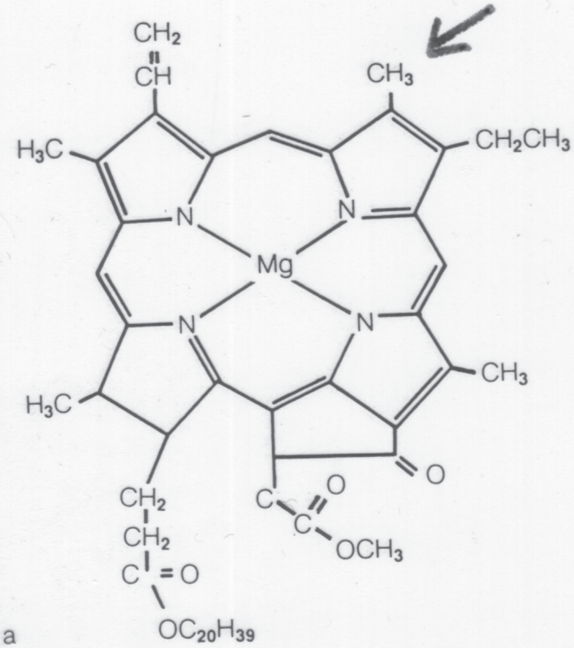
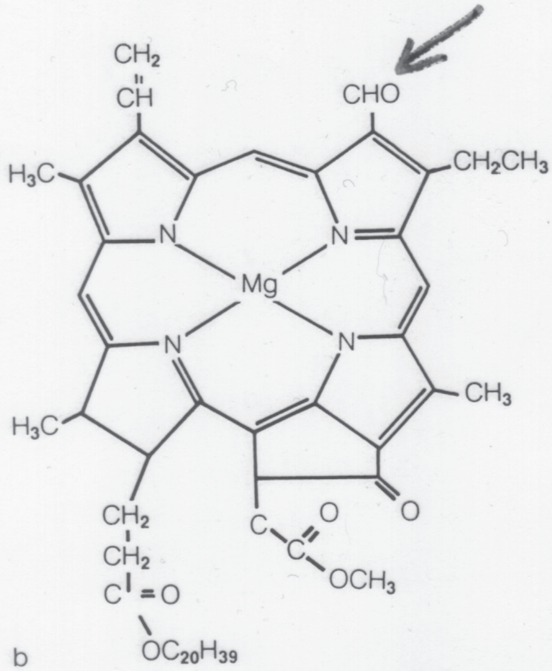
CHLOROPHYLLS

Chl a

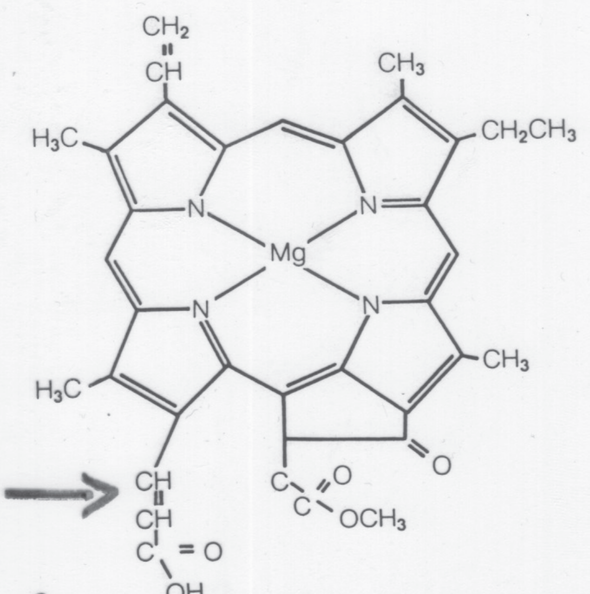


a

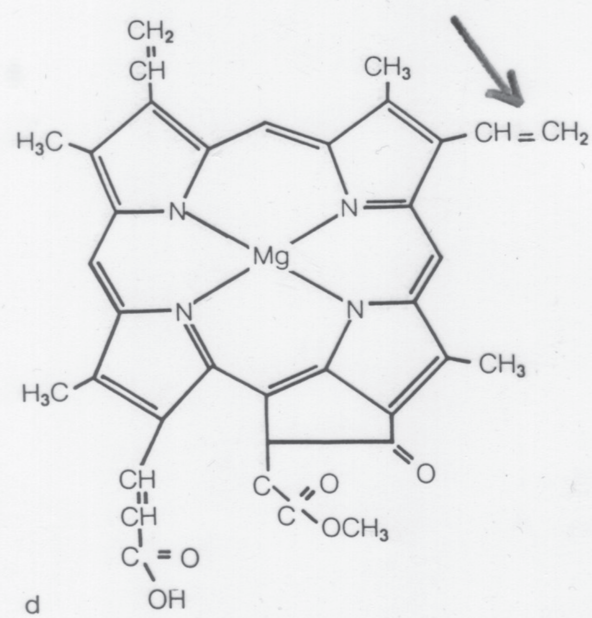
Chl b



b



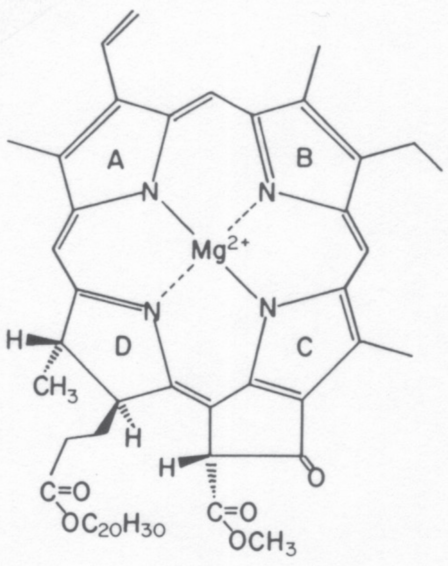
c



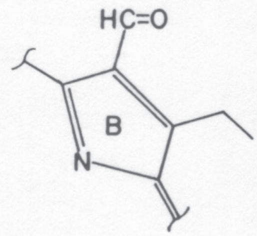
d

Chl c_1

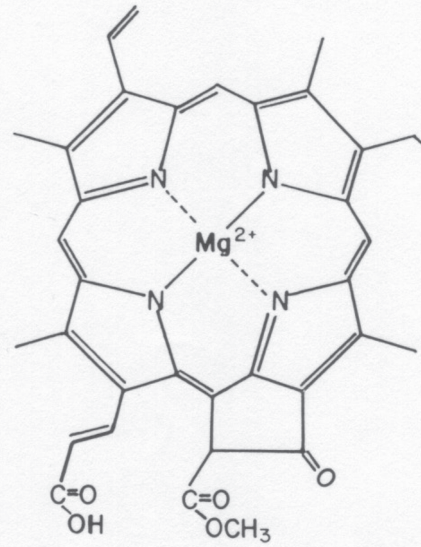
Chl c_2



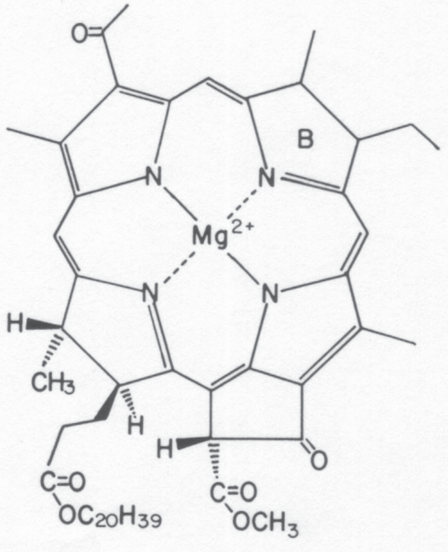
Chlorophyll a



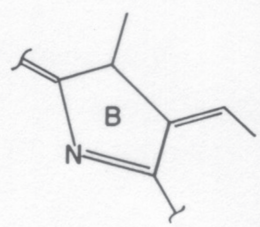
Chlorophyll b



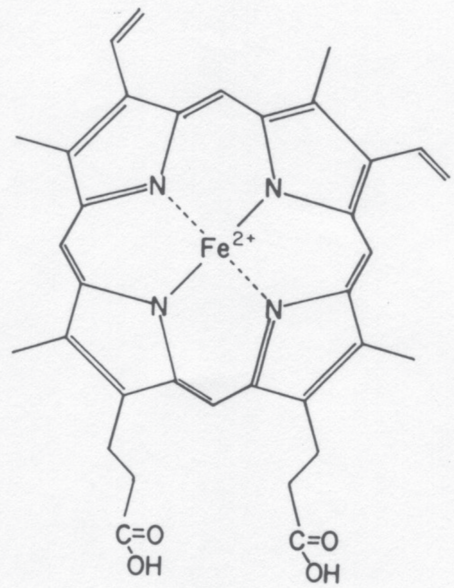
Chlorophyll c_1



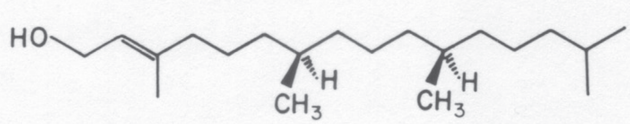
Bacteriochlorophyll a



Bacteriochlorophyll b



Heme



Phytol ($HOC_{20}H_{39}$)

