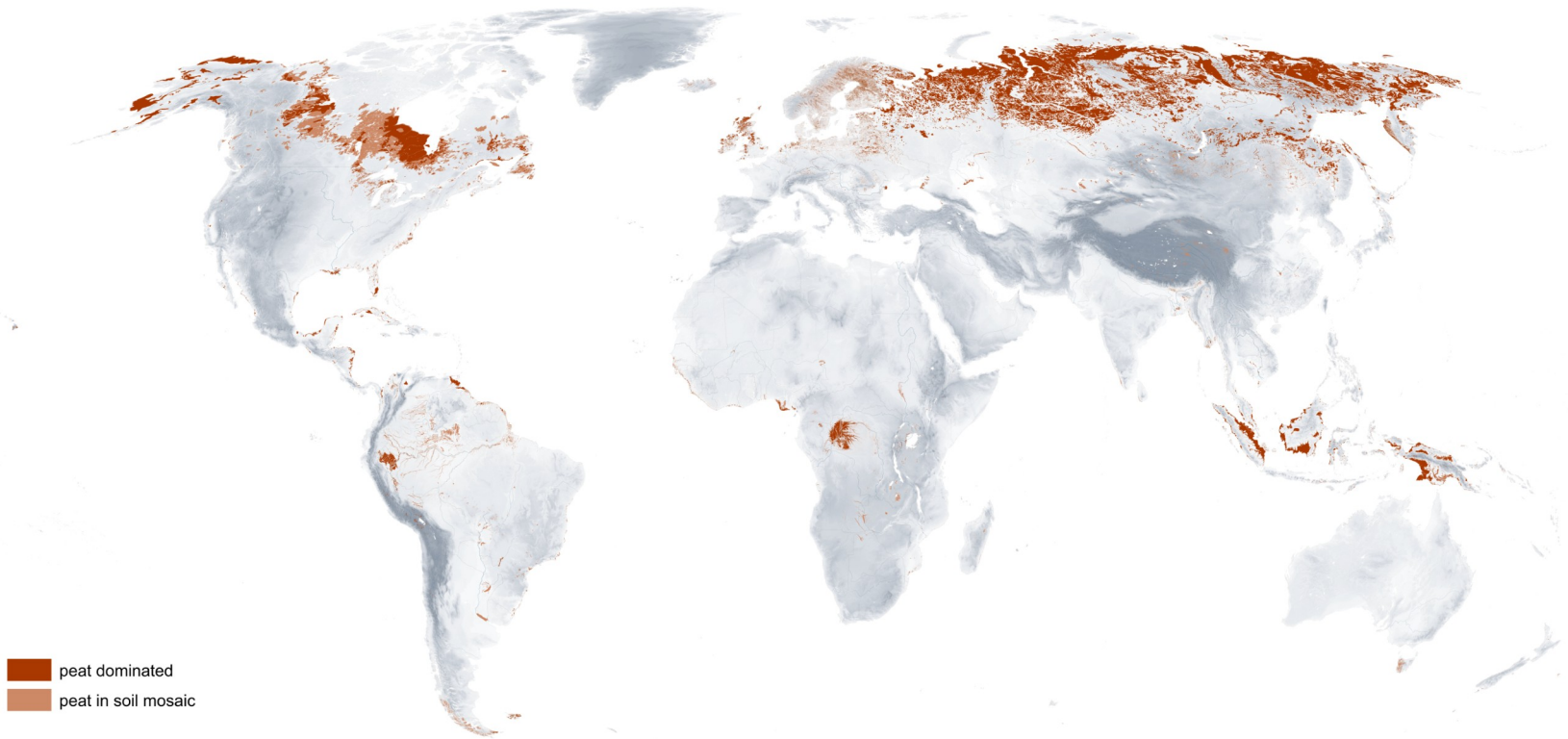
## Cylindrocystis



acidic peatlands  
phytobenthos

zygnematophycean algae in peatland habitats

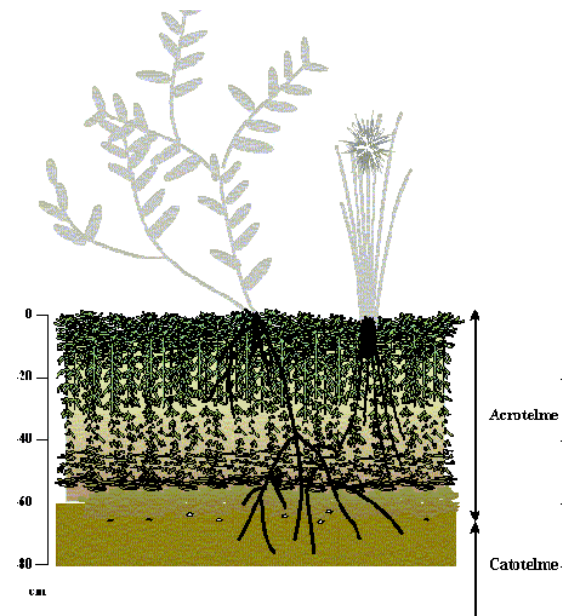




## *Sphagnum*-dominated boreal peatlands

acrotelm vs. catotelm  
(anaerobic, permanently humid)

acidity caused by dissociation of humic acids



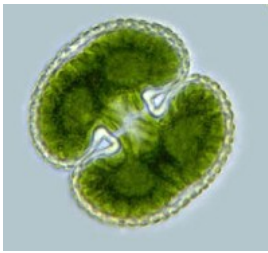
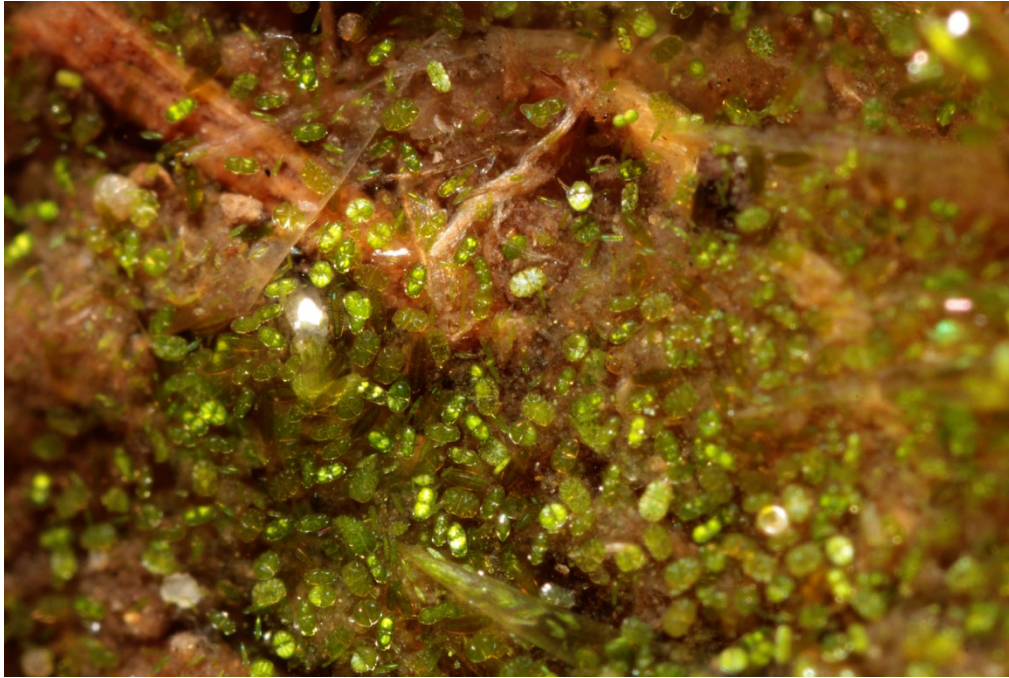


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bogs, transient bogs, fens  $\longleftrightarrow$  ombrothopic, minerotrophic  $\longleftrightarrow$  catotelm, acrotelm

# Desmidiatales



unicellular or chain-like filamentous taxa

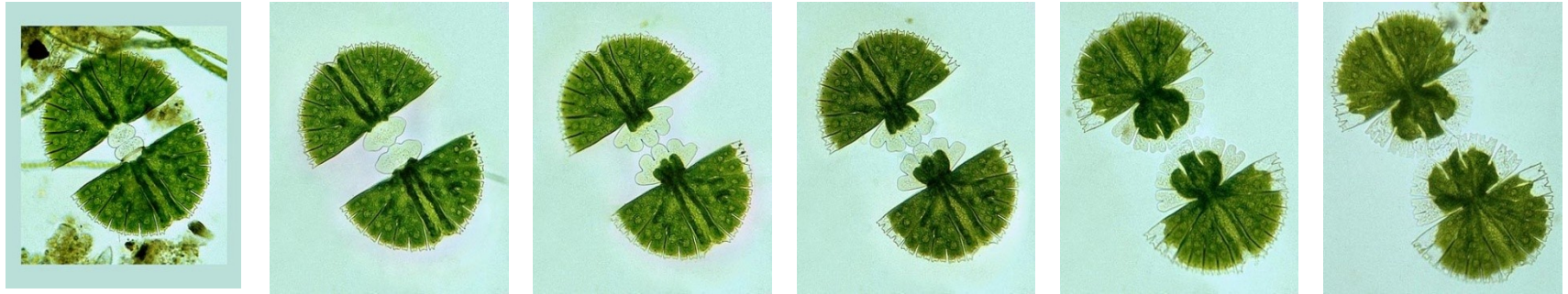
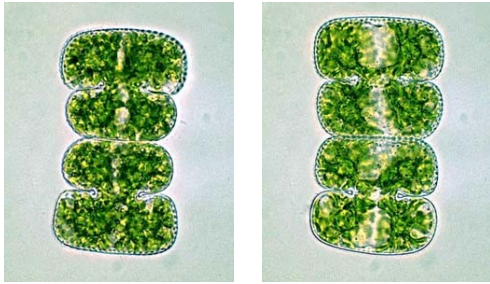
cells formed by two opposite semicells mirroring each other (Desmidiaceae)

pores in the cell wall (mostly Desmidiaceae)

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



# asexual reproduction

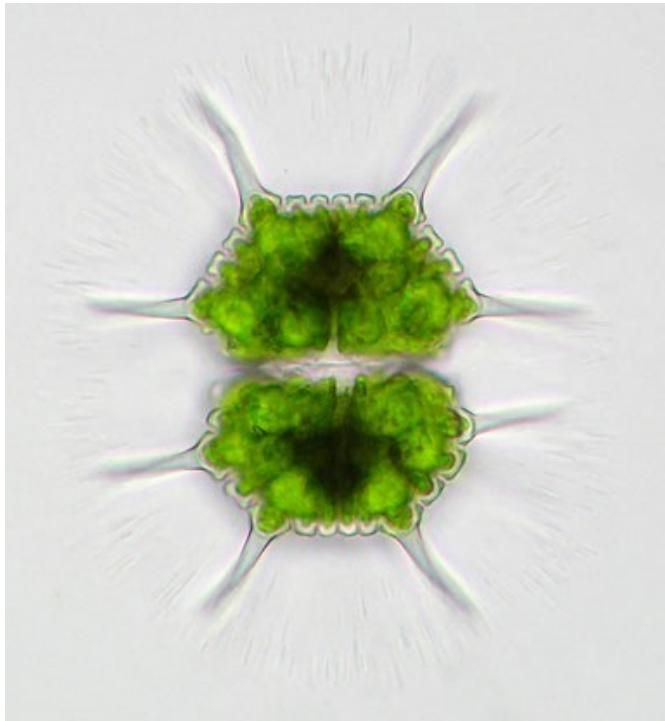
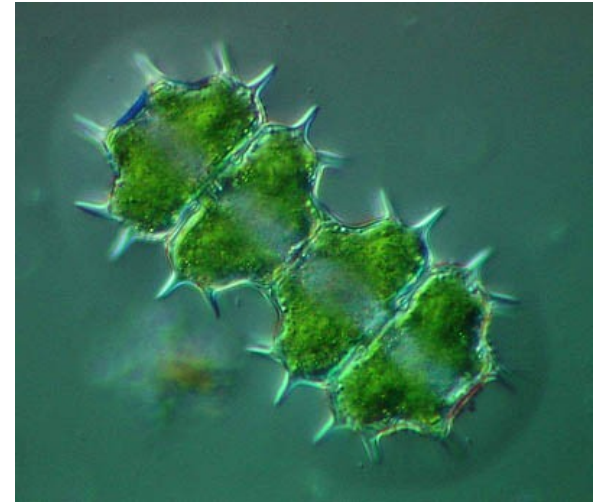
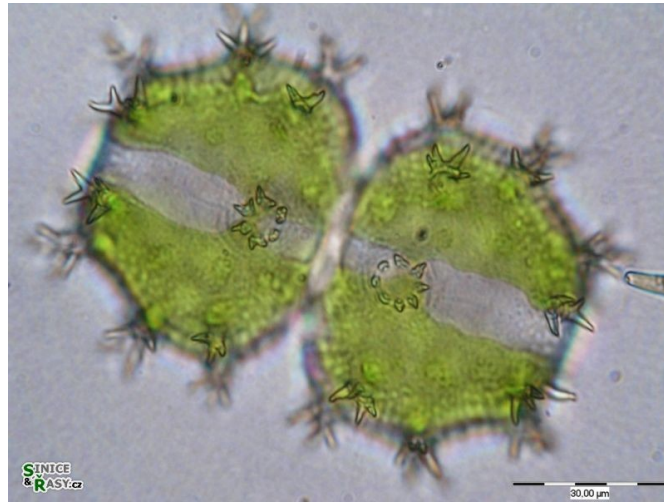


