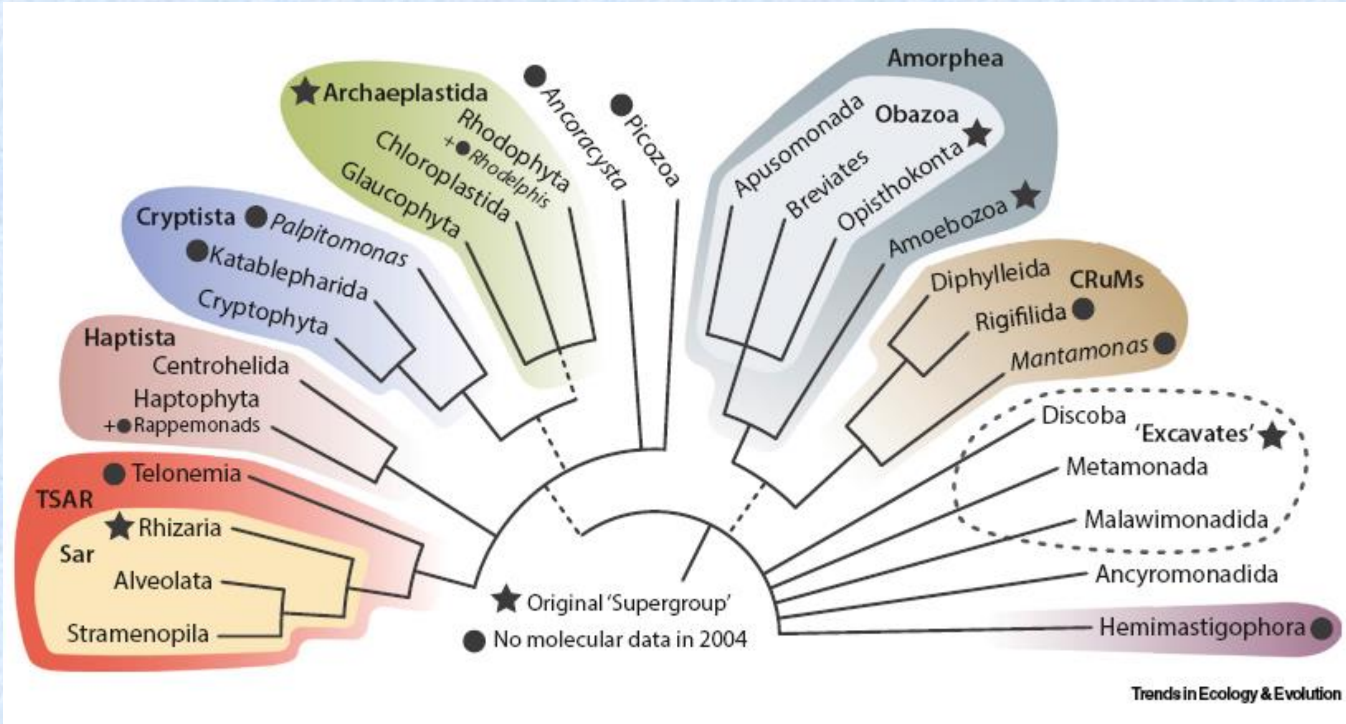
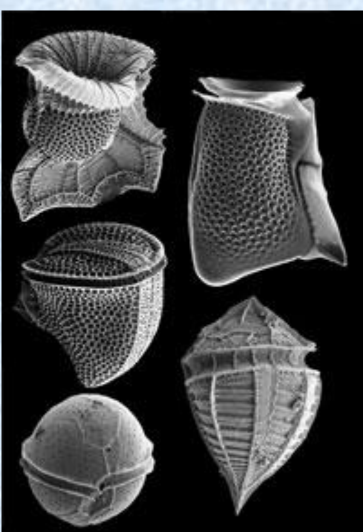
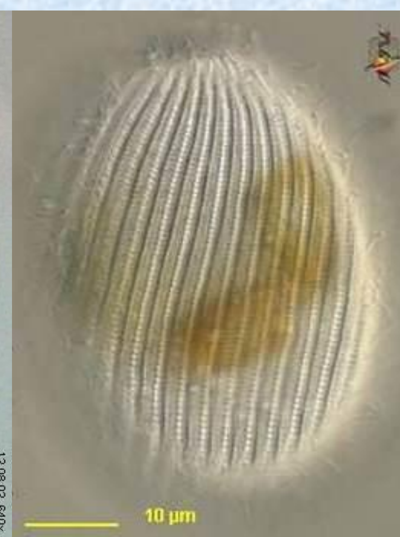
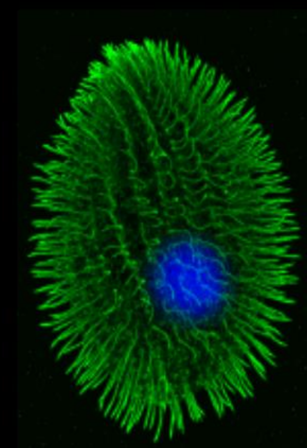
Alveolata


Archaeplastida
Rhodophyta
+ Rhodelphis
Chloroplastida
Glaucophyta
Ancoracysta
Picozoa
Amorphea
Apusomonada
Obazoa
Breviates
Opisthokonta
Amoebozoa
Cryptista
Palpitomonas
Katablepharida
Cryptophyta
Haptista
Centrohelida
Haptophyta
+ Rappemonads
Diphylleida
CRuMs
Rigifilida
Mantamonas
Discoba
'Excavates'
Metamonada
Malawimonadida
Ancyromonadida
Hemimastigophora
Telonemia
TSAR
Rhizaria
Sar
Alveolata
Stramenopila
Original 'Supergroup'
No molecular data in 2004
Trends in Ecology & Evolution

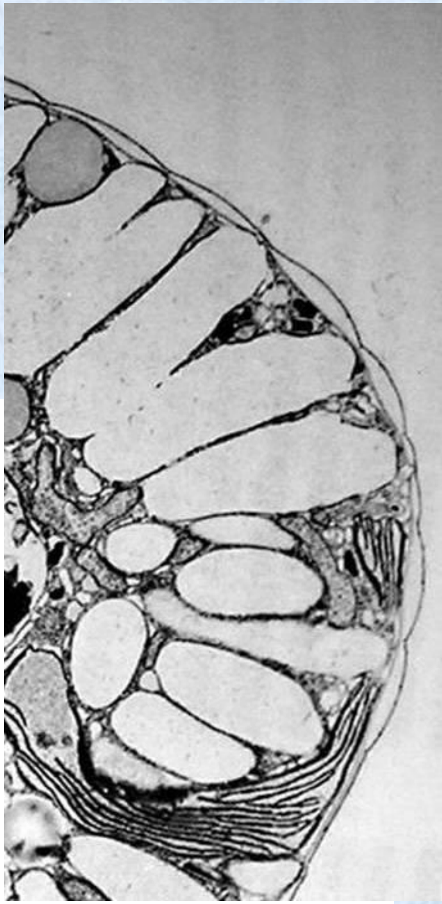



10 µm



Alveolates

- large group of protists
- 3 main groups, distinct in morphology, life strategies...
- **Ciliata, Apicomplexa, Dinophyta**
- common ultrastructural features
  - micropores
  - cortical alveoli + extrusomes (ejectosomes)



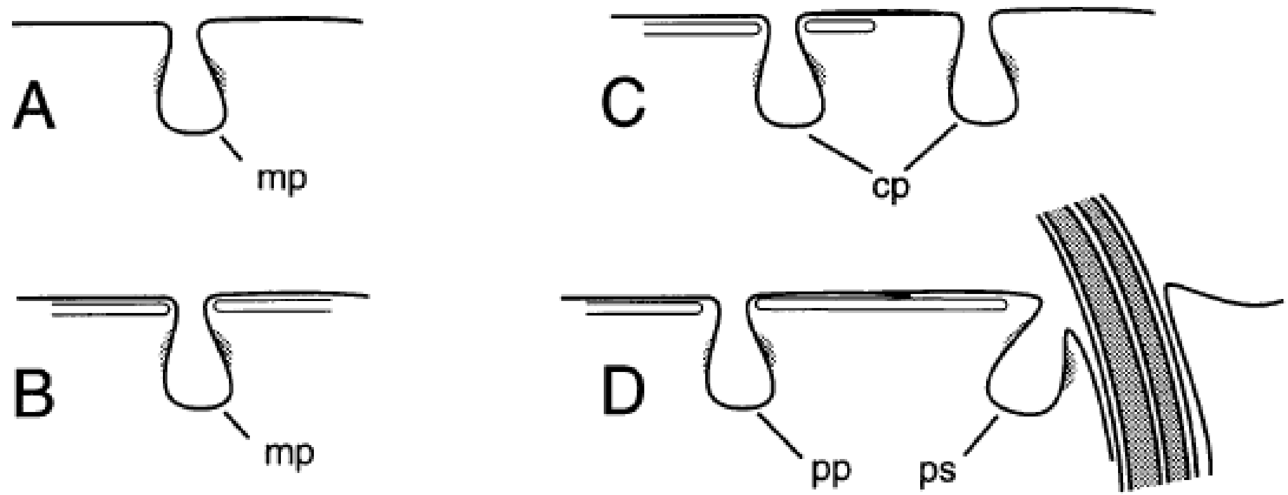
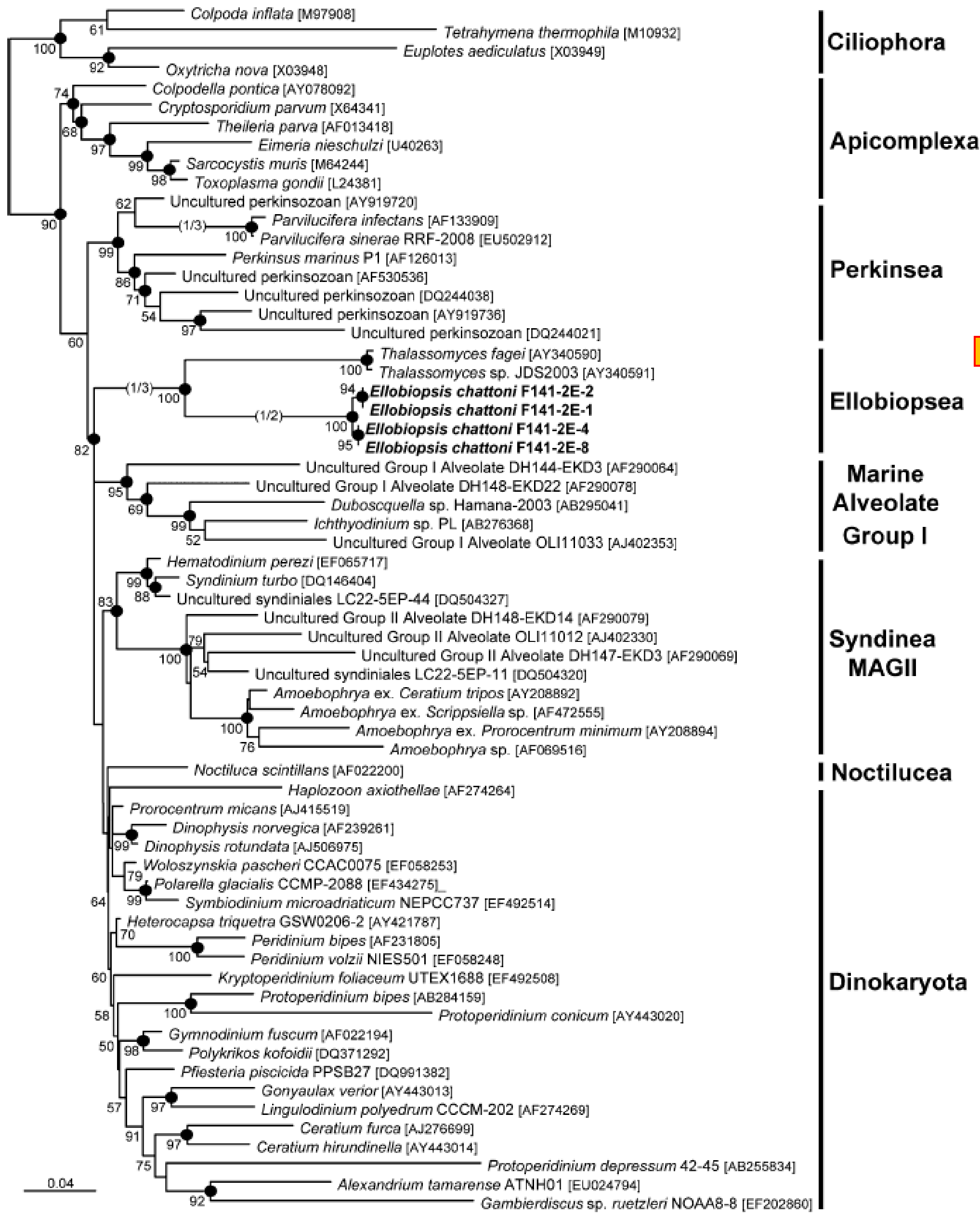
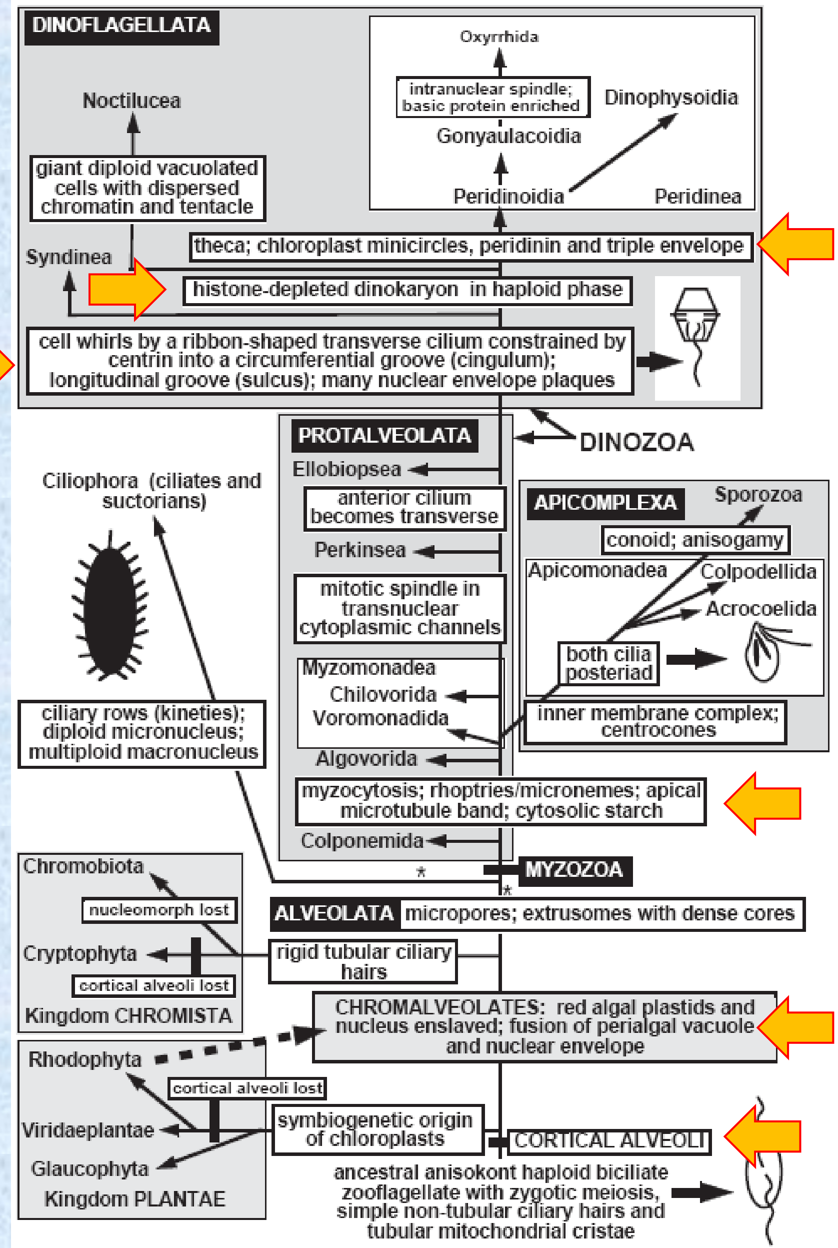


Fig. 2. Ultrastructural characteristics of pinocytic structures in the Alveolata including micropores (mp) of (A) apicomplexans and (B) *Perkinsus* species as well as (C) the collared pits (cp) of dinoflagellates and (D) the pellicular pores (pp) and parasomal sacs (ps) of ciliates.

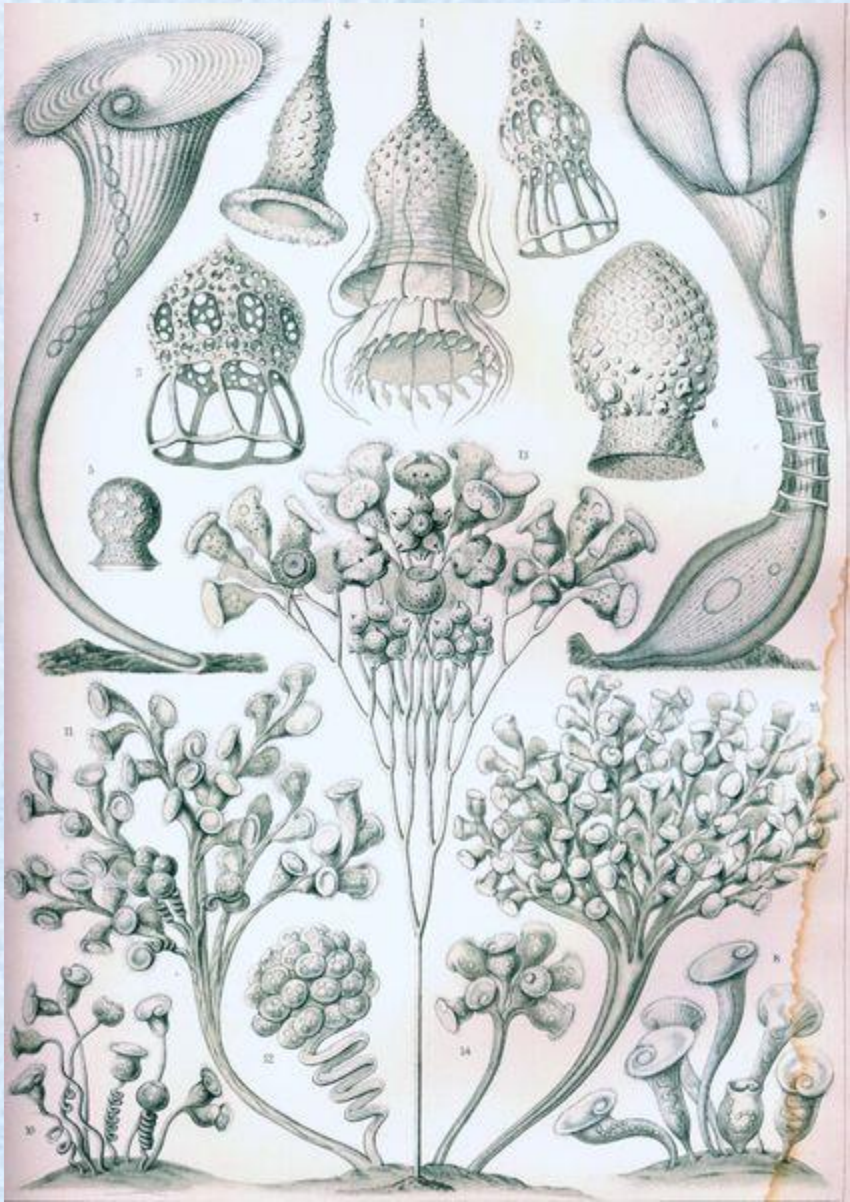
Alveolates


Colpoda inflata [M97908]
Tetrahymena thermophila [M10932]
Euplotes aediculatus [X03949]
Oxytricha nova [X03948]
Colpodella pontica [AY078092]
Cryptosporidium parvum [X64341]
Theileria parva [AF013418]
Eimeria nieschulzi [U40263]
Sarcocystis muris [M64244]
Toxoplasma gondii [L24381]
Uncultured perkinsozoan [AY919720]
Parvilucifera infectans [AF133909]
Parvilucifera sinerae RRF-2008 [EU502912]
Perkinsus marinus P1 [AF126013]
Uncultured perkinsozoan [AF530536]
Uncultured perkinsozoan [DQ244038]
Uncultured perkinsozoan [AY919736]
Uncultured perkinsozoan [DQ244021]
Thalassomyces fagei [AY340590]
Thalassomyces sp. JDS2003 [AY340591]
Ellobiopsis chattoni F141-2E-2
Ellobiopsis chattoni F141-2E-1
Ellobiopsis chattoni F141-2E-4
Ellobiopsis chattoni F141-2E-8
Uncultured Group I Alveolate DH144-EKD3 [AF290064]
Uncultured Group I Alveolate DH148-EKD22 [AF290078]
Duboscquella sp. Hamana-2003 [AB295041]
Ichthyodinium sp. PL [AB276368]
Uncultured Group I Alveolate OLI11033 [AJ402353]
Hematodinium perezi [EF065717]
Syndinium turbo [DQ146404]
Uncultured syndiniales LC22-5EP-44 [DQ504327]
Uncultured Group II Alveolate DH148-EKD14 [AF290079]
Uncultured Group II Alveolate OLI11012 [AJ402330]
Uncultured Group II Alveolate DH147-EKD3 [AF290069]
Uncultured syndiniales LC22-5EP-11 [DQ504320]
Amoebophrya ex. Ceratium tripos [AY208892]
Amoebophrya ex. Scrippsiella sp. [AF472555]
Amoebophrya ex. Prorocentrum minimum [AY208894]
Amoebophrya sp. [AF069516]
Noctiluca scintillans [AF022200]
Haplozoon axiothellae [AF274264]
Prorocentrum micans [AJ415519]
Dinophysis norvegica [AF239261]
Dinophysis rotundata [AJ506975]
Woloszynskia pascheri CCAC0075 [EF058253]
Polarella glacialis CCMP-2088 [EF434275]
Symbiodinium microadriaticum NEPCC737 [EF492514]
Heterocapsa triquetra GSW0206-2 [AY421787]
Peridinium bipes [AF231805]
Peridinium volzii NIES501 [EF058248]
Kryptoperidinium foliaceum UTEX1688 [EF492508]
Protoperidinium bipes [AB284159]
Protoperidinium conicum [AY443020]
Gymnodinium fuscum [AF022194]
Polykrikos kofoidii [DQ371292]
Pfiesteria piscicida PPSB27 [DQ991382]
Gonyaulax verior [AY443013]
Lingulodinium polyedrum CCCM-202 [AF274269]
Ceratium furca [AJ276699]
Ceratium hirundinella [AY443014]
Protoperidinium depressum 42-45 [AB255834]
Alexandrium tamarense ATNH01 [EU024794]
Gambierdiscus sp. ruetzleri NOAA8-8 [EF202860]
0.04
Ciliophora
Apicomplexa
Perkinsea
Ellobiopsea
Marine Alveolate Group I
Syndinea MAGII
Noctilucea
Dinokaryota


DINOFLAGELLATA
Oxyrrhida
intranuclear spindle; basic protein enriched
Dinophysoidia
Gonyaulacoidia
Peridinoidia
Peridinea
Noctilucea
giant diploid vacuolated cells with dispersed chromatin and tentacle
Syndinea
theca; chloroplast minicircles, peridinin and triple envelope
histone-depleted dinokaryon in haploid phase
cell whirls by a ribbon-shaped transverse cilium constrained by centrin into a circumferential groove (cingulum); longitudinal groove (sulcus); many nuclear envelope plaques
PROTALVEOLATA
DINOZOA
Ellobiopsea
anterior cilium becomes transverse
Perkinsea
mitotic spindle in transnuclear cytoplasmic channels
Myzomonadea
Chilovorida
Voromonadida
Algovorida
myzocytosis; rhoptries/micronemes; apical microtubule band; cytosolic starch
Colponemida
MYZOZOA
APICOMPLEXA
Sporozoa
conoid; anisogamy
Apicomonadea
Colpodellida
Acrocoelida
both cilia posterial
inner membrane complex; centrocones
Ciliophora (ciliates and suctorians)
ciliary rows (kineties); diploid micronucleus; multiploid macronucleus
ALVEOLATA micropores; extrusomes with dense cores
Chromobiota
nucleomorph lost
Cryptophyta
cortical alveoli lost
rigid tubular ciliary hairs
Kingdom CHROMISTA
CHROMALVEOLATES: red algal plastids and nucleus enslaved; fusion of perialgal vacuole and nuclear envelope
Rhodophyta
cortical alveoli lost
Viridaeplantae
symbiogenetic origin of chloroplasts
CORTICAL ALVEOLI
Glaucophyta
Kingdom PLANTAE
ancestral anisokont haploid biciliate zooflagellate with zygotic meiosis, simple non-tubular ciliary hairs and tubular mitochondrial cristae

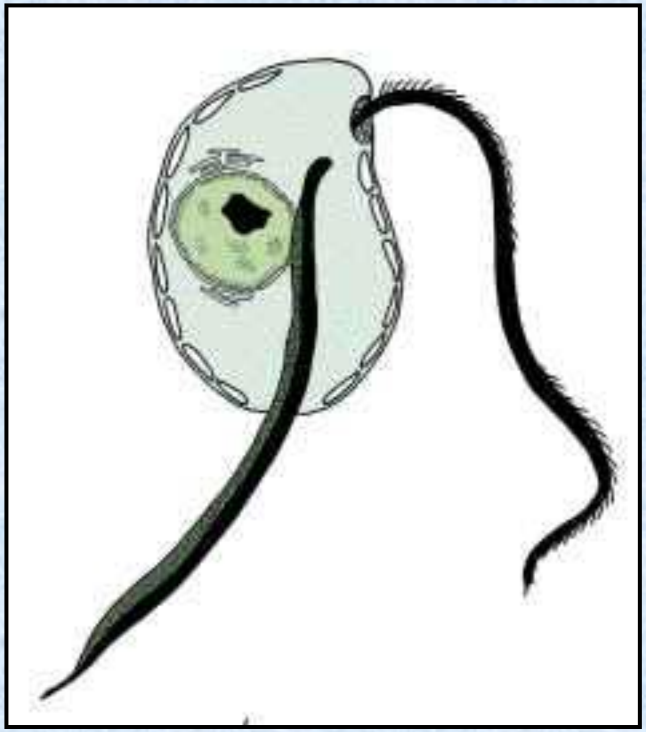
Alveolata, Ciliata

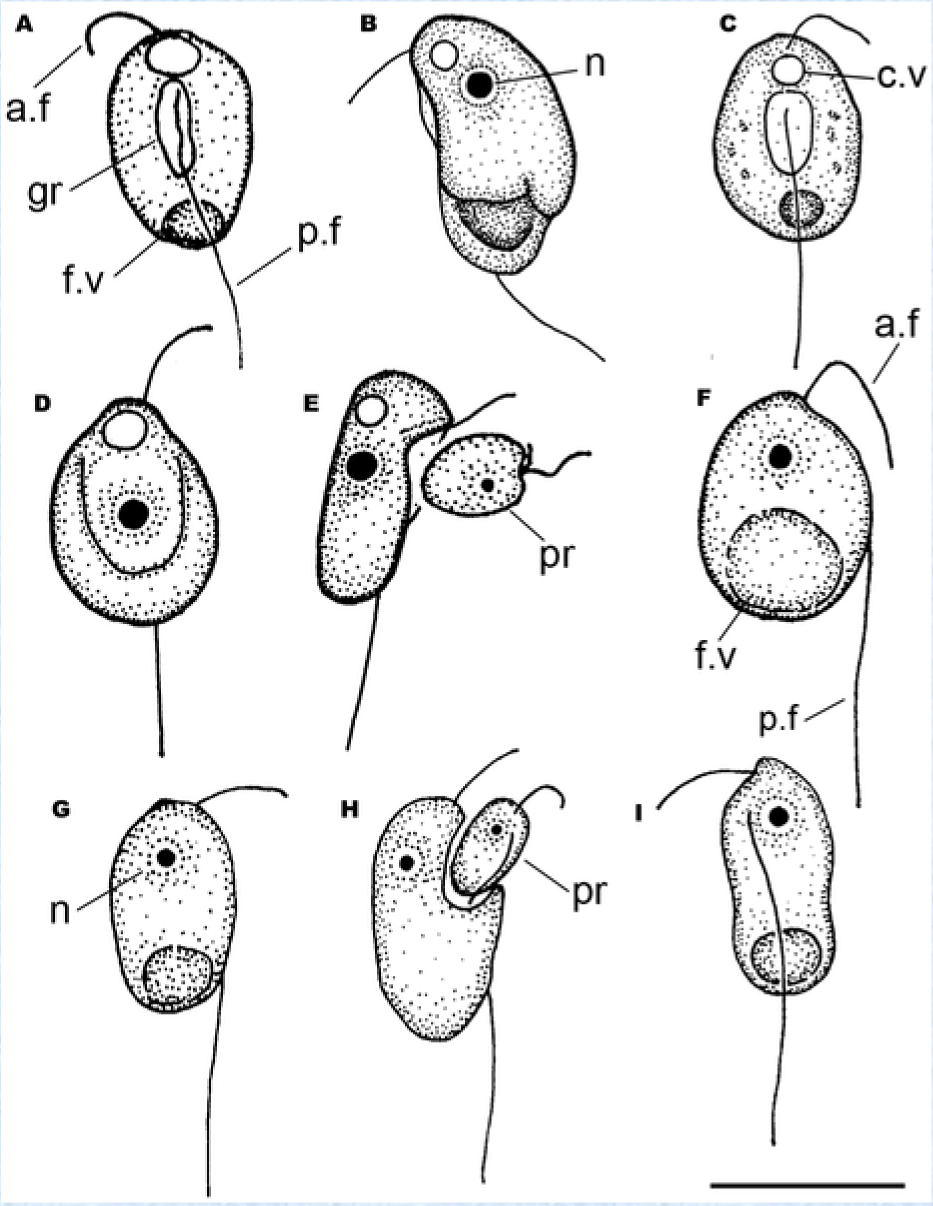
- one of the most common group of protists (nálevníci)
- cilia covering the cell surface
- lakes, ponds, oceans, soil
- free-living, symbionts, parazites
- 2 nuclei types: micronuclei, macronuclei



Alveolata, Colponemida

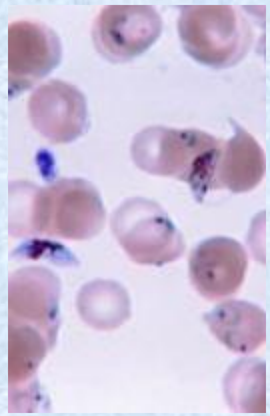
- *Colponema*
- ancestral Alveolate morphology

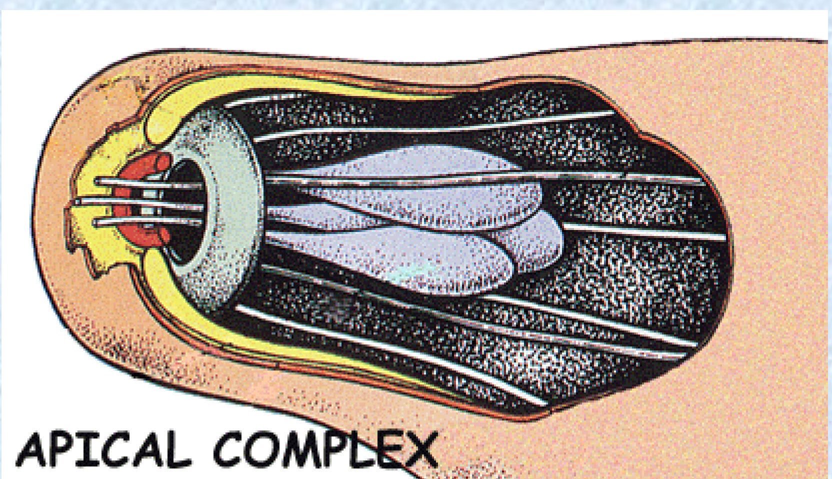


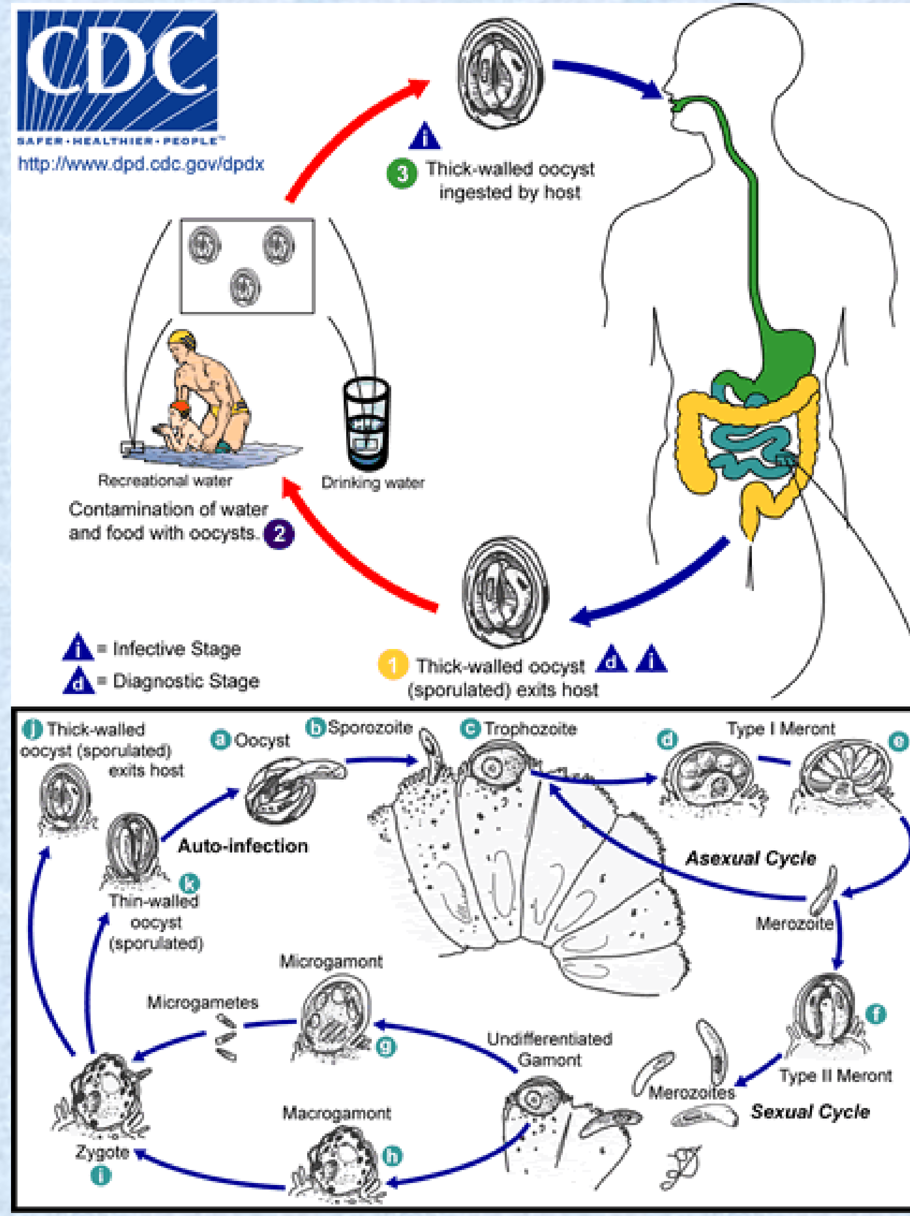


Alveolata, Apicomplexa

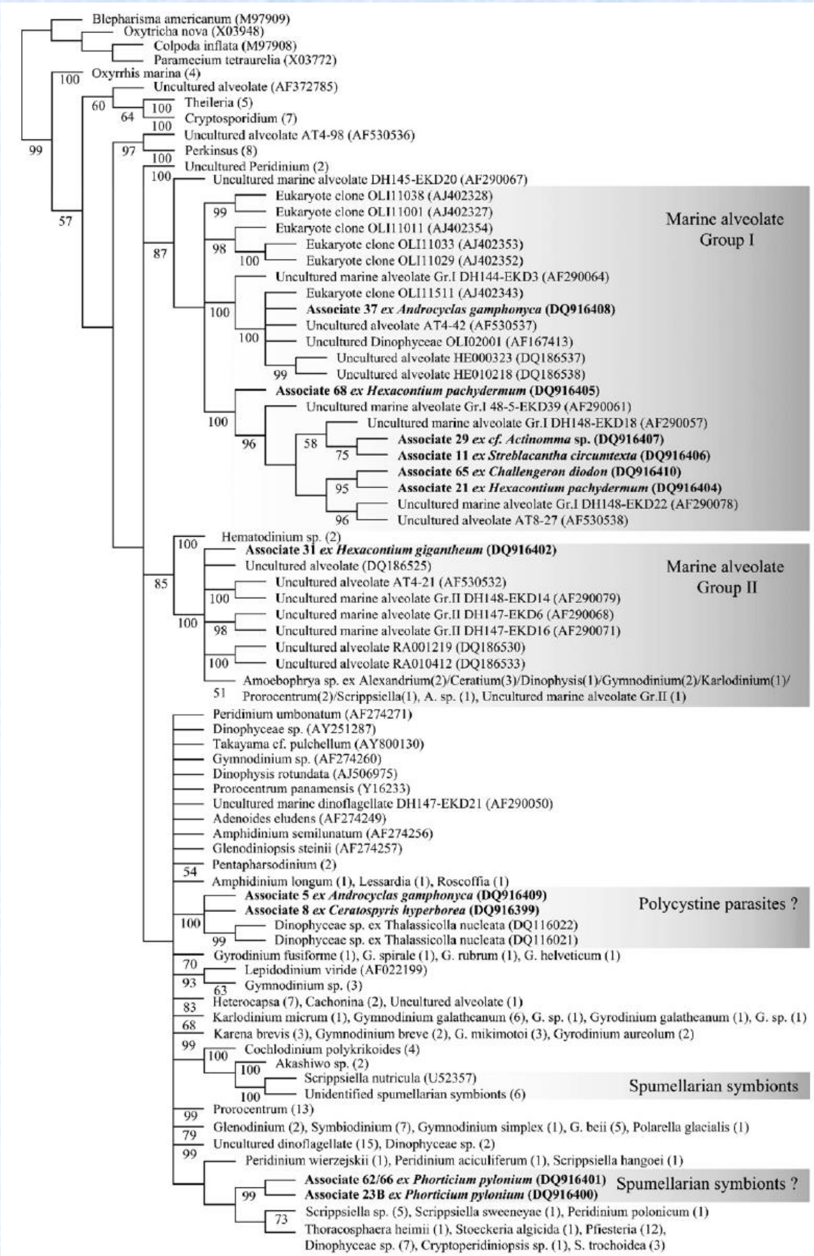
- apicoplast (organelle of plastid origin)
- animal parasites
- *Plasmodium* (malaria)
- *Toxoplasma*
- *Cryptosporidium*







Alveolata, MAG I a II



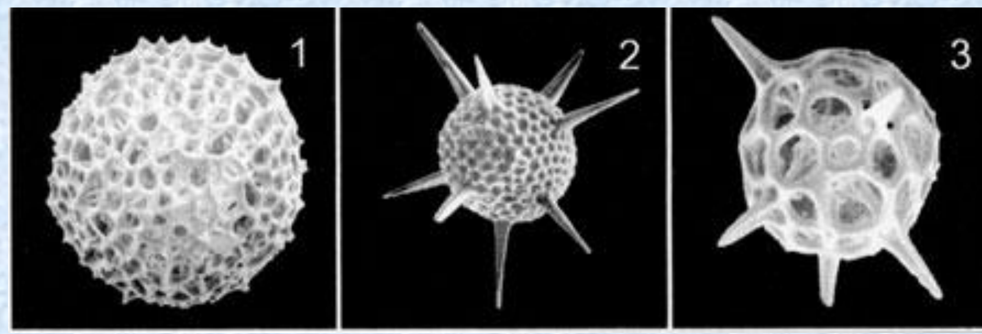
Protist, Vol. 158, 65–76, January 2007
http://www.elsevier.de/protis
Published online 7 November 2006

Protist

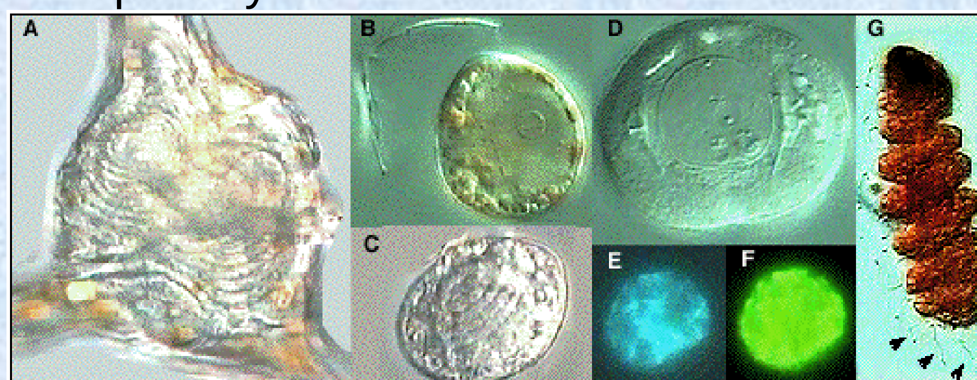
ORIGINAL PAPER

Molecular Diversity of Alveolates Associated with Neritic North Atlantic Radiolarians

Jane K. Dolven[a,1], Charlotte Lindqvist[a], Victor A. Albert[a], Kjell R. Bjørklund[a], Tomoko Yuasa[b], Osamu Takahashi[c], and Shigeki Mayama[d]