TABLE 3.2. Distribution of Chlorophylls among Photosynthetic Organisms

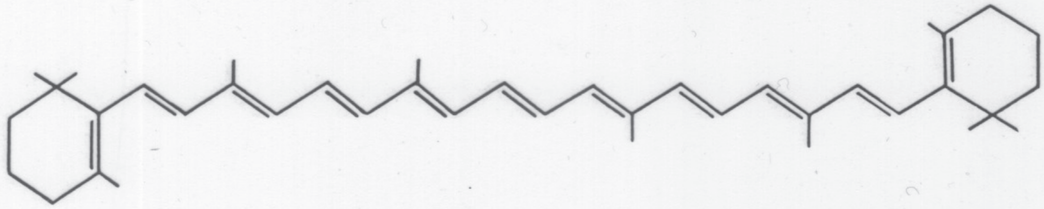
Organism	Chlorophyll *a*	Chlorophyll *b*	Chlorophyll *c*
Cyanophyta	+	−	−
Rhodophyta	+	−	−
Cryptophyta	+	−	+
Dinophyta	+	−	+
Chrysophyta			
Xanthophyceae	+	−	−
Chrysophyceae	+	−	+, −
Bacillariophyceae	+	−	+
Phaeophyta	+	−	+
Euglenophyta	+	+	−
Chlorophyta	+	+	−
Higher Plants	+	+	−

(+) Indicates the presence and (−) indicates the absence of the specific form of chlorophyll.