results in cells composed of two unequally old semicells

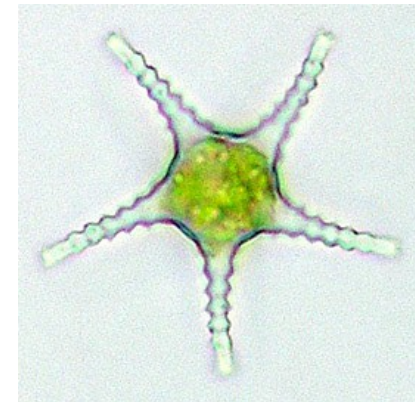
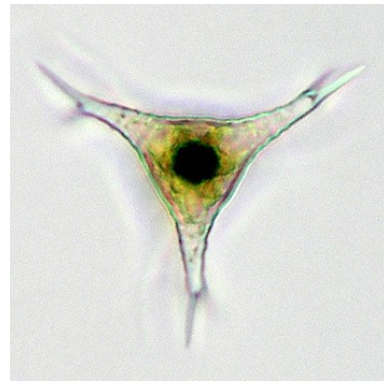
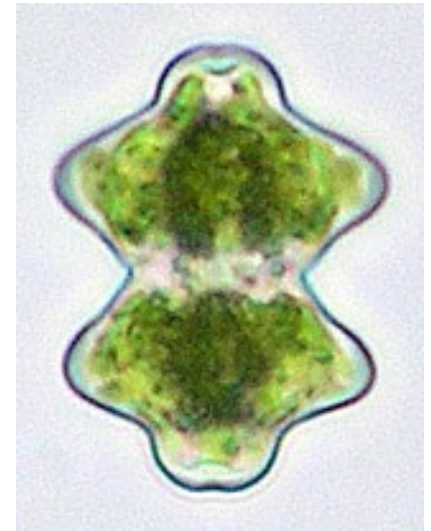
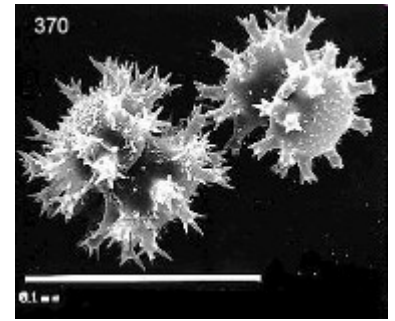
# Closterium



# Xanthidium

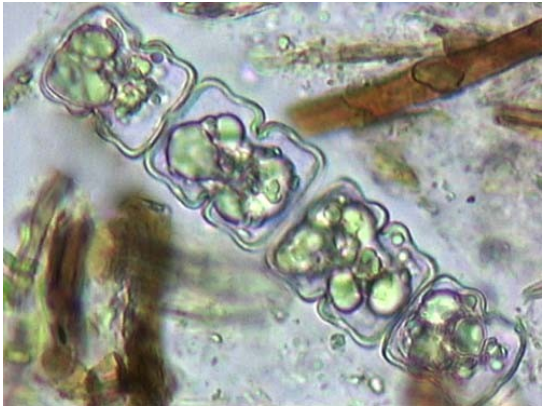
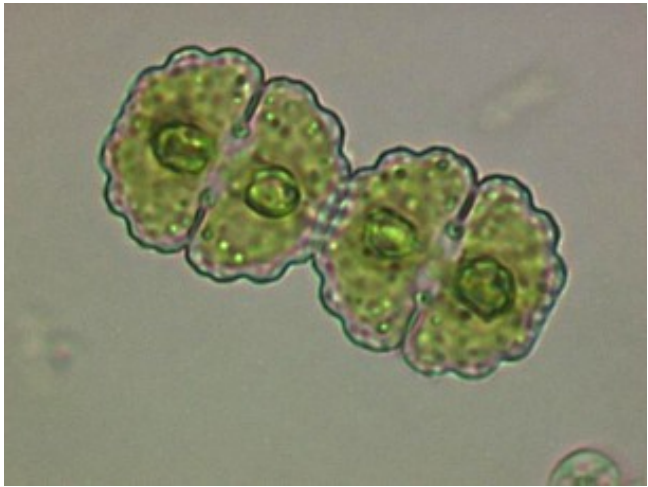
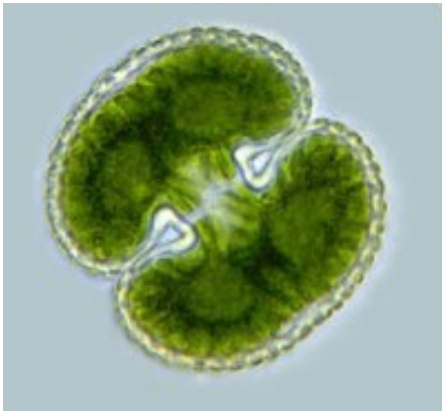


# Staurastrum

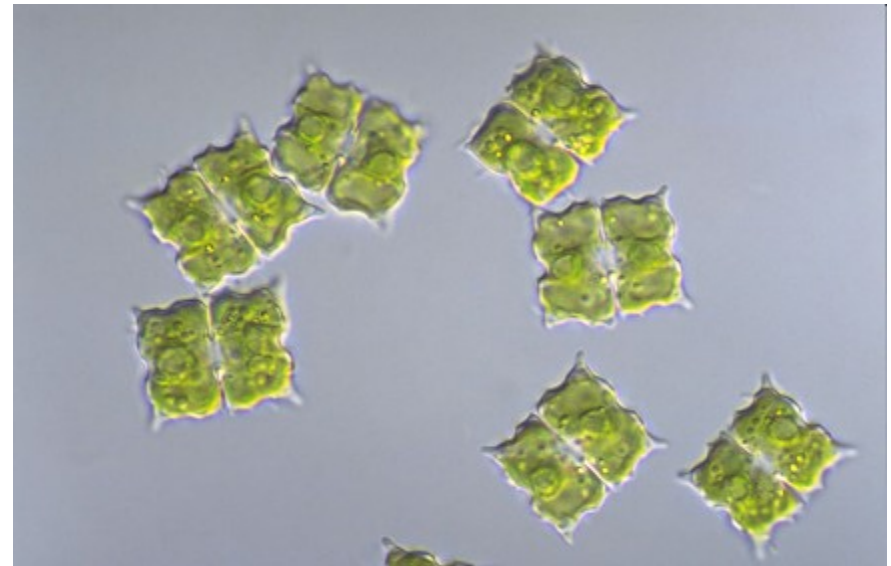
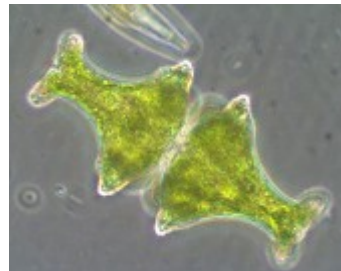
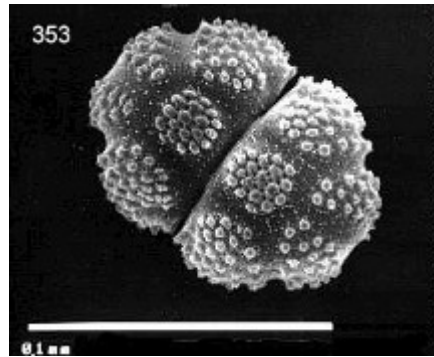
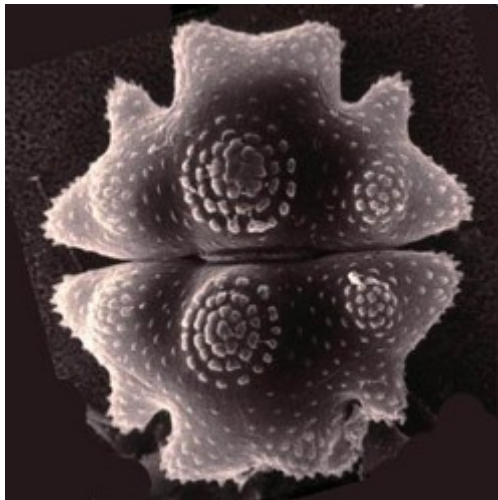
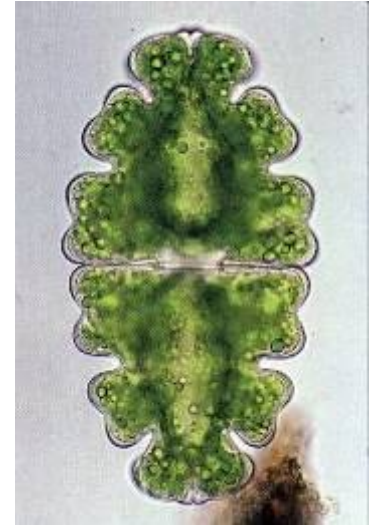
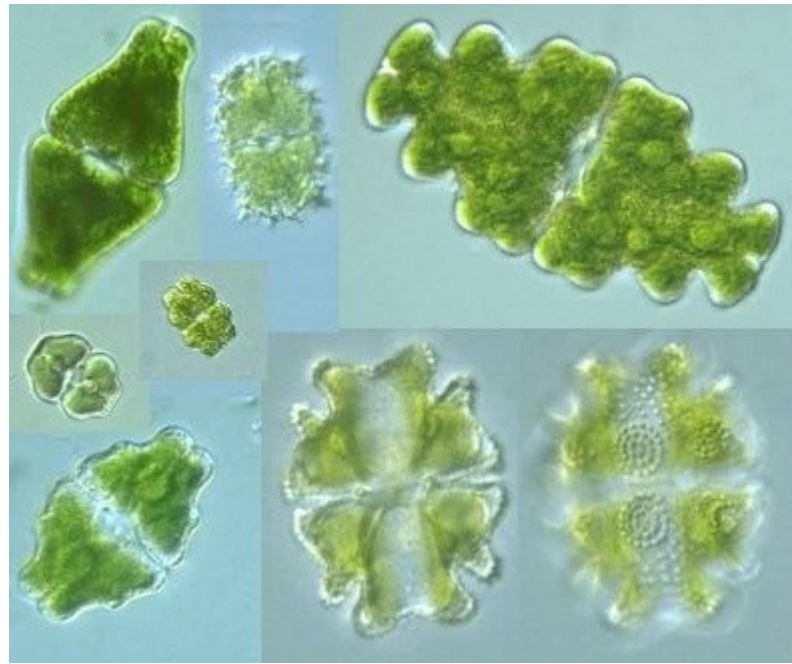
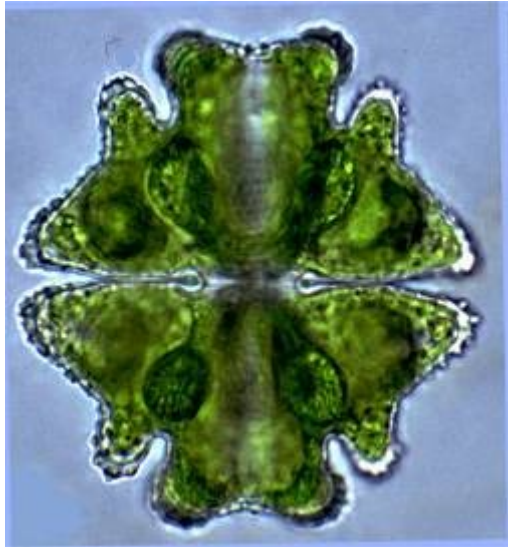


