Chlorophyta

Prasinophyta

Ulvophyceae

Jak získala Chlorella chitin???

We presented evidence suggesting that Chlorella could have acquired components of its chitin biosynthetic pathway by horizontal gene transfer from a chlorovirus or a microorganism.

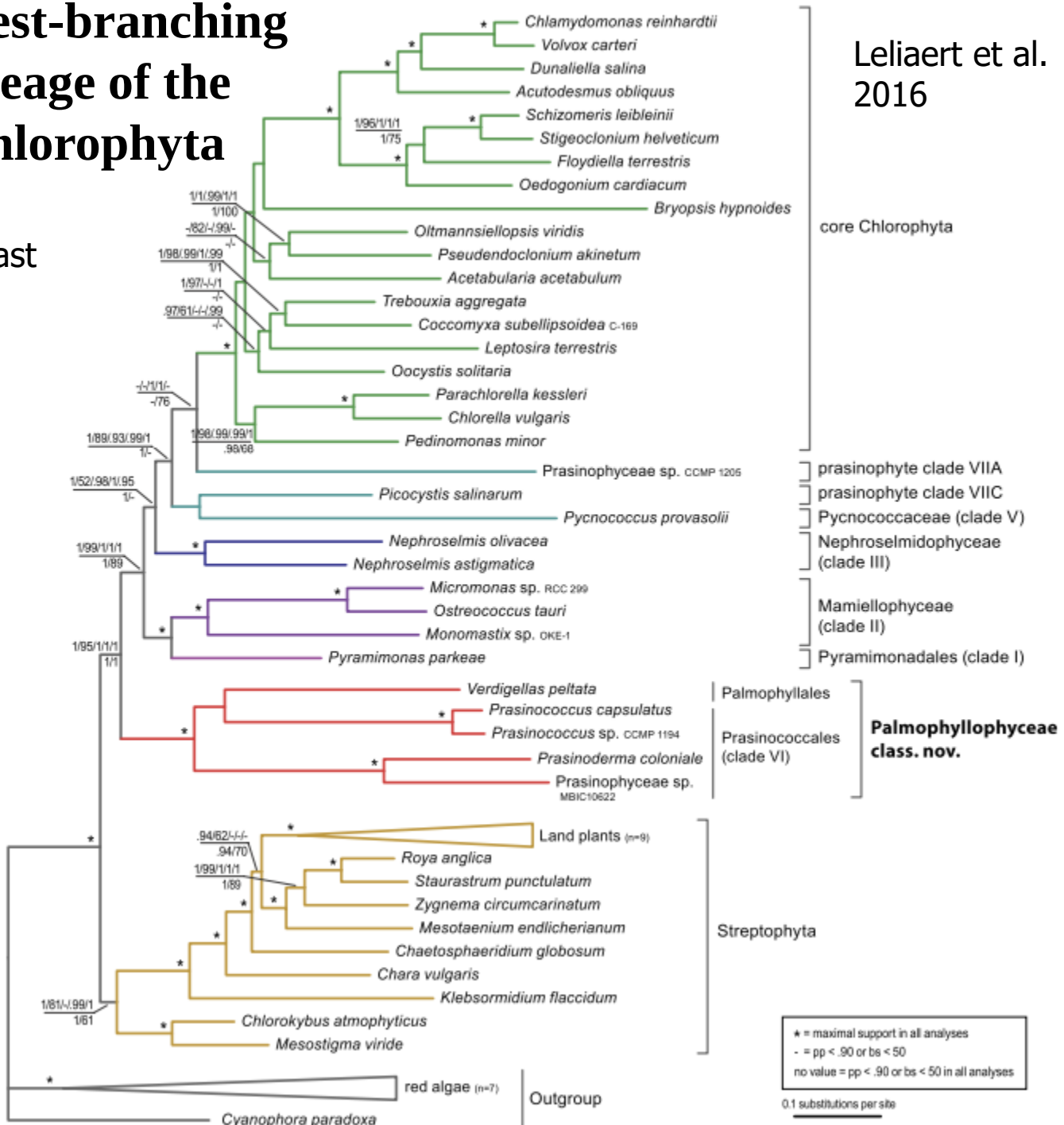
In the case of Chlorella, the acquisition of a chitinous cell wall may have conferred a protective barrier against other viral and bacterial parasites lacking the chitinase/chitosanase enzymes required to penetrate and/or escape the algal cell. This might have increased the fitness of Chlorella compared with its ancestors unable to synthesize chitin. This HGT might be the key event that promoted the radiation and success of the Chlorella genus (i.e., Chlorella may have achieved a cosmopolitan distribution because most of its previous parasites failed to penetrate its newly acquired chitinous cell wall).

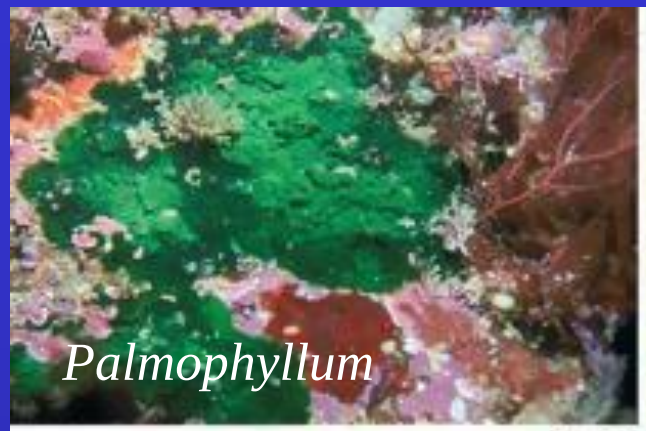
Blanc et al. 2010 The Plant Cell, Vol. 22: 2943–2955

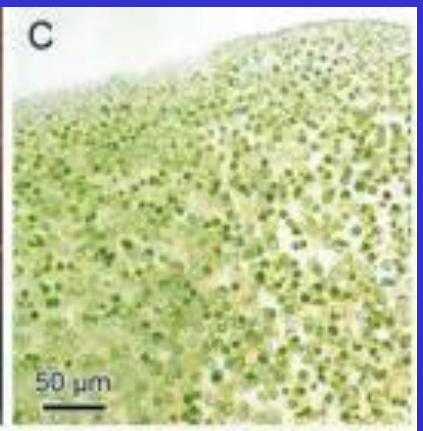
deepest-branching lineage of the Chlorophyta

Chloroplast genom

Leliaert et al. 2016

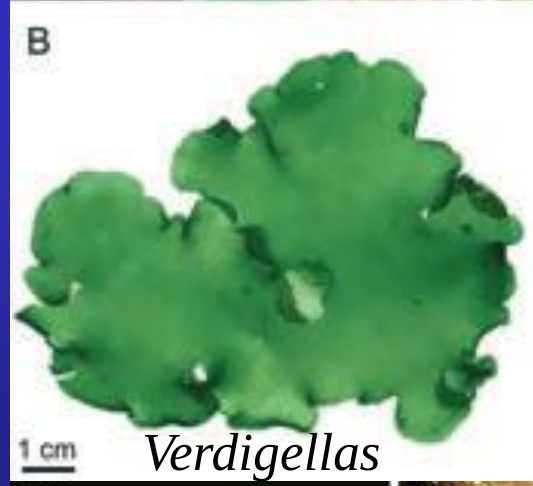


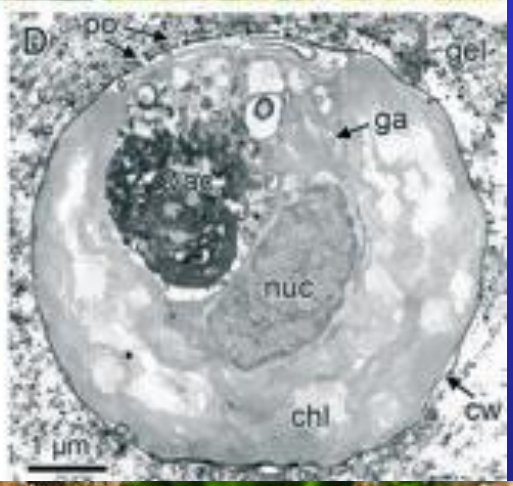


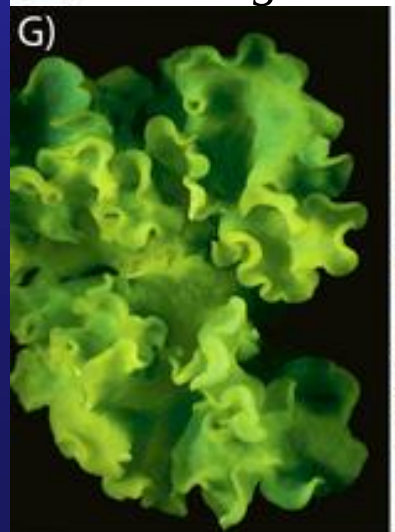


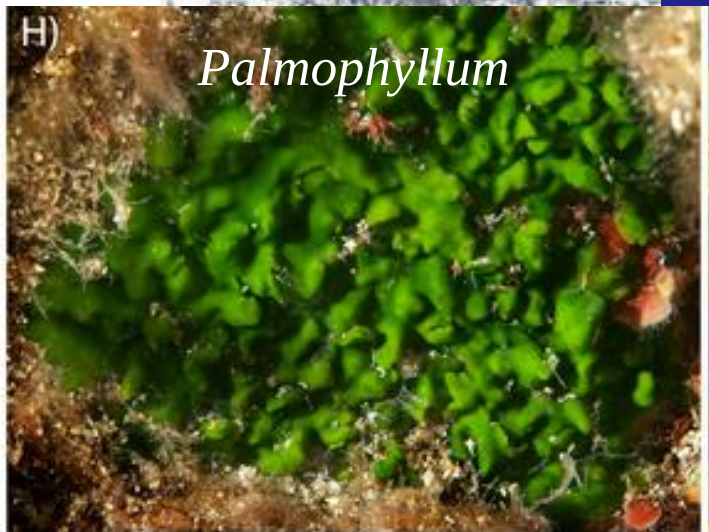
Phalmophyllales

deep-marine group of algae

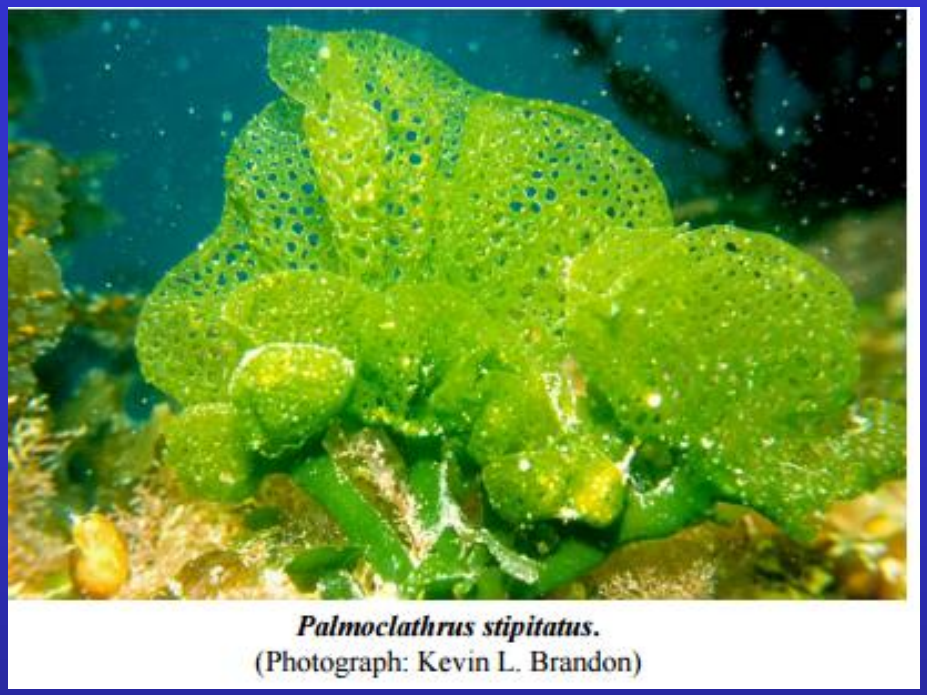








Palmophyllum crassum –
Mediterranien Sea

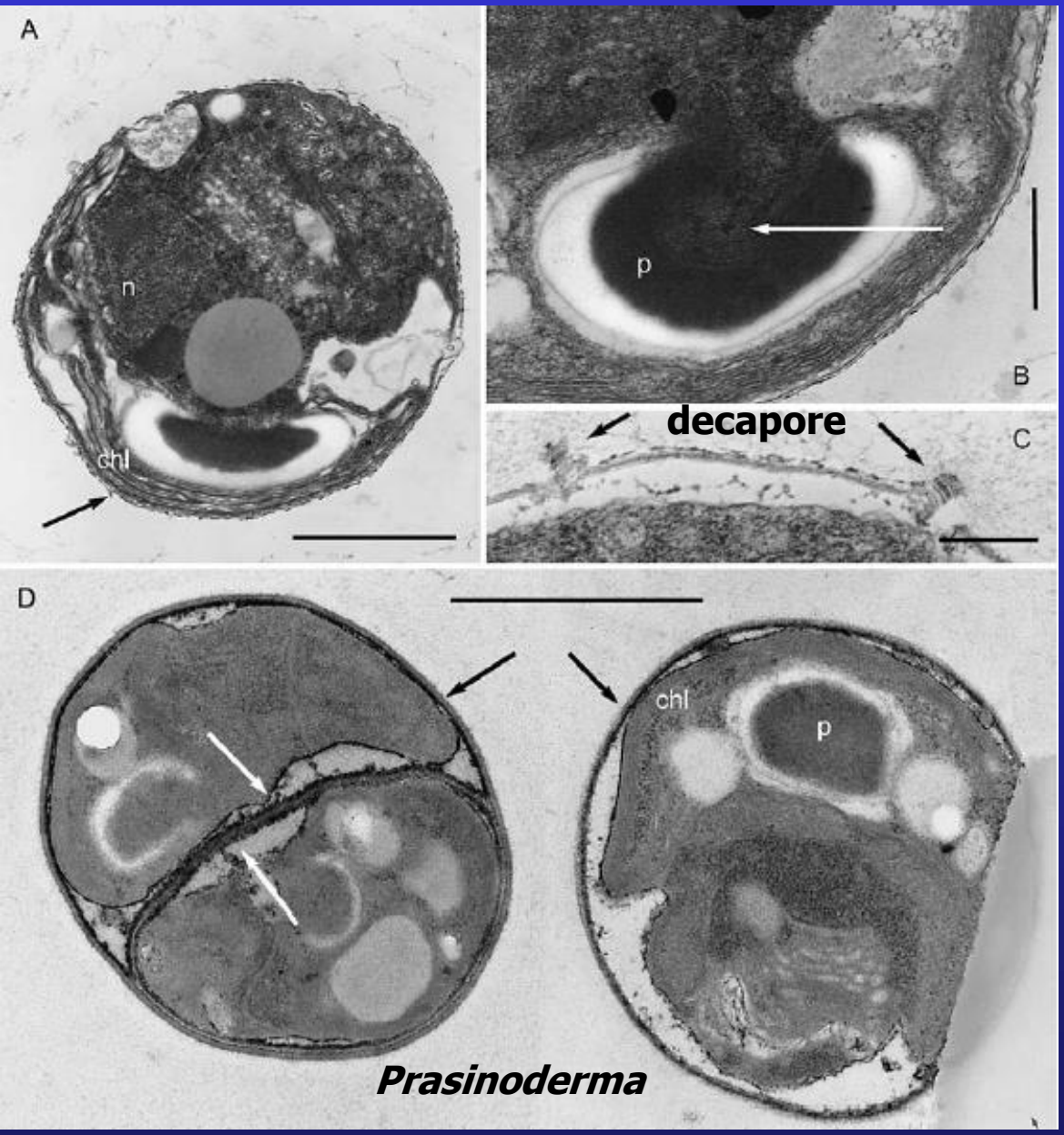


Palmoclathrus stipitatus.
(Photograph: Kevin L. Brandon)

Palmoclathrus stipitatus.
This rare and remarkable alga has a stem that shows annular rings, out of which grows a delicate, cupshaped, perforated membranous blade. Individual plants up to 8 years of age have been recorded
South Australia

higher ch b/ch a ratio
no siphonaxanthin and siphonein

Prasinococcus cf *capsulatus*

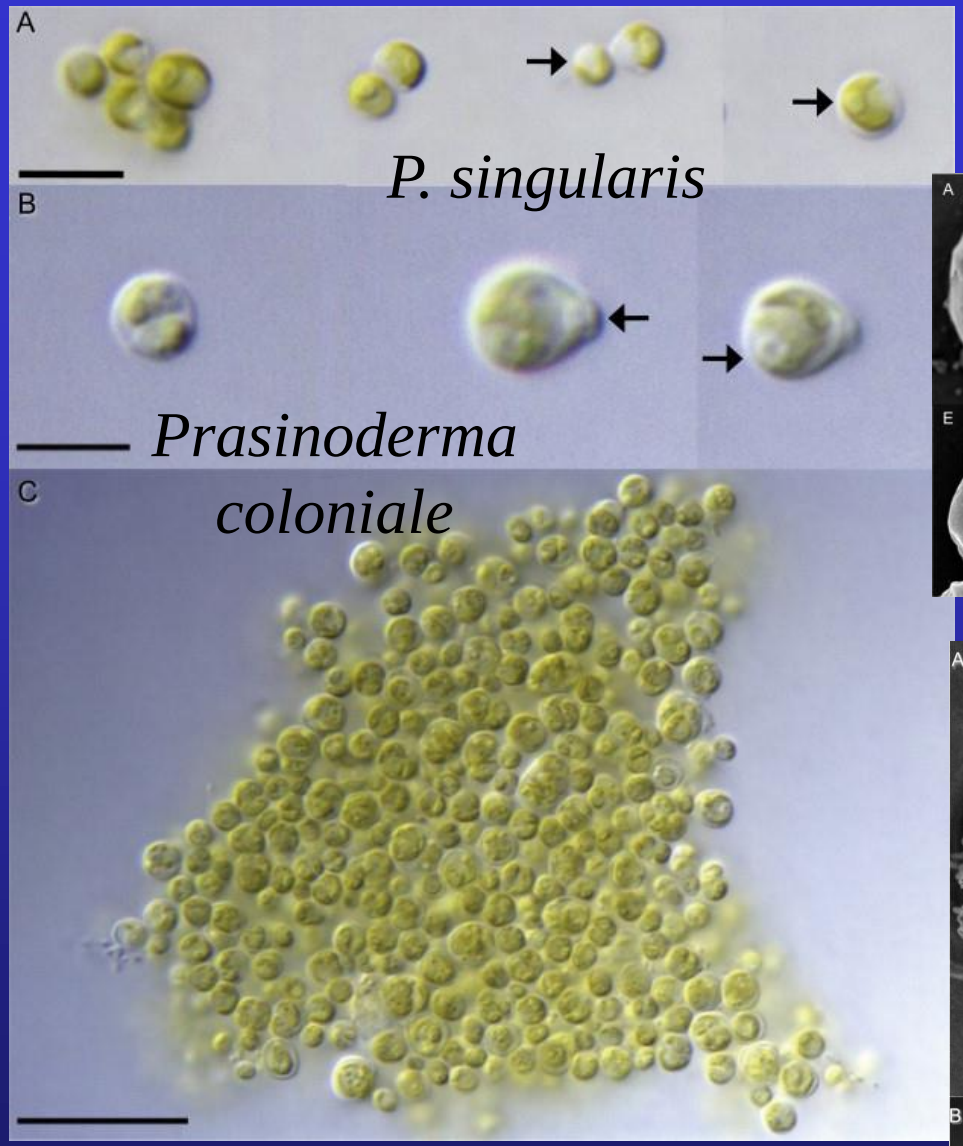


Coccal (pico)planktonic prasinofyte - 3.5 to 5.2 µm

Asexual reproduction is achieved by unequal binary fission in which one of the daughter cells retains the parent wall, while the other is released with a newly produced cell wall

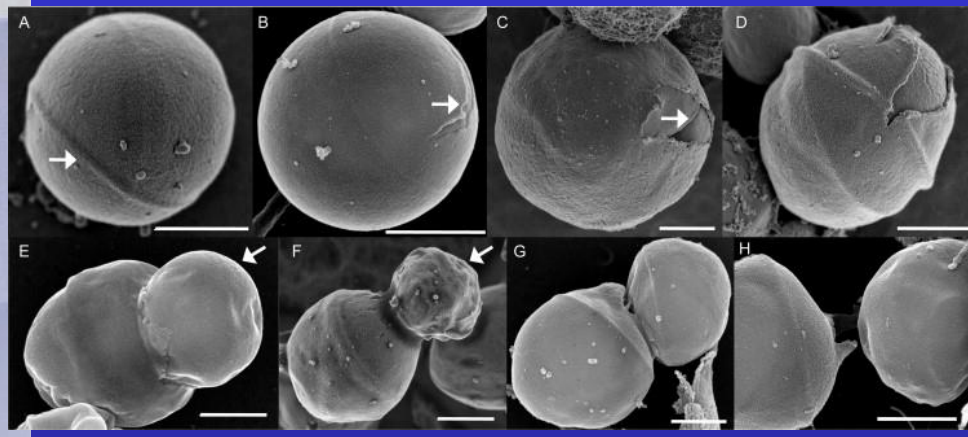
Guillou et al. 2004

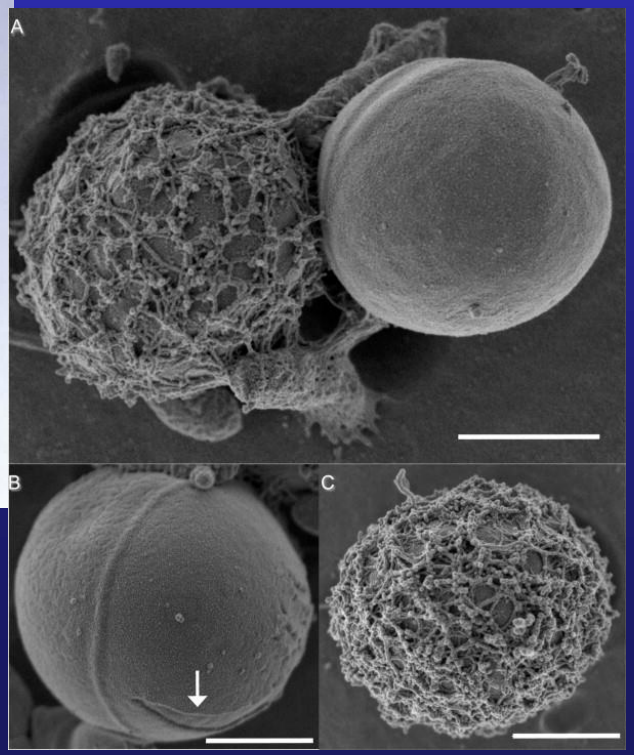
Prasinoderma



P. singularis

Prasinoderma coloniale



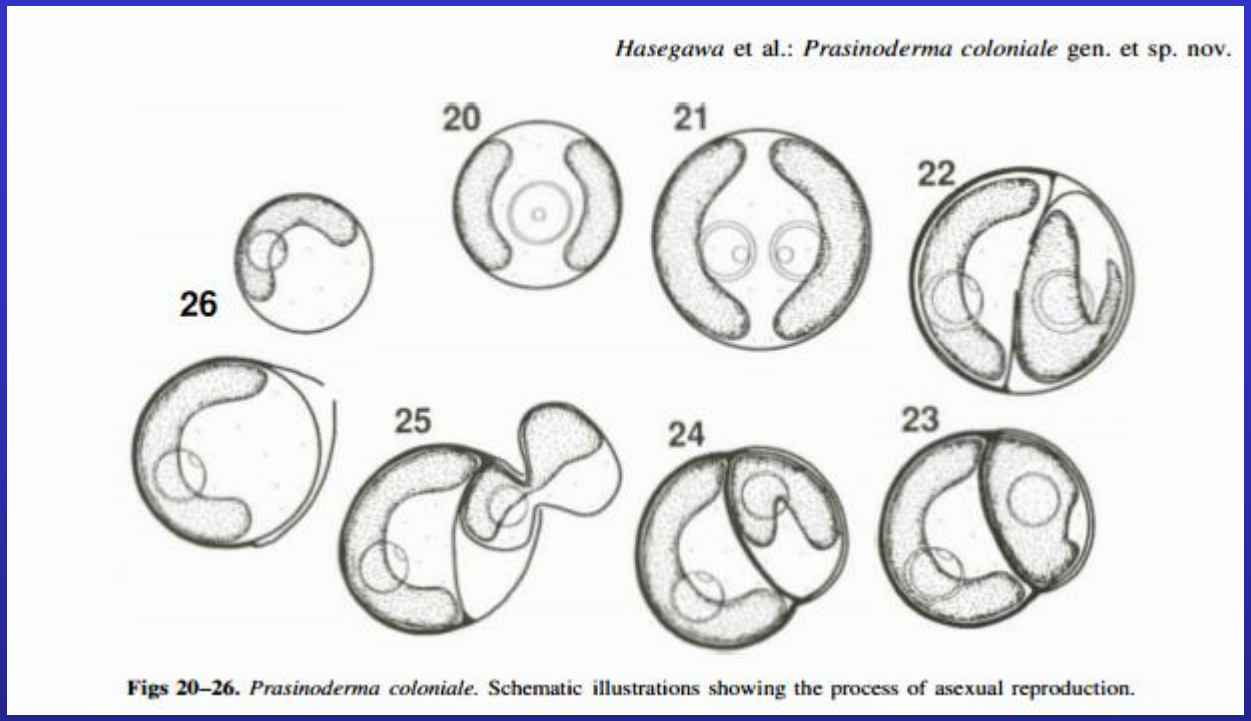


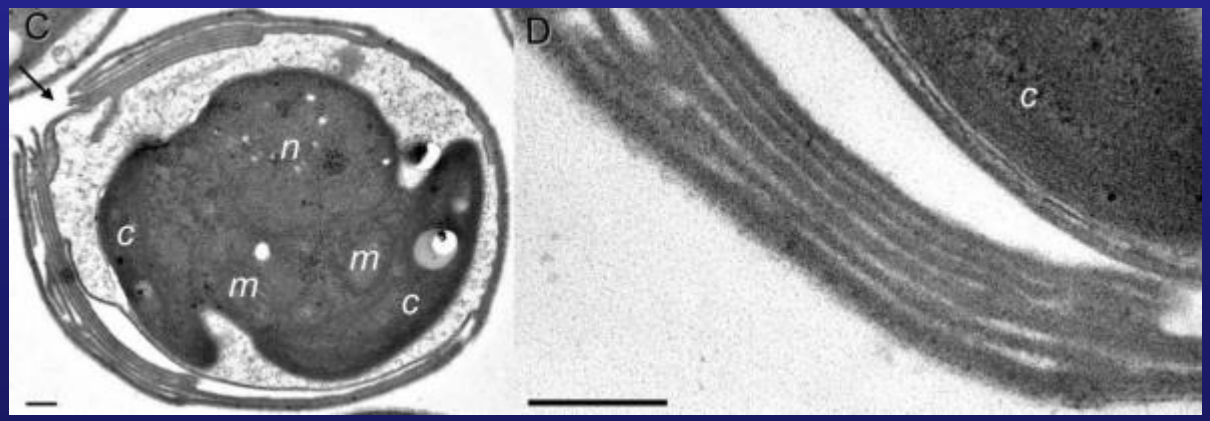
Surface water of Pacific Ocean.

(Jouenne et al. 2011)

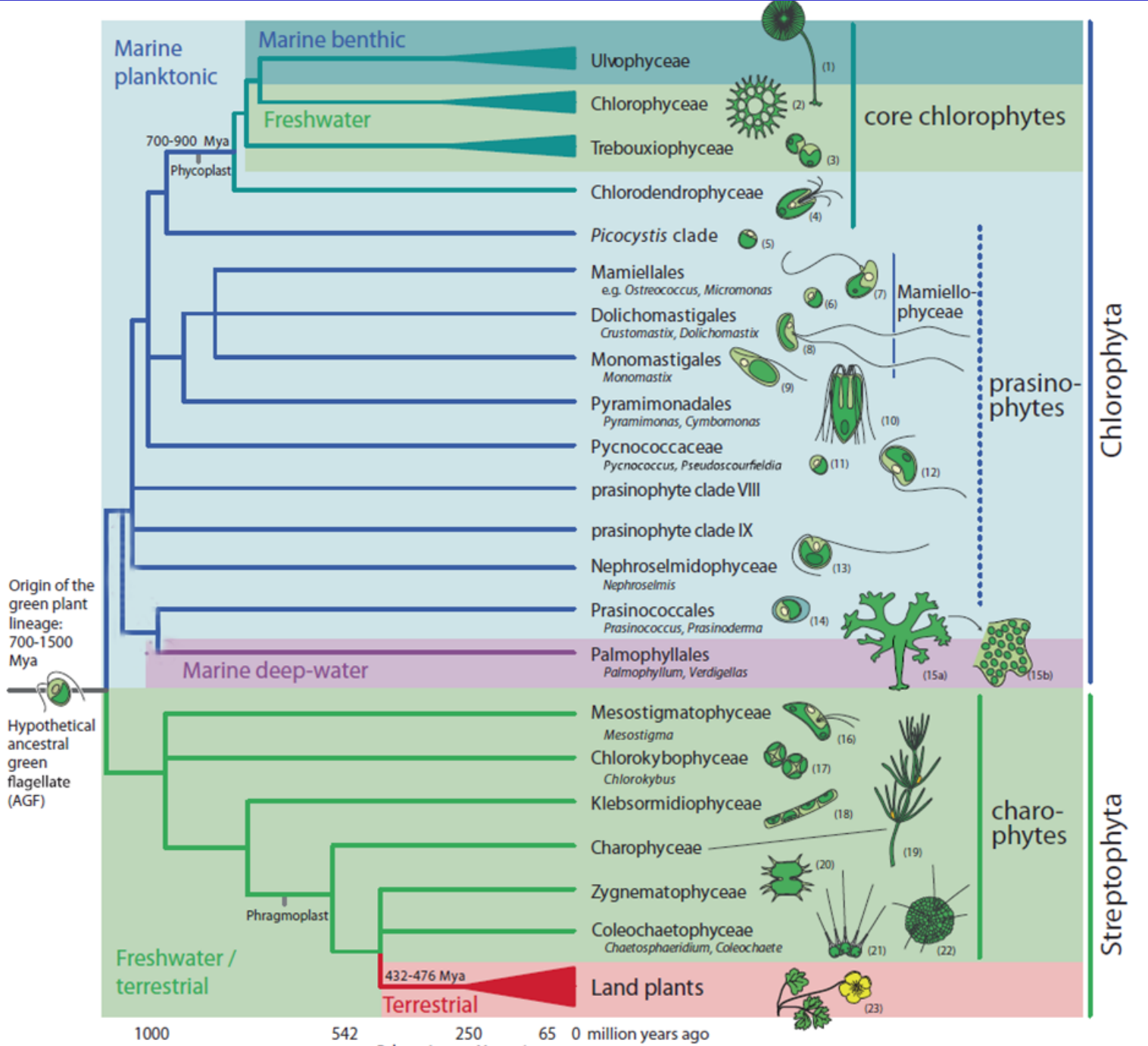
Prasinoderma coloniale

(HASEGAWA et al. 1996)





(Jouenne et al. 2011)


Marine planktonic
Marine benthic
Freshwater
700-900 Mya
Phycoplast
Ulvophyceae
Chlorophyceae
Trebouxiophyceae
core chlorophytes
Chlorodendrophyceae
Picocystis clade
Mamiellales
e.g. Ostreococcus, Micromonas
Dolichomastigales
Crustomastix, Dolichomastix
Monomastigales
Monomastix
Pyramimonadales
Pyramimonas, Cymbomonas
Pycnococcaceae
Pycnococcus, Pseudoscourfieldia
prasinophyte clade VIII
prasinophyte clade IX
Nephroselmidophyceae
Nephroselmis
Prasinococcales
Prasinococcus, Prasinoderma
Palmophyllales
Palmophyllum, Verdigellas
Mamiello-phyceae
prasino-phytes
Chlorophyta
Marine deep-water
Origin of the green plant lineage: 700-1500 Mya
Hypothetical ancestral green flagellate (AGF)
Mesostigmatophyceae
Mesostigma
Chlorokybophyceae
Chlorokybus
Klebsormidiophyceae
Charophyceae
Zygnematophyceae
Coleochaetophyceae
Chaetosphaeridium, Coleochaete
charo-phytes
Streptophyta
Phragmoplast
Freshwater / terrestrial
432-476 Mya
Terrestrial
Land plants
(1)
(2)
(3)
(4)
(5)
(6)
(7)
(8)
(9)
(10)
(11)
(12)
(13)
(14)
(15a)
(15b)
(16)
(17)
(18)
(19)
(20)
(21)
(22)
(23)
1000
542
250
65
0 million years ago
Mesoproterozoic
Neoproterozoic
Paleozoic
Cambr. Silur. Carbon.
Ordov. Devon. Perm.
Mesozoic
Triassic Cretac.
Jurassic
Cen.

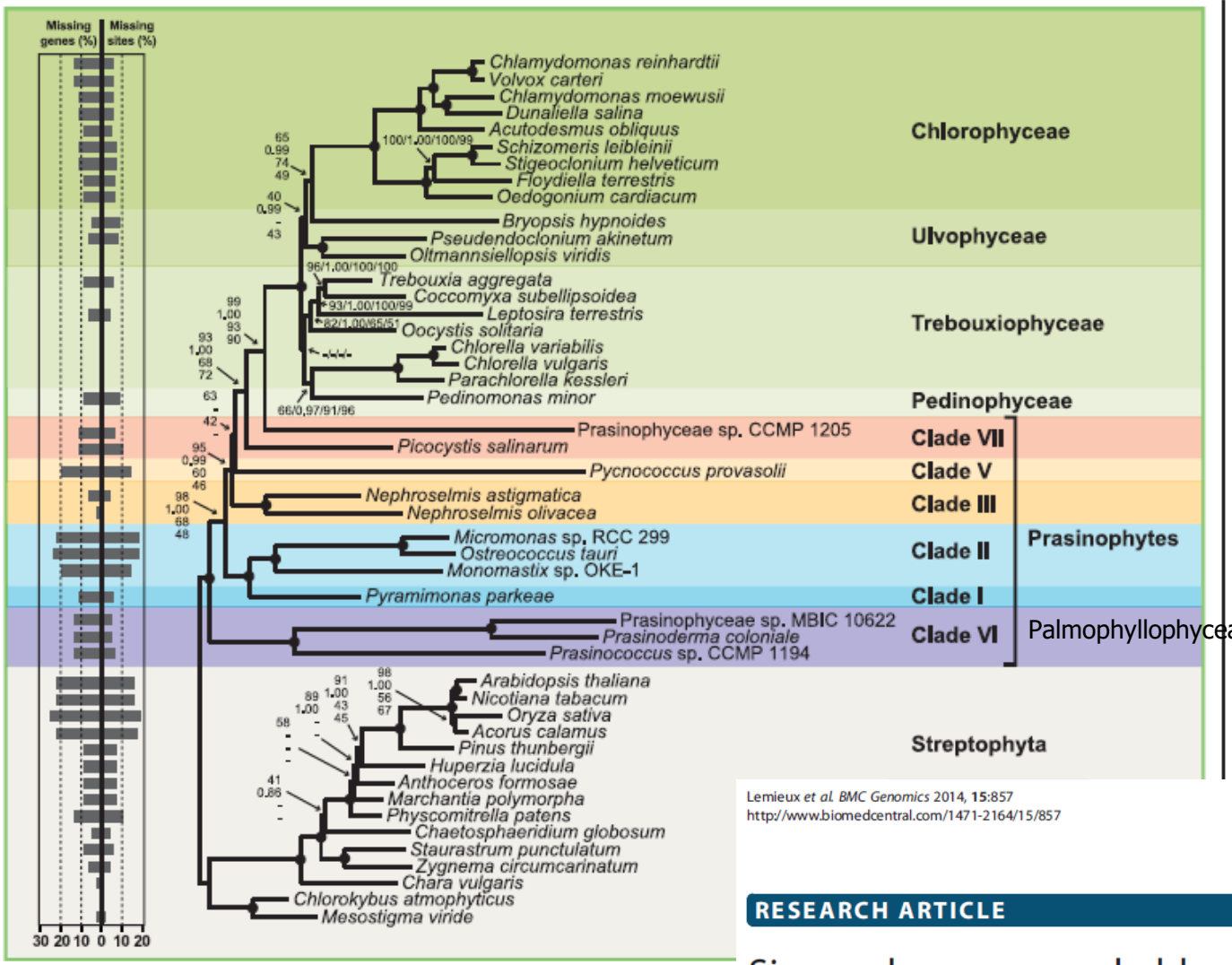


Figure 6 Relationships among prasinophyte lineages inferred using a data set of 1 proteins of 47 green plant taxa. Trees were inferred using PhyloBayes under the CATGTR- models. In the ML analyses, the data set was partitioned by gene, with the model applied to ea tree is presented. Support values are reported on the nodes: from top to bottom, or from left t analyses, the PP values for the CATGTR + Γ4 analyses, and the BP values for the LG4X and gcpR 40% BP support values; black dots indicate that the corresponding nodes received 1.00 PP and the proportion of missing genes and missing sites for each taxon. The scale bar denotes the es

Lemieux *et al. BMC Genomics* 2014, **15**:857
http://www.biomedcentral.com/1471-2164/15/857

BMC Genomics

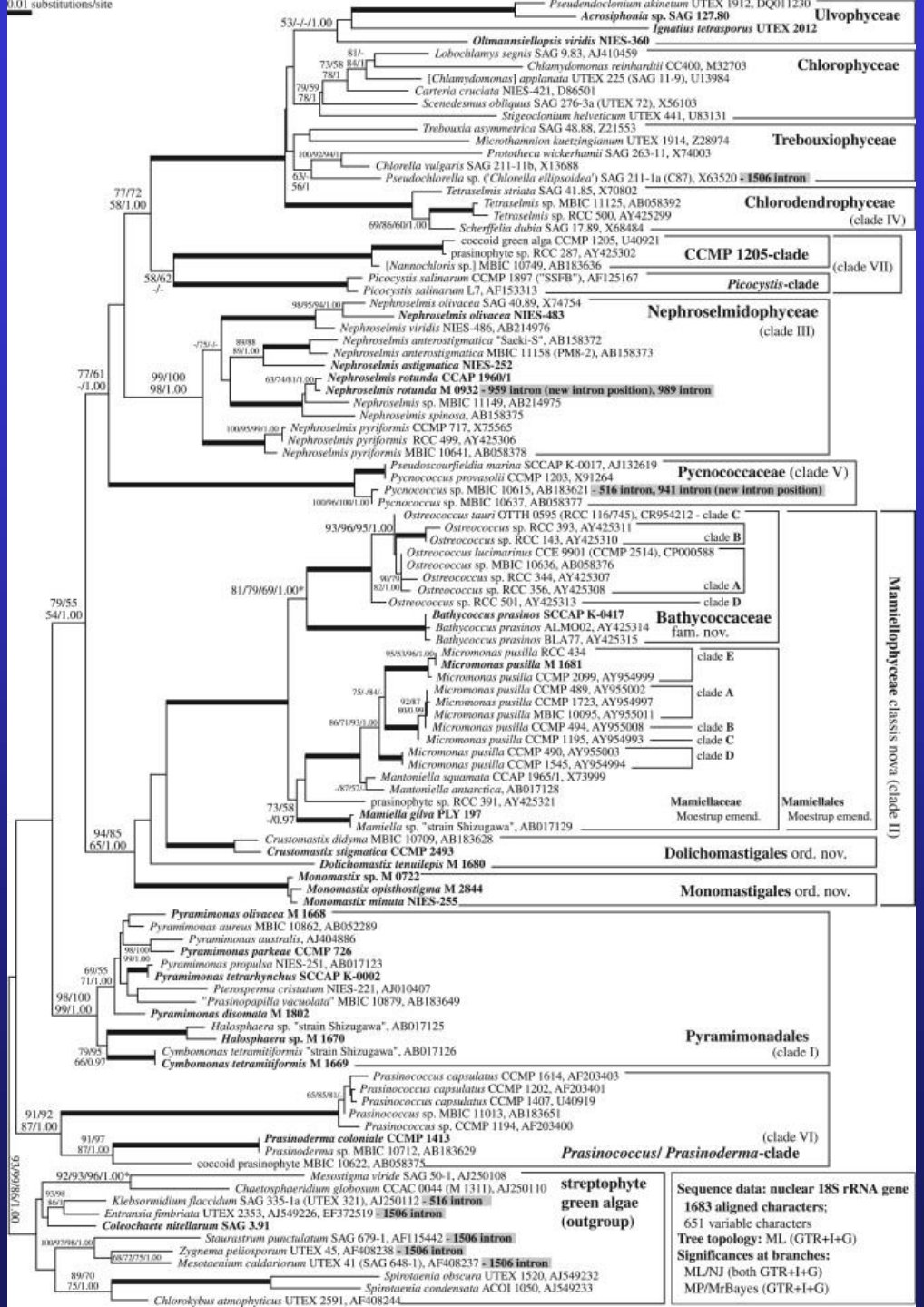
RESEARCH ARTICLE Open Access

Six newly sequenced chloroplast genomes from prasinophyte green algae provide insights into the relationships among prasinophyte lineages and the diversity of streamlined genome architecture in picoplanktonic species

Claude Lemieux*, Christian Otis and Monique Turmel

Molecular phylogeny and classification of the Mamiellophyceae class. nov. (Chlorophyta) based on sequence comparisons of the nuclear- and plastid-encoded rRNA operons

by: **B. Marin**, **M. Melkonian** **Protist 2010**



Core chloro-phytes

Chlorodendrophyceae

Picocystis clade

Nephroselmidophyceae

Pycnococcaceae

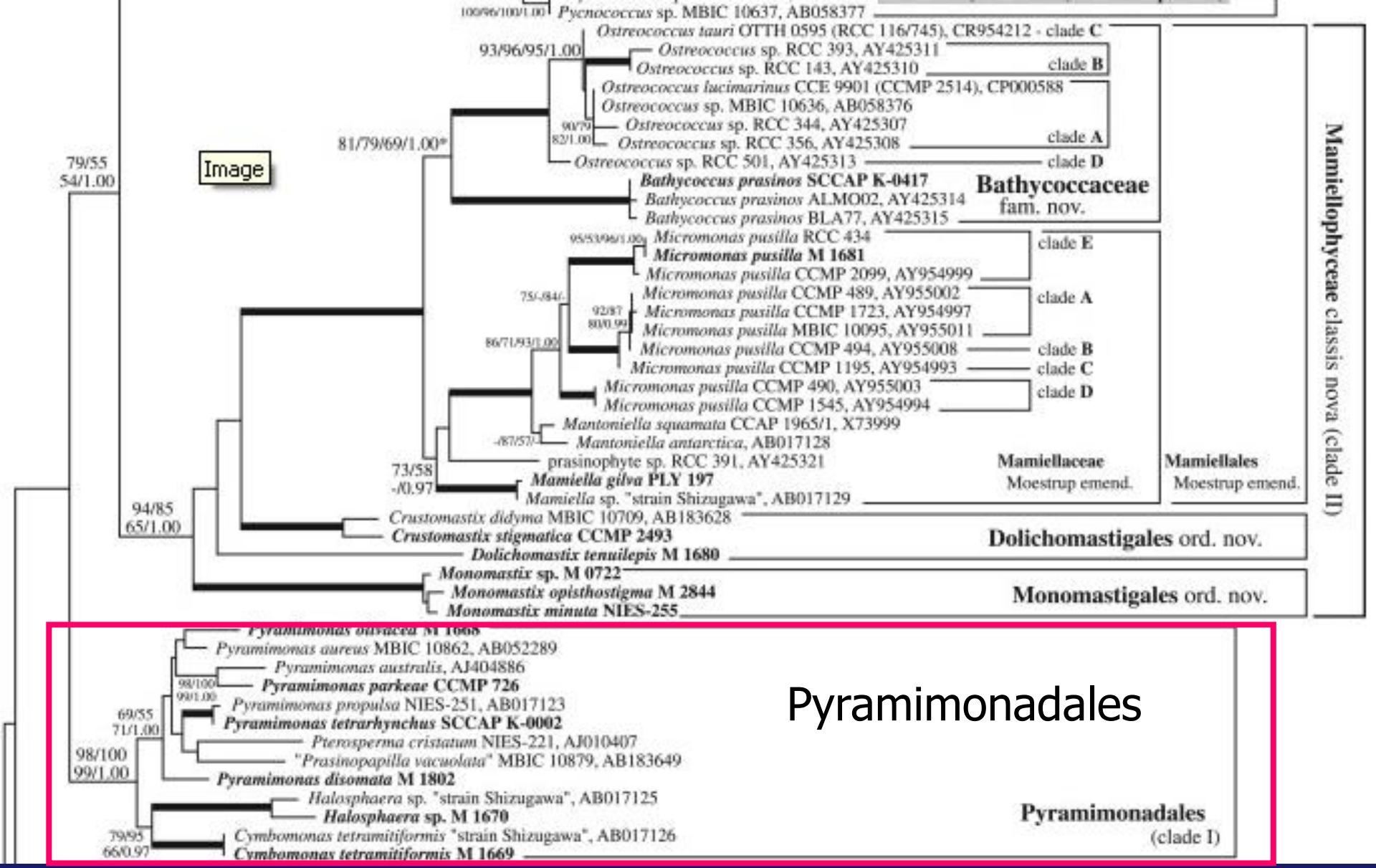
Mamiellophyceae

Pyramimonadales

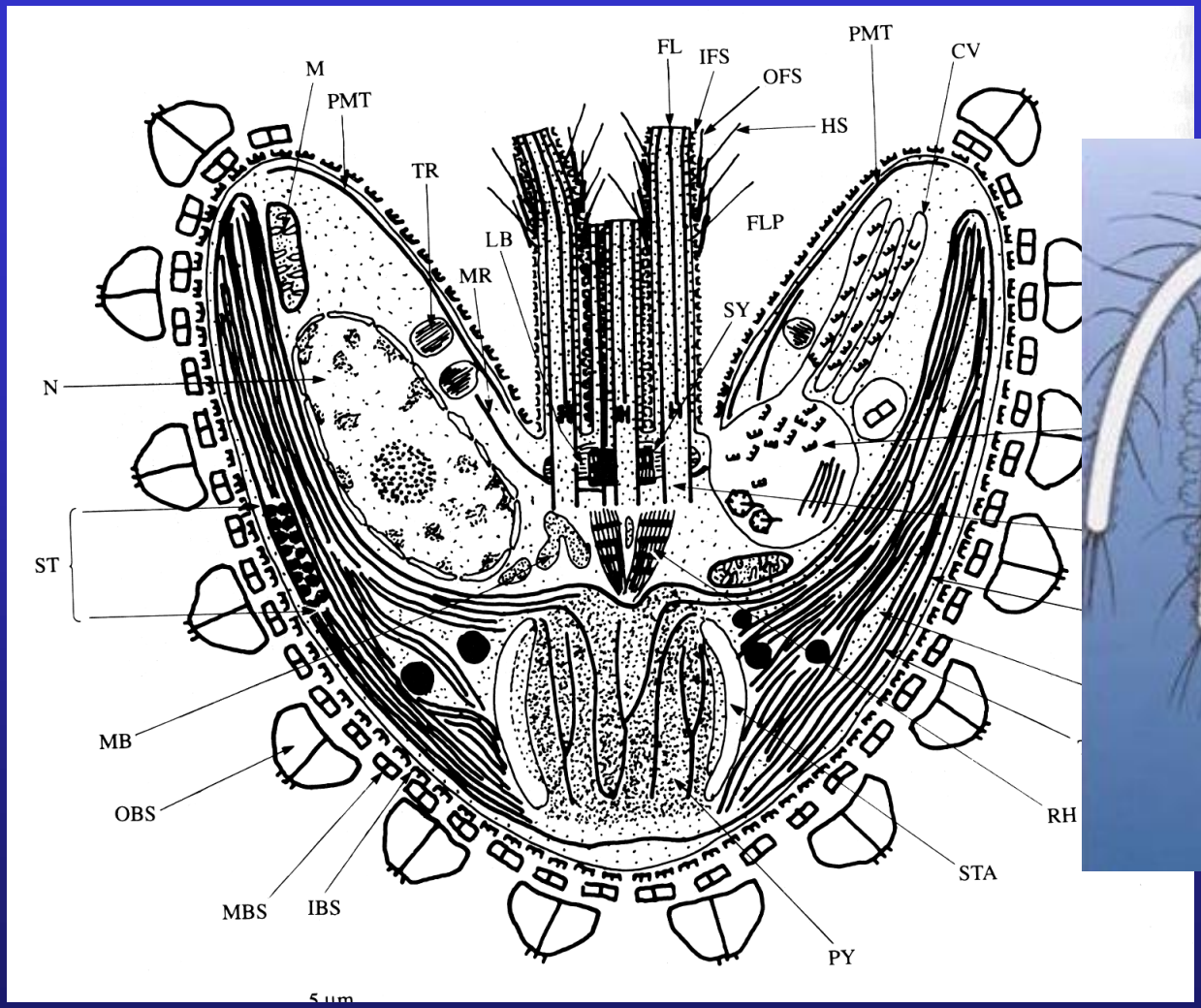
Palmophyllophyceae

Marin & Melkonian

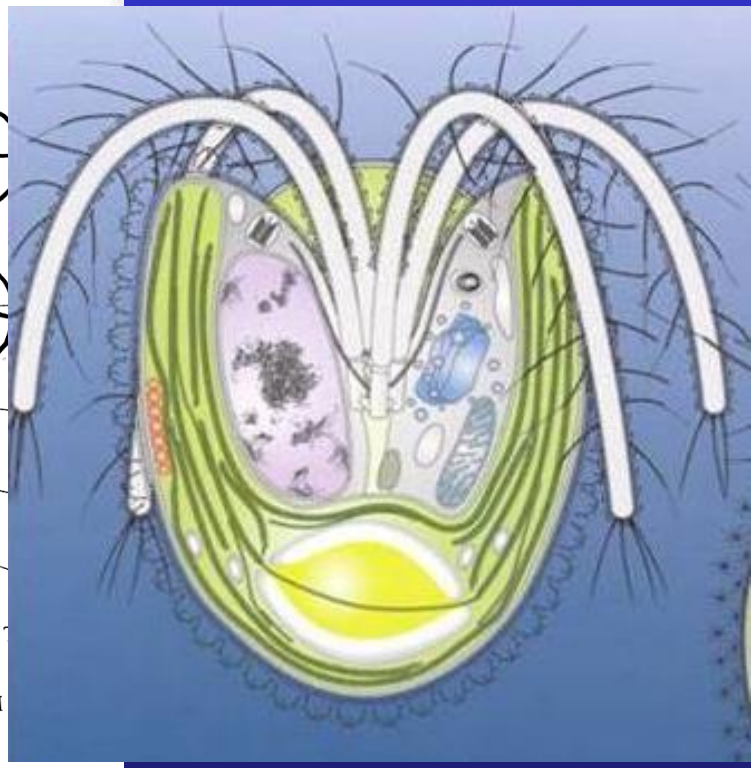
Protist 2010


Pycnococcus sp. MBIC 10637, AB058377
Ostreococcus tauri OTTH 0595 (RCC 116/745), CR954212 - clade C
93/96/95/1.00
Ostreococcus sp. RCC 393, AY425311
Ostreococcus sp. RCC 143, AY425310
clade B
Ostreococcus lucimarinus CCE 9901 (CCMP 2514), CP000588
Ostreococcus sp. MBIC 10636, AB058376
Ostreococcus sp. RCC 344, AY425307
82/1.00
Ostreococcus sp. RCC 356, AY425308
clade A
81/79/69/1.00*
Ostreococcus sp. RCC 501, AY425313
clade D
79/55
54/1.00
Image
Bathycoccus prasinos SCCAP K-0417
Bathycoccus prasinos ALM002, AY425314
Bathycoccus prasinos BLA77, AY425315
Bathycoccaceae
fam. nov.
Micromonas pusilla RCC 434
Micromonas pusilla M 1681
Micromonas pusilla CCMP 2099, AY954999
clade E
Micromonas pusilla CCMP 489, AY955002
92/87
Micromonas pusilla CCMP 1723, AY954997
Micromonas pusilla MBIC 10095, AY955011
clade A
Micromonas pusilla CCMP 494, AY955008
clade B
Micromonas pusilla CCMP 1195, AY954993
clade C
Micromonas pusilla CCMP 490, AY955003
Micromonas pusilla CCMP 1545, AY954994
clade D
Mantoniella squamata CCAP 1965/1, X73999
Mantoniella antarctica, AB017128
prasinophyte sp. RCC 391, AY425321
73/58
-/0.97
Mamiella gilva PLY 197
Mamiella sp. "strain Shizugawa", AB017129
Mamiellaceae
Moestrup emend.
Mamiellales
Moestrup emend.
94/85
65/1.00
Crustomastix didyma MBIC 10709, AB183628
Crustomastix stigmatica CCMP 2493
Dolichomastigales ord. nov.
Dolichomastix tenuilepis M 1680
Monomastix sp. M 0722
Monomastix opisthostigma M 2844
Monomastix minuta NIES-255
Monomastigales ord. nov.
Mamiellophyceae classis nova (clade II)
Pyramimonas aureus MBIC 10862, AB052289
Pyramimonas australis, AJ404886
98/100
99/1.00
Pyramimonas parkeae CCMP 726
Pyramimonas propulsa NIES-251, AB017123
69/55
71/1.00
Pyramimonas tetrarhynchus SCCAP K-0002
Pterosperma cristatum NIES-221, AJ010407
"Prasinopapilla vacuolata" MBIC 10879, AB183649
98/100
99/1.00
Pyramimonas disomata M 1802
Halosphaera sp. "strain Shizugawa", AB017125
Halosphaera sp. M 1670
79/95
66/0.97
Cymbomonas tetramitiformis "strain Shizugawa", AB017126
Cymbomonas tetramitiformis M 1669
Pyramimonadales
(clade I)
Pyramimonadales