Group I – symbionts of Radiolaria

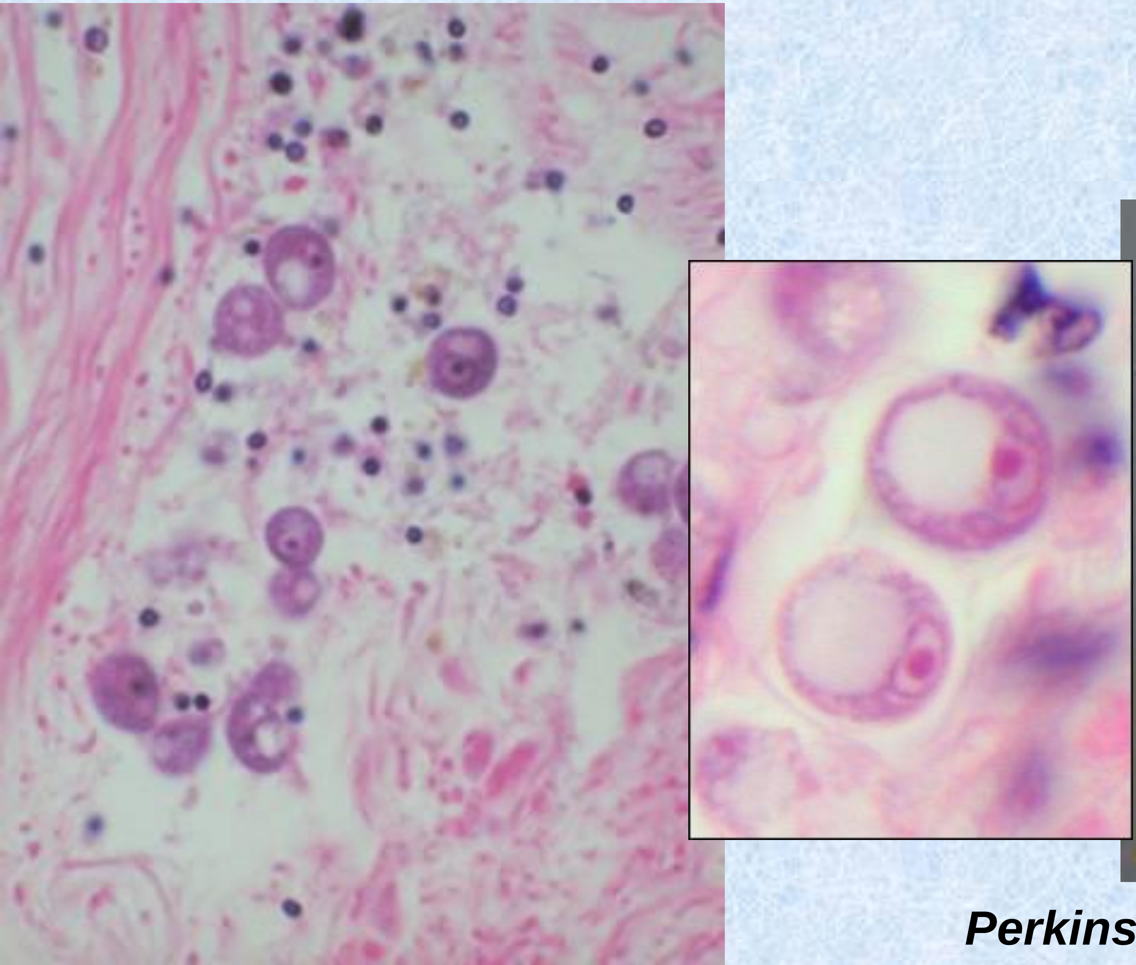


Group II – parasites of dinoflagellates

Alveolata, Perkinsea

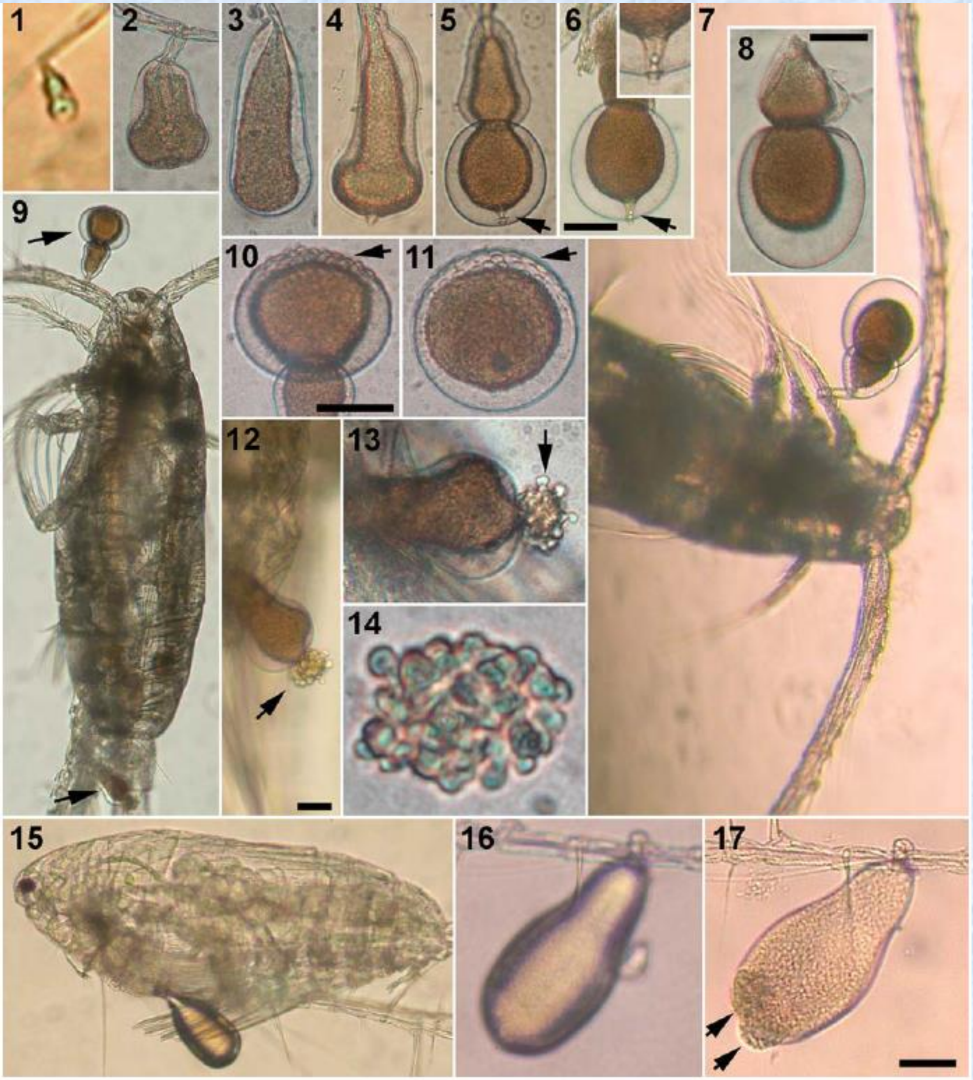
- parasites of mussels

scallop (hřebenatka)



Perkinsus marinus

Alveolata, Ellobiopsea

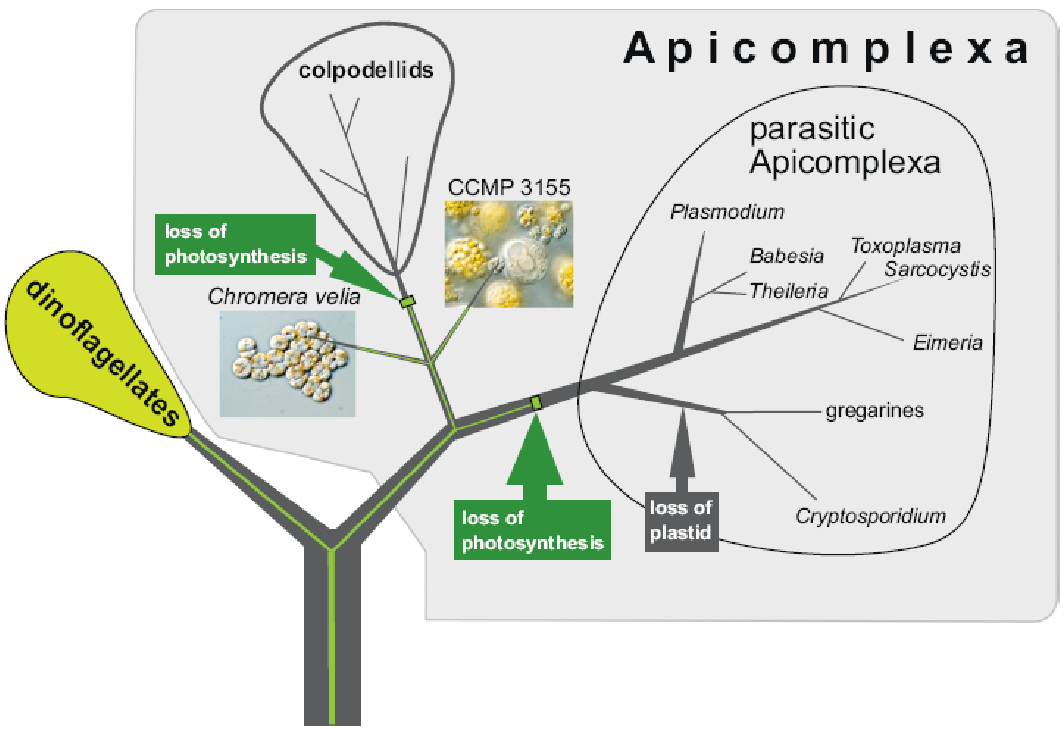


Figs. 1–17 Light micrographs of different life-cycle stages of *Ellobiopsis chattoni* parasitising copepods collected from the Bay of Marseille, NW Mediterranean Sea. 1–6. Different stages of the development; 5–6. the *arrows* indicate a tube-like structure in the distal part of the gonomere. 7–8. Specimen infecting *Acartia clausi* used for single-cell PCR. 9–14. Two parasites at different degrees of maturation in the same host; 10–11. the *arrows* indicate the irregular surface on the distal part of the gonomere; 12–13. the *arrows* indicate the budding of immature spores. 15–17. Live infected copepod; the *arrows* indicate the budding of spores formed after half an hour of observation. 1–14. Ethanol-fixed specimens collected on May 29th, 2008. 15–17. Live specimen collected on June 10th, 2008. *Scale-bar*: 50 μm

Ellobiopsis, Thalassomyces
- parazites of crustaceans

Alveolata, Chromerida

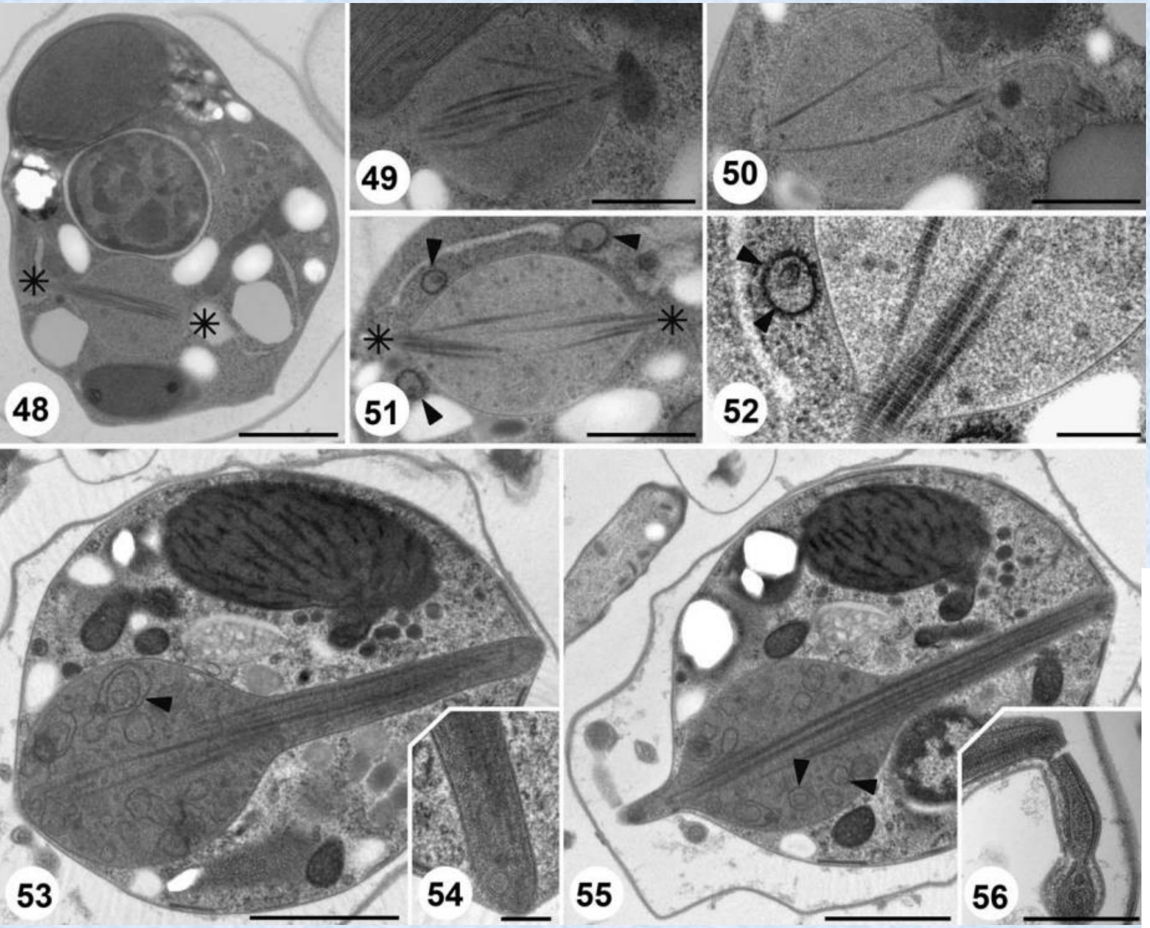
- phylogenetically related to Apicomplexa
- photosyntetic



originally isolated from a coral thallus in Sydney Harbour

simply cultivated (testing the anti-parasitic drugs?)

Chromerida, Chromera



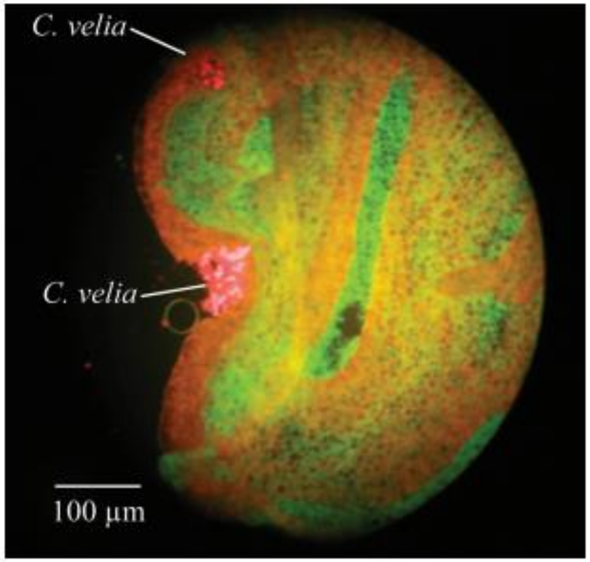
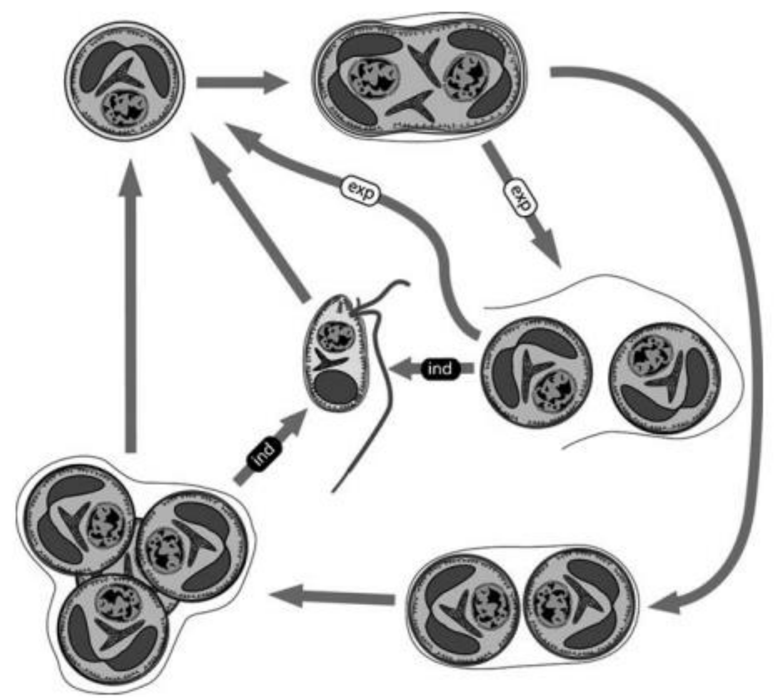
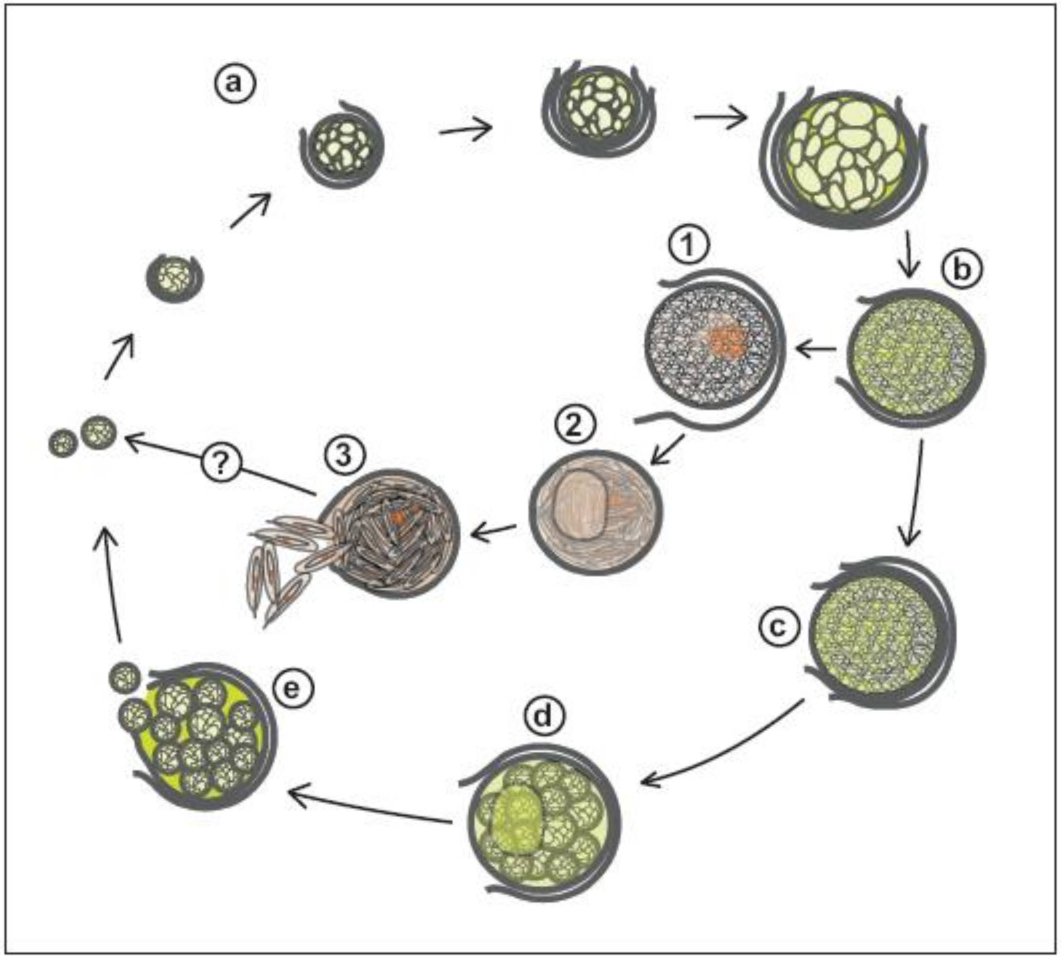


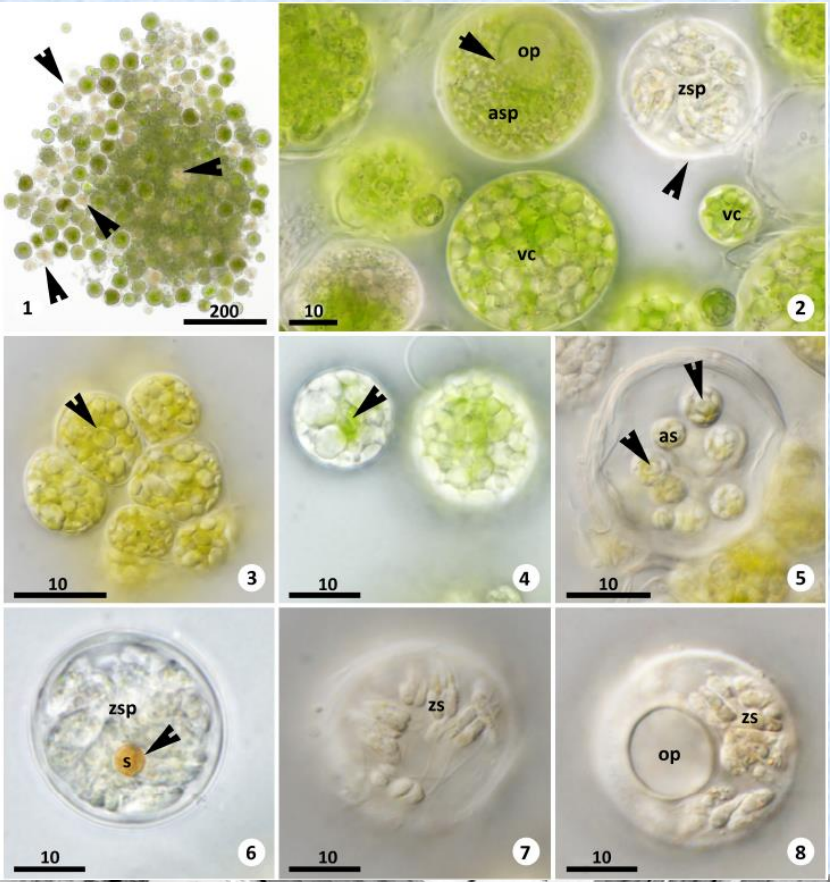
Fig. 1 Two *Chromera velia* clumps fluorescing bright red colliding with an *Acropora digitifera* larva. The larger clump appears to be digesting the ectoderm. The smaller clump has possibly been internalised. Green and red fluorescence proteins are also evident in the larva.

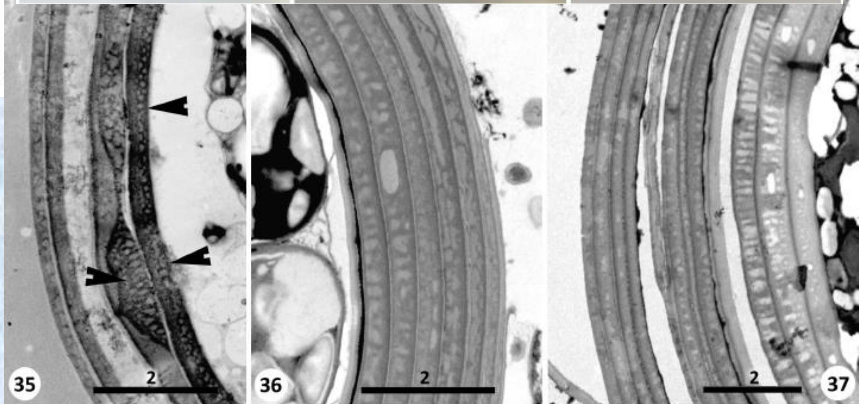


Chromerosome

Chromerida, Vitrella





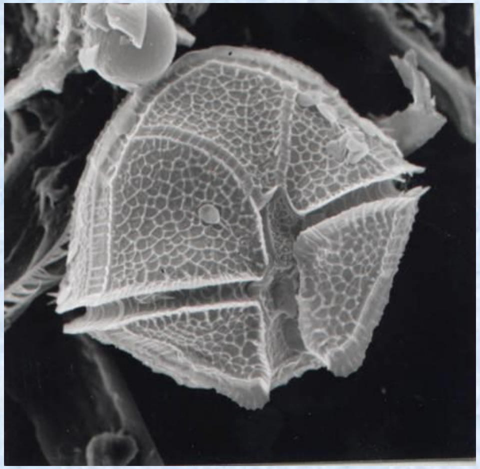


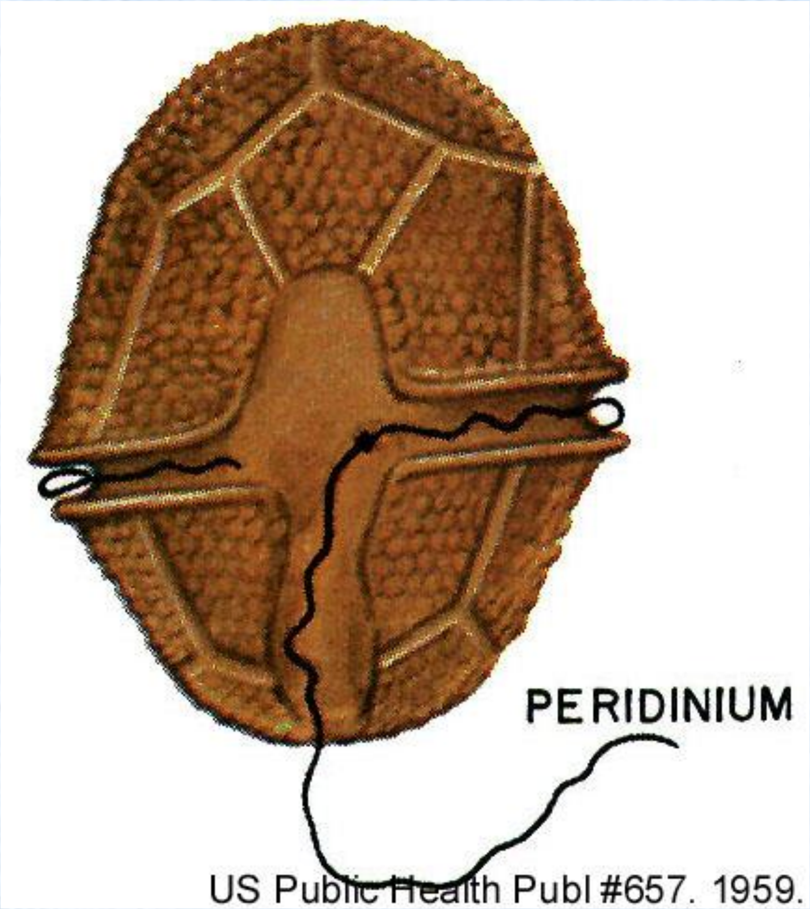
sporangia surrounded by a large number of cell wall layers

Alveolata, Dinophyta

Alveolata, Dinophyta

- marine and freshwater algae
- autotrophic and heterotrophic

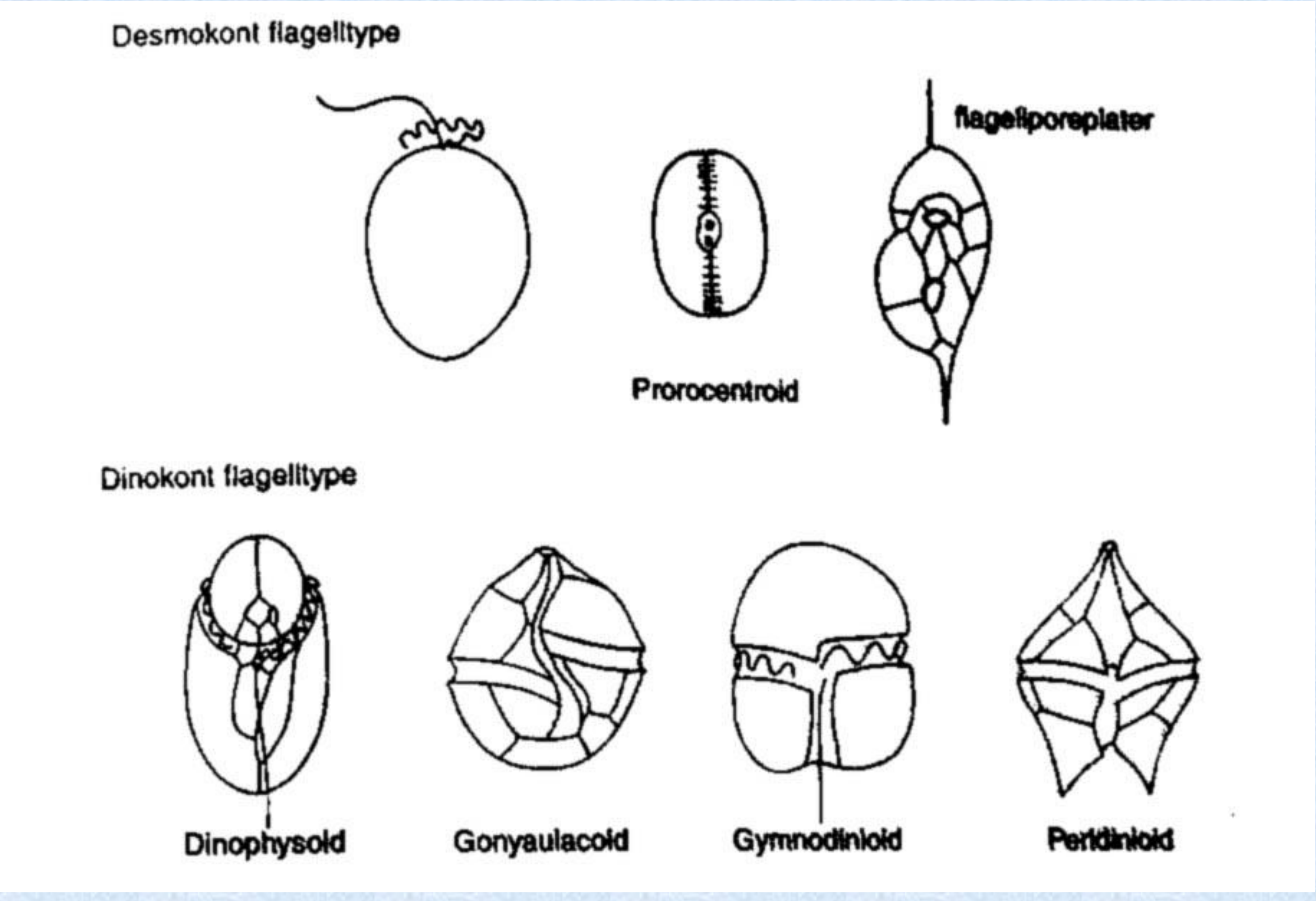




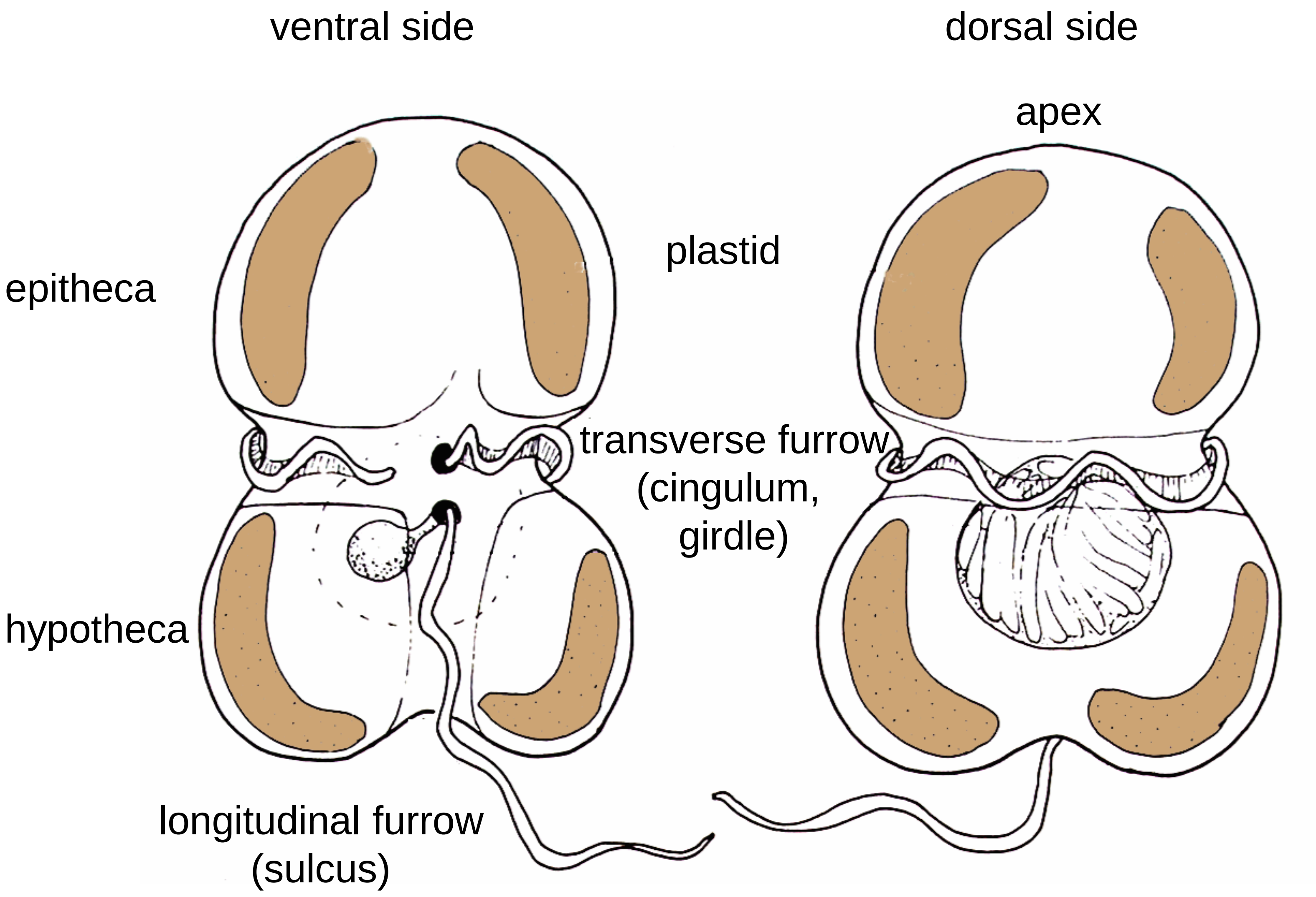
General characteristics

- cca 130 genera, 2000 species
- monanoid, amoeboid, capsal, coccal, or filamentous thallus
- 90% of known species marine
- autotrophic and heterotrophic
- enormous primary production