semicells with more than two radially symmetric parts

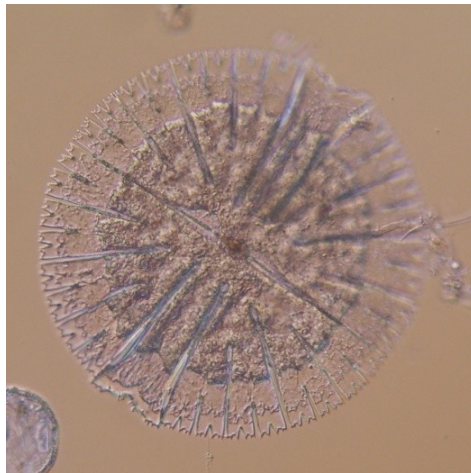
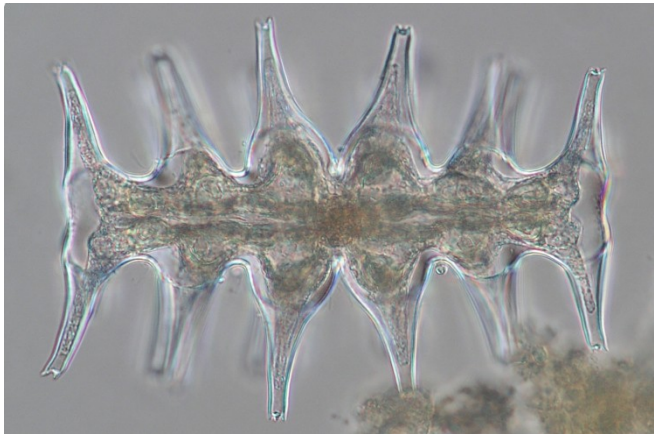
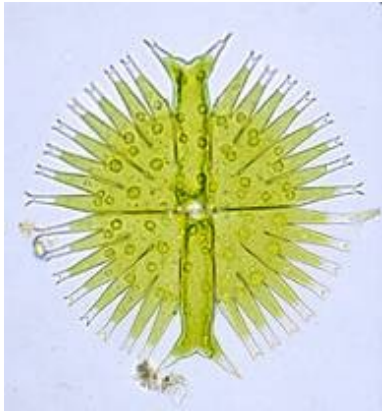
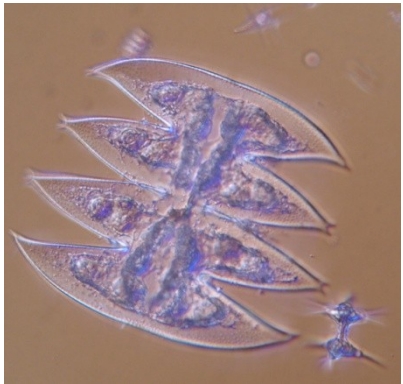
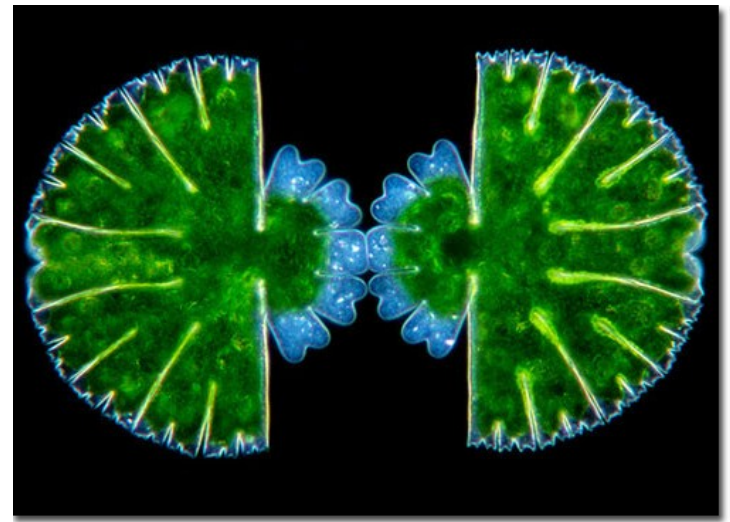
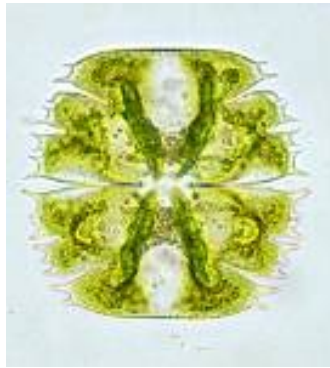
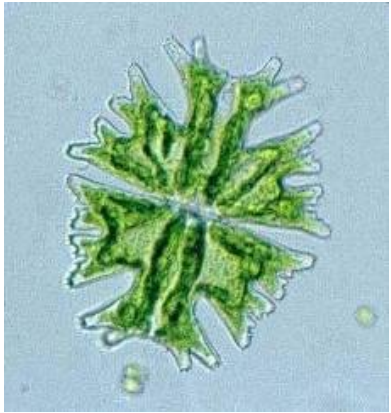
# Cosmarium



# Euastrum



# Micrasterias



# lobe patterning in developing turgor-reduced cells

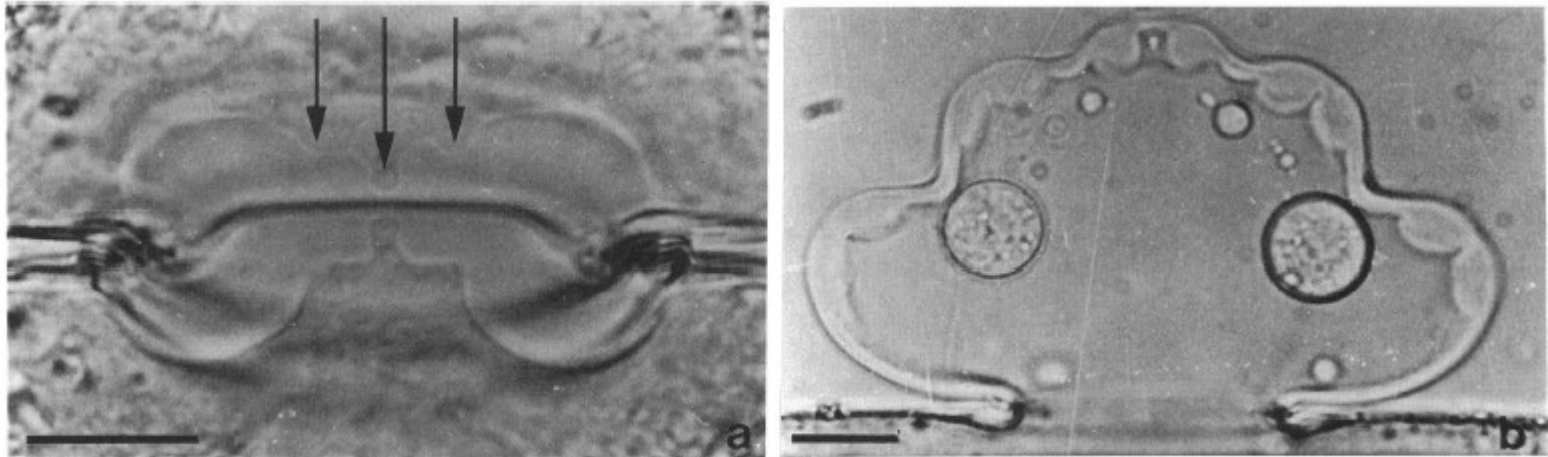


FIG. 11. (a) Septum initial pattern developed in 0.22 M glucose. At both sides of the septum, one central (arrow) and two lateral (arrows) minimum zones are visible. Bar, 20  $\mu$ m. Reprinted from reference 28 with permission. (b) Accumulation pattern of primary-wall material resulting from turgor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

concept of the morphogenetic plasmatic templates

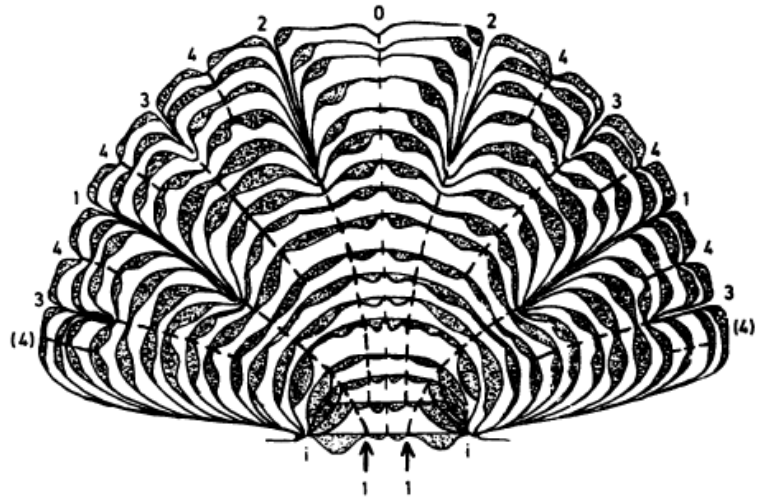
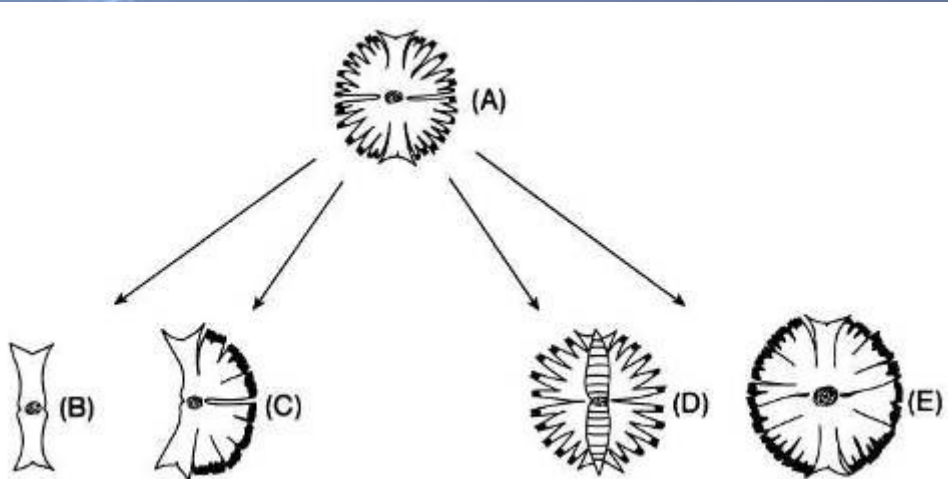
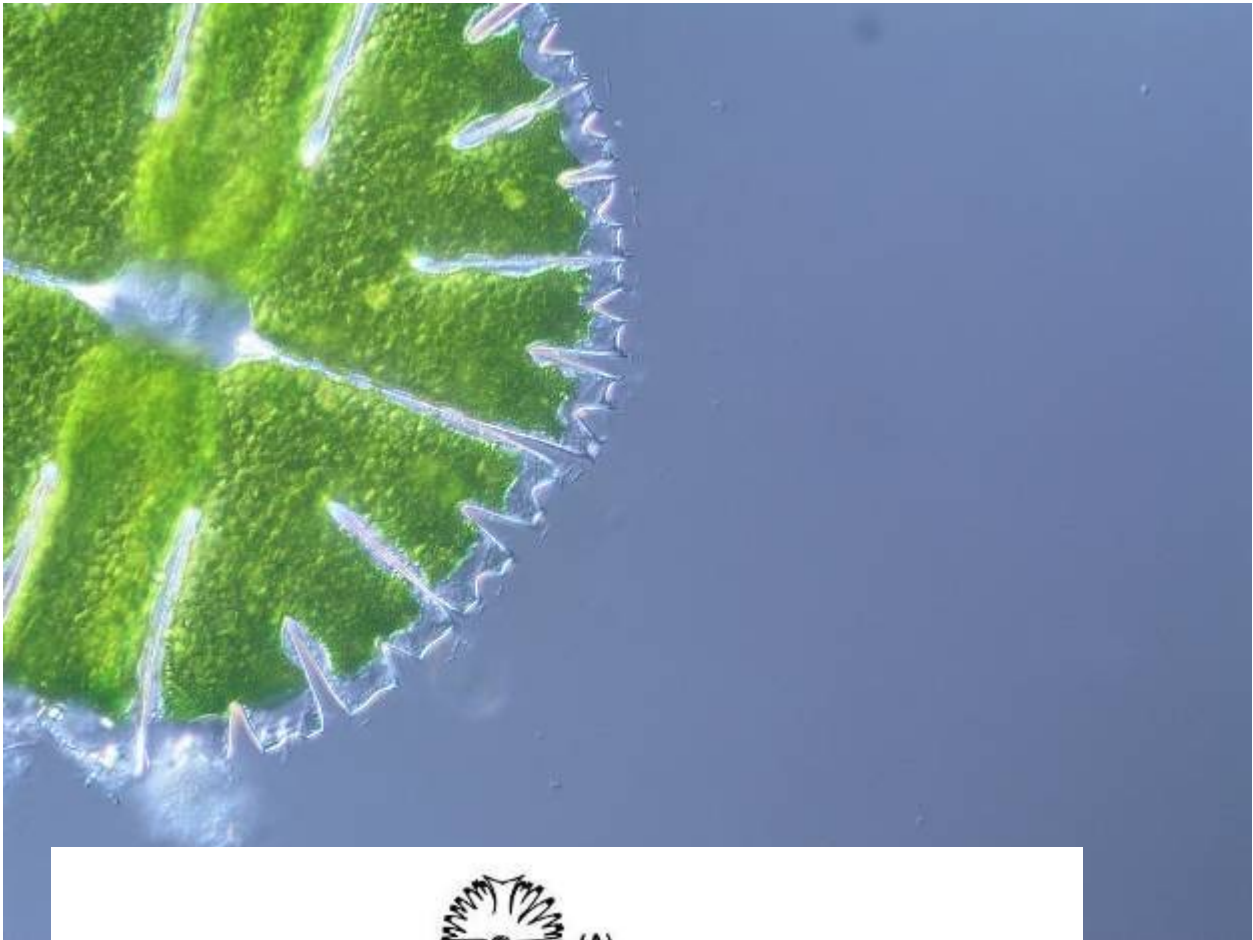
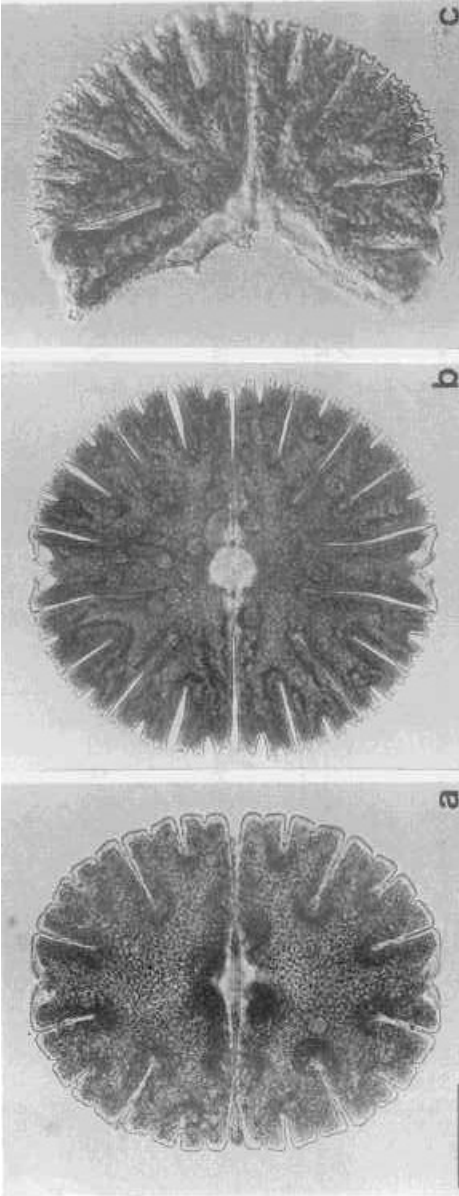