CAROTENOIDS

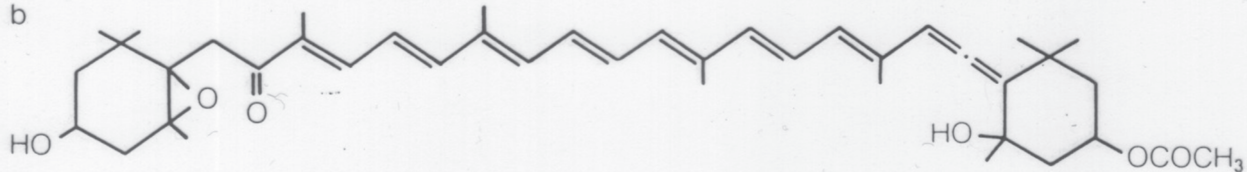
β carotene

a



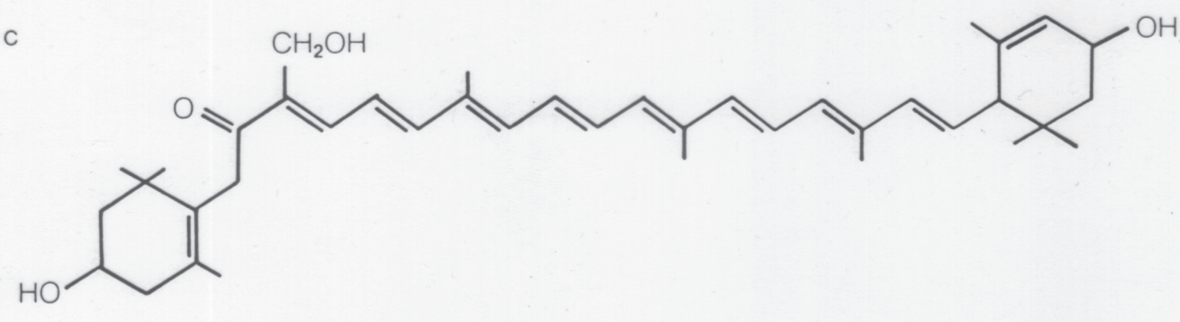
fucoxanthin

b



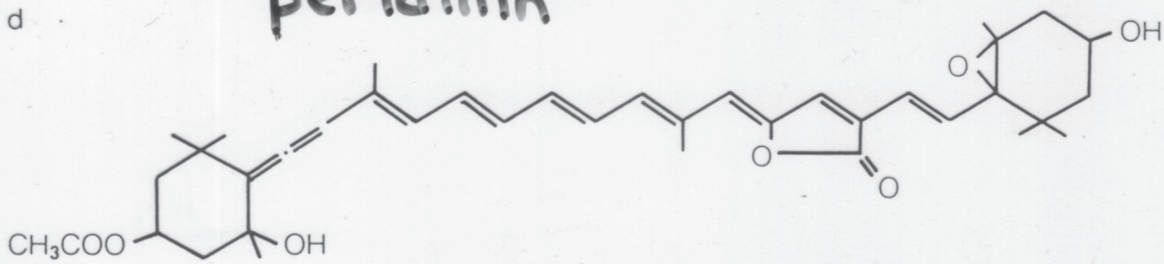
siphonaxanthin

c

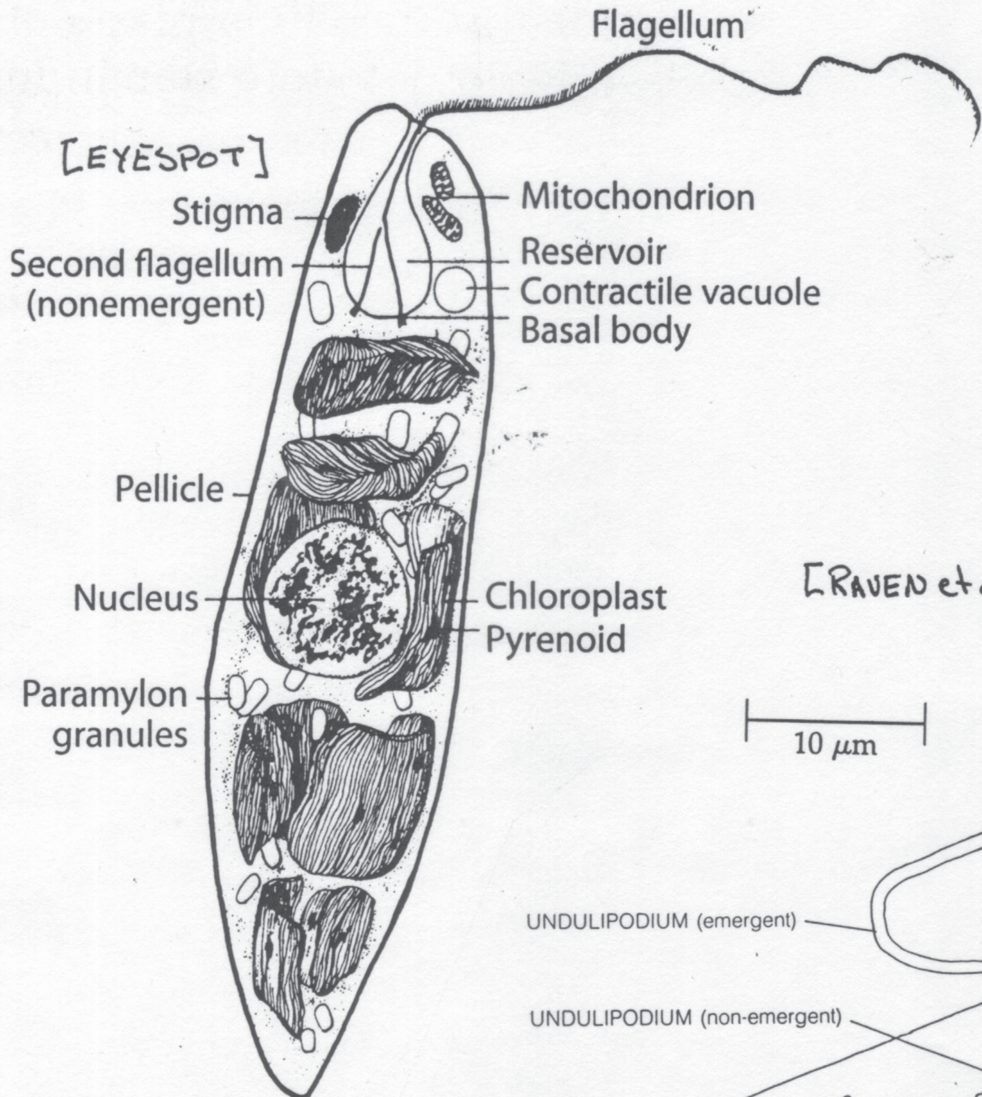


peridinin

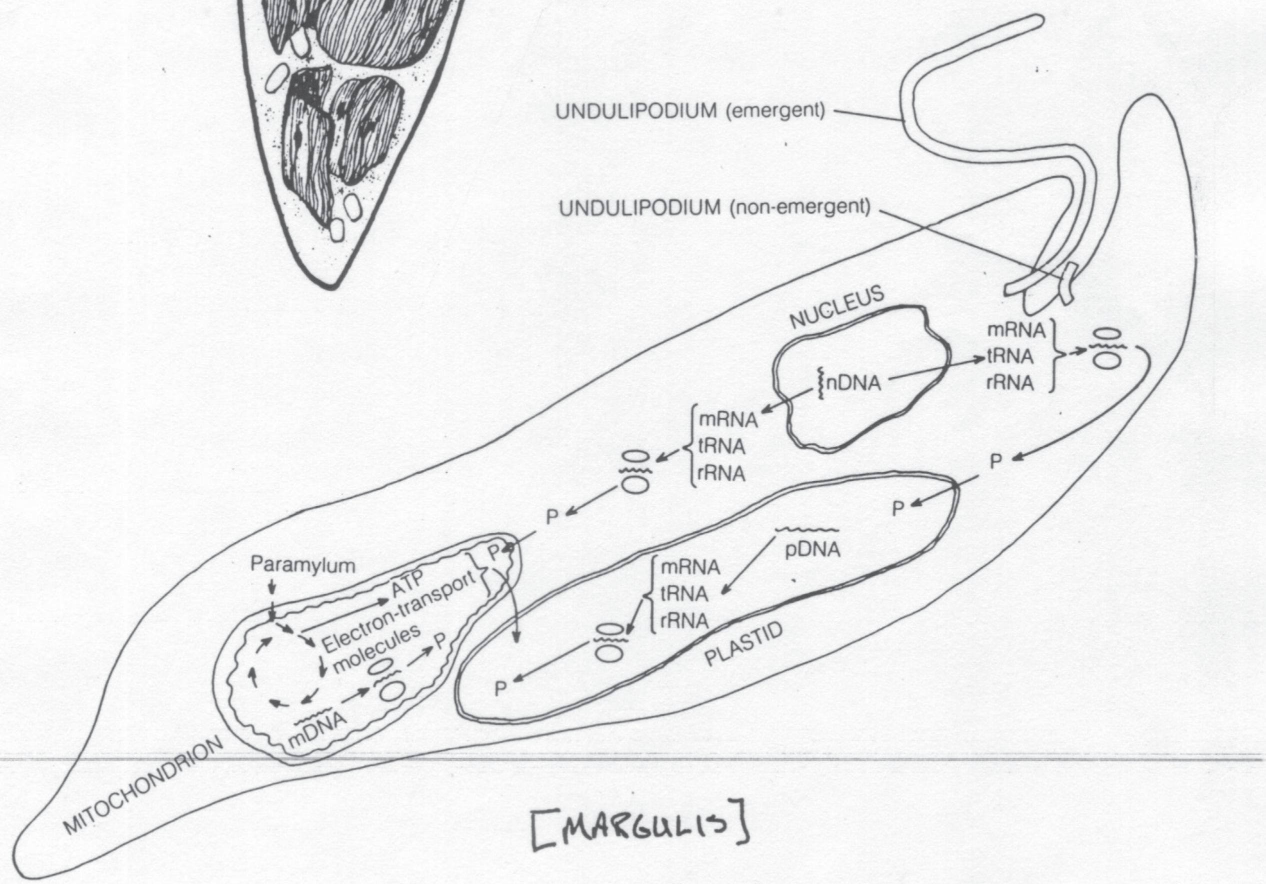
d



1

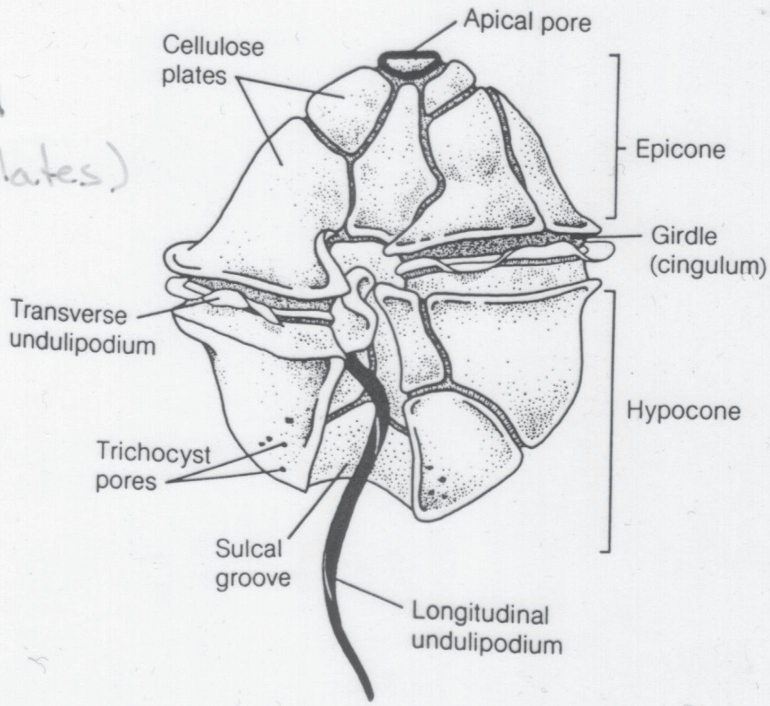


[RAVEN et al.]

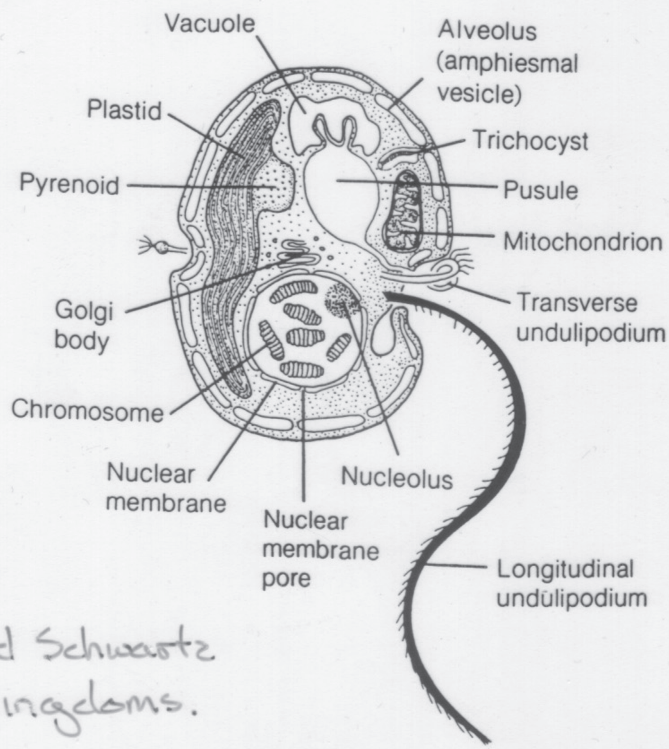


[MARGULIS]

DINOPHYTA
(Dinoflagellates)



EXTERIOR VIEW



source:
Margulis and Schwartz
1998 Five Kingdoms.
Freeman.

CUTAWAY VIEW

Saxitoxin, Diacetate, *Gonyaulax* sp.	559385	1 µmol	339.00

(STx)

Liquid. In dilute aqueous acetic acid. A powerful neurotoxin with a mechanism of action similar to that of Tetrodotoxin. Potent, reversible Na^+ channel-blocking agent. Useful for discriminating high affinity and low affinity Na^+ channels. *Purity: ≥98% by HPLC.* RTECS UY8708500, CAS 220355-66-8, M.W. 419.4.

Ref.: *Merck Index* **12,** 8533; Narahashi, T.Q., et al. 1994. *Neurotoxicology.* **15,** 545; Lonnendonker, V. 1991. *Eur. Biophys. J.* **20,** 135; Terlau, H., et al. 1991. *FEBS Lett.* **293,** 93.

WARNING! Highly Toxic. LD_{50} of ≤50 mg/kg.

BREVETOXINS

The brevetoxins are lipid-soluble polyether marine toxins produced by the red tide dinoflagellate *Ptychodiscus brevis*, found along the Gulf Coast of Florida. They are voltage-dependent Na^+ channel activators that cause contractile paralysis in animal models by binding to a unique site of these Na^+ channels. The excitatory action of brevetoxins on nerve and muscle membranes is responsible for a wide spectrum of toxic effects, including massive transmitter release from nerve endings, muscle fasciculations, and ventricular fibrillation. The toxin does not bind either to tetrodotoxin or aconitine/veratridine sites. PbTx-1 is soluble in aprotic solvents such as acetone, acetonitrile, or ethyl acetate. PbTx-2 and its derivatives are soluble in acetone, alcohols, ethyl acetate or water.

Ref.: Baden, D.J., et al. 1994. *Nat. Toxins* **2,** 212; Rein, K., et al. 1994. *J. Org. Chem.* **59,** 2107; Edwards, R.A., et al. 1992. *Mol. Brain Res.* **14,** 64; Trainer, V.L. 1991. *Mol. Pharmacol.* **40,** 988; Tsai, M.C., and Chen, M.L. 1991. *Br. J. Pharmacol.* **103,** 1126; Trainer, V.L., et al. 1990. *ACS Symposium Series* **418,** 166; Baden, D.G., et al. 1988. *Toxicon* **26,** 97; Poli, M.A., et al. 1986. *Mol. Pharmacol.* **30,** 129; Shimizu, Y., et al. 1986. *J. Am. Chem. Soc.* **108,** 514; Baden, D.G., et al. 1982. *Toxicon* **19,** 455; Catterall, W.A., and Risk, M. 1981. *Mol. Pharmacol.* **19,** 345.

Brevetoxin PbTx-1, *Ptychodiscus brevis*	203730	100 µg	262.00

(Brevetoxin A; GbTx-1)

Light tan solid. PACKAGED UNDER INERT GAS. *Purity: ≥95% by HPLC. Soluble in EtOAc and H_2O.* RTECS EE4554800, CAS 98112-41-5, M.W. 867.1.