Cell organisation

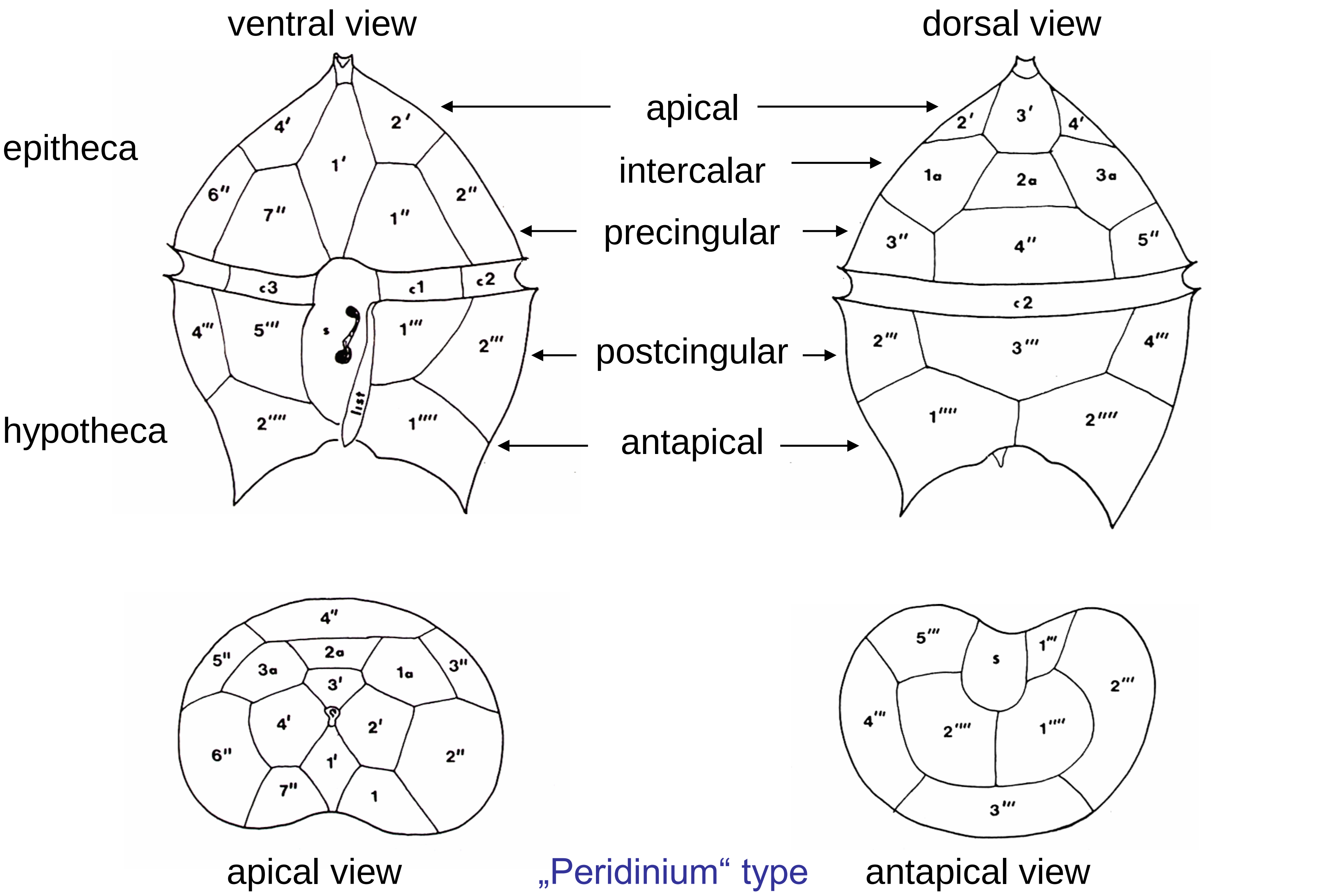


Cell organisation

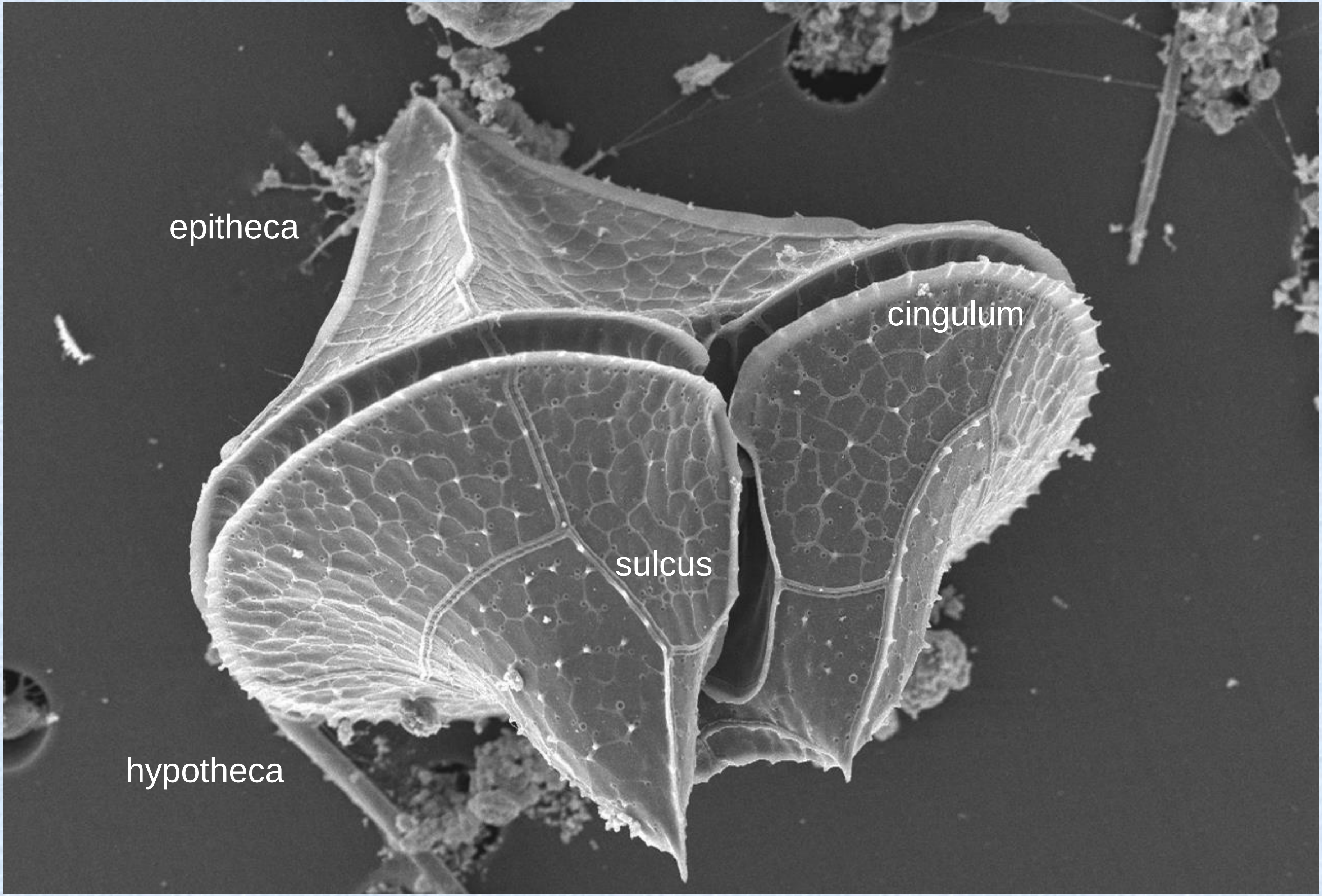


„Gymnodinium“ type

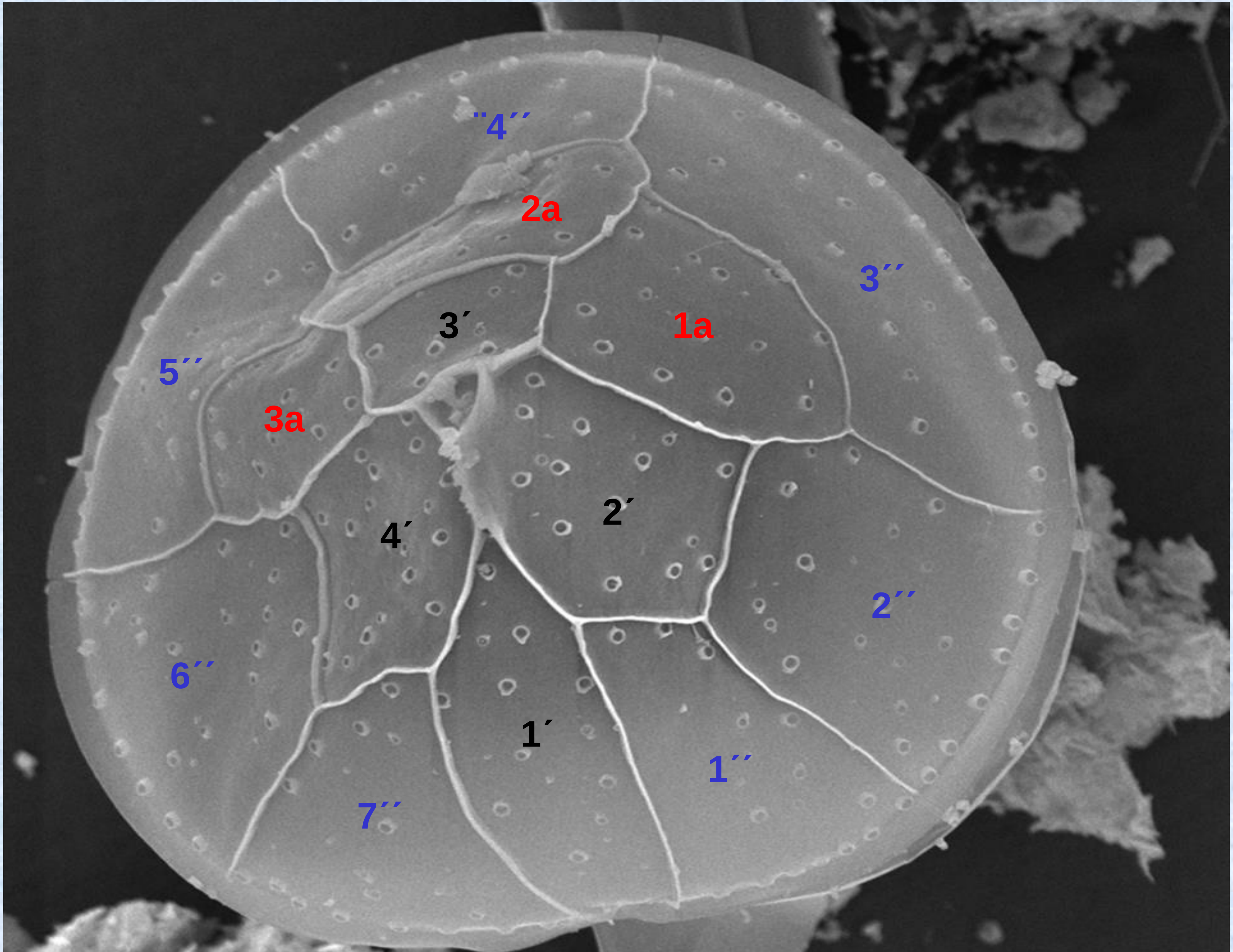
Cell organisation



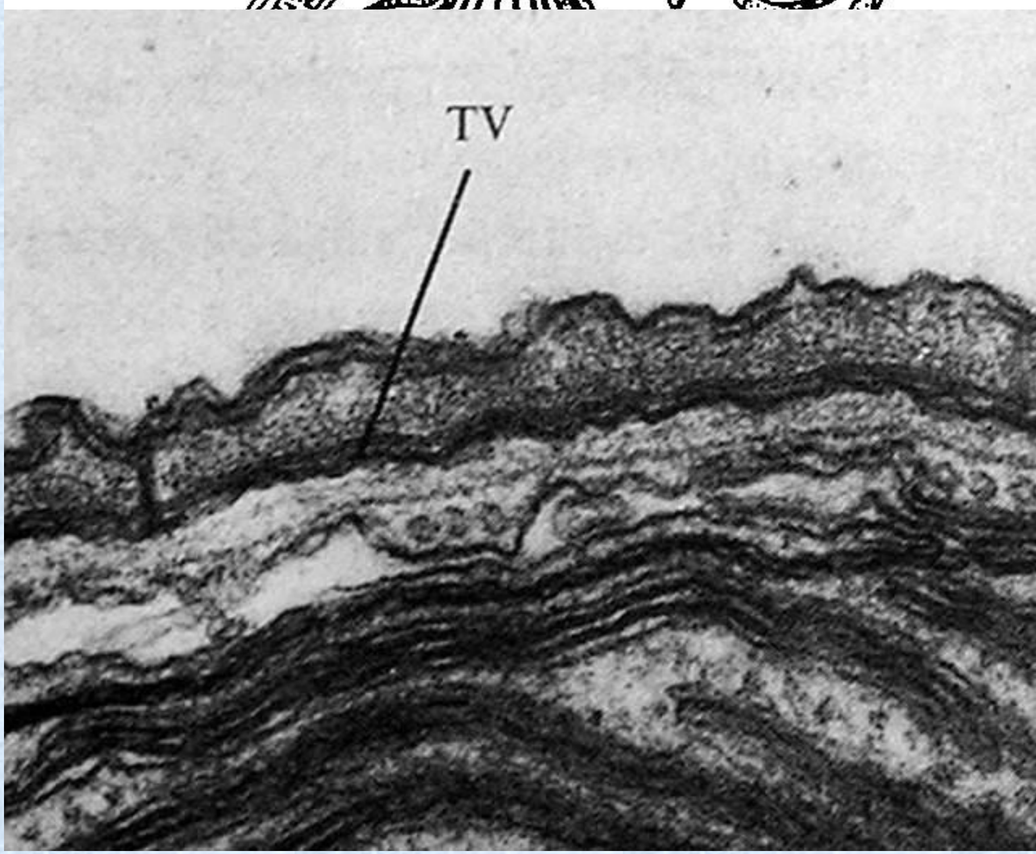
Cell organisation

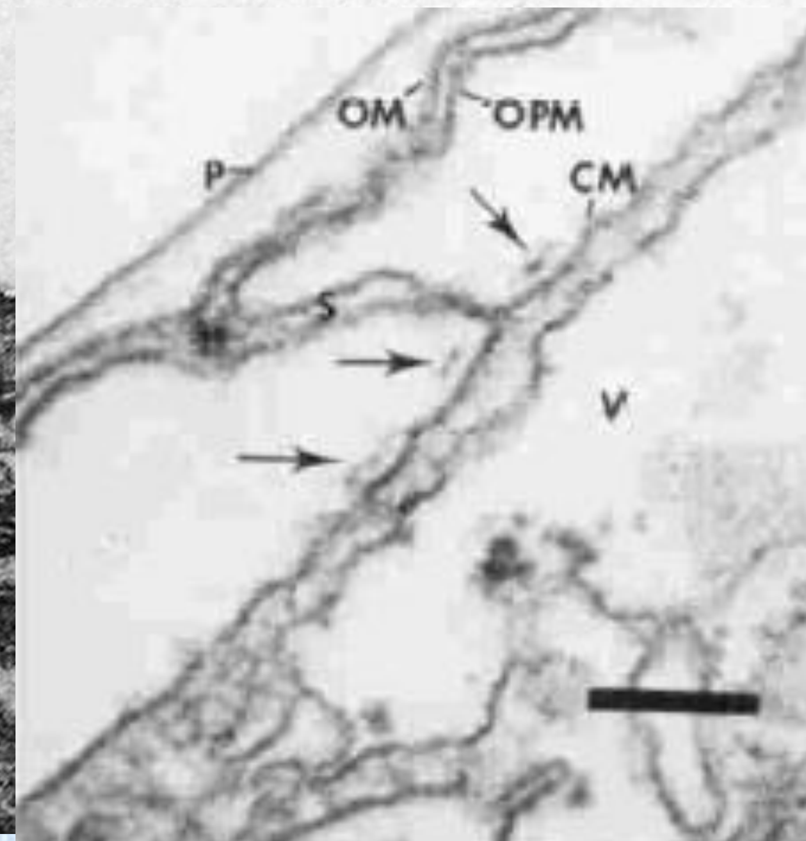


Cell organisation

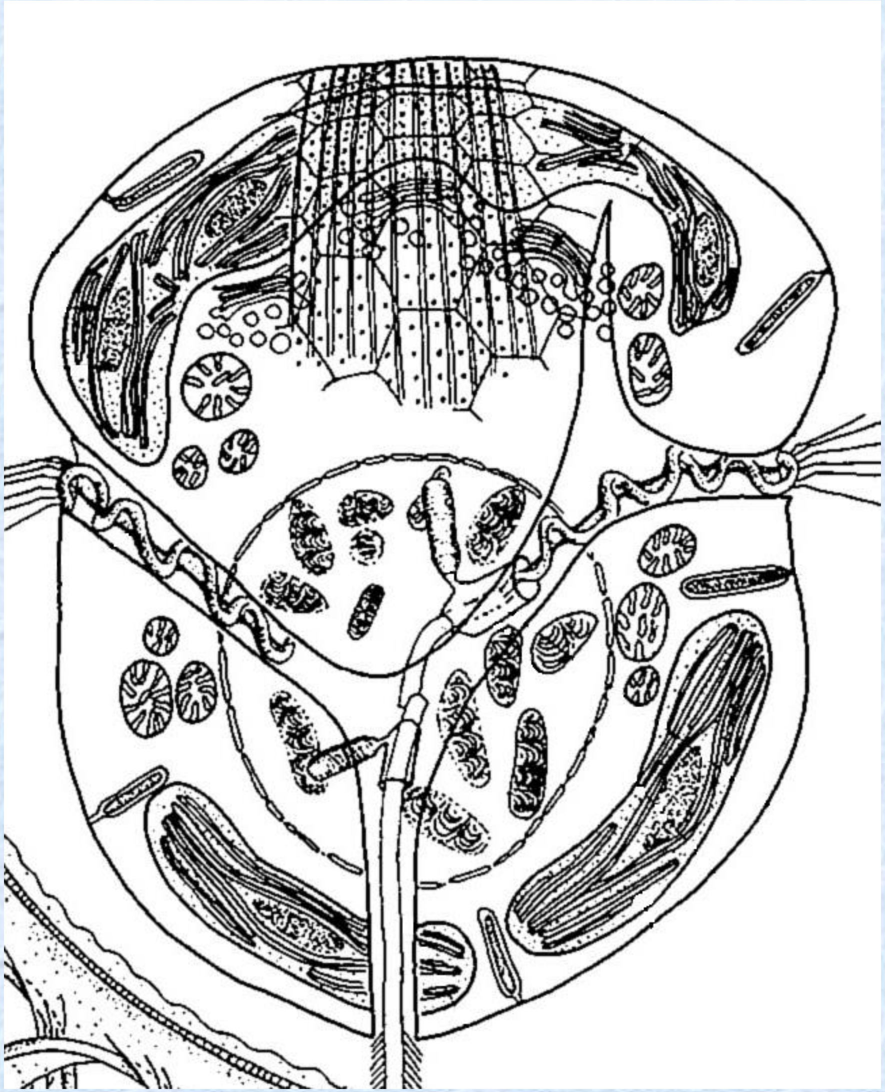


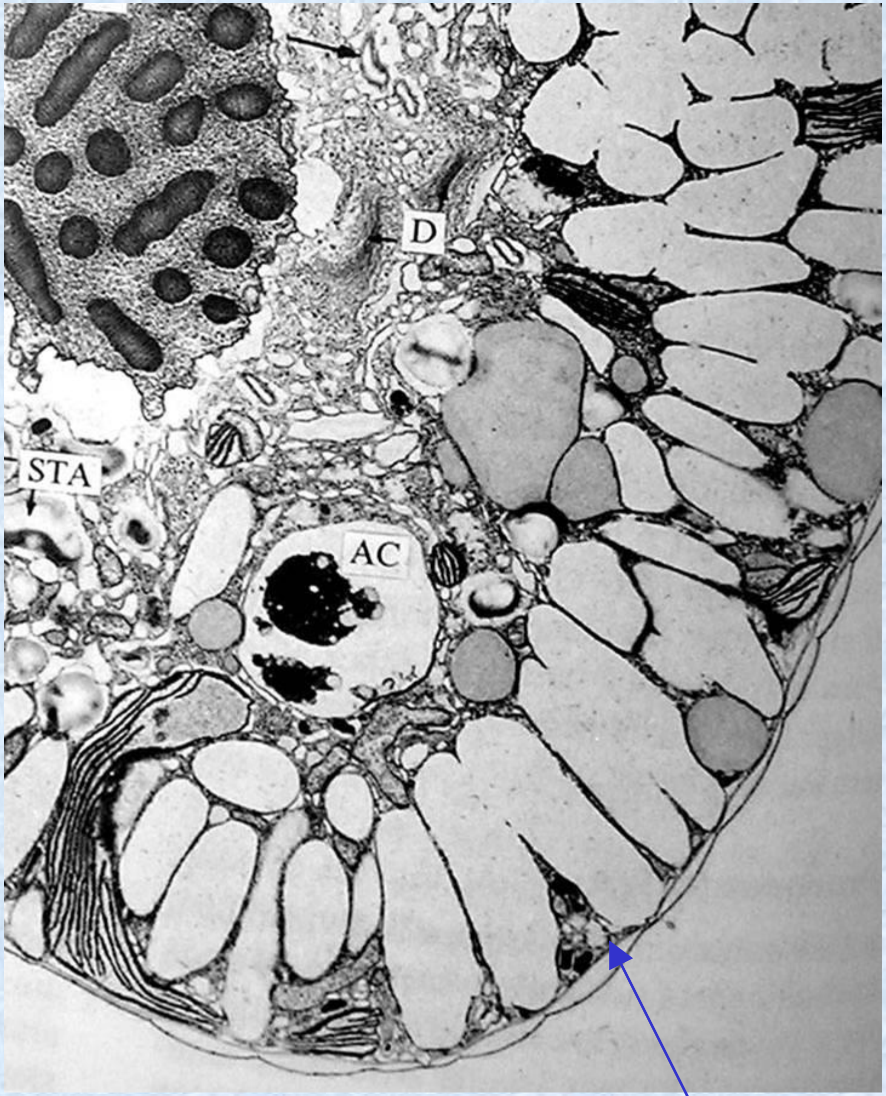
Cell organisation





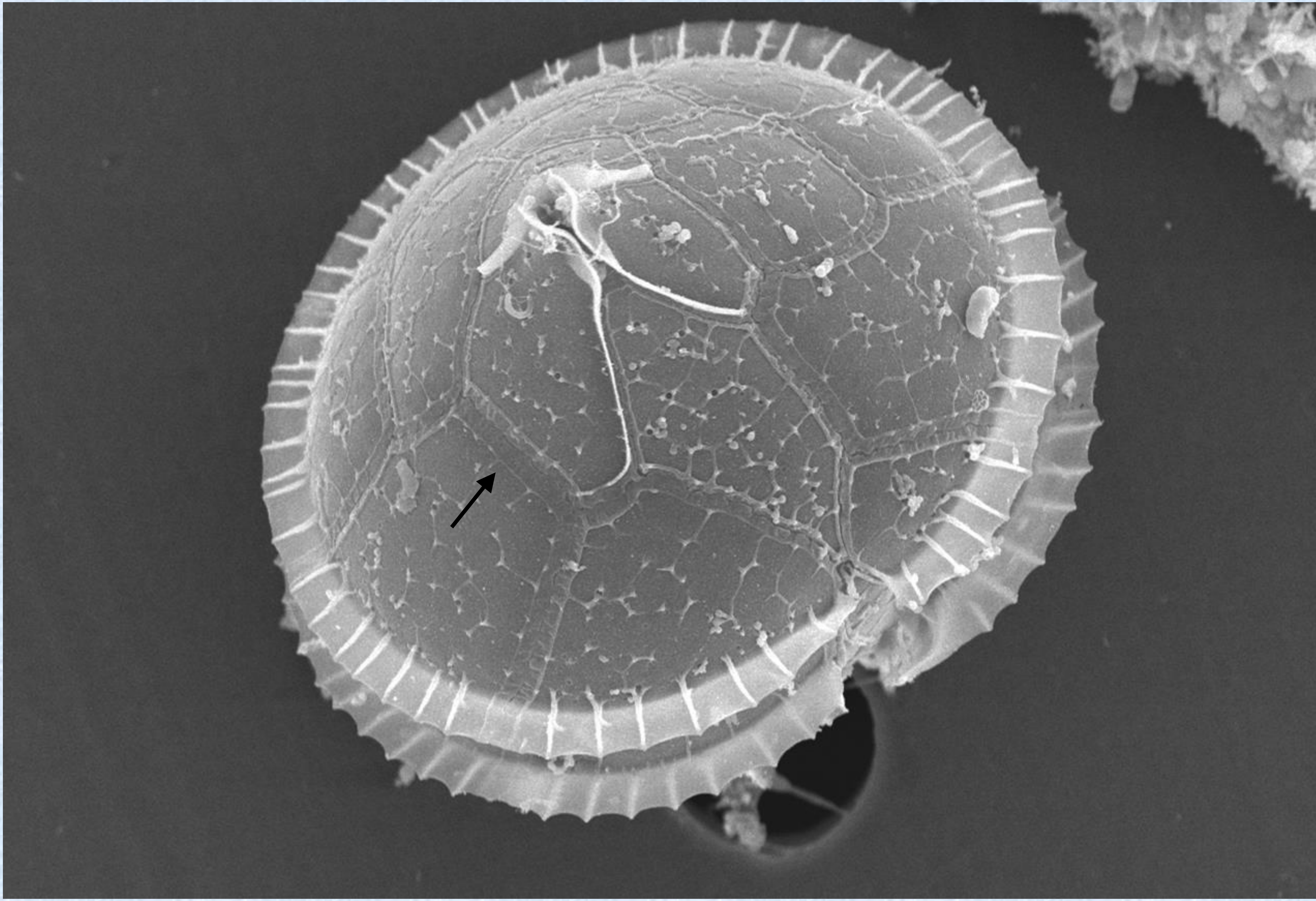
Cell organisation





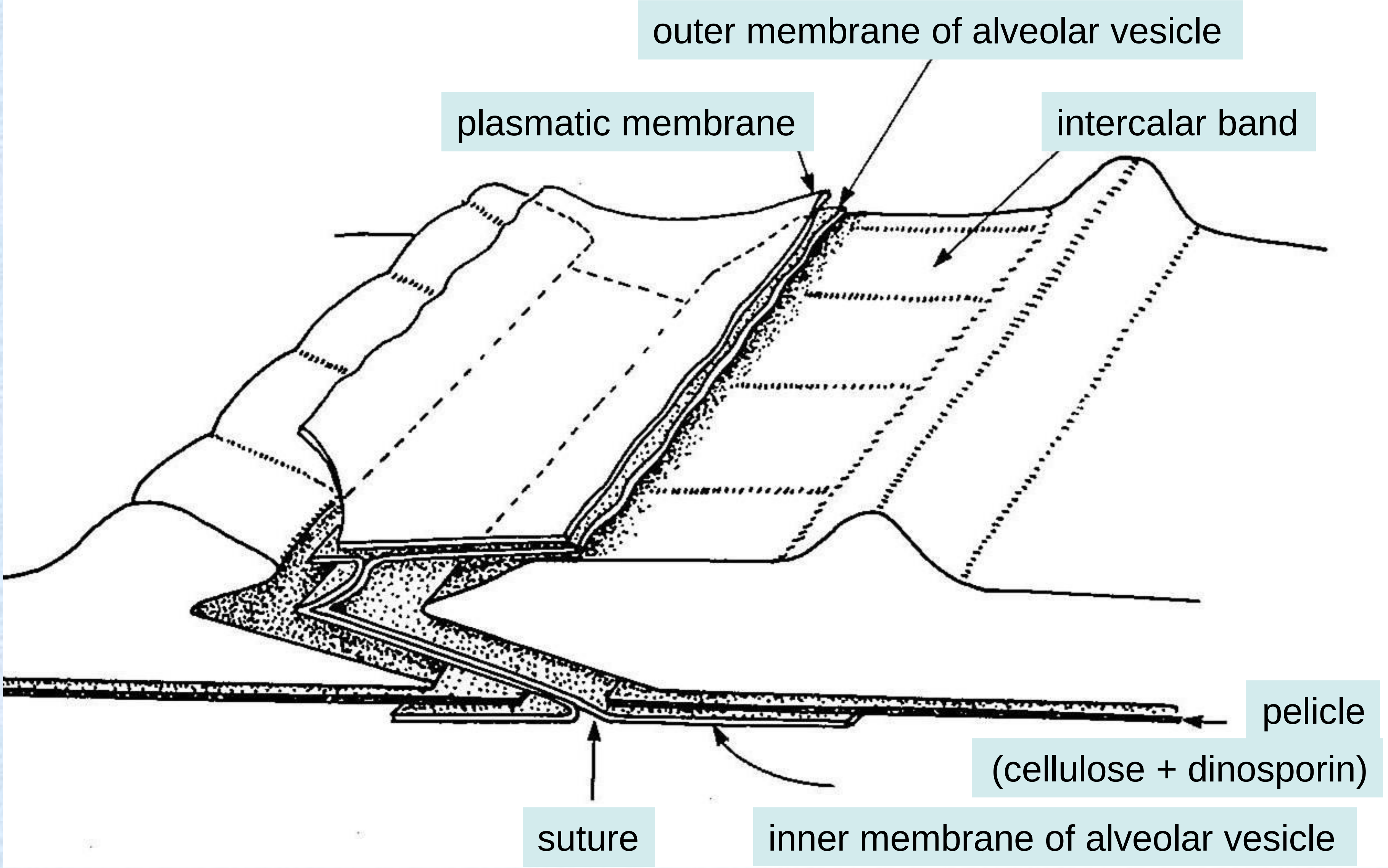
alveolar vesicles with amorphous material

Cell organisation



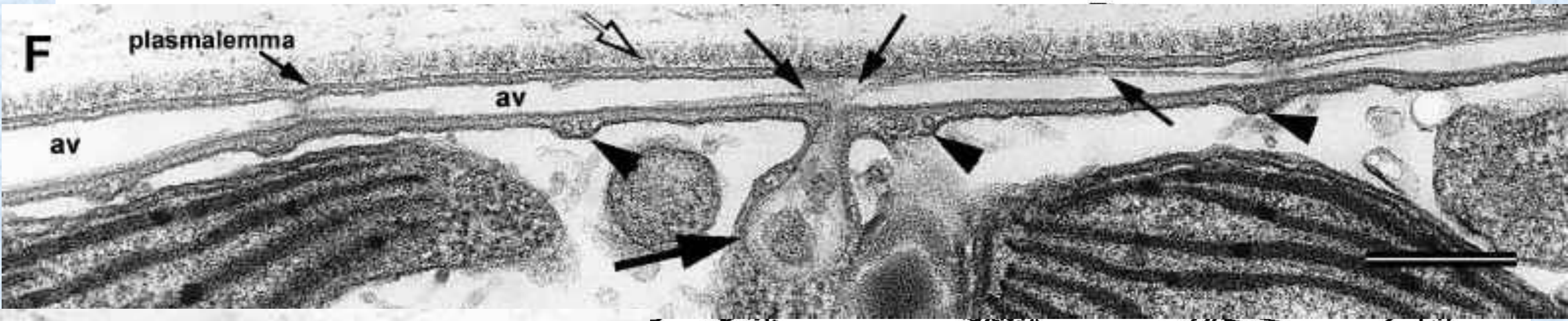
Cell organisation

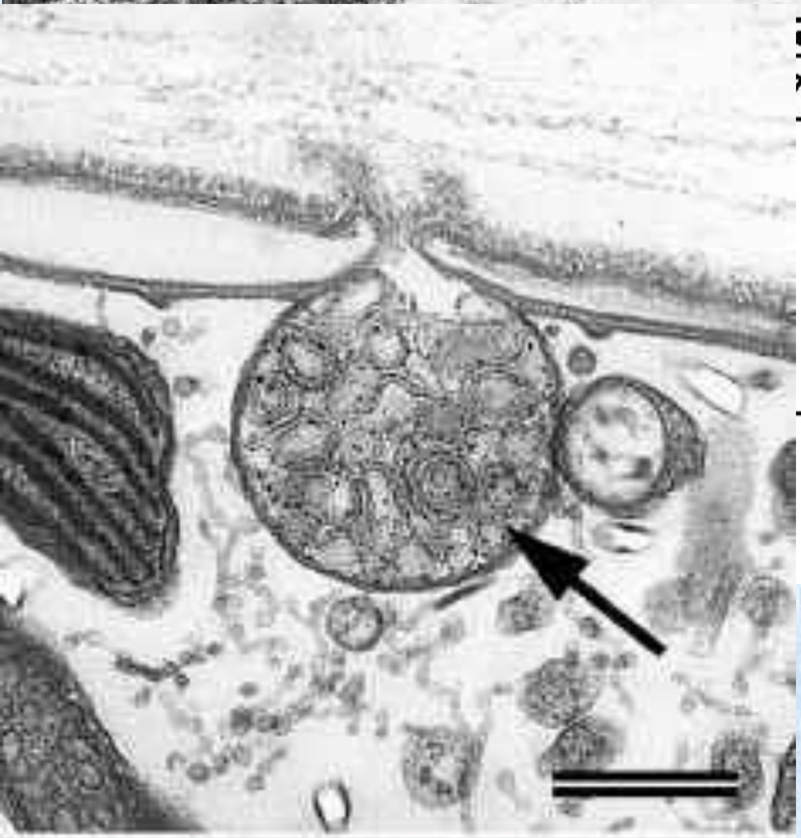
connection of two adjacent plates

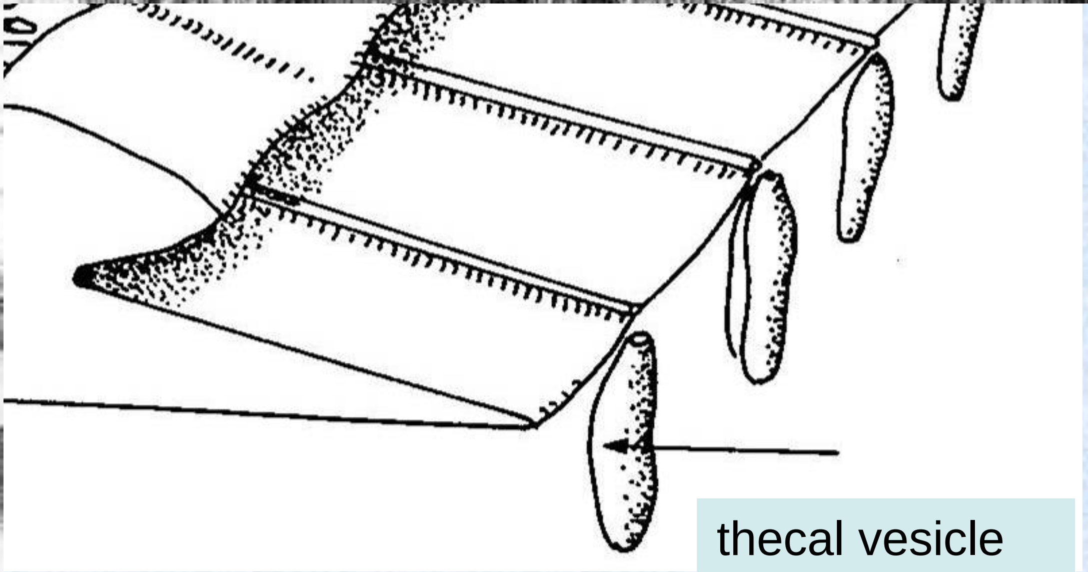


Cell organisation

structure of the thecal plate



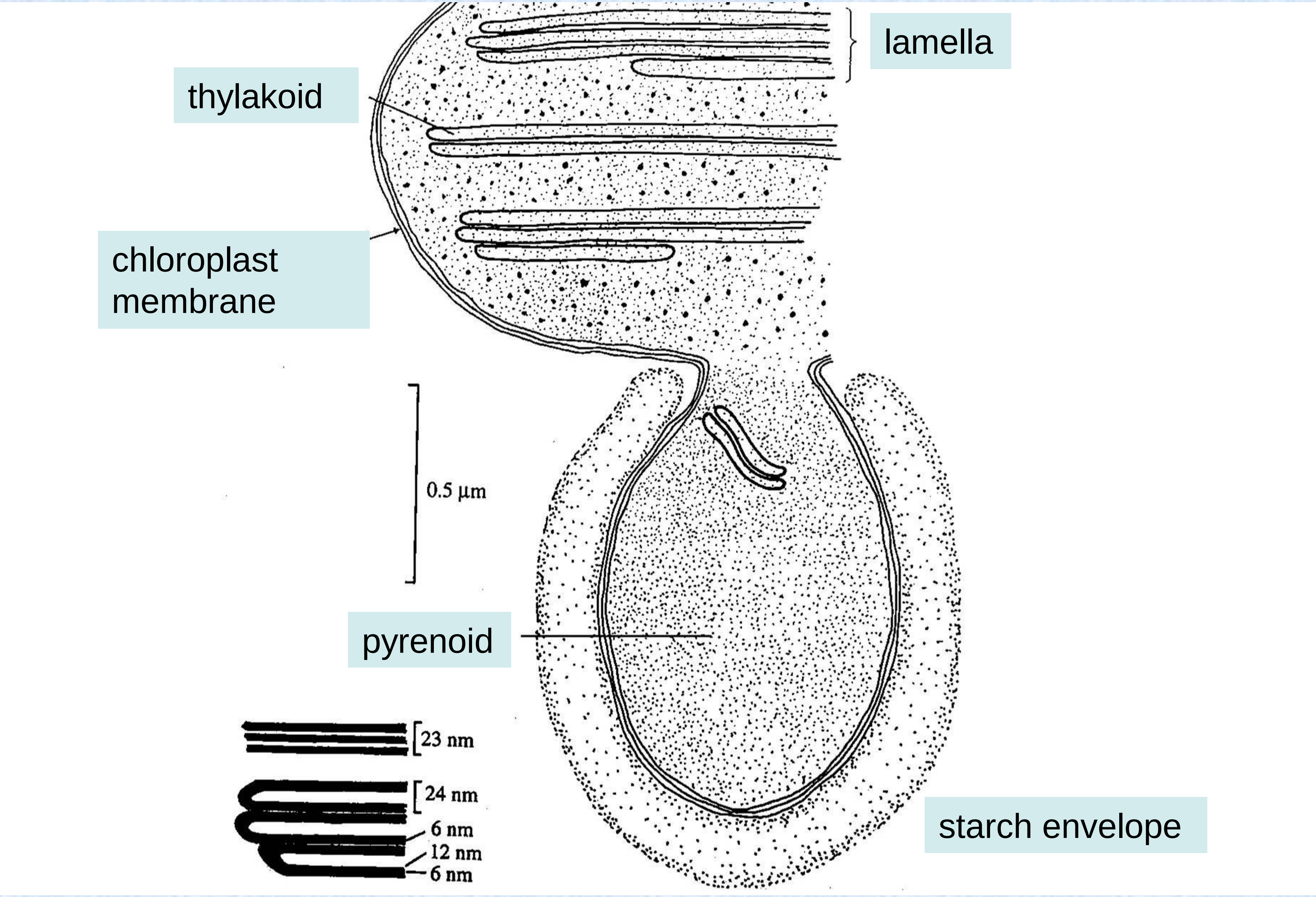




Plastids

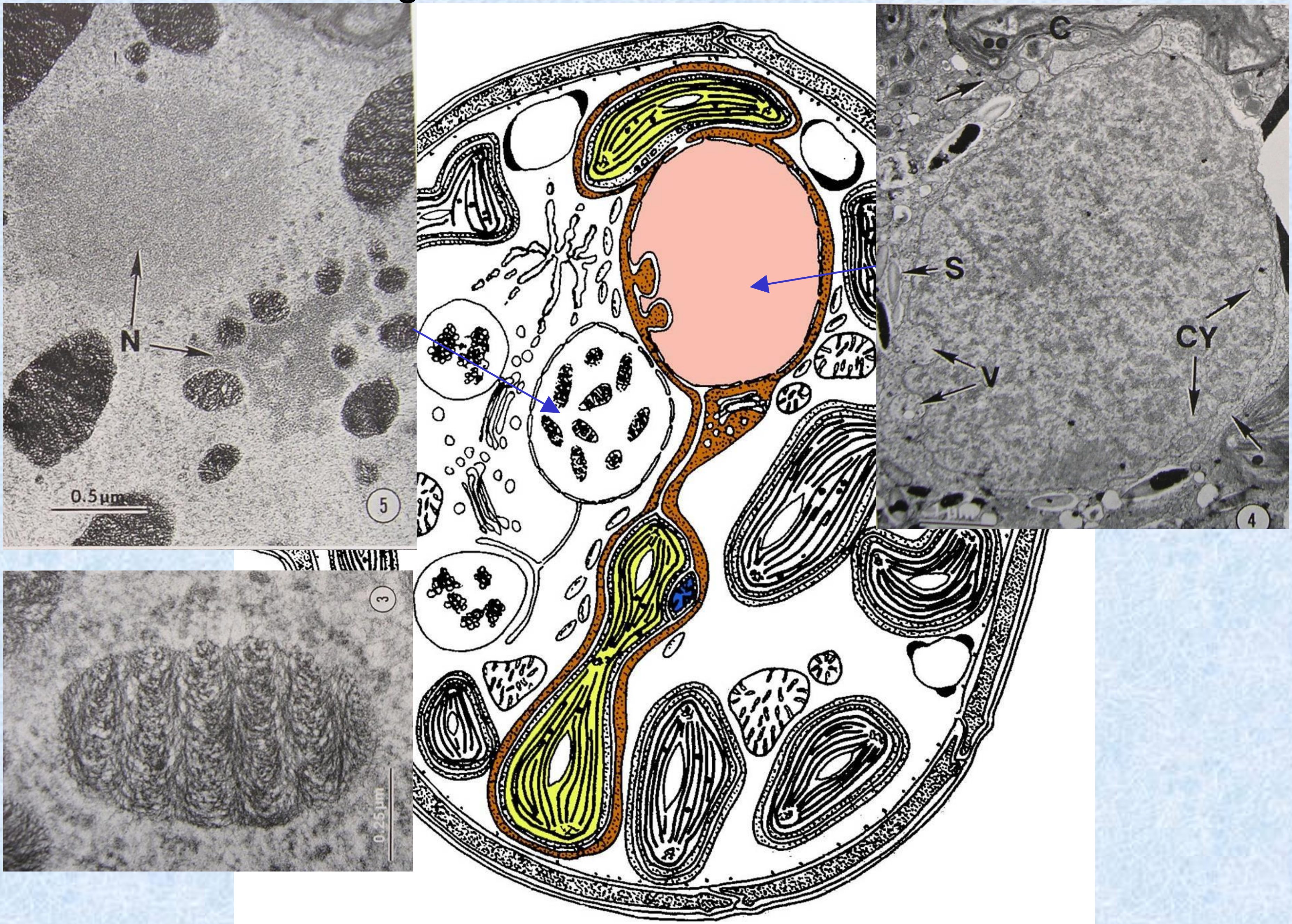
- only in 50% of species
- chl a, c_2, β-caroten, peridinin (or fukoxanthin), diadinoxanthin, dinoxanthin
- thylakoids stacked in triplets
- 3 membranes

Plastids

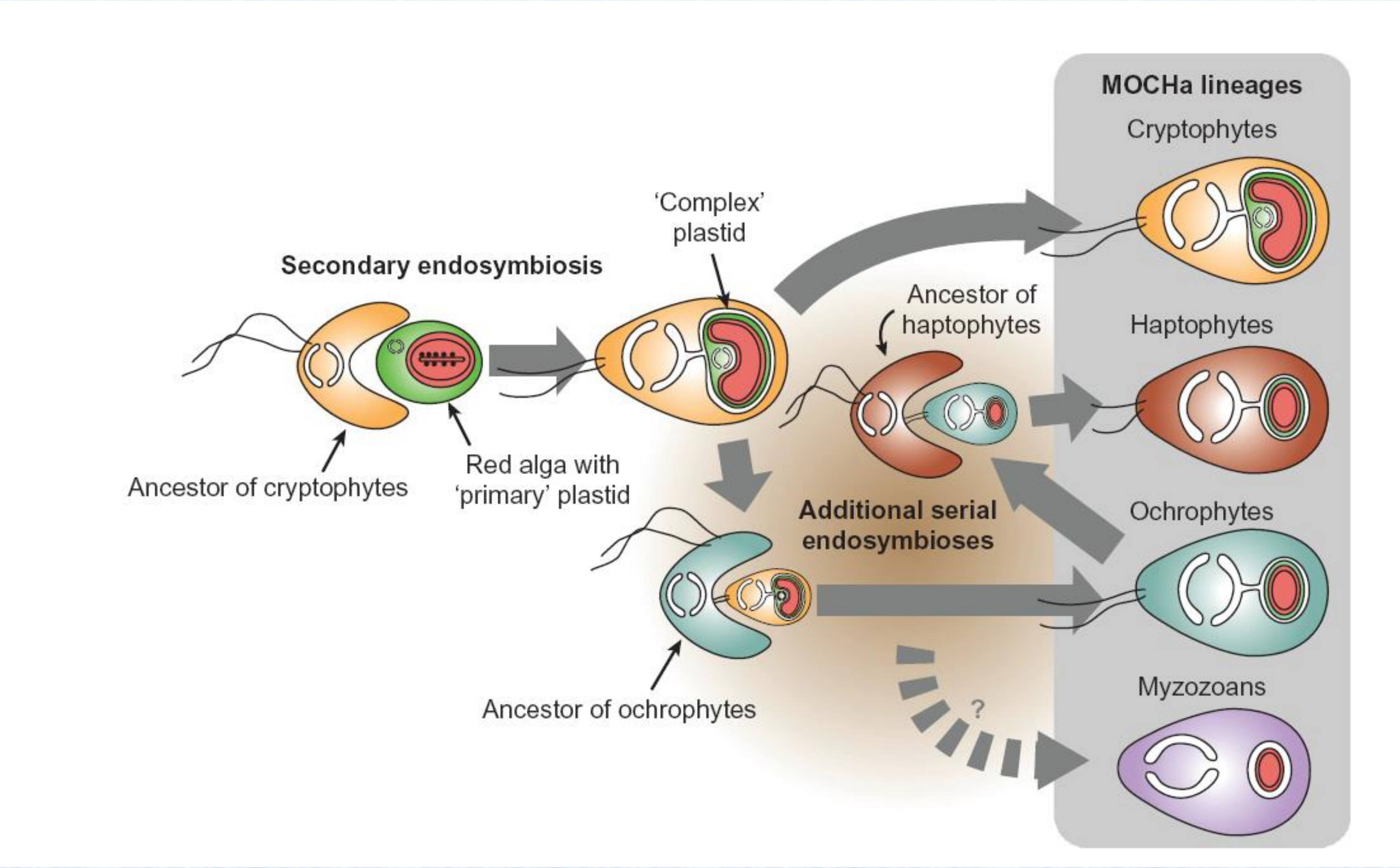


lamella
thylakoid
chloroplast membrane
0.5 µm
pyrenoid
23 nm
24 nm
6 nm
12 nm
6 nm
starch envelope

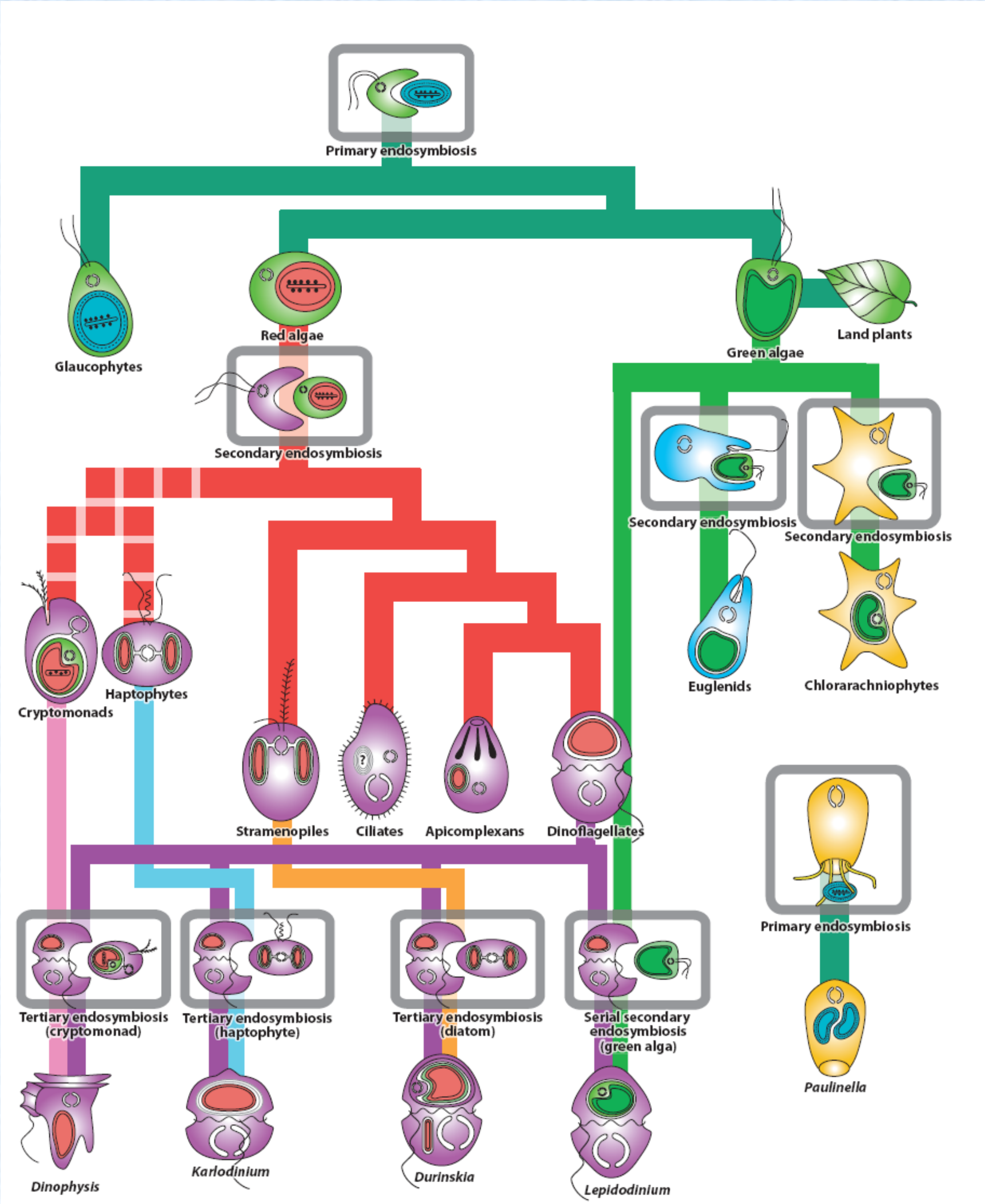
Cell organisation in *Peridinium balticum*