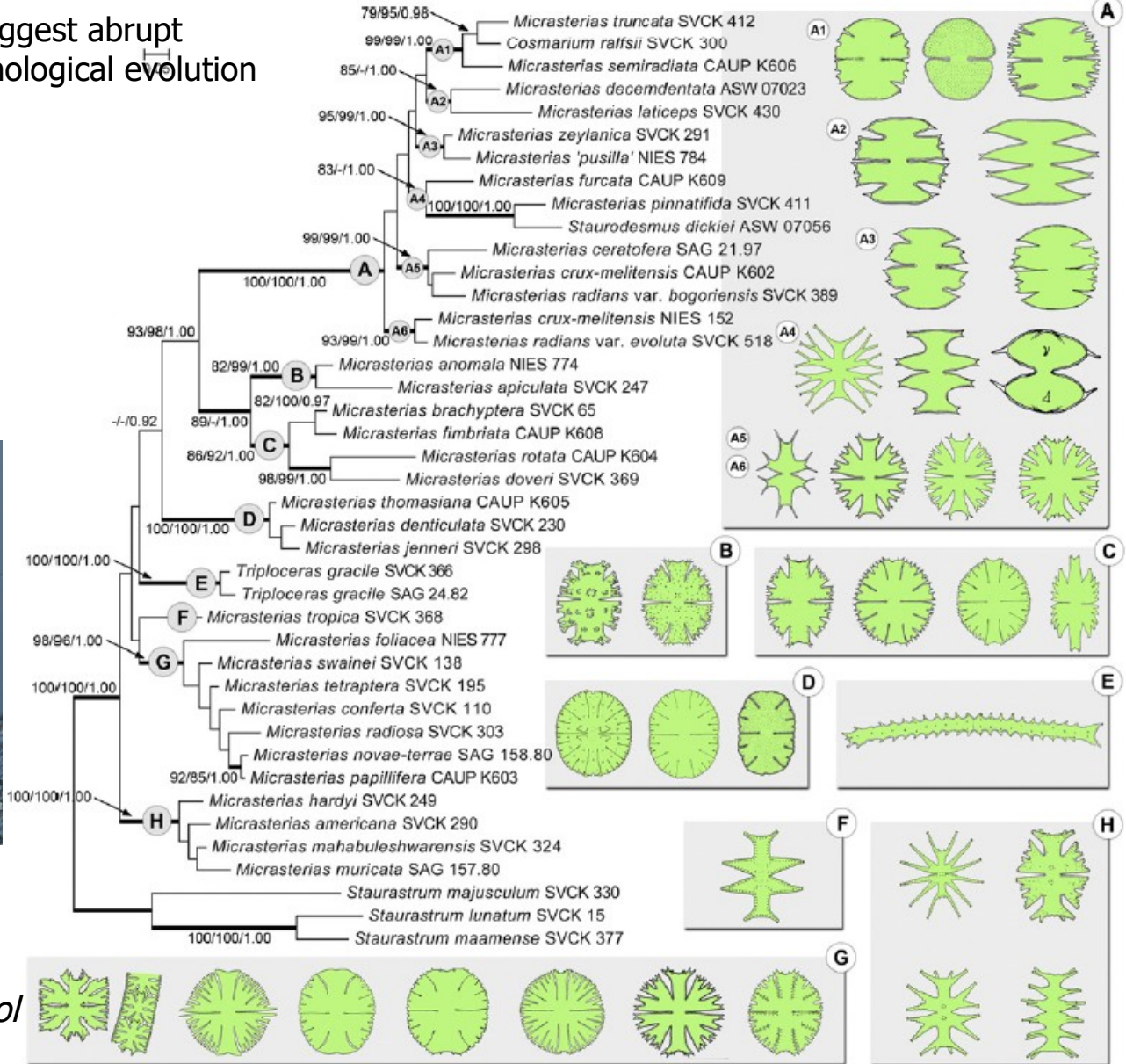
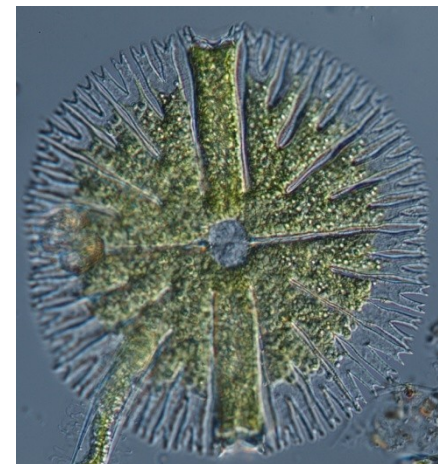
FIG. 12. Pattern of wall material accumulation under turgor reduction and schematic representation of the developmental steps in *M. denticulata*. The minimum zones visualized by turgor reduction correspond to the indentations forming later in cell development. The numbers indicate the lobe indentations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



modular morphogenesis



# Micrasterias phylogeny suggest abrupt changes in rates of morphological evolution

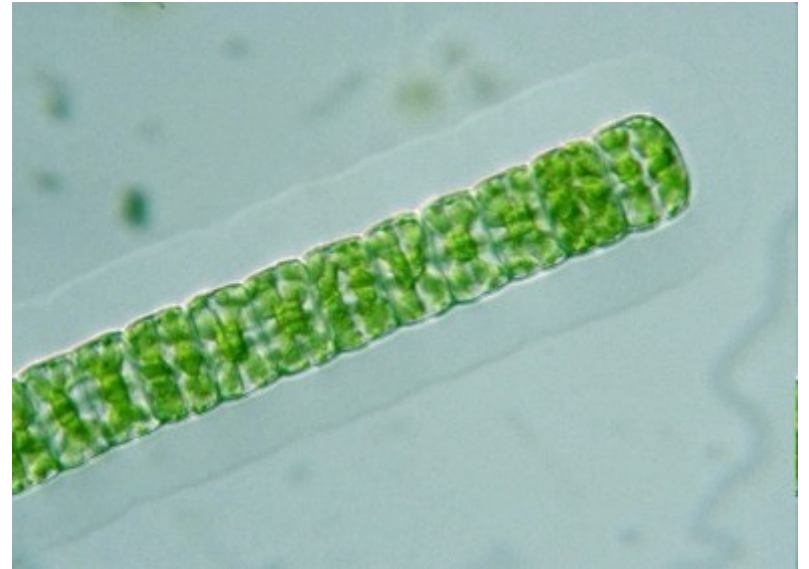
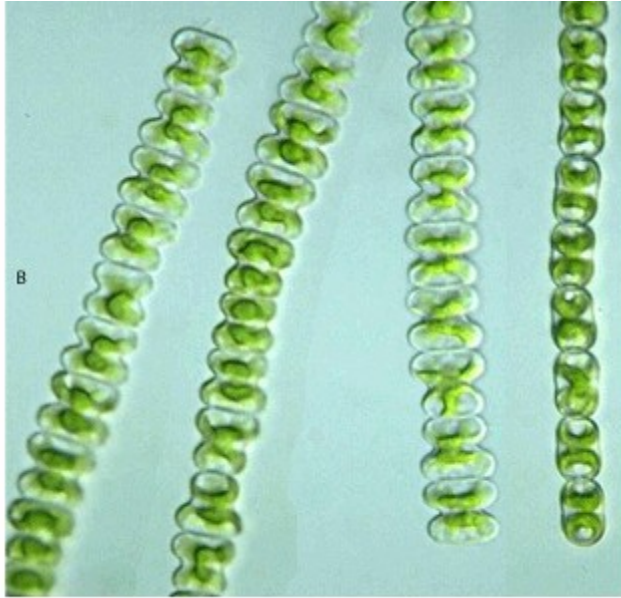
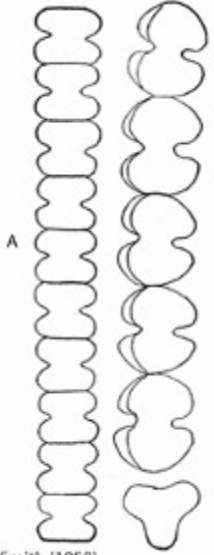


Škaloud et al., 2011, Mol Phyl Evol 61: 933-943.