Pyramimonadales



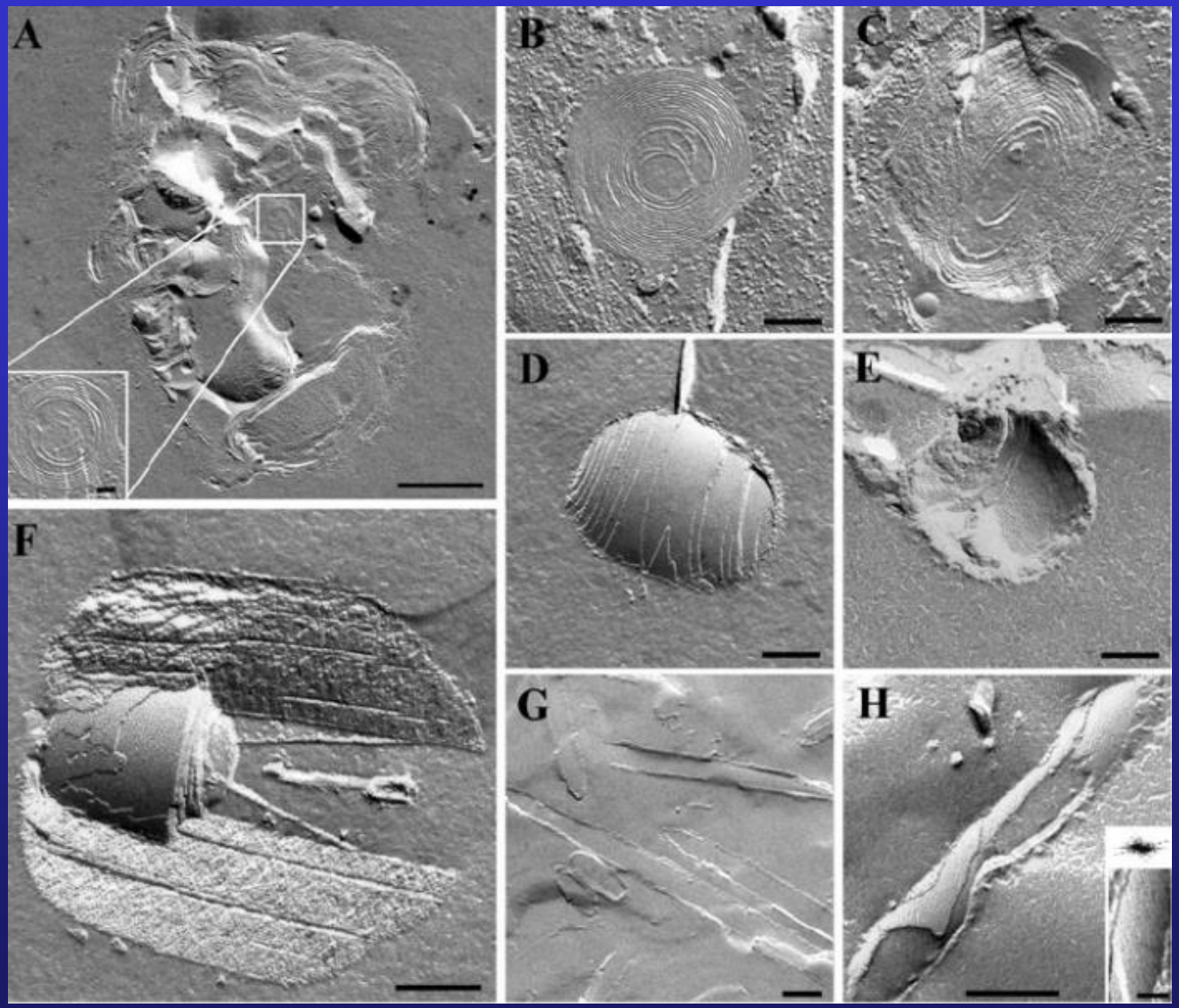
trichocysts- extracellular digestion



rhizoplast attached to the chloroplast surface

ultrastructure of *Pyramimonas*

Ejectisomes



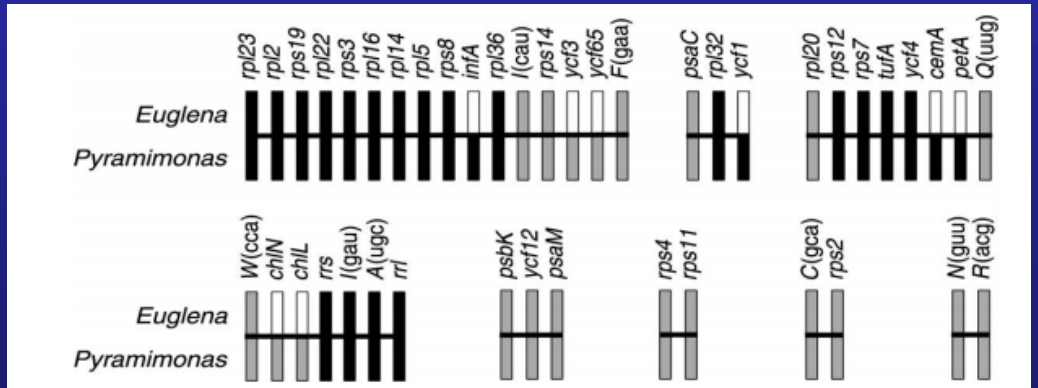
Discharged ejectisomes measured up to 26 μm
still furled measured up to 900 nm in width and 1 μm in length

Rhiel et al.
Protoplasma 2013

Micrographs of freeze-fractured ejectisomes of P. grossii. In freeze-fractured Pyramimonas cells

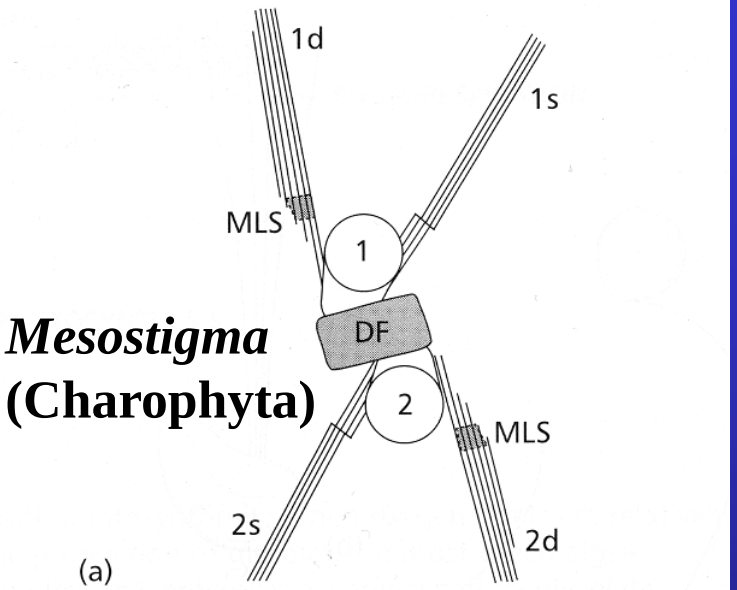
Pyramimonas parkeae - the closest relative to the euglena chloroplast

Plastid genoms share unique gene clusters

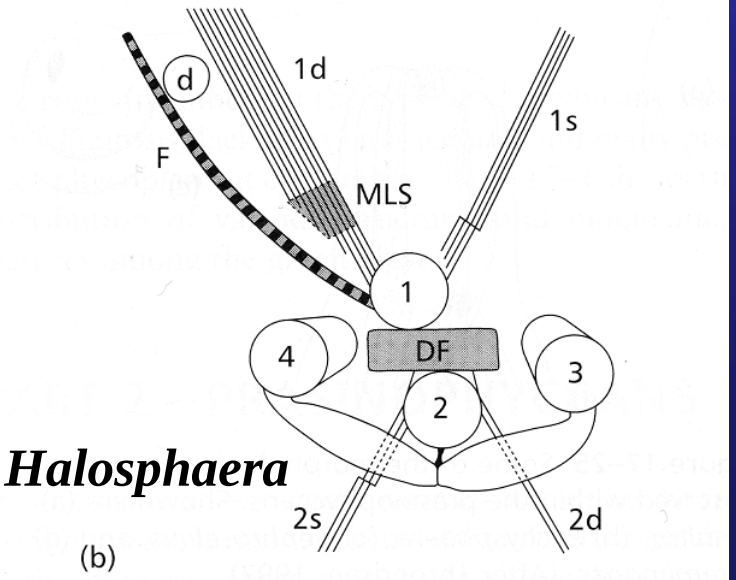


Obr. 1. Genové klastry unikátně sdílené cpDNA organismů *Euglena* a *Pyramimonas* podle Turmelové et al. (2009). Černě vybarvená políčka naznačují ancestrální uspořádání těchto klastrů (vyskytující se i u jiných zelených řas), šedá políčka odkazují na derivované oblasti (specifické pro *Euglena* a *Pyramimonas*) a prázdná políčka označují chybějící geny.

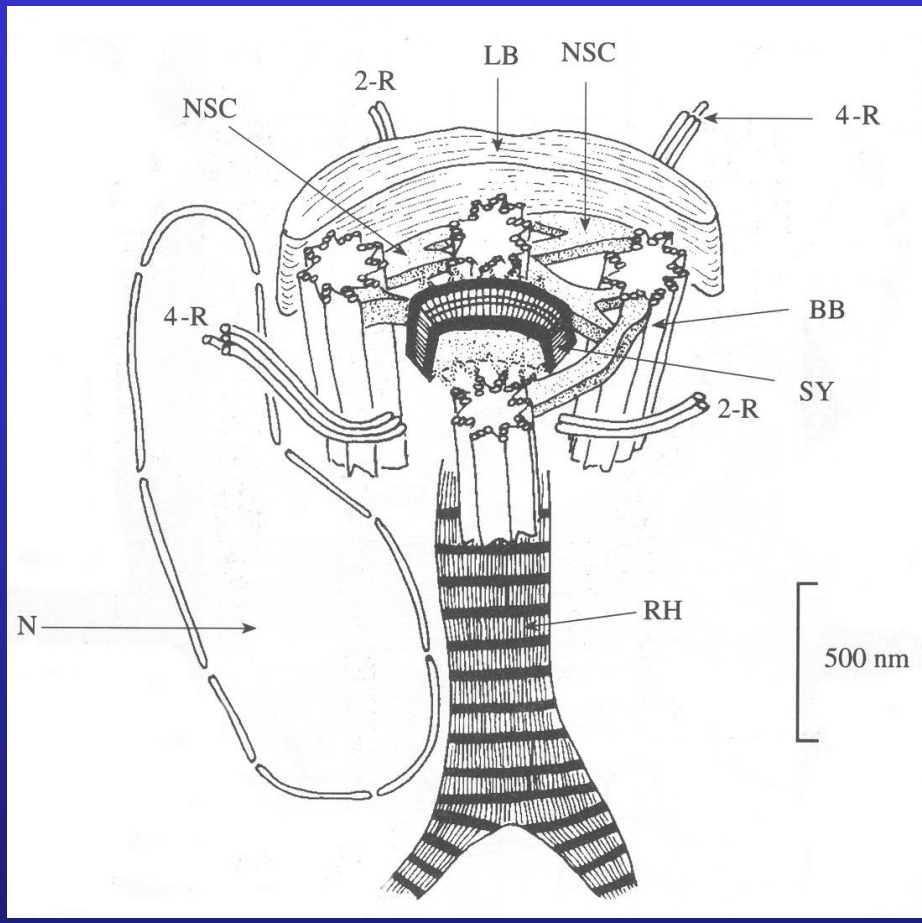
Flagellar apparatus



***Mesostigma* (Charophyta)**

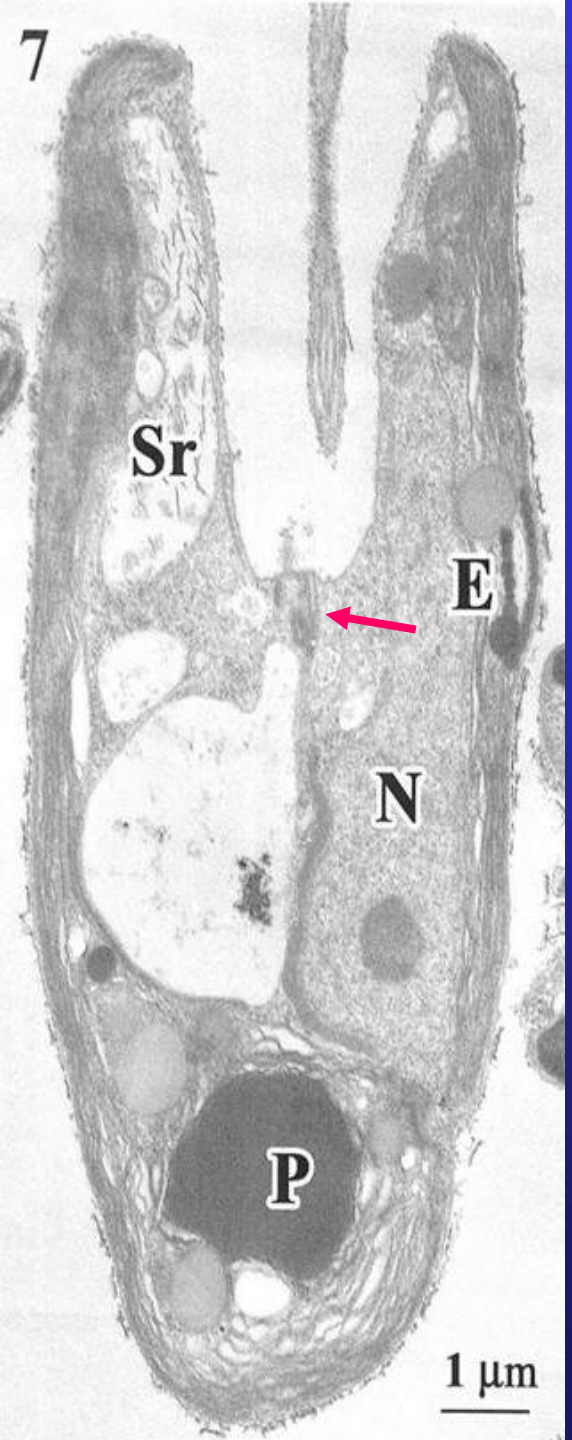


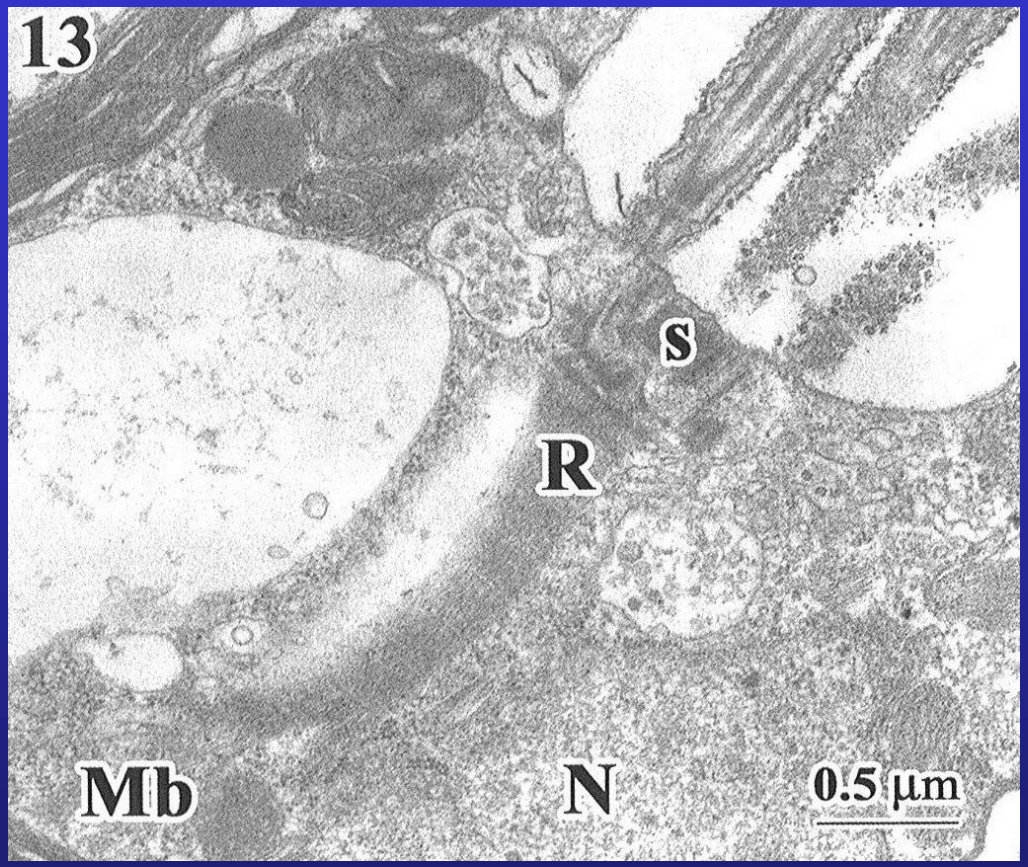
Halosphaera



Pyramimonas

Rhizoplast

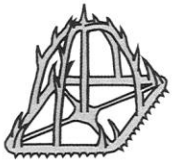
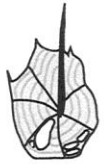
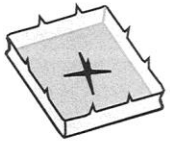
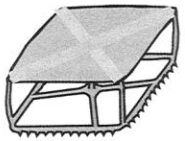
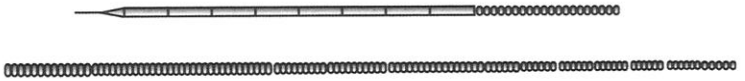
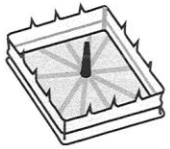
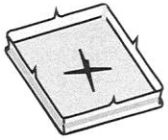
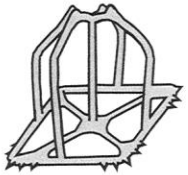
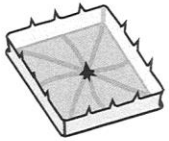
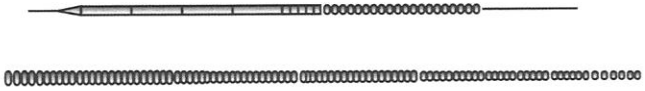




Pyramimonas

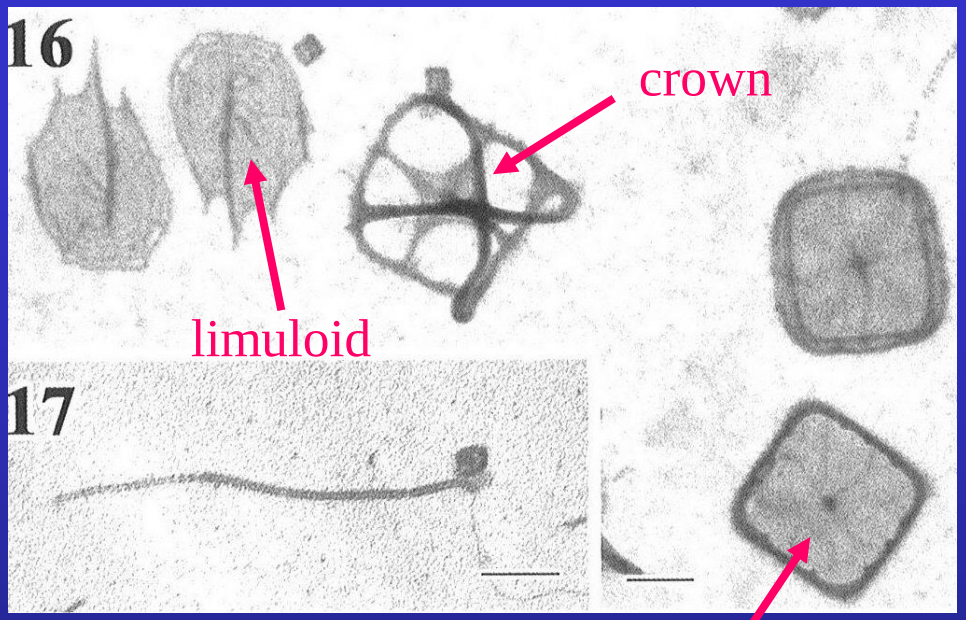
Organic scales

Table 3. Comparison of the body (box and crown) scales and the flagellar (limuloid and hair) scales among species of *Pyramimonas* subgenus *Punctatae*.

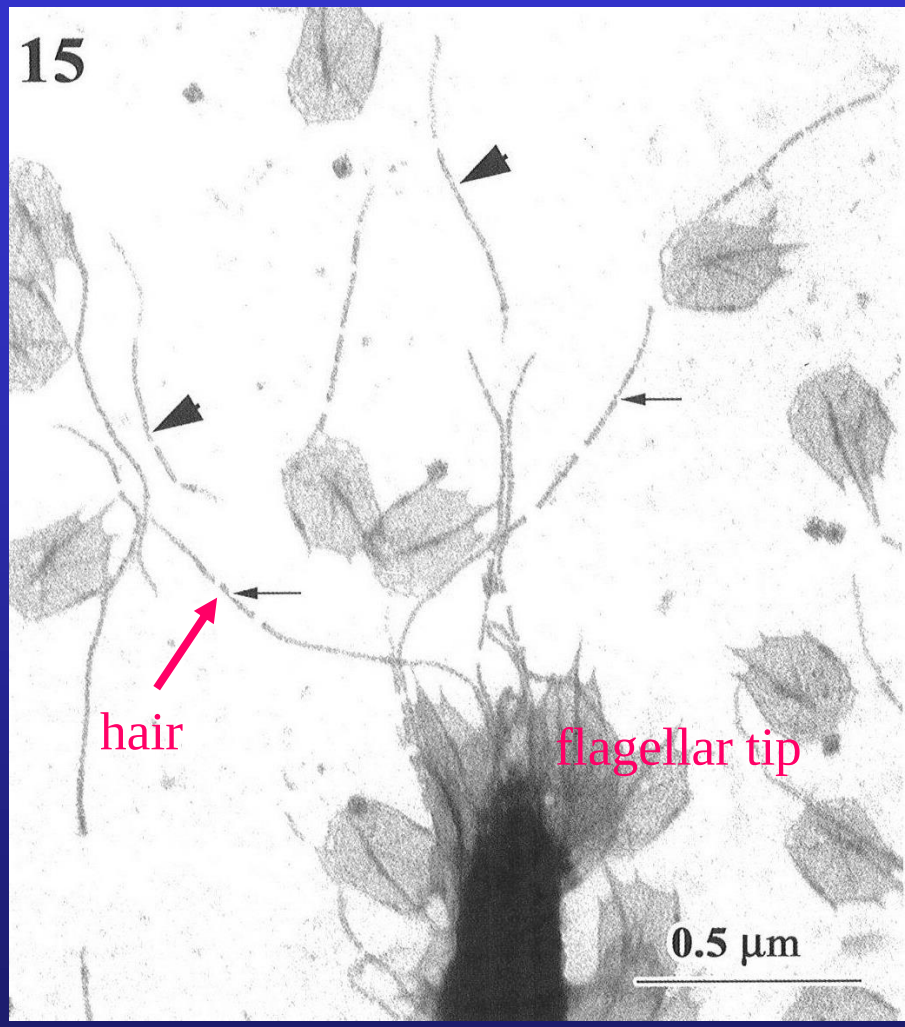
species	body scales		flagellar scales	
	box scale	crown scale	limuloid scale	hair scale
P. formosa[1]				
P. mucifera[2]				
P. olivacea[3]				
P. robusta[4]				
P. aurea[5]				

[1]Sym & Pienaar 1999; [2]Sym & Pienaar 1991, Pienaar & Sym 1997; [3]McFadden *et al.* 1987, Pienaar & Sym 1997; [4]Pienaar & Sym 1997; [5]this study

Organic scales



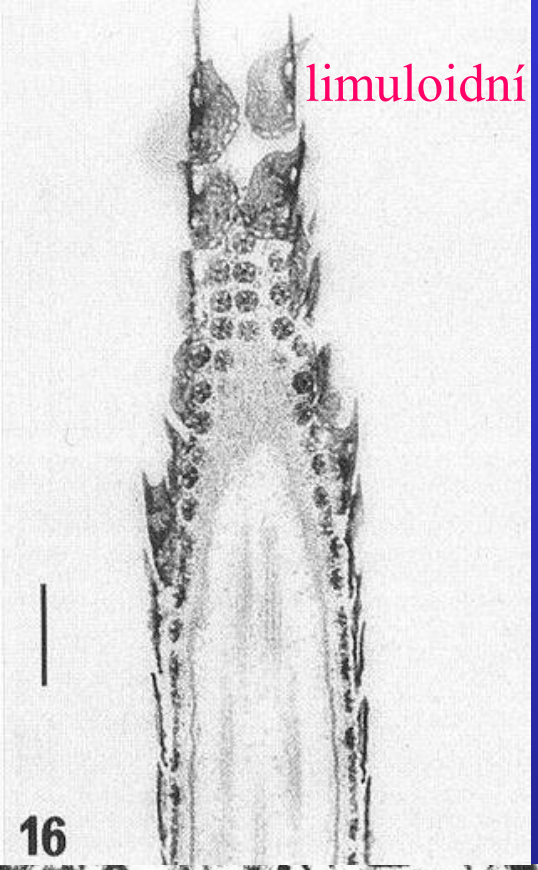
Pyramimonas aurea

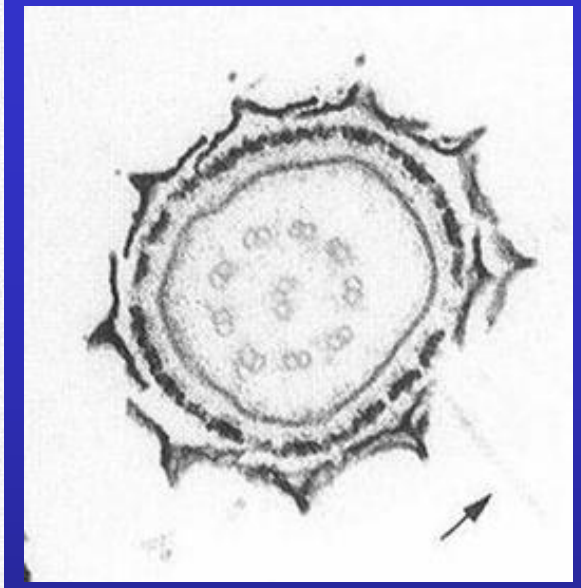


carbohydrate similar to pectin

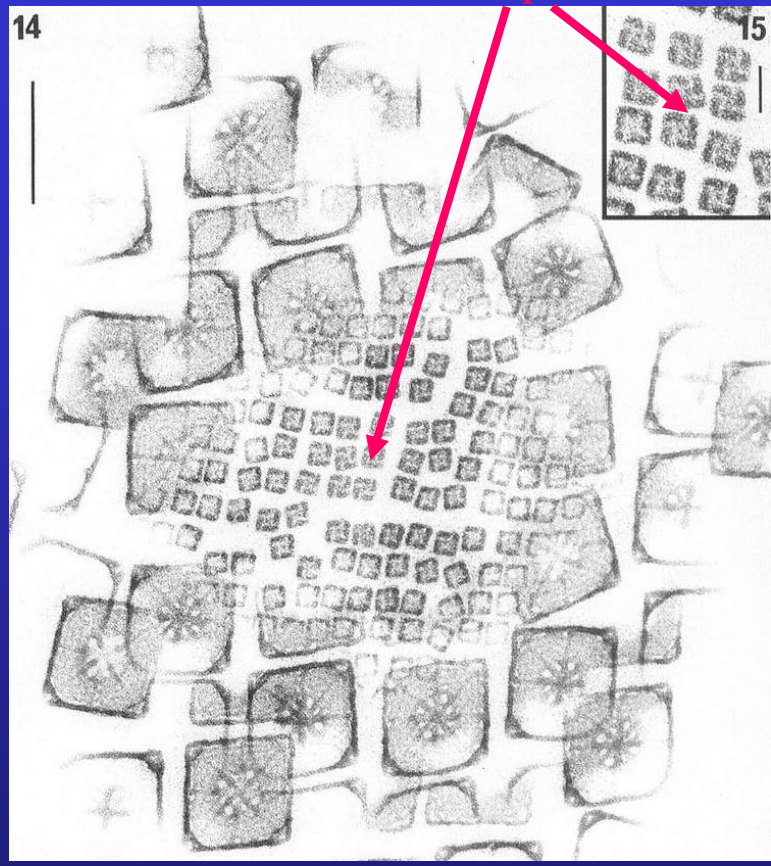
Organic scales

limuloidní





small square



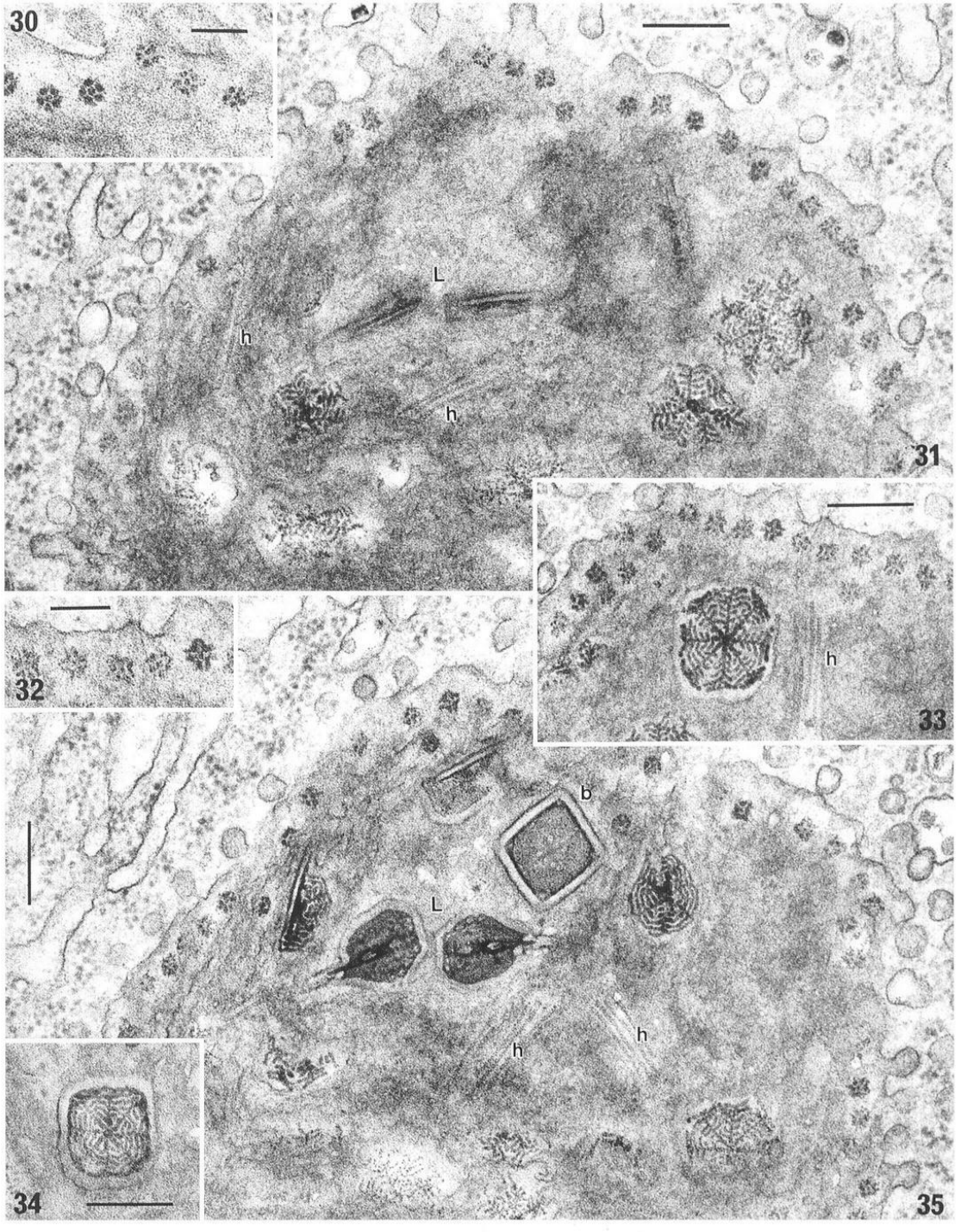
Cymbomonas tetramitiformis

box

Šupiny produkovány GA – všechny typy tělových i bičíkových šupin mohou být podukovány v jedné GA cisterně, vylučovány na povrch v oblasti inserce bičíků (flagellar pit)

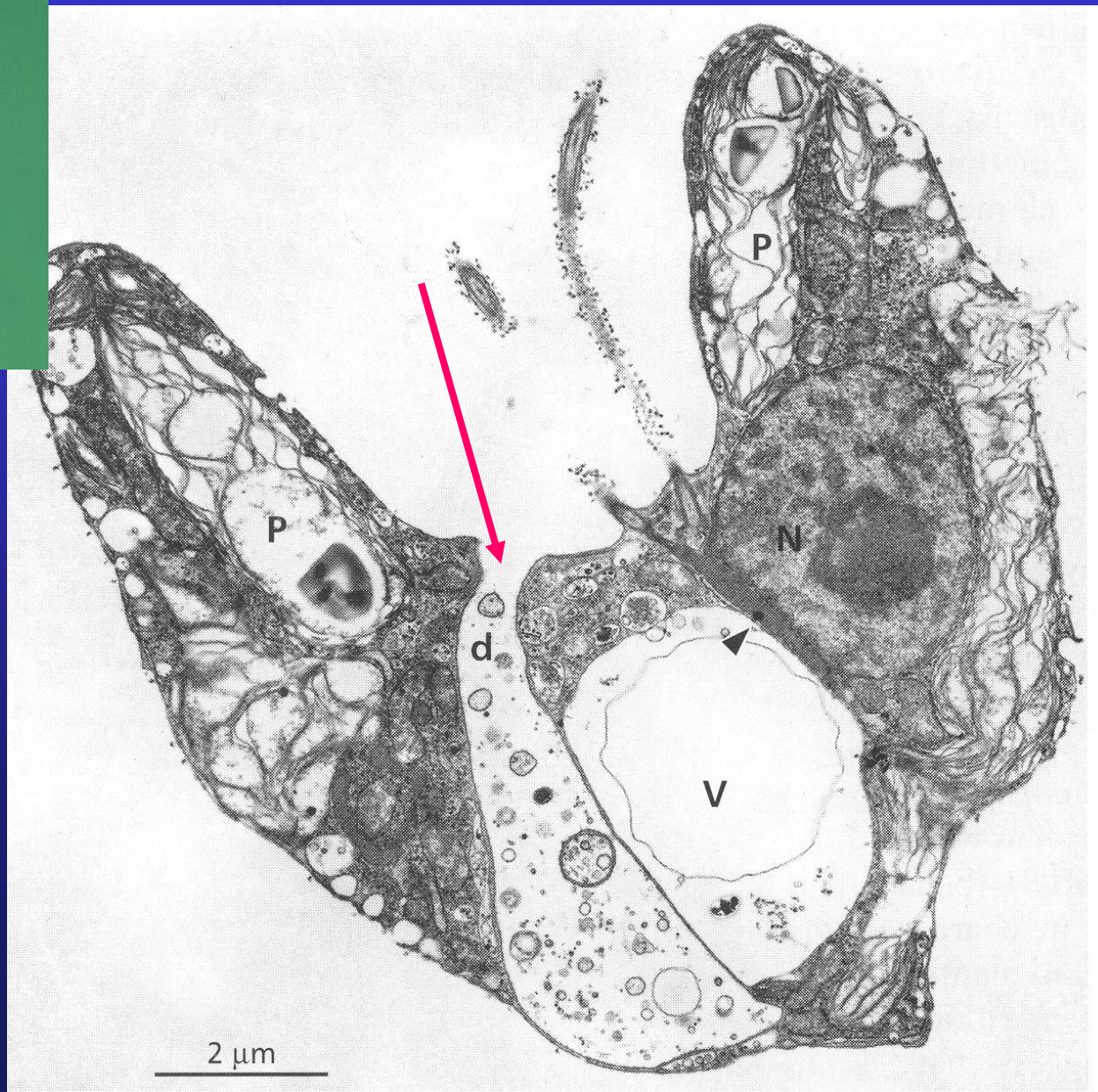
x křemičité šupiny chrysofyt

Cymbomonas

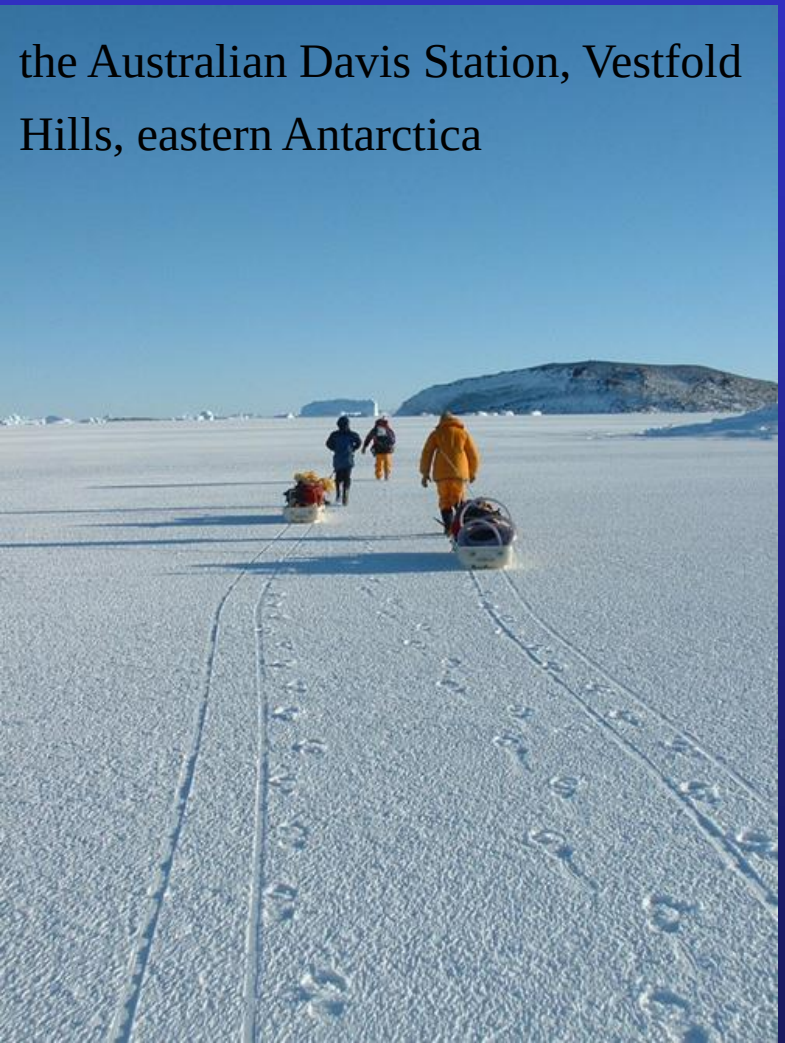


Organic scales

Halosphaera – specializovaný kanál, kterým se šupiny uvolňují, vestigiální cytopharinx ancestrální fagotrofní buňky

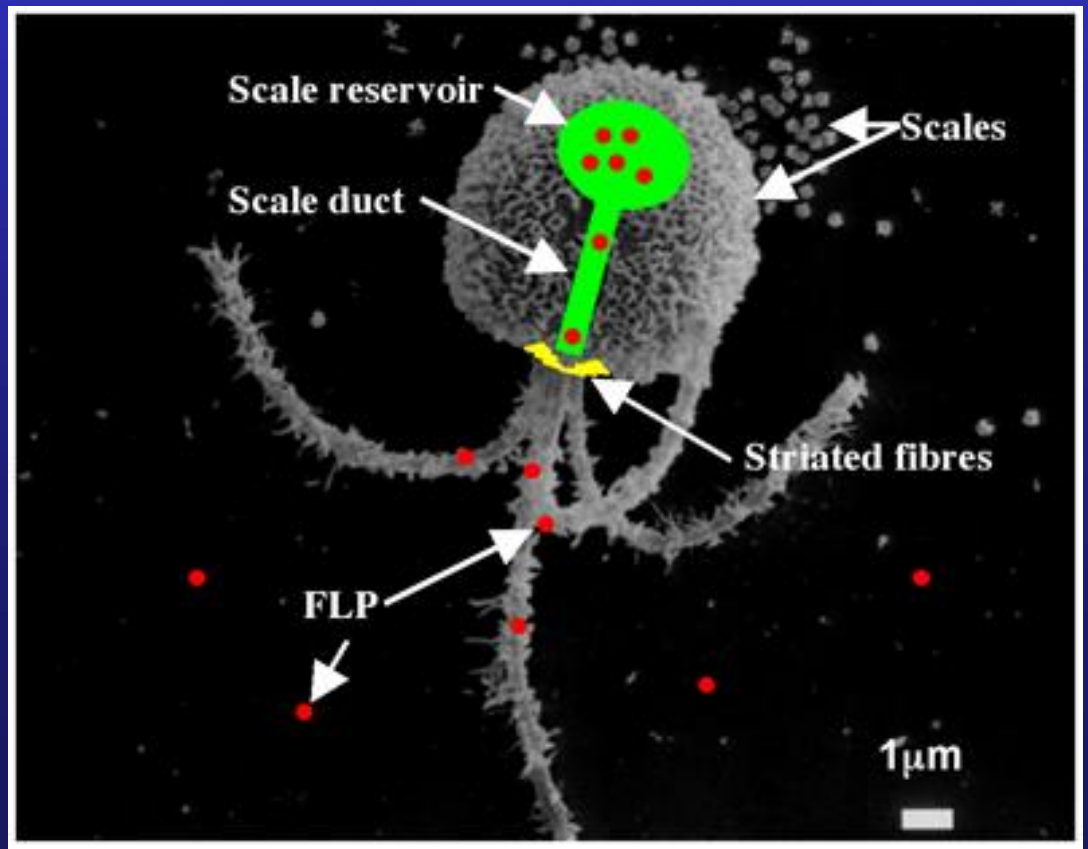


mixotrofie „zapnuta“ pouze za extrémních podmínek (total winter darkness and again when ice thickness was maximal and PAR levels in the water column low) – trophic plasticity

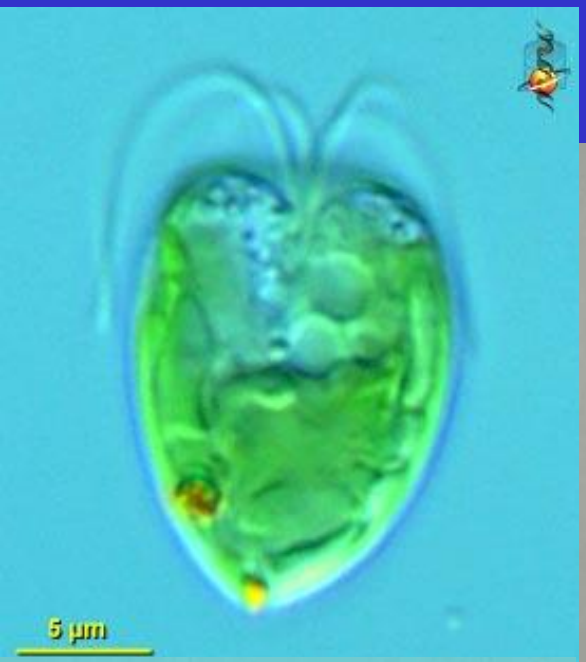


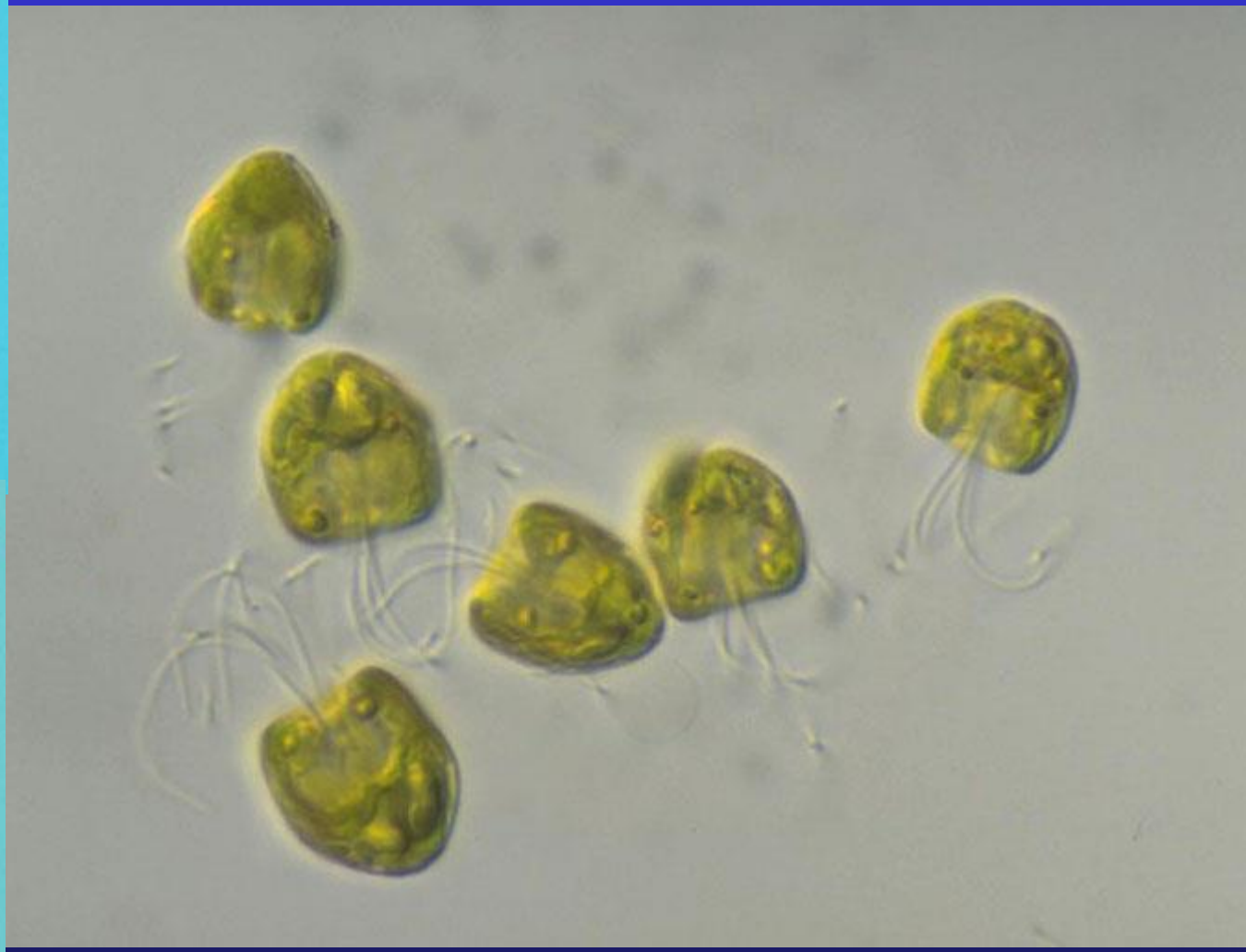
the Australian Davis Station, Vestfold Hills, eastern Antarctica

Diagrammatic representation of *Pyramimonas gelidicola* ultrastructure illustrating scale duct and reservoir thought to be involved in prey uptake. FLP, fluorescently labelled prey.