WARNING! Highly Toxic. LD_{50} of ≤50 mg/kg.

OKADAIC ACID AND DERIVATIVES

Okadaic Acid, *Prorocentrum concavum*	495604	10 µg	29.00
		25 µg	47.00
		100 µg	170.00

BULK!

(OA)

White crystalline solid. PROTECT FROM LIGHT. PACKAGED UNDER INERT GAS. An ionophore-like polyether derivative of a C_{38} fatty acid compound that has tumor promoting properties. Potent inhibitor of protein phosphatase 1 (IC_{50} = 10 - 15 nM) and protein phosphatase 2A (IC_{50} = 0.1 nM). Does not affect the activity of tyrosine phosphatases, alkaline phosphatases, or acid phosphatases. Useful for the study of protein phosphatases in cell extracts as well as in intact cells. Induces apoptosis in human breast carcinoma cells (MB-231 and MCF-7) and in myeloid cells but inhibits glucocorticoid-induced apoptosis in T cell hybridomas. Has marked contractile effects on smooth muscle and heart muscle. Implicated as causative agent of diarrhetic shellfish poisoning. *Purity: ≥95% by HPLC. Soluble in DMSO and EtOH.* RTECS AA8227800, CAS 78111-17-8, M.W. 805.0.

Ref.: *Merck Index* **12,** 6958; Gjertsen, B.T., et al. 1994. *J. Cell Sci.* **107,** 3363; Kiguchi, K., et al. 1994. *Cell Growth Differentiation* **5,** 995; Ohaka, Y., et al. 1993. *Biochem. Biophys. Res. Commun.* **197,** 916; Gopalakrishna, R., et al. 1992. *Biochem. Biophys. Res. Commun.* **189,** 950; Kreienbuhl, P., et al. 1992. *Blood* **80,** 2911; Nomura, M., et al. 1992. *Biochemistry* **31,** 11915; Song, Q., et al. 1992. *J. Cell Physiol.* **153,** 550; Tada, Y., et al. 1992. *Immunopharmacol.* **24,** 17; Cohen, P., et al. 1990. *Trends Biochem. Sci.* **15,** 98; Cohen, P. 1989. *Annu. Rev. Biochem.* **58,** 453; Cohen, P., and Cohen, P.T.W. 1989. *J. Biol. Chem.* **264,** 21435; Haystead, T.A., et al. 1989. *Nature* **337,** 78.

WARNING! Toxic. LD_{50} of ≤200 mg/kg but >50 mg/kg. May be carcinogenic/teratogenic.

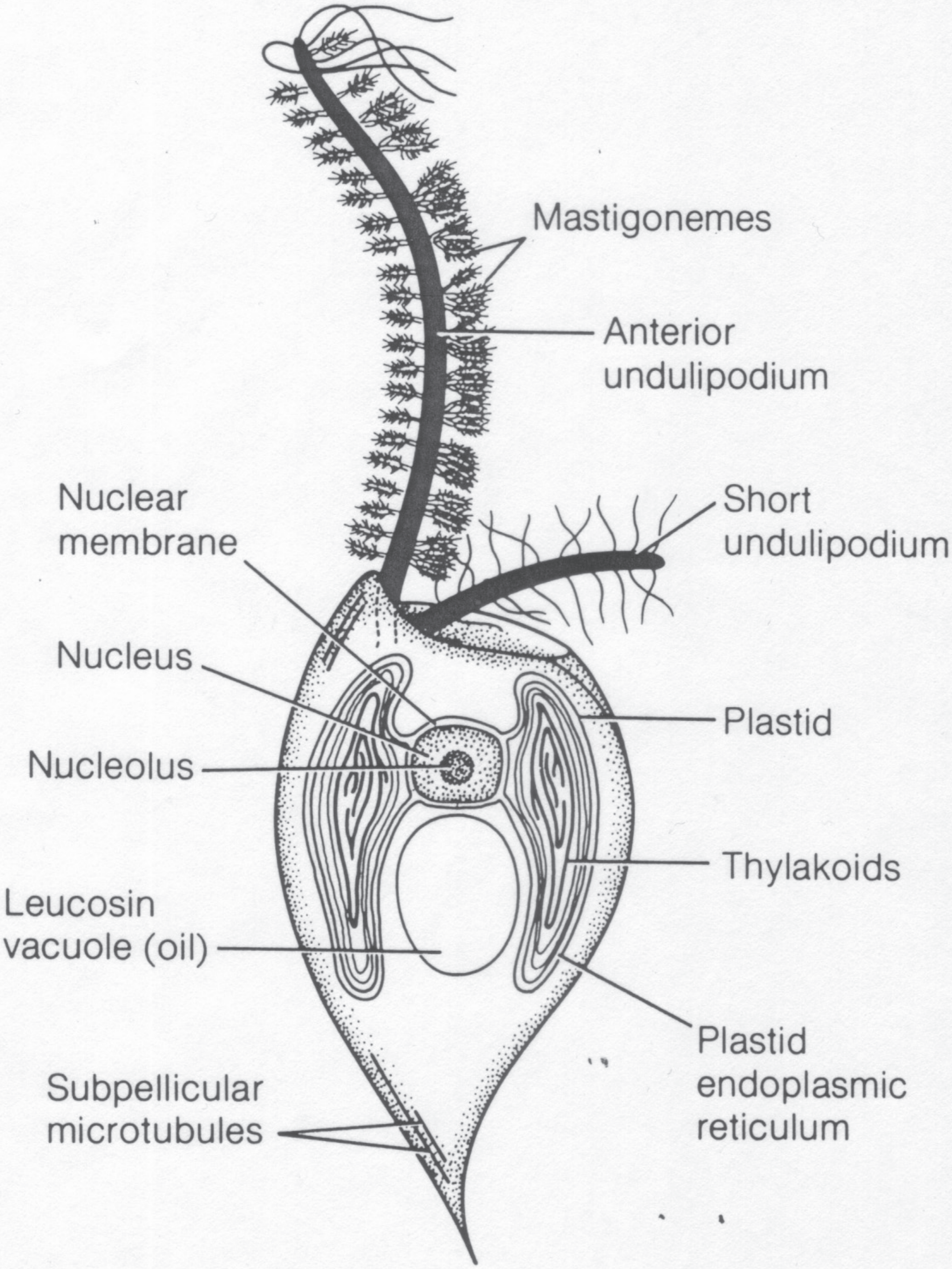
Maitotoxin, *Gambierdiscus toxicus*	442620	10 µg	193.00
		25 µg	448.00

(MTX)

White solid. PROTECT FROM LIGHT. Marine toxin that mobilizes intracellular Ca^{2+} stores. Activates both voltage-sensitive and receptor-operated Ca^{2+} channels. Activities include depolarization of membranes and stimulation of inositol production in numerous cell types. *Purity: ≥90% by HPLC. Soluble in EtOH, MeOH, and H_2O.* RTECS OM5470000, CAS 59392-53-9, M.W. 3425.9.

Ref.: Wang, K.K.W., et al. 1996. *Arch. Biochem. Biophys.* **331,** 208; Musgrave, I.F., et al. 1994. *Biochem. J.* **301,** 437; Murata, M., et al. 1993. *J. Am. Chem. Soc.* **115,** 2060; Meucci, O., et al. 1992. *J. Neurochem.* **59,** 679; Soergel, D.G., et al. 1992. *Mol. Pharmacol.* **41,** 487; Yokoyama, A., et al. 1988. *J. Biochem.* **104,** 184.