Fig. 3. Bayesian analysis based on the combined and partitioned SSU rDNA, *psaA*, and *coxIII* dataset using a GTR +  $\Gamma$  model for SSU rDNA region and 3rd codon position of *psaA* gene, F81 +  $\Gamma$  model for 1st and 2nd codon position of *psaA* and *coxIII* genes, and HKY model for 3rd codon position of *coxIII* 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

Spondylosium



A after Smith (1950)

B © Y. Tsukii, see [http://protist.i.hosei.ac.jp/Protist\\_menuE.html](http://protist.i.hosei.ac.jp/Protist_menuE.html)

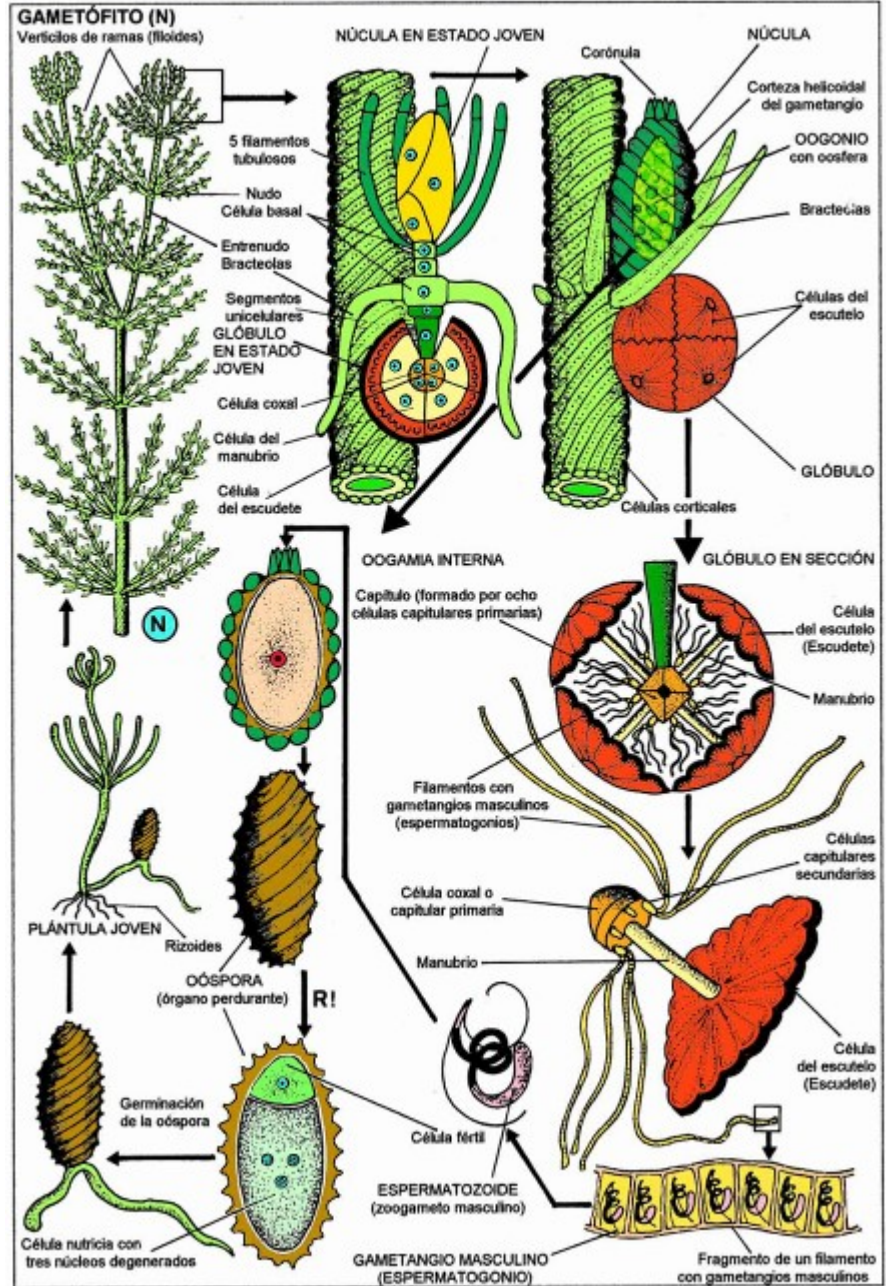


# Charophyceae

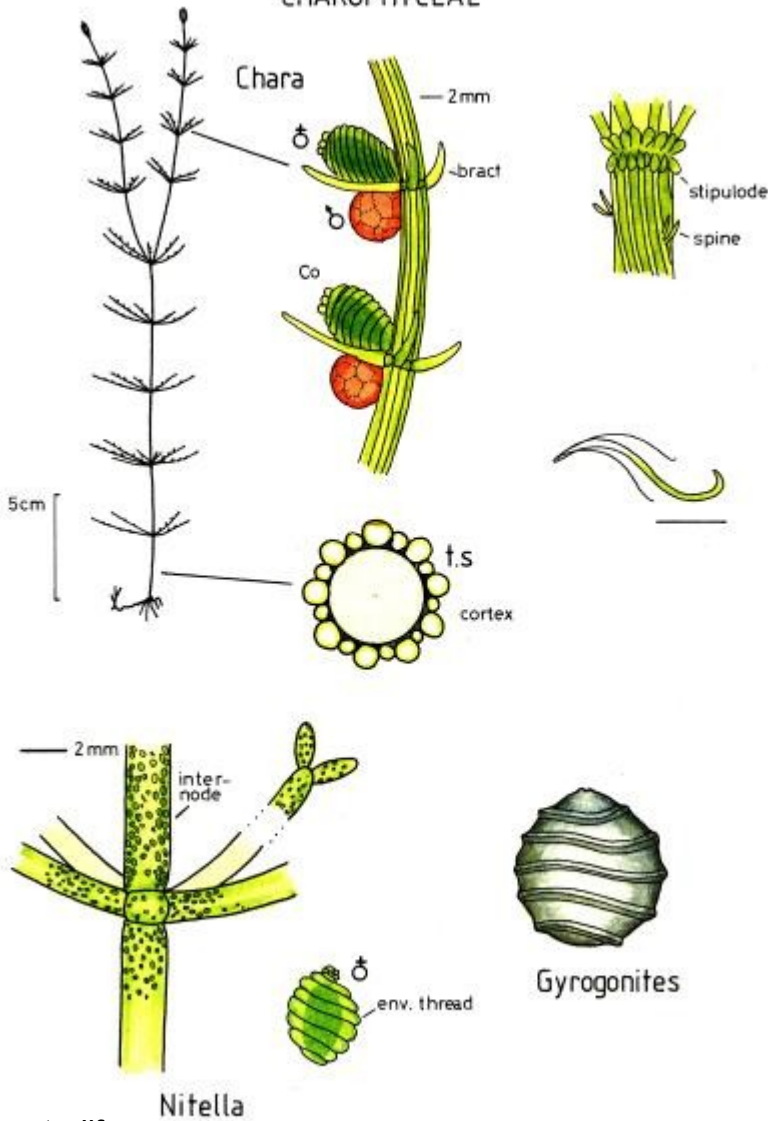
(stoneworts, parožnatky)



**CICLO DE *CHARA SP.* (MONOICA) (Carofíceas, algas verdes)  
MONOGÉNÉTICO HAPLOFÁSICO. ORGANISMO HAPLOBIÓNTICO**

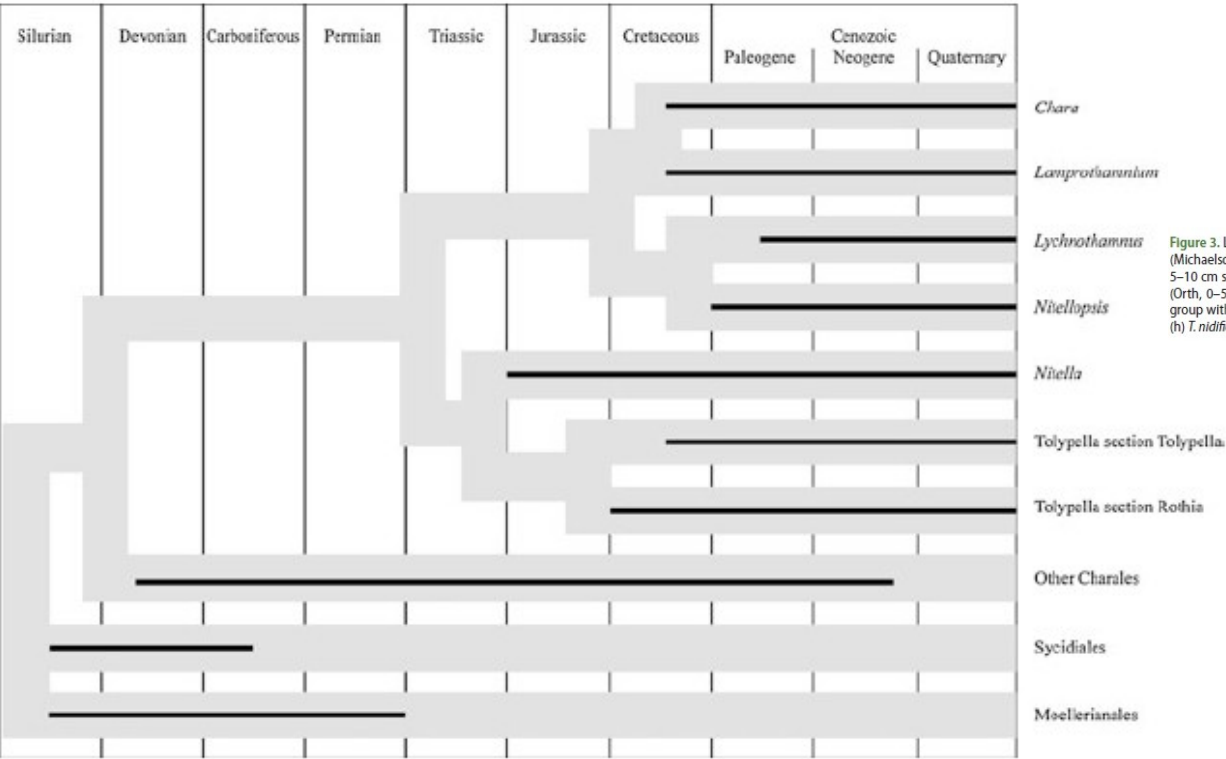


**CHAROPHYCEAE**



[freshwaterlife.org](http://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 Moelleriales. 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)

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

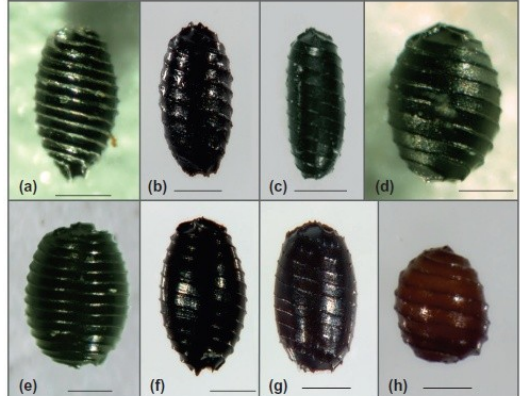


Figure 3. Lateral view of the oospores of the charophytes (scale bars = 200 µm). (a) *C. aspera* with prominent ridges and basal cage (Michaelsdorf, 0–5 cm sediment depth); (b) intermediate form of the *C. canescens/C. aspera* group without basal cage (Michaelsdorf, 5–10 cm sediment depth); (c) *C. canescens*, 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).

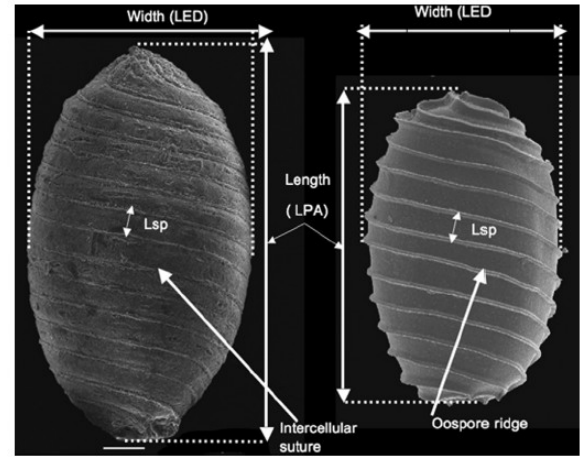
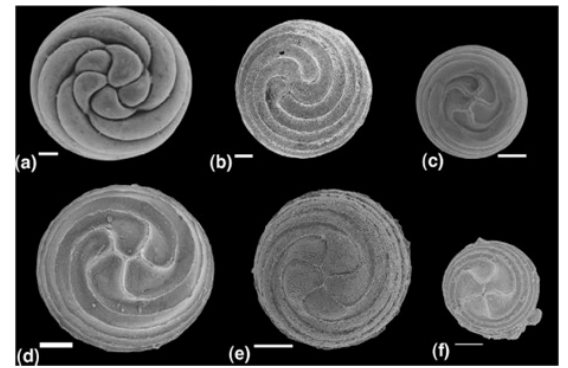


Fig. 9. Parameters for measurements and description of gyrogonites (left) and oospores (right). Scale bar: 100 µm.