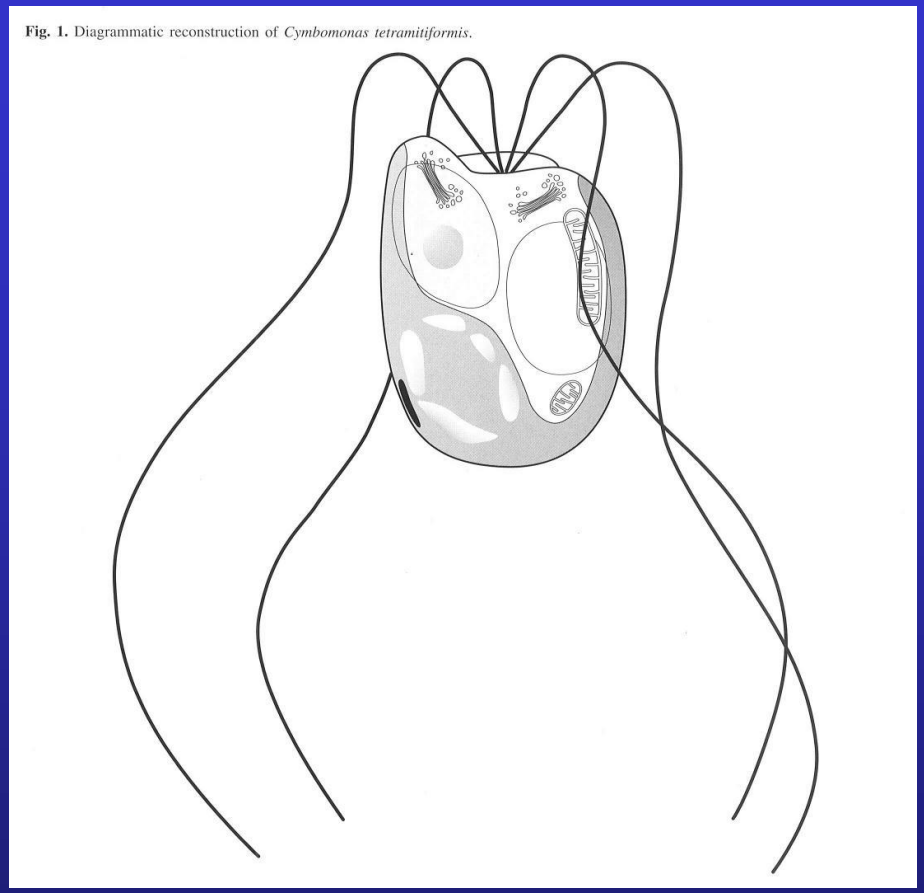
Pyramimonadales





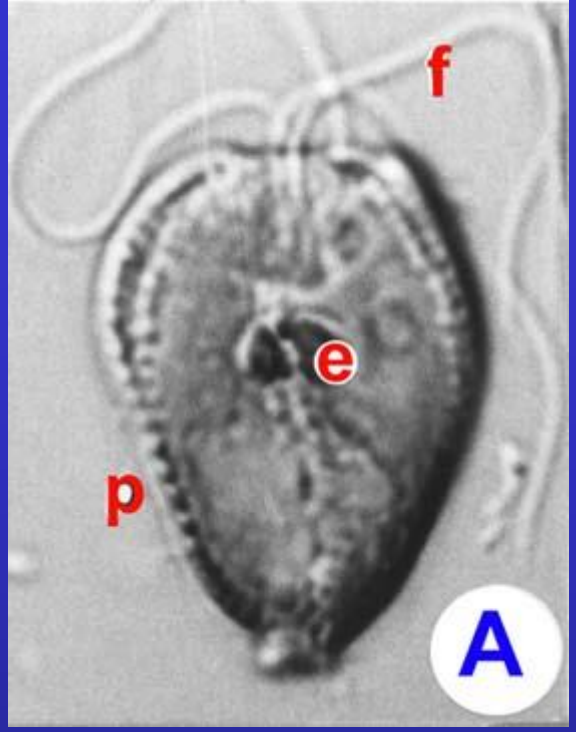
Pyramimonas

Pyramimonadales



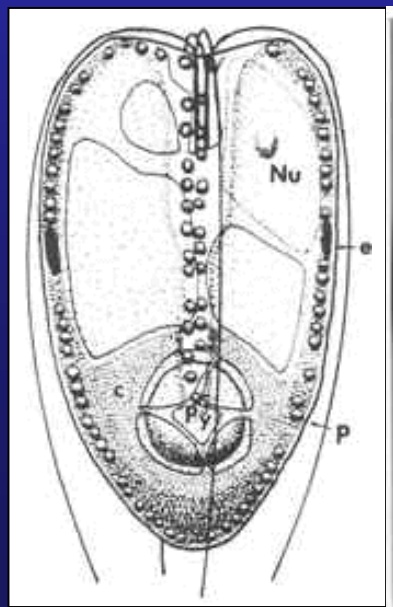
Cymbomonas tetramitiformis

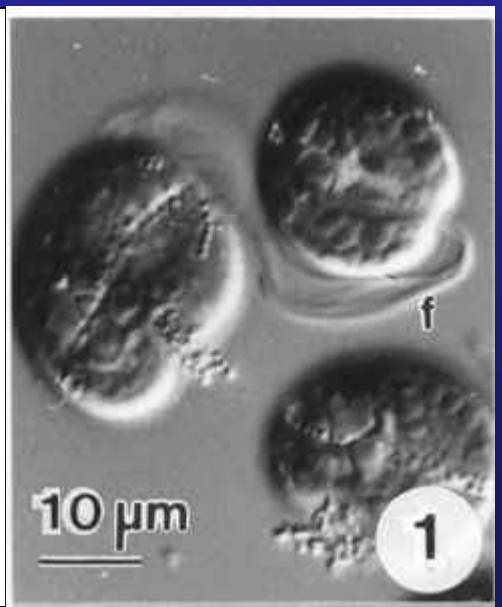
Pyramimonas sp.



Pyramimonas mucifera

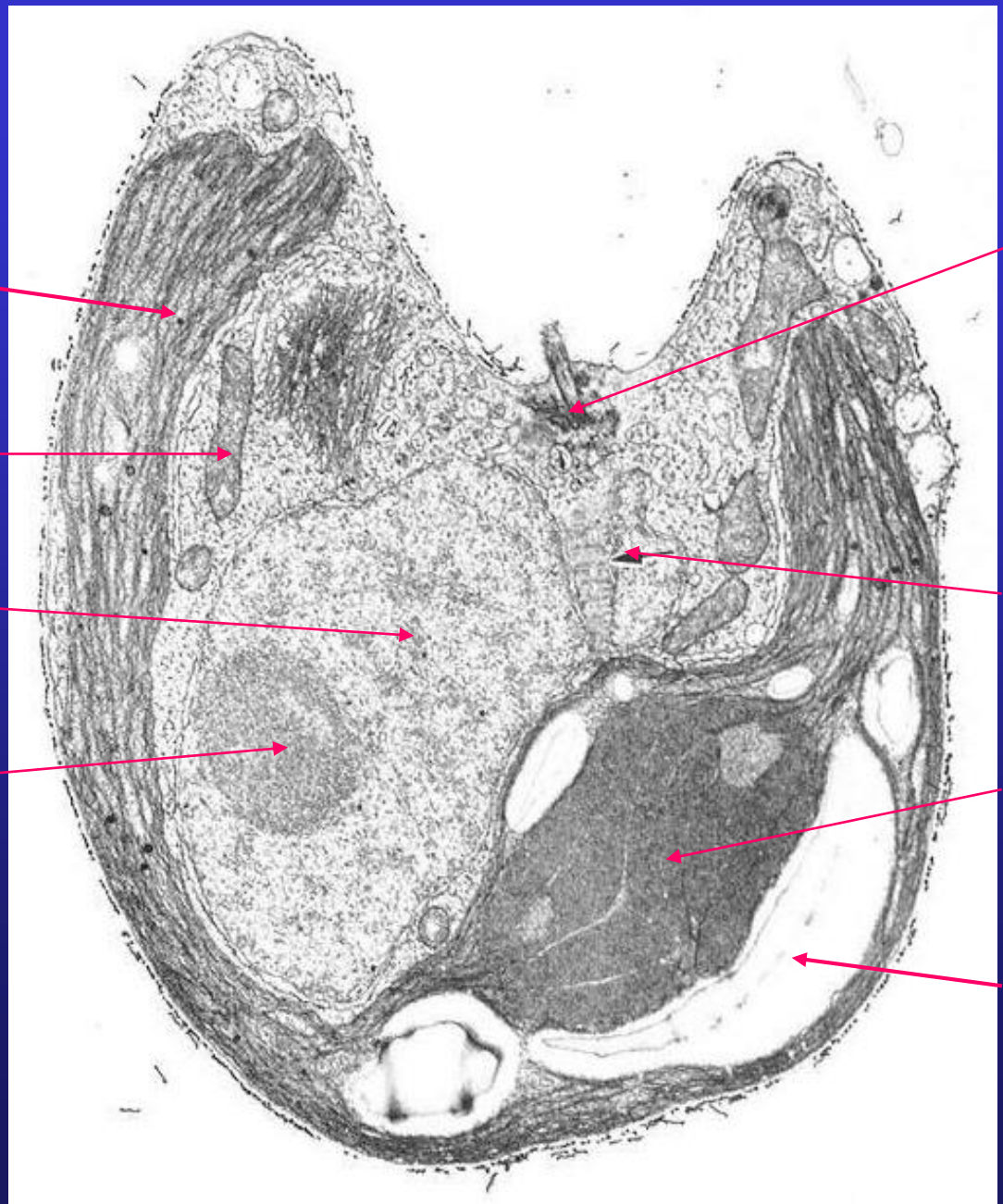
bentic species, produces slime – adaptation to bentic environment



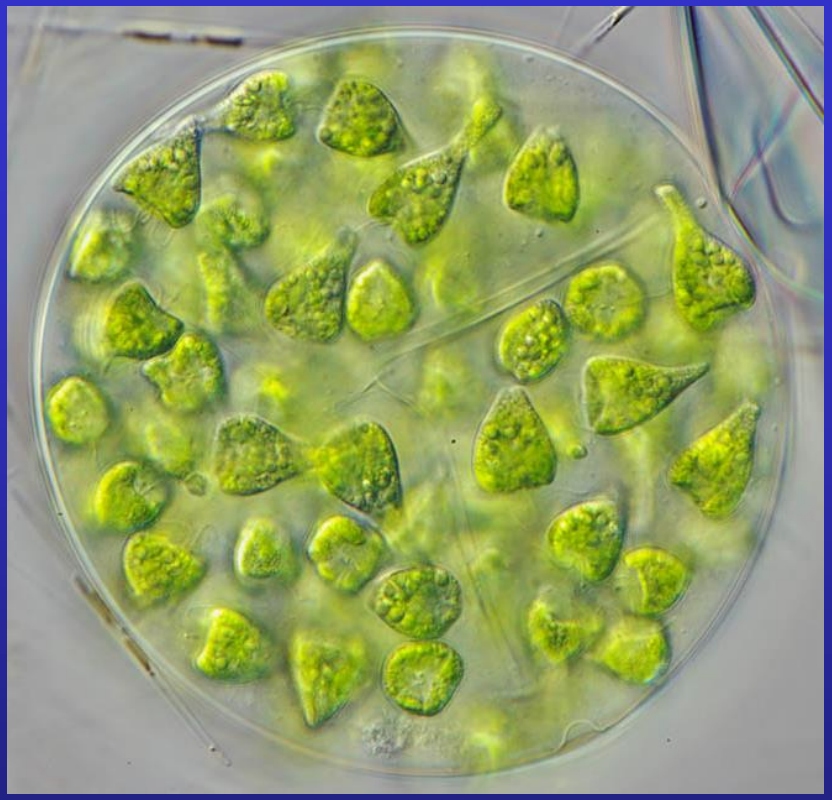


Pyramimonadales

Cymbomonas



Pyramimonadales



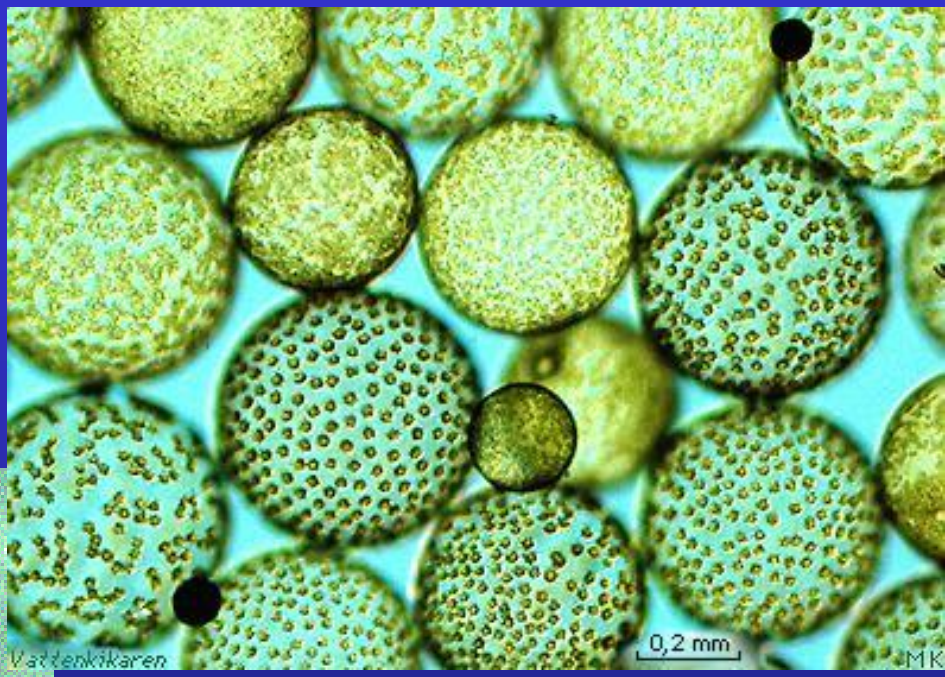
Phycoma (=asexual cyst)
calm winter seas

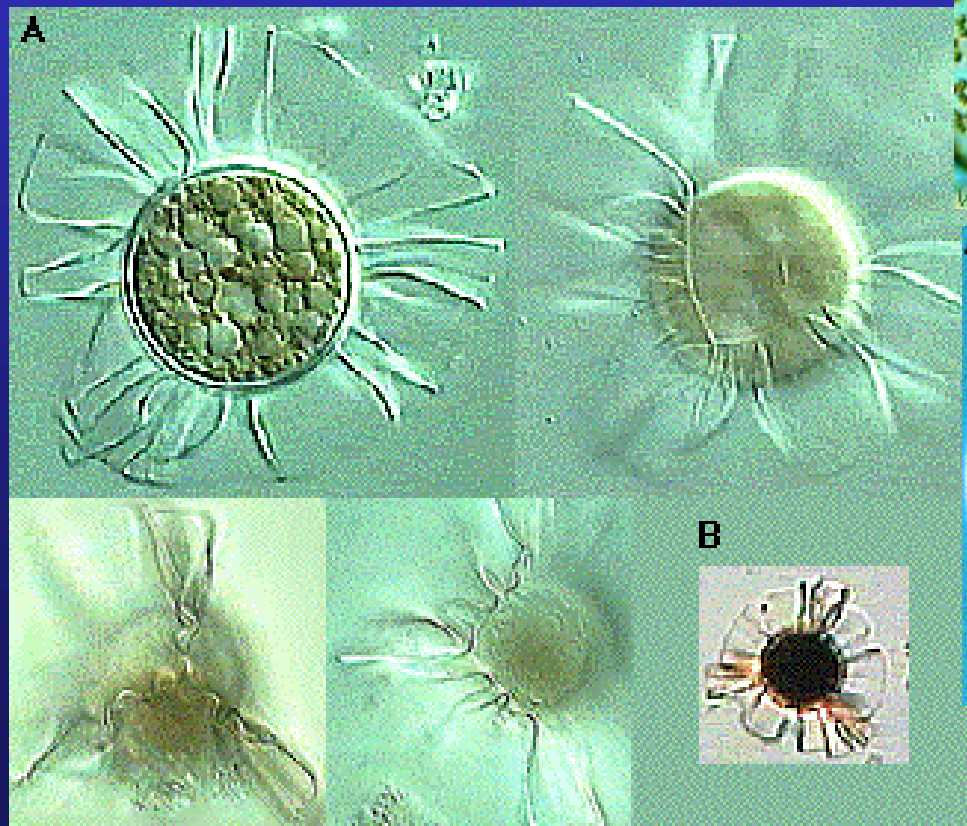
Halosphaera - fagotrophy,
mixotrophic nutrition

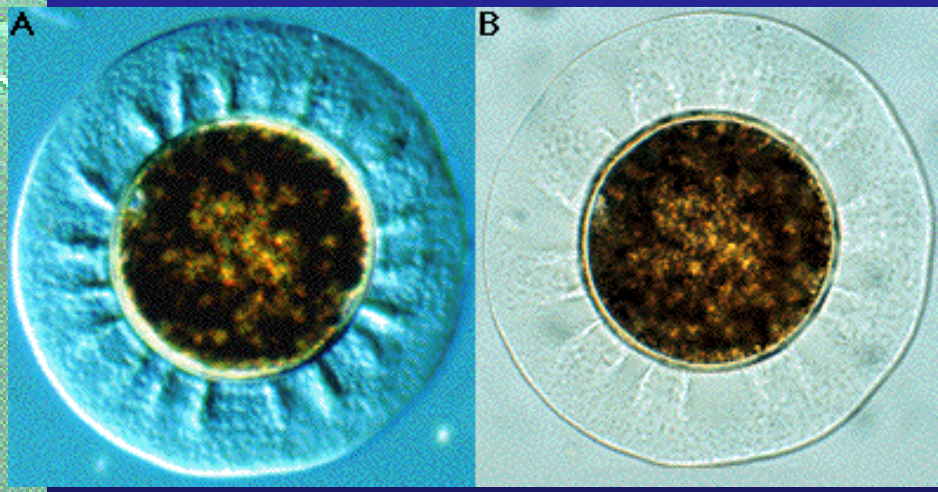
Phycoma

- asexual cysts, resistent outer cell wall
- fossil records from Precambrium (250-540 mya)

Halosphaera





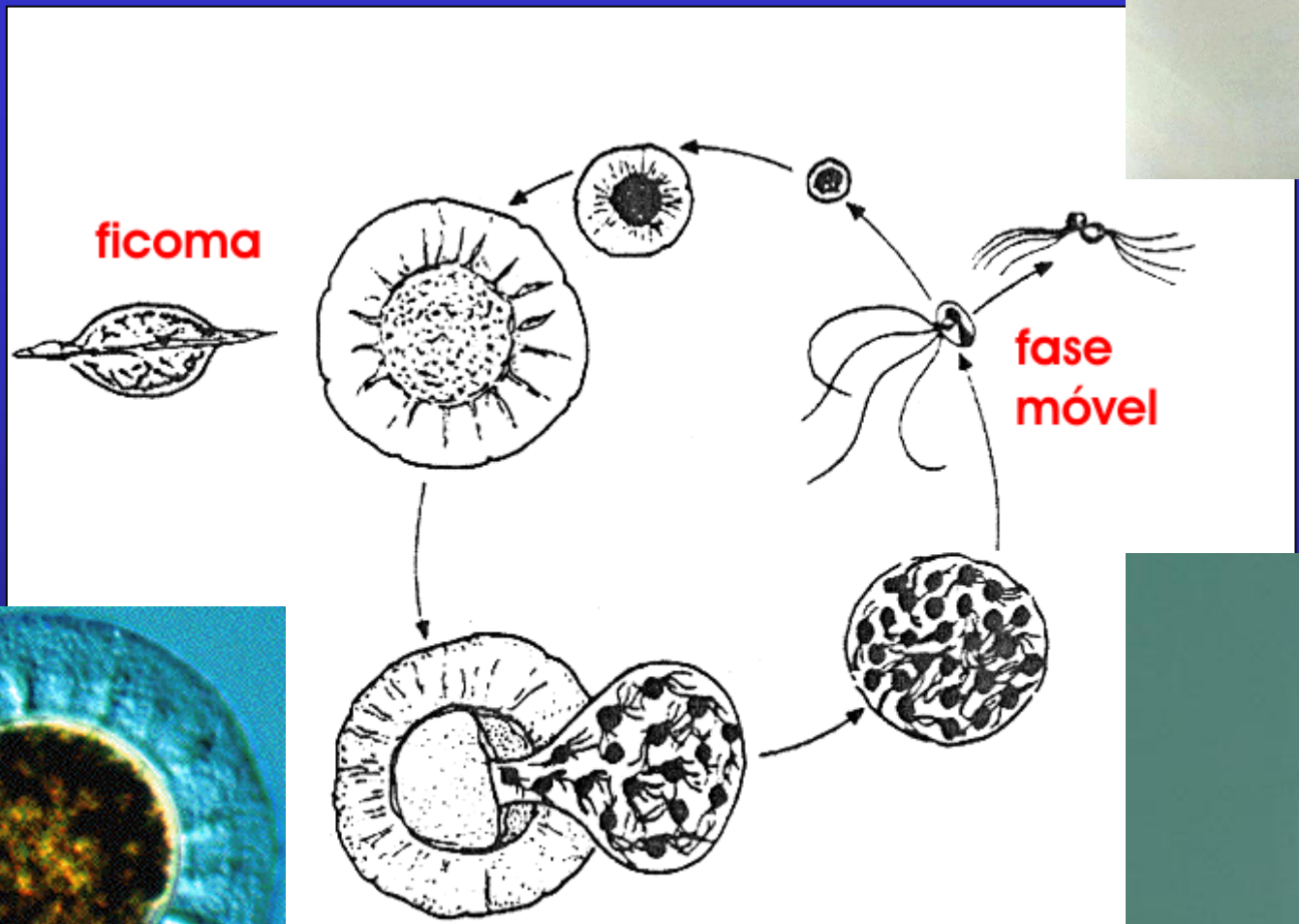


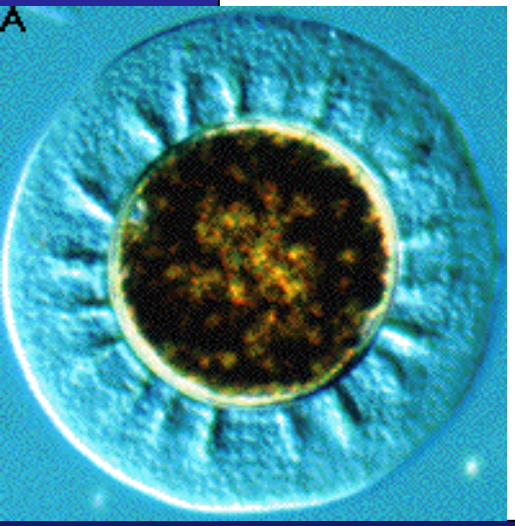
Pterosperma

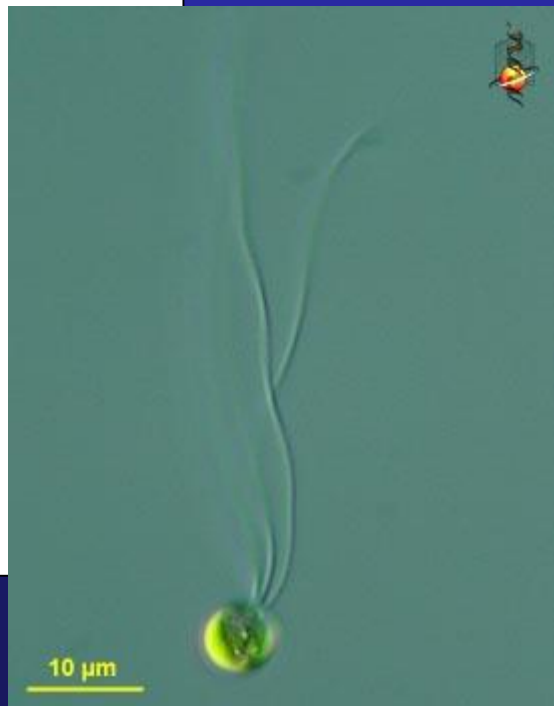
Pyramimonadales

Halosphaera – během jara a počátkem léta se mohou phycomata hromadit v povrchových vrstvách (nesena proudy a větrem) a působí vegetační zákal – zelená olejovitá voda.

Pyramimonadales





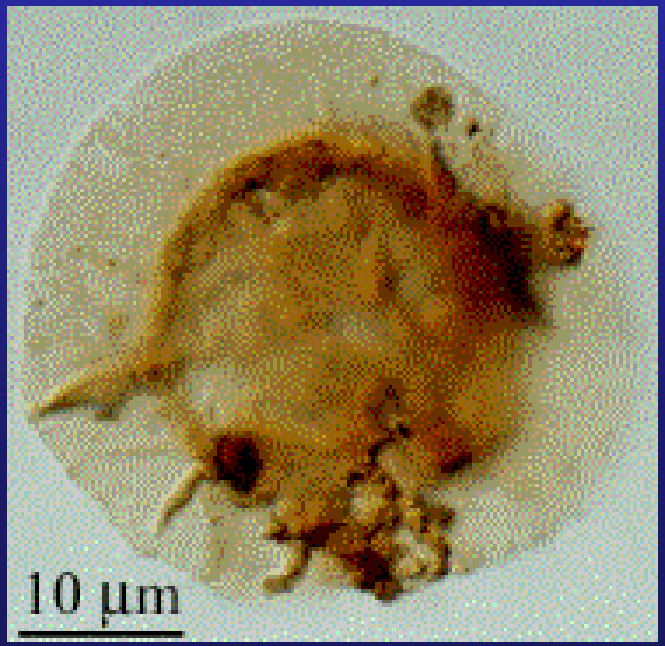


Pterosperma – live cycle

Fossil species

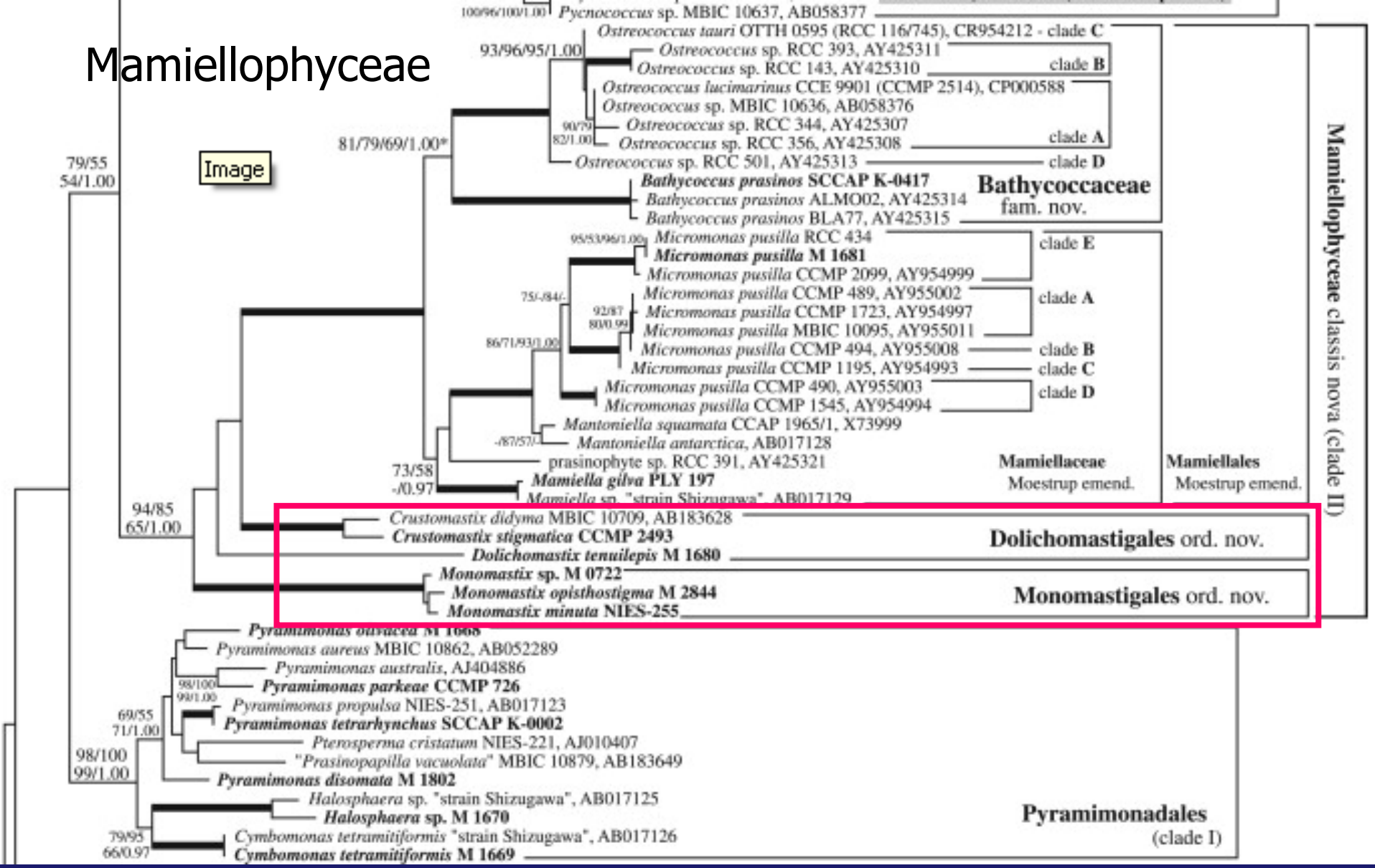
Tasmanites

600 mya - Precambrium



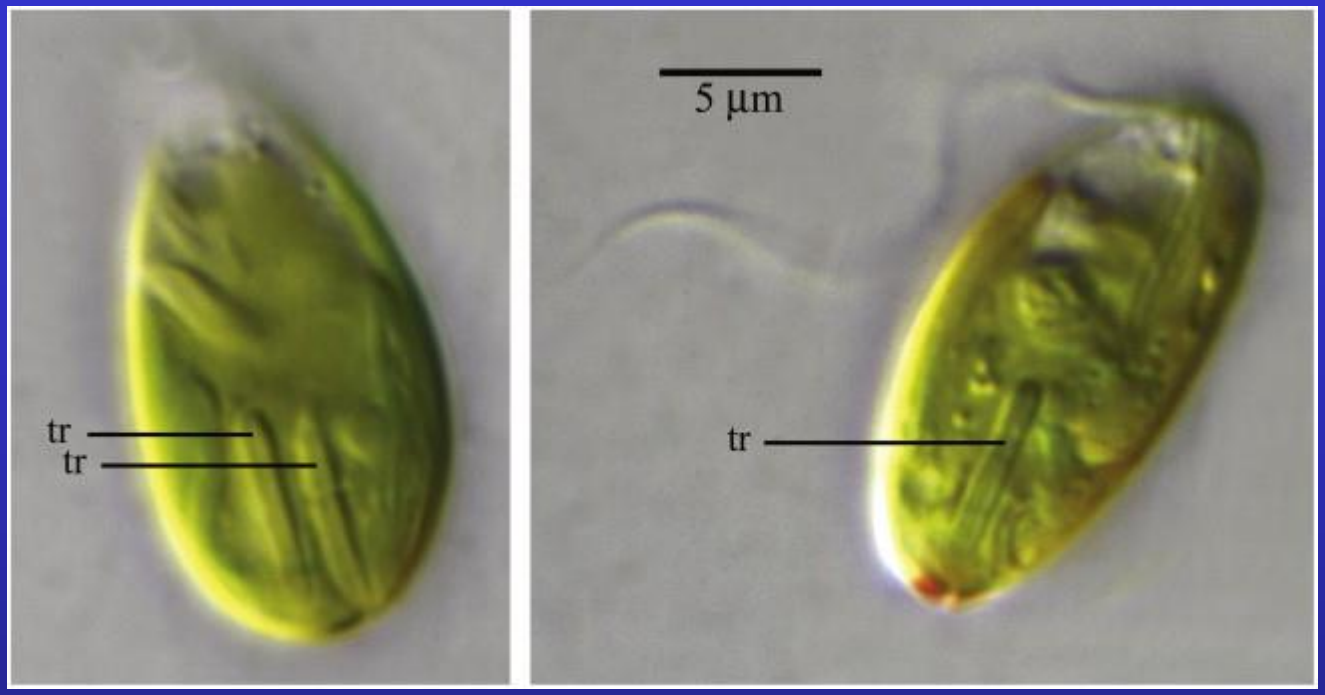
Pterospermella

Mamiellophyceae



Monomastigales – freshwater

Monomastigales



trychocysts=
ejectosomes

Light micrographs of *Monomastix opisthostigma*

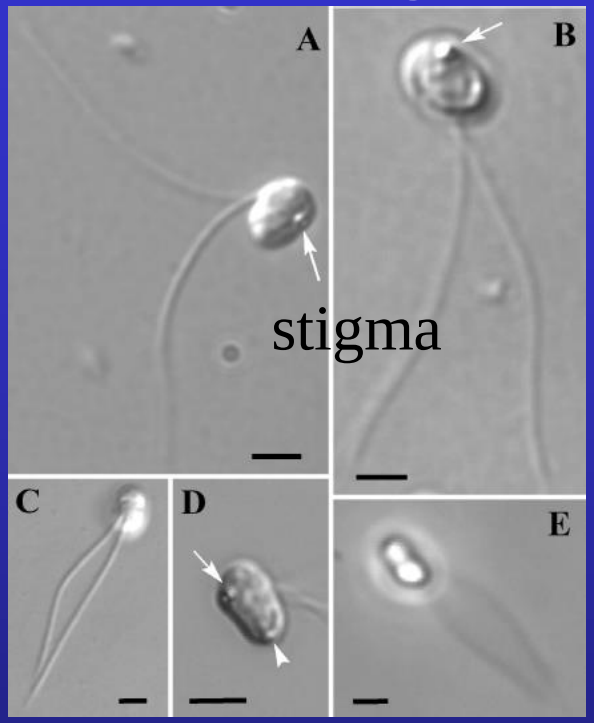
basal lineage – large cells up to 20 µm

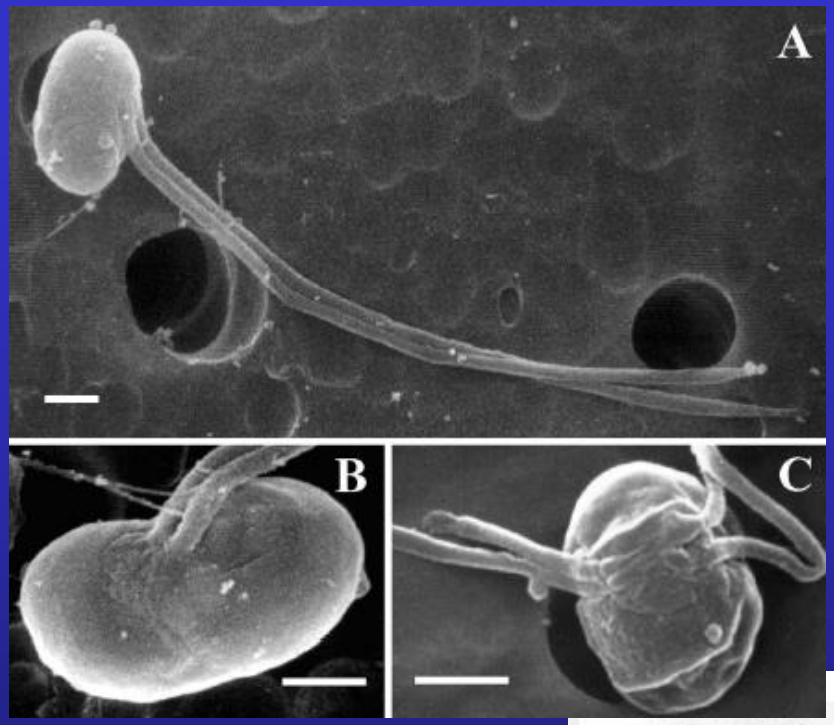
Dolichomastigales and the Mamiellales cells are usually no longer than 5 µm and in two lineages (Bathycoccaceae and *Micromonas*) are reduced to the size of the smallest eukaryotes (1 µm; Courties et al. 1994). Cell size reduction is accompanied by loss of the flagellar apparatus and eyespot (Bathycoccaceae) and/or the scaly covering (*Ostreococcus* and *Micromonas*).