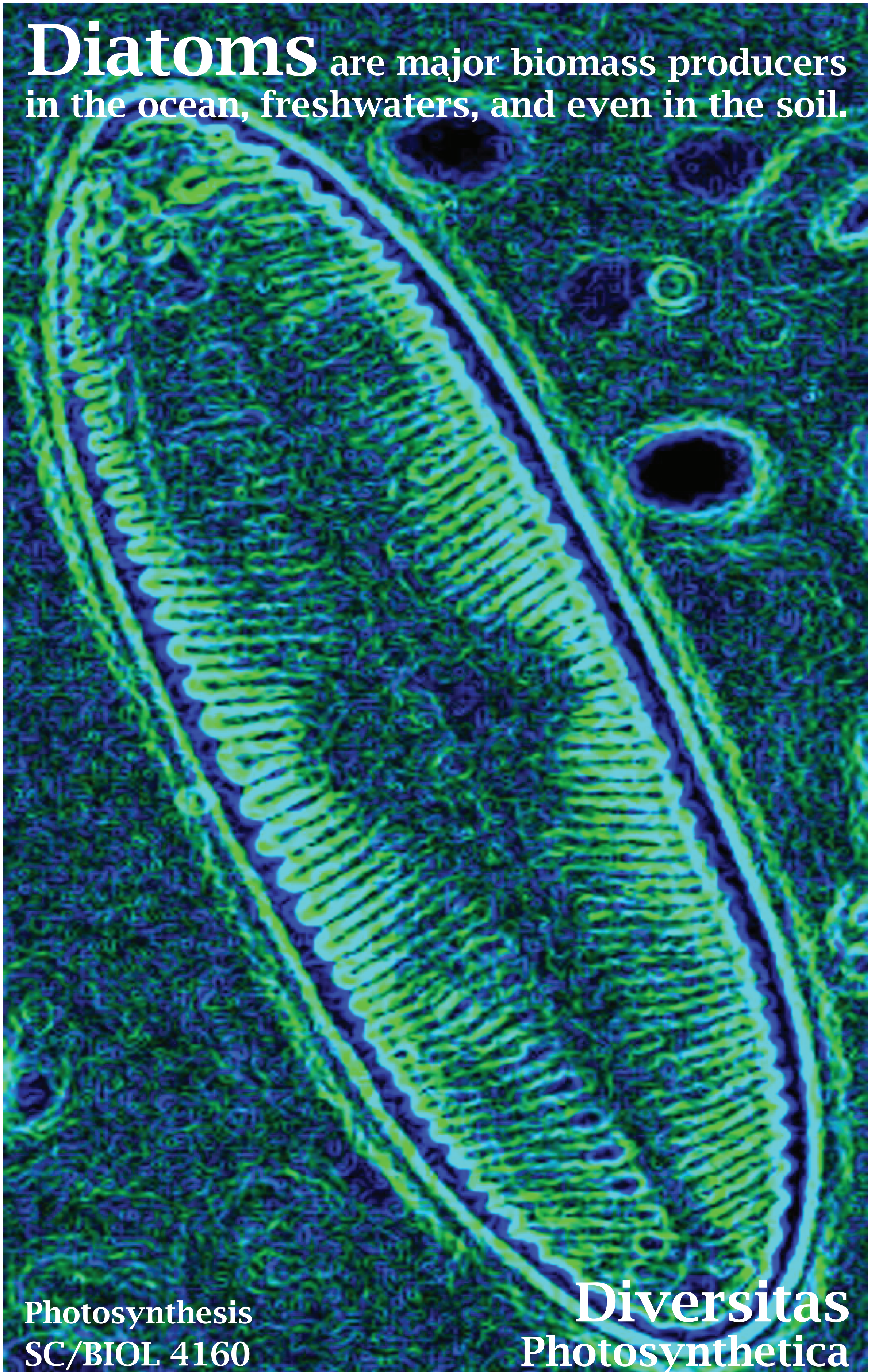
WARNING! Highly Toxic. LD_{50} of ≤50 mg/kg.

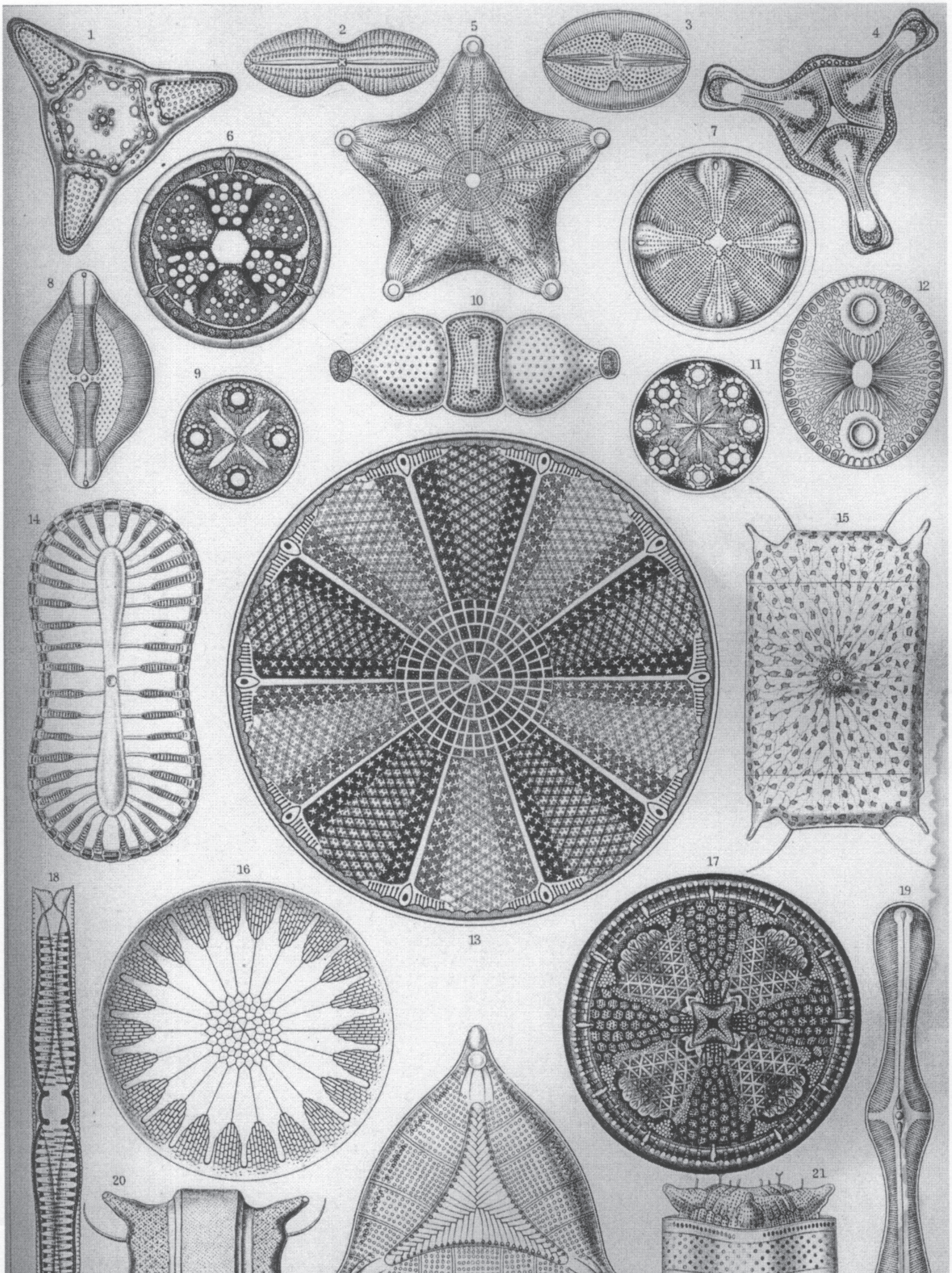


C The freshwater, single-cell chrysomonad *Ochromonas danica;* the ultrastructures of *Ochromonas* cells and of single *Synura* cells are similar. [Drawing by M. Lowe.]

CHRYSOPHYTA

source: Margulis and Schwartz 1998 Five Kingdoms 3rd edition. Freeman.