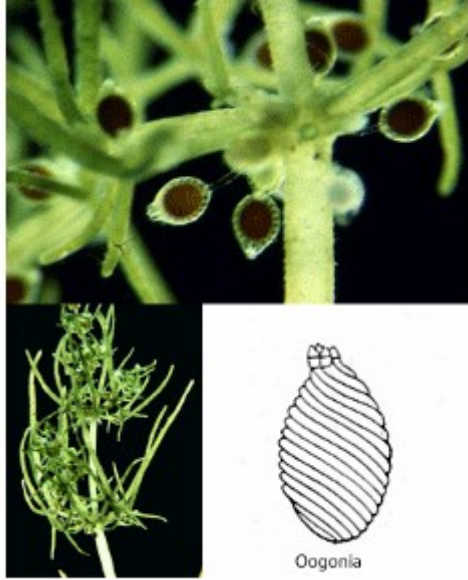


# Tolypella

Tolypella



A, D after Prescott (1951)  
B, C © A. van Beem, see <http://www.kranswieren.nl/>

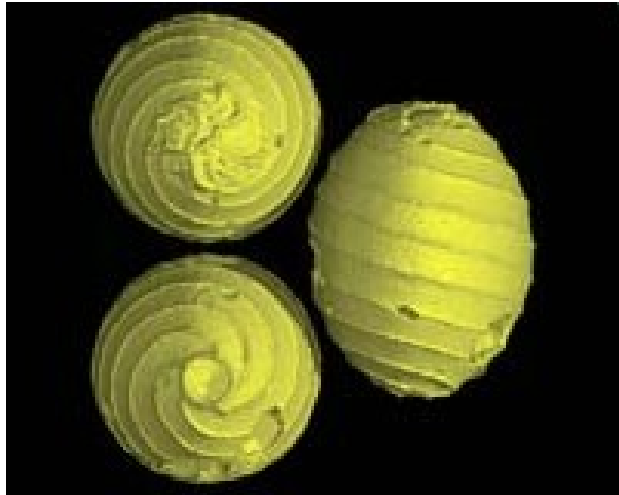


Oogonia

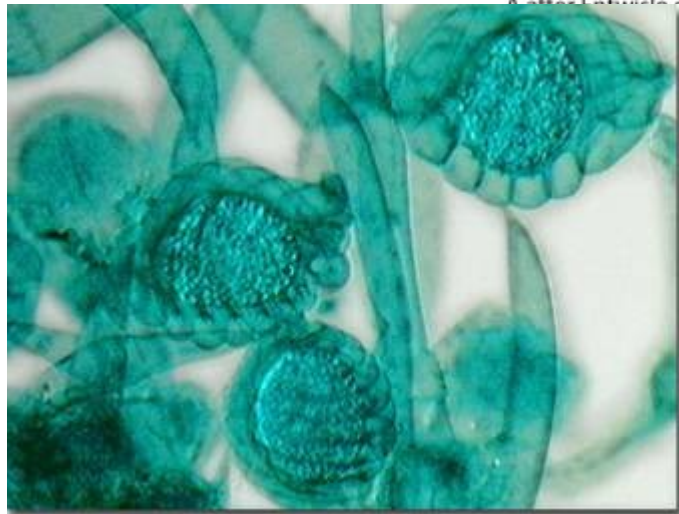
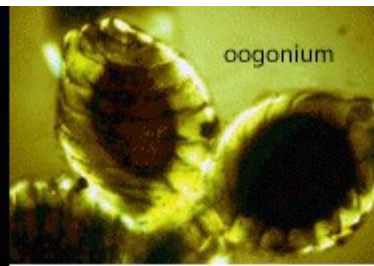
# Chara



fossilized zygotes (gyrogonites)



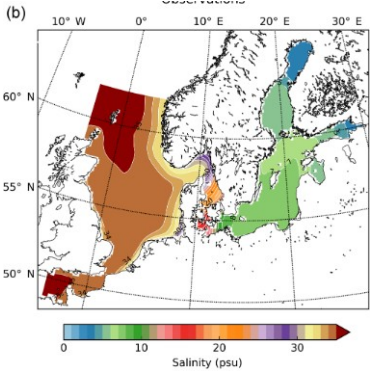
# Nitella



A after Estuade et al. (1997), B after Prescott (1951)  
see <http://www.kranswieren.nl/>



# distribution and ecology of stoneworts



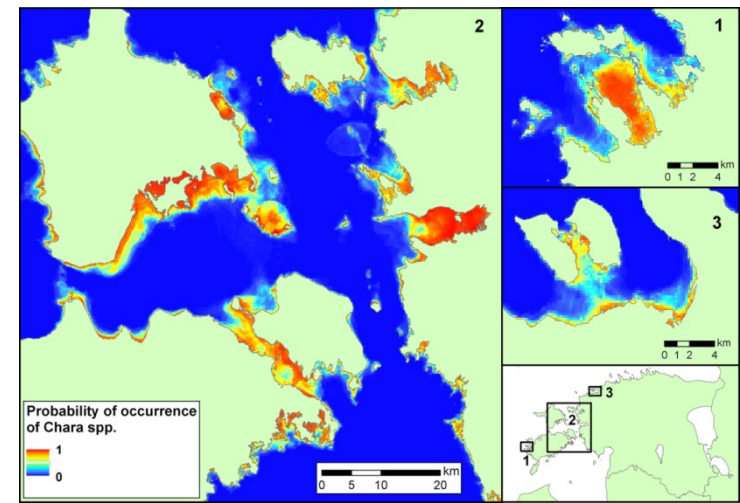
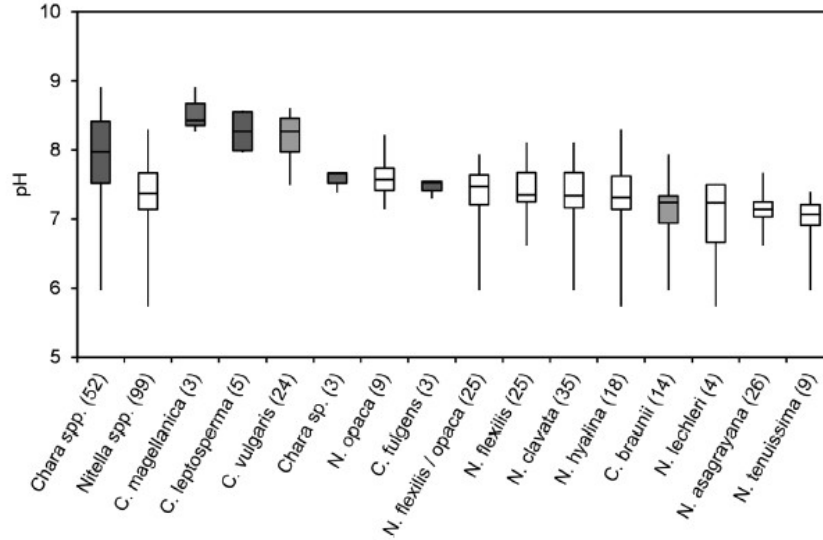


Fig. 3. Probability of occurrence of charophytes as predicted by the BRT model. The full spatial extent of the modelled prediction is not shown as the zoom level for the full display would render the map hard to read. Instead of the full extent, three areas of higher probability of *Chara* spp. are shown.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

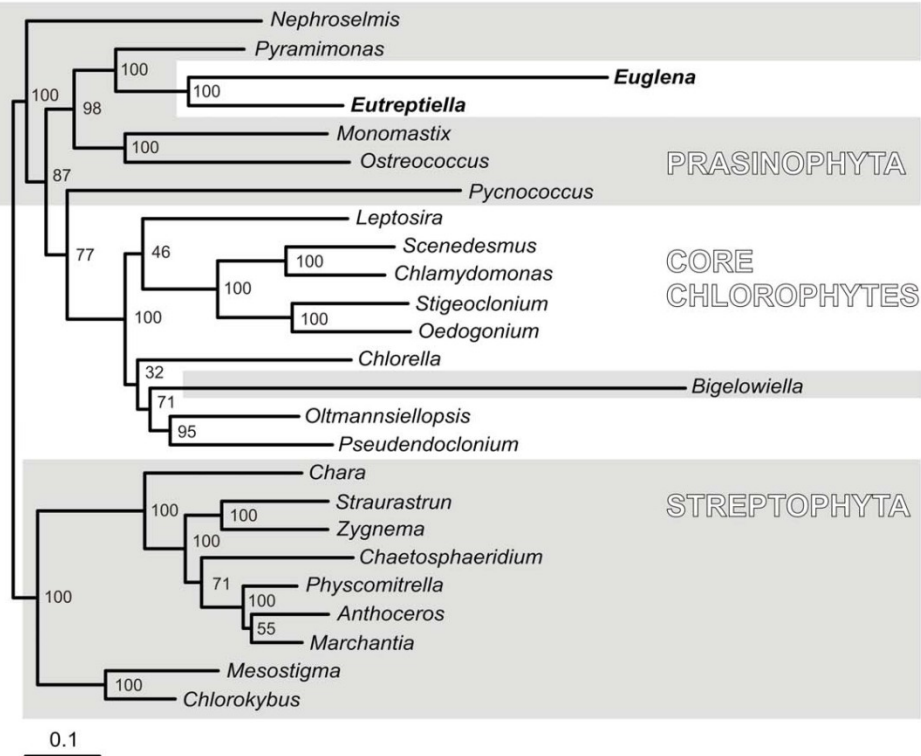


vast majority of charaleans  
needs **neutral to alkaline** pH

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

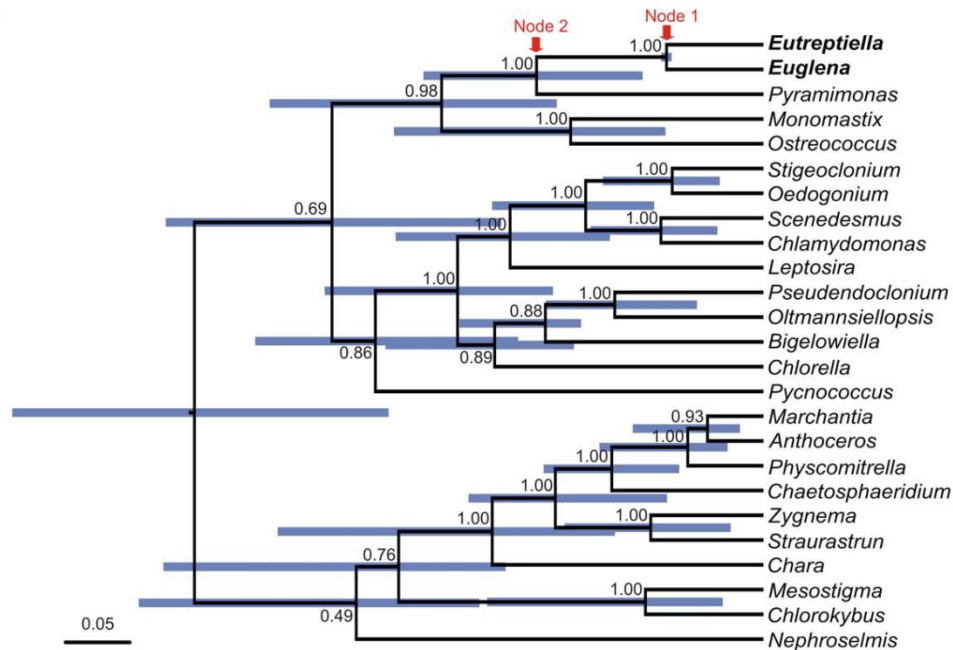
Figure 2. Box-Whisker plot of pH values for taxa with at least 3 values in the water chemistry dataset. Minimum, maximum and median pH are given as well as 50% and 75% quartiles (boxes). Number of values are given in brackets; *Chara* spp. marked in grey.