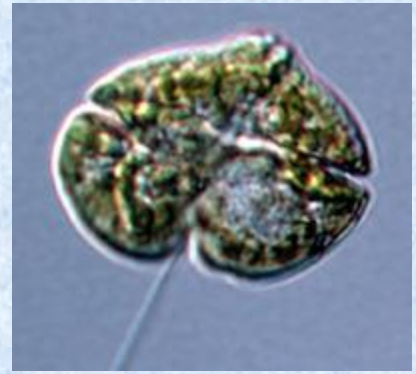


Complex endosymbioses

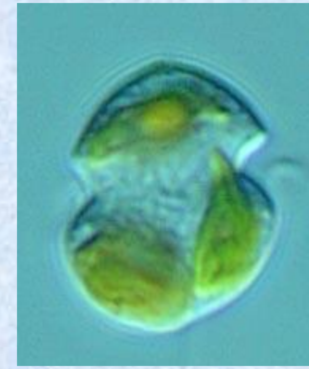


Complex endosymbioses





Karenia



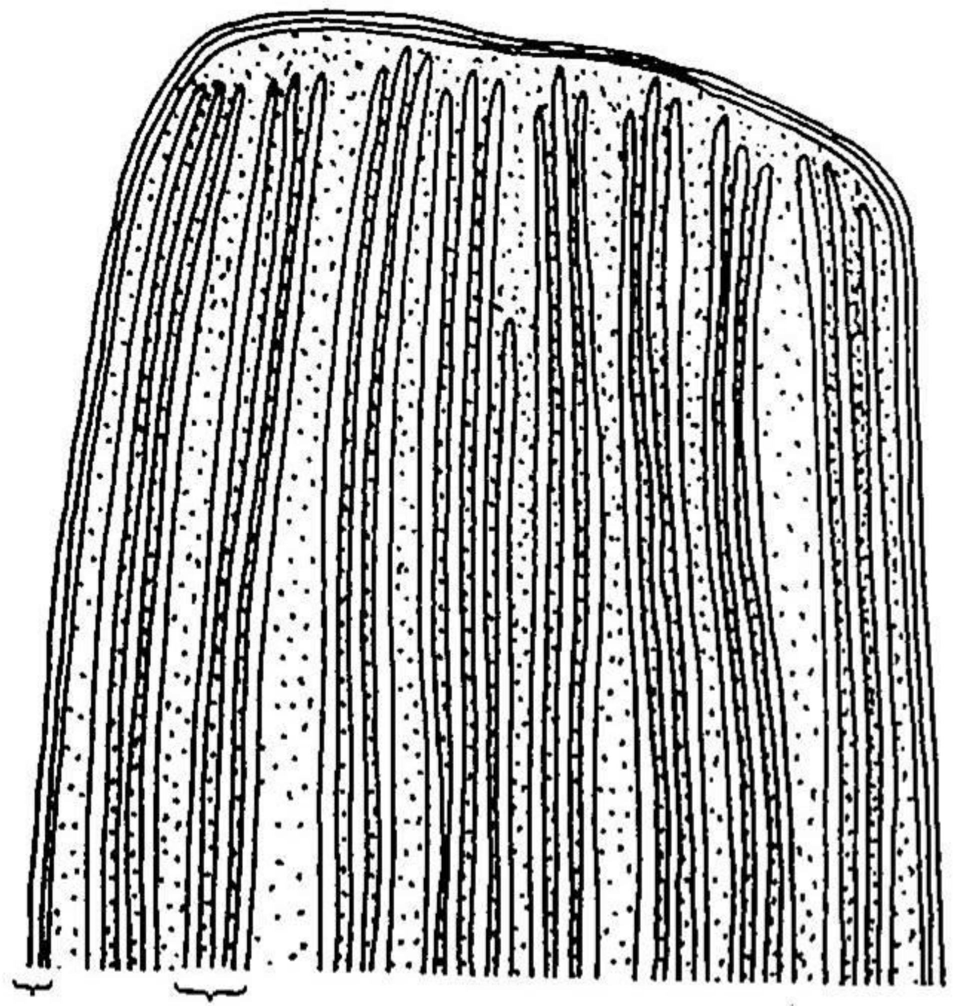
Karlodinium

Lepidodinium

Dinophysis

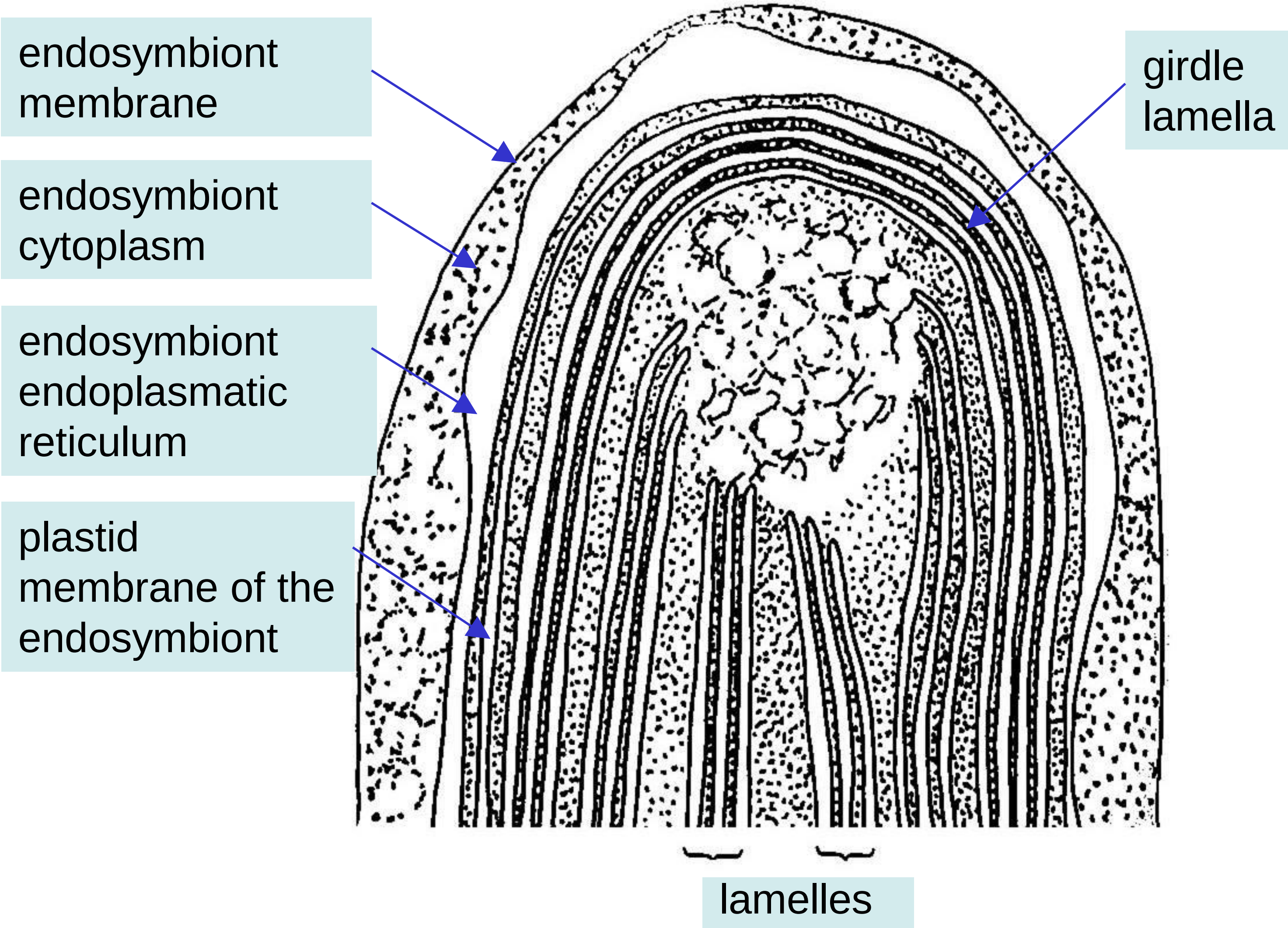
Plastid types

Type I. – typical plastid (peridinin)



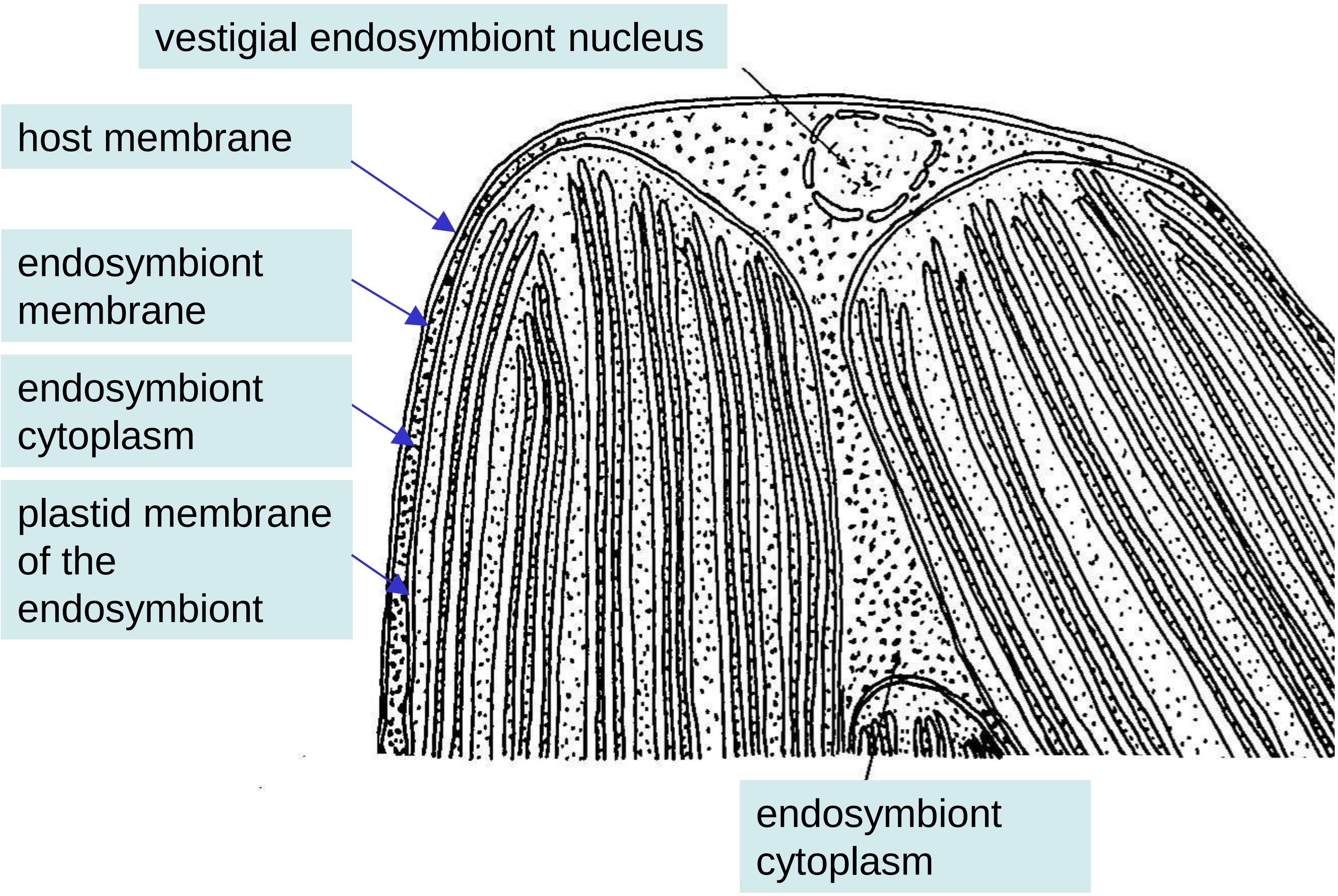
Plastid types

Type II. – reduced Stramenopile endosymbiont (fucoxanthin)



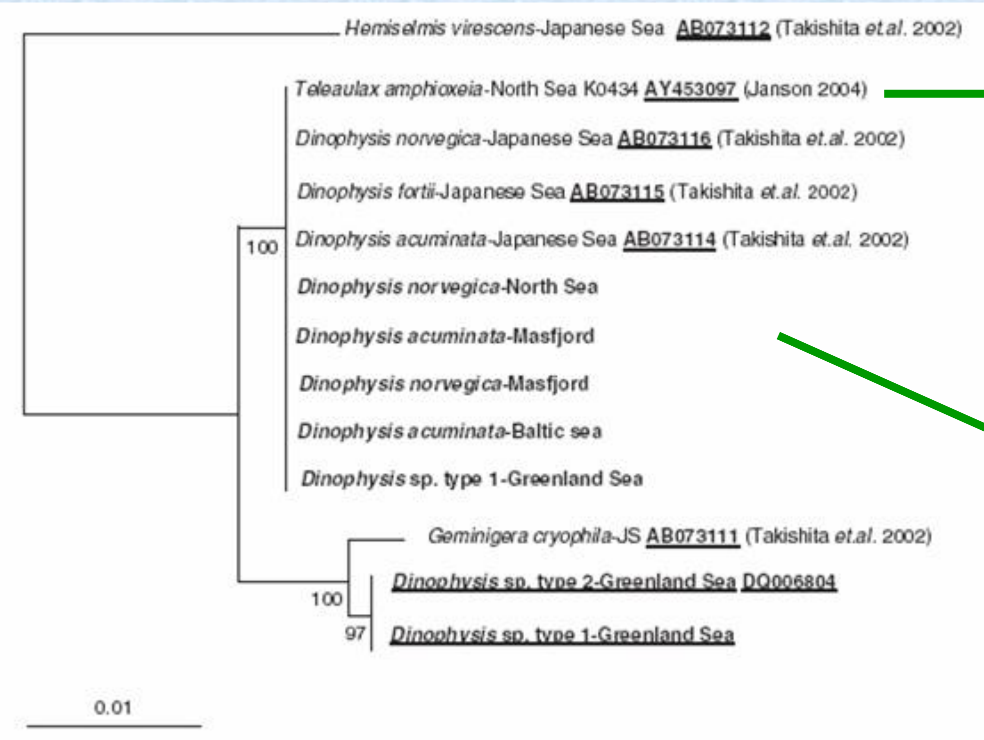
Plastid types

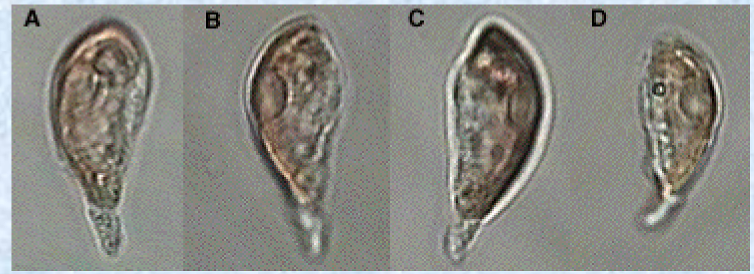
Type III. – reduced green endosymbiont (chl a + b)



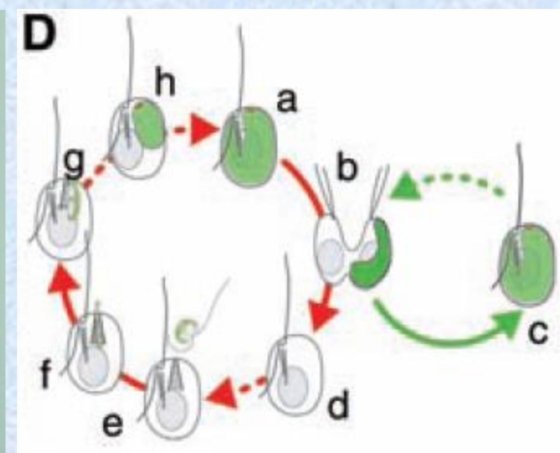
Recent endosymbioses

Dinophysis – plastids continuously replaces from Cryptophytes





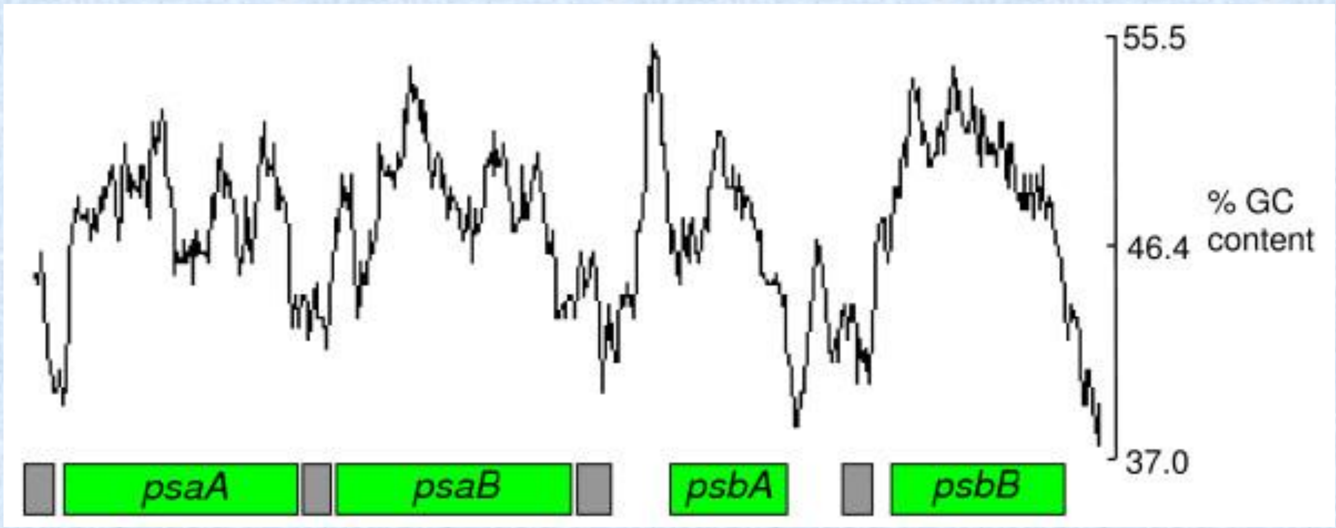
Hatena (Katablepharids), plastids from the green alga *Nephroselmis*

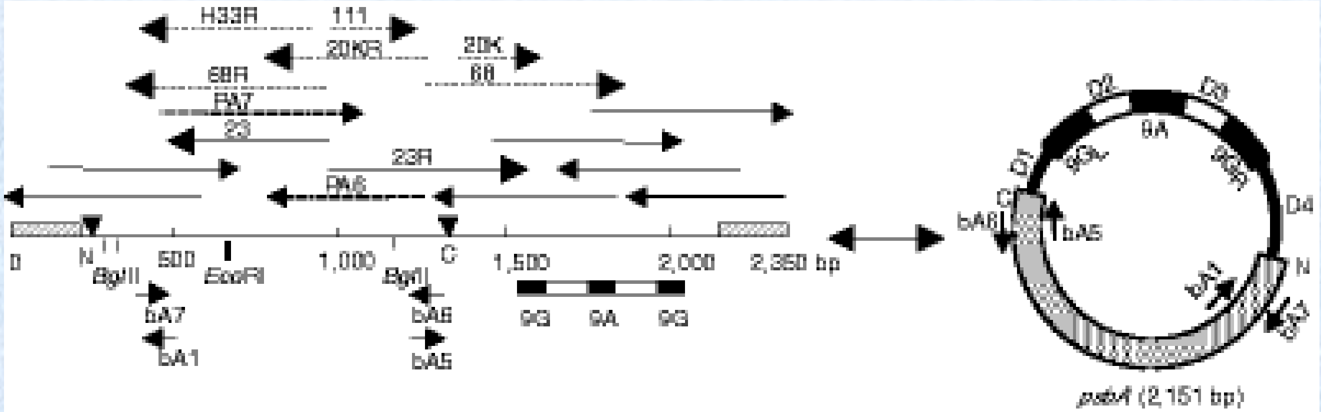


Chloroplast genome

Minicircles – extremely reduced genome

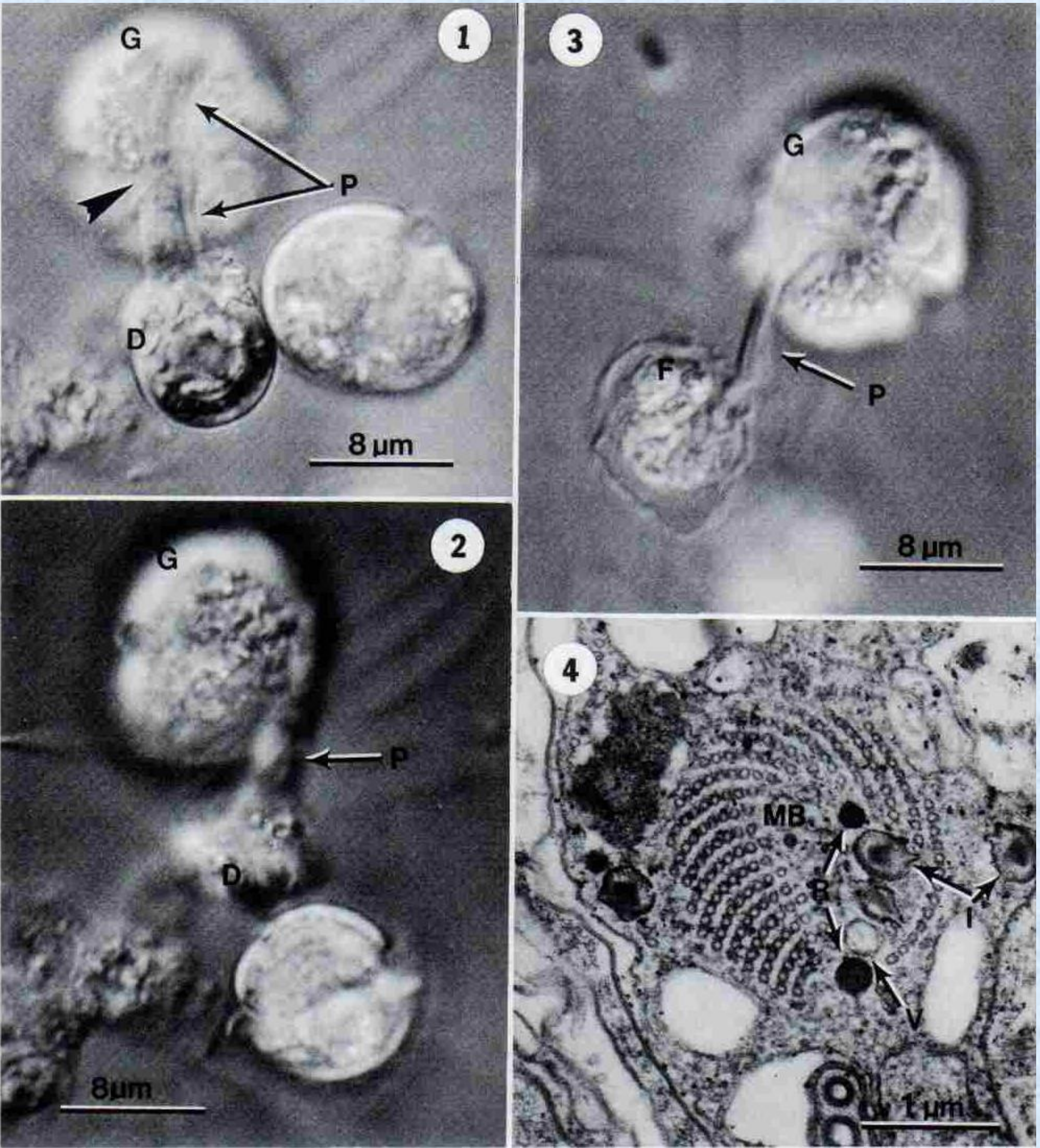
- only 14 photosinthesis-related proteins coded
- Laatsch et al. (2004): minicircles found in the nucleus
    - facilitation of tertiary endosymbiosis

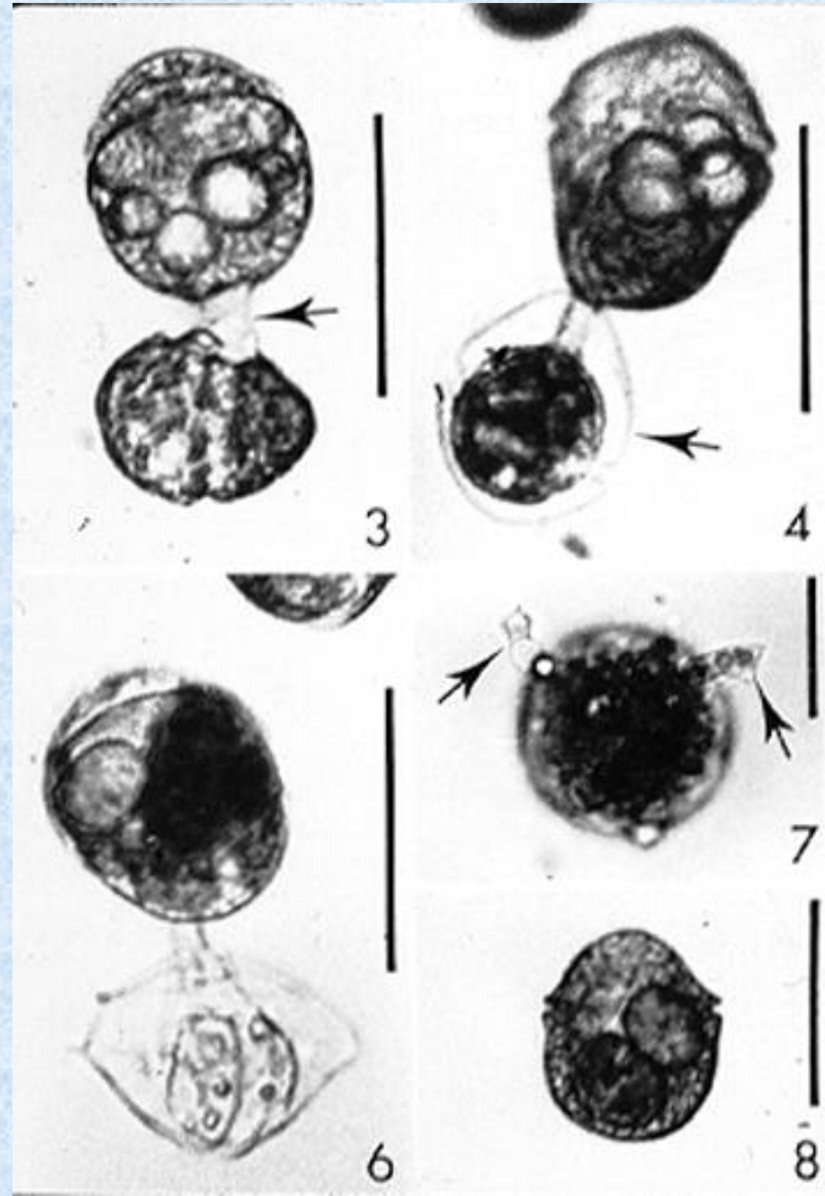




Heterotrophic nutrition

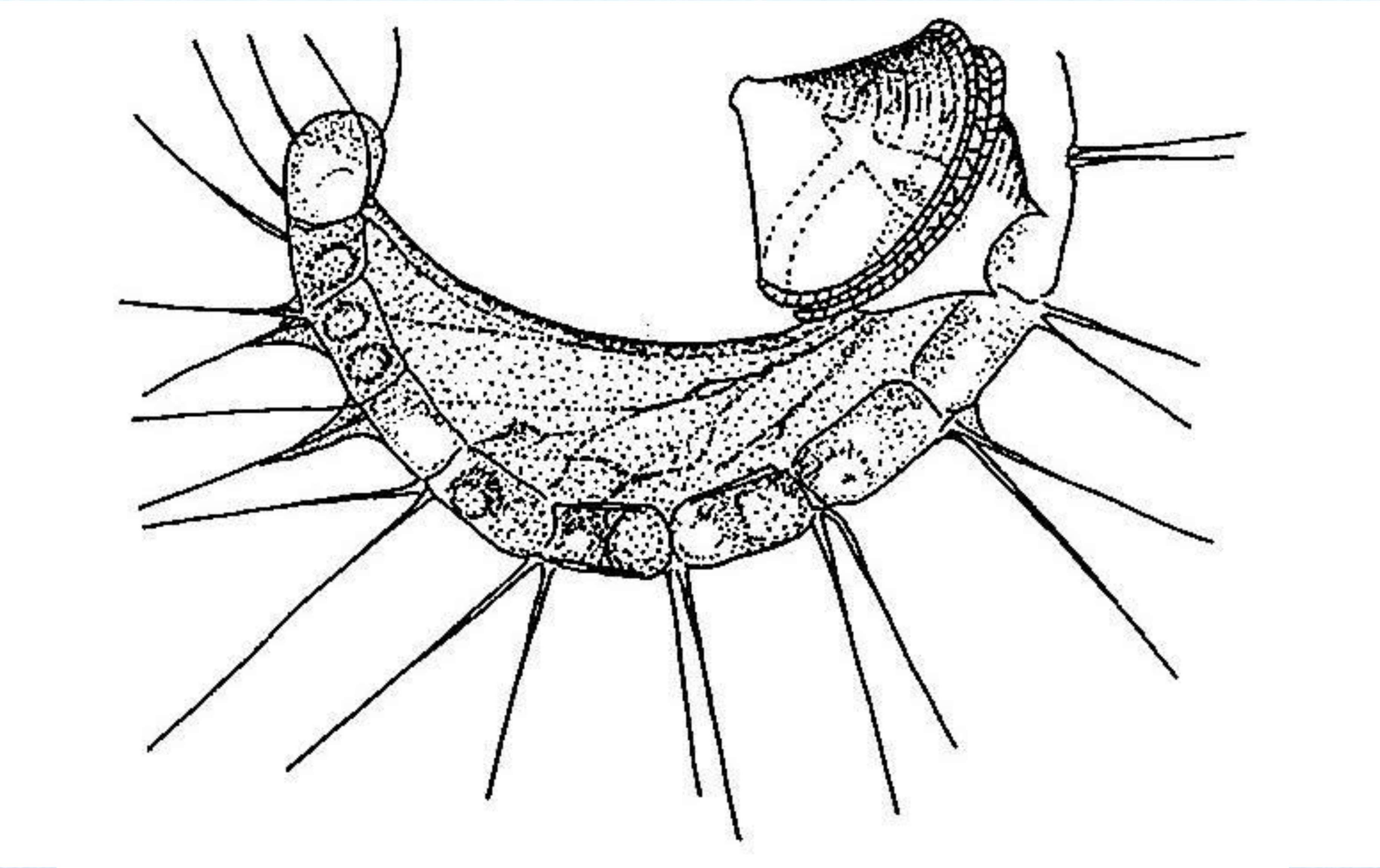
Katodinium, *Gymnodinium* – pedunculus





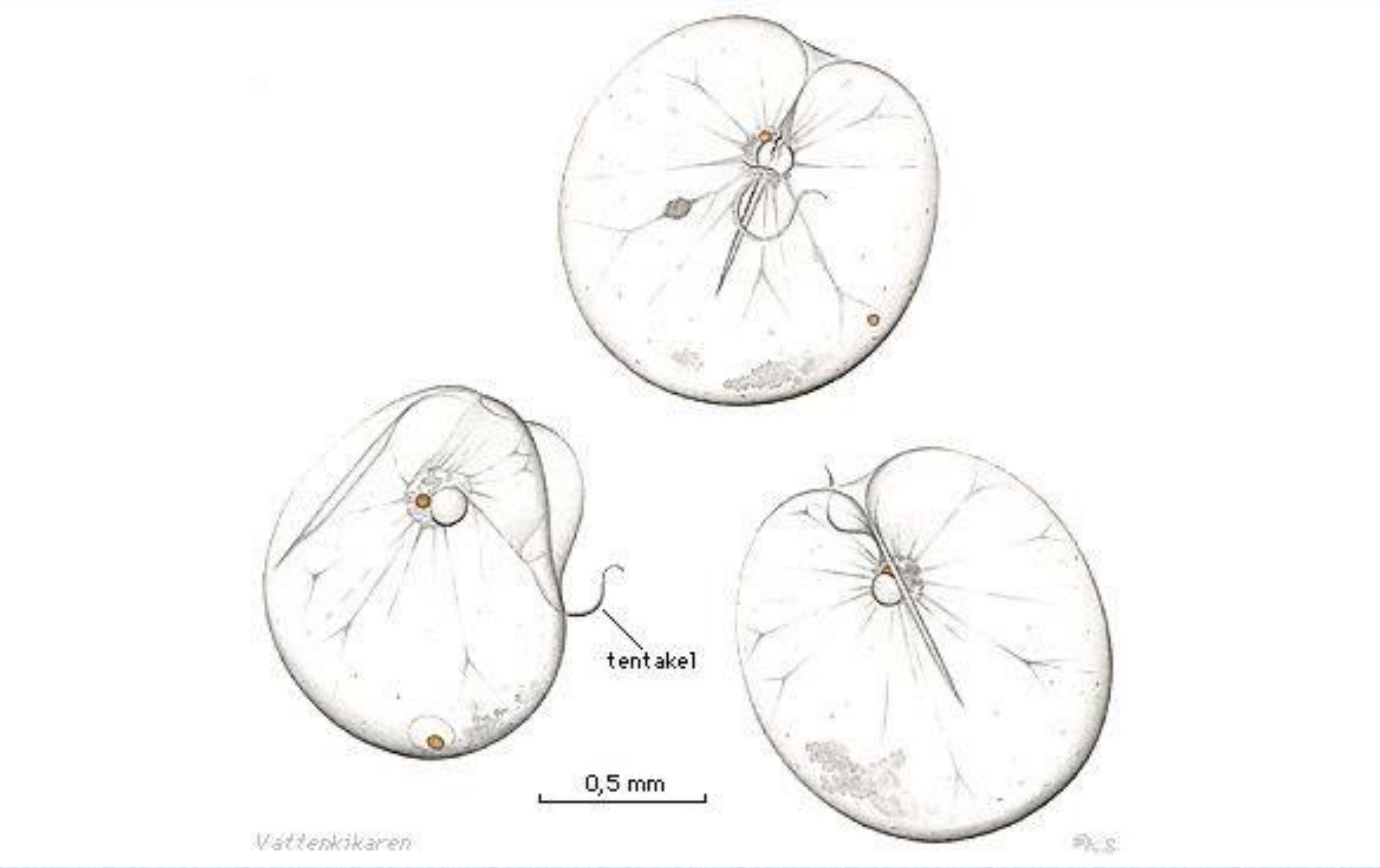
Heterotrophic nutrition

Protoperidinium – pedunculus, palium



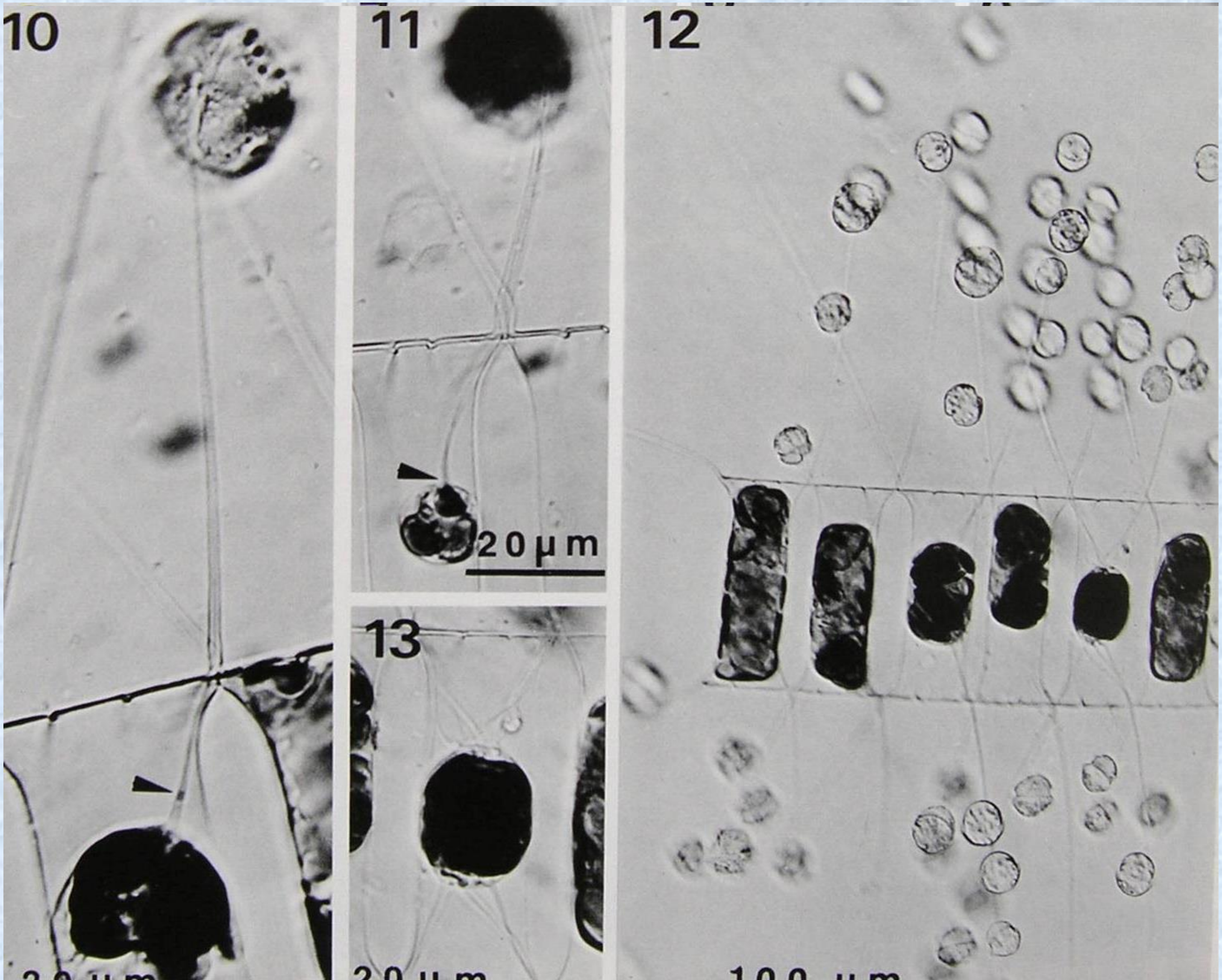
Heterotrophic nutrition

Noctiluca scintillans – tentacle (modified pedunculus)