Diatoms are major biomass producers
in the ocean, freshwaters, and even in the soil.
Photosynthesis
SC/BIOL 4160
Diversitas
Photosynthetica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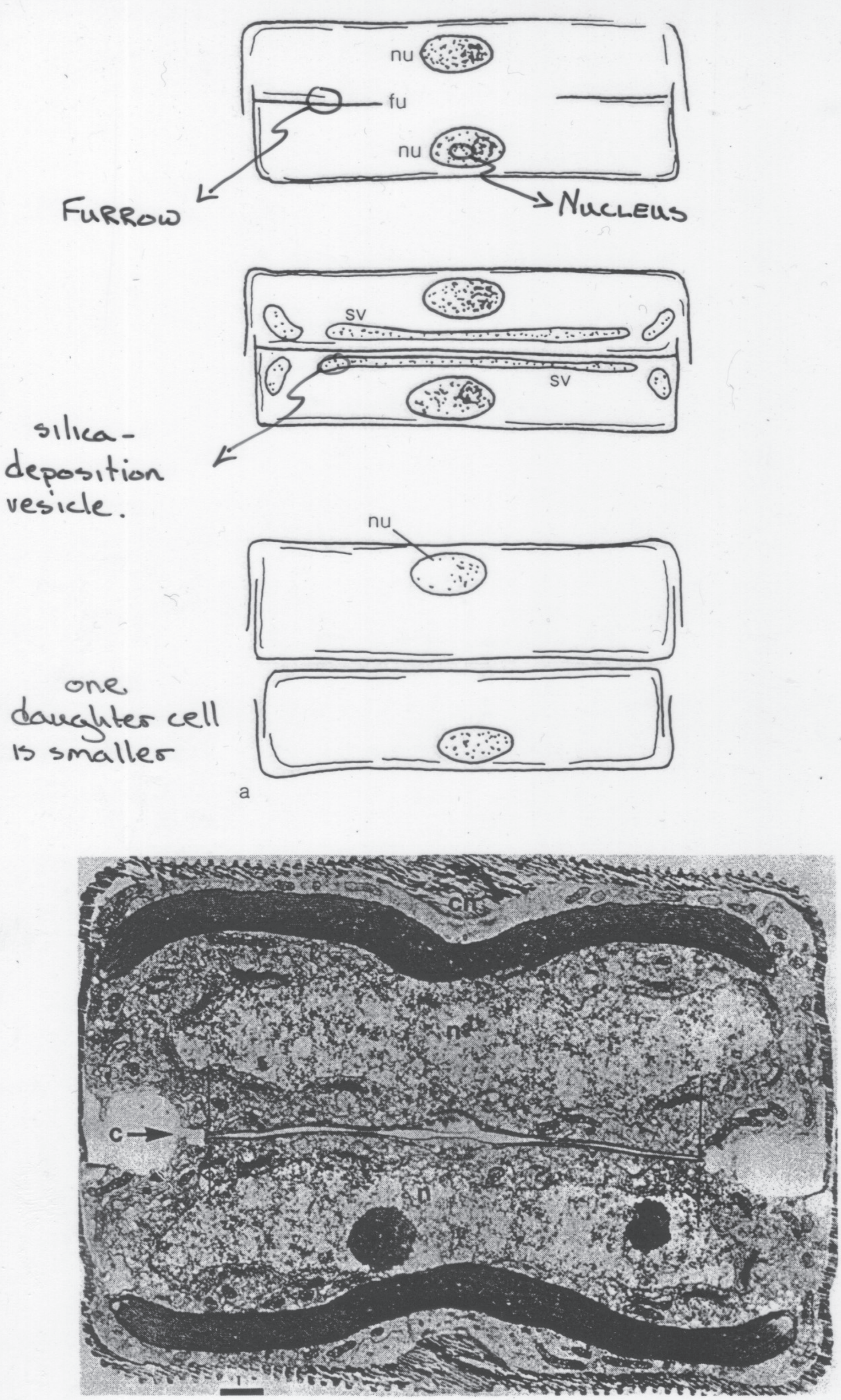
nu
fu
nu
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sv
silica-
deposition
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nu
one
daughter cell
is smaller
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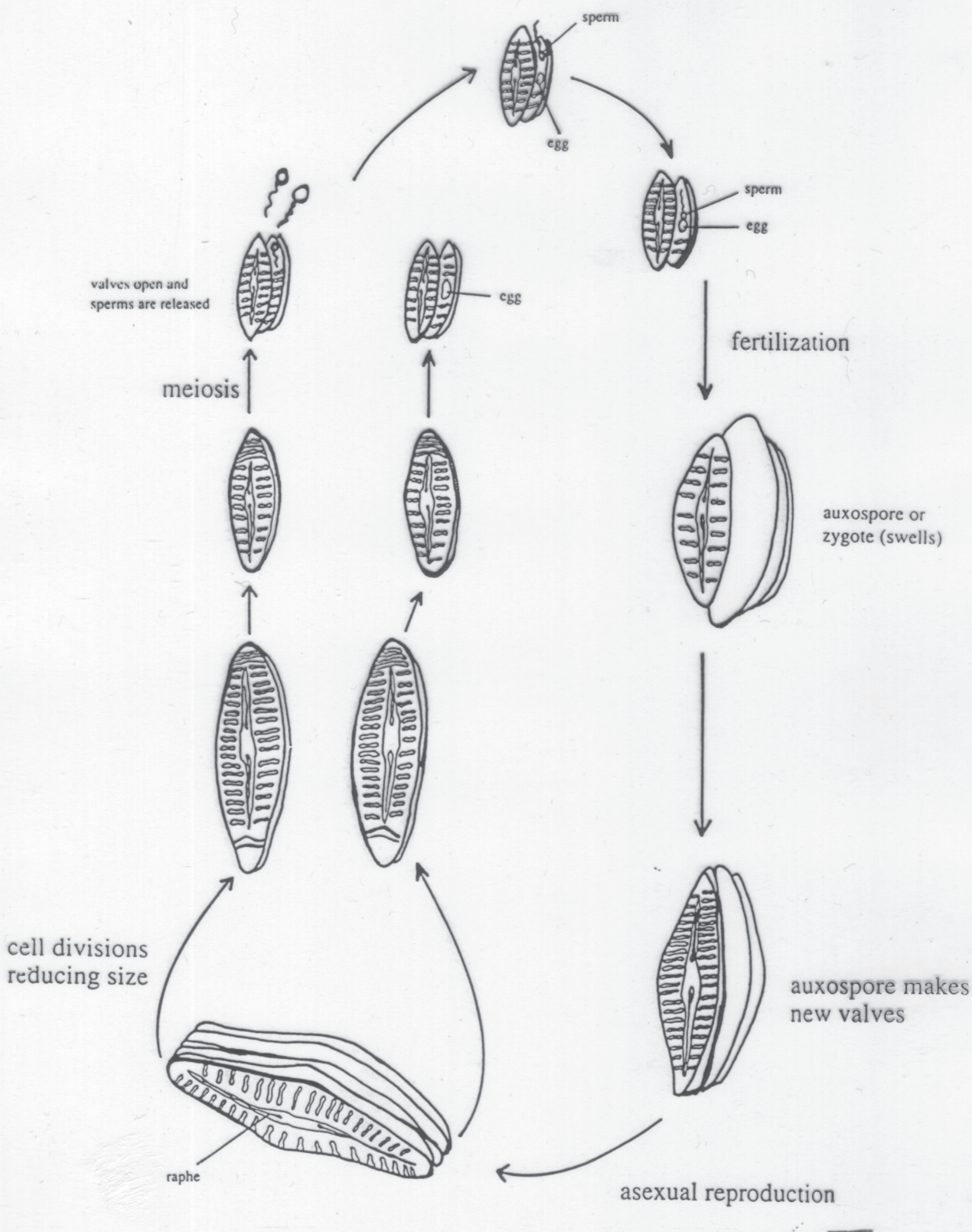
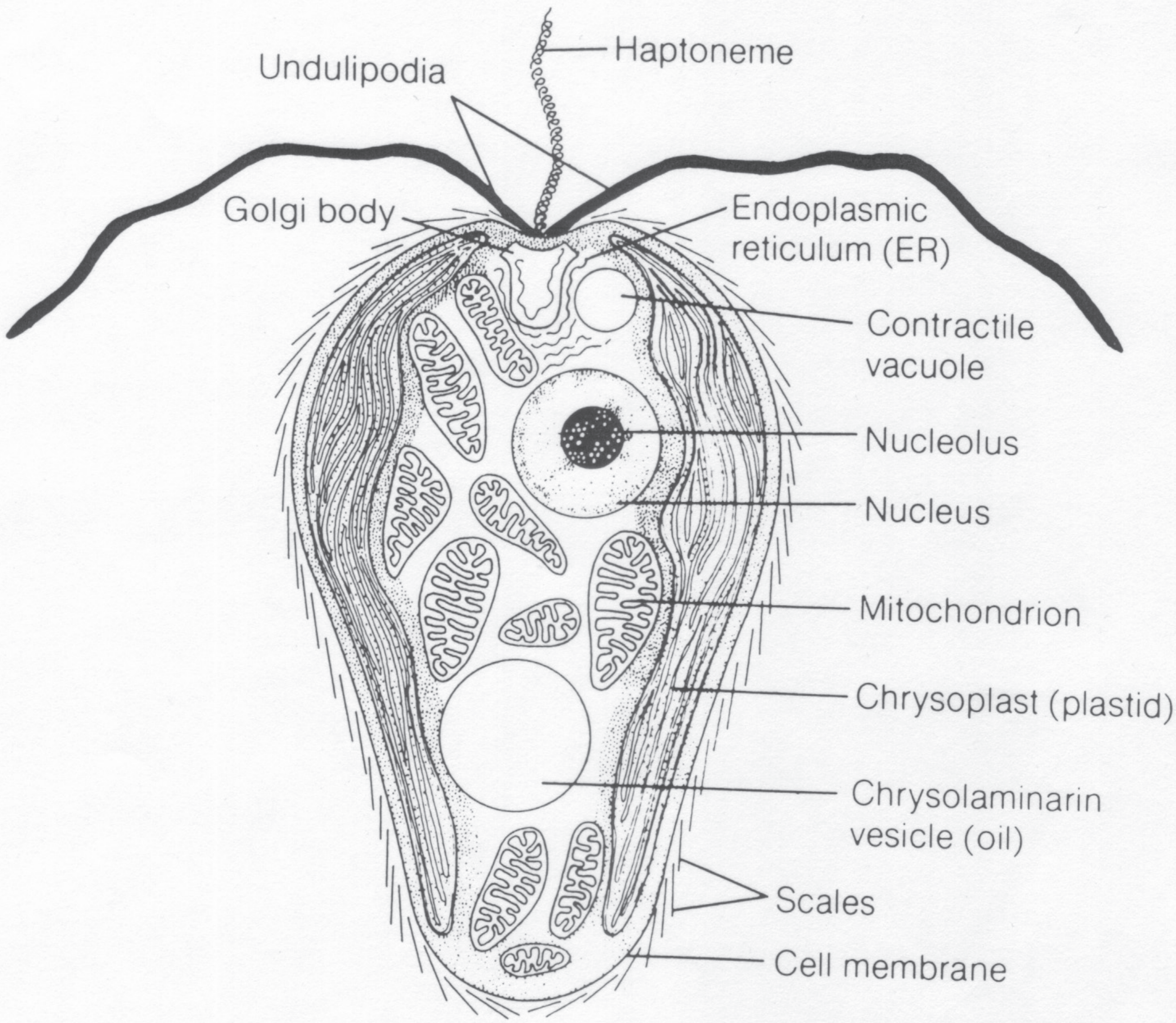
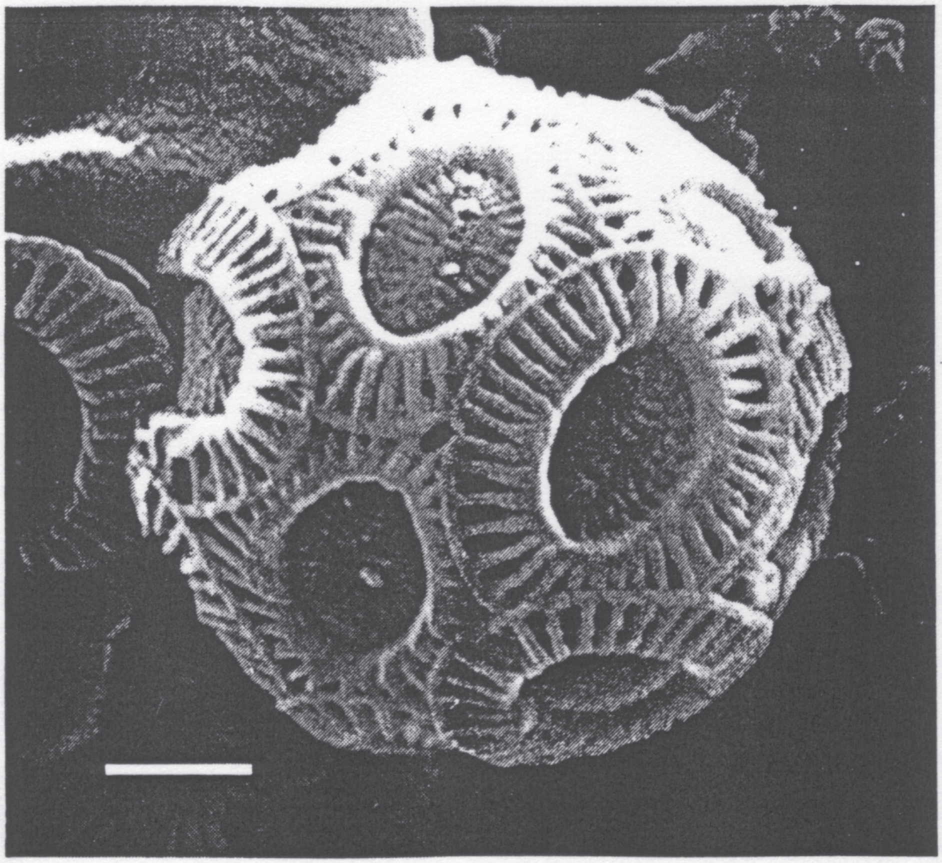