Dolichomastigales

Crustomastix stigmatica

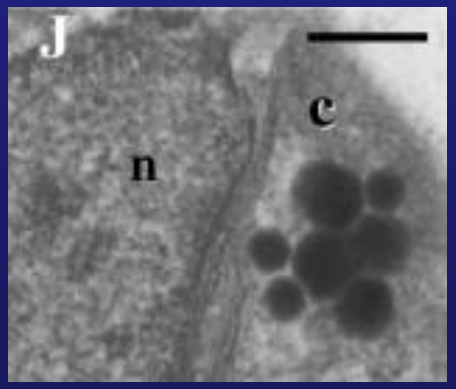
Zingone et al.2002



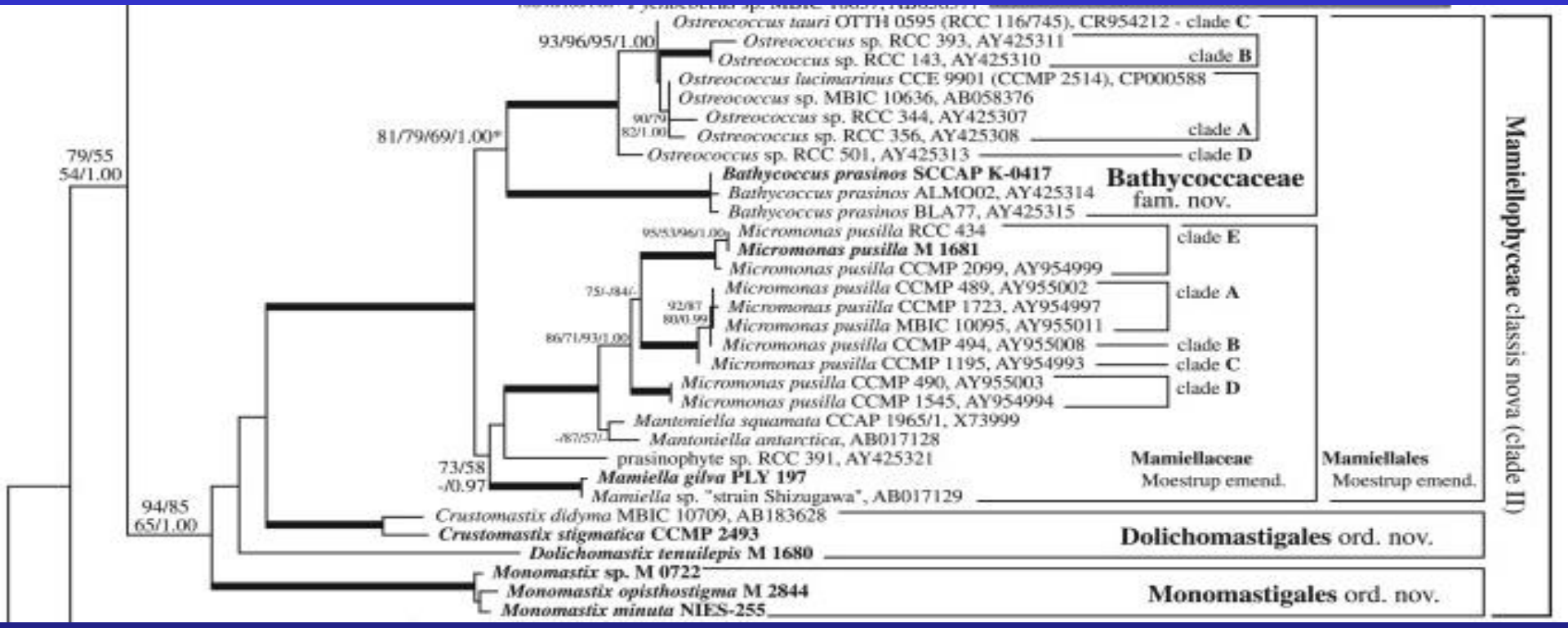


3-5 µm, scales on flagella, stigma; isolated from Mediterranean Sea

dividing cells

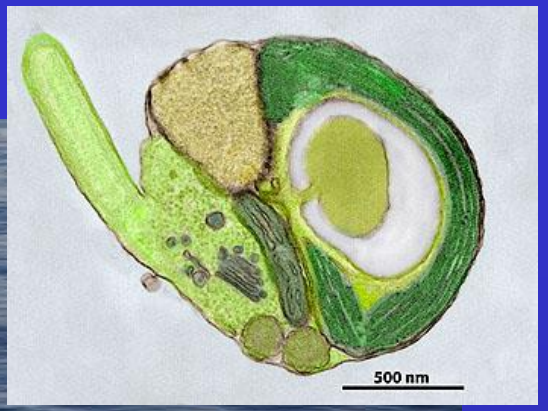


Mamiellalles

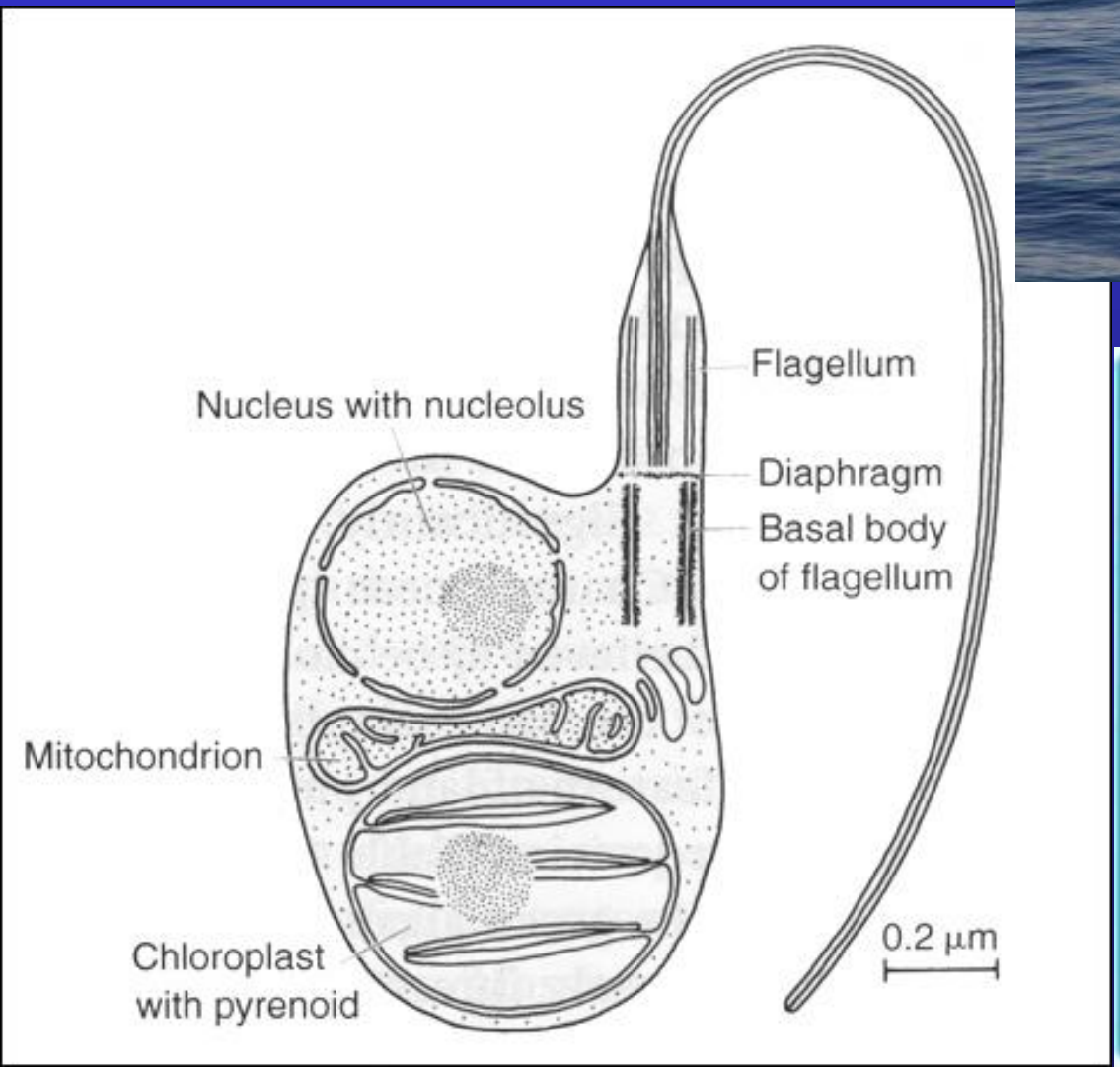


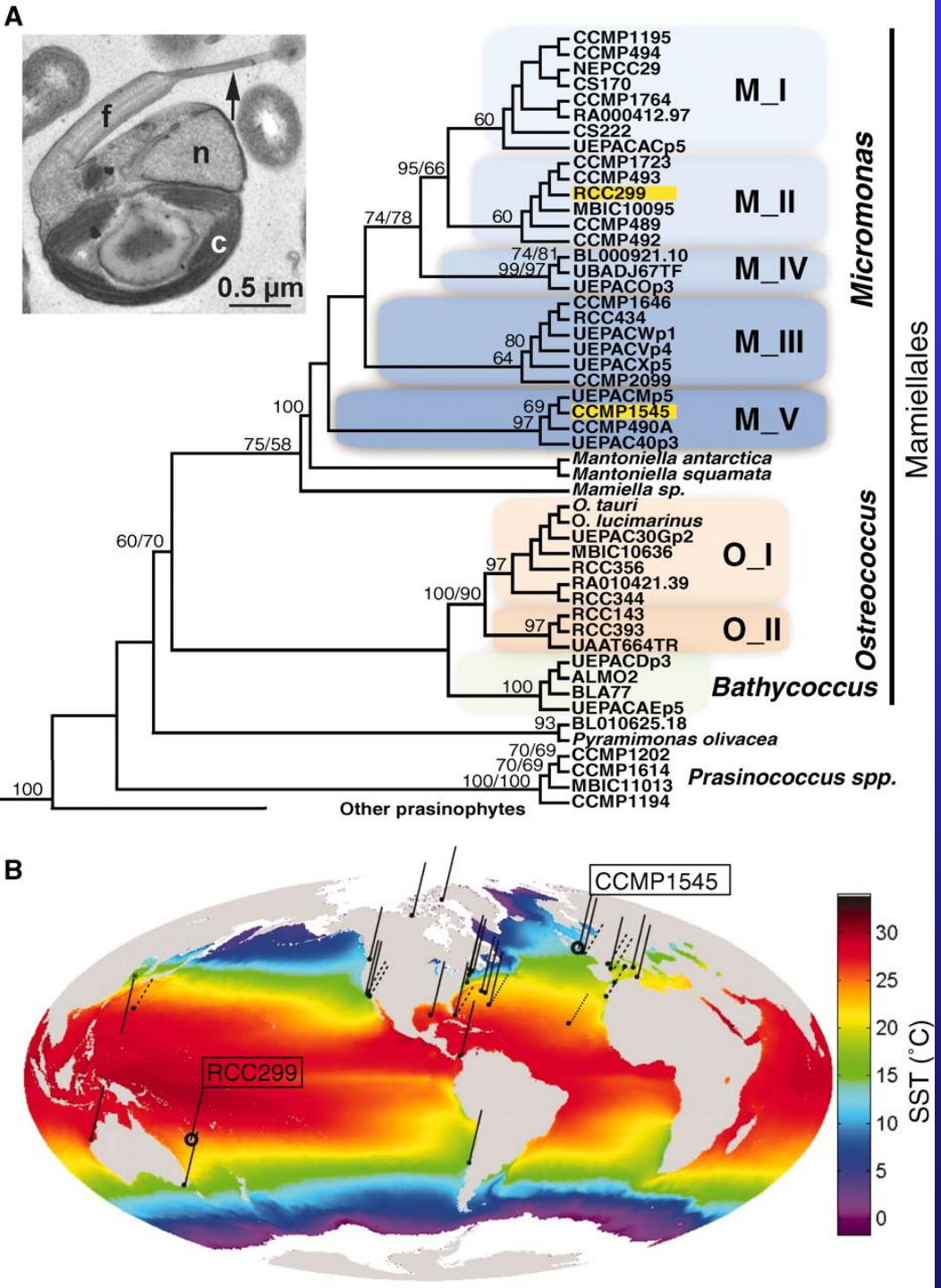
Mamiellales

Micromonas pusilla –
without scales



oceanic picoplankton

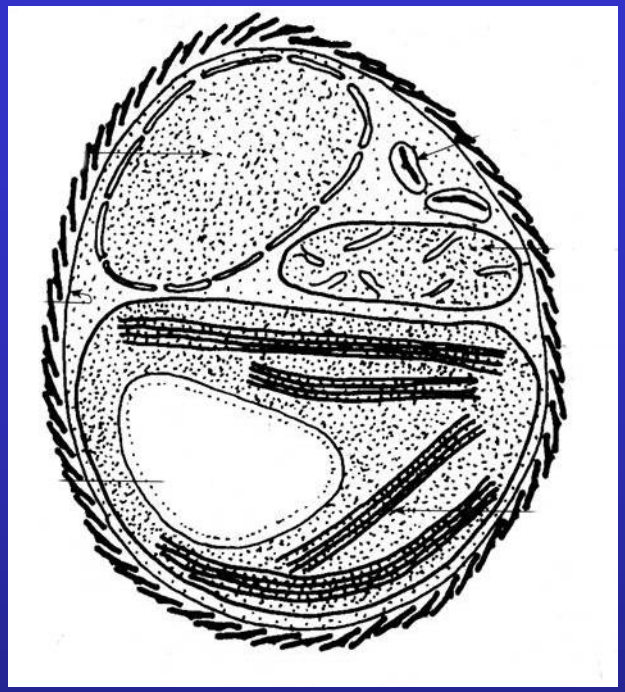


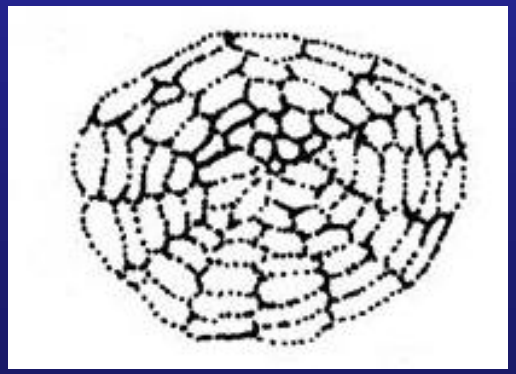


Micromonas phylogeny and distribution NJ tree. (**B**) Mean sea surface temperature (SST) for 2006 measured with global high-resolution SST (GHRSST) blended infrared and microwave SSTs, and locations where *Micromonas* (solid lines and circles around the isolates used in this work) and *Ostreococcus* (dashed lines) 18*S* rDNA sequences have been recovered. *Micromonas* appeared in all temperature regimes.

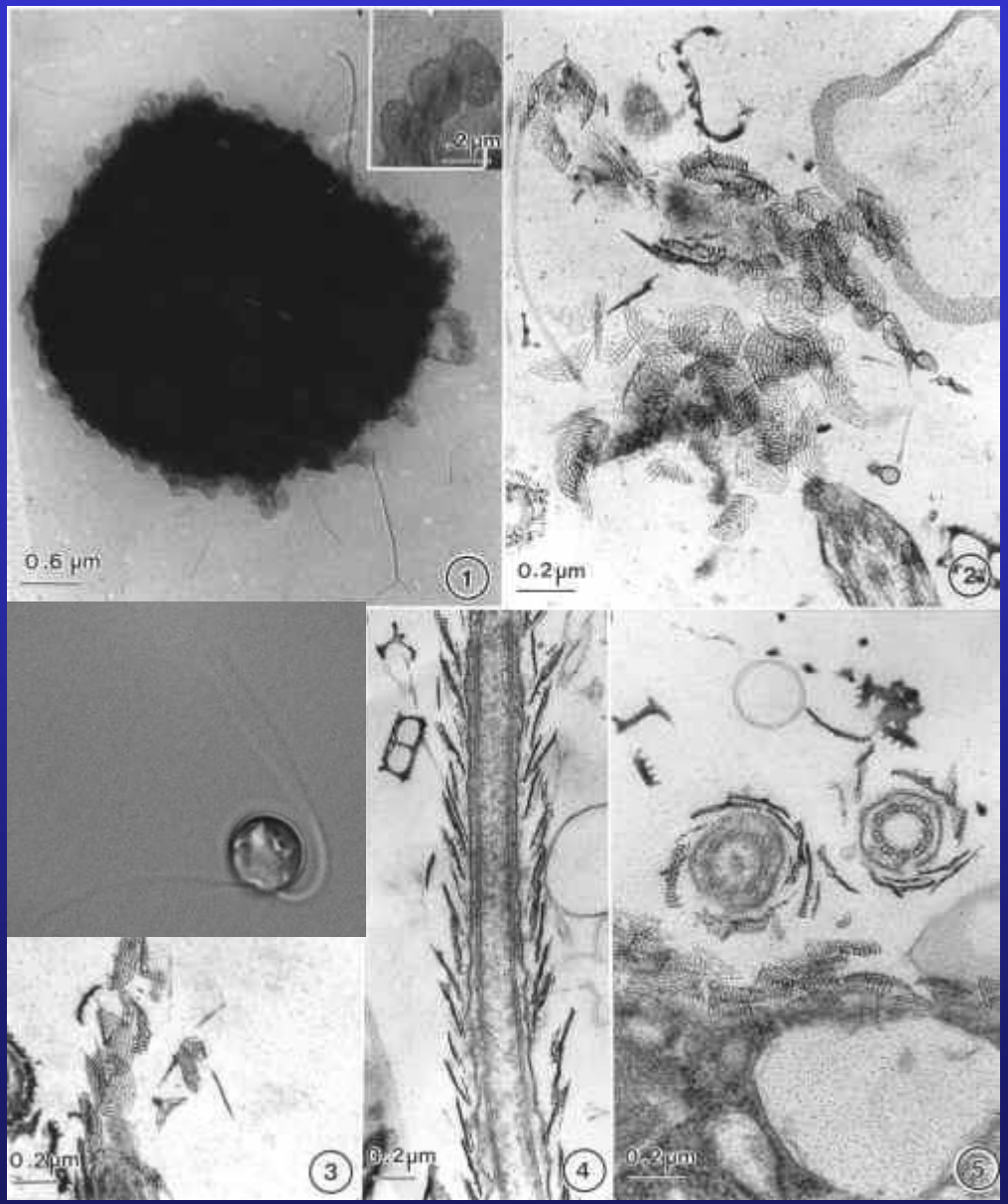
Worden *et al. 2009*

Mamiellophyceae



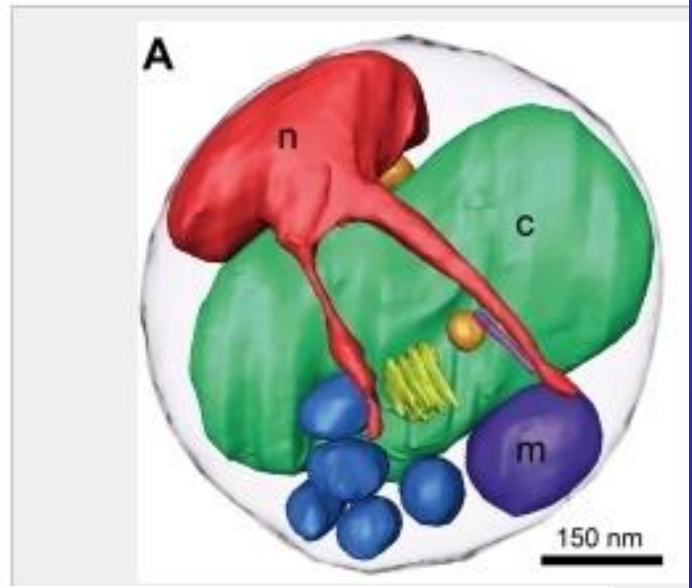


Bathycoccus – lost of flagellum
North Atlantic



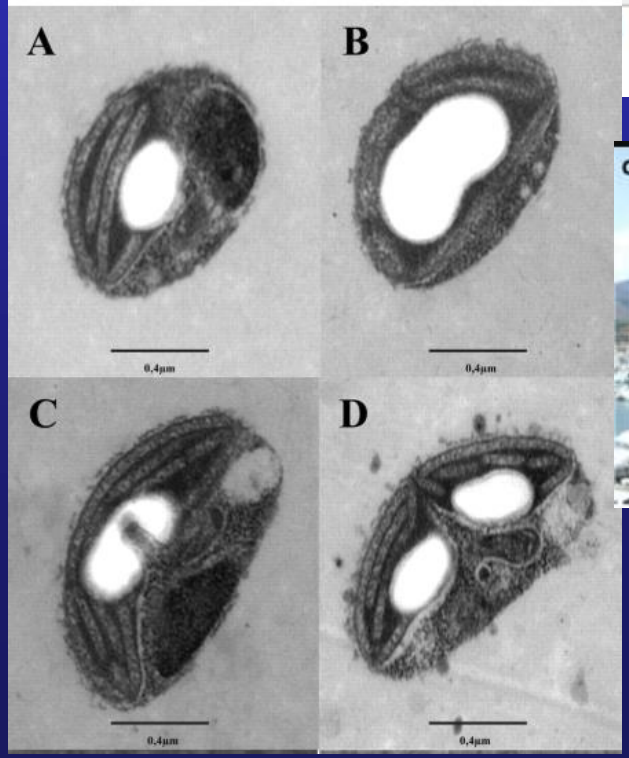
Mamiella gilva

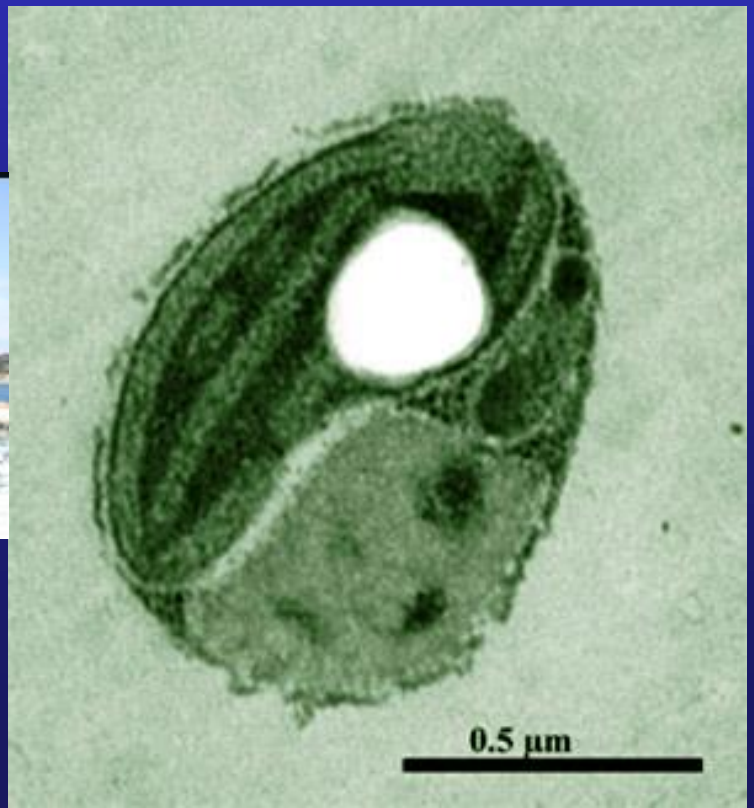
Mamiellales

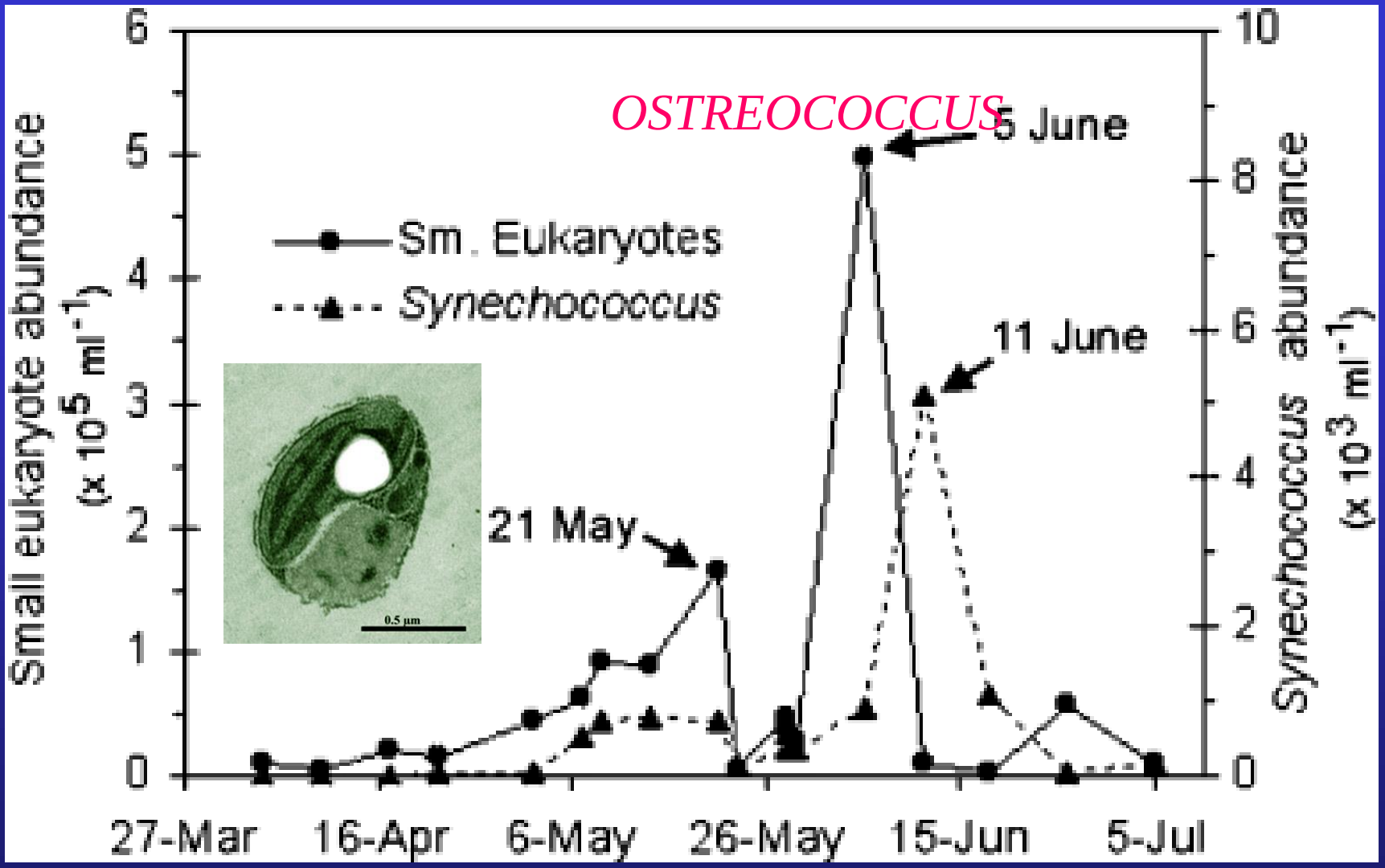


Ostreococcus belongs to the is reported as a globally abundant, single-celled alga thriving in the upper (illuminated) water column of the oceans.

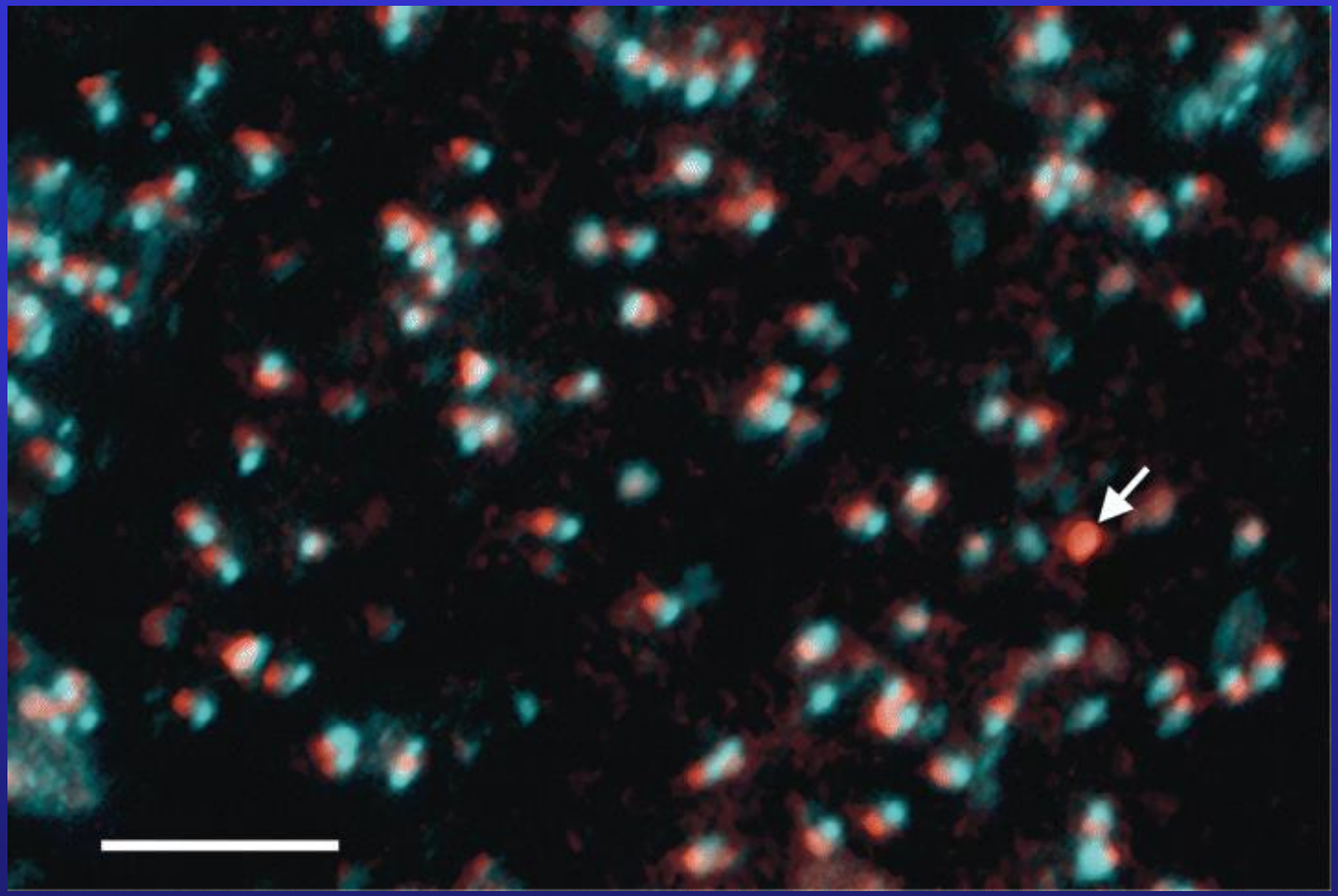
Blooms in the sea, the smallest eukaryotic genom







1. Abundances of small eukaryotes and *Synechococcus* cells over the 2001 study period in West Neck Bay, New York as counted by flow cytometry. Major bloom events are indicated. Note difference in scales.



Color composite epifluorescence micrograph showing DAPI-stained *Ostreococcus*-like cells with nuclei (cyan) and chloroplasts (red autofluorescence). A single *Synechococcus* cell (arrow) is also present. Scale bar, 10 μm.

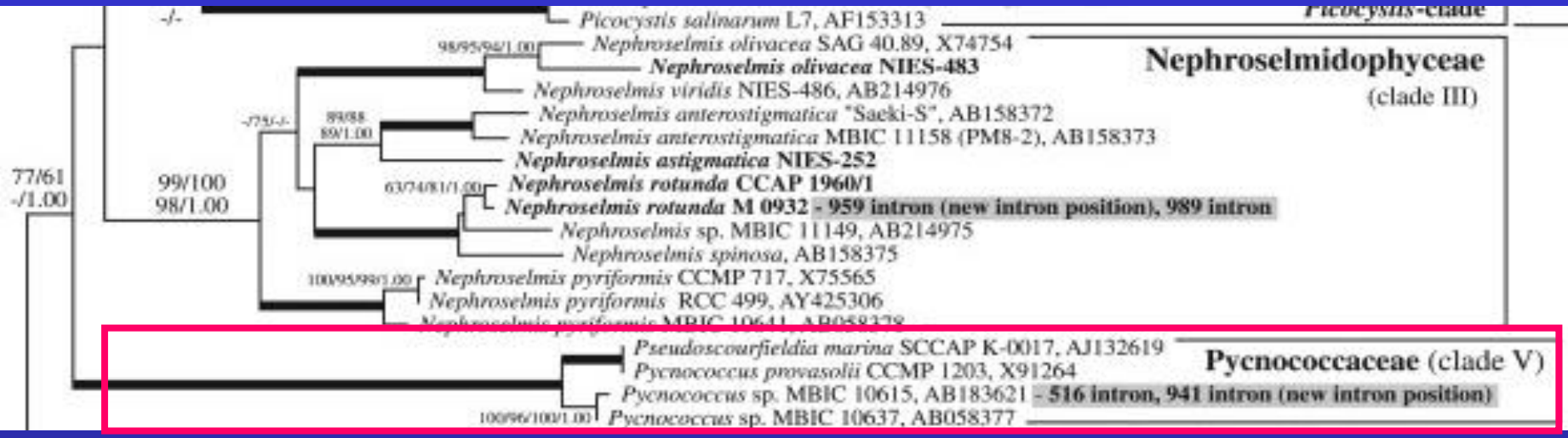
O'Kelly et al. 2003

Mamiellophyceae

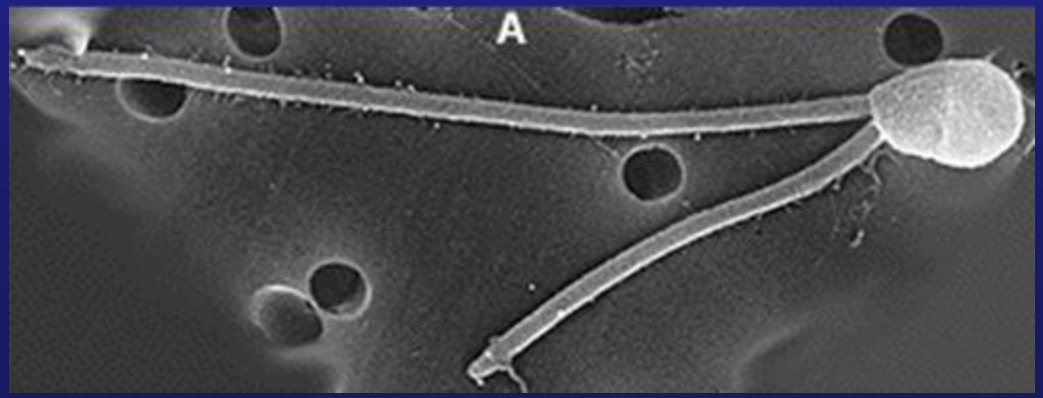
Do they reproduced sexually???

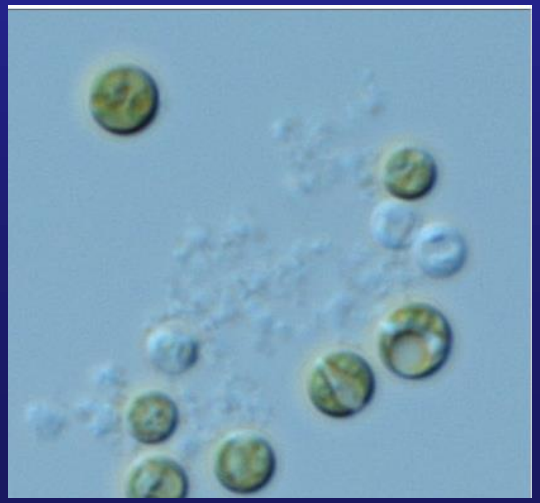
Ostreococcus as well as *Micromonas* may contain meiotic genes and thus reproduce sexually (Derelle et al. 2006; Worden et al. 2009), but experimental proof for sexual reproduction in the Mamiellophyceae is still lacking.

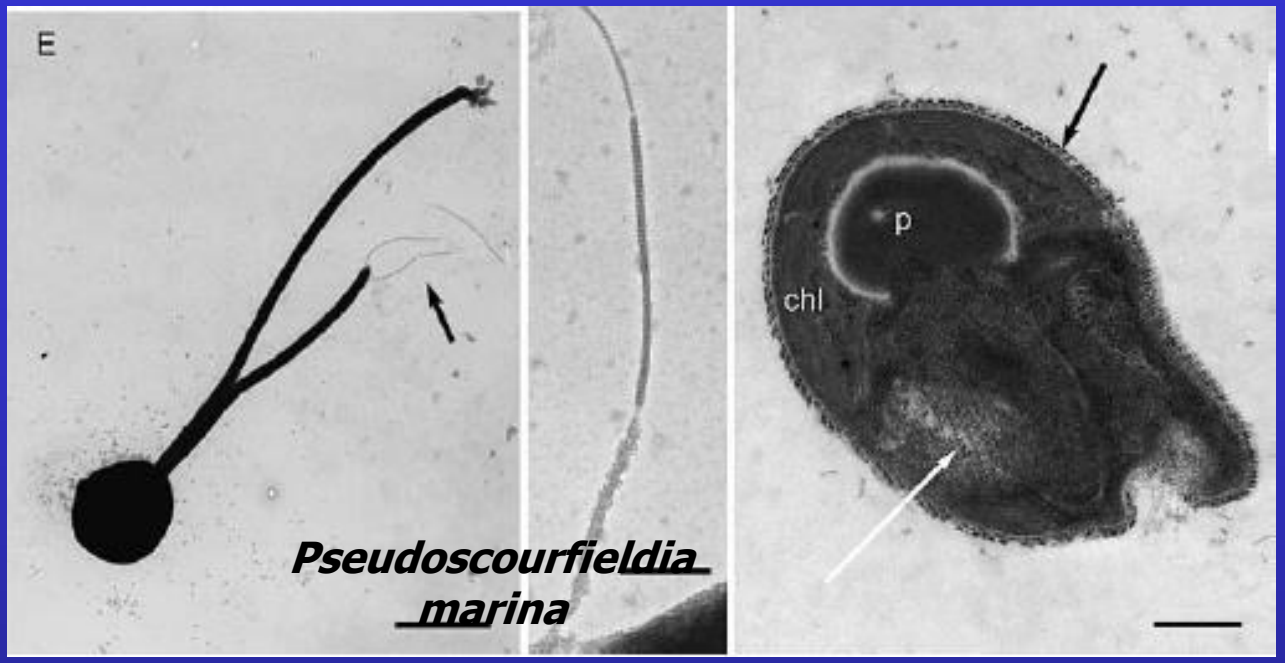
Pycnococcaceae



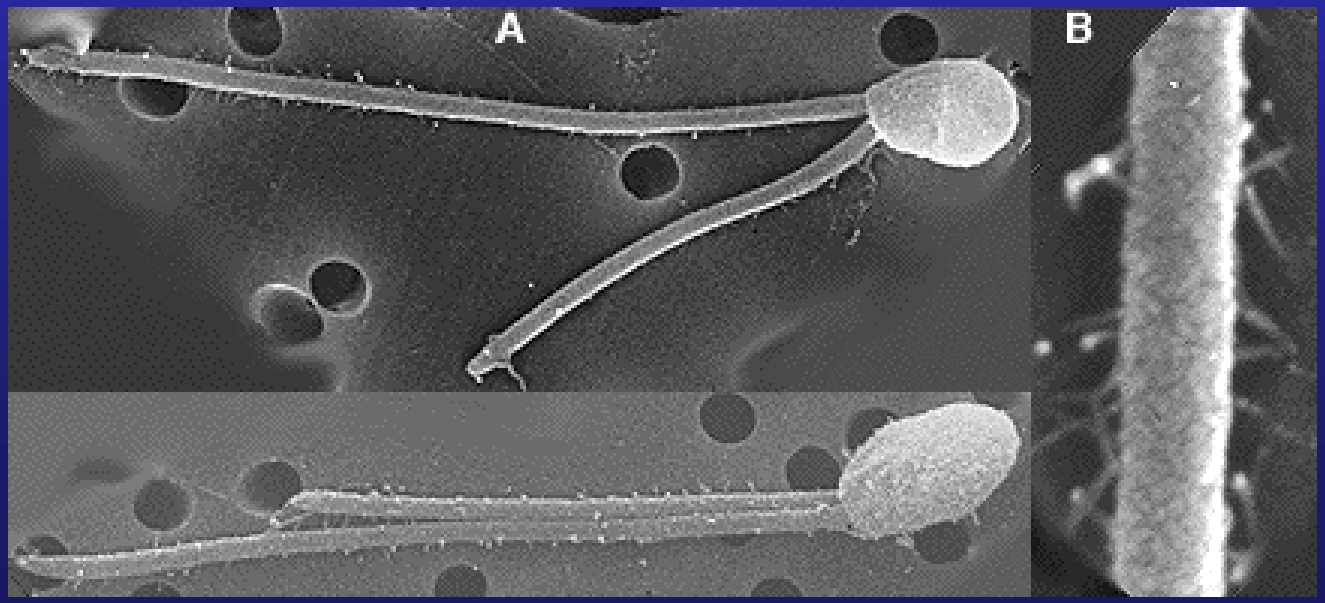
Pseudoscourfieldia marina and *Picnococcus provasolii* are genetically identical and presumably represent different life history stages of a single taxon; unpubl.



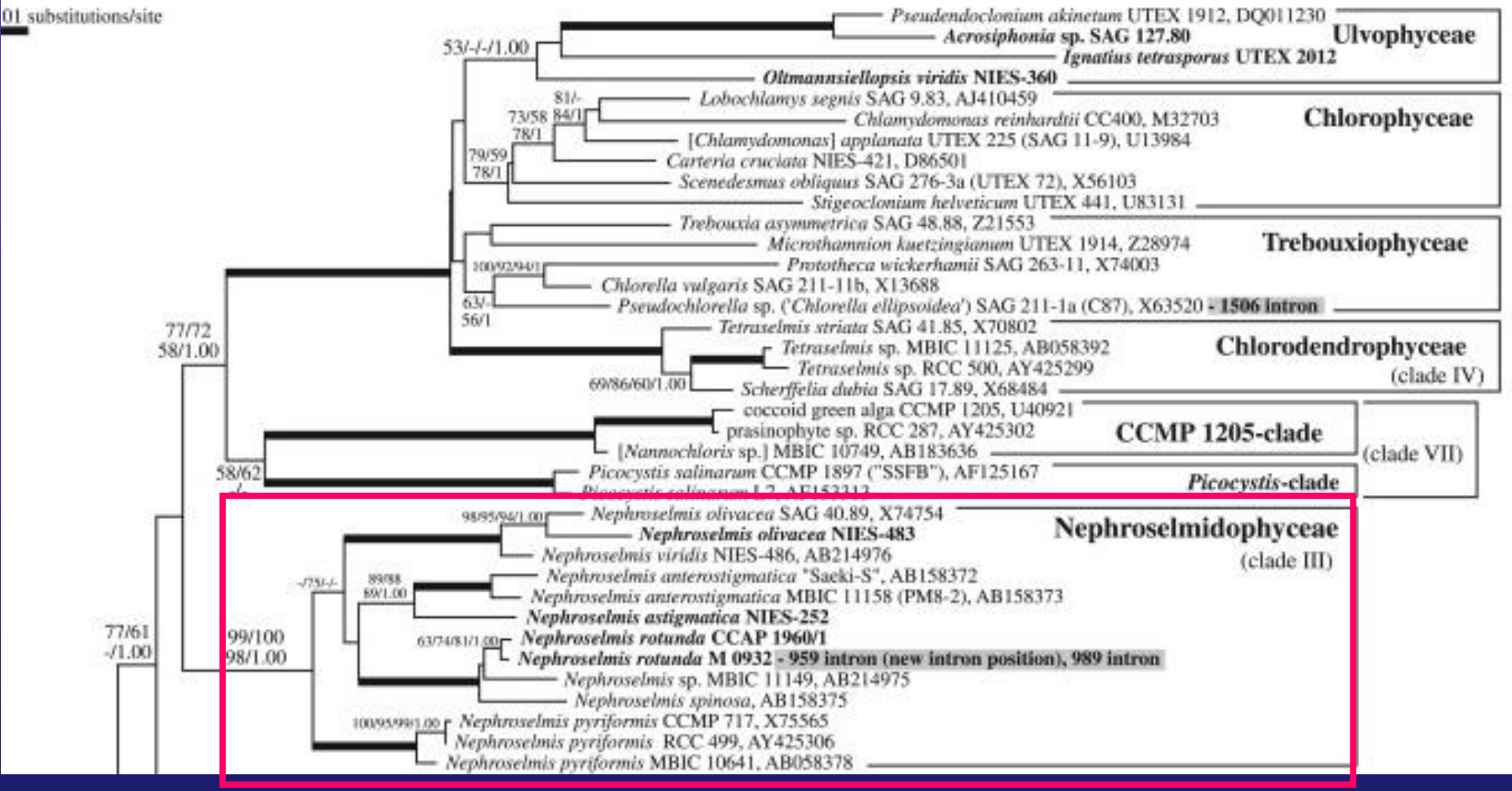




Guillou et al. 2004

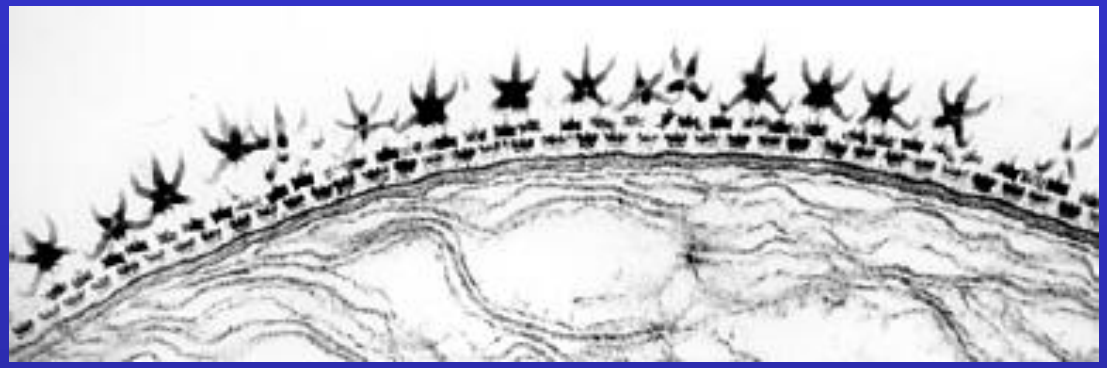


Nephroselmidophyceae

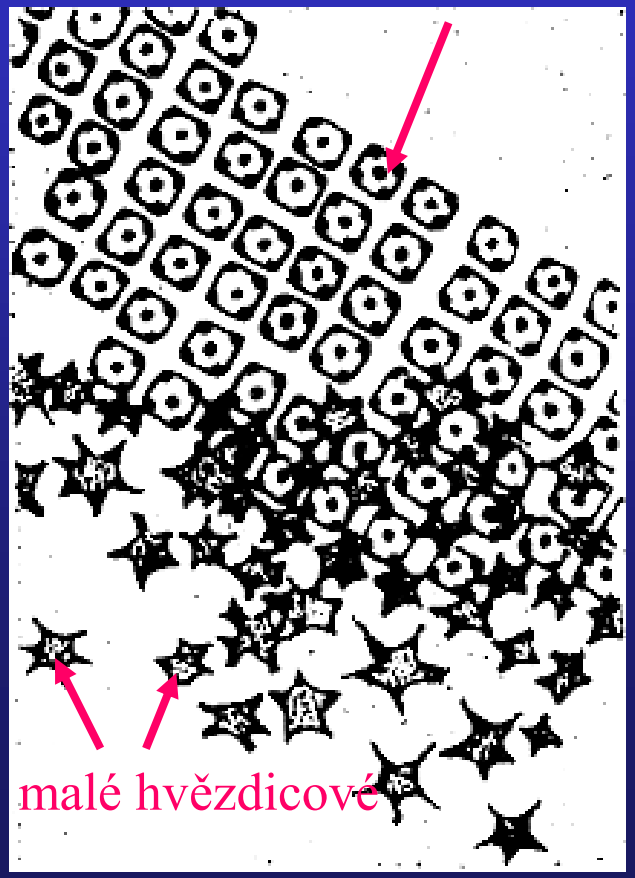


Organic scales

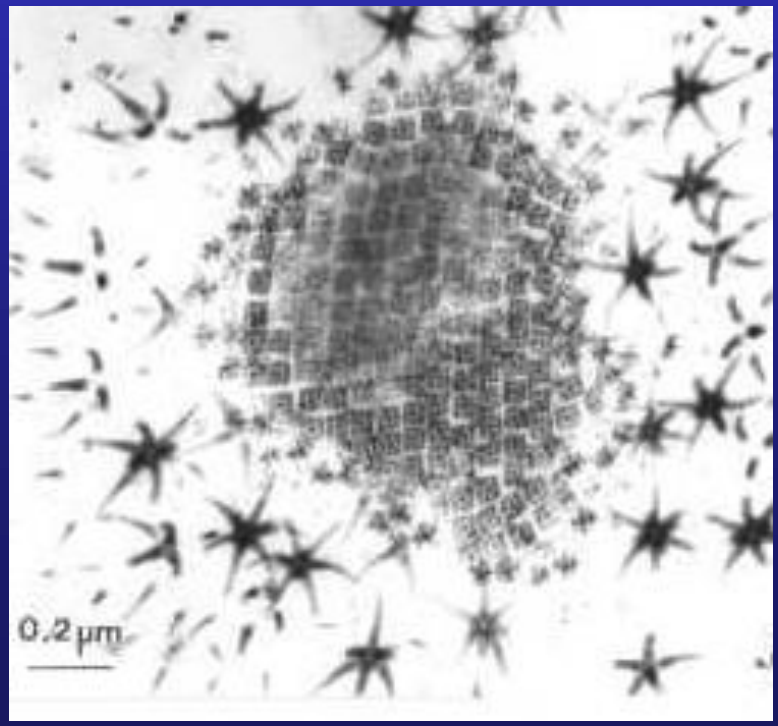
Nephroselmis



malé čtvercové

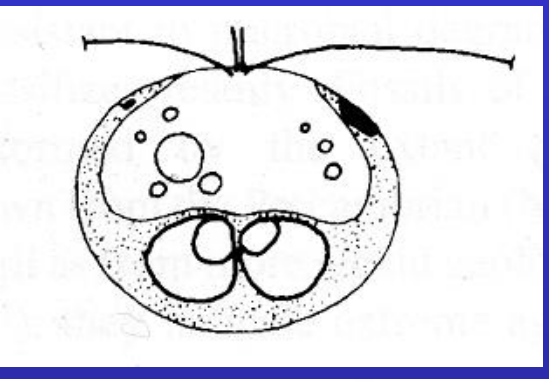


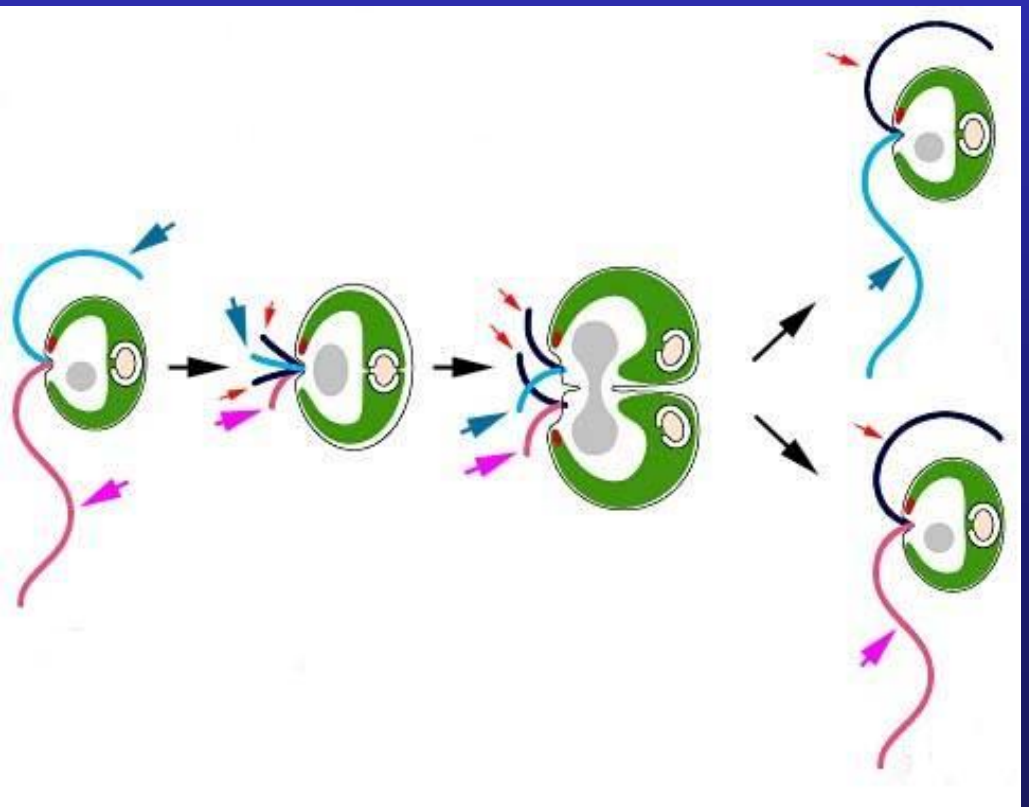
velké hvězdicové



Mitosis and cytokinesis

- schizotomy

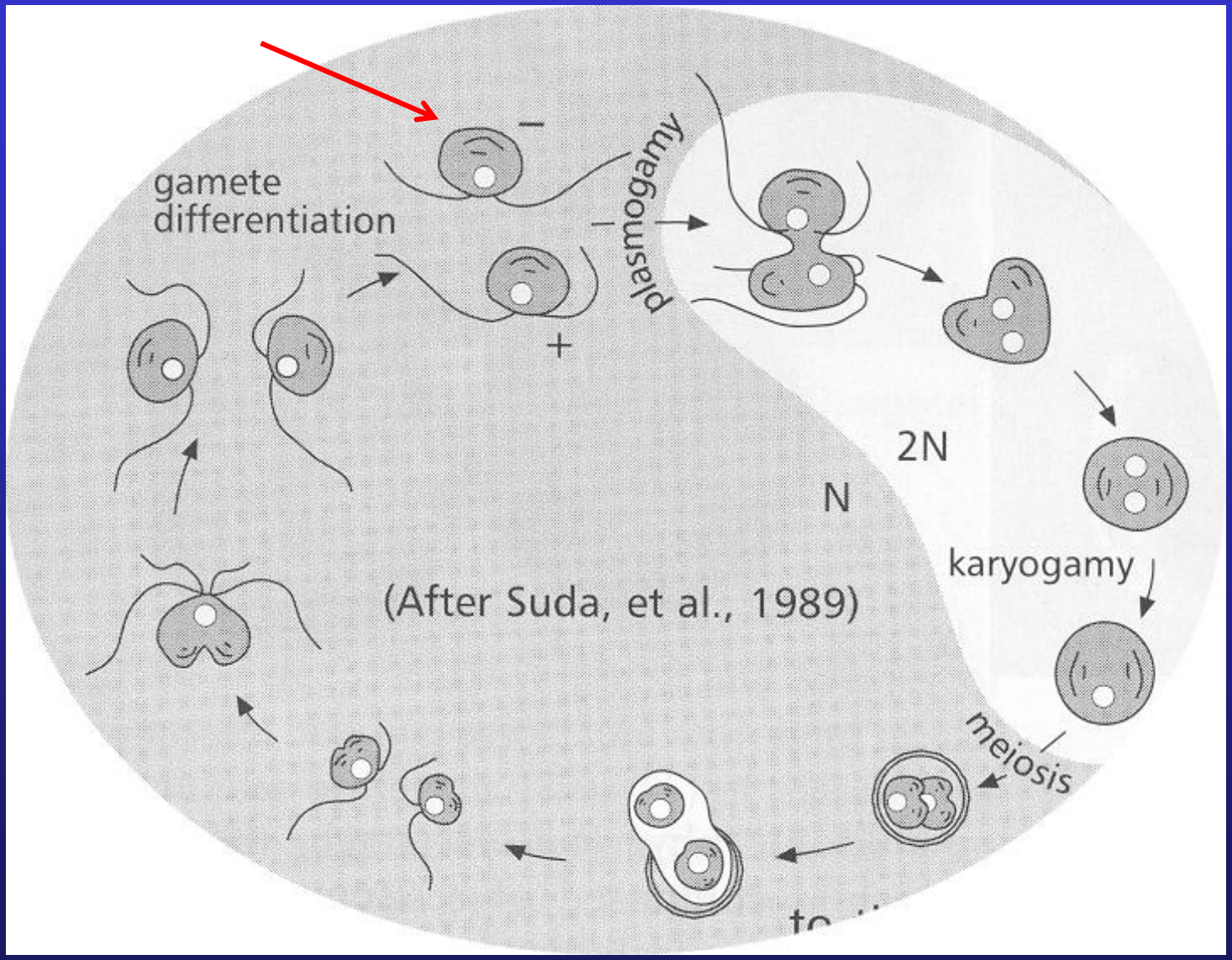




Nephroselmis rotunda

Sexual reproduction

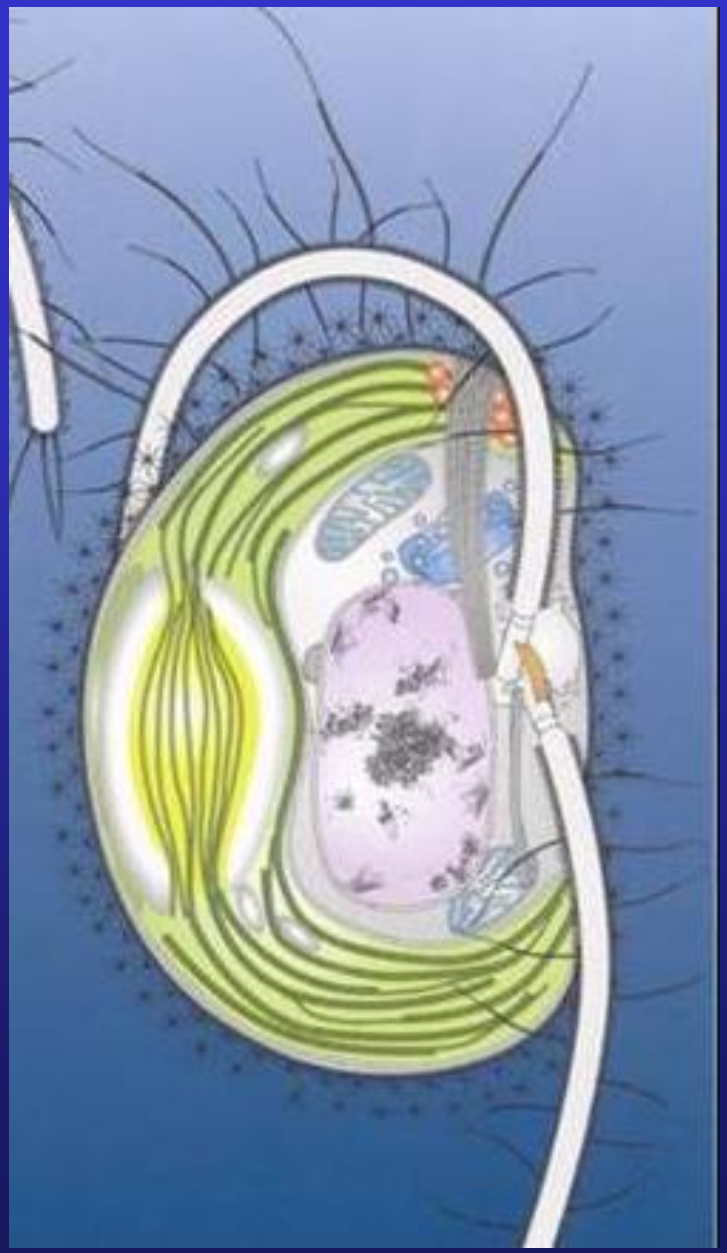
Haplontic life cycle, izogamy, heterothalism