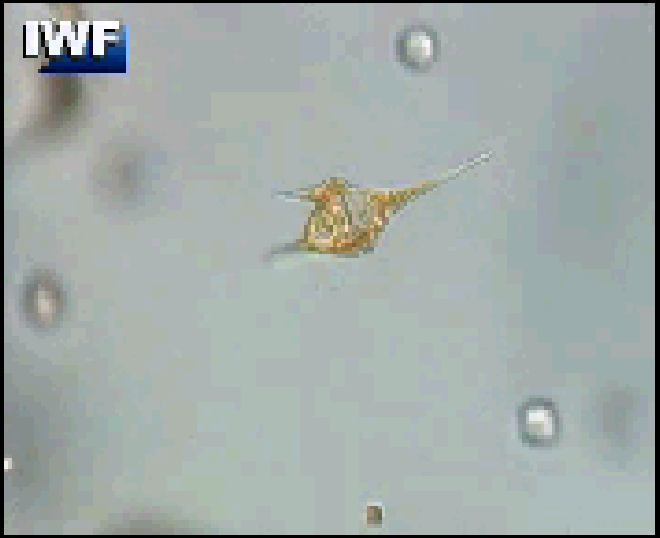
Heterotrophic nutrition

Paulsenella chaetoceratis – feeding tube penetrating into the diatom setae



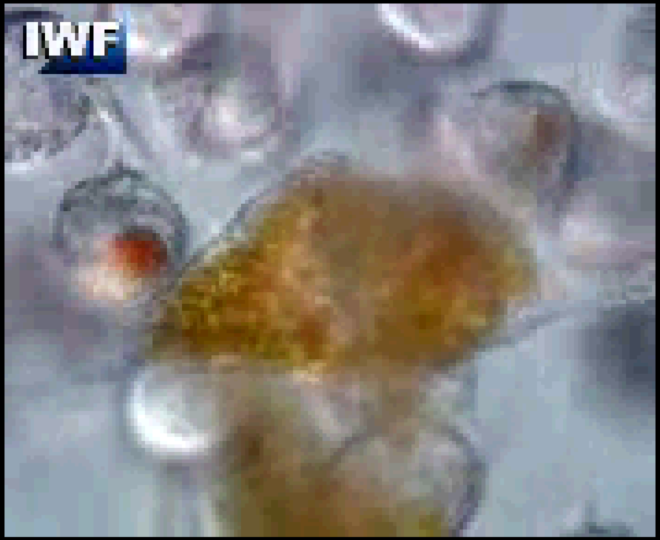
Heterotrophic nutrition

Peridiniopsis

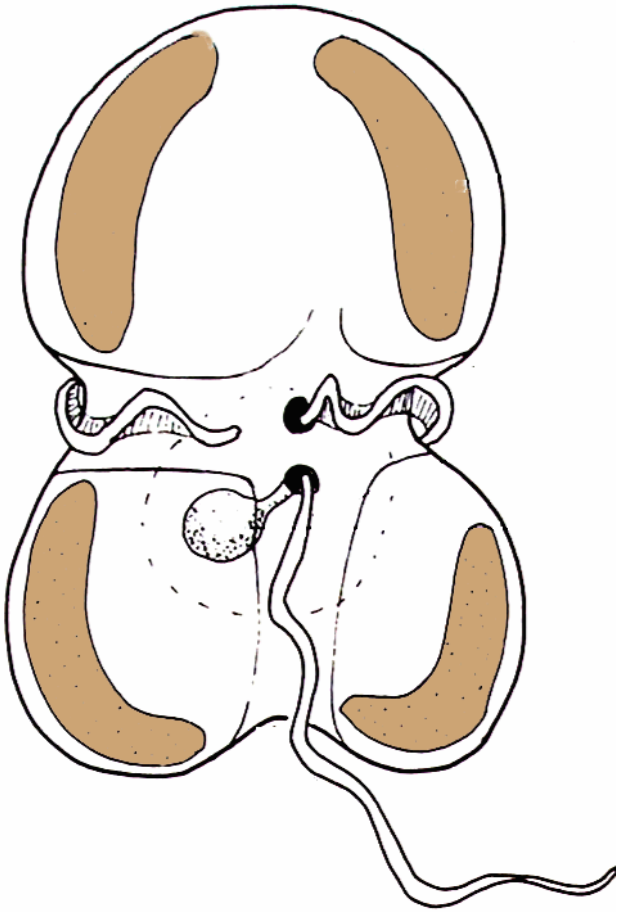


Heterotrophic nutrition

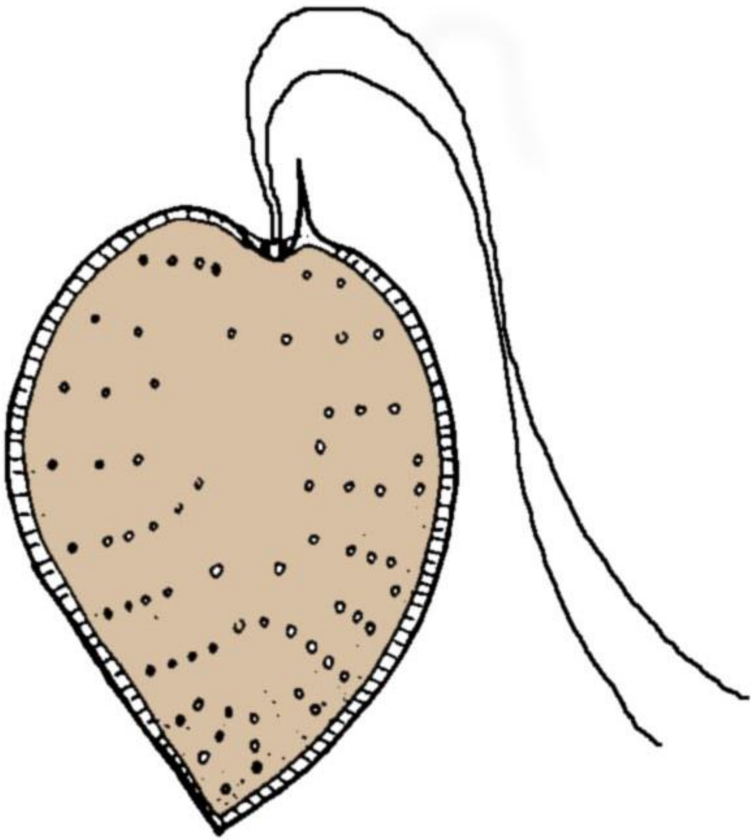
Peridiniopsis



Flagella

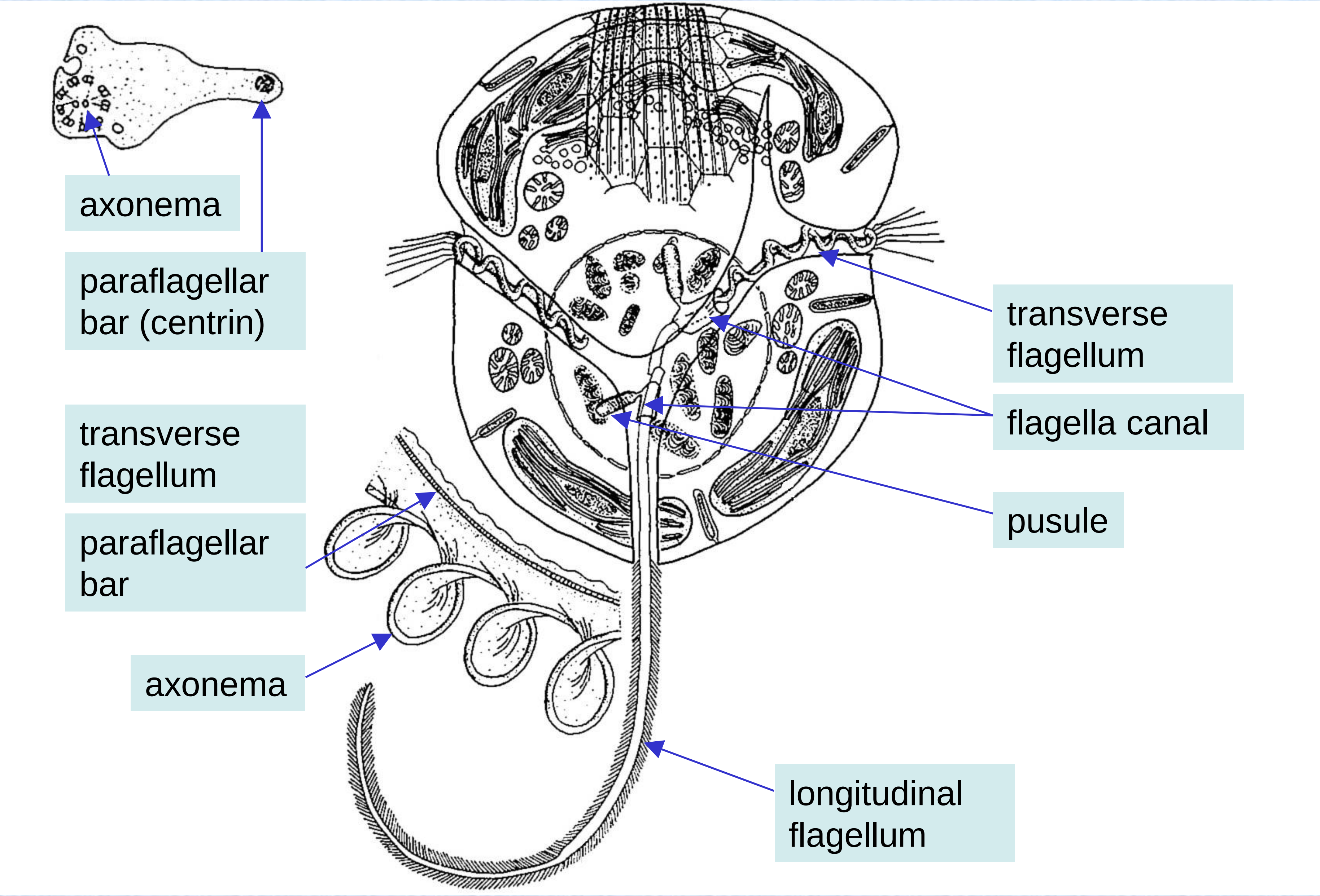


dinokont

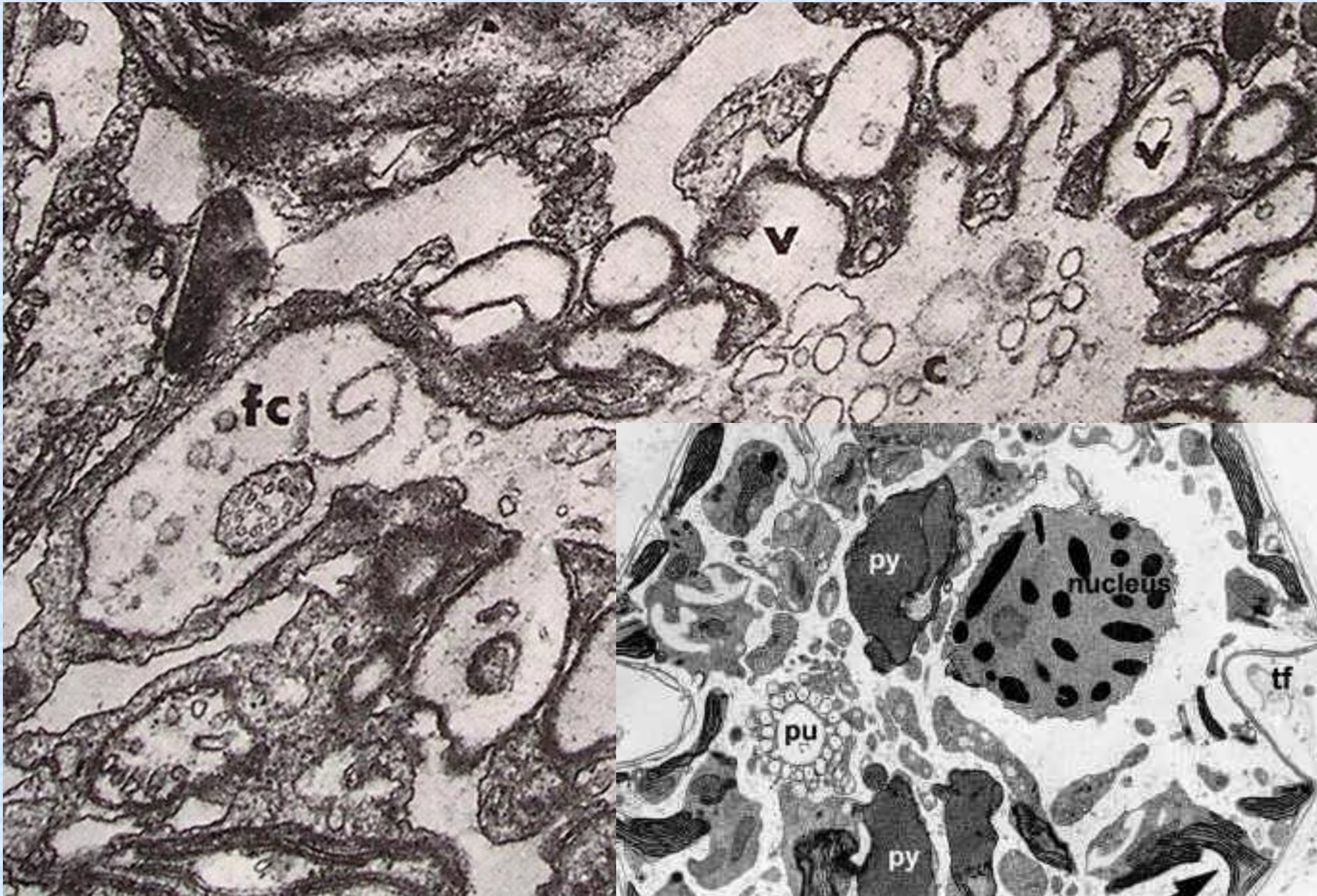


desmokont

Flagella

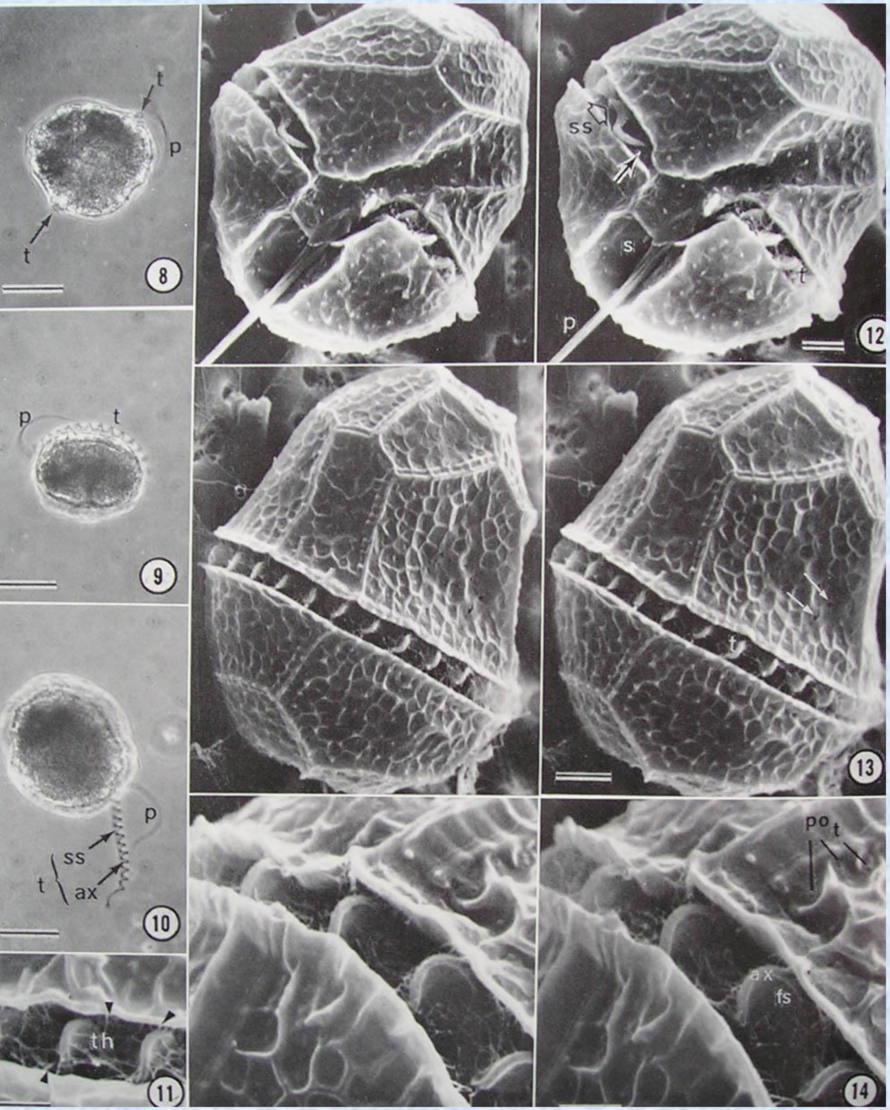

axonema
paraflagellar bar (centrin)
transverse flagellum
paraflagellar bar
axonema
transverse flagellum
flagella canal
pusule
longitudinal flagellum

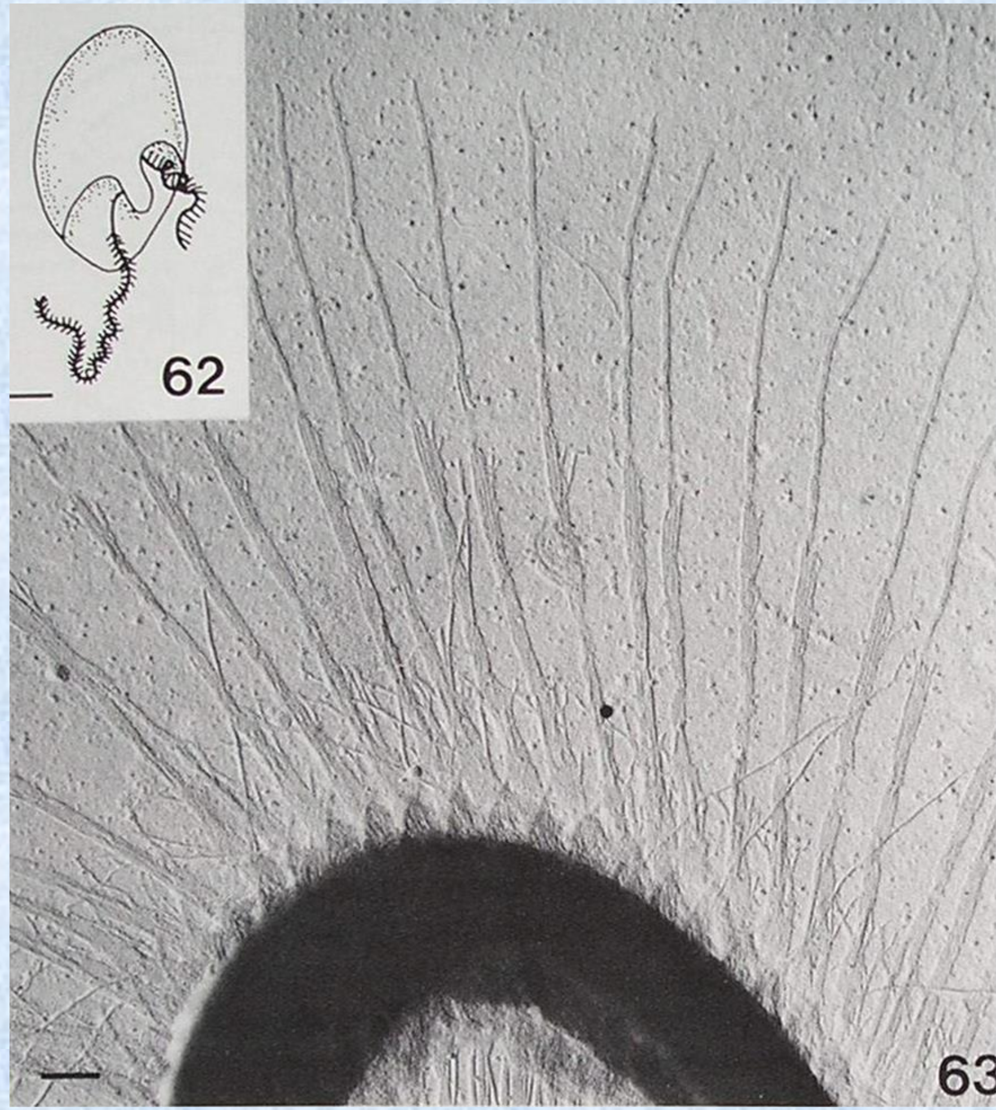
Flagella, pusule



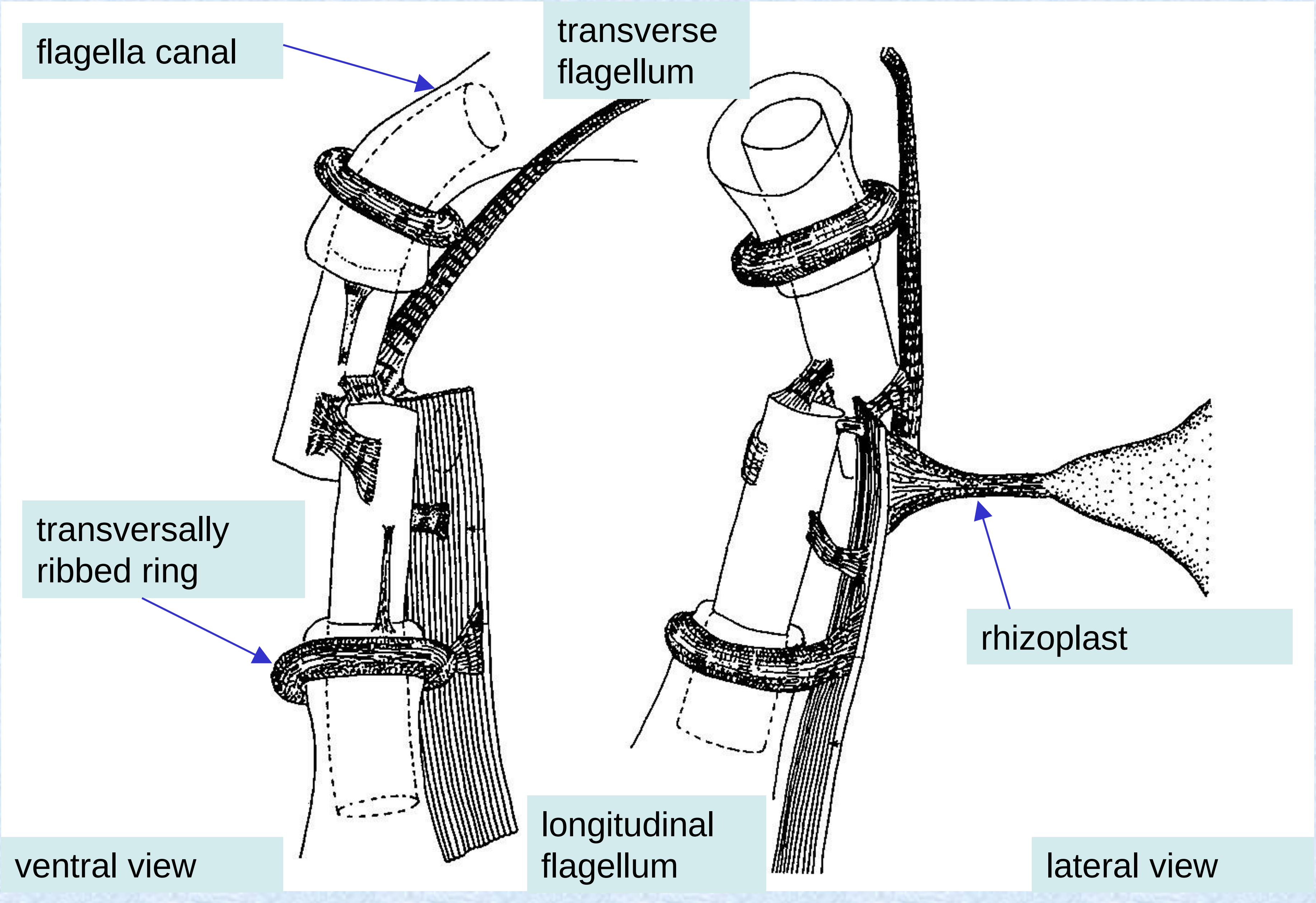
Flagella

transverse flagellum

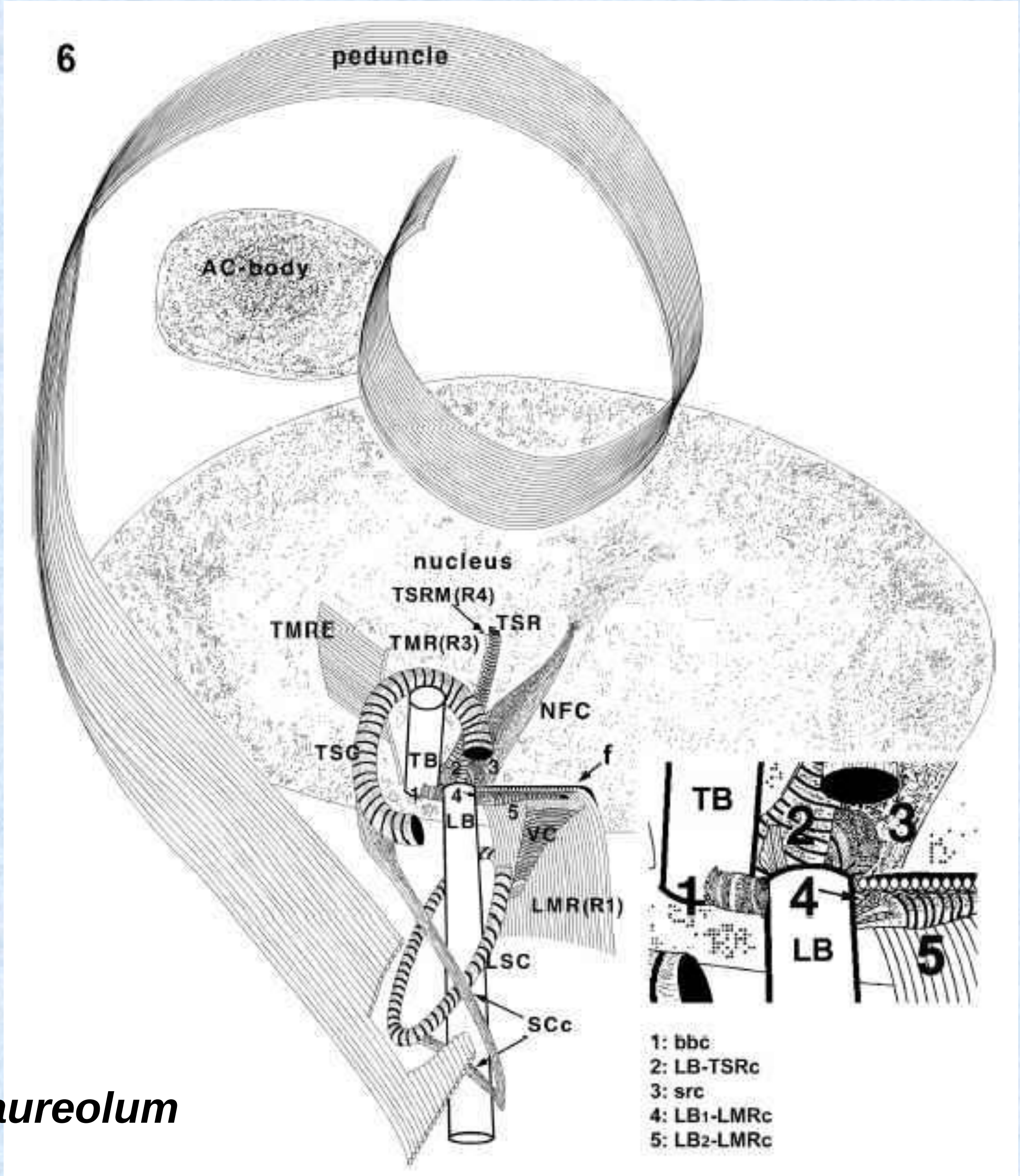




Flagella roots



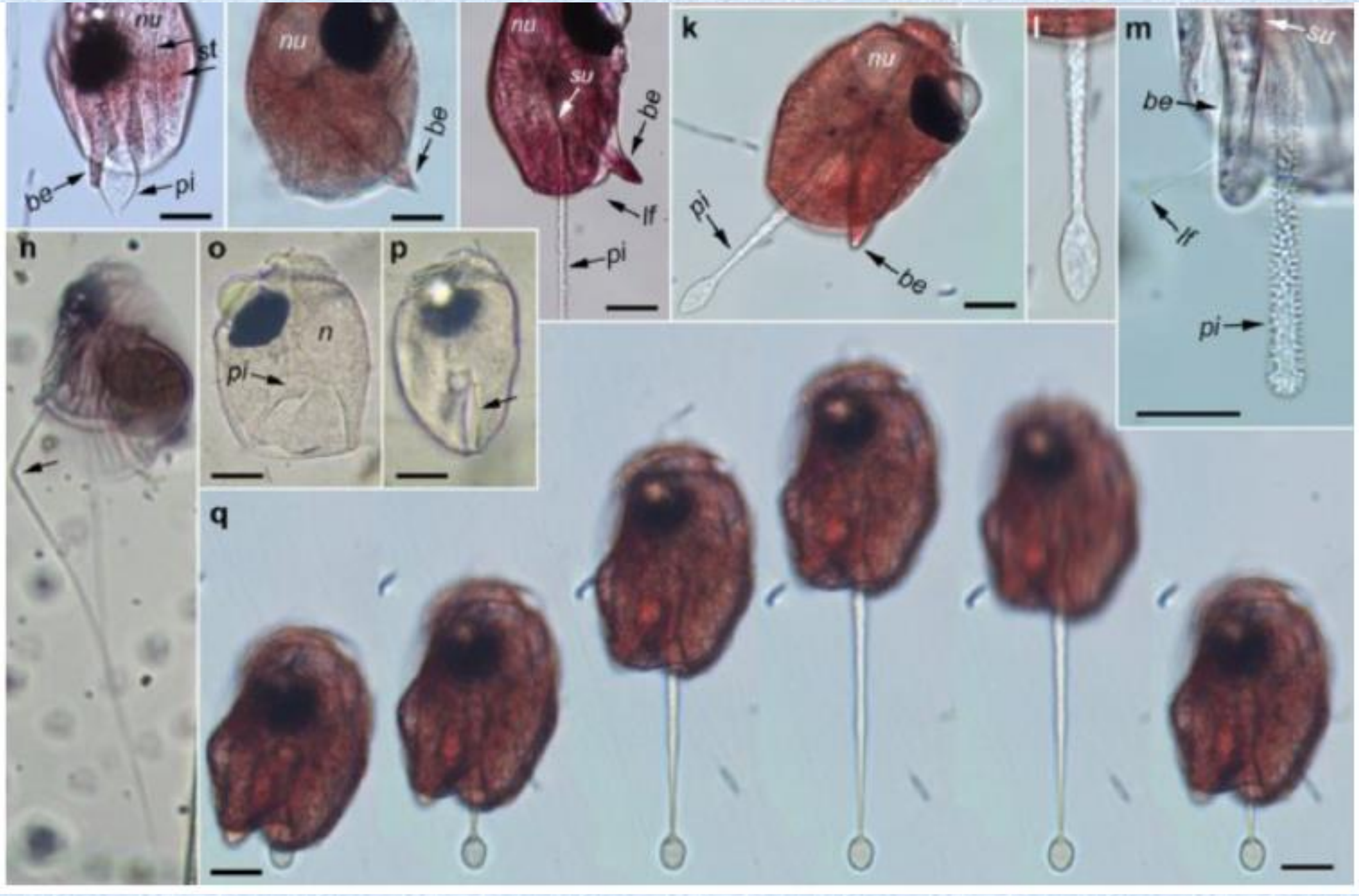
Flagella roots - peduncle



Gymnodinium aureolum

Piston

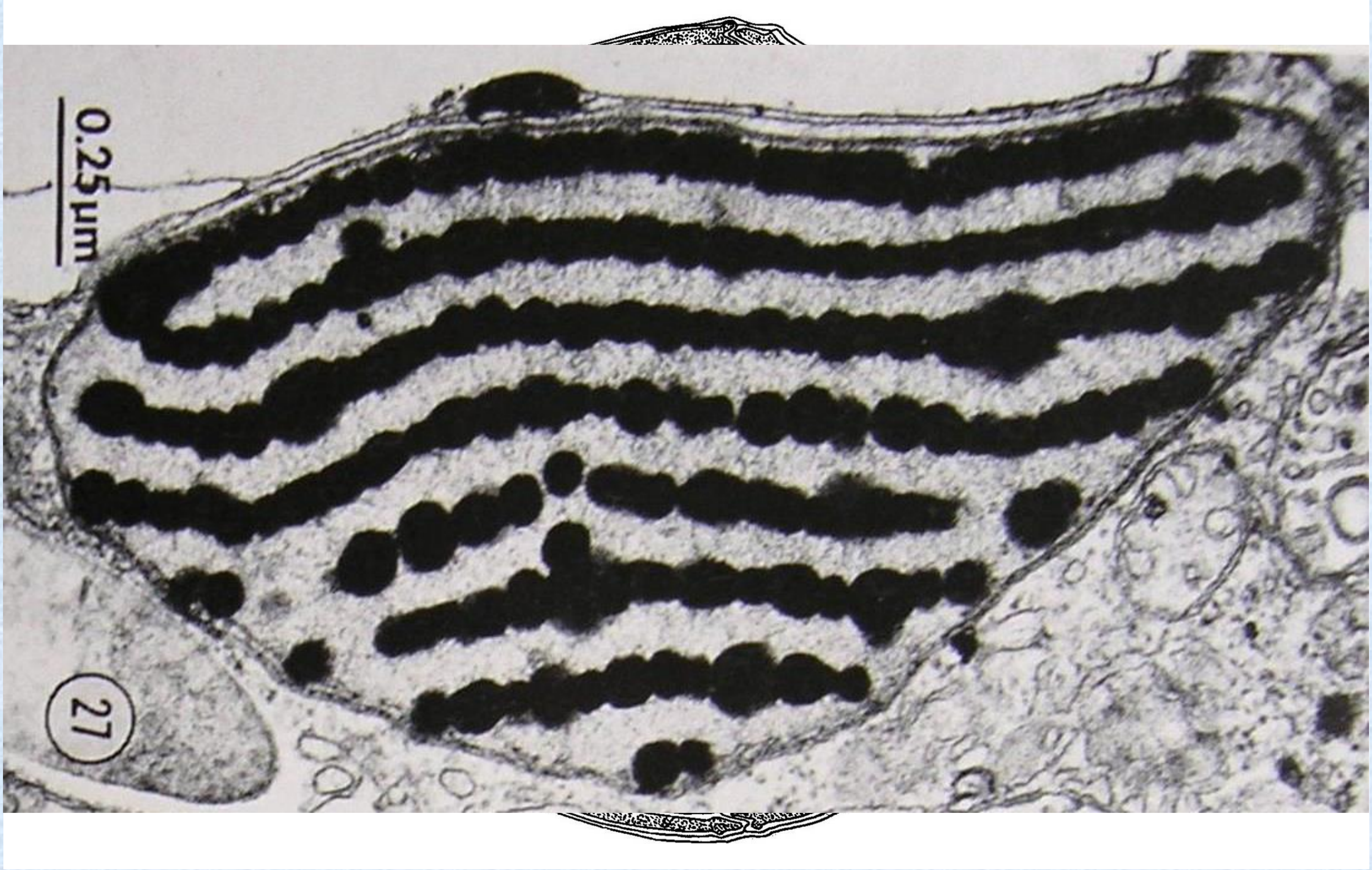
- repetitive and dramatic contractile motion
- suggested function for locomotion, prey capture or defense



Piston

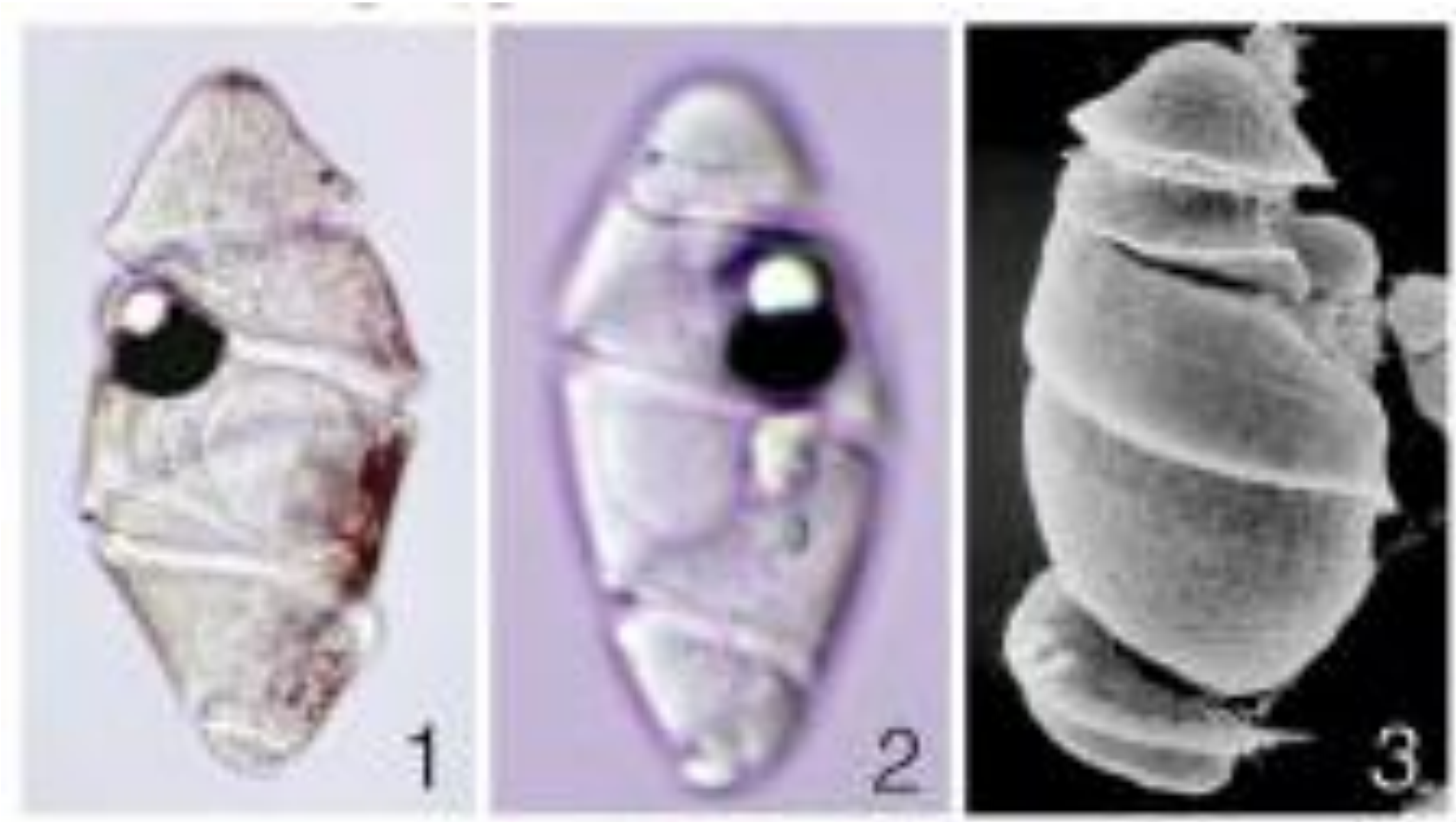
Stigma

Peridinium balticum – lipid granule

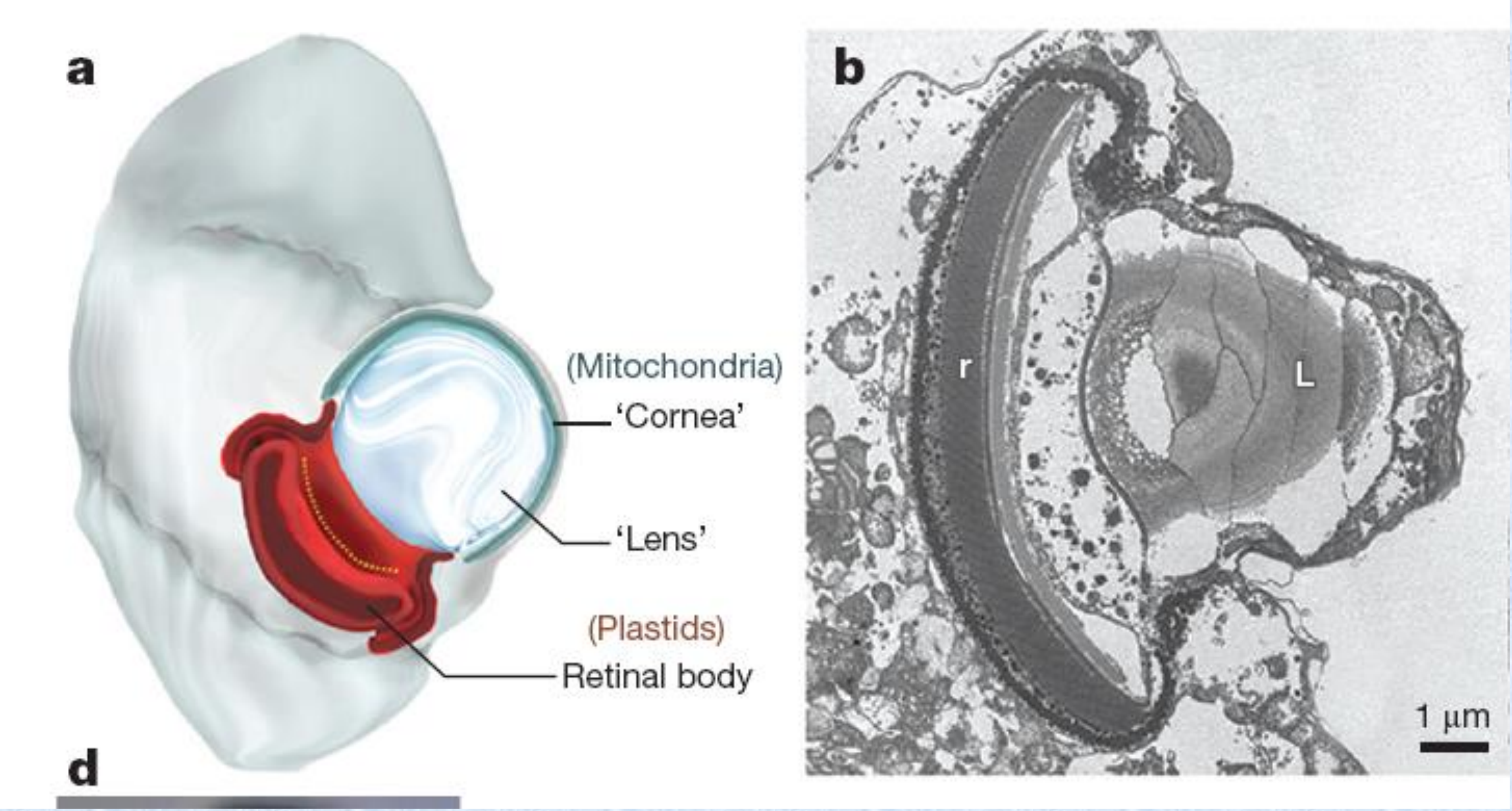


Stigma

Warnowia – complex stigma (ocelloid)