Reproductive Cycle of a Representative Diatom, *Rhoicosphenia*

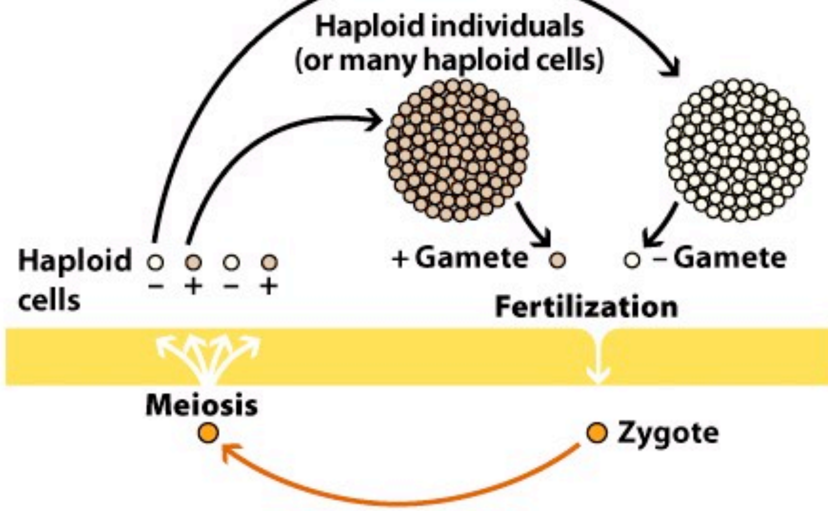
Figure 1.2. Mode of division of diatoms



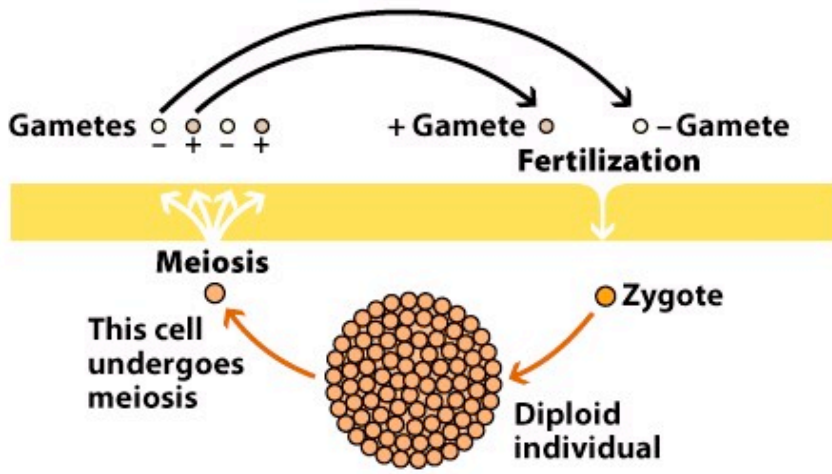
C *Prymnesium parvum*, the free-swimming haptonemid stage of a haptomonad. The surface scales shown here are not those on which coccoliths form. [Drawing by R. Golder.]



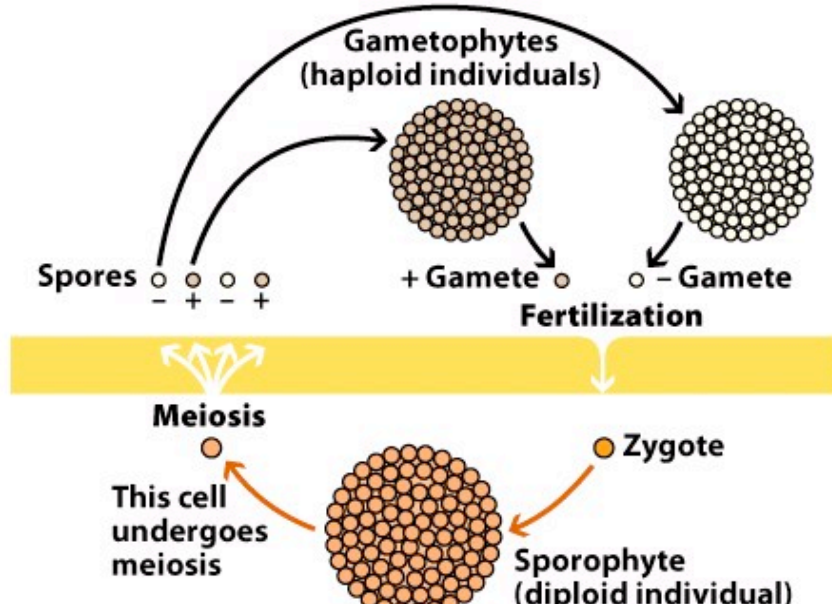
B *Emiliania huxleyi,* a coccolithophorid from the Atlantic. That coccolithophorids are resting stages of haptomonads has been realized only in the past decade. SEM, bar = 1 μm. [Courtesy of S. Honjo.]