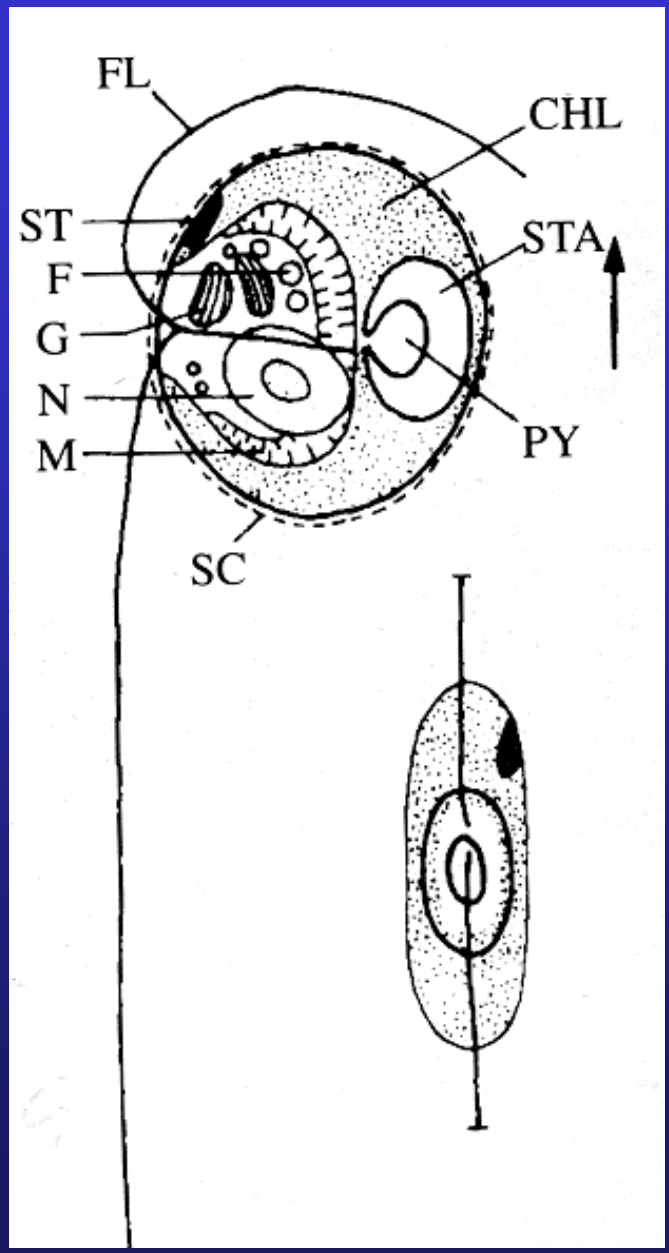


Nephroselmis olivacea

Nephroselmidophyceae

Nephroselmis



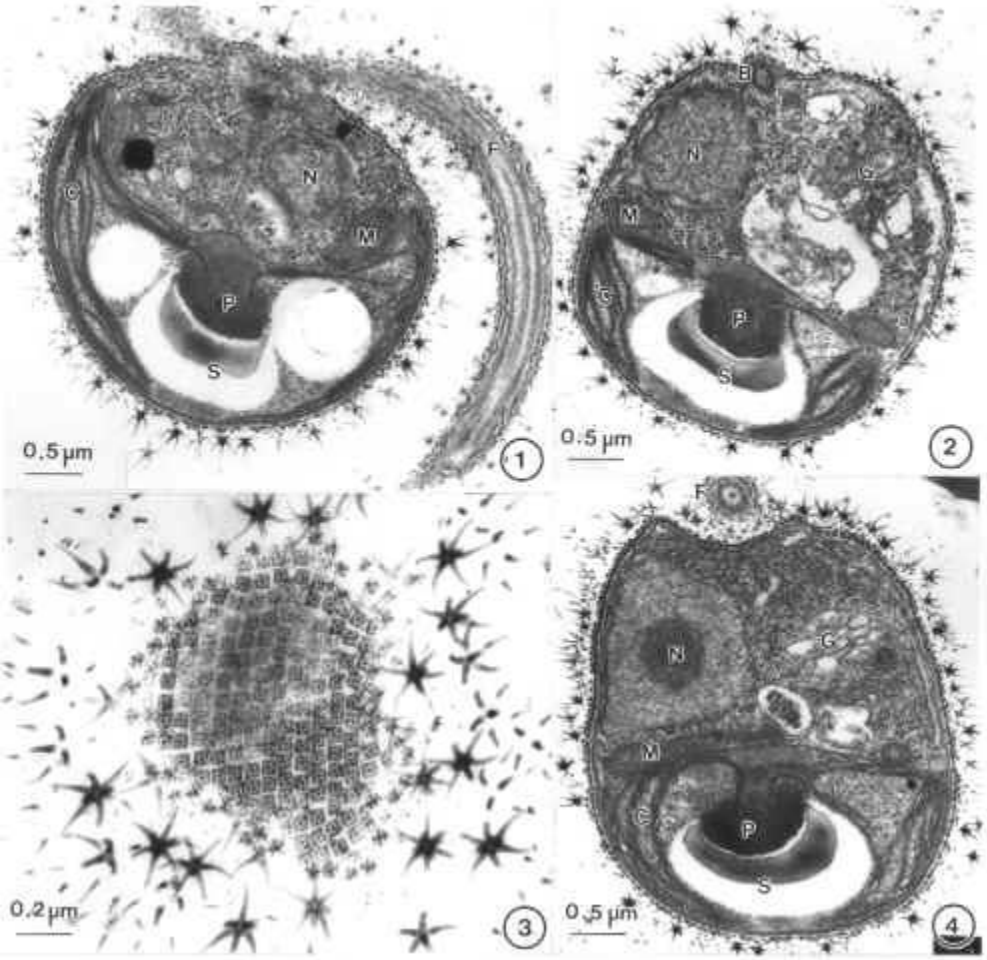


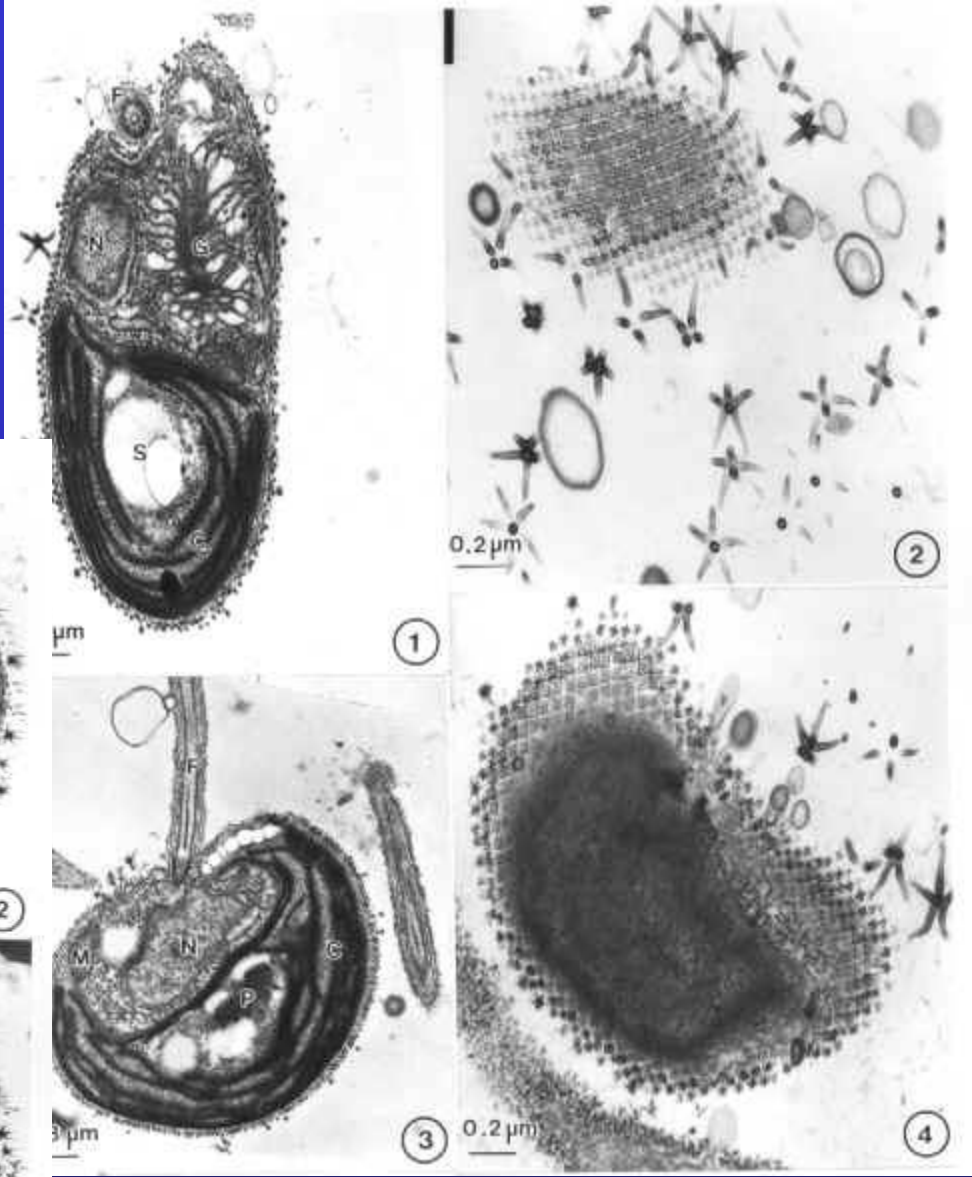
Nephroselmis - ultrastructure

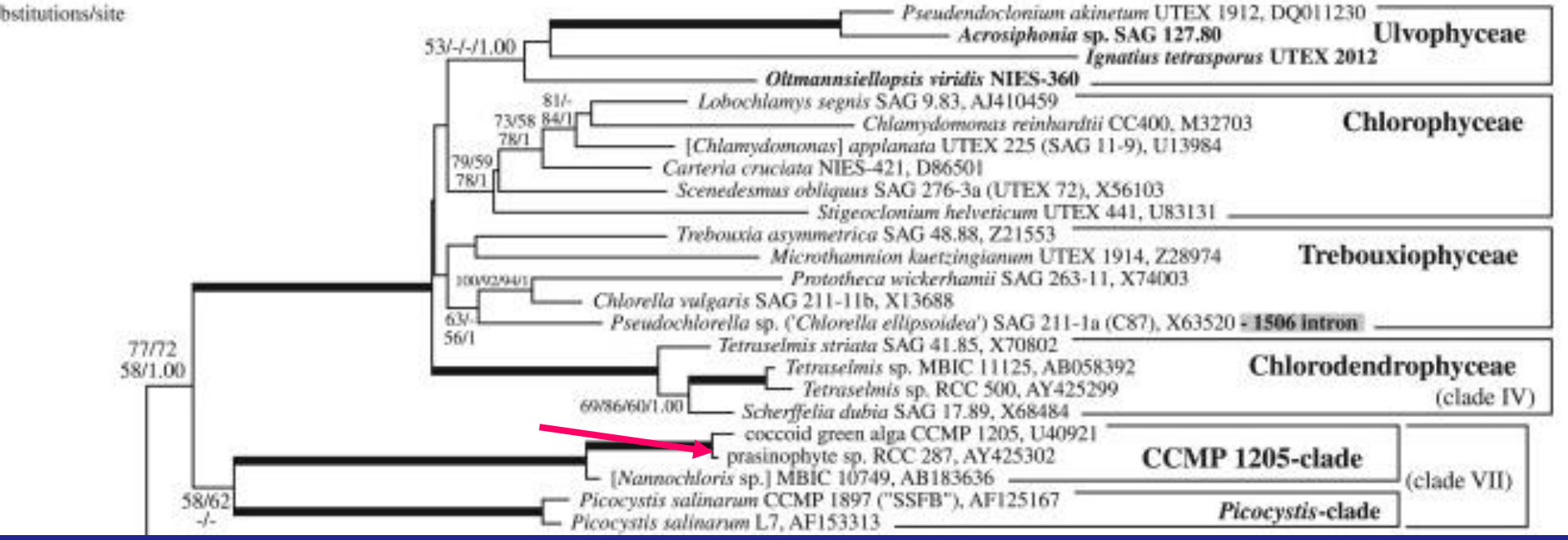
malé čtvercové

malé hvězdicové

velké hvězdicové

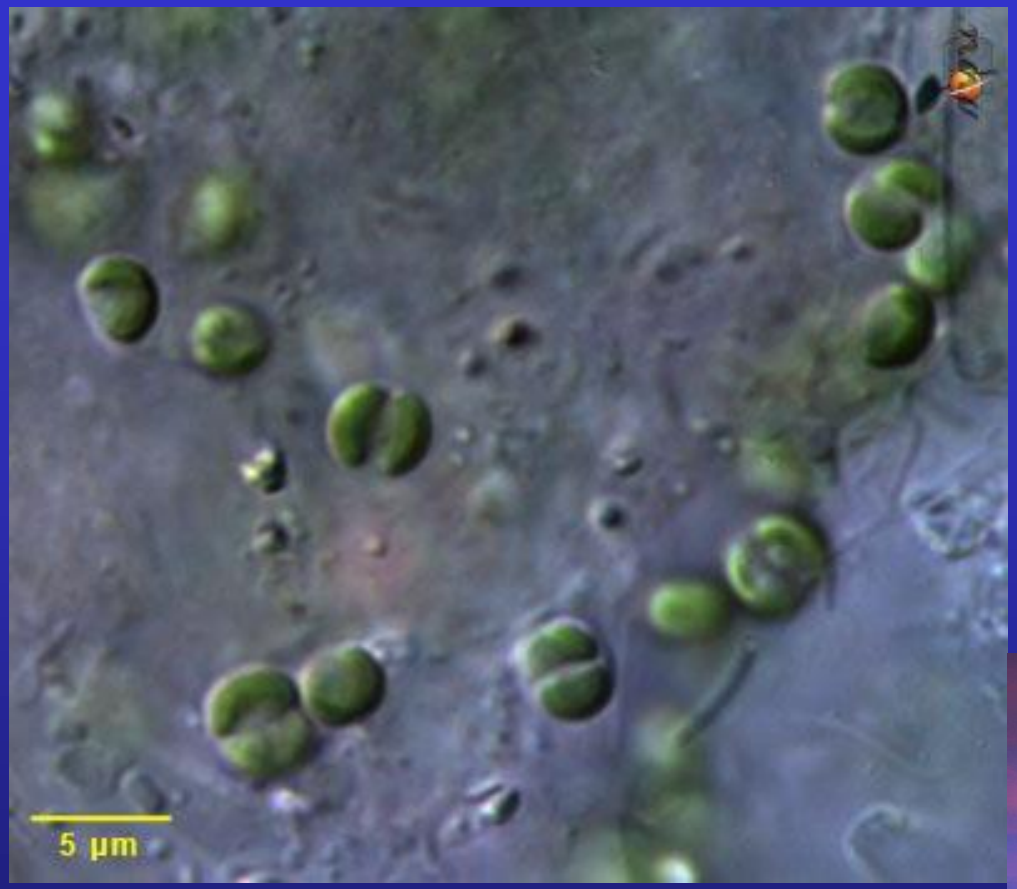




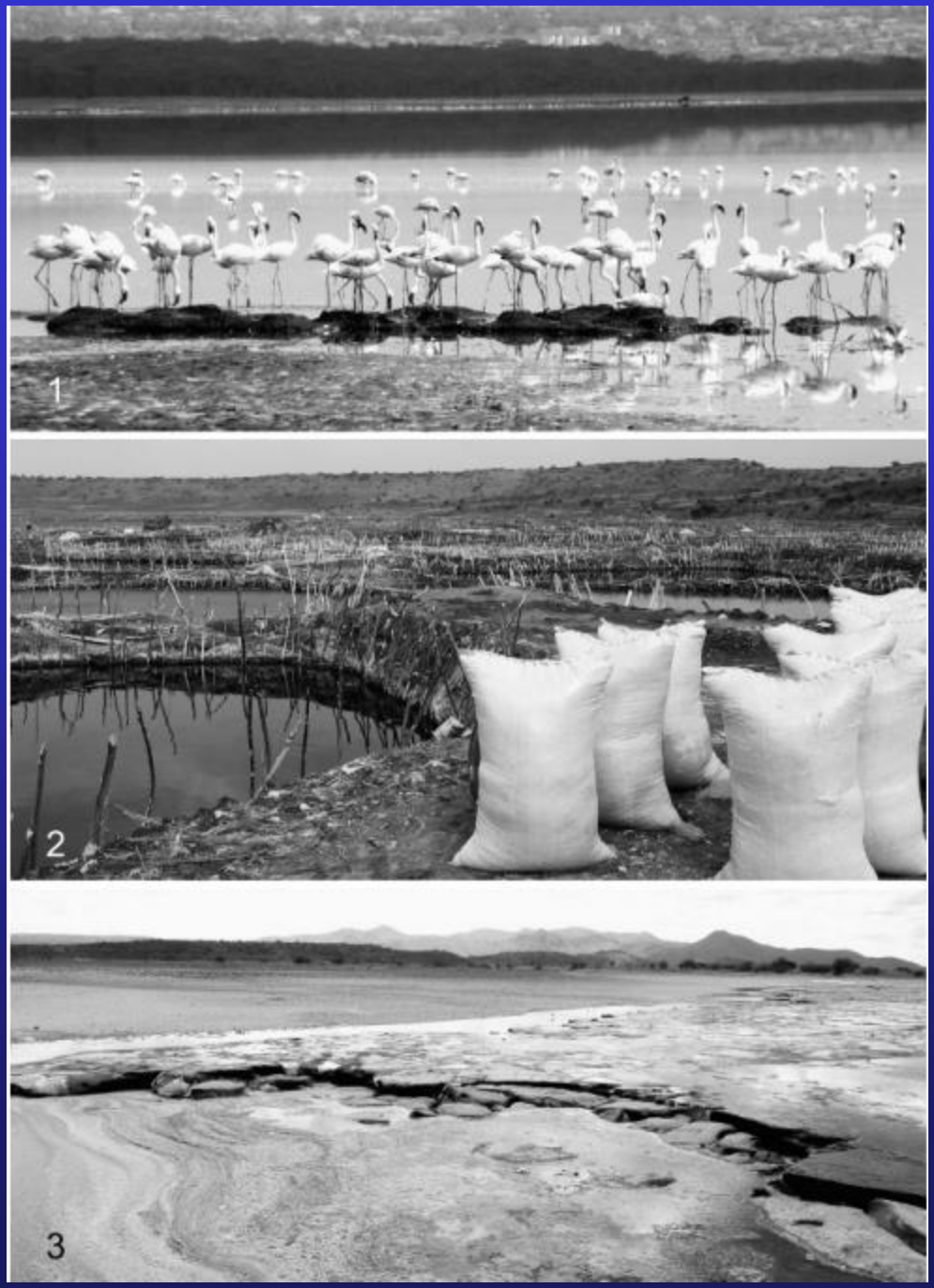


Transmission electron micrographs of *RCC 287*

Picocystis salinarum

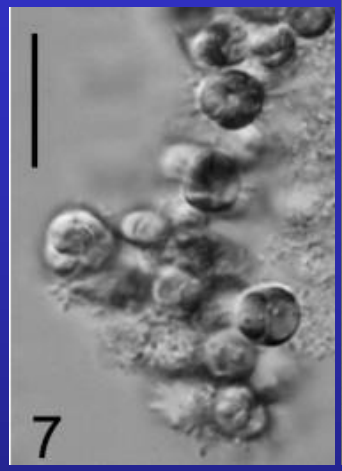


Mono Lake California



Krienitz et al. 2012

Picocystis salinarum (Chlorophyta) in saline lakes and hot springs of East Africa

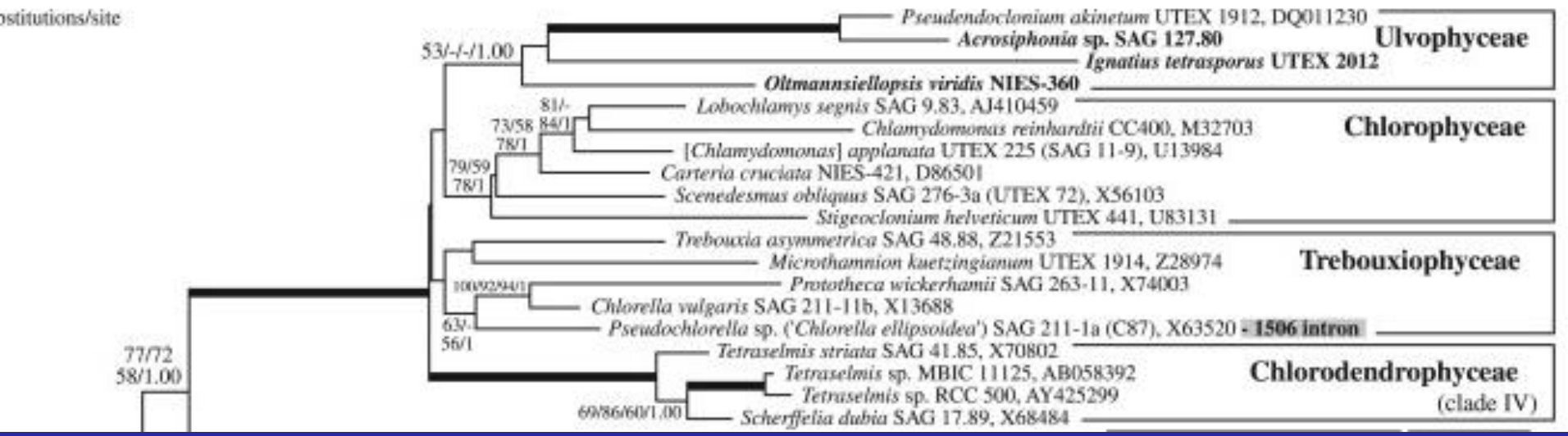


Picocystis occasionally replaces the dominant cyanobacterium (*Arthrospira fusiformis*), which is the main food resource of Lesser Flamingos, in soda lakes of Bogoria and Nakuru

Východní Afrika – alkalická „soda lakes“

např. jezero Bogoria

Chlorodendrophyceae

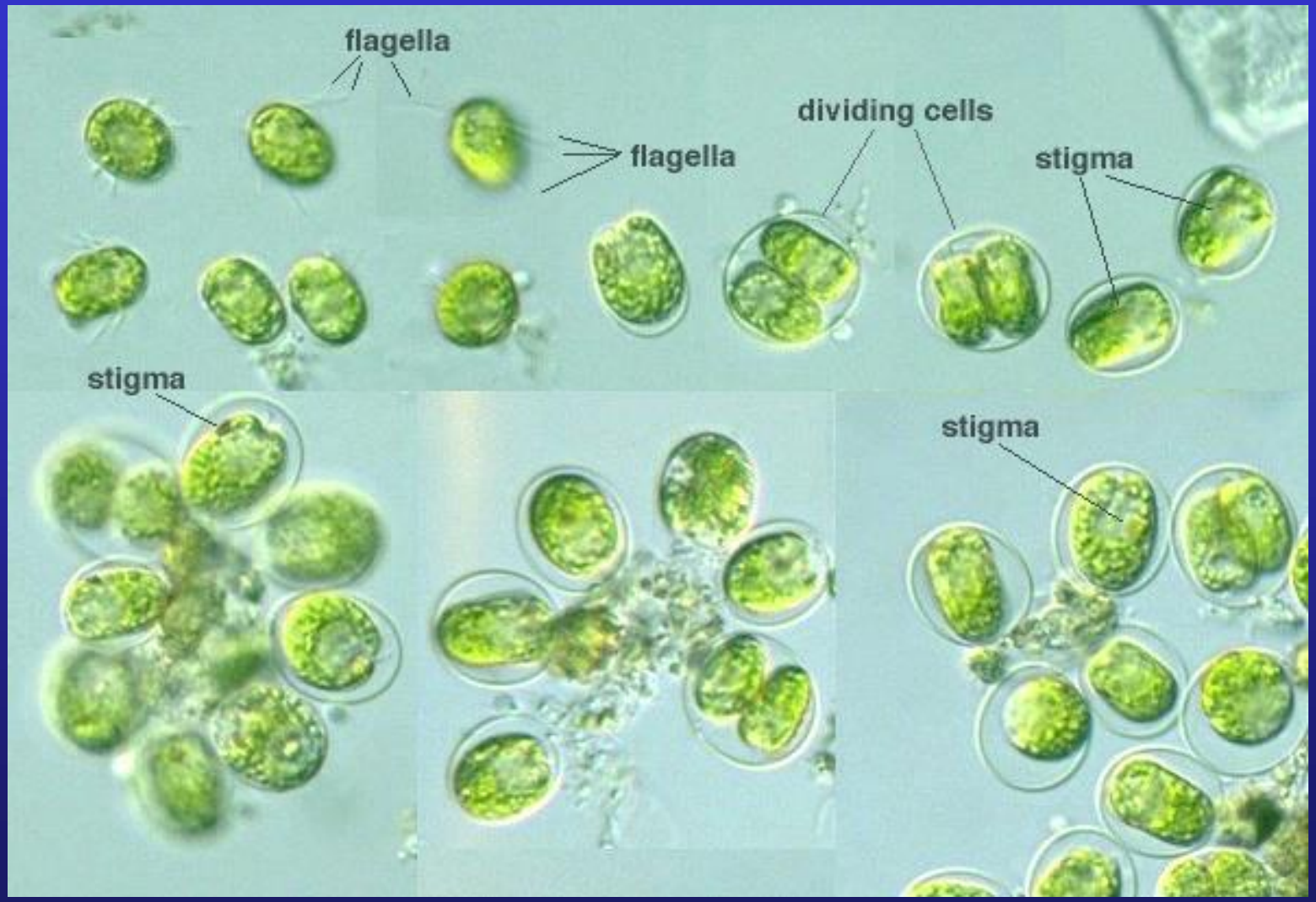


Core chlorophytes:
Ulvophyceae/Chlorophyceae/Trebouxiophyceae/Chlorodendrophyceae/
Pedinophyceae

Scherffelia

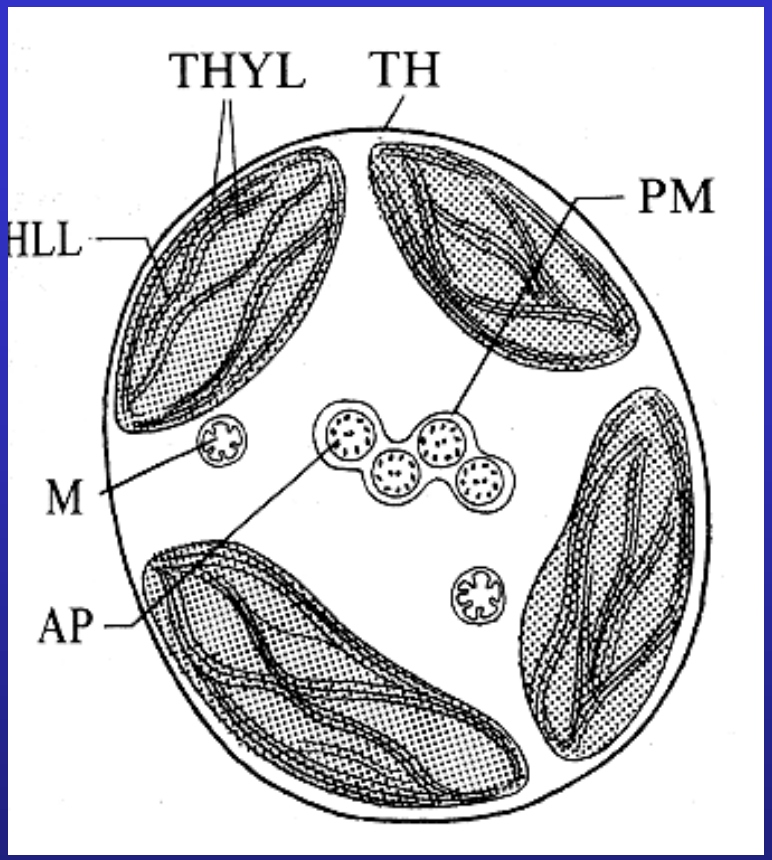
Tetraselmis

Chlorodendrophyceae

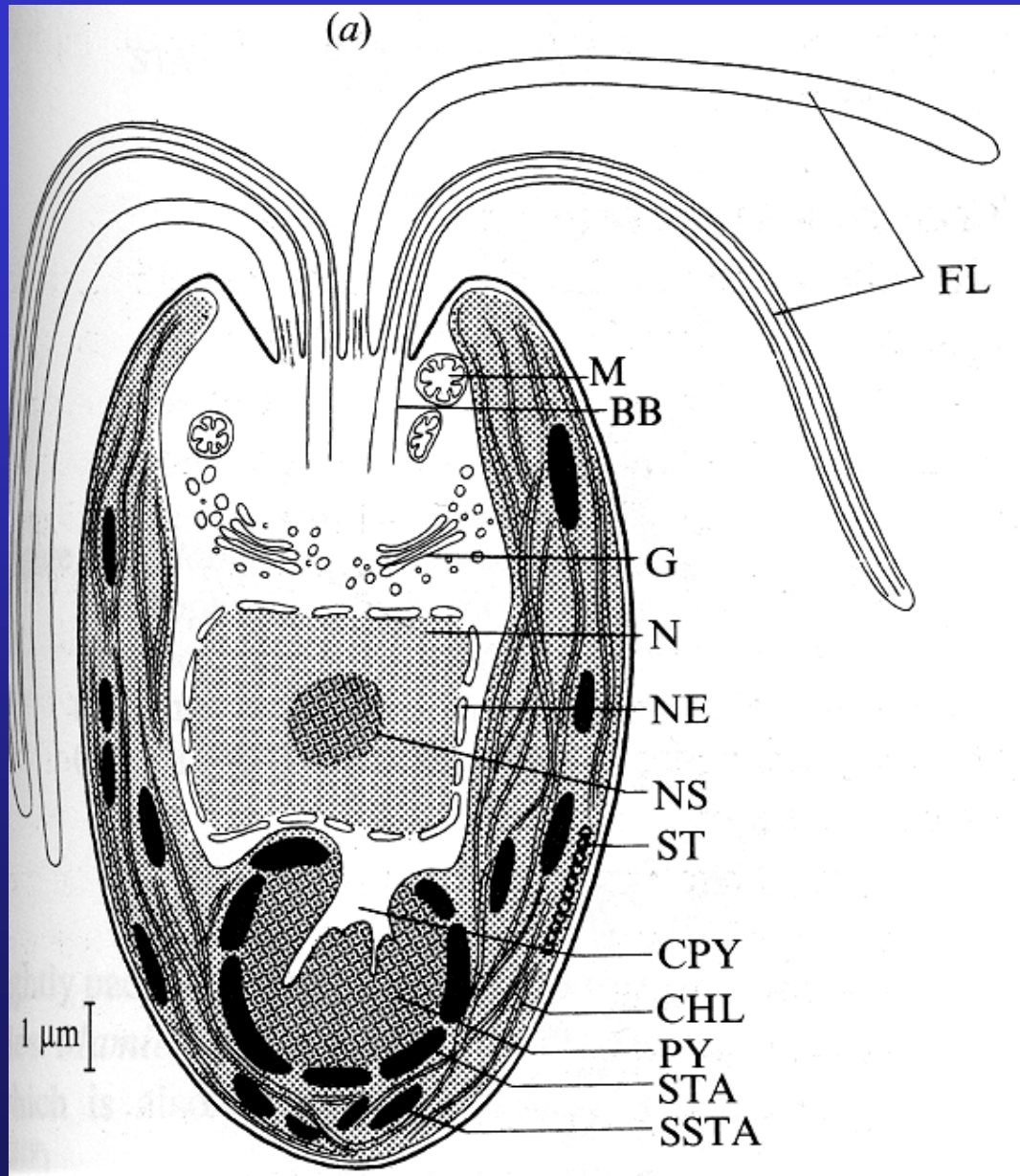


Tetraselmis

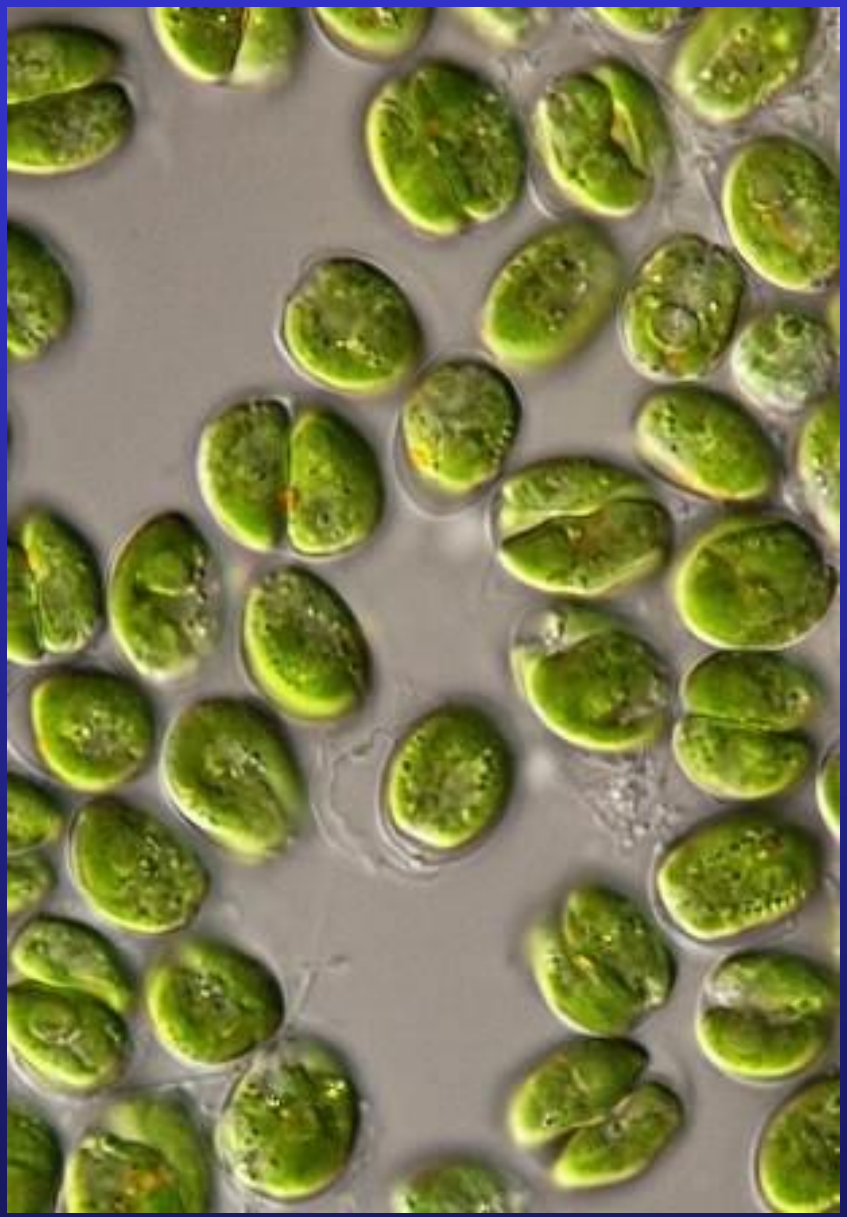
Chlorodendrophyceae



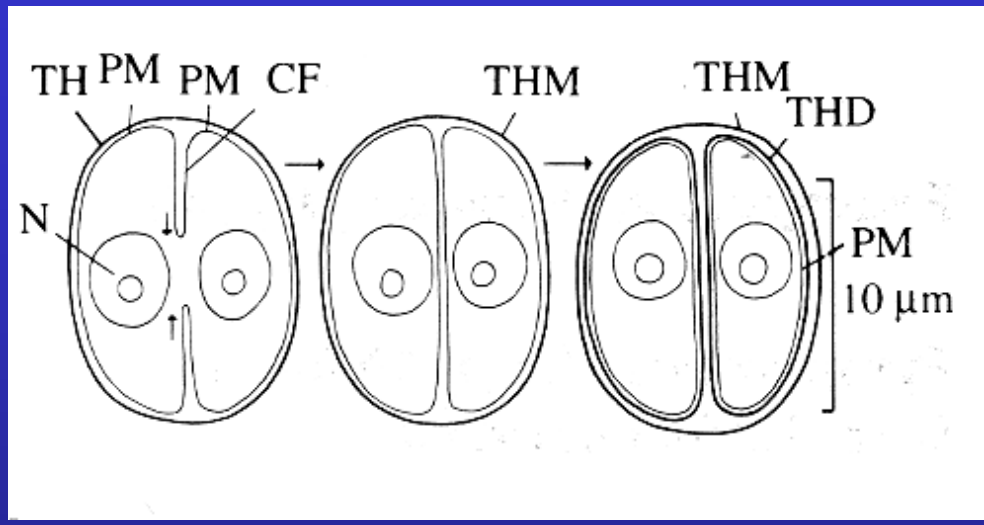
Tetraselmis suecica



Mitóza a cytokineze



- na povrchu kryté thékou

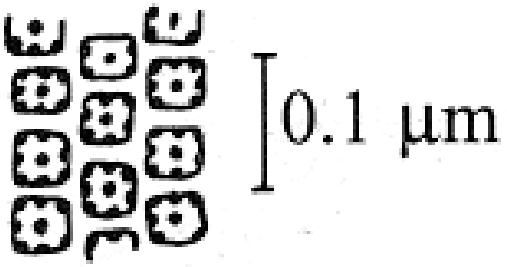


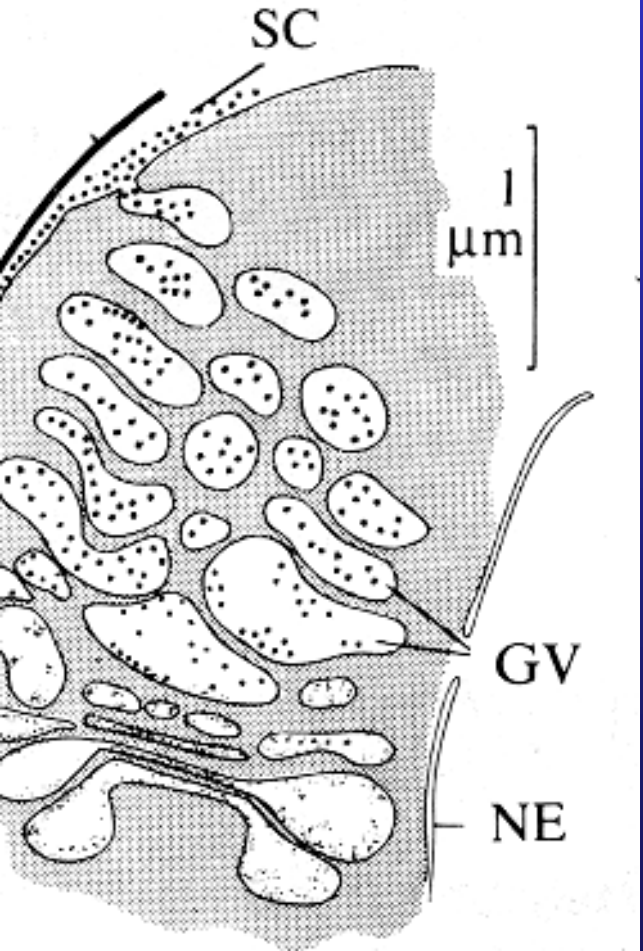
Tetraselmis suecica

shed flagella - division within the mother theca

Scales fuse to form organic theca

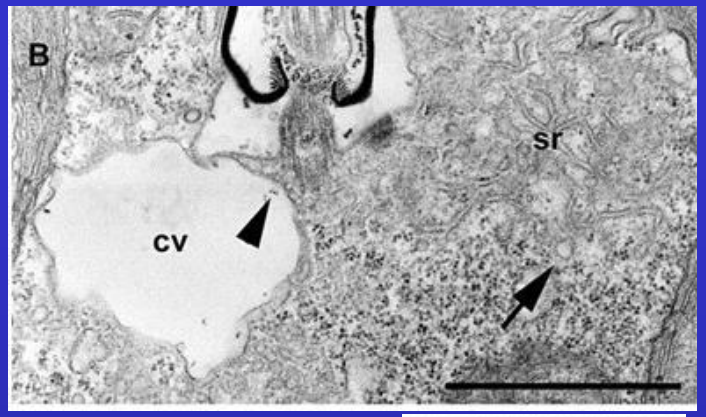
Chlorodendophyceae

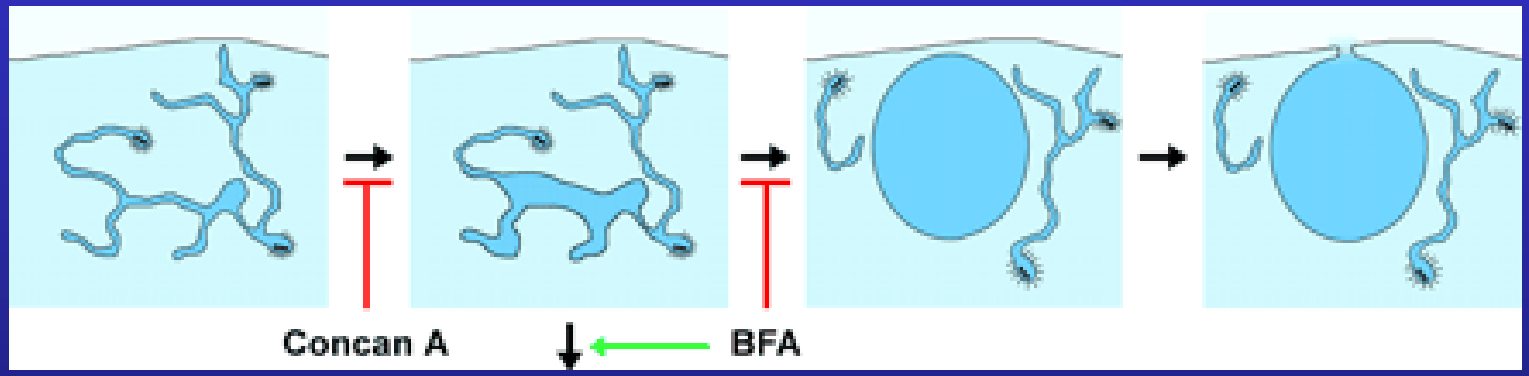




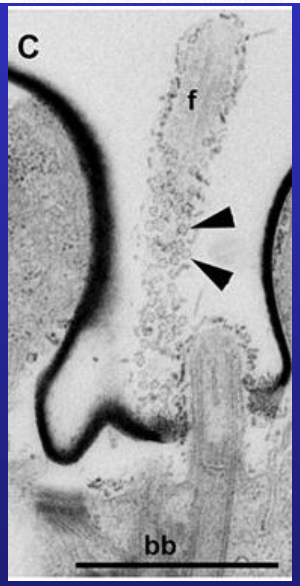
Tetraselmis

Contractile vacuoles





CV cycle



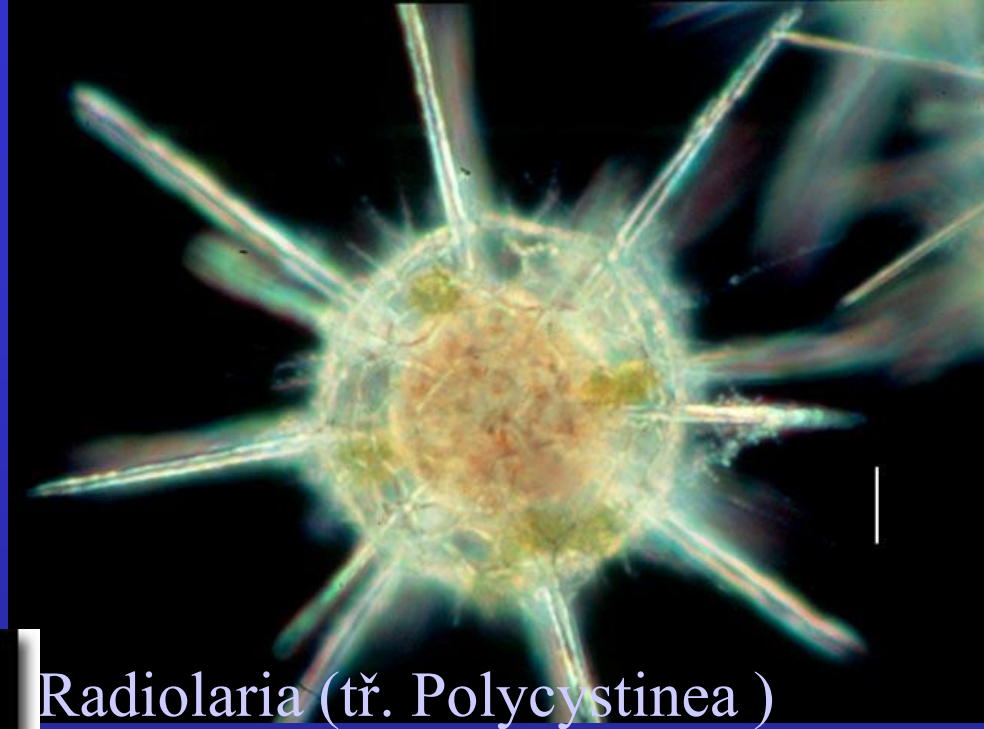
Scherffelia

Fig. 2 BFA interferes with the function of the CV. Upon addition of BFA to *S. dubia* cells, the two CVs swell (B, 5 min of BFA treatment) and form a large central vacuole (LCV) at later stages (C, 10 min of BFA treatment). (A) Control cells as seen in the light microscope.