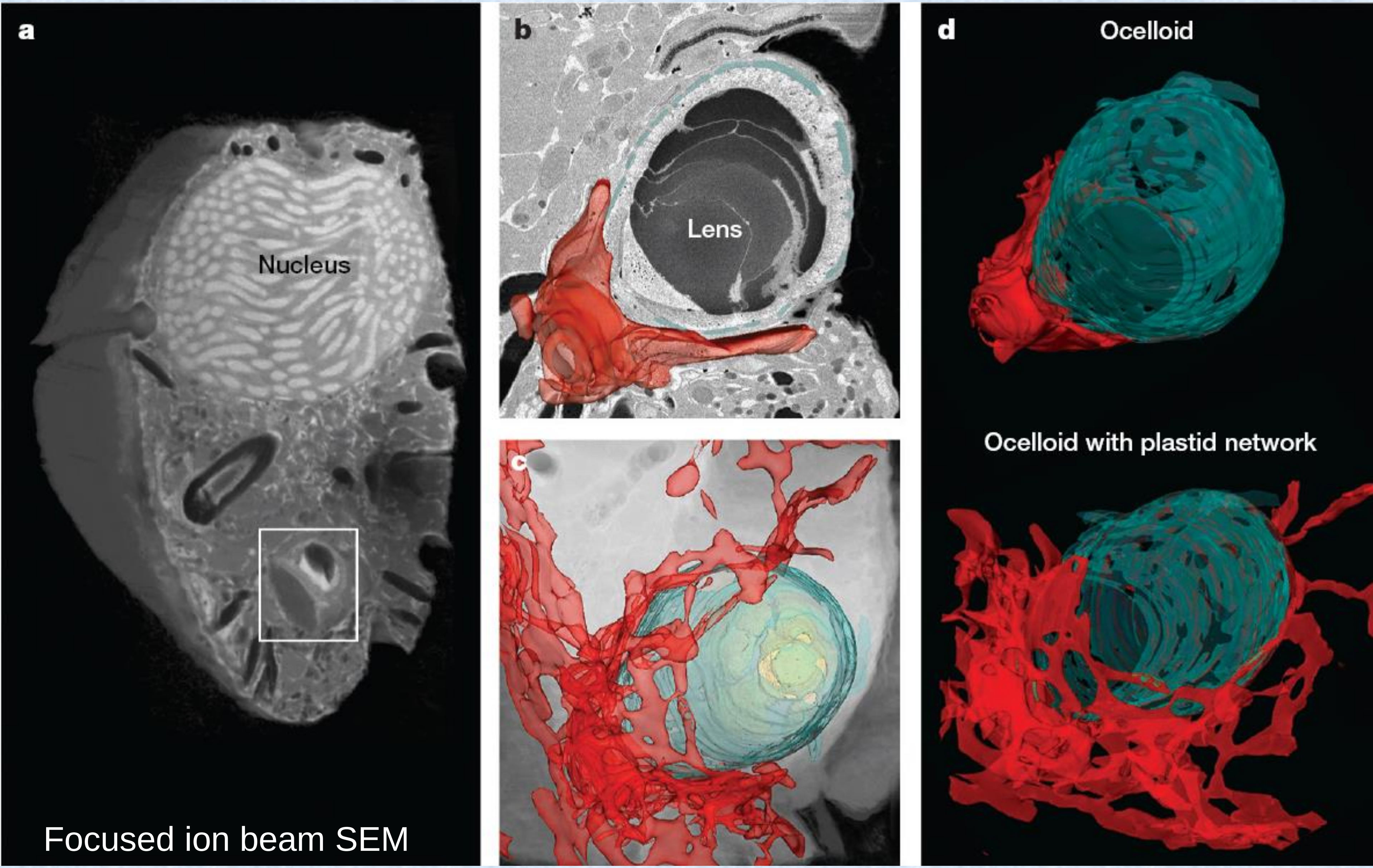


Ocelloid

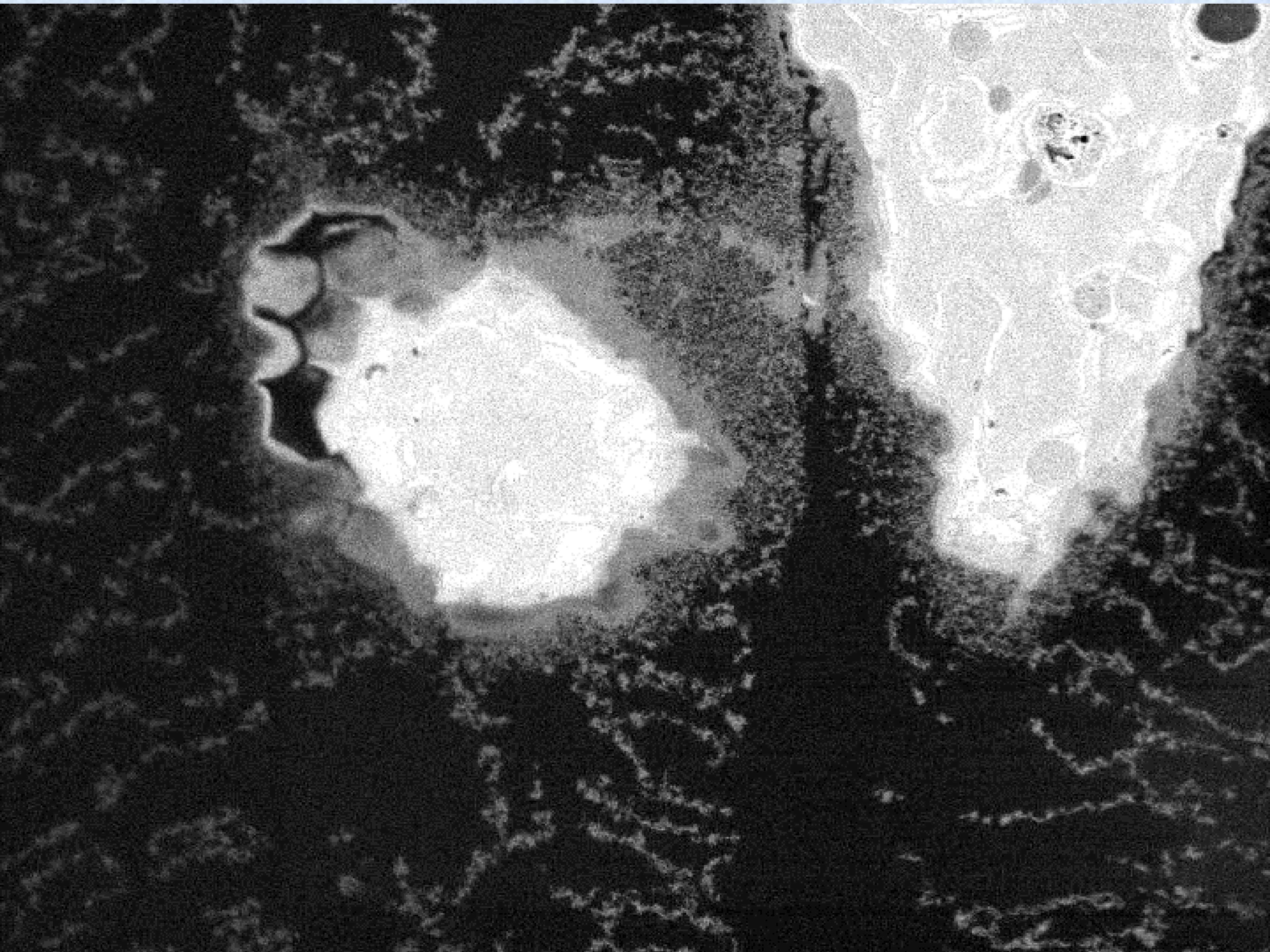


Gavelis et al. 2015, Nature

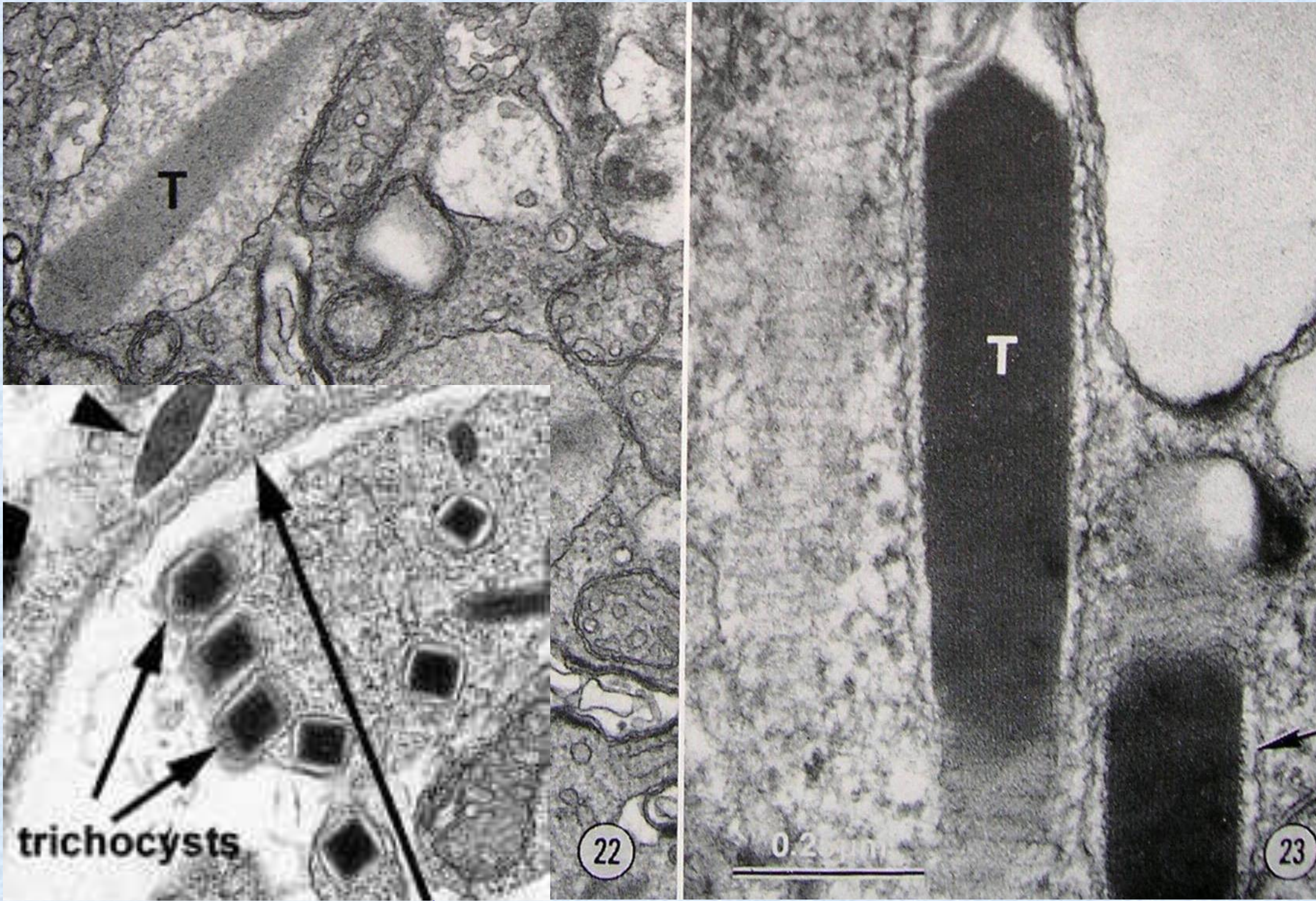
Ocelloid



Gavelis et al. 2015, Nature

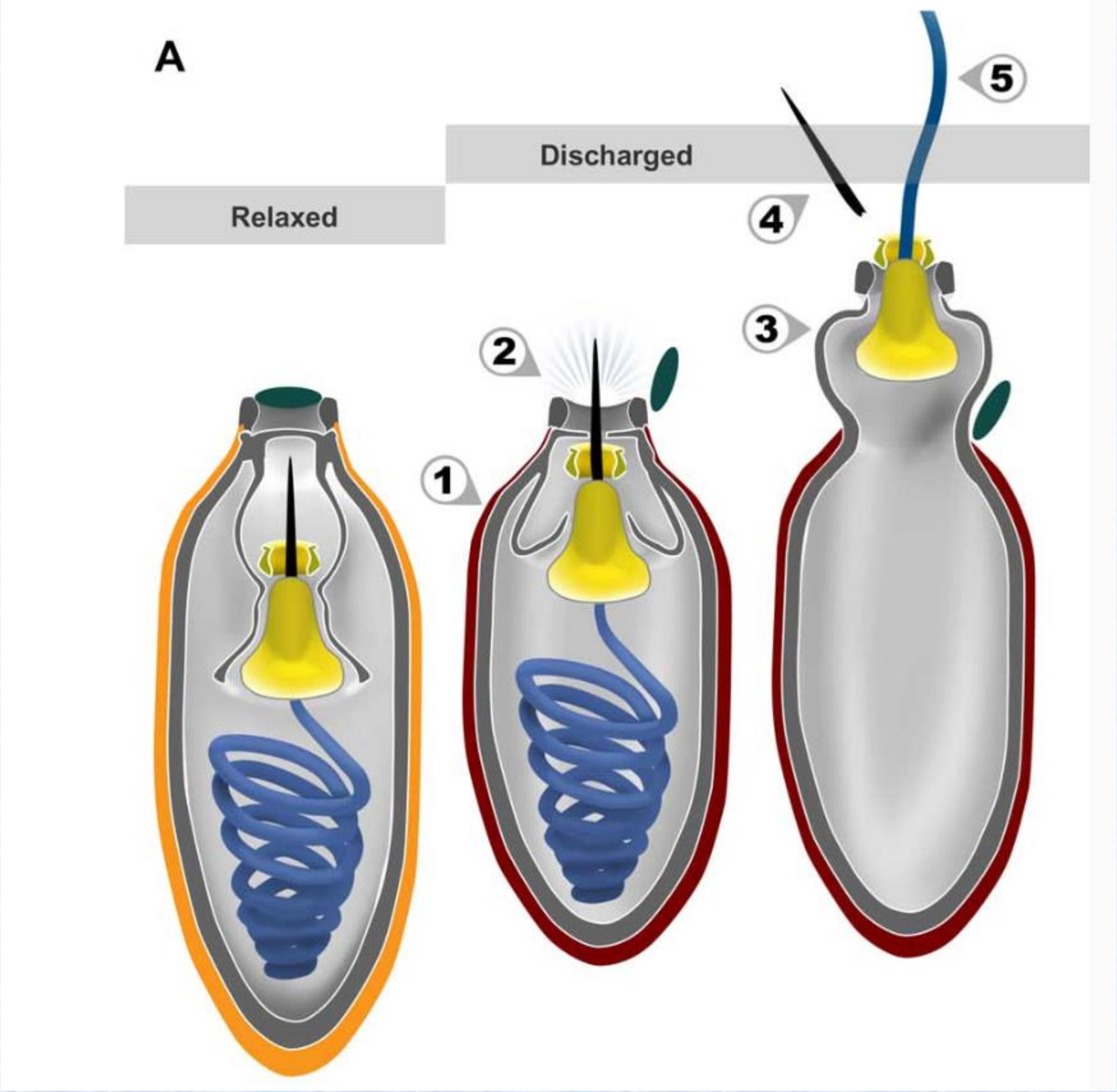


Trichocysts



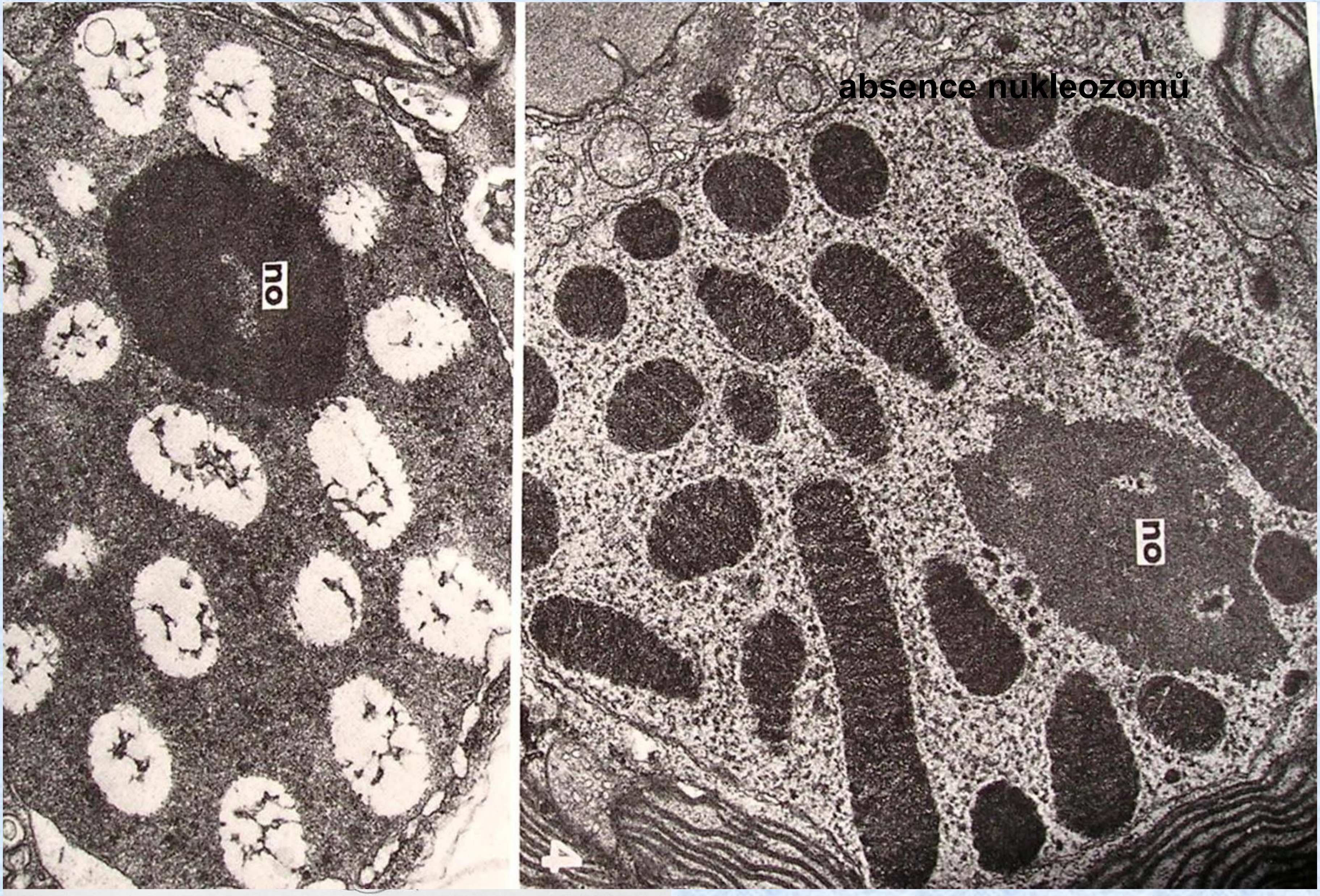
Nematocysts

- ballistic multi-barrel guns for taking out prey



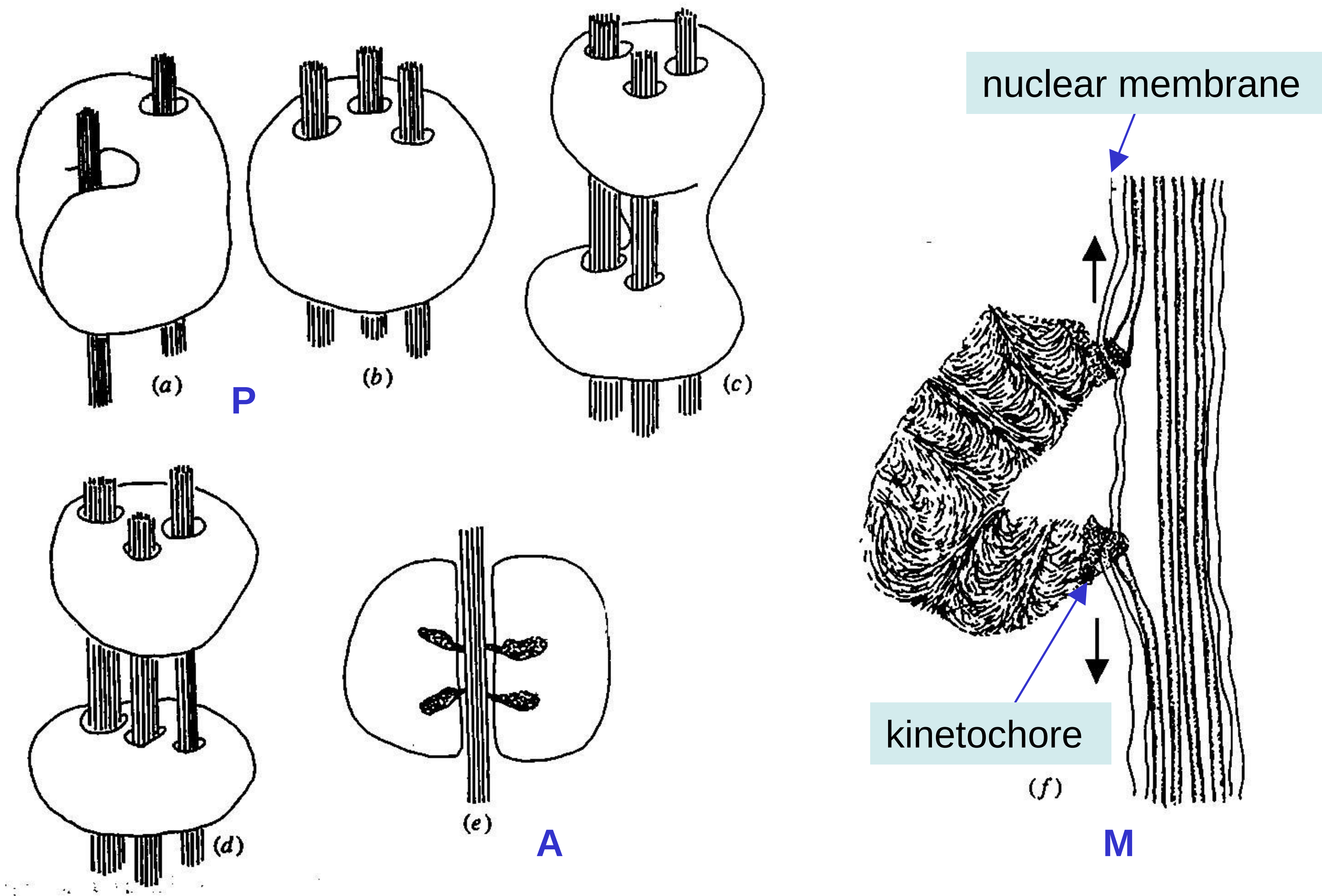
Nematocysts

Dinokaryon

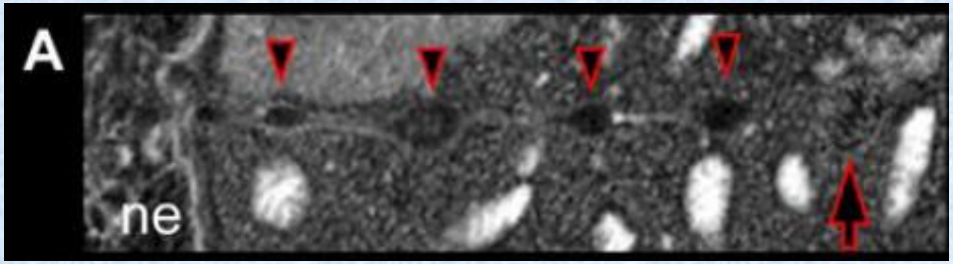


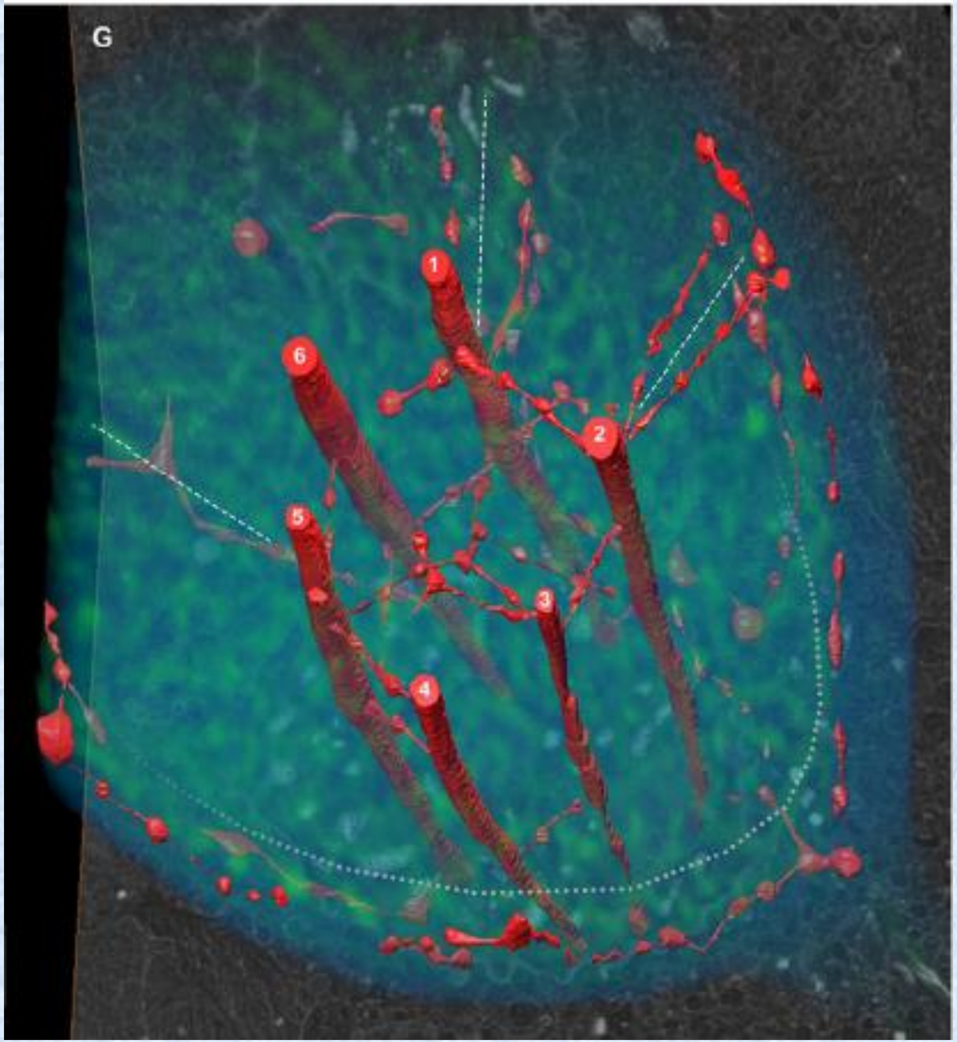
Dinokaryon

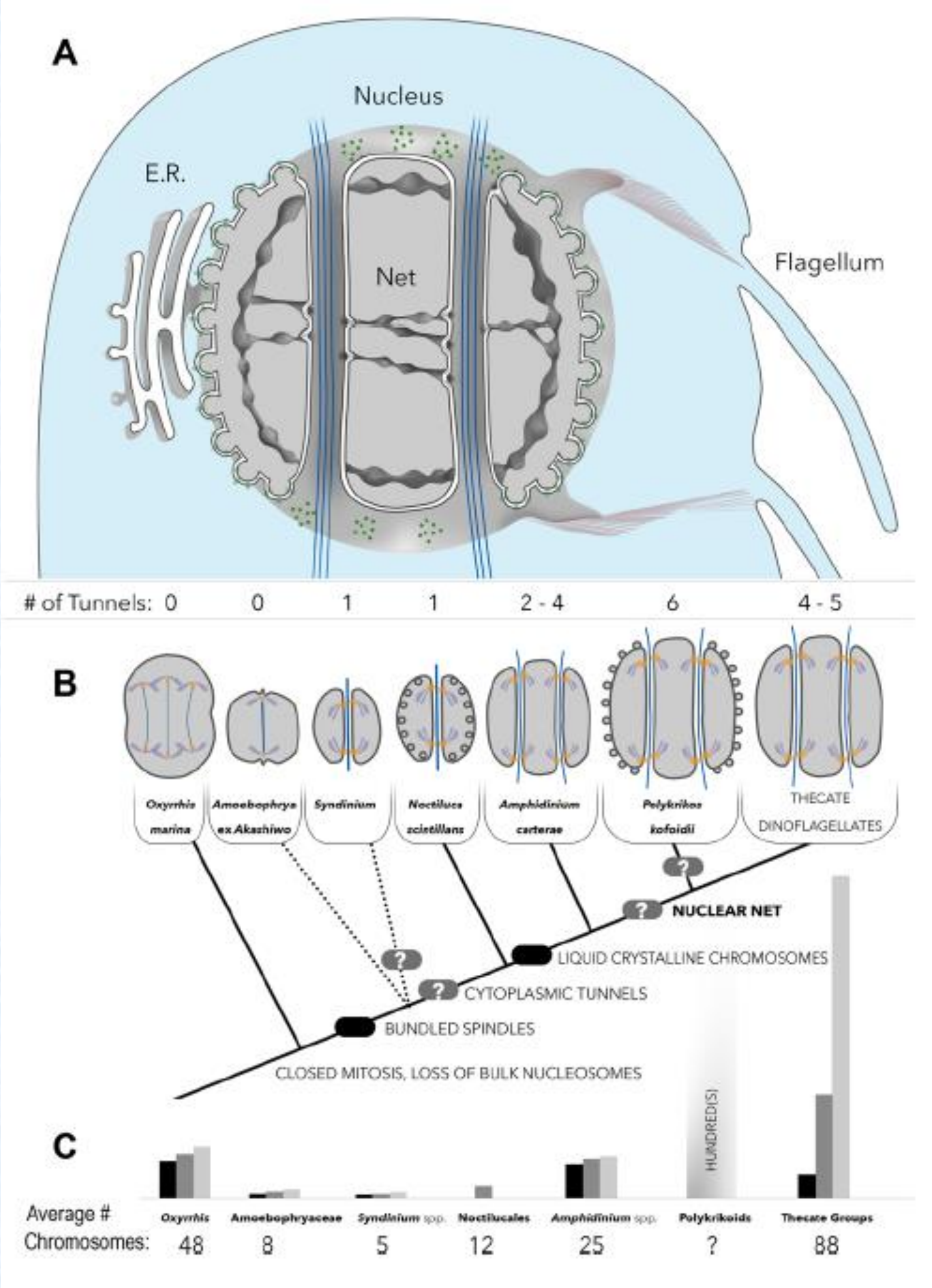
Mitosis



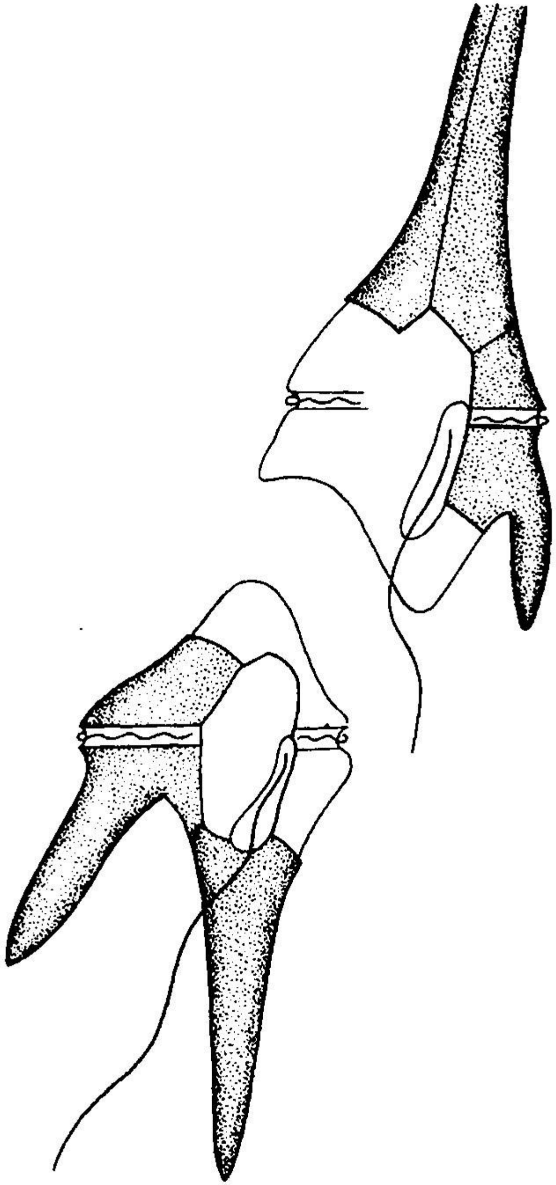
Nuclear net


A
ne


G
1
2
3
4
5
6

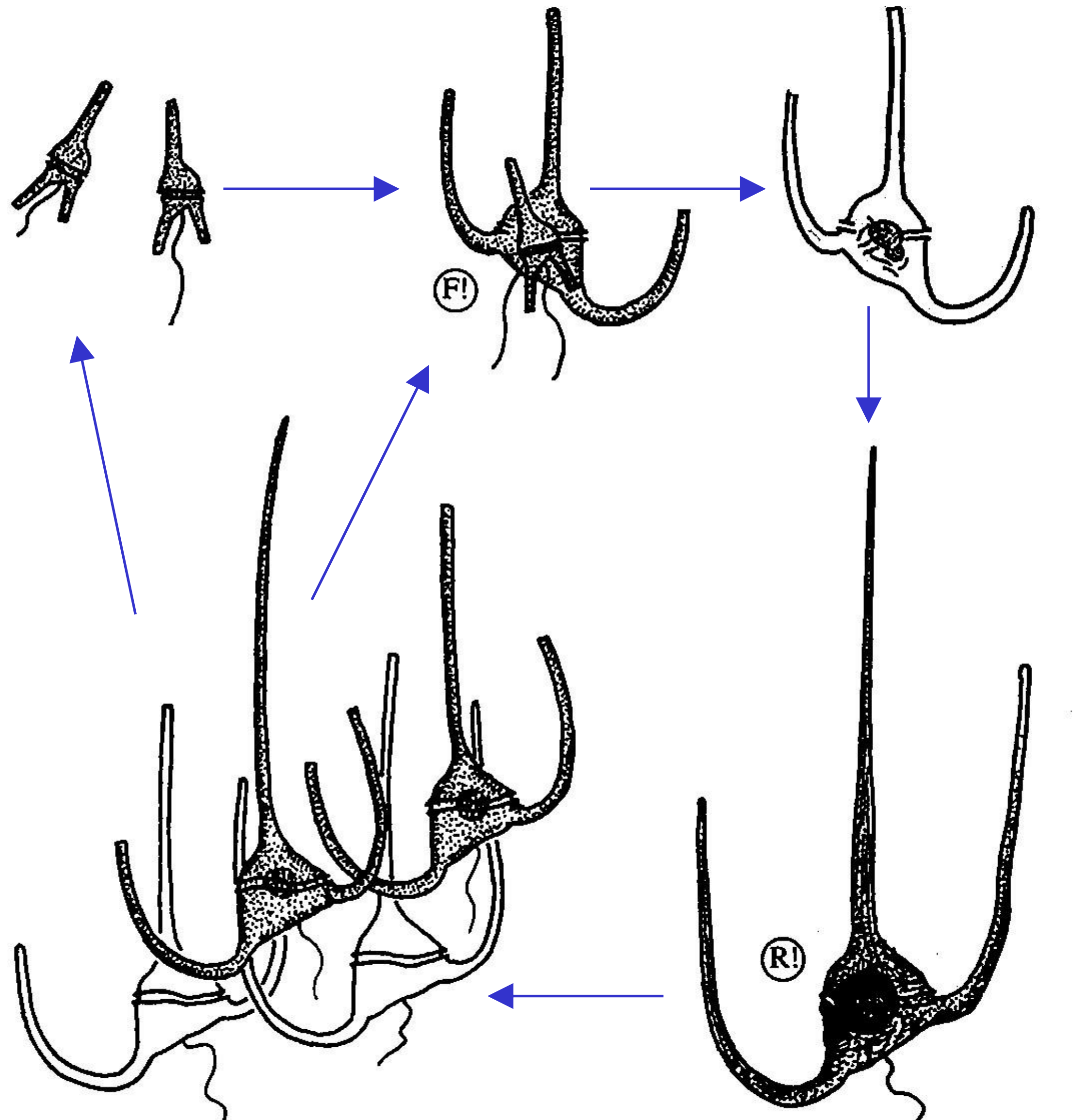

A
Nucleus
E.R.
Net
Flagellum
# of Tunnels: 0 0 1 1 2 - 4 6 4 - 5
B
Oxyrrhis marina
Amoebophrya ex Akashiwo
Syndinium
Noctiluca scintillans
Amphidinium carterae
Polykrikos kofoidii
THECATE DINOFLAGELLATES
NUCLEAR NET
LIQUID CRYSTALLINE CHROMOSOMES
CYTOPLASMIC TUNNELS
BUNDLED SPINDLES
CLOSED MITOSIS, LOSS OF BULK NUCLEOSOMES
C
HUNDRED(S)
Average # Chromosomes:
Oxyrrhis 48
Amoebophryaceae 8
Syndinium spp. 5
Noctilucales 12
Amphidinium spp. 25
Polykrikoids ?
Thecate Groups 88