A



## Phylogenetic history of secondary chloroplasts

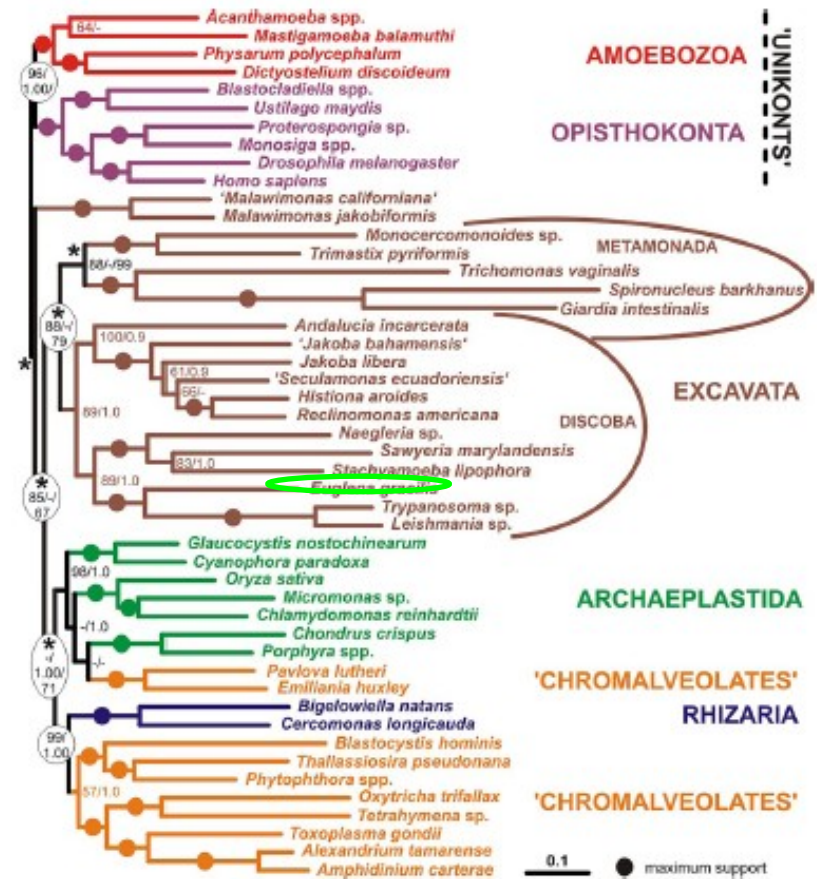
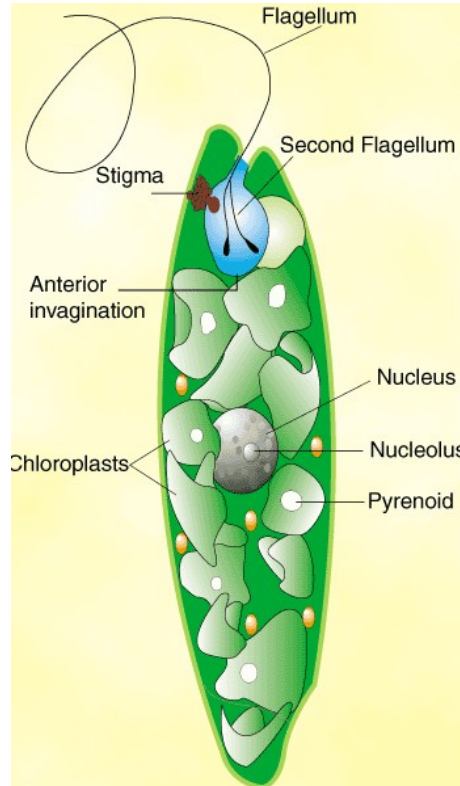
B



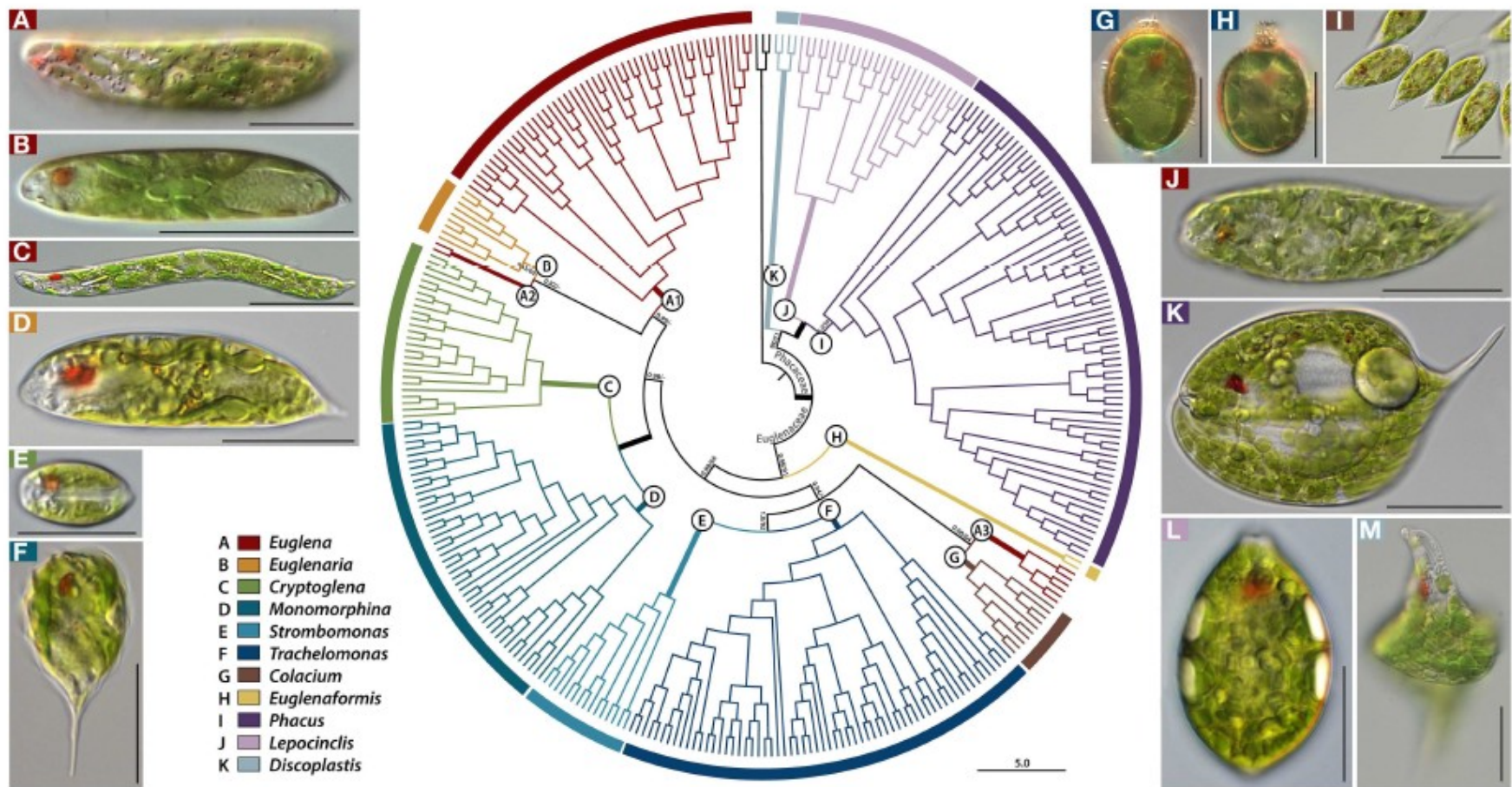
# Euglenophyta (Euglenozoa, Euglenida)

skupina sladkovodních bičíkoců patří do superskupiny Excavata; mají sekundární chloroplasty

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 +  $\Gamma$  model; branch-lengths were calculated in RAXML using the WAG +  $\Gamma$  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.



**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)** *Monomorpha pyrum* with larger discoid chloroplast; **(G)** *Trachelomonas* sp. with

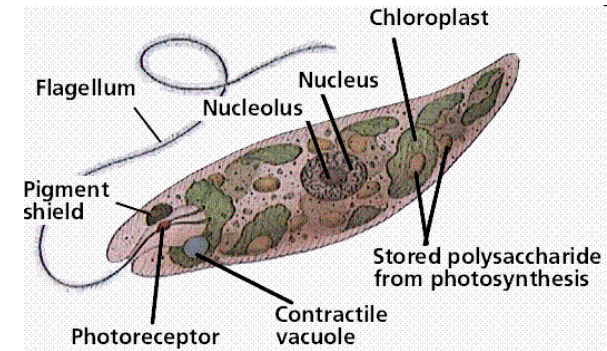
diplopyrenoid in larger discoid chloroplast; **(H)** *Trachelomonas* sp. with haplopyrenoid in larger discoid chloroplast; **(I)** *Colacium* sp. Songianggol033107B with haplopyrenoid in larger discoid chloroplast; **(J)** *Euglena* cf. *velata* with diplopyrenoid in deeply lobed chloroplast; **(K)** *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  $\mu$ m.

# Euglena

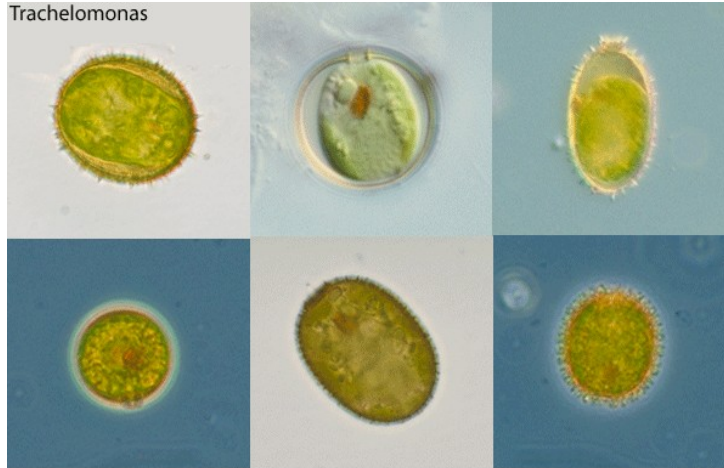
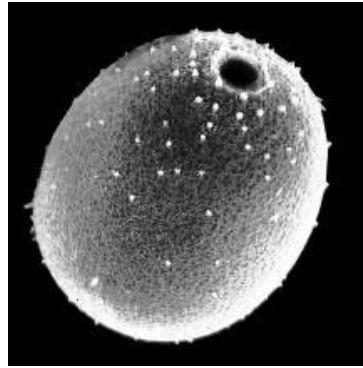
hojný rod ve sladkovodním fytoplanktonu a fyto-bentosu  
více než 80 druhů  
výskyt: přes extrémně kyselé tůňky až po eutrofní plankton



All after Entwisle et al. (1997)



# Trachelomonas a Strombomonas - polysacharidové loriky; Fe<sup>2+</sup>, [Mn<sup>2+</sup>]



All after Entwisle et al. (1997)