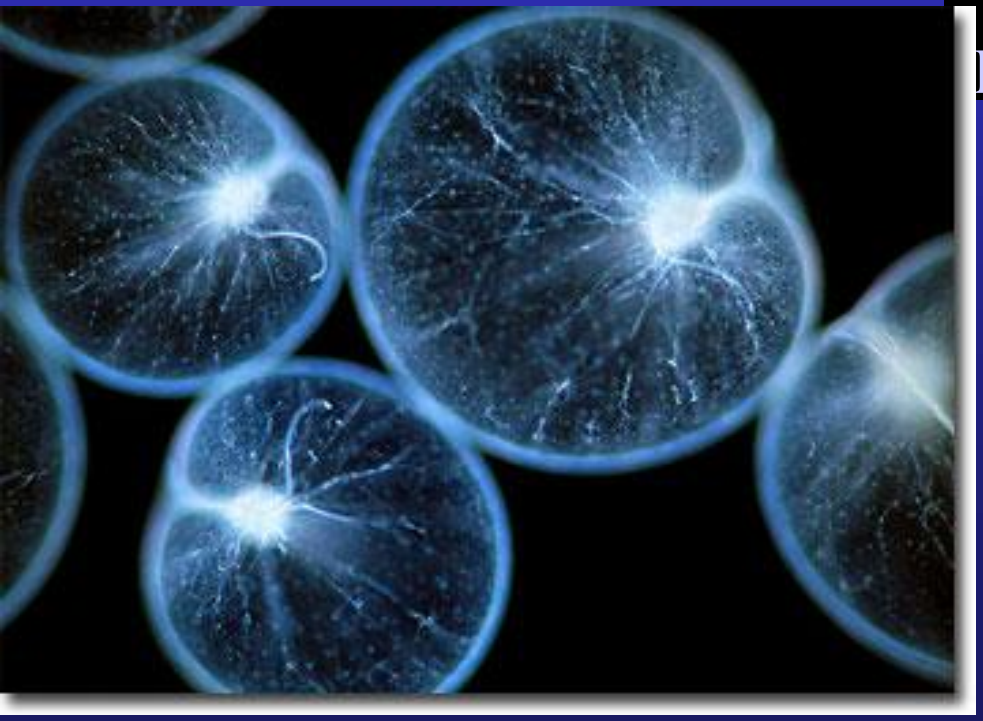
(Becker and Hickisch, 2005)

Ekology

symbionts of different heterotrophic organisms



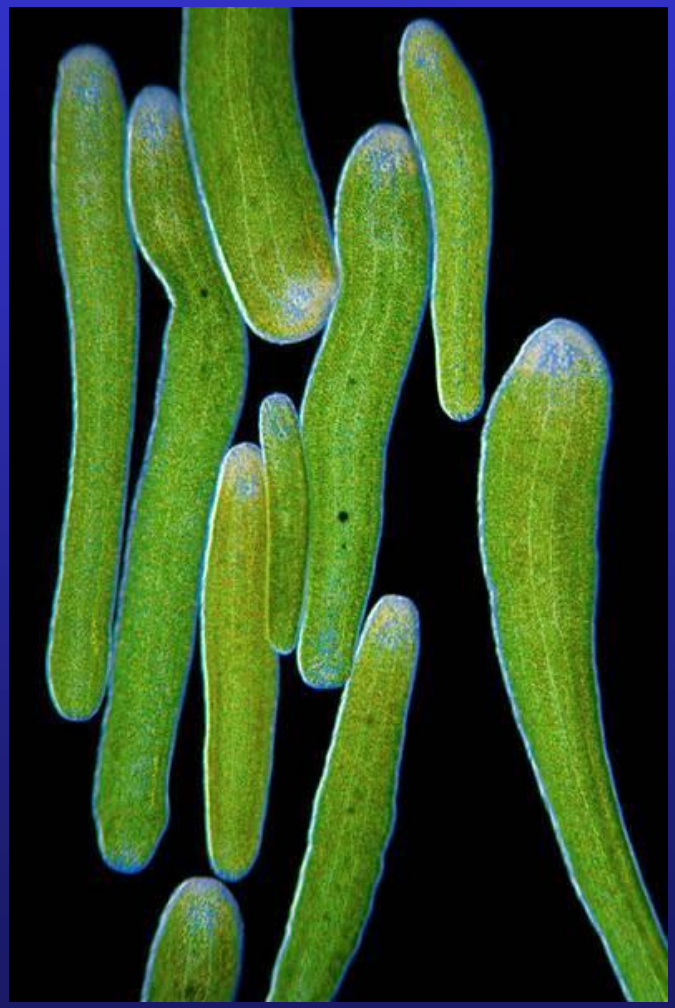
Radiolaria (tř. Polycystinea)

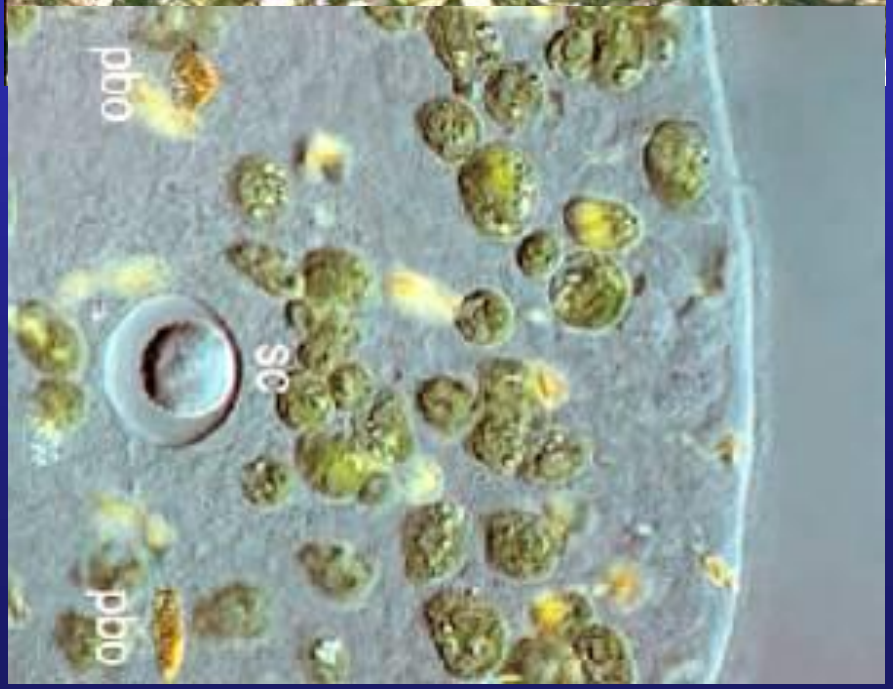


Noctiluca

Ekology

symbionts of different heterotrophic organisms





(Convoluta) Symsagittifera roscoffensis - flatworms Acoela– no mouth

Host
***(Convoluta)* provides:**

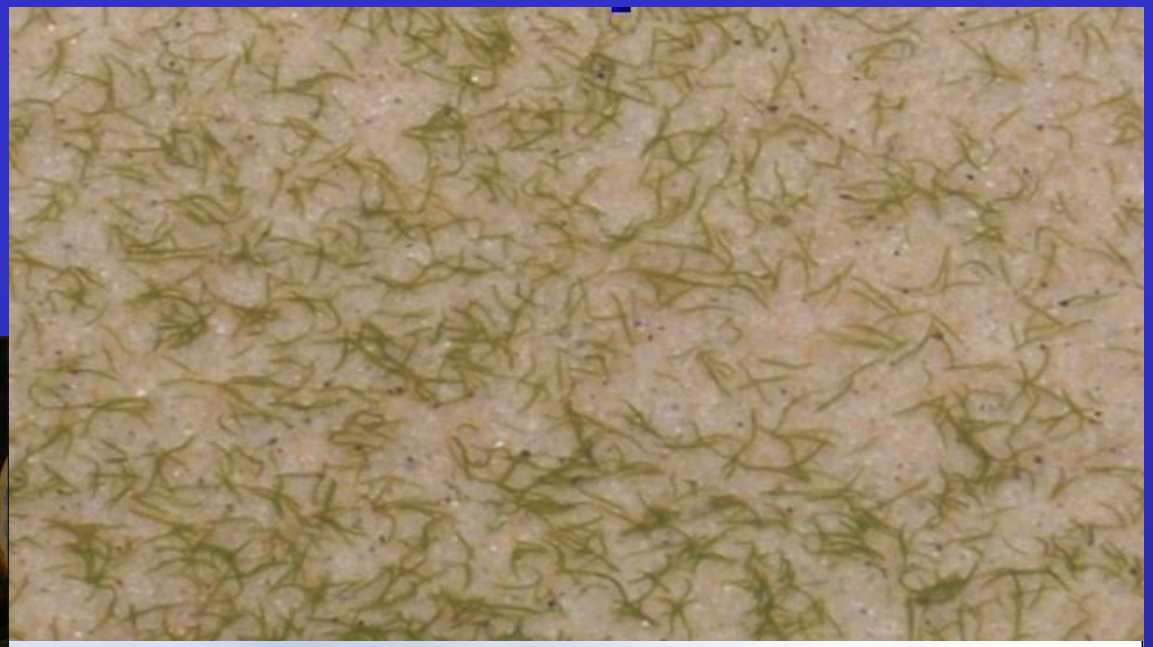
- shelter (against predation)
- constant milieu
- optimal photosynthetic conditions (light and CO_2)
- nutrition (N-compounds)

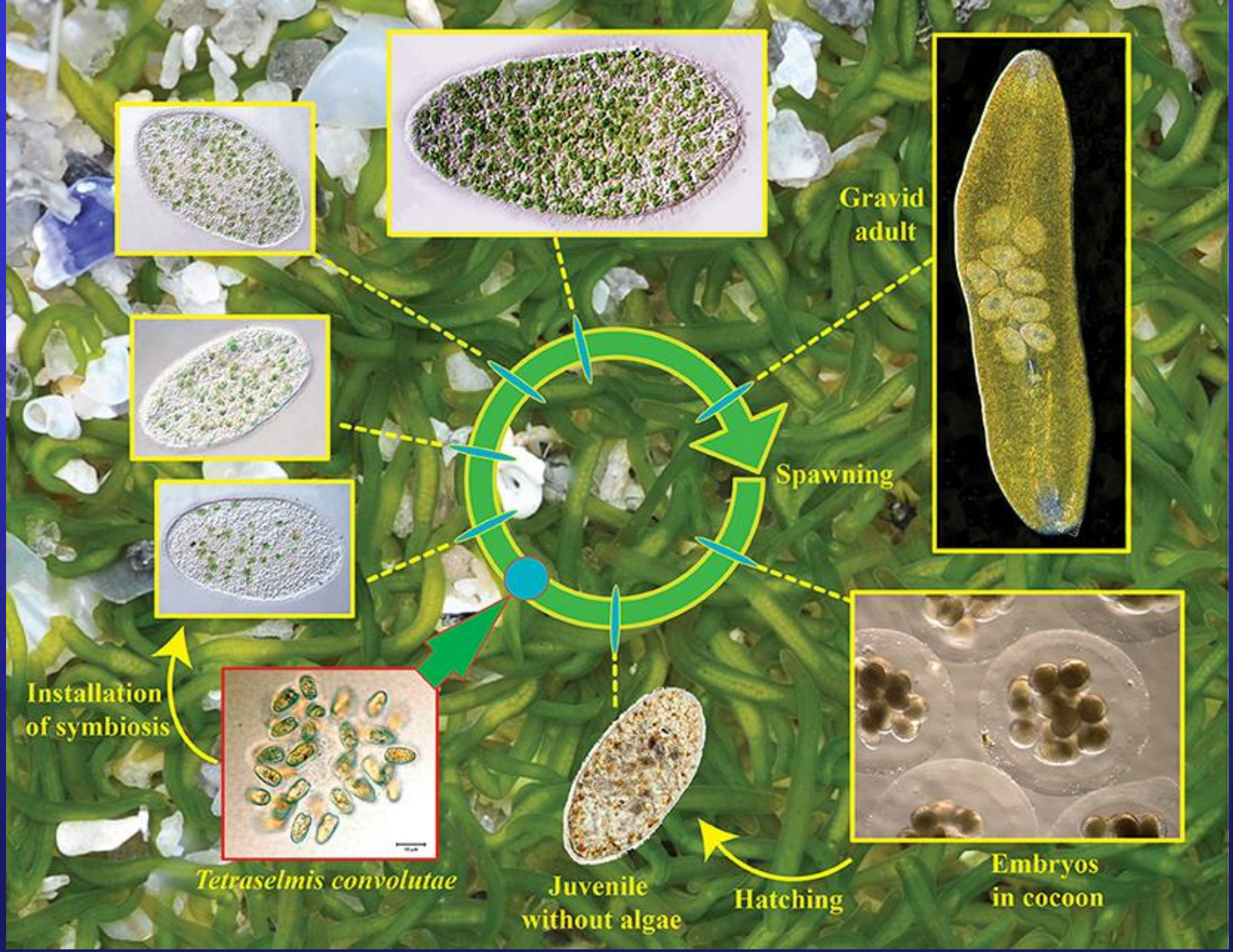
Symbiont
***(Tetraselmis)* provides:**

- sugars and O_2 as products of photosynthesis
- capability of adaptation under harsh environmental conditions

Akvitaine - France

Atlantic ocean shore

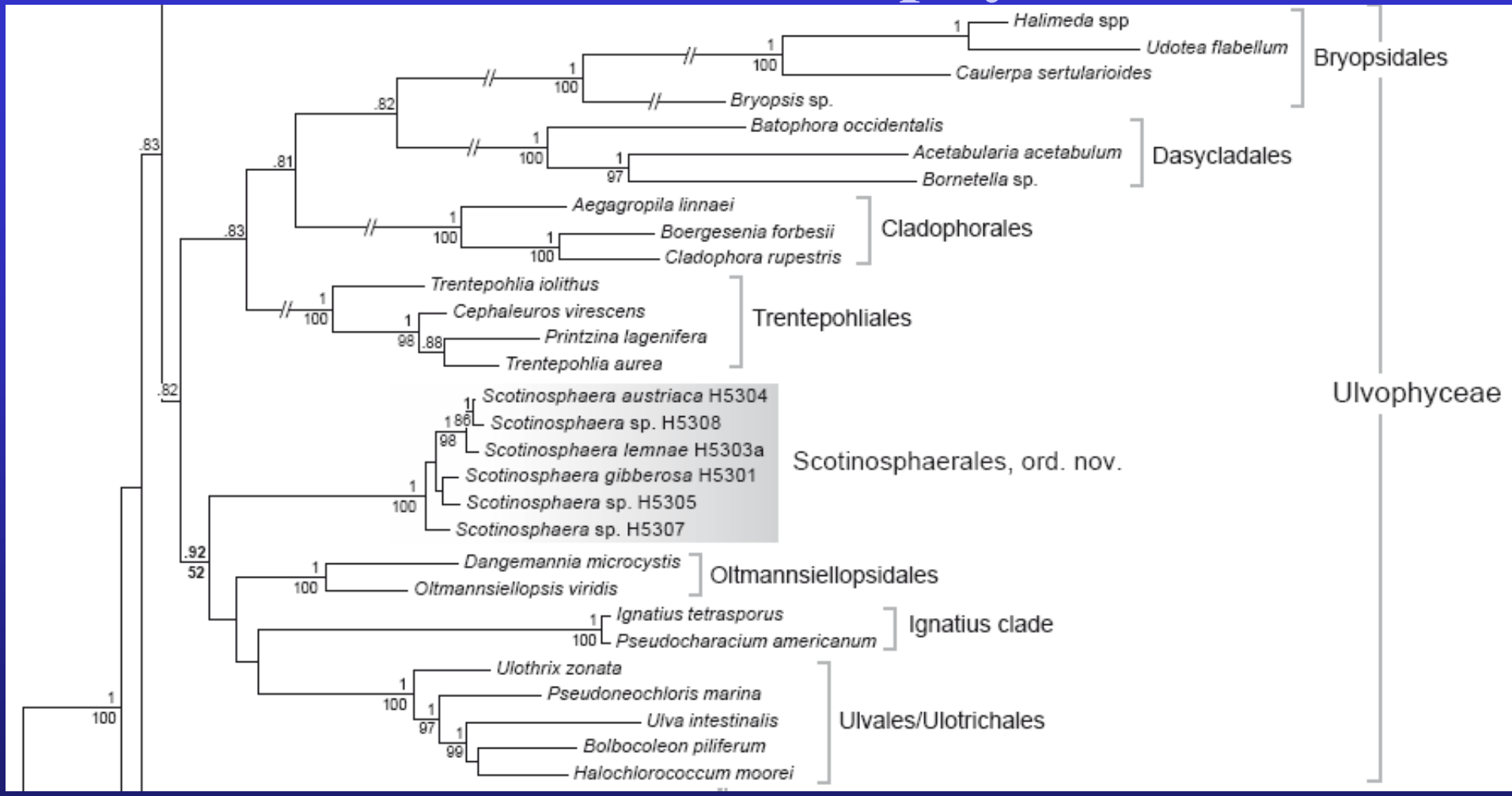



Gravid adult
Spawning
Embryos in cocoon
Hatching
Juvenile without algae
Installation of symbiosis
Tetraselmis convolutae

polyunsaturated fatty acids

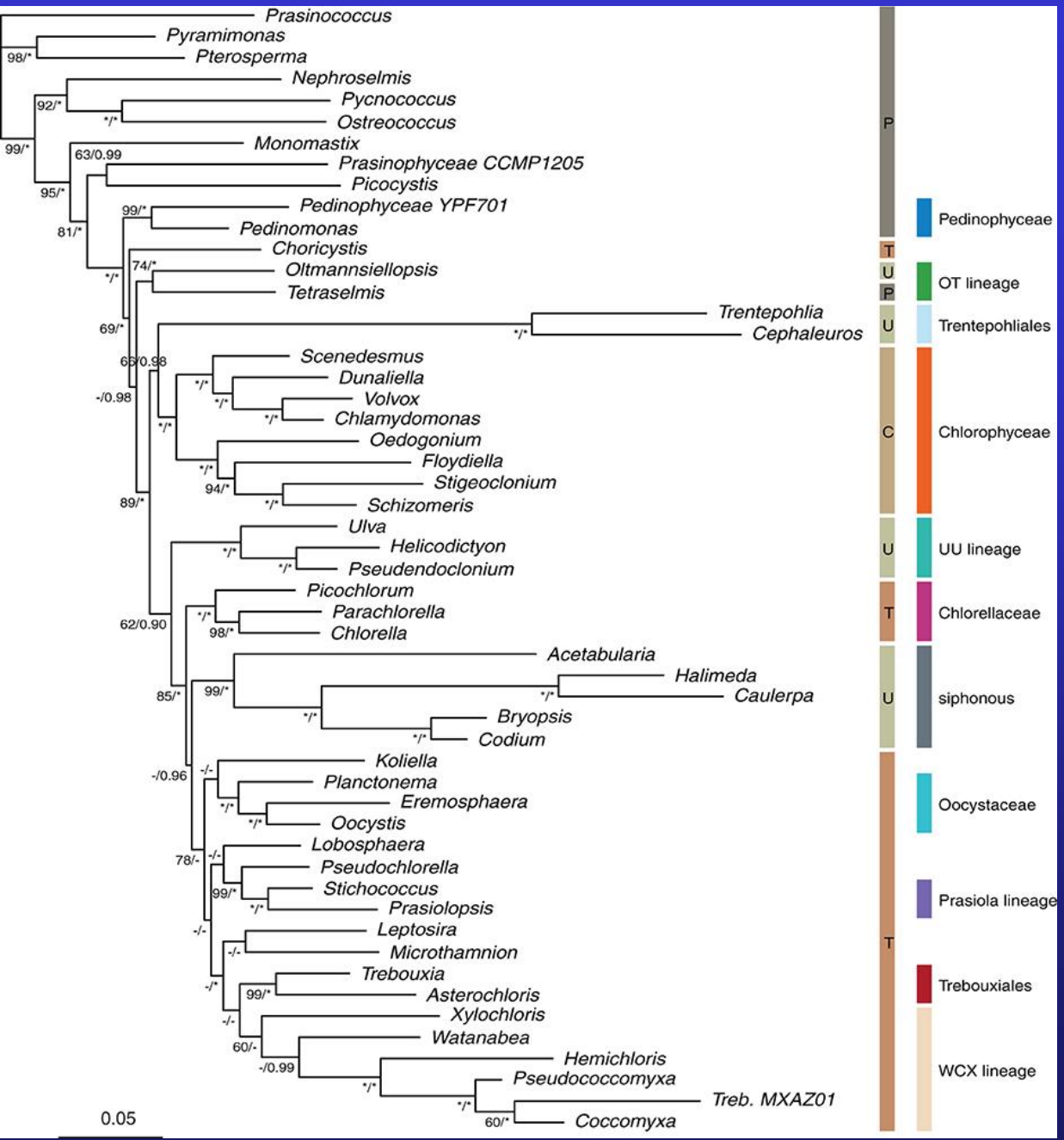
Live Foods for **Feeding** Aquarium Fish, Inverts & **Corals**

Třída: Ulvophyceae



Phylogeny of the Chlorophyta obtained by Bayesian inference of the concatenated SSU-rbcL alignment.

Škaloud et al. 2013



(Fucikova et al. 2014)

the classes Trebouxiophyceae and Ulvophyceae are likely **not monophyletic**

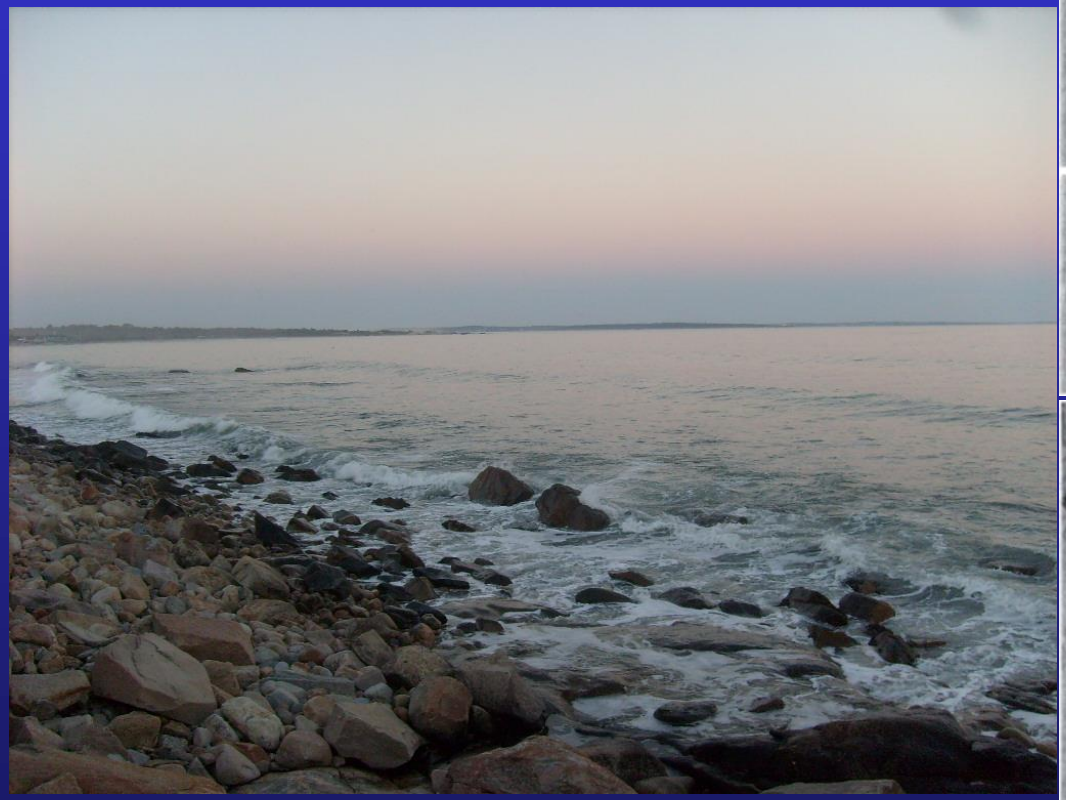
proposed the common term for UTC clade: core Chlorophyta

(for the well-supported clade containing Chlorophyceae, Ulvophyceae and Trebouxiophyceae, and the classes Chlorodendrophyceae and Pedinophyceae.

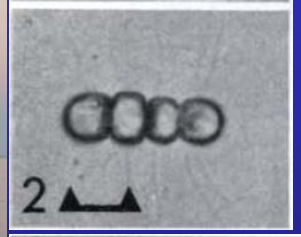
Figure 2. Maximum likelihood phylogeny inferred from the 8-gene alignment (80% slowest sites).

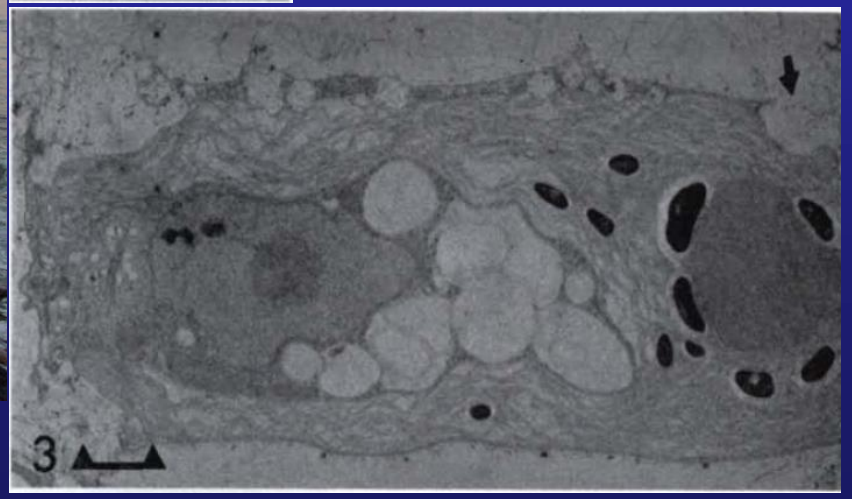
Oltmansiellopsidales

Oltmansiellopsis viridis -a quadriflagellate green alga is described from temperate coastal waters. It occurs primarily as four-celled colonies,



Narragansett Bay, Rhode Island, USA



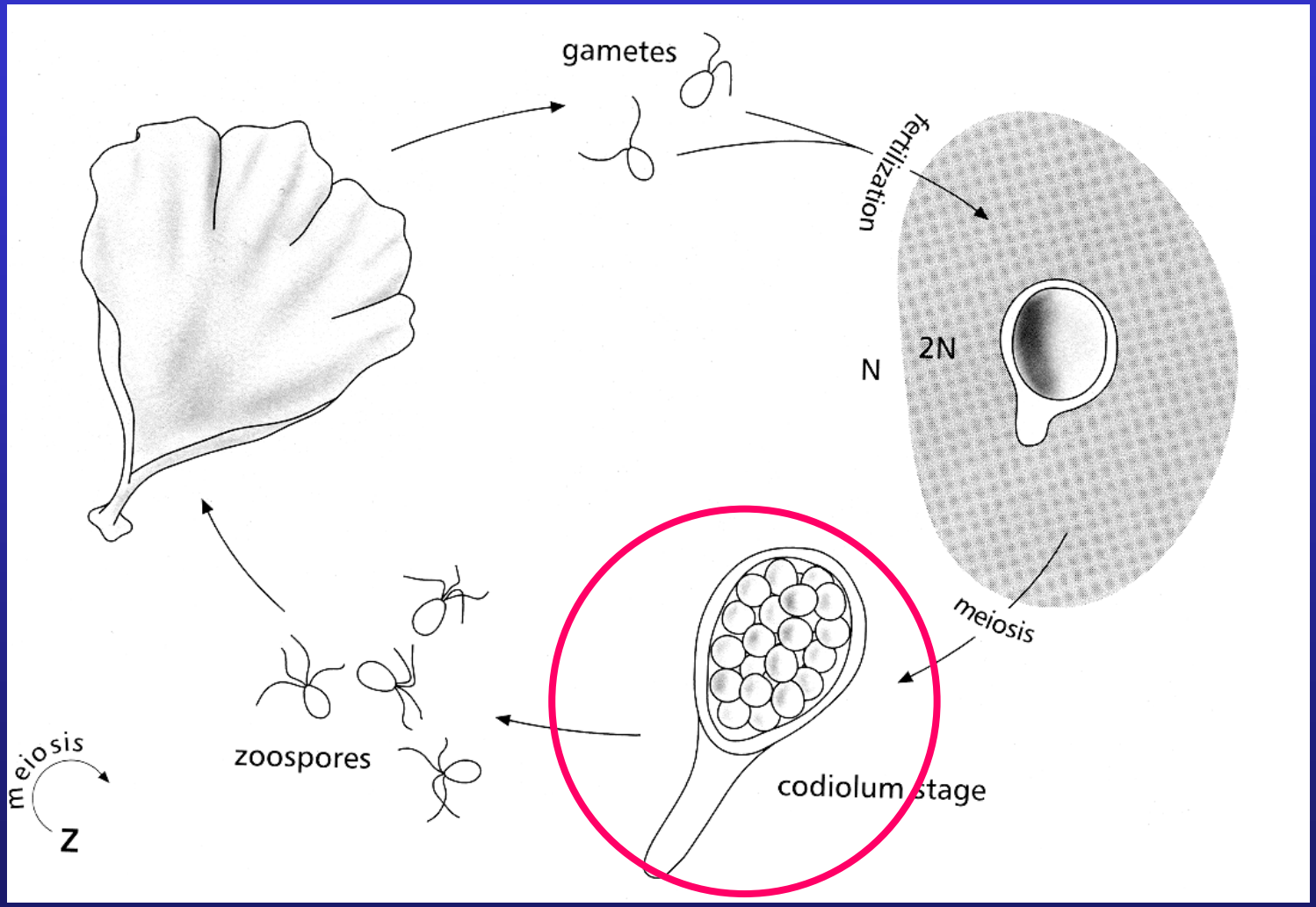


Ulvales/Ulotrichales

Základní charakteristika:

- stélka kokální, vláknitá, sifonální, pletivnou
- zoidi mají 2 nebo 4 bičíky (křížové uspořádání bičíkových kořenů, CCW orientace bazálních tělísek), někt. zástupci Ulotrichales – povrch zoidů pokryt rhomboidními šupinami
- mitóza uzavřená, perzistentní telofázové vřeténko (bez fykoplastu a fragmolastu)
- každá buňka obsahuje nástěnný chloroplast (páskovitý nebo hrncovitý), někdy perforovaný s jedním až několika pyrenoidy
- haplontní nebo diplo-haplontní životní cyklus, vznikají tlustostěnné hypnozygoty
- zástupci třídy téměř výhradně mořské organismy

Řád: Ulotrichales (Codiolales)



Monostroma

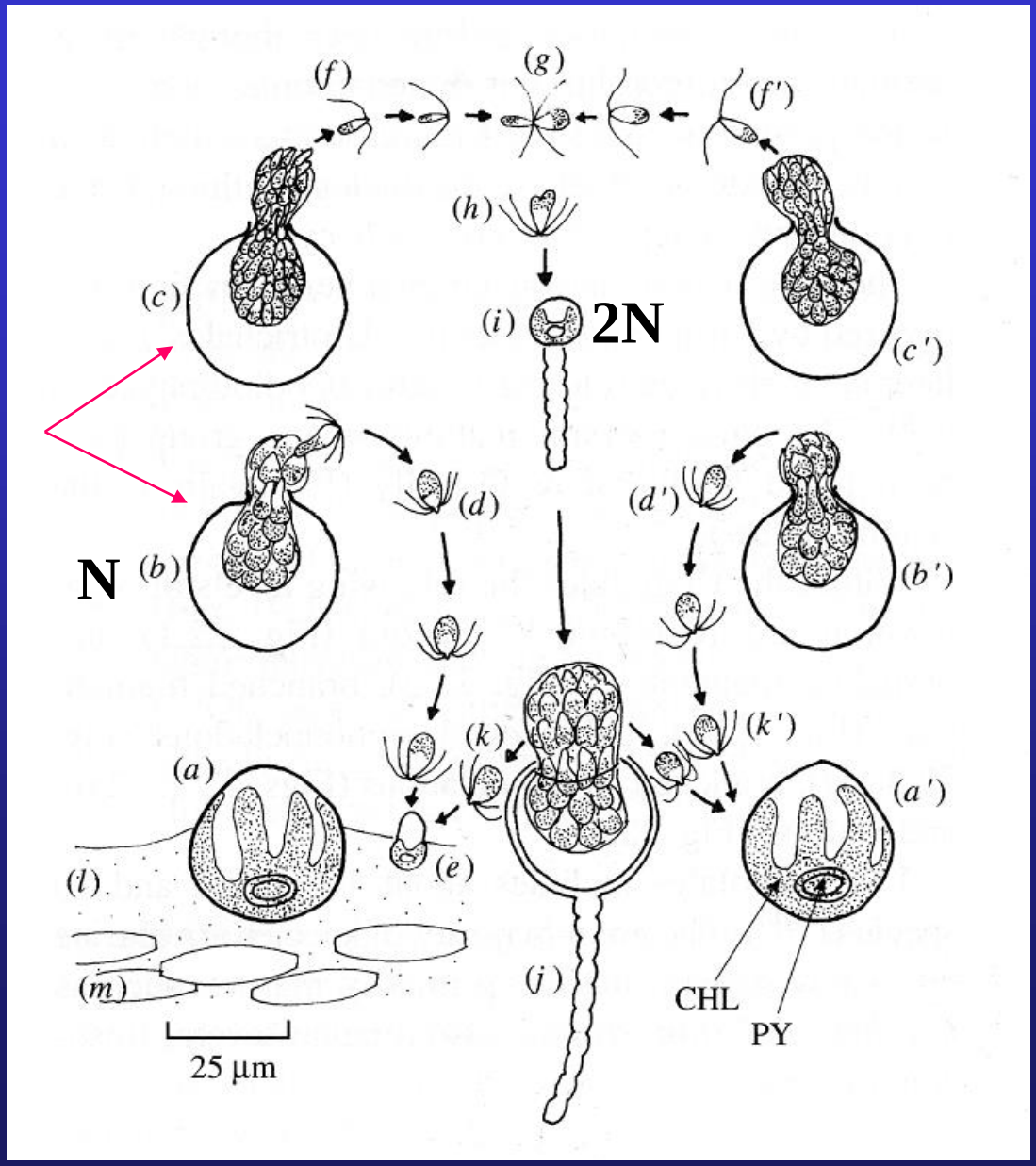
Chlorocystis

endophyte, haplontic life cycle, codiolus stage

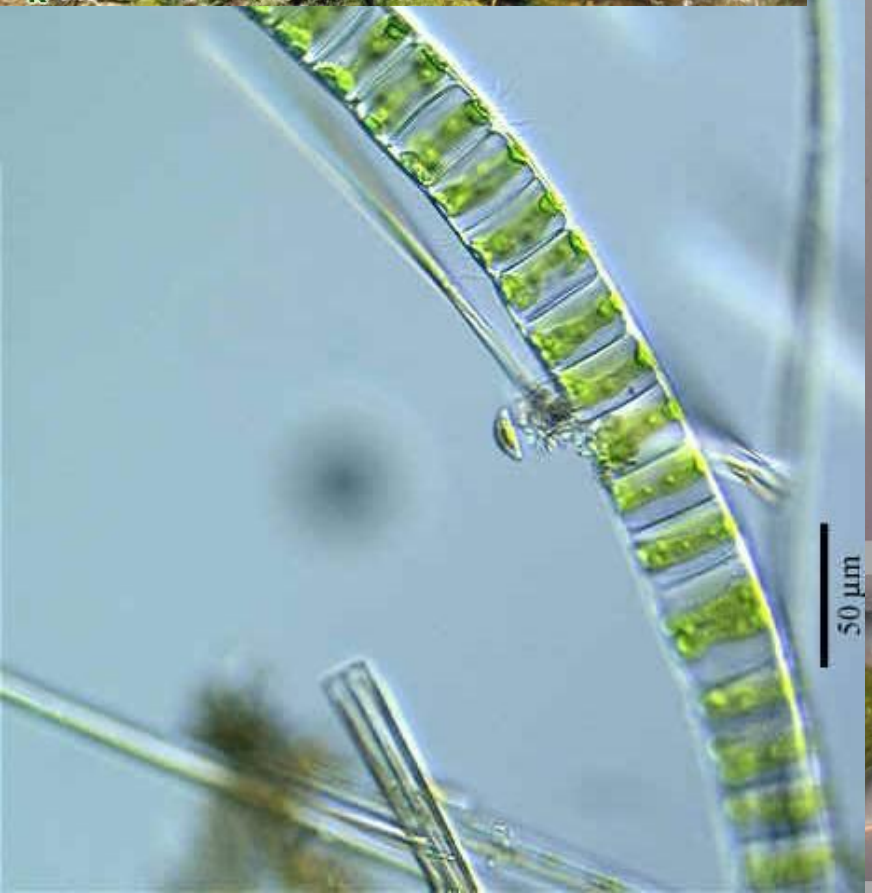
anizogamy

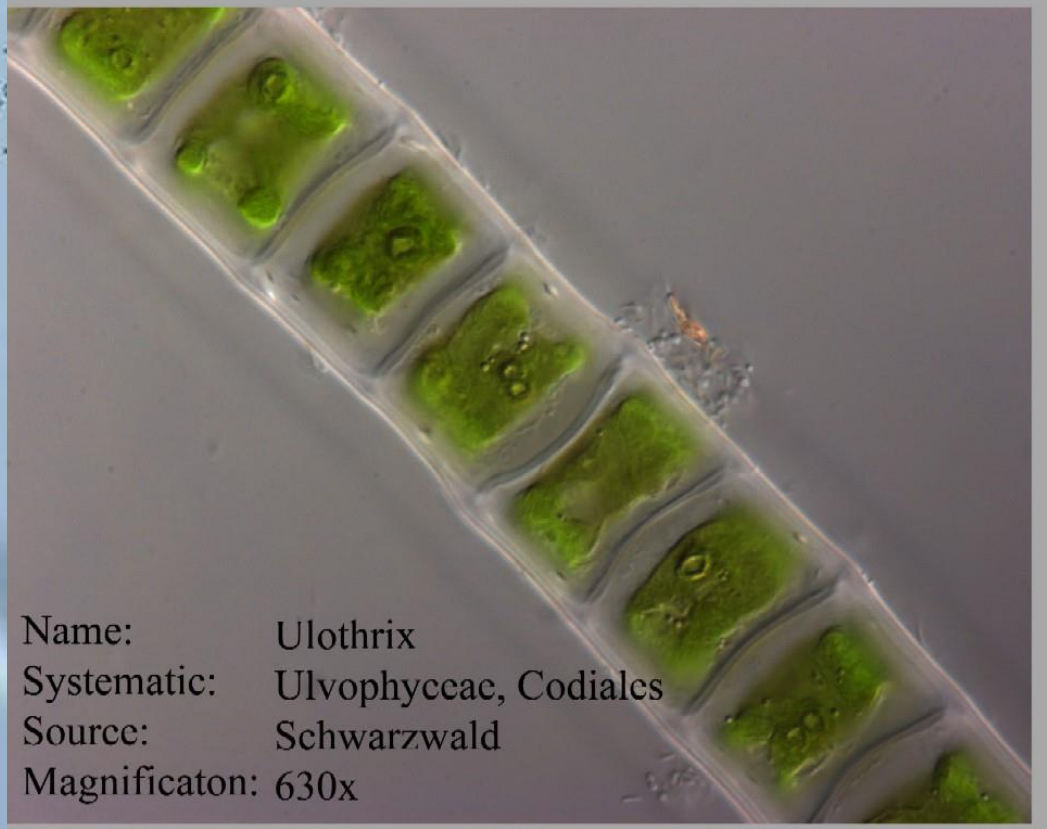
heterothalism

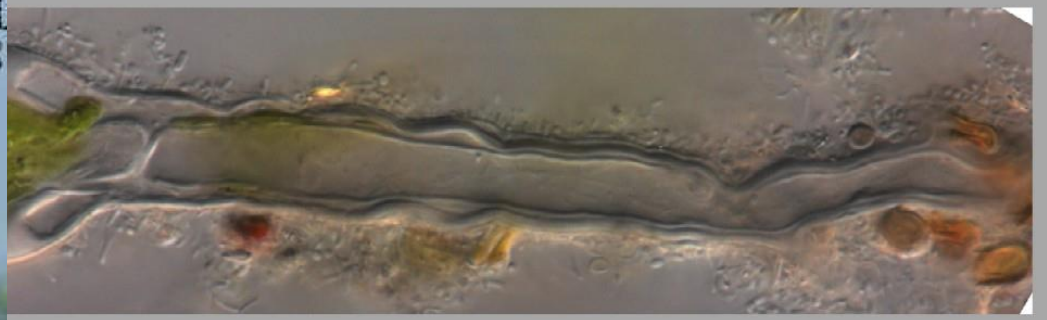
evolutionary parallelism (*Trebouxia*, *Chlorococcum*)



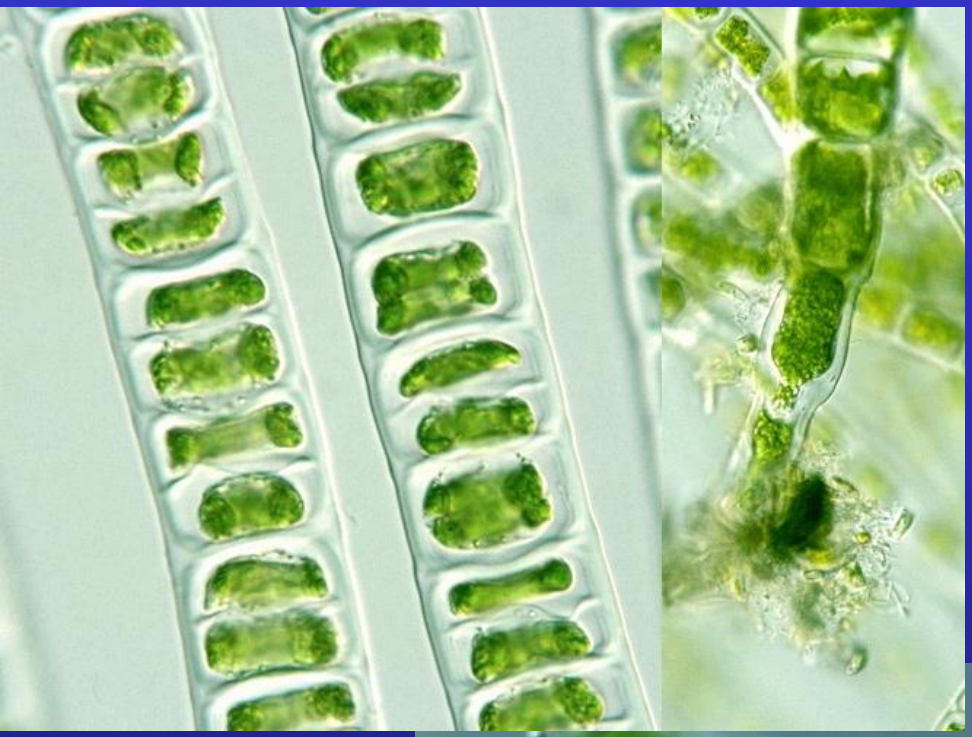
Ulothrix

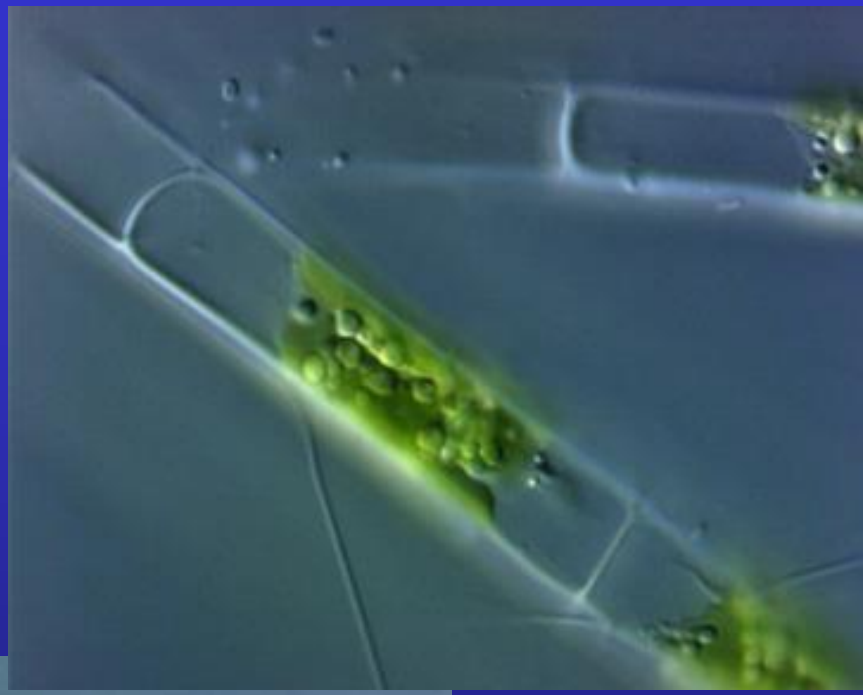

50 µm


Name: Ulothrix
Systematic: Ulvophyceae, Codiales
Source: Schwarzwald
Magnificaton: 630x