Asexual reproduction



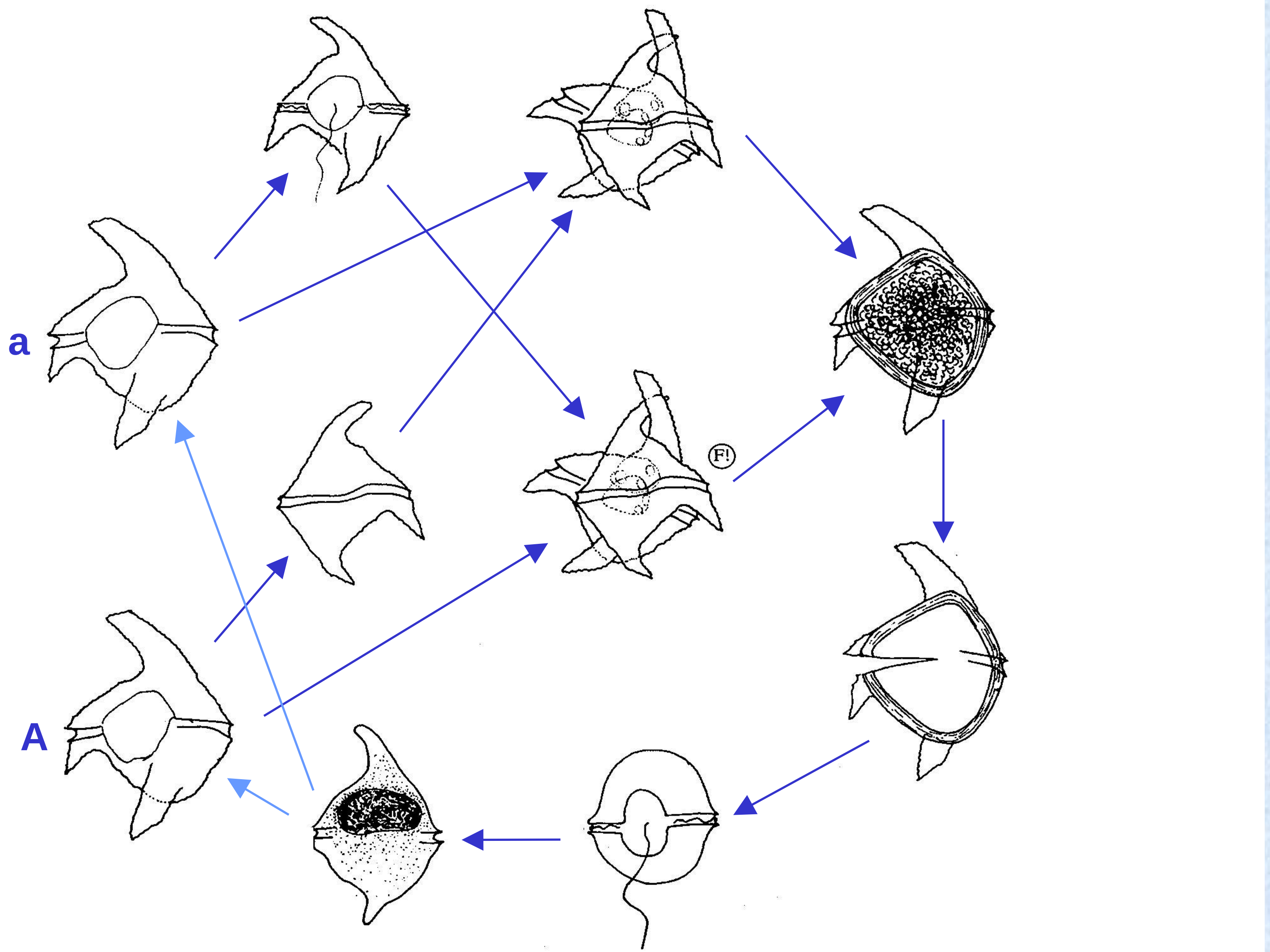
Sexual reproduction

Ceratium horridum – anisogamy, haplontic life cycle



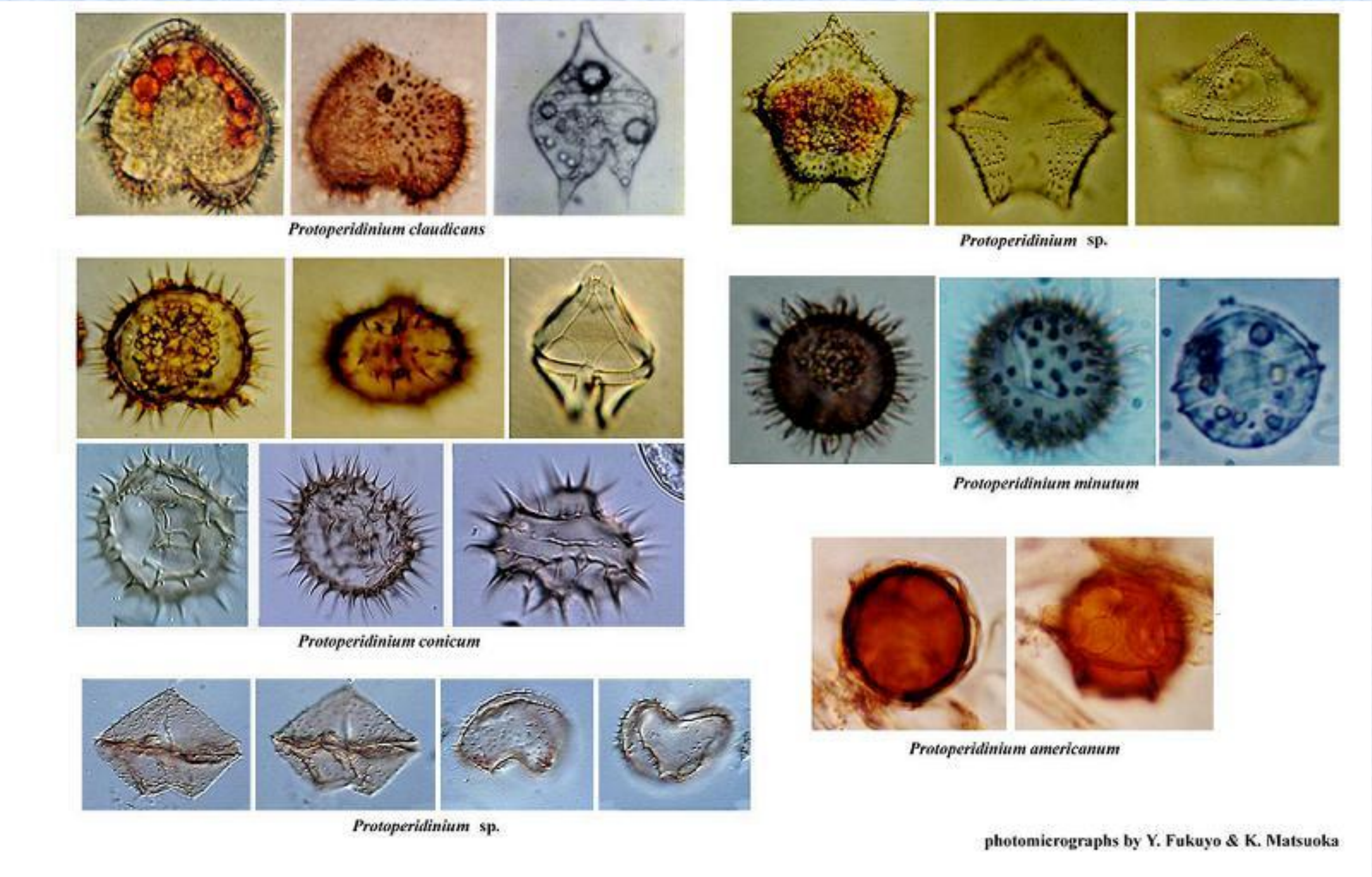
Sexual reproduction

Ceratium cornutum – isogamy, haplontic life cycle



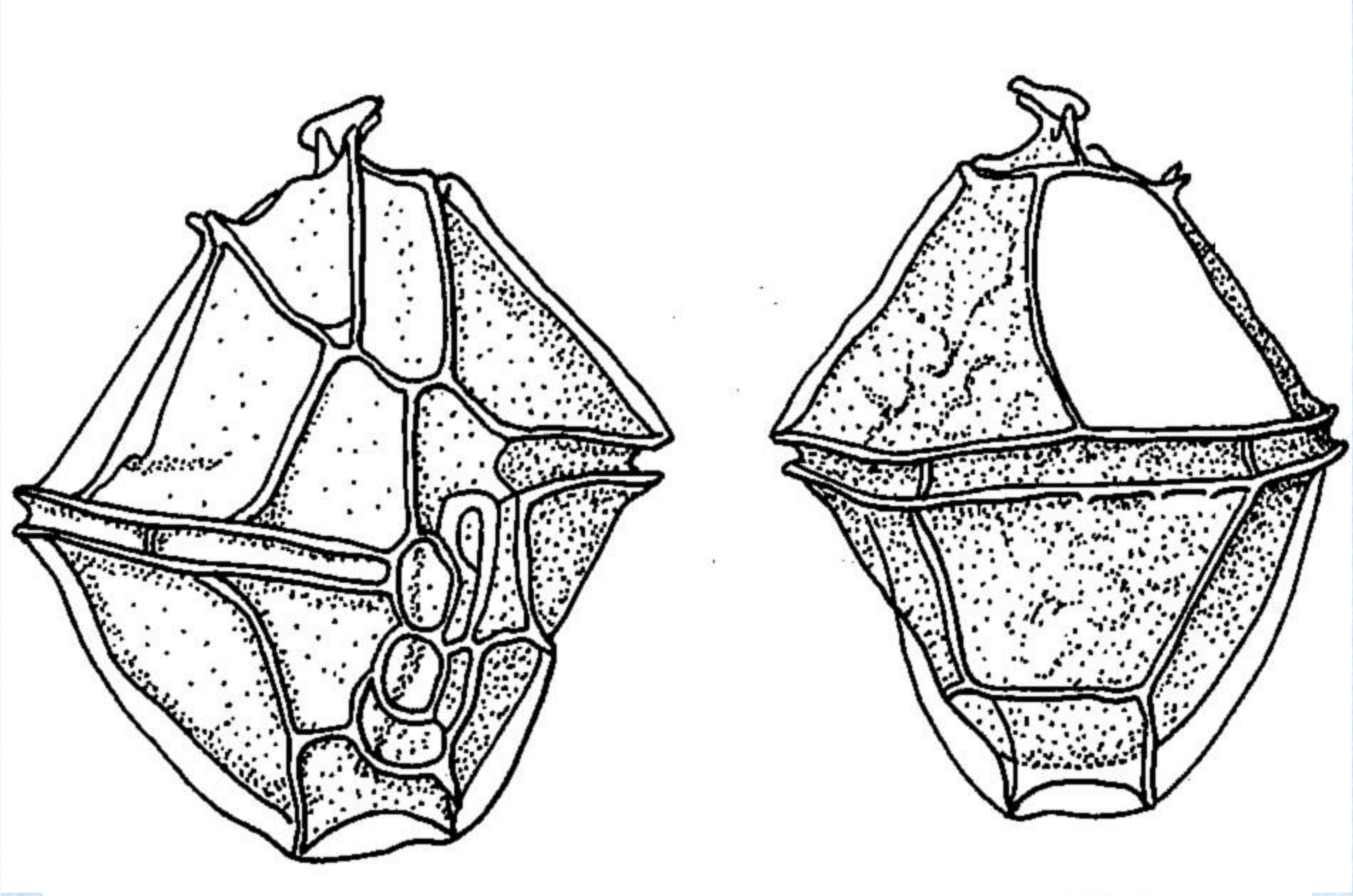
Cysts

- surviving for many years
- large inocula in coastal water sediments



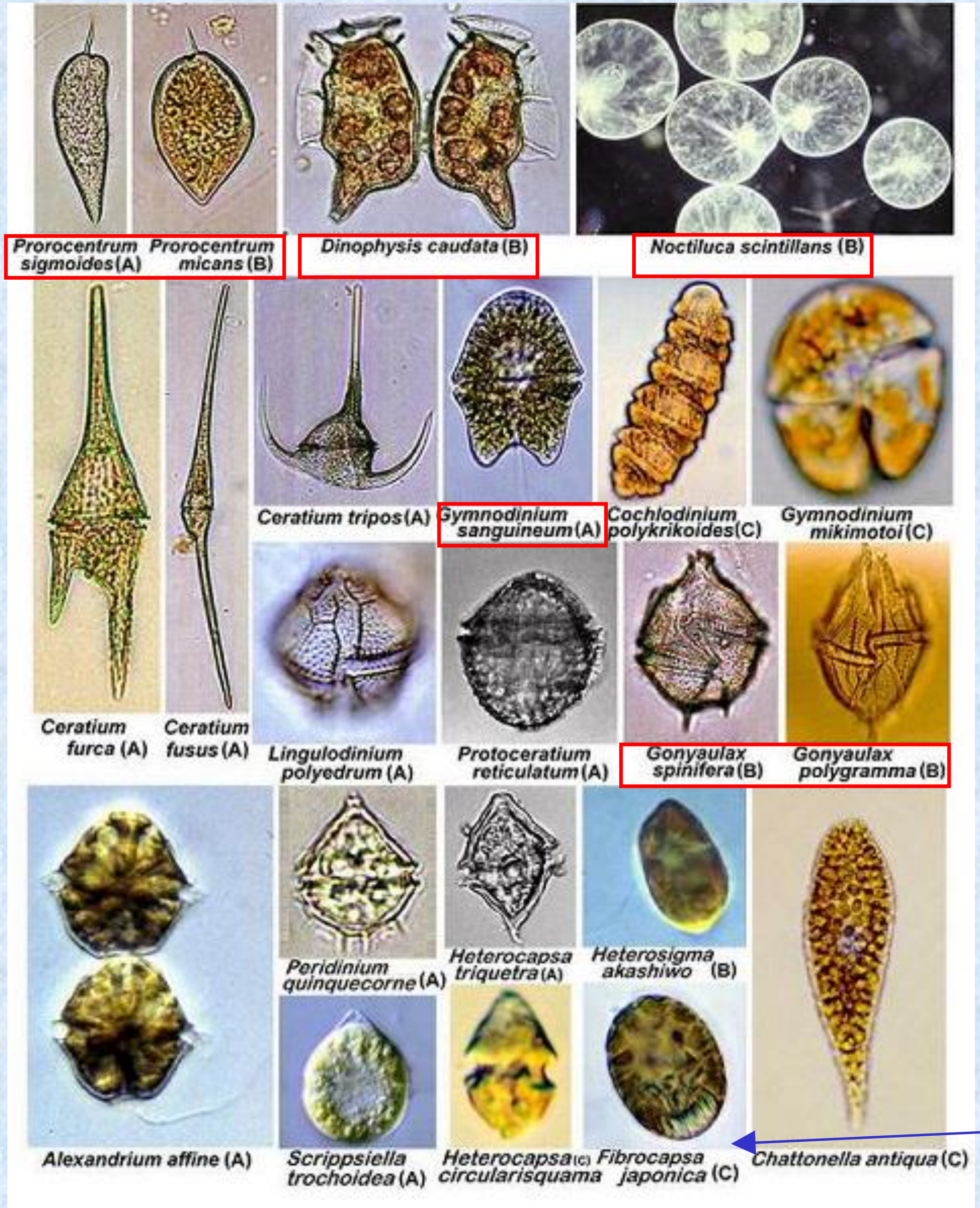
Fosil cysts - hystrichospheres

- age of up to 600 mil. years (precambrium)



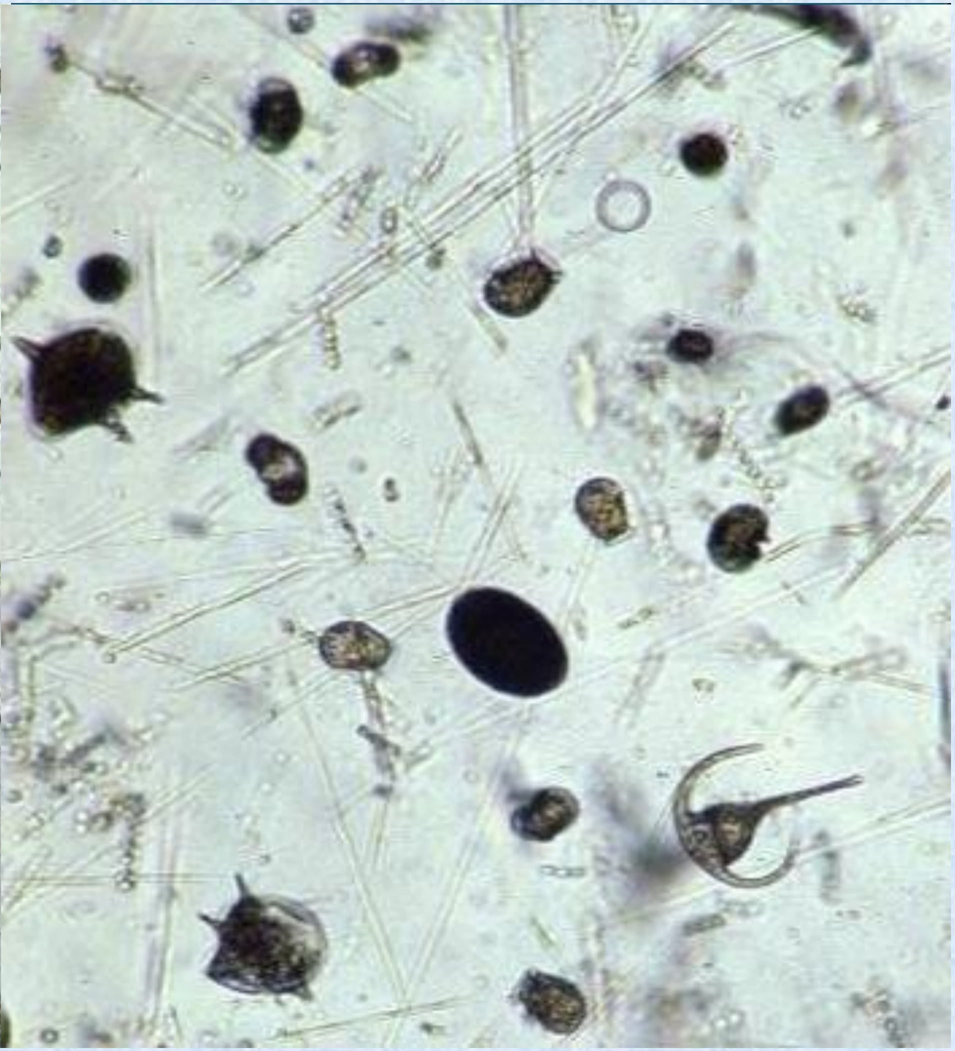
Red tides

Red tides

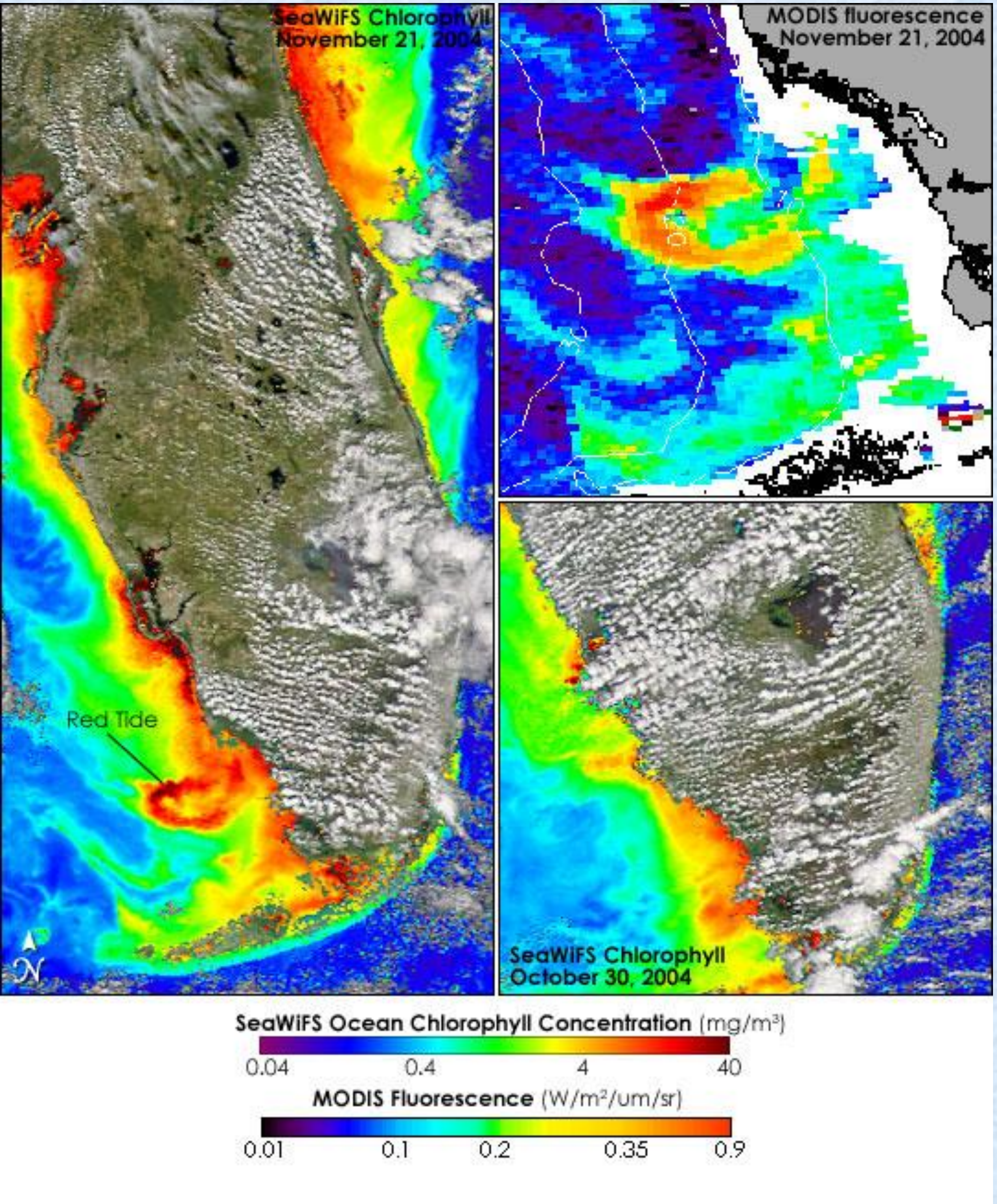


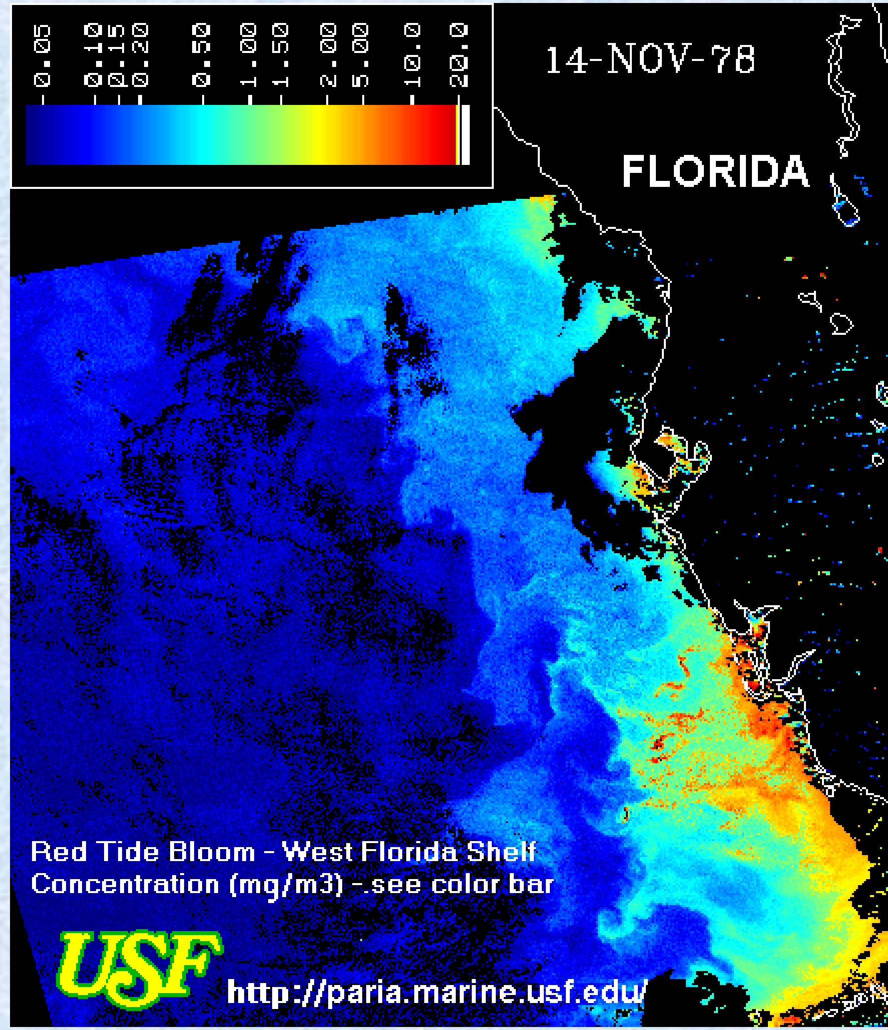
Raphidophyceae

Red tides



Red tides


SeaWiFS Chlorophyll
November 21, 2004
MODIS fluorescence
November 21, 2004
Red Tide
SeaWiFS Chlorophyll
October 30, 2004
SeaWiFS Ocean Chlorophyll Concentration (mg/m³)
0.04
0.4
4
40
MODIS Fluorescence (W/m²/um/sr)
0.01
0.1
0.2
0.35
0.9


0.05
0.10
0.15
0.20
0.50
1.00
1.50
2.00
5.00
10.0
20.0
14-NOV-78
FLORIDA
Red Tide Bloom - West Florida Shelf
Concentration (mg/m3) -.see color bar
USF
http://paria.marine.usf.edu/

Red tides

Red tides

Negative influence on marine organisms

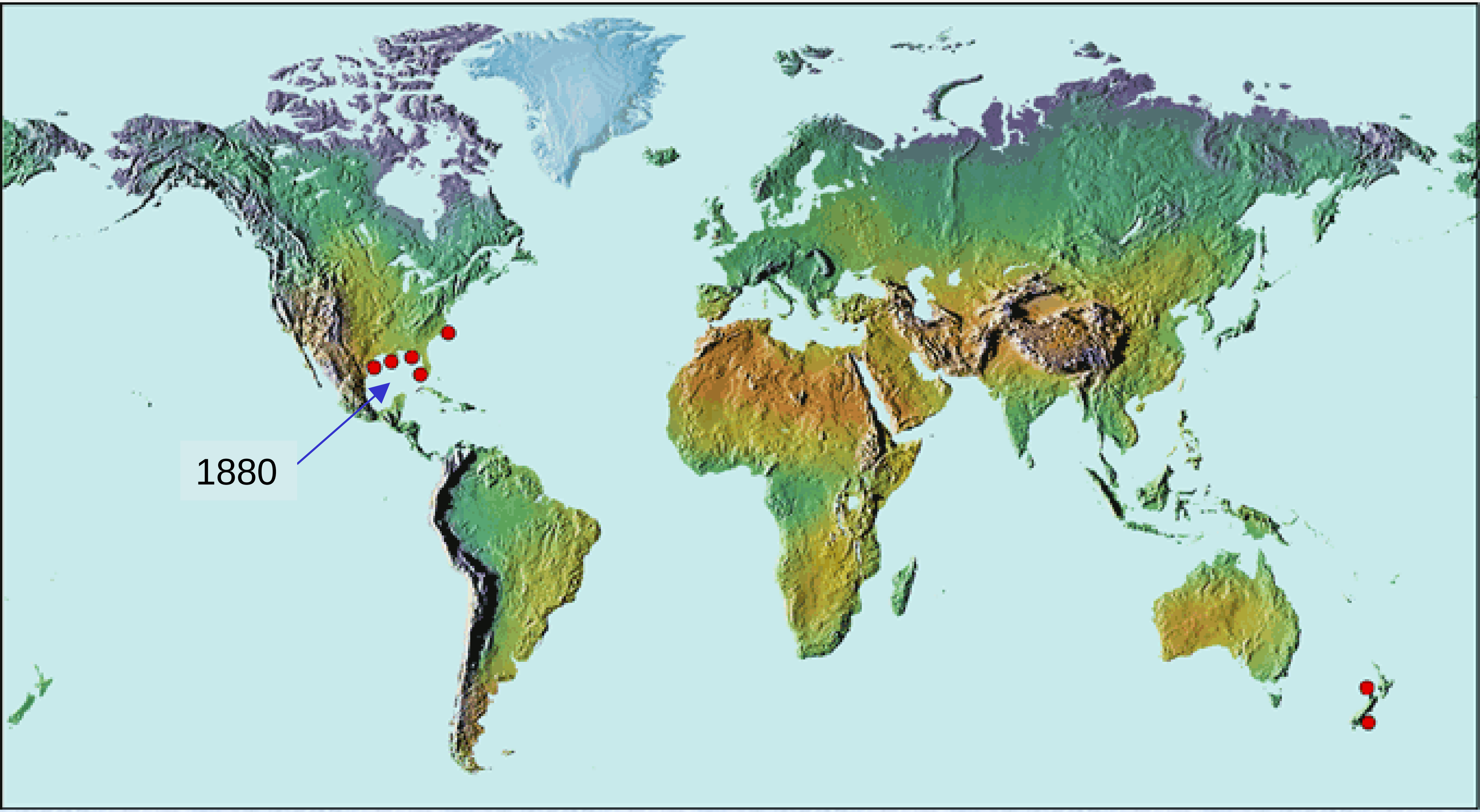
- formation of anoxic environment
- poor light penetration
- plugging of fish gills
- production of toxins

Red tides

Mass mortality of flat-fish by a red tide of *Cochlodinium polykrikoides*

Red tides

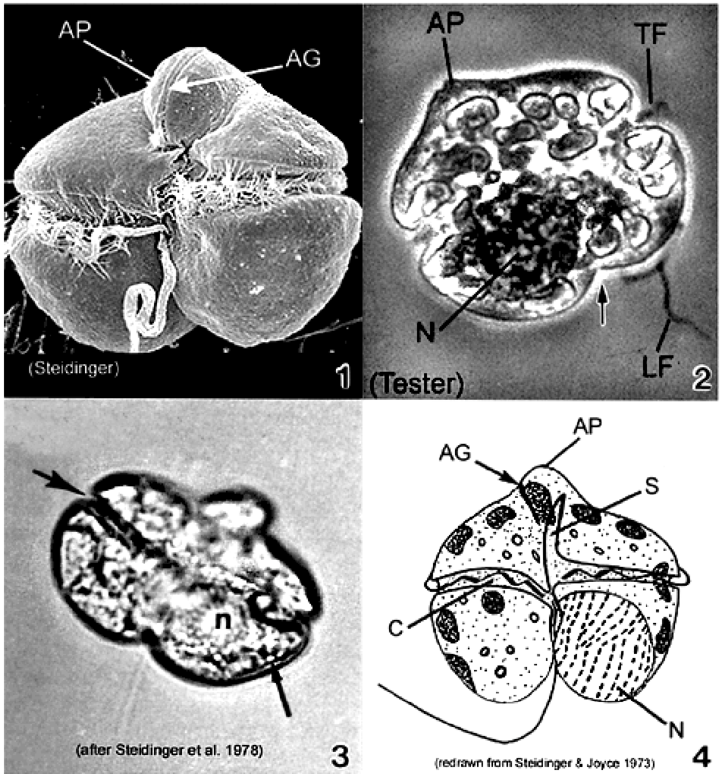
NSP - Neurotoxic Shellfish Poisoning



Red tides

NSP - Neurotoxic Shellfish Poisoning

- *Gymnodinium breve* – brevitoxin
- accumulation in mussel (water filtration)
- neurotoxin – influence on Na^+ canals
- gastroenteritis, neurological and respiratory problems (inhalation of aerosols)

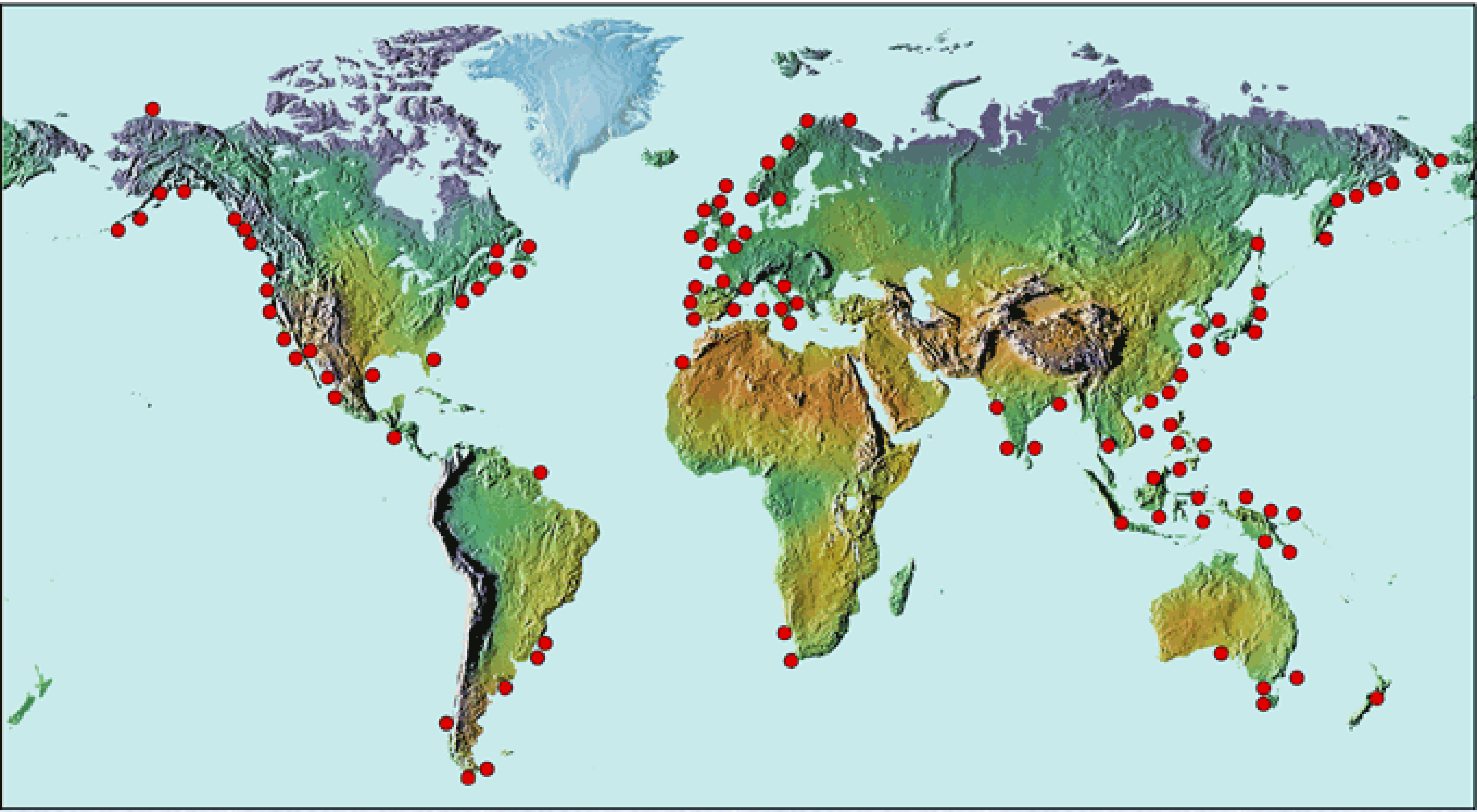


Red tides

NSP - Neurotoxic Shellfish Poisoning

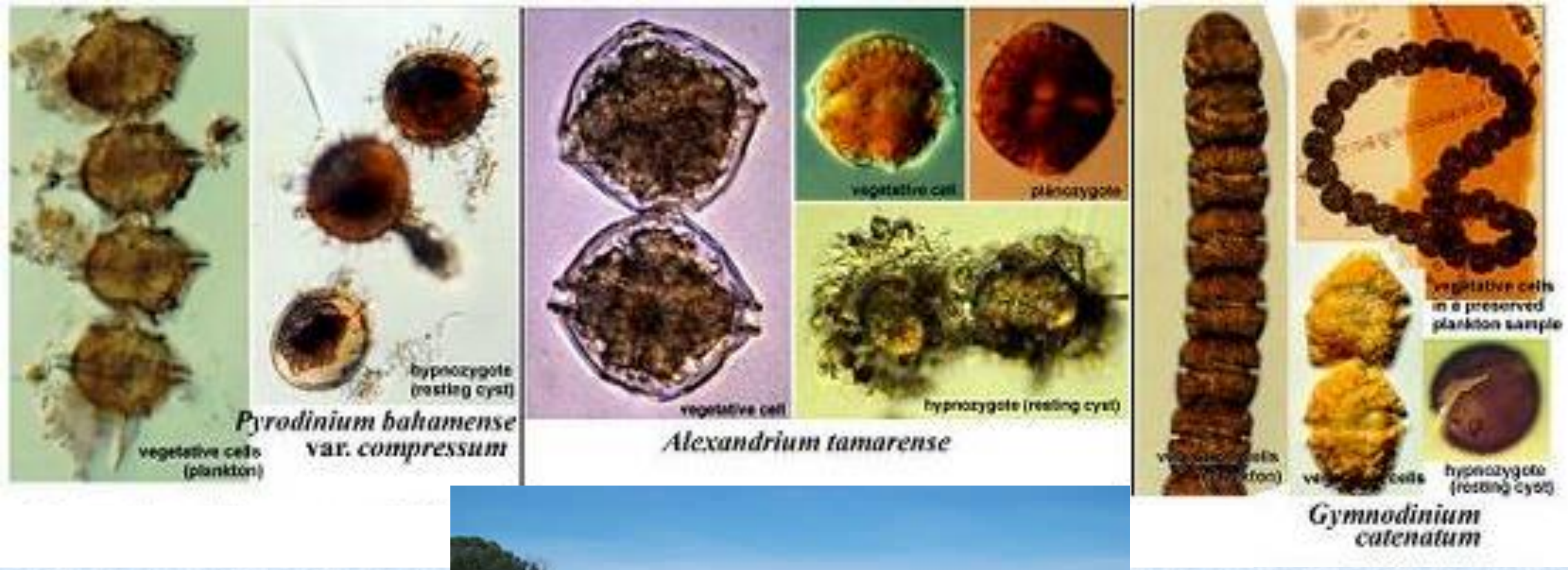
Red tides

PSP - Paralytic Shellfish Poisoning



Red tides

PSP - Paralytic Shellfish Poisoning



Red tides

PSP - Paralytic Shellfish Poisoning

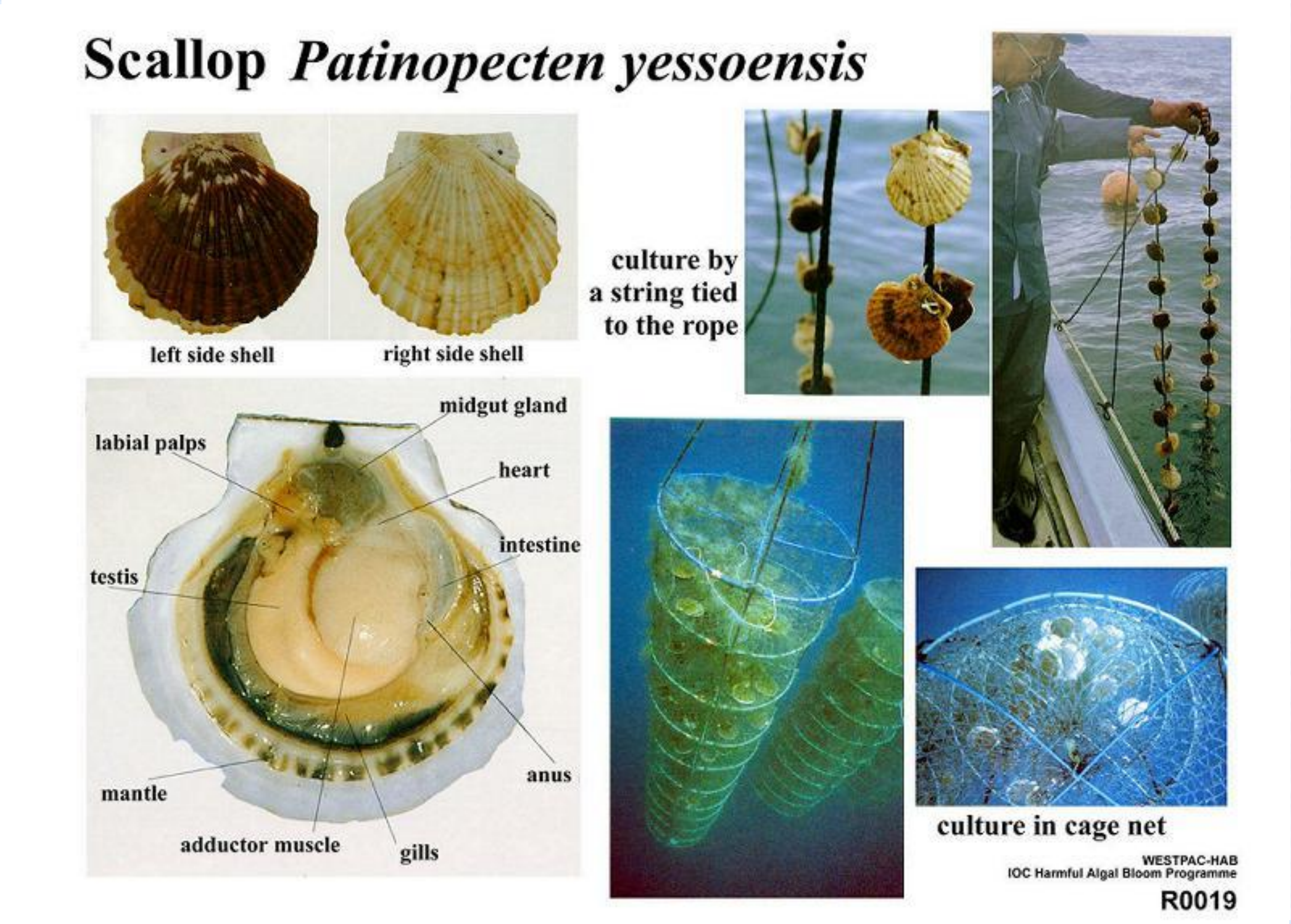
- saxitoxin, neosaxitoxin
- accumulation in mussels
- nausea, vomiting, diarrhea, abdominal pain, brain dysfunction
- rarely complete paralysis, death by suffocation
- no antitoxin
- mortality 8,5 – 9,5 %

Red tides

PSP - Paralytic Shellfish Poisoning

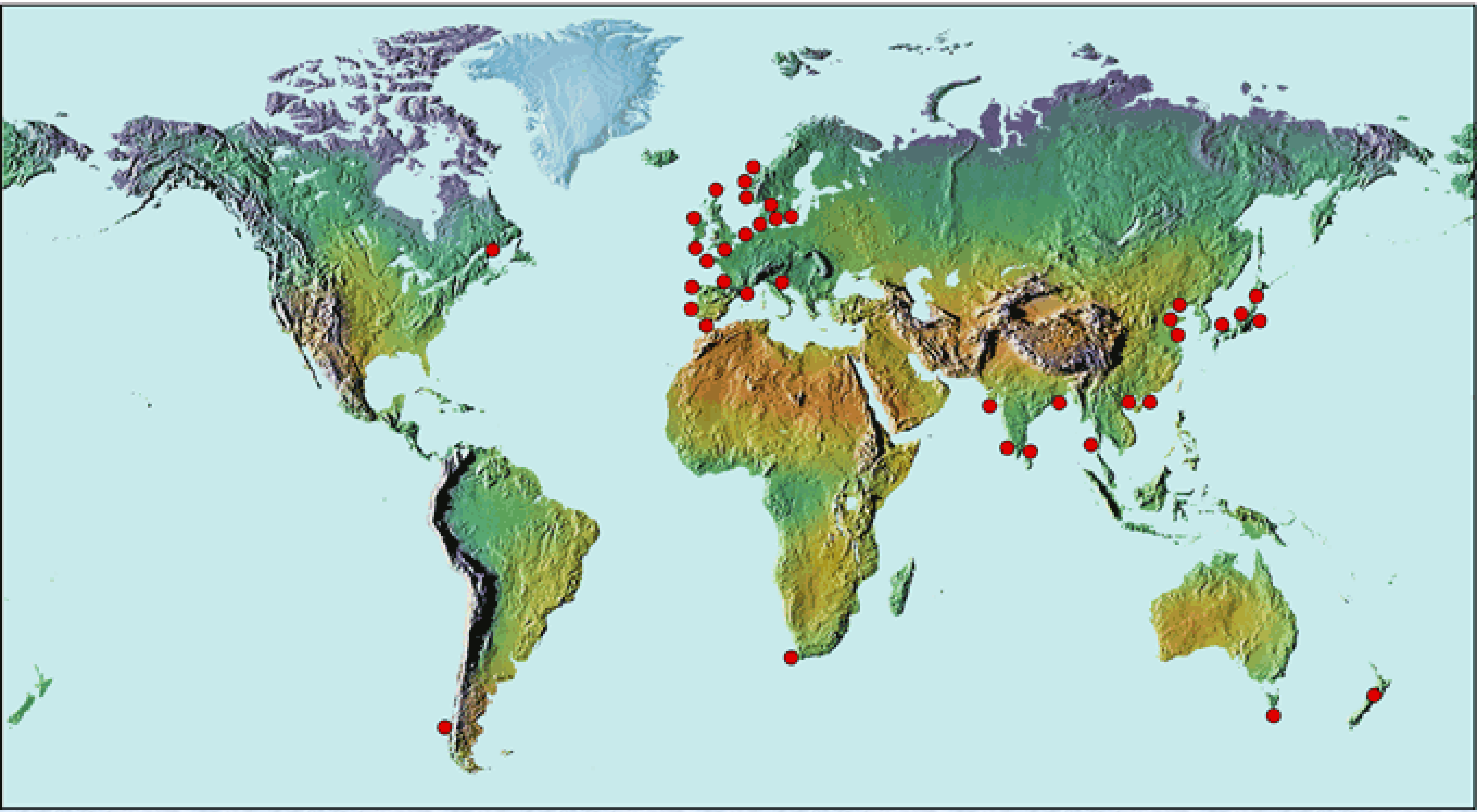
Guatemala 1978: 50 % of all infected children died

Red tides


Scallop *Patinopecten yessoensis*
left side shell
right side shell
culture by
a string tied
to the rope
midgut gland
labial palps
heart
intestine
testis
mantle
anus
adductor muscle
gills
culture in cage net
WESTPAC-HAB
IOC Harmful Algal Bloom Programme
R0019