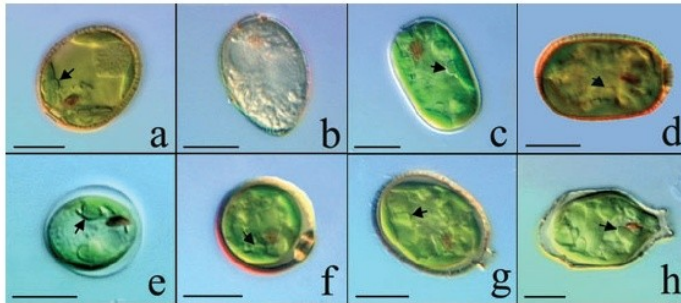
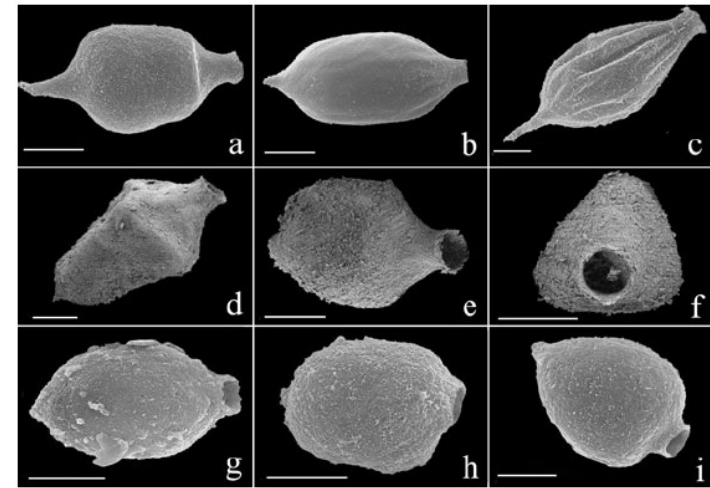
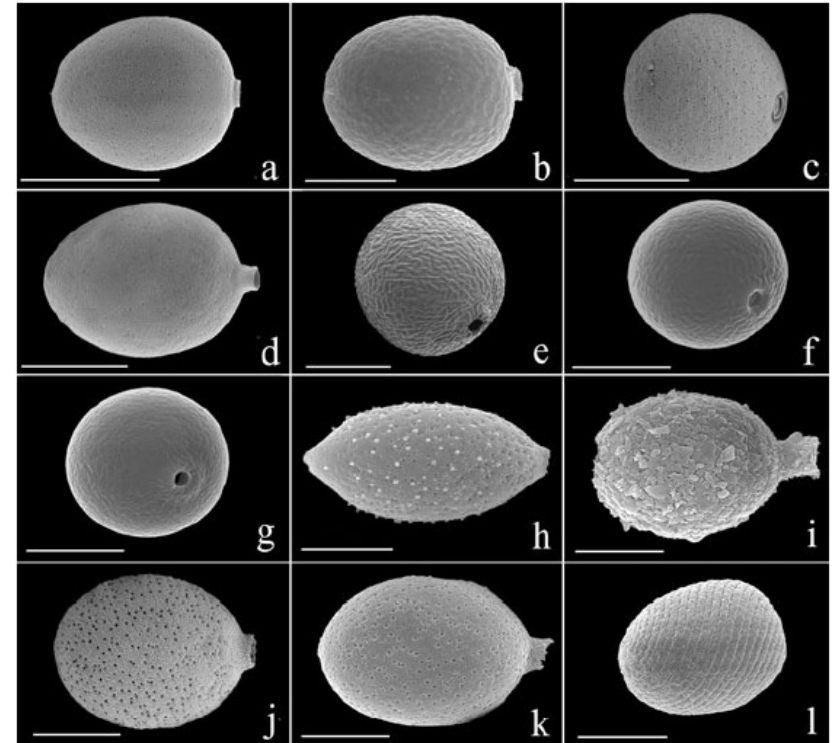


Fig. 5. Light micrographs of *Trachelomonas* (a–g) and *Strombomonas* (h) taxa demonstrating chloroplast number and pyrenoid structure. (a) *Trachelomonas* strain T201. (b) *T. reticulata*. (c) *T. ellipsoidalis*. (d) *T. abrupta*. (e) *T. oblonga*. (f) *T. volvocinopsis*. (g) *T. lefevrei*. (h) *S.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

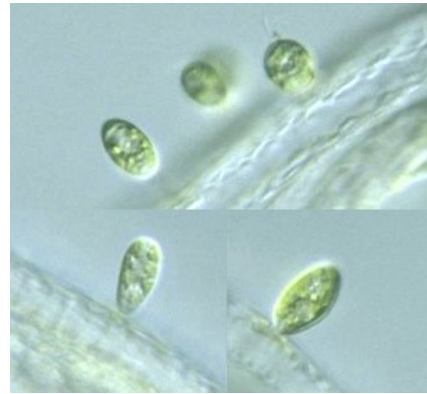


druhově nejbohatší rody (zejména *Trachelomonas*)  
mnoho druhů je ale nejistých  
žijí ve fytoplanktonu

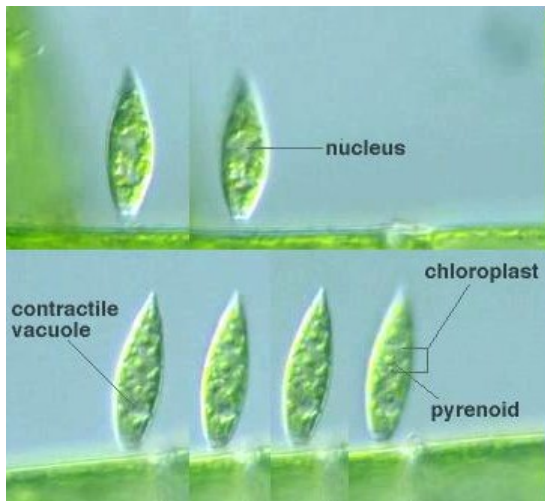
# Colacium



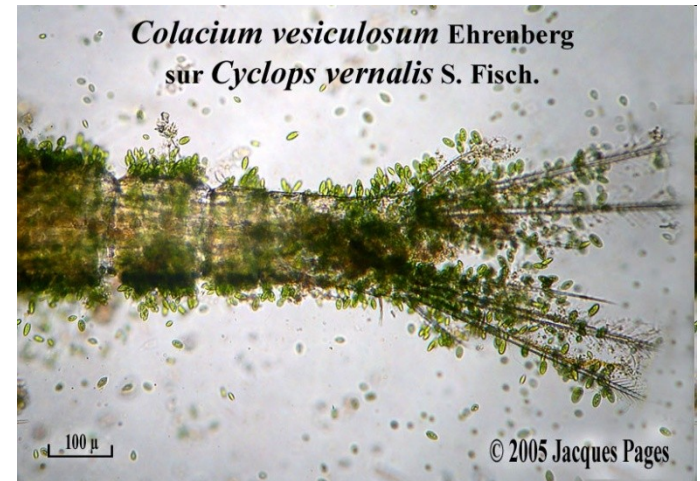
*C. cyclopicola*



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

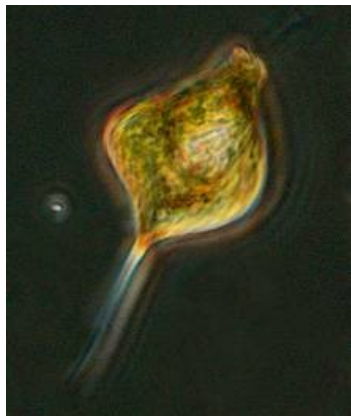


*C. mucronatum*

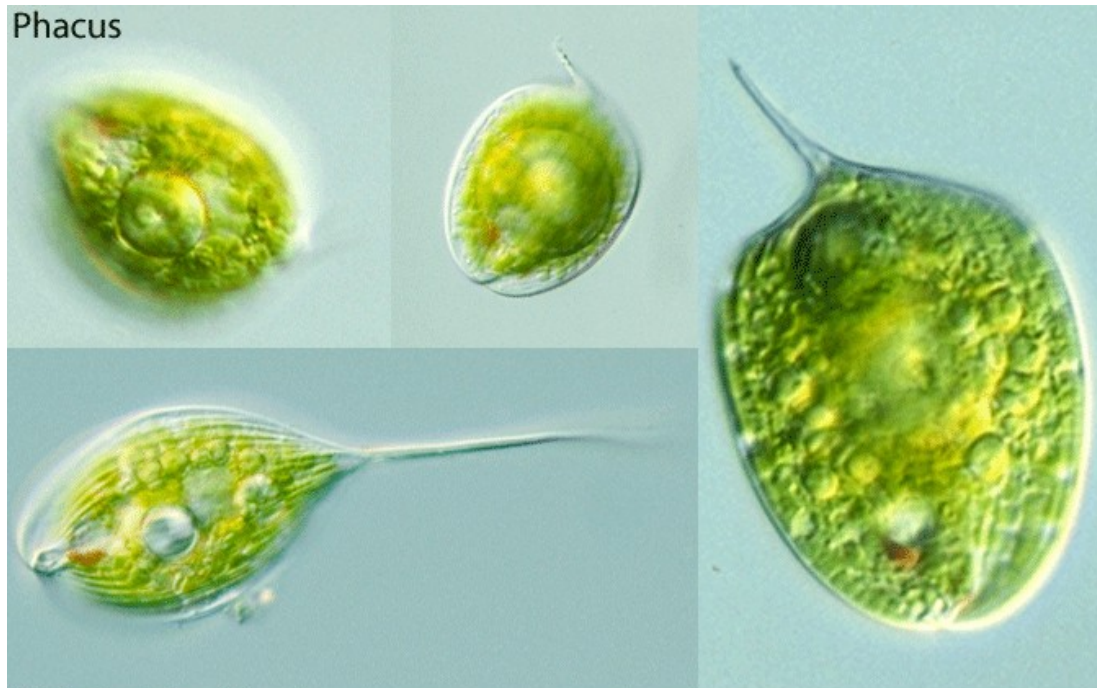




# Phacus



# Phacus



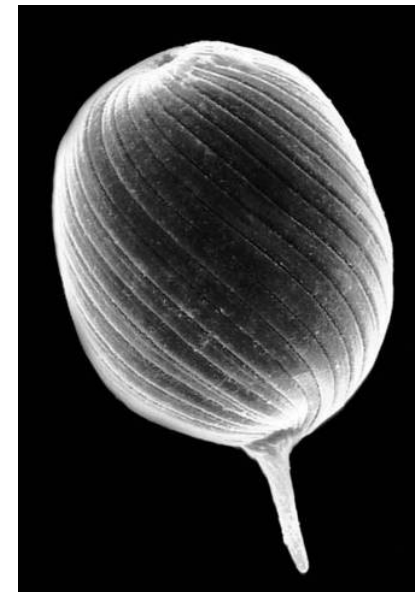
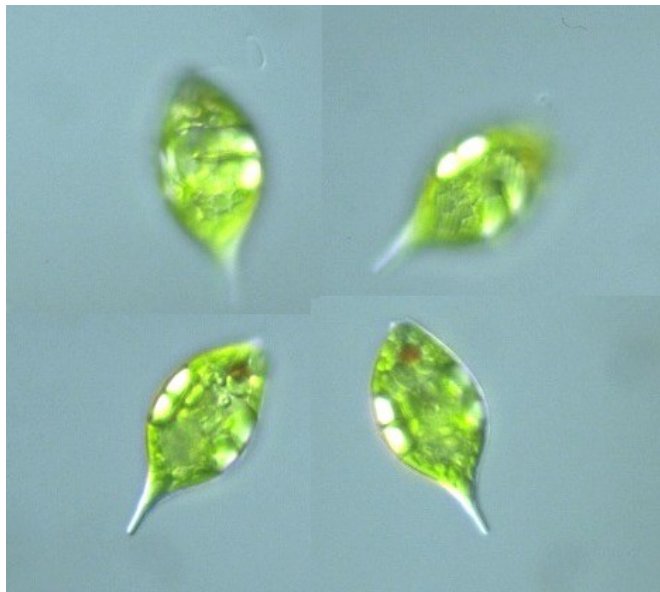
All after Entwisle et al. (1997)

řada druhů má spirální tvar

# Lepocinclis

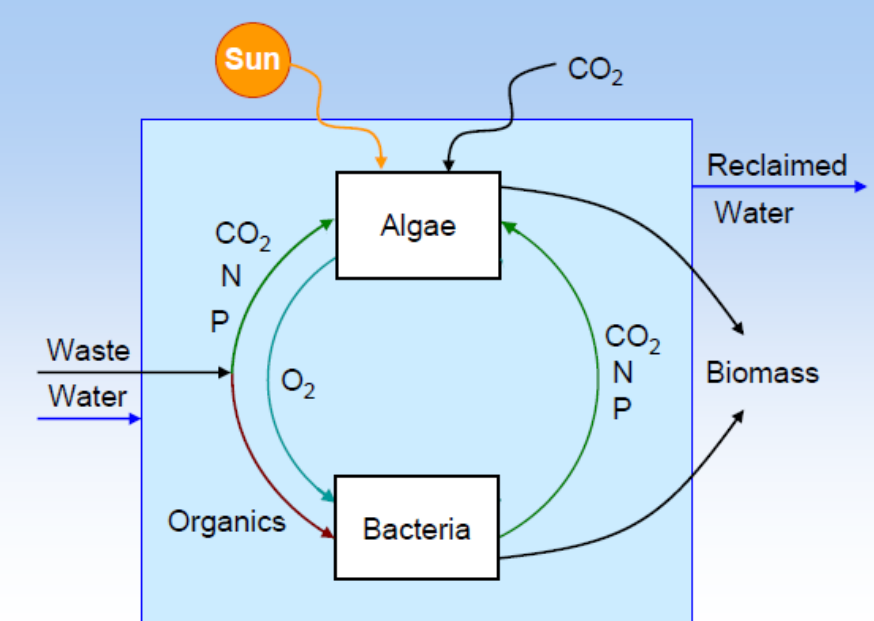


pevná pelikula



euglenoidní bičíkovci patří mezi důležité organismy v procesu čištění odpadních vod

### Algae-Based Wastewater Treatment



tradiční technologie - usazovací nádrže



# *Paulinella chromatophora* – výjimka na závěr...