Ulothrix





Ulothrix

haplontic cycle

izogamy

heterothalism

Ulothrix Life Cycle

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zygote

zygote settles

gametes pair and unite, forming a zygote

fertilization

2n

n

meiosis

sexual

gametes escape from parent cell

zoospores escape

zoospores escape from parent cell

asexual

zoospore settles

new filament arises through mitosis

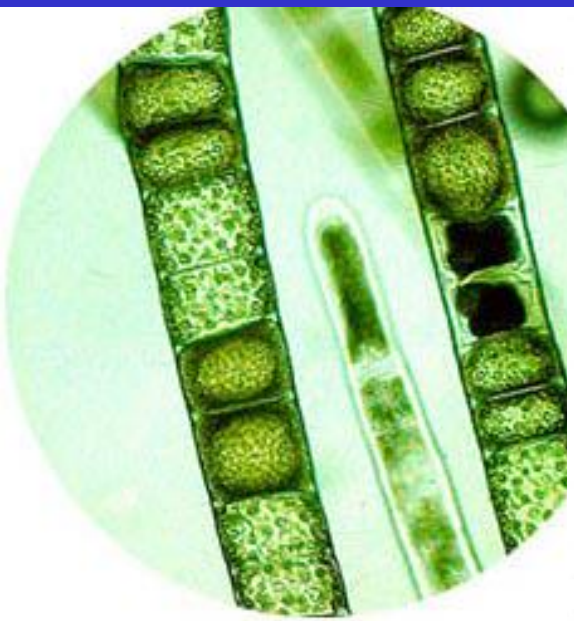
zoospore settles; new filament arises through mitosis

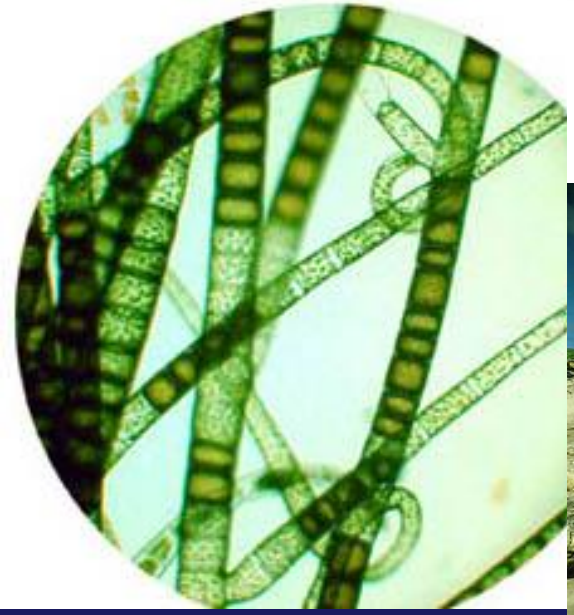
holdfast

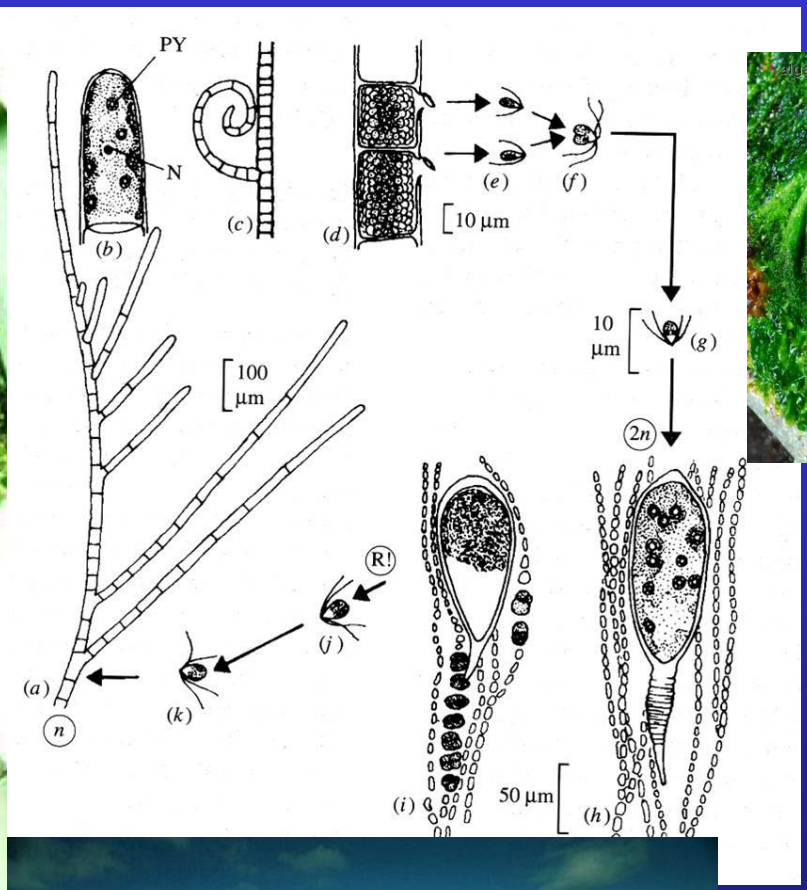
Ulothrix zonata

Spongomorpha

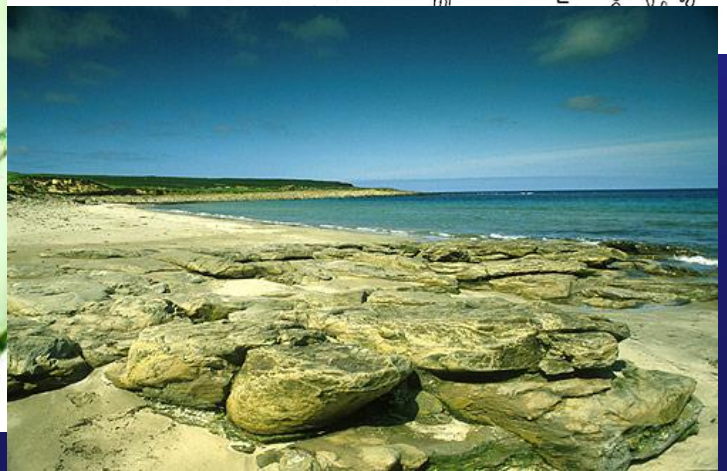
izogamy;
apical growth







uninuclear cells

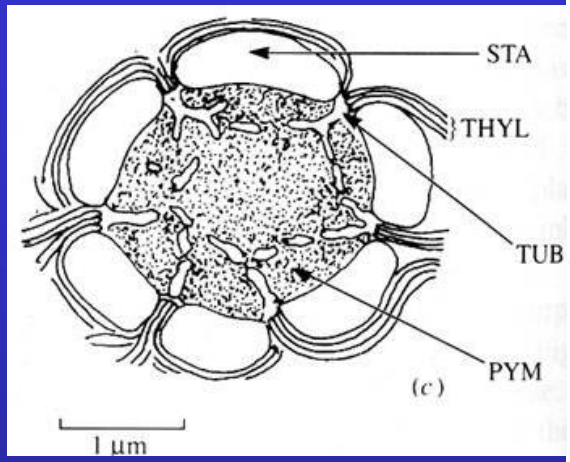


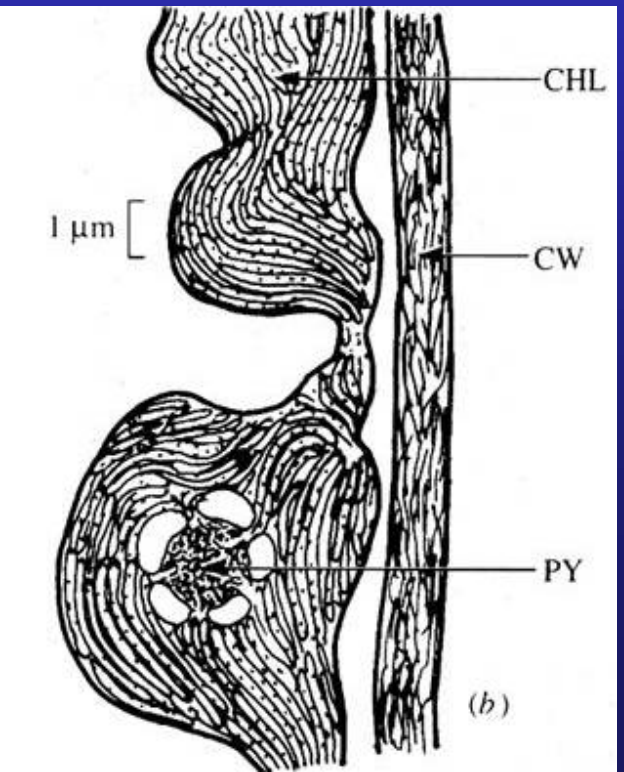
codiolus stage resembles *Petrocelis* (red alga)

eulitoral of North Altantic

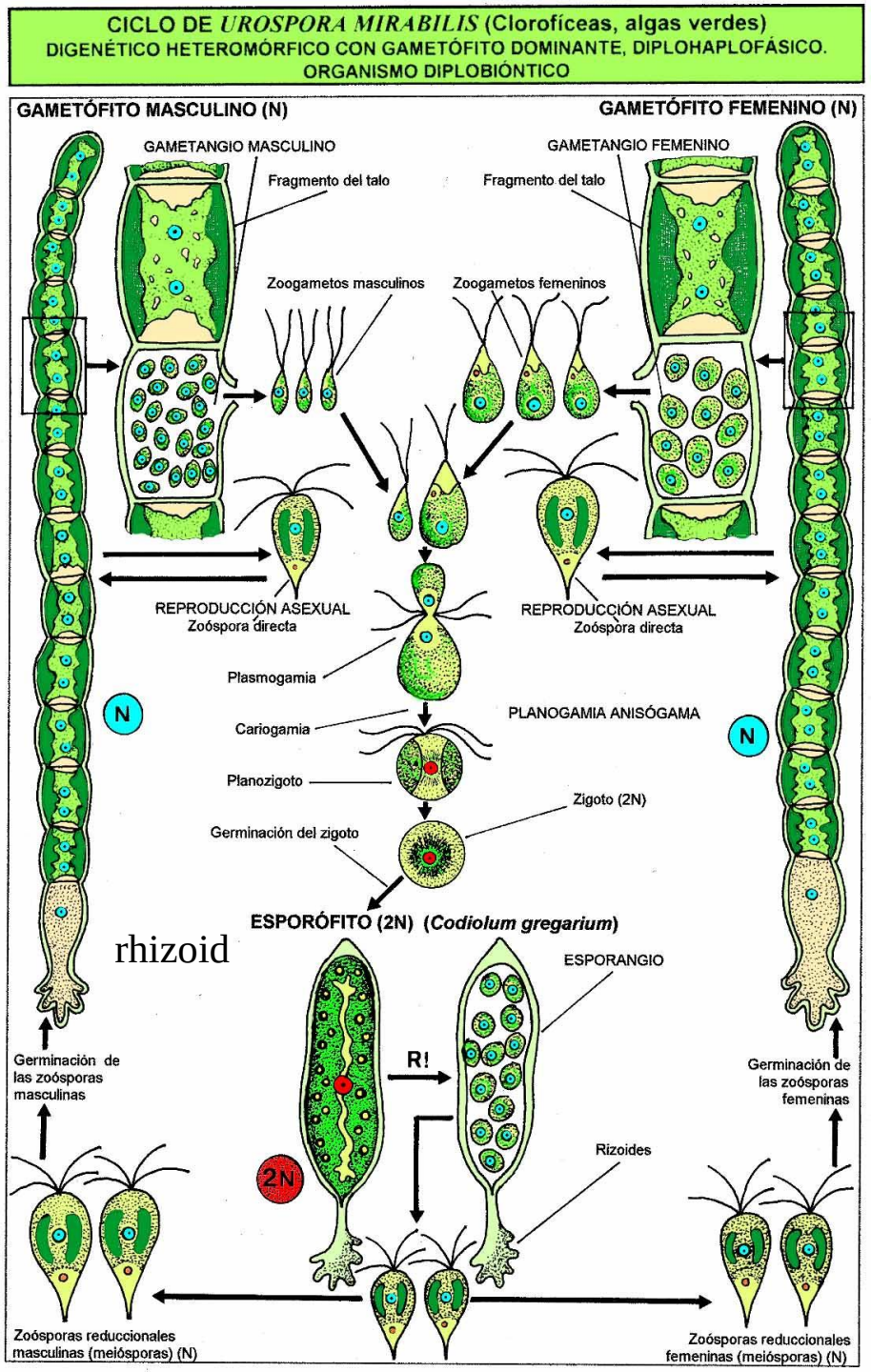
Urospora

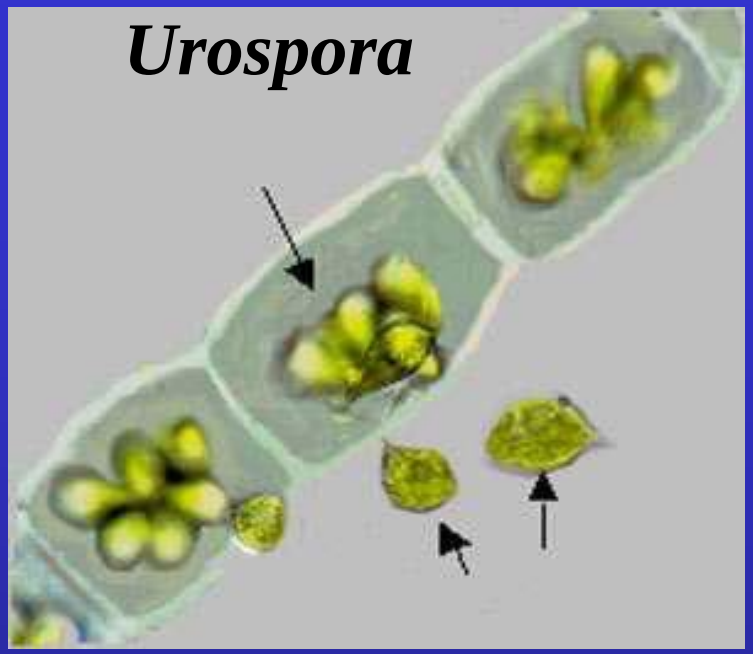
anizogamy
heterothalism





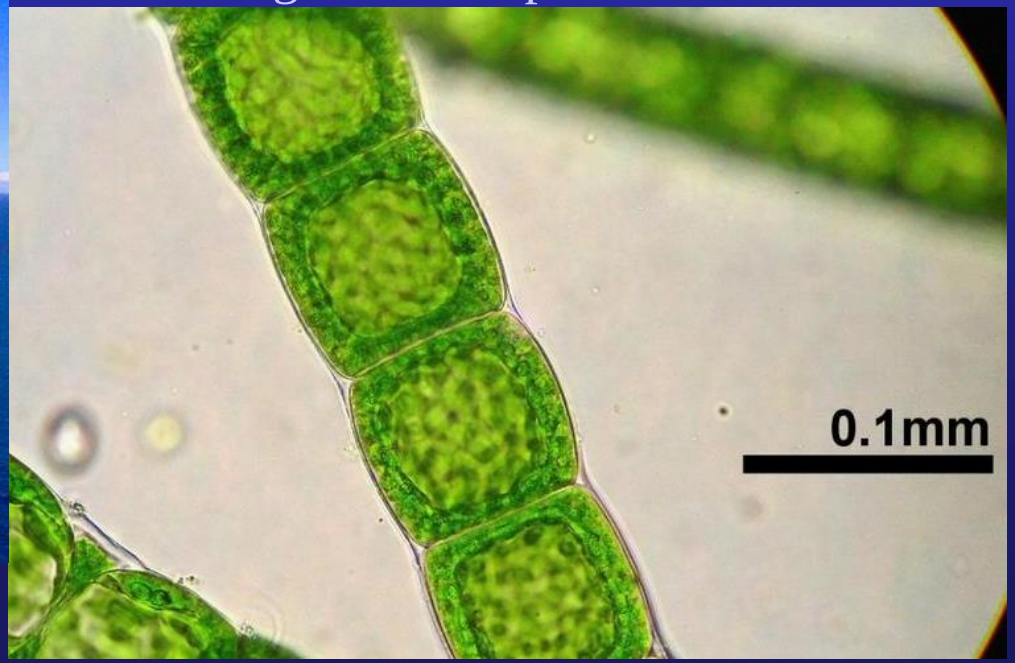
multinucleate
cells

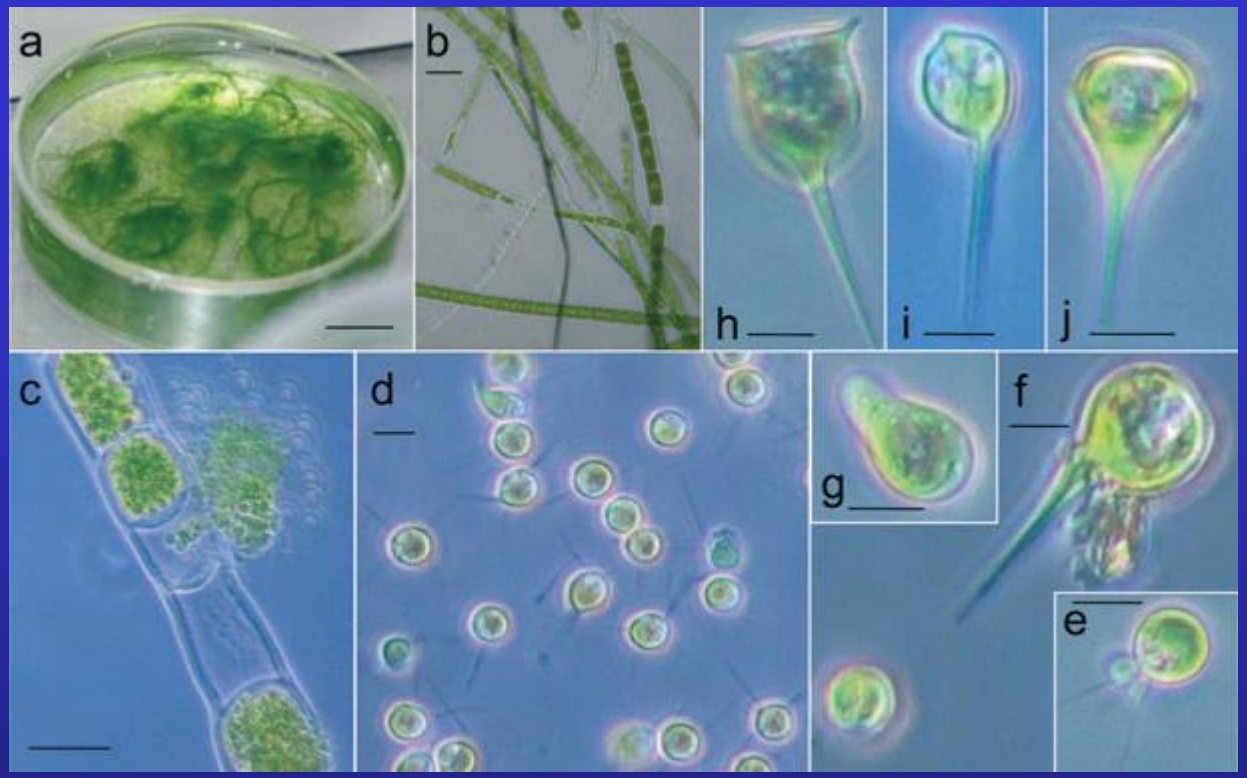




4-flagellate zoospores

Arctic and Antarctic sea





J. Phycol. **45,** 600–609 (2009)
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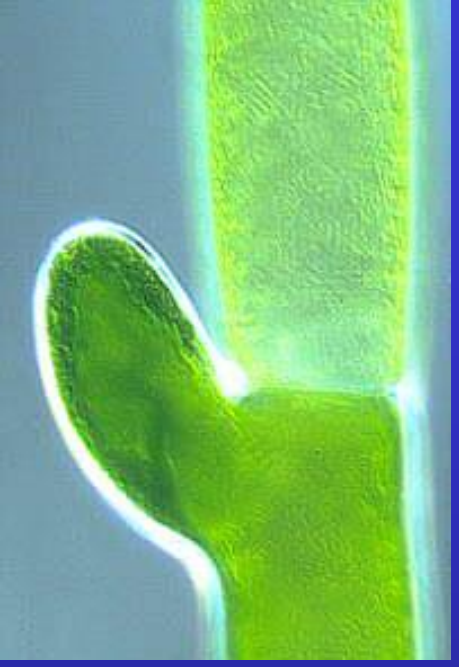
DOI: 10.1111/j.1529-8817.2009.00691.x

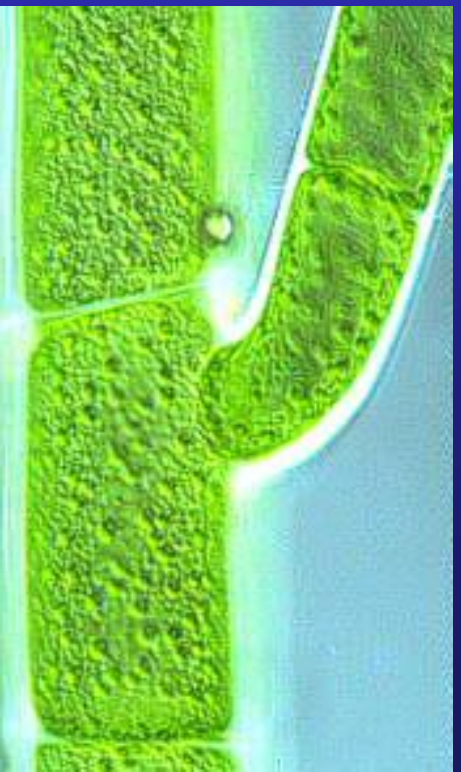
SENSITIVITY OF ANTARCTIC *UROSPORA PENICILLIFORMIS* (ULOTRICHALES, CHLOROPHYTA) TO ULTRAVIOLET RADIATION IS LIFE-STAGE DEPENDENT[1]

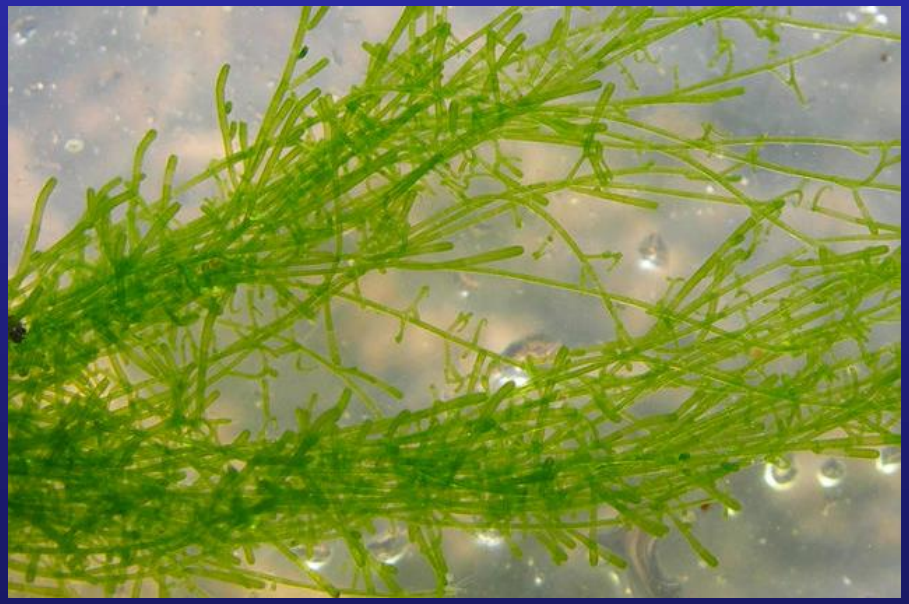
Michael Y. Roleda

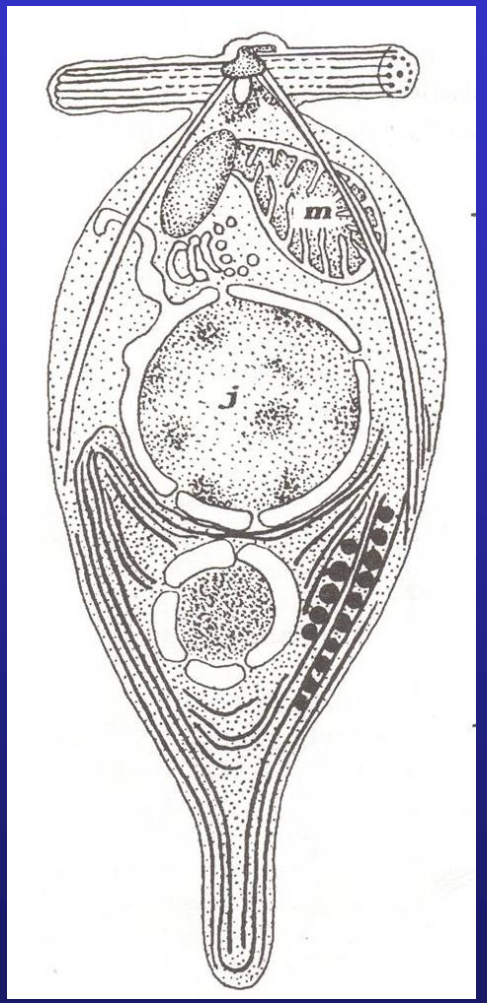
Institute for Polar Ecology, Wischhofstraße 1-3, Bldg. 12, D-24148 Kiel, Germany



Acrosiphonia

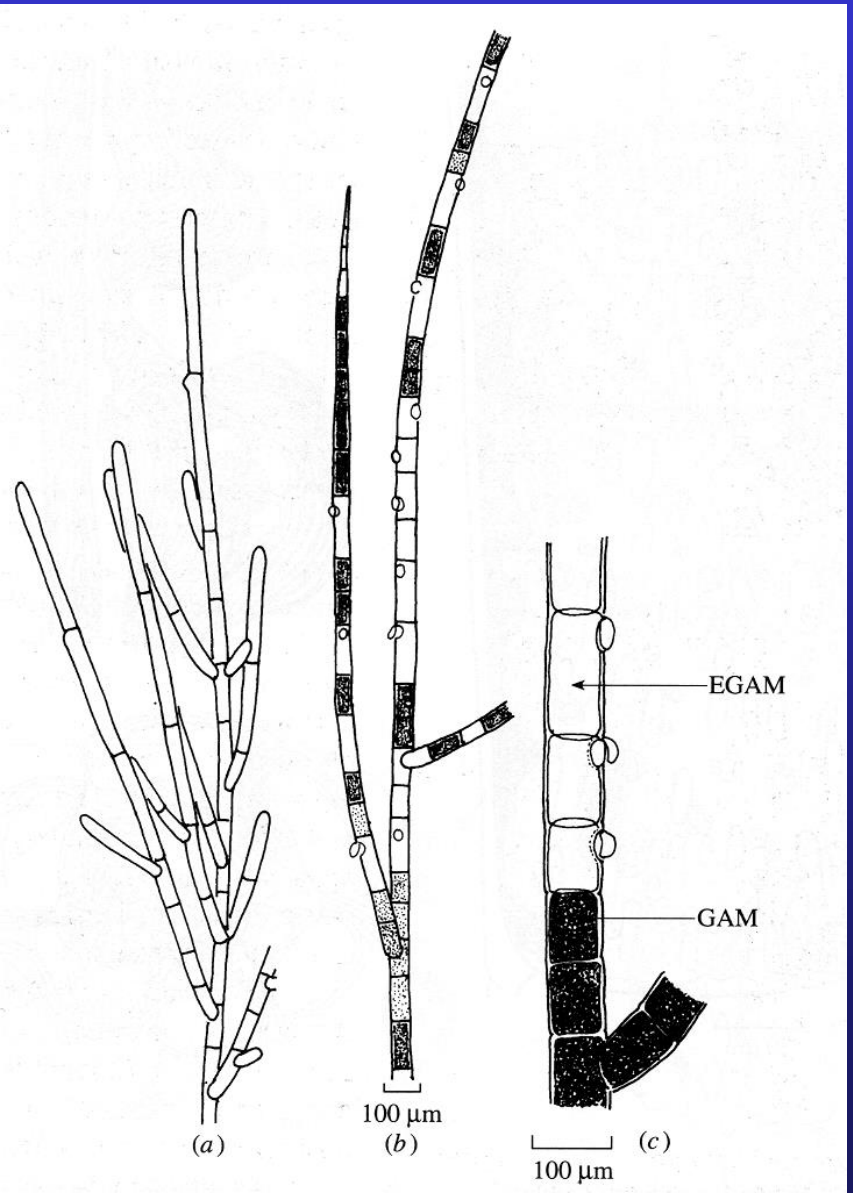


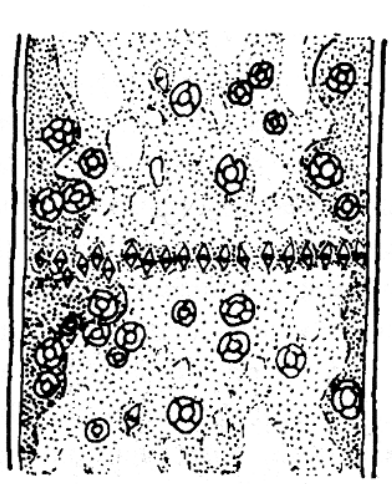


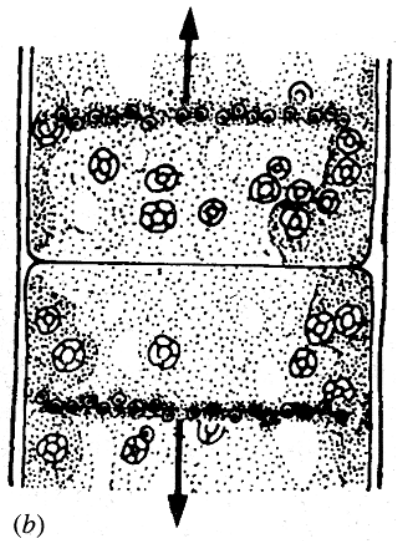


2-flagellate gamete

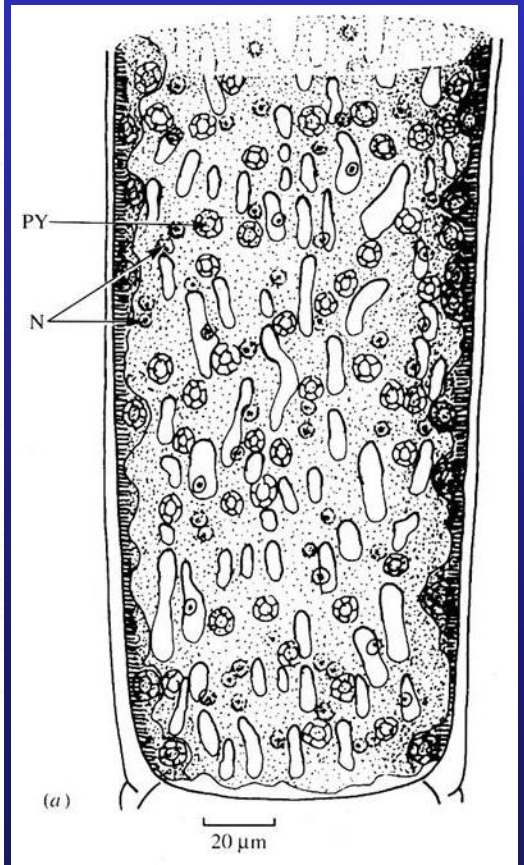
Acrosiphonia





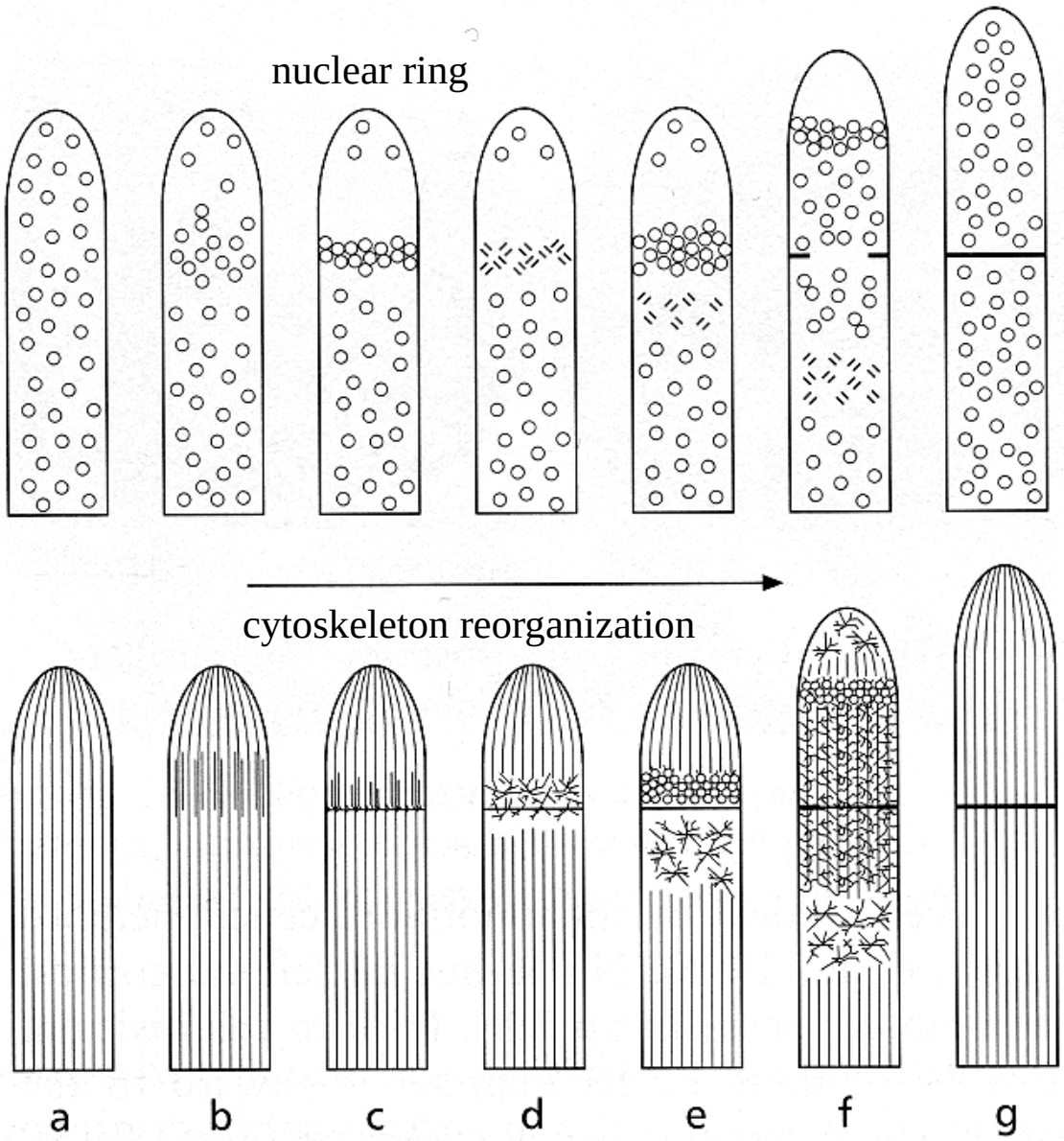


synchronous mitosis



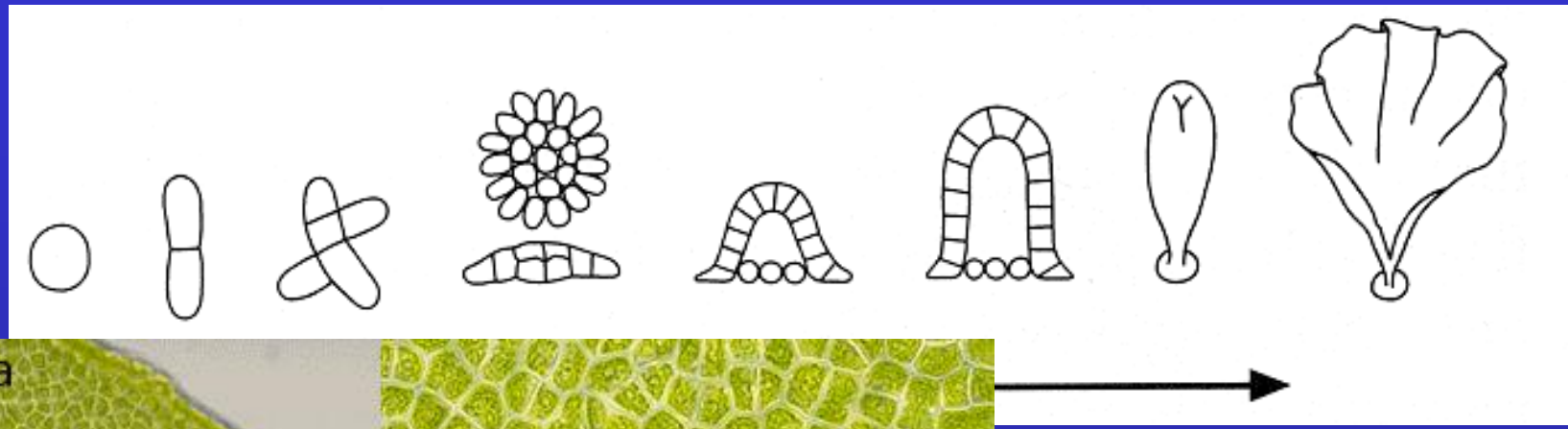
perforated chloroplast

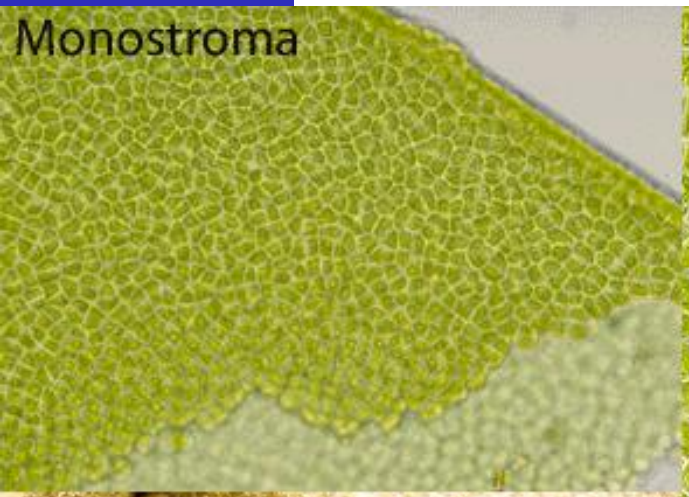
Acrosiphonia

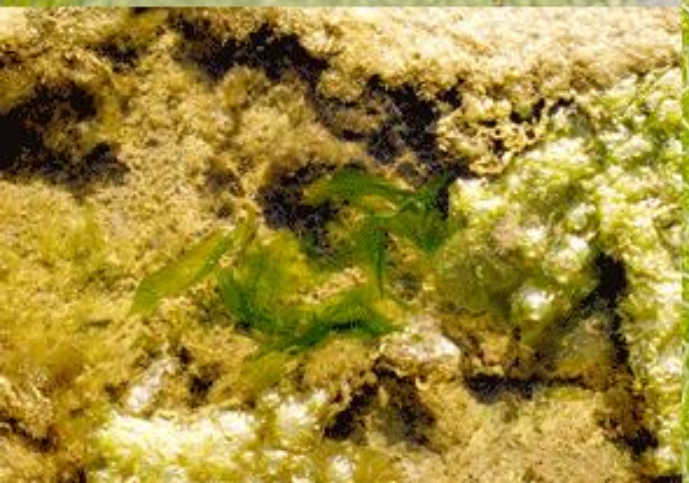


behaviour of nuclei and microtubuli during mitosis

Monostroma







thallus formation from the short filaments

monostromatic thallus

Monostroma

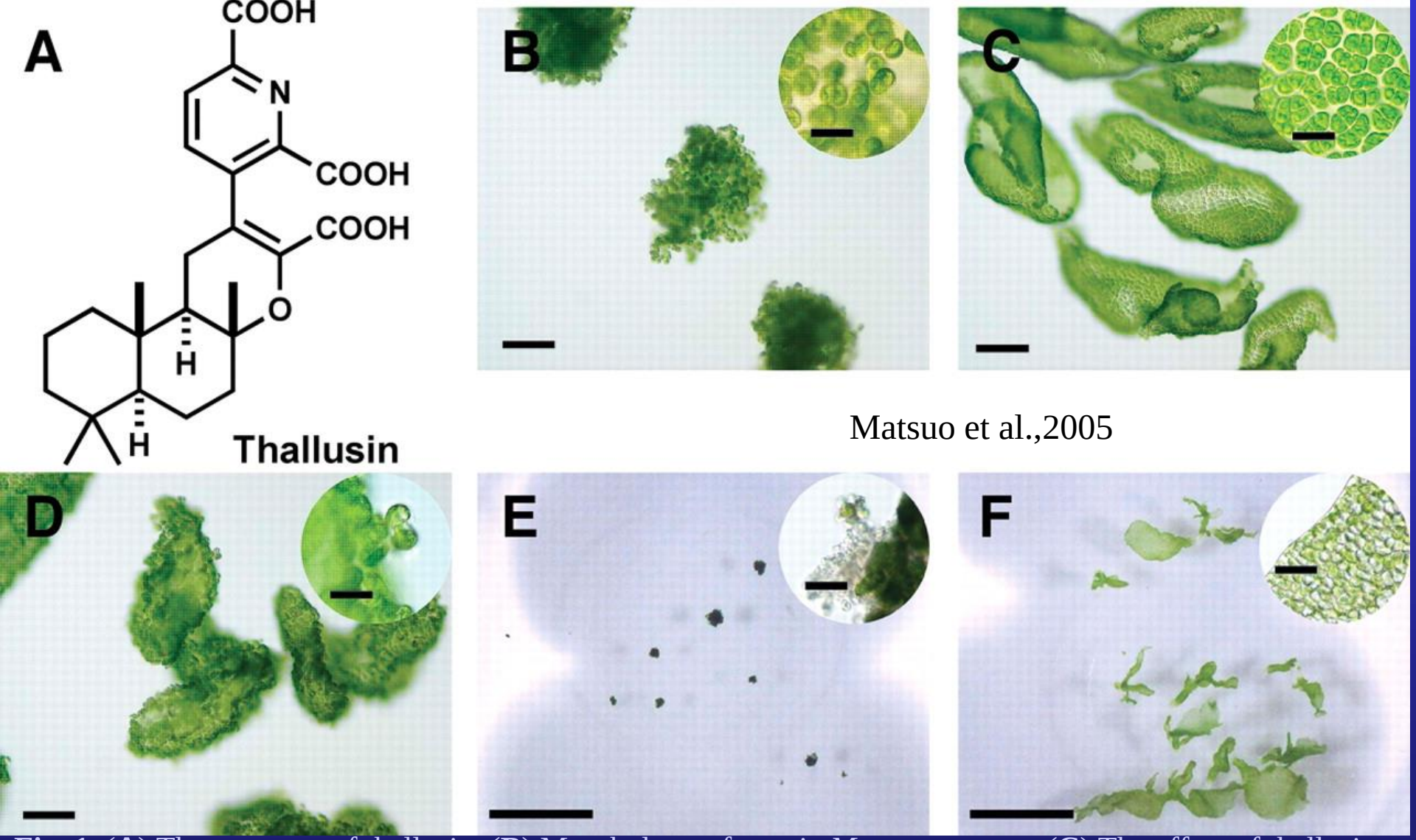
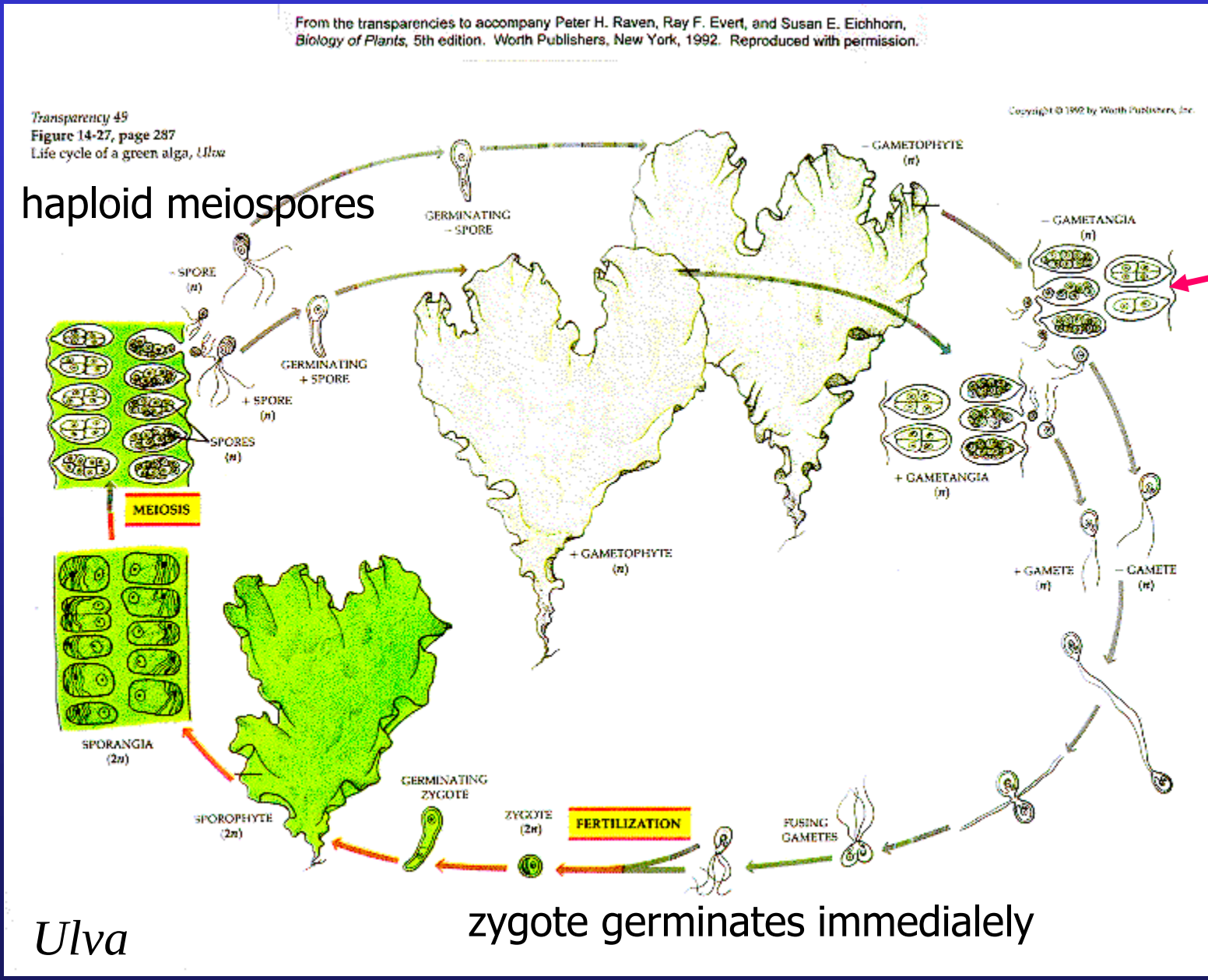


Fig. 1. (**A**) The structure of thallusin. (**B**) Morphology of axenic *M. oxyspermum*. (**C**) The effect of thallusin on *M. oxyspermum* (an initial concentration of 1 ng ml–1). (**D**) Dedifferentiation given a lack of thallusin (an initial concentration of 1 pg ml–1). Inset: Protruding cells from disintegrating thalli. (**E**) Small callus-like morphology of *U. pertusa*, after 2 months of cultivation under aseptic conditions. Inset: Colorless protrusions from the lateral cell walls. (**F**) The effect of thallusin (1 ng ml–1) on *U. pertusa*. Inset: A foliaceous distromatic blade.