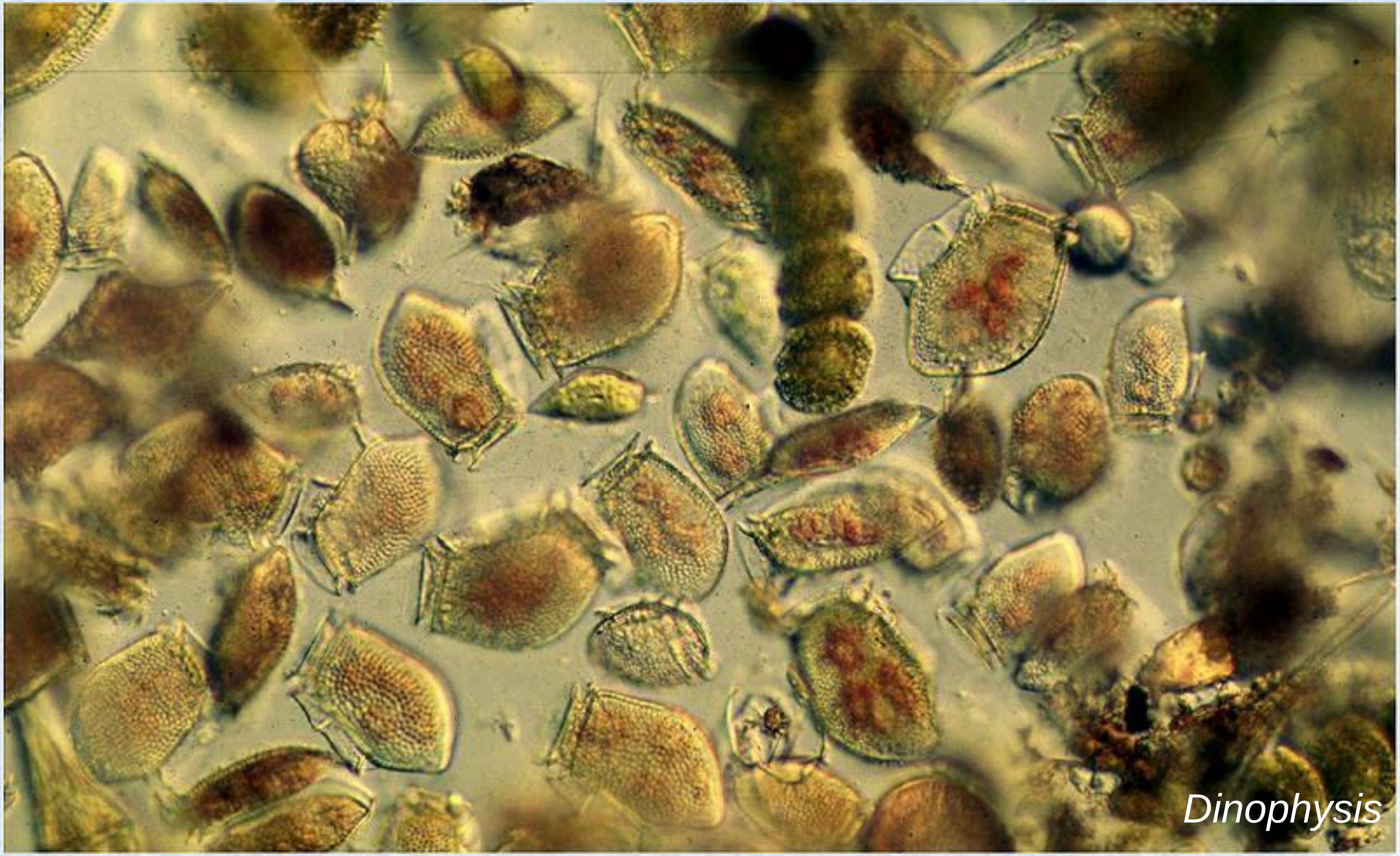
Red tides

DSP - Diarrhetic Shellfish Poisoning



Red tides

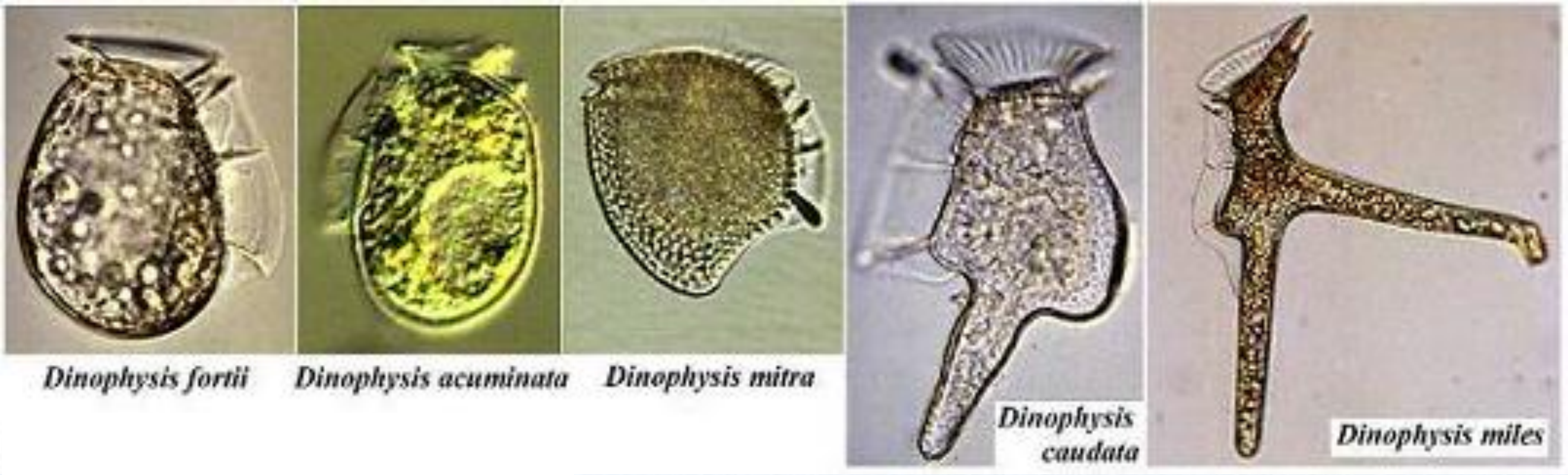
DSP - Diarrhetic Shellfish Poisoning



Red tides

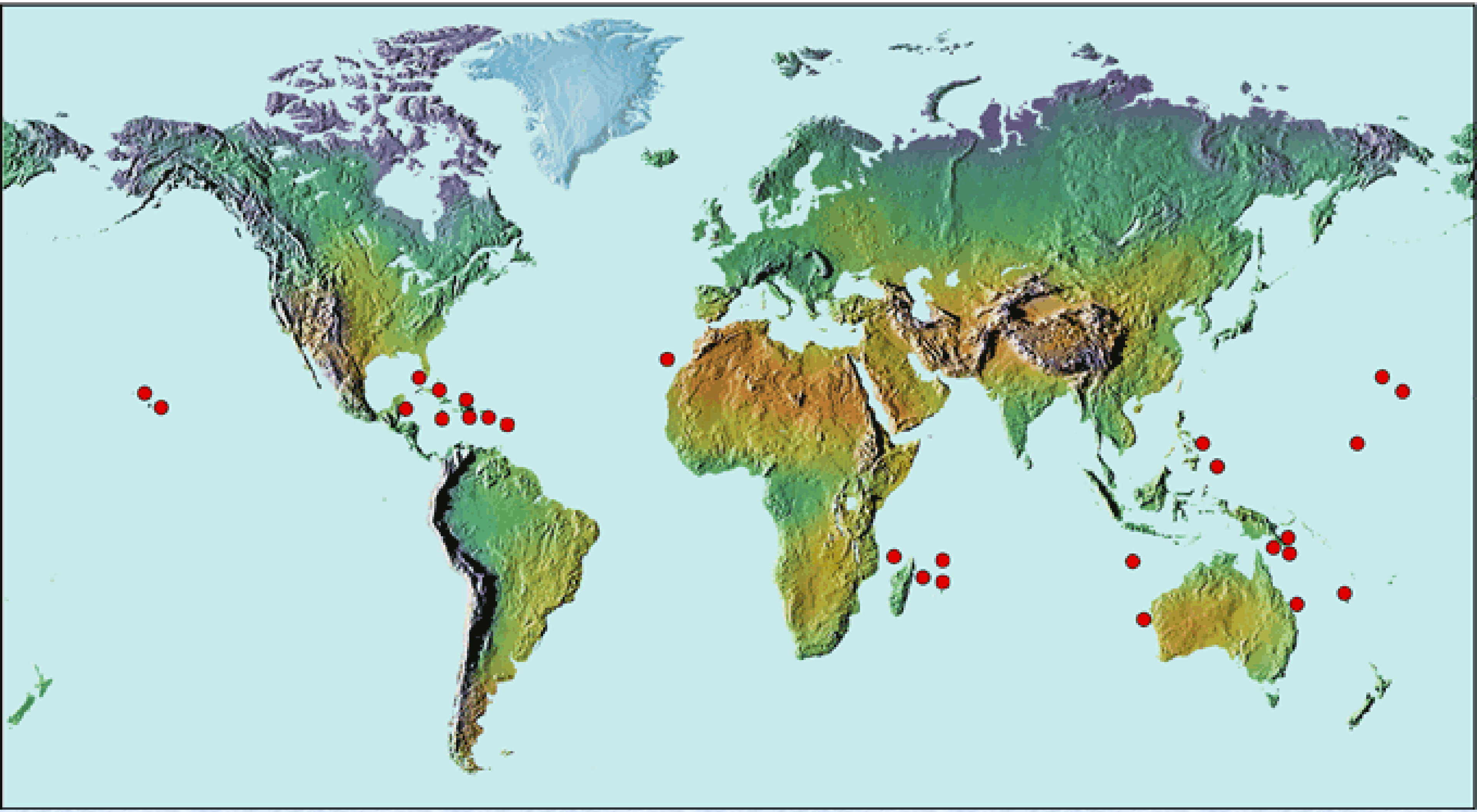
DSP - Diarrhetic Shellfish Poisoning

- gastrointestinal symptoms, no neurological symptoms
- accumulation in mussles
- diarrhea, vomiting, hospitalisation not needed



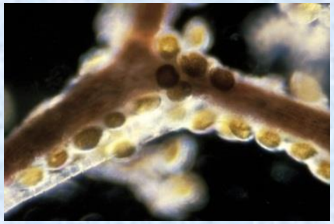
Red tides

CFP – Ciguaterra Fish Poisoning



Red tides

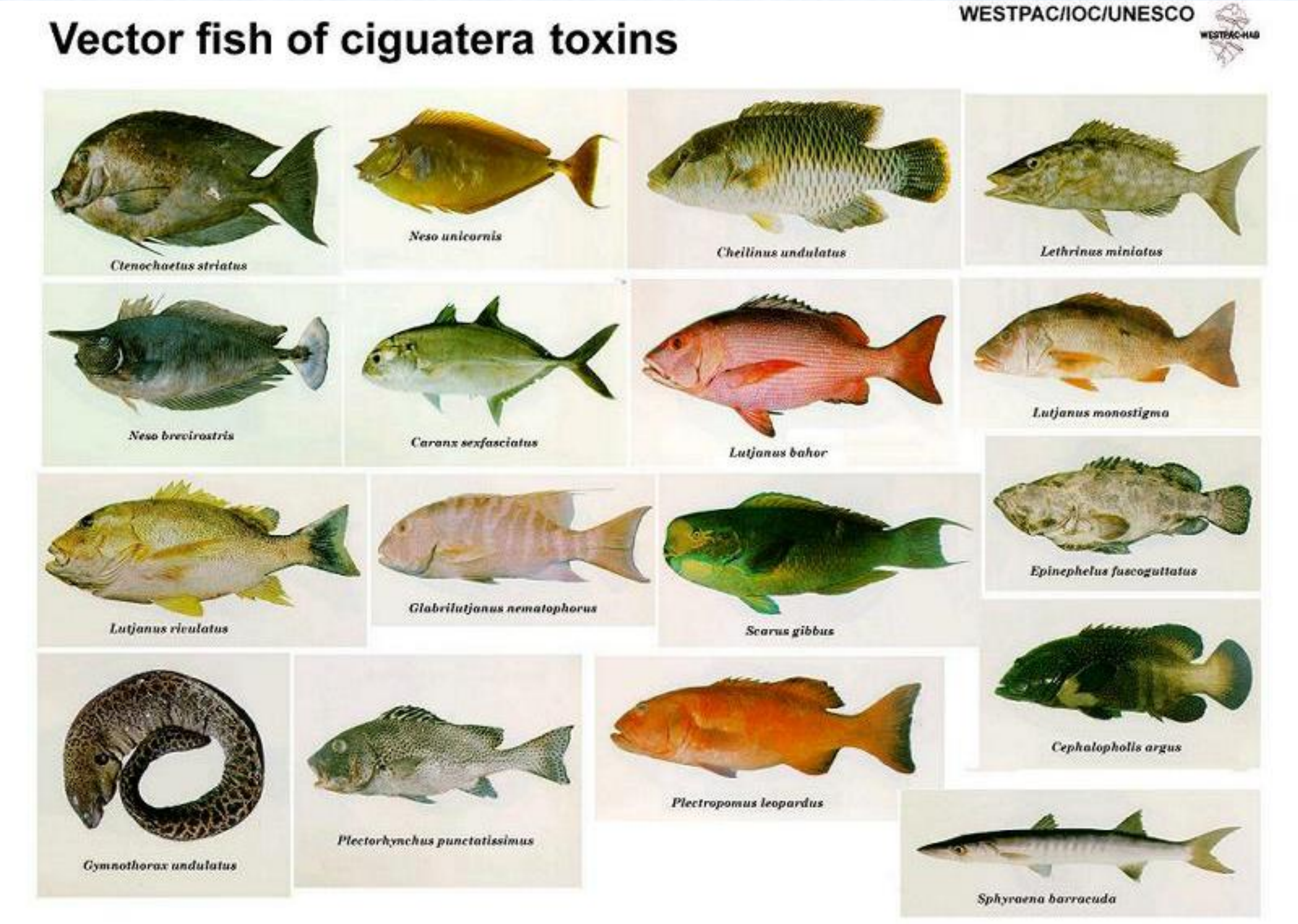
CFP – Ciguaterra Fish Poisoning



- the most common disease caused by marine toxins (50 000 cases per year)
- *Gambierdiscus toxicus*
- accumulation in marine tropical fish (barracuda, ...)
- <u>gastrointestinal symptoms:</u> diarrhea, vomiting <u>neurological symptoms</u>: hallucinations, burning sensation on contact with cold <u>cardiological symptoms</u>: arytmia, cardiac arrest
- mortality 0,1 – 12 % (pulmonary arrest, cardiac arrest)

Red tides

CFP – Ciguaterra Fish Poisoning



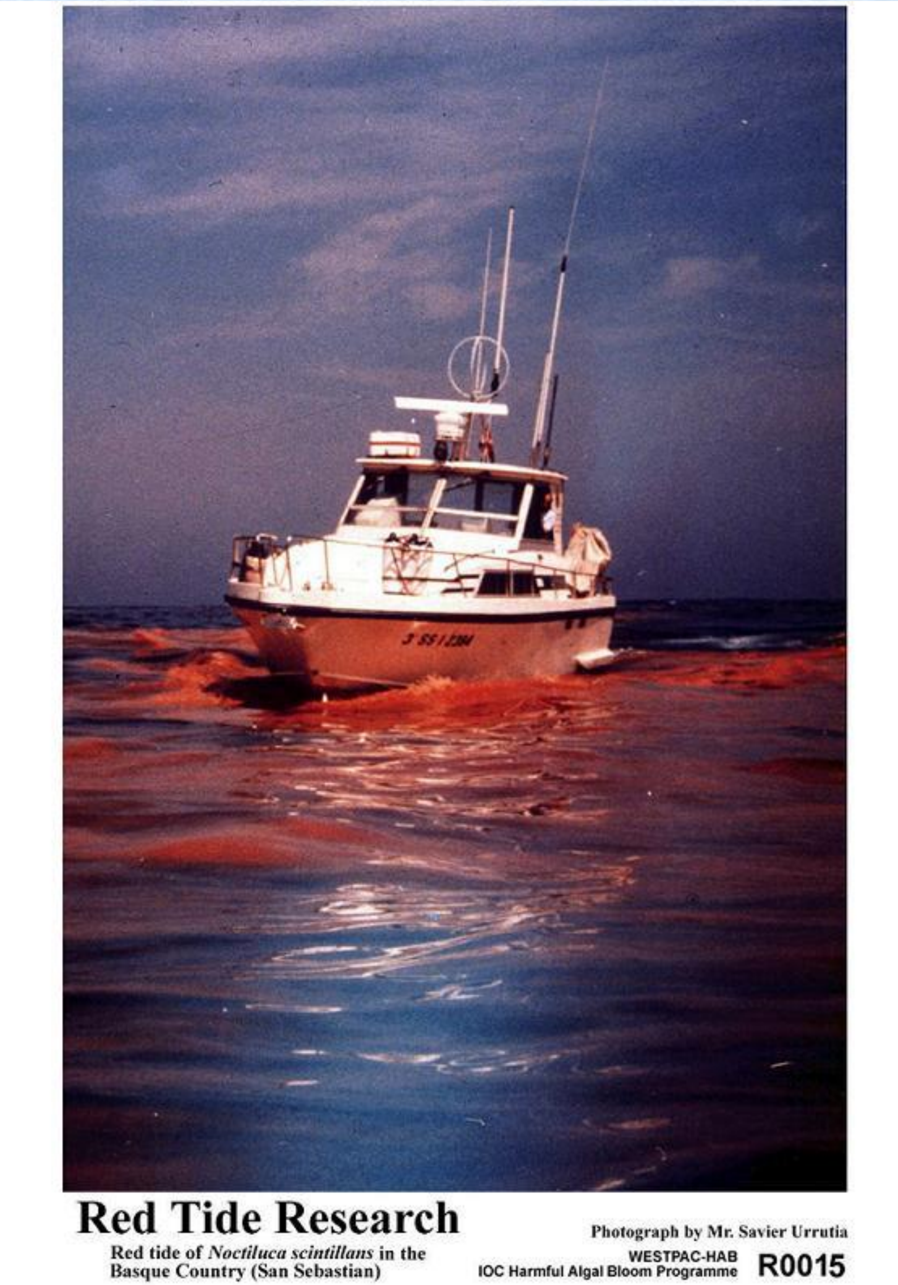
Red tides

Shrimp culture farms in mangrove along the coast of the Gulf of Thailand

Photo by Dr. Thaithaworn Lirdwitayaprasit of the Department of Fisheries of Thailand

IOC-WESTPAC HAB R0006

Red tides



Red alert . . . commercial fisherman Ted Allan with a sample of the red algae at Little Manly yesterday PHOTO: Julian Andrews

Pollution alert

SWIMMERS were warned to stay out of the water yesterday as a tide of red algae washed into Manly Cove and storm-water pollution fouled Queenscliff Beach.

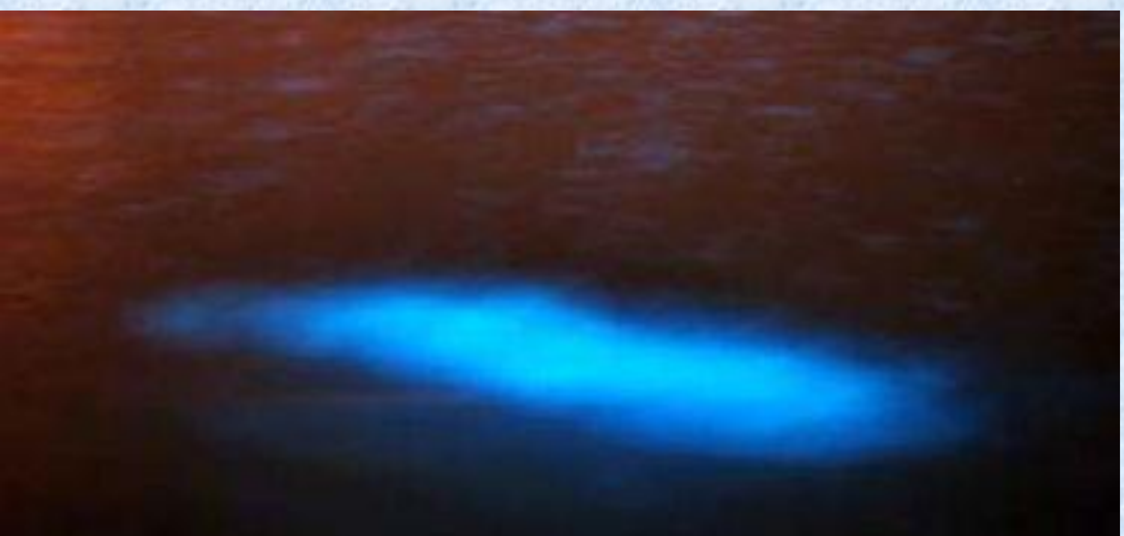
Beachwatch manager Steve Higham and ocean beaches by recent heavy rain.

Commercial fisherman Ted Allan said he was initially alarmed at the sight of the red substance, which he thought might have been ballast water dumped from a ship.

(The Manly Daily, 19th February, 1997)

Bioluminescence

- animals, bacteria, …; among autotrophic organisms only dinoflagellates
- lucipherin (oxidation catalyzed by lucipherase)
- reduction of predation
- mechanically, chemically or osmotically mediated

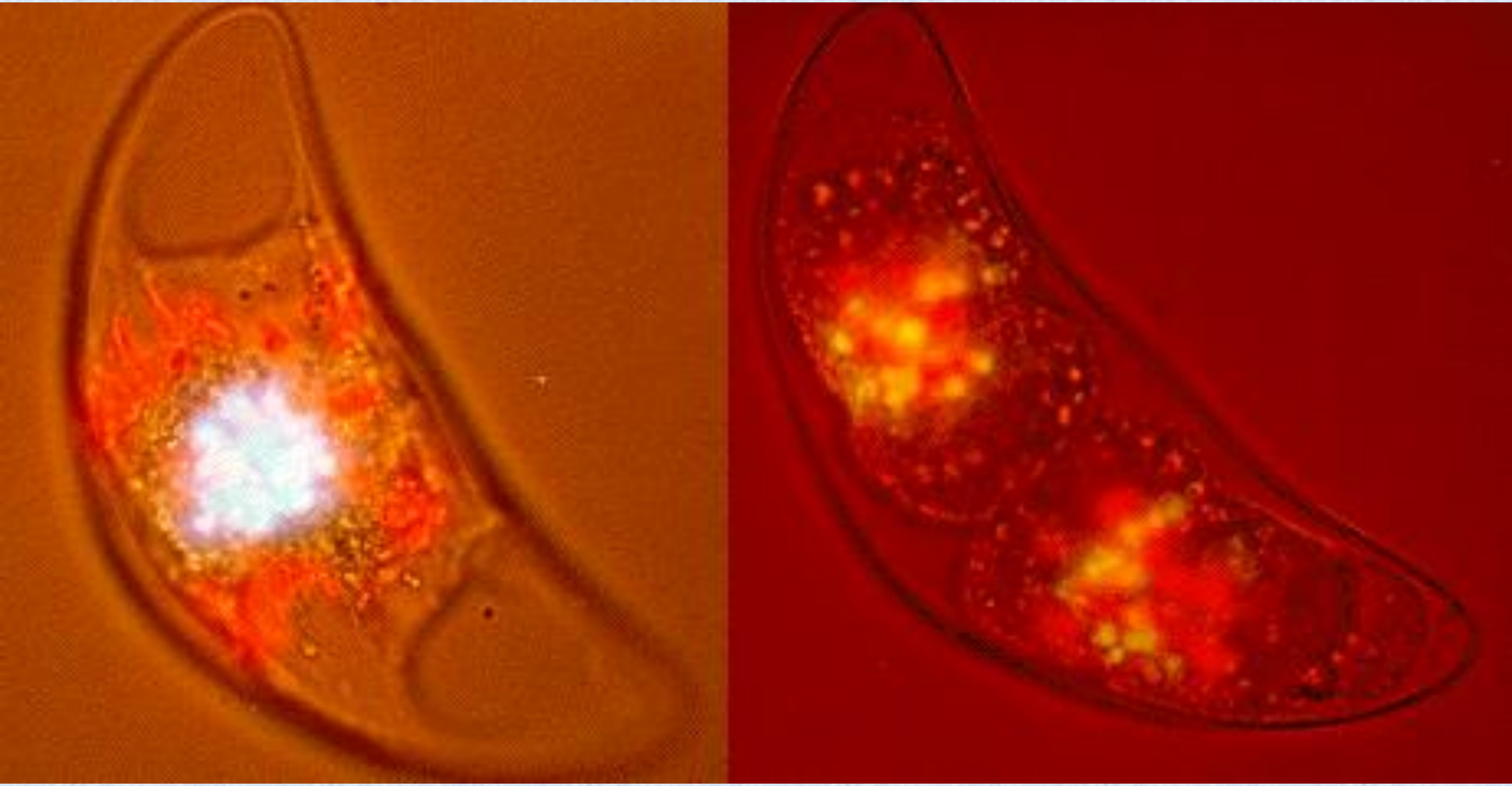


Bioluminescence

Noctiluca scintillans - scintilons

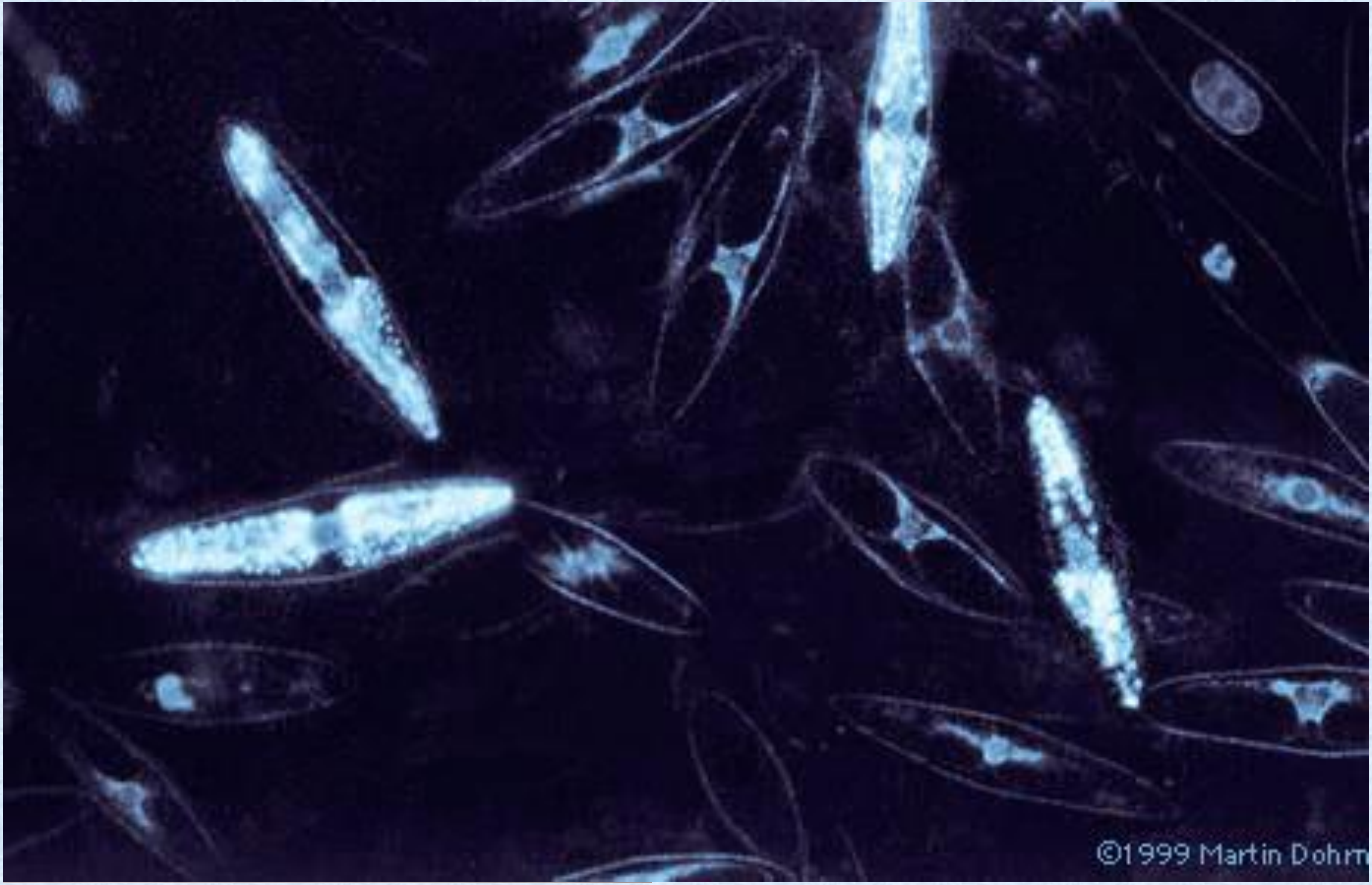
Bioluminescence

Pyrocystis - scintilons



Bioluminescence

Pyrocystis fusiformis



Bioluminescence

Pyrocystis fusiformis

Lights From The Sea *(Pyrocystis fusiformis)* is a study in Marine Science. These tiny plants live in the ocean. They are unicellular algae, which look like delicate, beautiful, golden eyes, and produce oxygen and sugars like all plants do. In the dark, Lights From The Sea produce glowing blue light. *Pyrocystis* sets its bioluminescence by a biological clock (just like our sleep patterns). At sunset the cells produce the chemicals that cause a luciferin-luciferase reaction. You can see the general shape of the plant through a magnifying glass. You do not need to feed them since they use the light in your room to photosynthesize producing their own oxygen and food. Lights From The Sea can last several weeks to months. You must treat them as you would a delicate plant or a bouquet of flowers. They need light but prefer to remain between 50 and 70 degrees Fahrenheit. *Pyrocystis fusiformis* is a visually exciting marine science, great for science fairs, classroom learning, and special events. Lights From The Sea Price List

QUANTITY/PRODUCT	SHIP U.S. PRIORITY
(3) 50 ml bags	$20.00
(10) 50 ml bags	$50.00
(30) 3 ml vials	$30.00
(30) 10 ml tubes	$45.00
(1) 1 liter container	$80.00

Why the dinoflagellates shine?

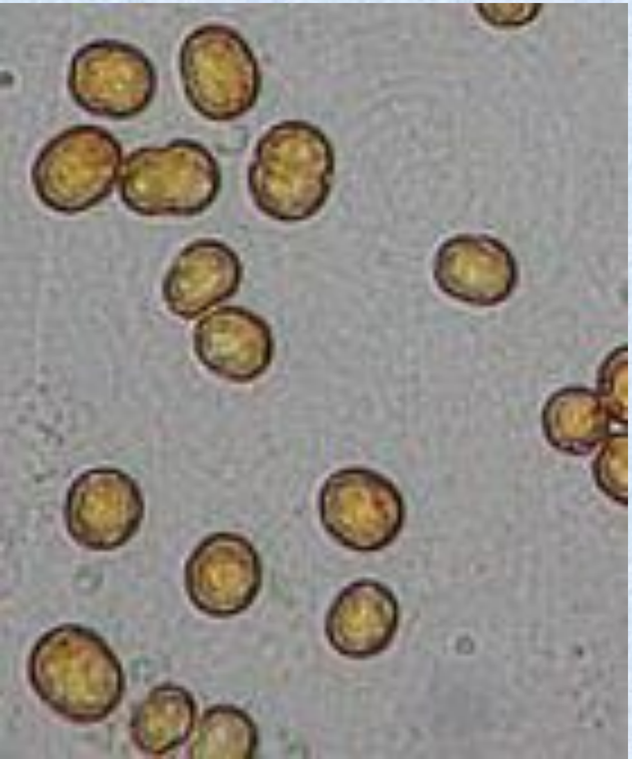
(A) startling predatory copepods
(B) warning potential predators of toxicity,
(C) drawing the attention of higher order visual predators to the copepod's location.

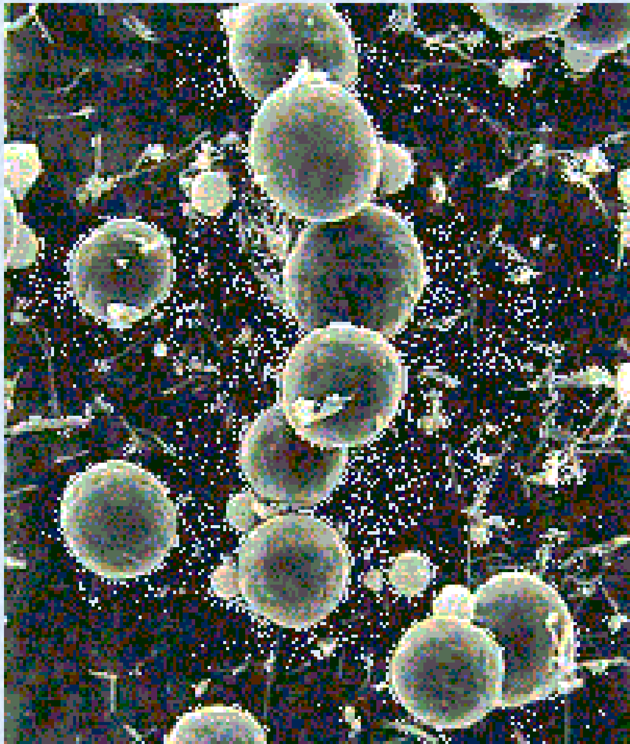
Why the dinoflagellates shine?

They probably produce the light to help predators preying herbivors of dinoflagellates http://www.youtube.com/watch?v=bCNjXaMPZxw

Symbiotic dinoflagellates

- green algae (zoochlorells) - in freshwater habitats and terrestrial ecosystems
- dinoflagellates (zooxanthels) – in marine environments





Symbiotic dinoflagellates

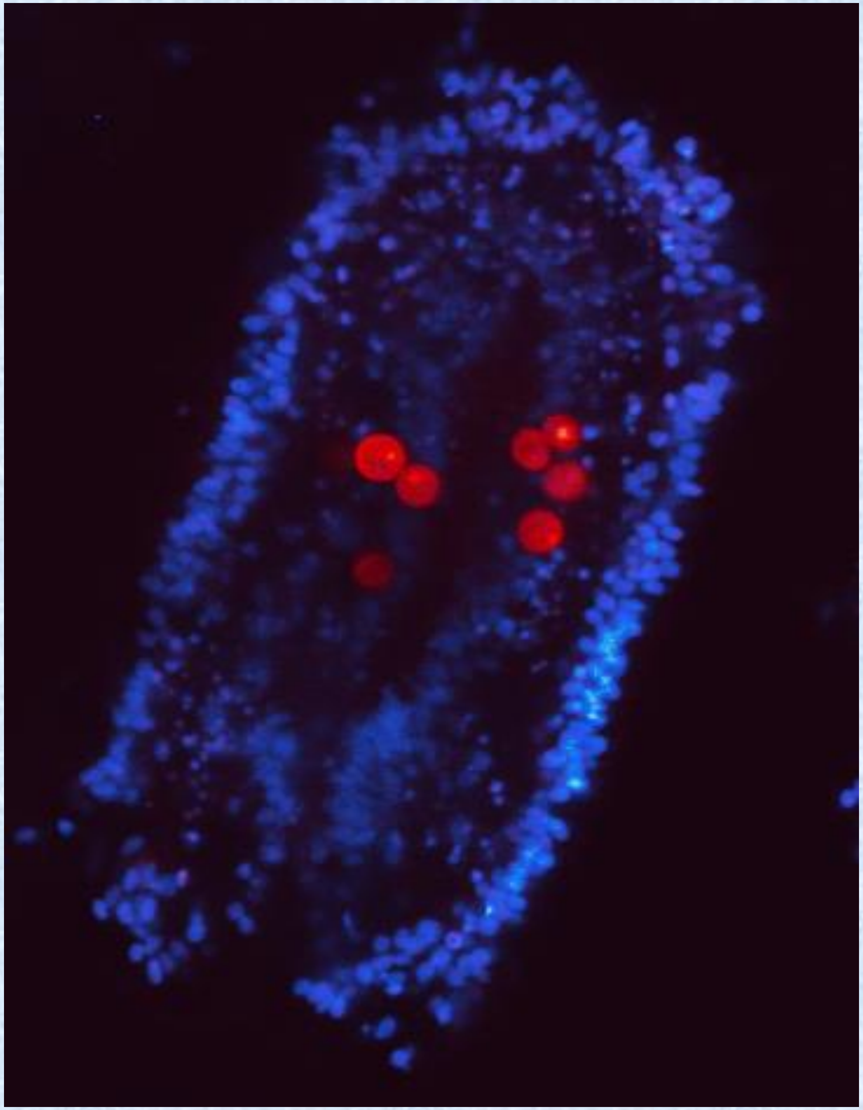
cnidarians - corals

Symbiotic dinoflagellates

cnidarians – sea anemones

Symbiotic dinoflagellates

Fungia scutaria, planula

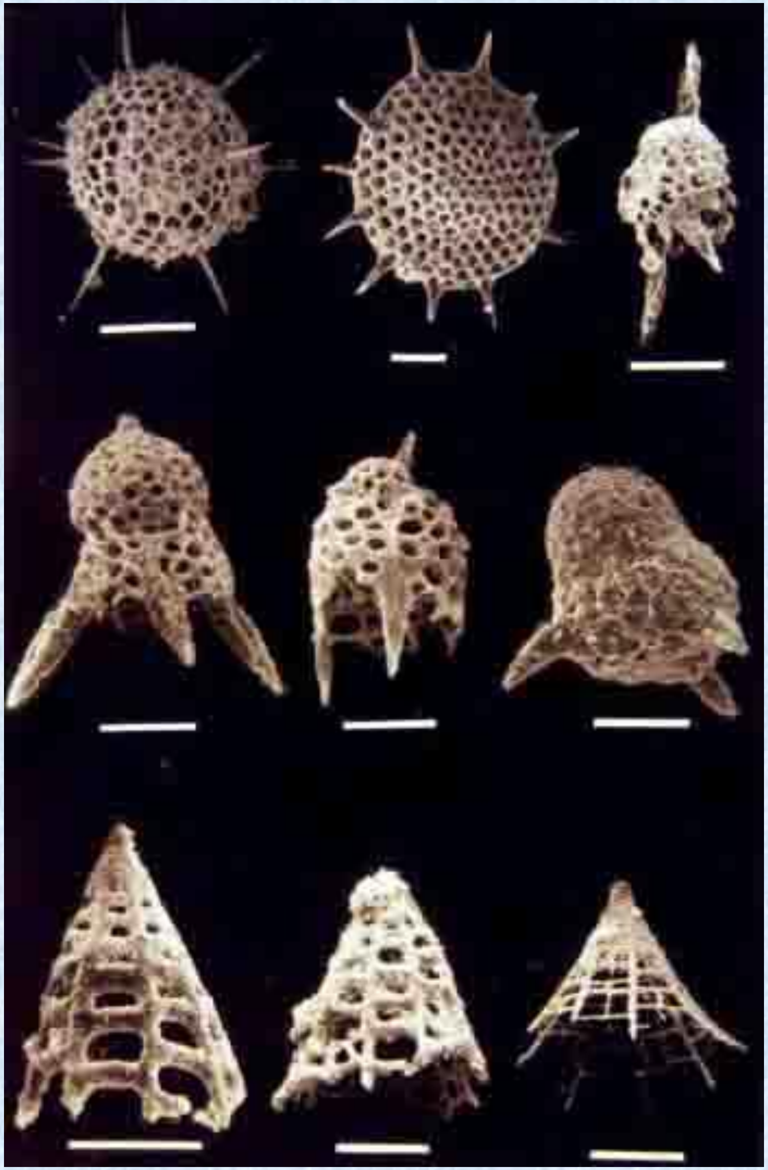


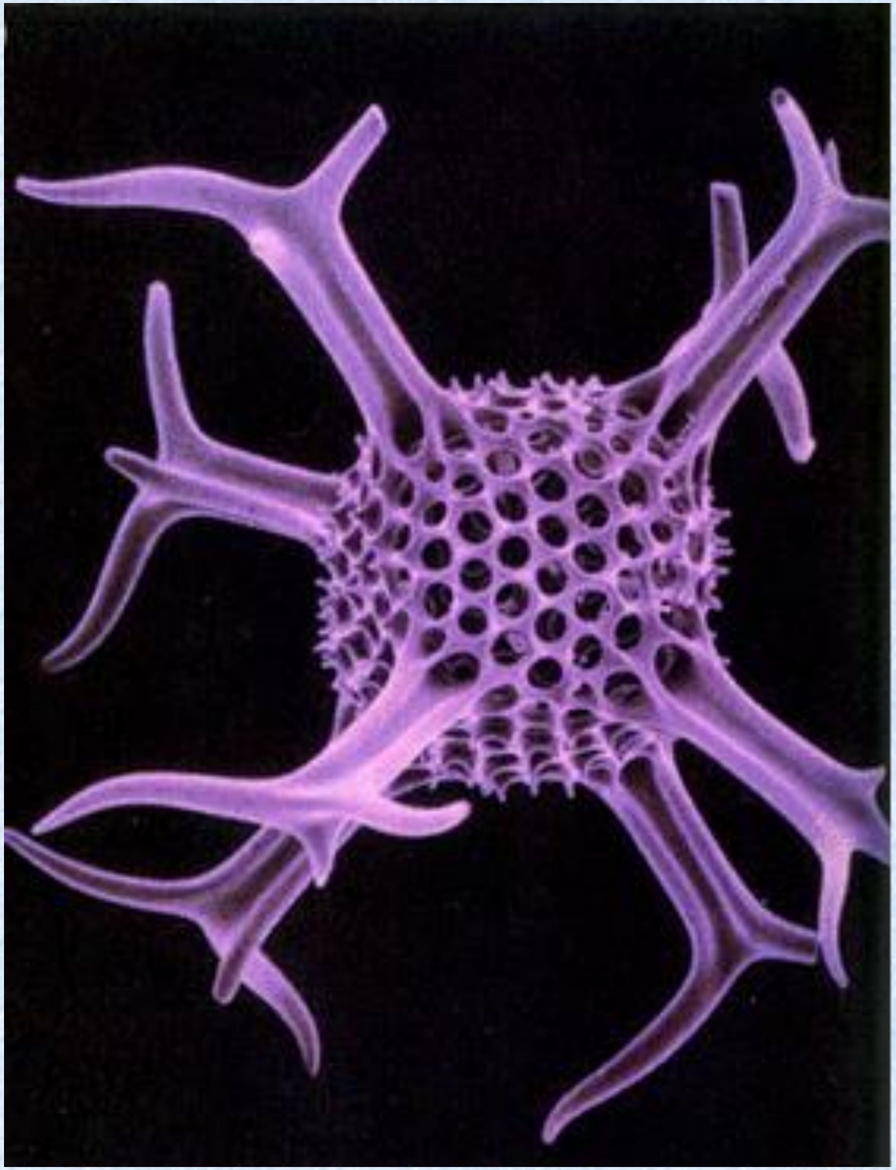
Symbiotic dinoflagellates

cnidarians - jellyfish

Symbiotic dinoflagellates

Radiolaria





Symbiotic dinoflagellates

Foraminifera