Řád: Ulvales


From the transparencies to accompany Peter H. Raven, Ray F. Evert, and Susan E. Eichhorn, Biology of Plants, 5th edition. Worth Publishers, New York, 1992. Reproduced with permission.
Transparency 49
Figure 14-27, page 287
Life cycle of a green alga, Ulva
haploid meiospores
– GAMETOPHYTE (n)
GERMINATING – SPORE
– SPORE (n)
– GAMETANGIA (n)
GERMINATING + SPORE
+ SPORE (n)
SPORES (n)
+ GAMETANGIA (n)
MEIOSIS
+ GAMETOPHYTE (n)
+ GAMETE (n)
– GAMETE (n)
SPORANGIA (2n)
GERMINATING ZYGOTE
SPOROPHYTE (2n)
ZYGOTE (2n)
FERTILIZATION
FUSING GAMETES
Ulva
zygote germinates immedialely

Ulvaria

monostromatic thallus (single layer of cells)

temperate regions of the Northern hemisphere

North Atlantic, North Pacific

Ulvaria - cosmopolitan in temperate waters of the northern hemisphere; subtidal and intertidal zones on stones, shell, algae and other hard substrates.

Ulvaria obscura (Kützing) P. Gayral ex C. Bliding

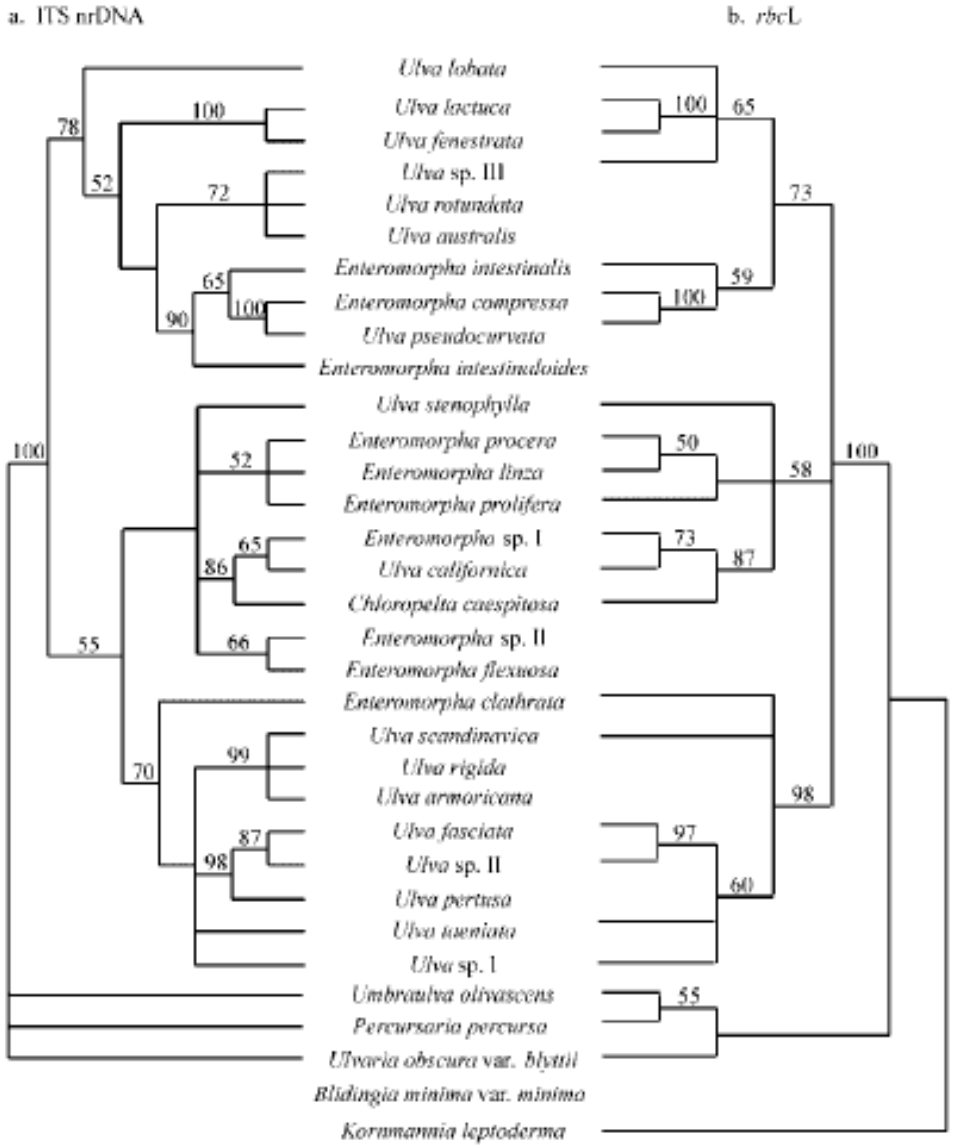
Enteromorpha=Ulva

Hayden et al. 2003 synonimize both genera

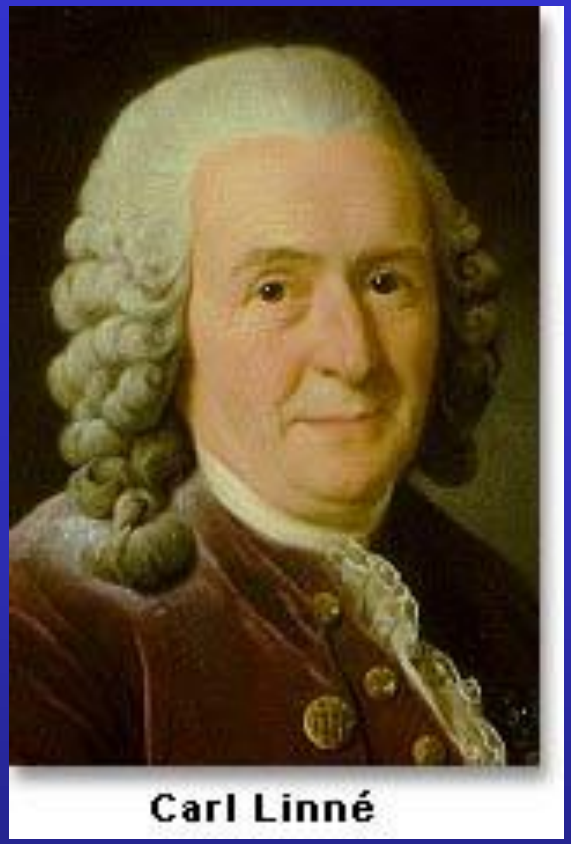
All after Entwisle et al. (1997)

Table 3. Characters used to delimit species of *Ulva* and *Enteromorpha* based on Koeman and van den Hoek (1981) and Bliding (1963, 1968). Characters noted with (E) and (U) are used only in *Enteromorpha* and *Ulva*, respectively.

Character
Gross morphology, including colour and texture of mature plant
Structure of plant base
Arrangement and shape of cells in surface view
Structure of branch tips (E)
Number of pyrenoids per cell
Shape of chloroplast in surface view
Cell size at base, middle and apex of thallus
Height-to-width ratio of cells in cross section (U)
Thallus thickness (U)
Morphology of young germling
Mode of reproduction
Ecology



Hayden et al. 2003. Linnaeus was right all along: *Ulva* and *Enteromorpha* are not distinct genera. *European Journal of Phycology*. 38: 277-294.



Carl Linné

(1719-1772)

CAROLI A LINNÉ
EQUIT. AURAT. DE STELLA POLARI,
ACAD. PARIS. MEMBR. &C.

SYSTEMA NATURÆ

PER

REGNA TRIA NATURÆ,

SECUNDUM

CLASSES, ORDINES,
GENERA, SPECIES,

(1767)

1204. TREMELLA. *Fructificationes* vix manifestæ, 1625. in corpore gelatinoso.

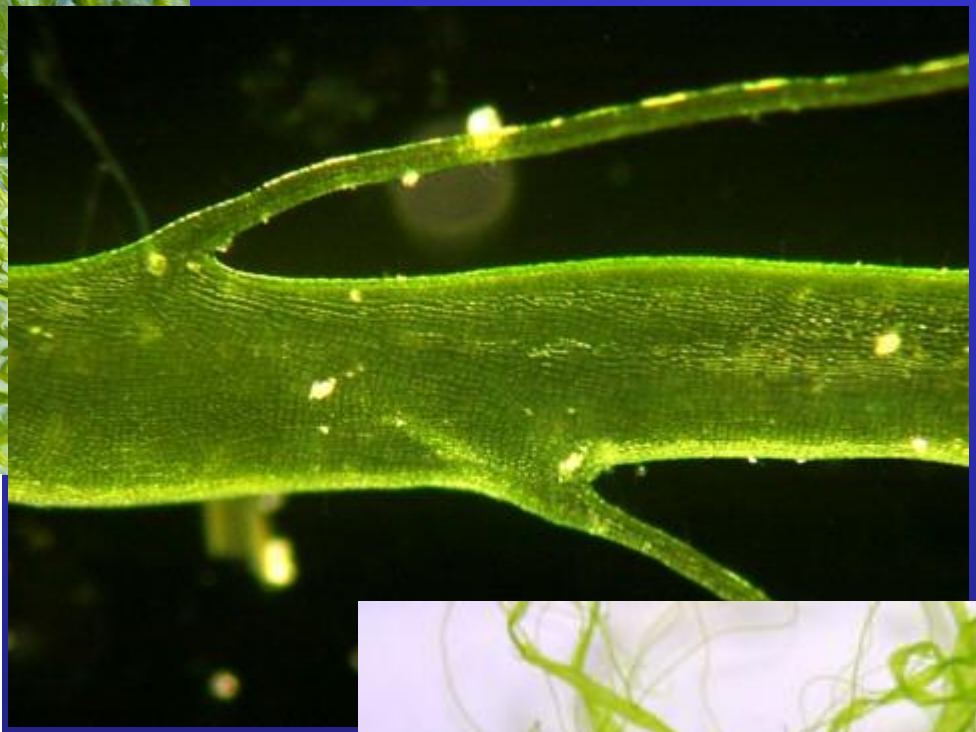
juniperin. 1. T. sessilis membranacea auriformis fulva.
Nostoc. 2. T. plicata undulata.
lichenoides. 4. T. erecta plana: margine crispo lacinulato. *Dill. musc. t.* 19. *f.* 32, 34, 35.
verrucosa. 5. T. tuberculosa solida rugosa. *Dill. musc. t.* 10. *f.* 16.
difformis. 8. T. subrotunda sinuata difformis gelatinosa.
hemisph. 6. T. hemisphærica sparsa.
purpurea. 7. T. subglobosa sessilis solitaria glabra.
adnata. 9. T. rotunda imbricata livida.

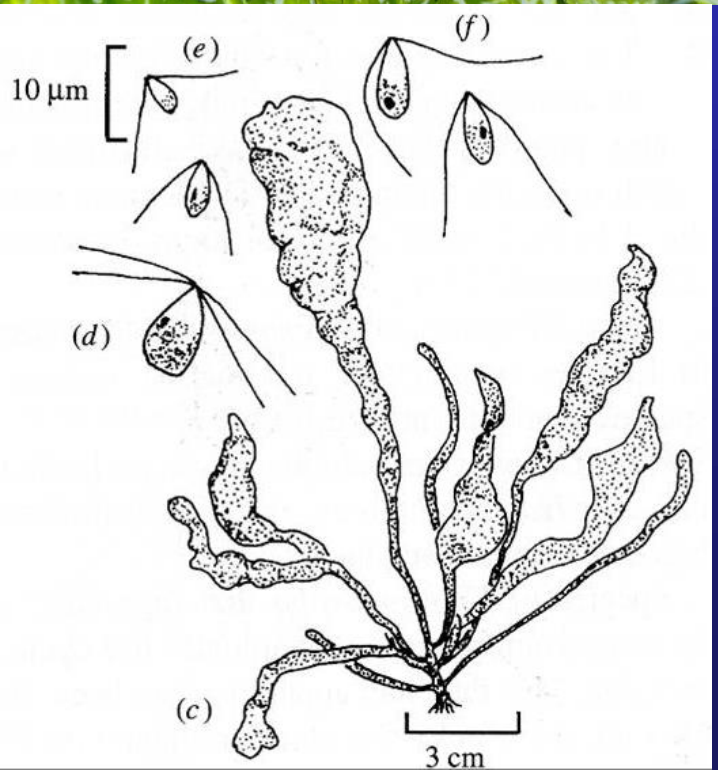
1205. FUCUS. MASC. *Vesiculæ* villis intertextæ. 1626. FEM. *Vesiculæ* adspersæ granis immersis apice prominulis. *Sem.* solitaria.

ovarius. 36. F. caule filiformi ramoso, fol. confertis ovatis fornicatis. *Habitat in O. Asiatico.* Folia *conferta in racemum, retrorsum fornicata, membranacea, purpurascentia, parva. Fructificationes non vidi.*

only 5 algal genera discerned (Tremella, Fucus, Ulva, Conferva, Corallina + Volvox (=animal like plant)

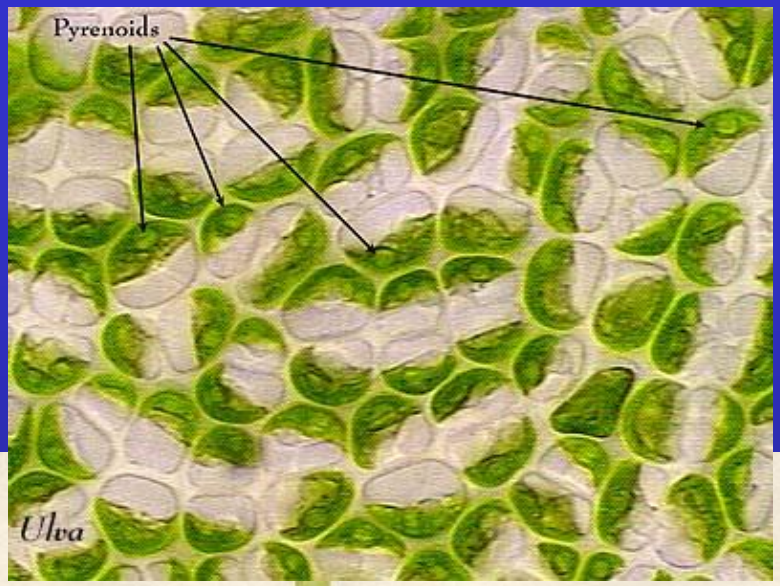
Enteromorpha=Ulva





release of gametes influenced by lunar cycle

Ulva



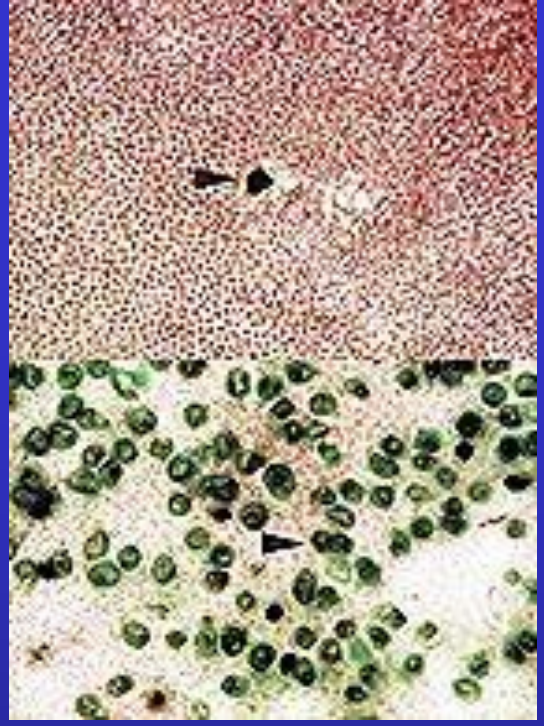
(Qingdao on 18.7.2011)
South China

Going Green: Beach Carpet

2013

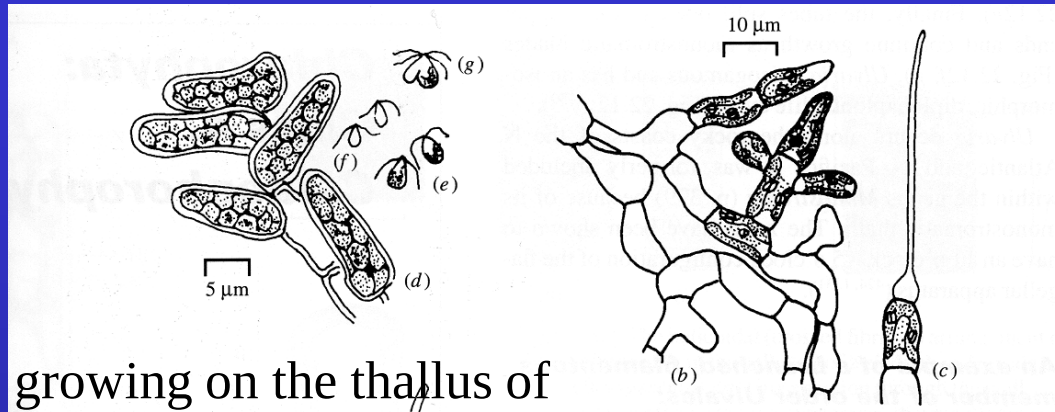
1. 7. 2008 - Sailing course for the Olympic Summer Games. Qingdao, China

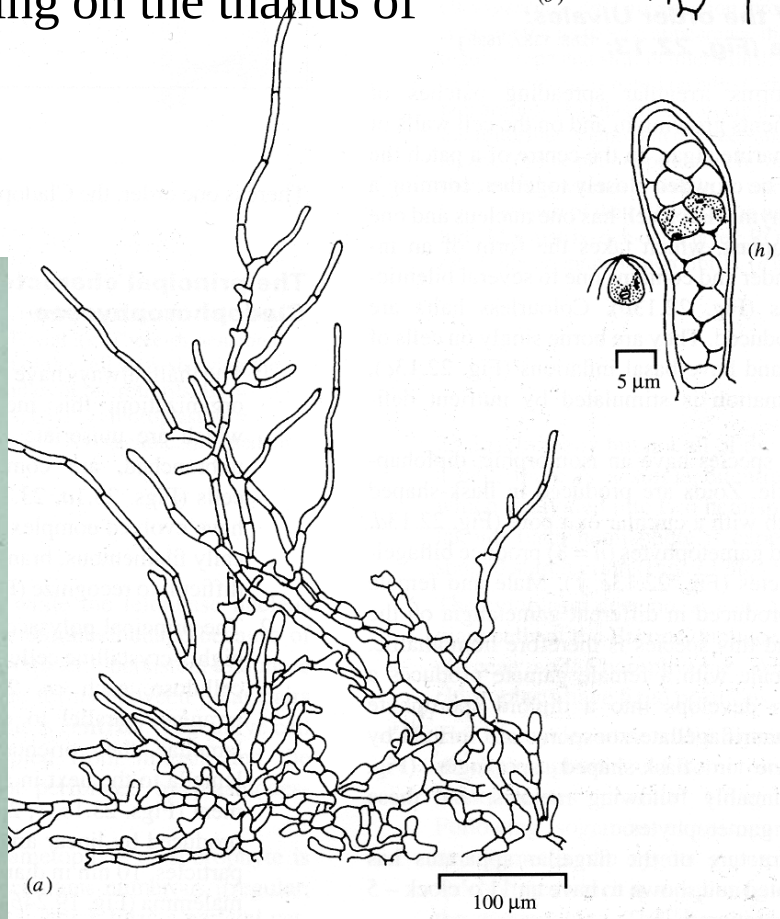
Acrochaete - parasite



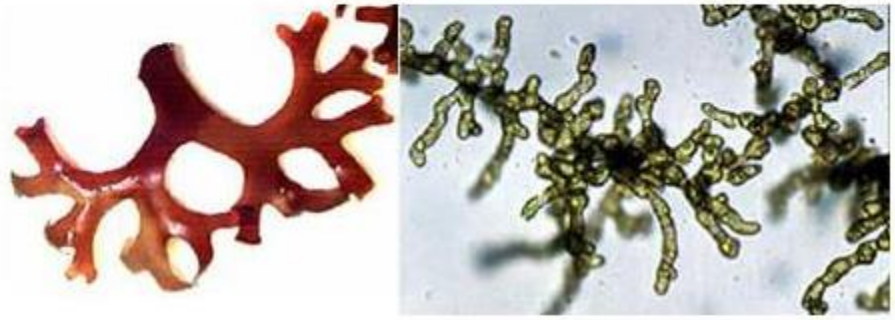
Acrochaete
Chondrus

growing on the thallus of



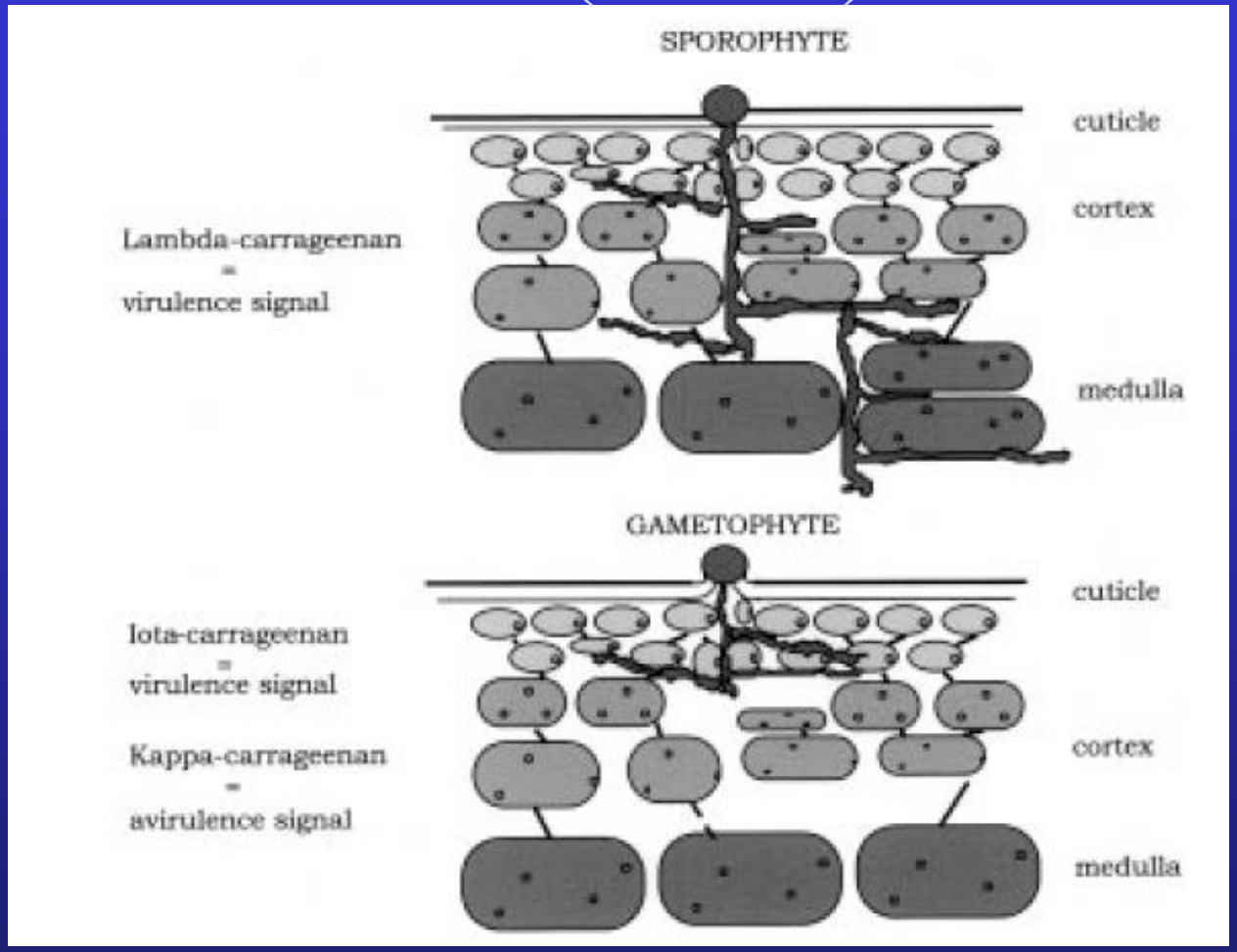


Induced defence of red algae against pathogens



We investigate the alga/pathogen interaction in the system of the red alga Chondrus crispus (left on top) and the green algal pathogen Acrochaete operculata (below left), which is able to grow within the tissue of the red algal host. This process, called endophytism, can be inhibited during certain developmental phases of C. crispus. During the resistant, gametophytic, phase of the life cycle, C. crispus can recognise the attacker and kill it by an immediate release of hydrogen peroxide. We found that carrageenans from the red alga induce the release of asparagine from the green algal parasite. The free amino acid itself acts as a substrate for an amino acid oxidase of the host that releases micromolar amounts of hydrogen peroxide, sufficient to contain the attacker. The aim of a related collaborative project (European Union EPIFIGHT) is to understand the biological

The virulence of *Acrochaete* mediated by CW composition of the host (*Chondrus*)

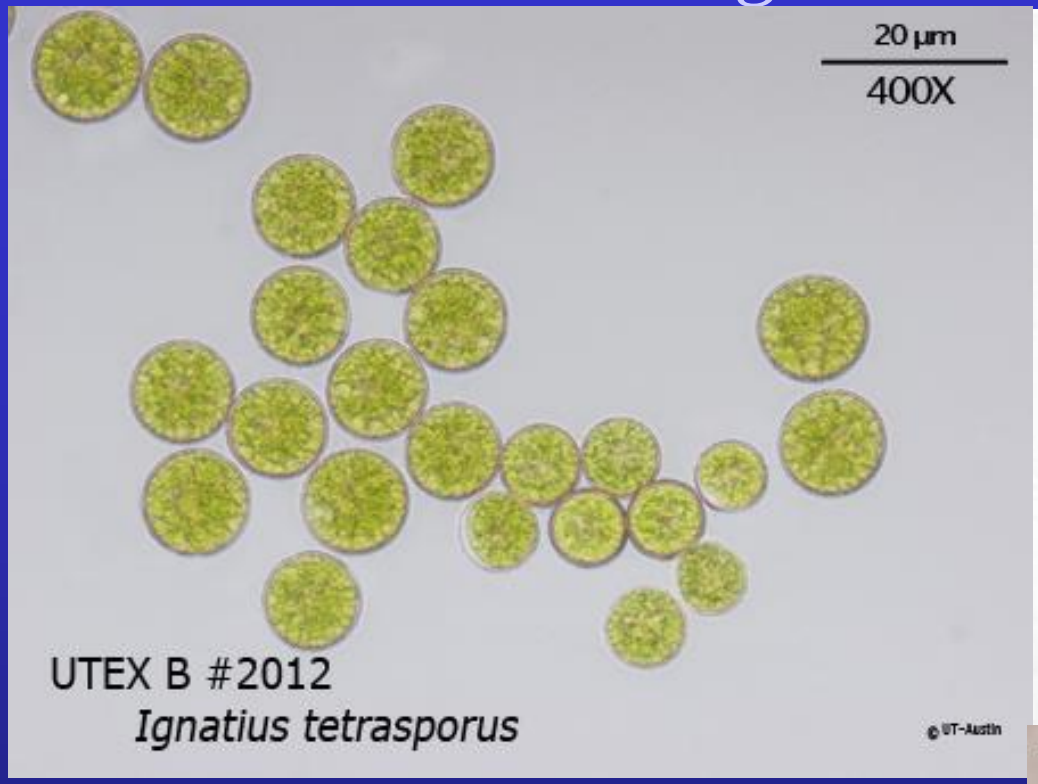


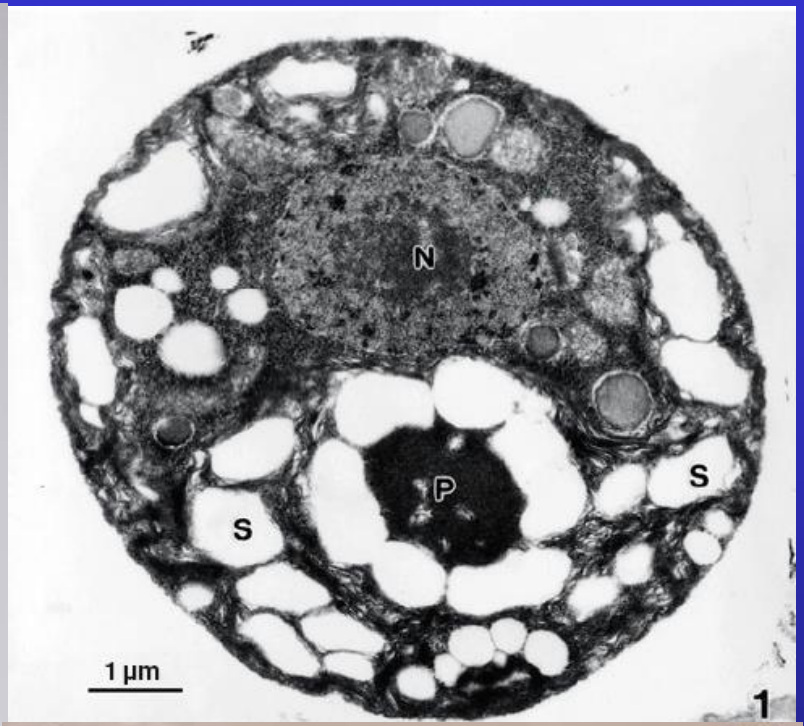
susceptible to infection

resistant

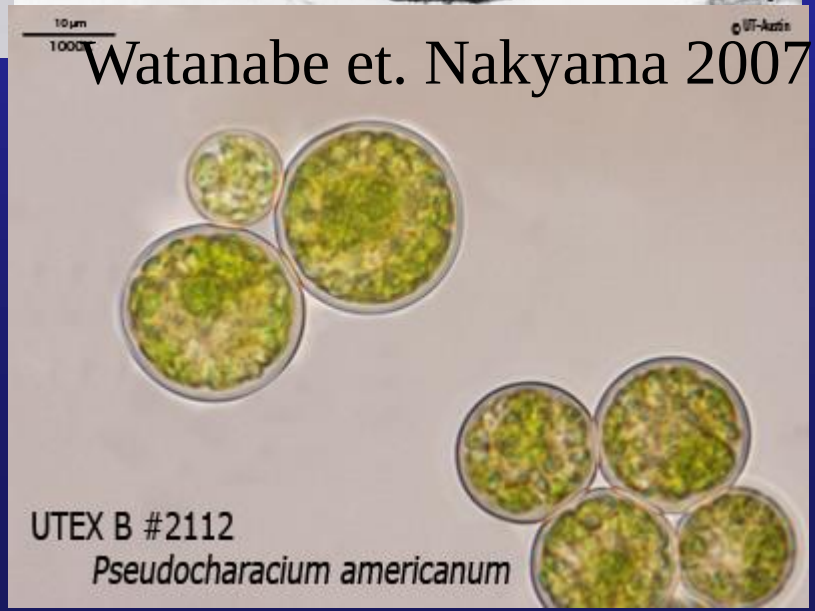
In this pathosystem,the host gametophytes are resistant to the pathogen, whereas the sporophytic generation is susceptible to infection. The virulence of the green algal pathogen is mediated by the recognition of carrageenan oligosaccharides released from its red algal host: kappa-carrageenan oligosaccharides inhibit *A. operculata* virulence while lambda-carrageenan oligosaccharides enhance its pathogenicity. Bouarab et al. 2004

Ignatius clade





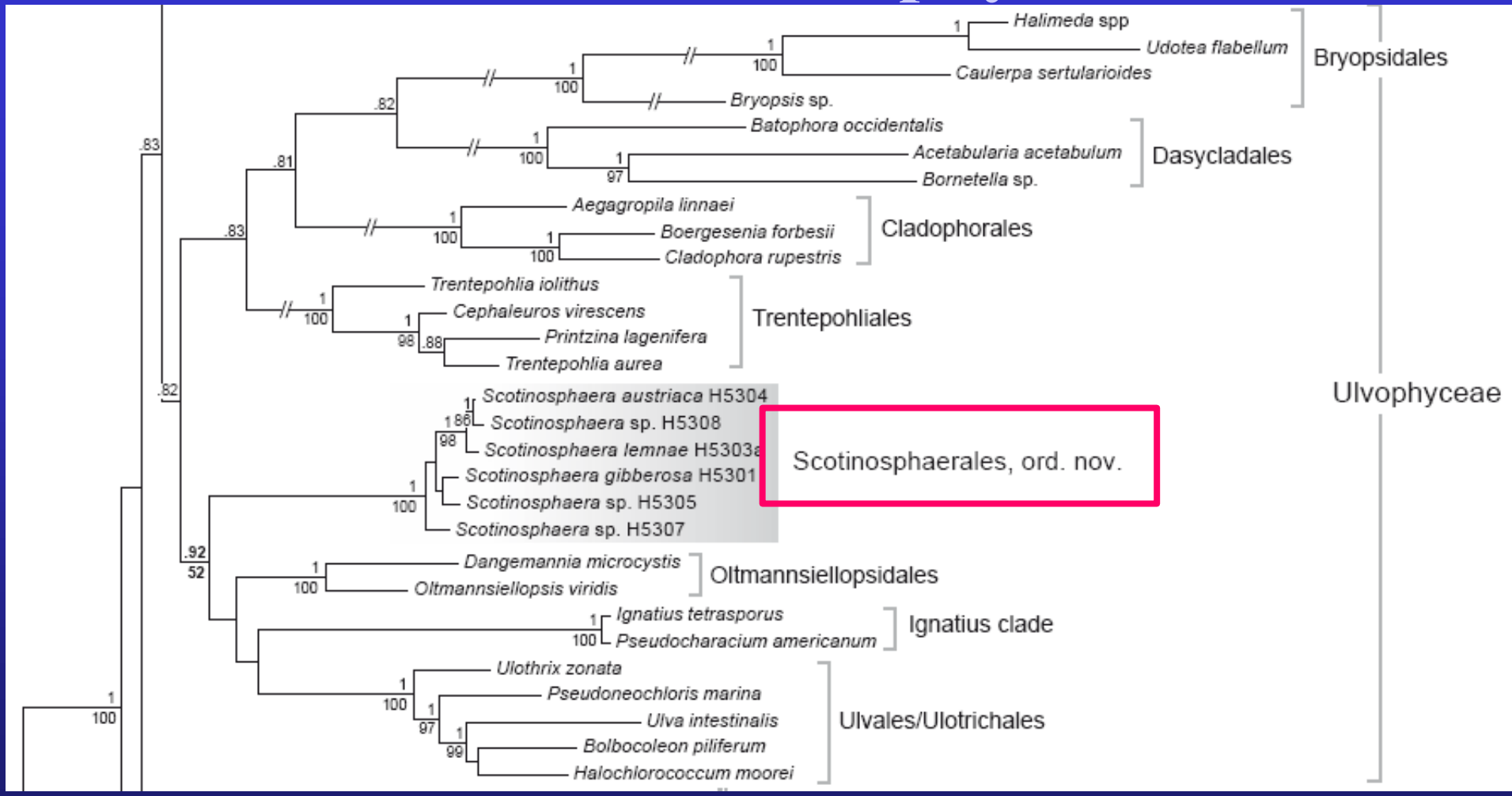
Watanabe et. Nakyama 2007



Coccoids from damp terrestrial habitats

A young vegetative cell included a single nucleus and a cup-shaped chloroplast that contained a pyrenoid and stroma starch grains

Třída: Ulvophyceae

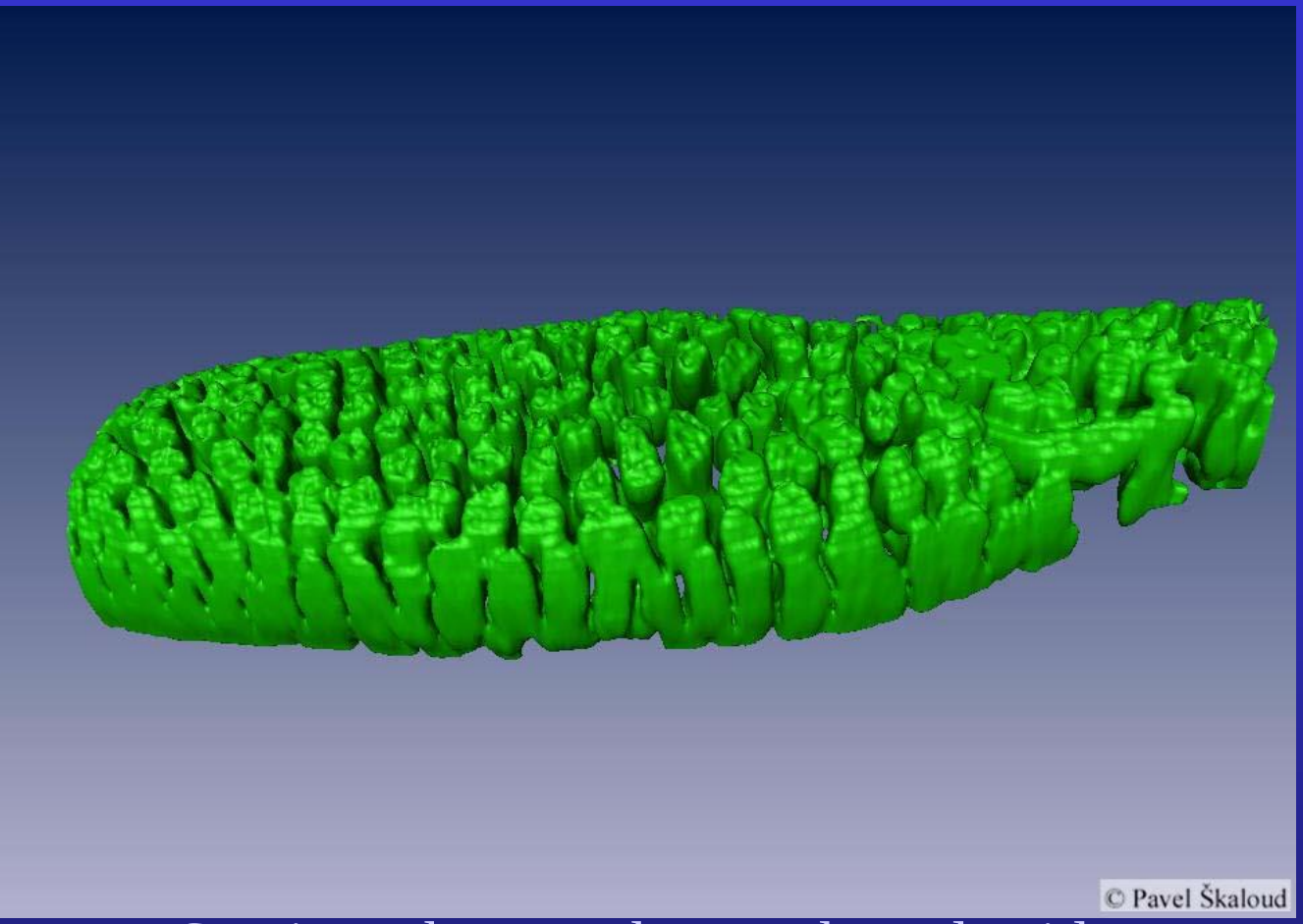


Phylogeny of the Chlorophyta obtained by Bayesian inference of the concatenated SSU-rbcL alignment.

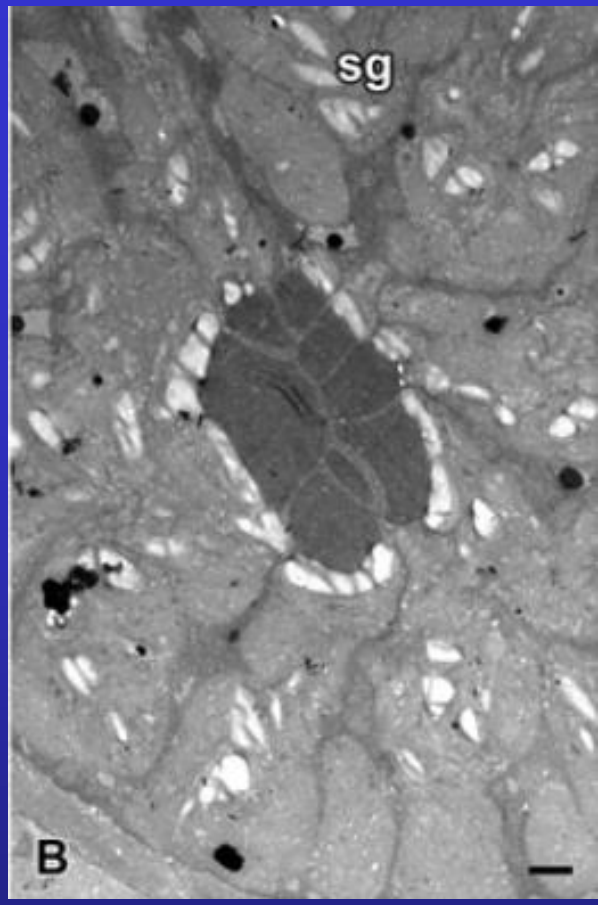
Škaloud et al. 2013

Scotinosphaerales

Scotinosphaera - freshwater, soil



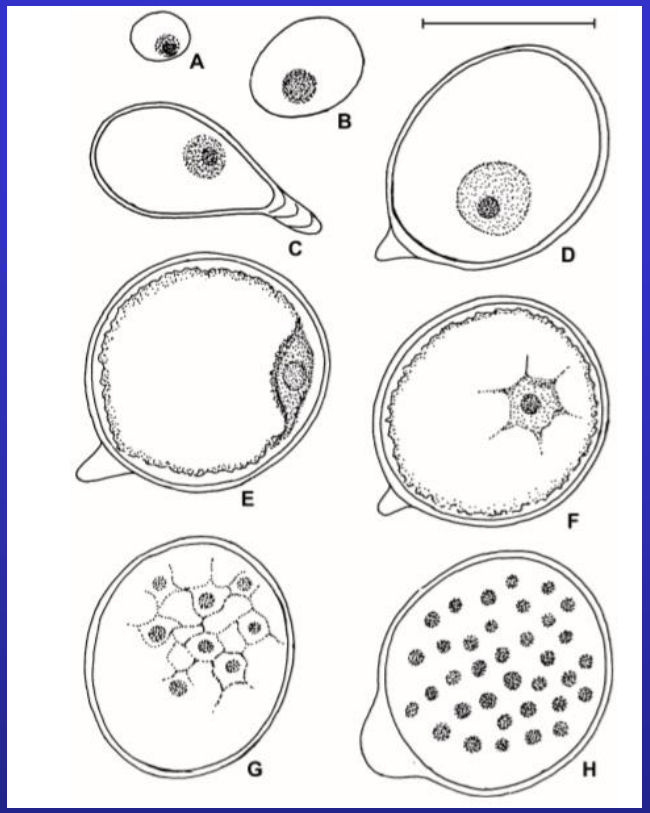
Scotinosphaera-rekonstrukce plastidu



pyrenoid

large cells bearing local cell wall thickenings, pyrenoid matrix dissected by numerous anastomosing cytoplasmatic channels, sporogenesis comprising the accumulation of secondary carotenoids in the cell periphery and almost simultaneous cytokinesis.

Simultaneous cytokinesis.



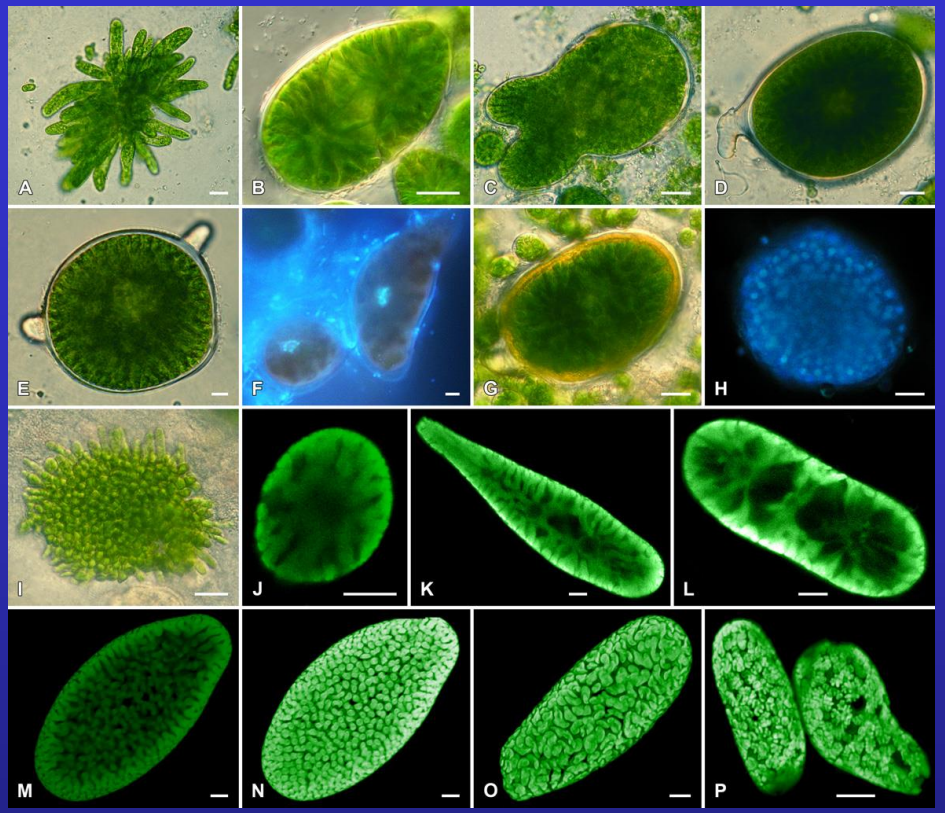


FIG. 6. Drawings of *Scotinosphaera* nuclear cycle based on material stained with aceto-iron-hematoxylin-chloral hydrate (CAUP H5301). (A–D) Vegetative cells. Large nucleus is located in the cell center. (E and F) Young sporangia with peripherally located, starlike nucleus. Secondary carotenoids are synthetized between the protoplasm and cell wall. (G) Cleavage of the protoplasm after simultaneous nuclear division. (H) Mature sporangium containing numerous nuclei of daughter cells. The daughter cell walls were not observed. The asexual spores are released by opening of the gelatinous bulge.

Škaloud et al. 2013, J. phycol