(a) **Zygotic meiosis—fungi, some algae**



(b) **Gametic meiosis—animals, some protists and algae**

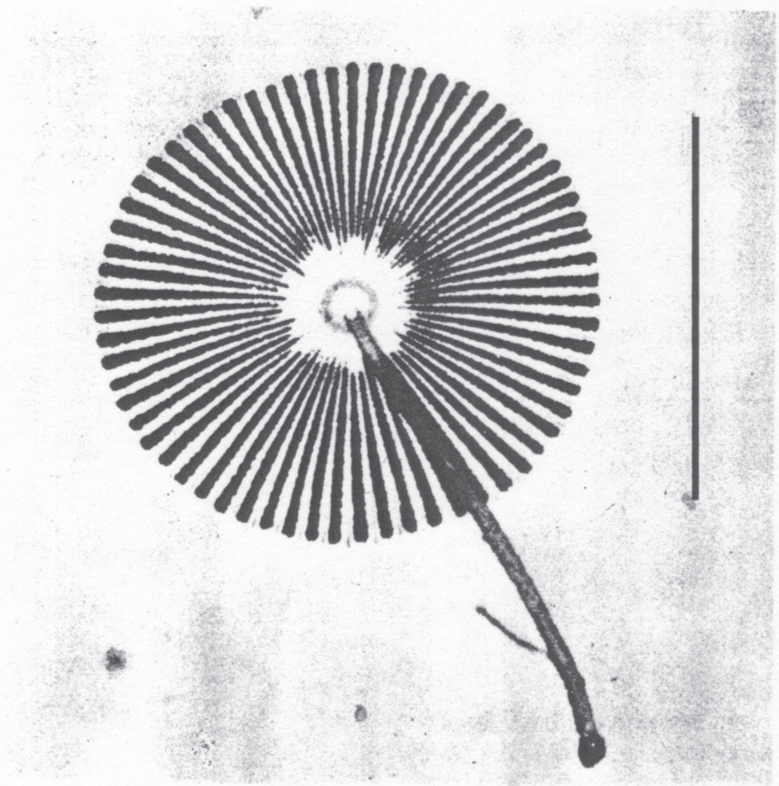


(c) **Sporic meiosis, or alternation of generations—plants, many algae**

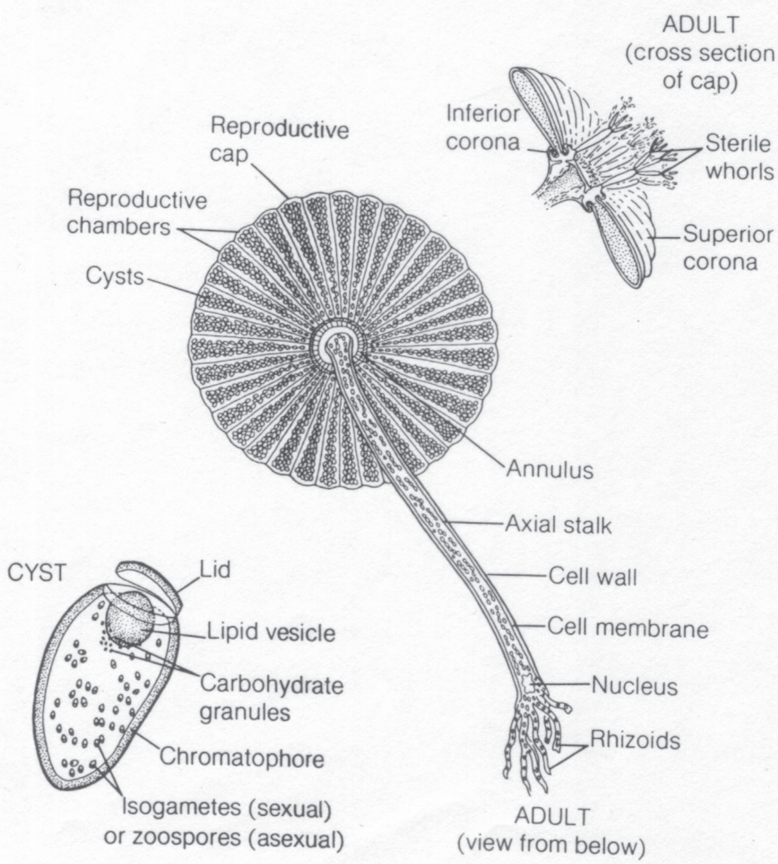
Figure 12-17

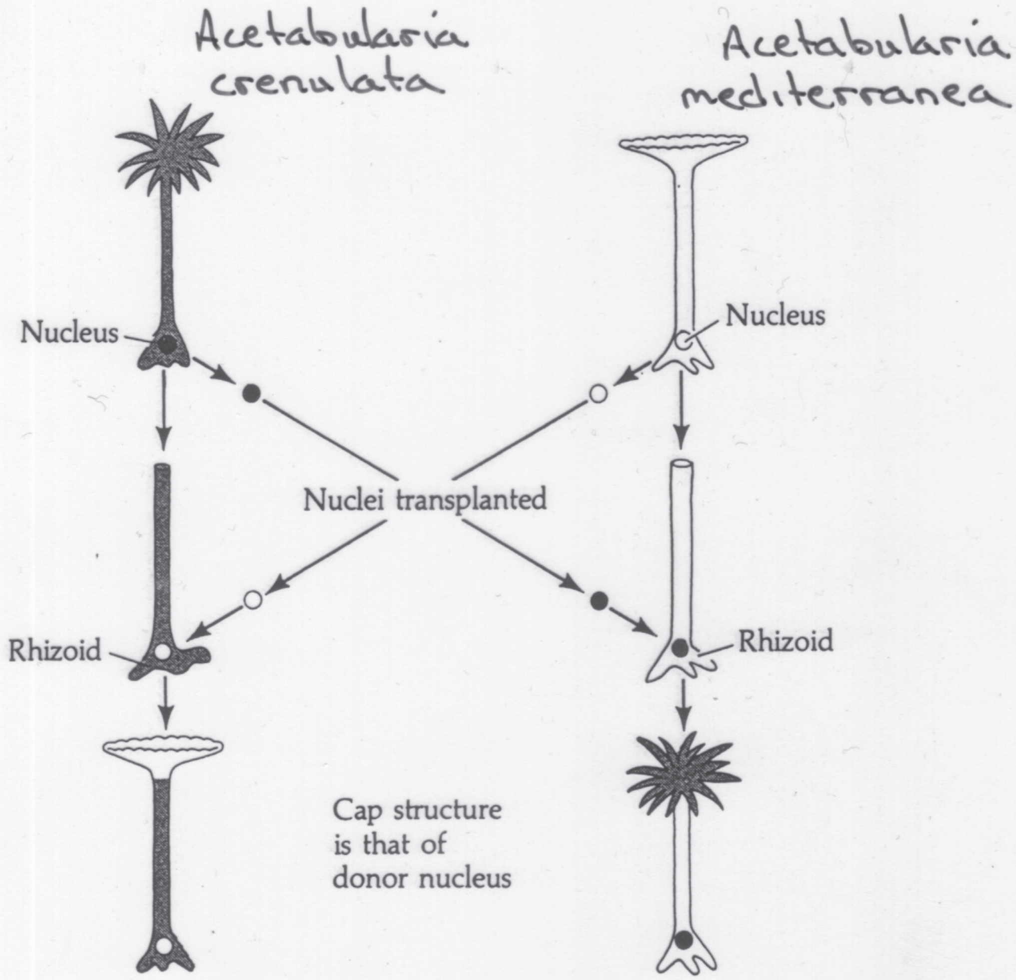
***Raven Biology of Plants*, Eighth Edition**

Plant Biology
SC/BIOL 2010

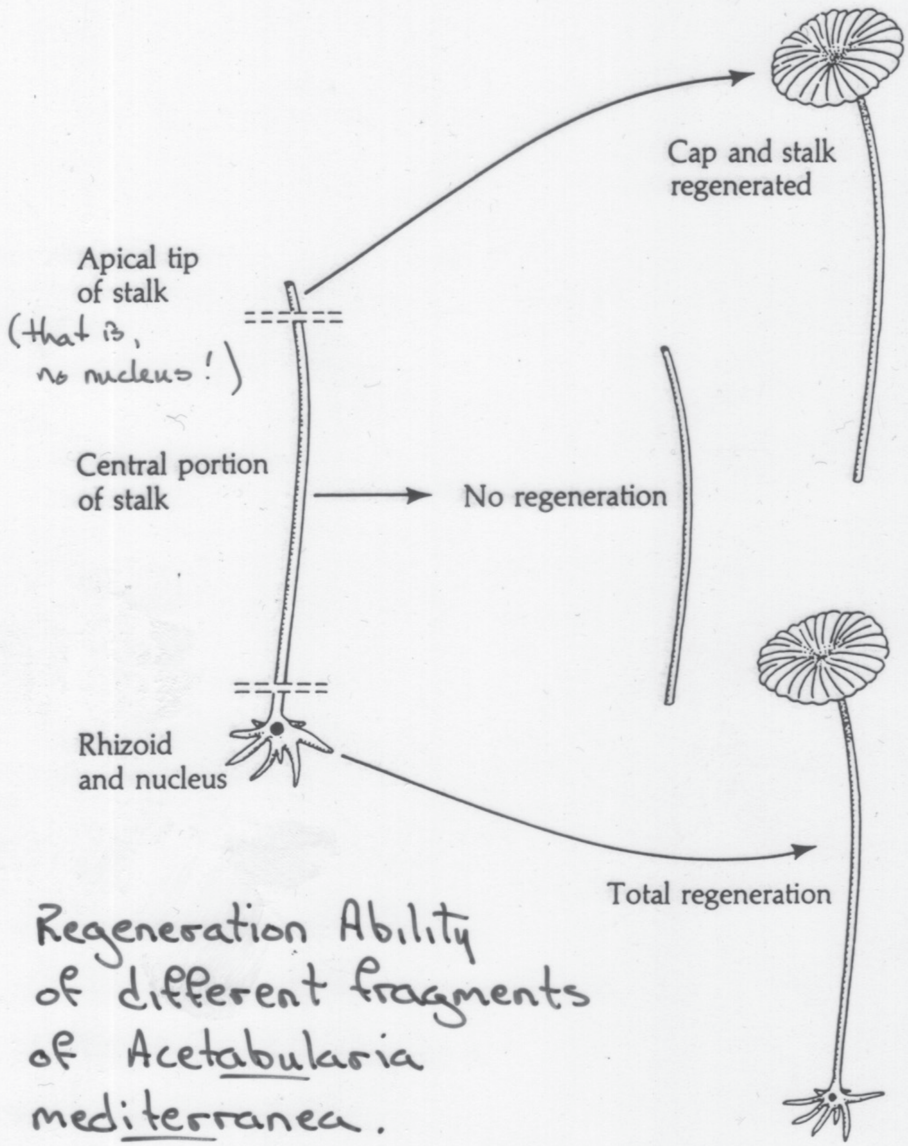


A *Acetabularia mediterranea,* a living alga from the Mediterranean Sea. Bar = 1 cm. [Courtesy of S. Puiseux-Dao.]



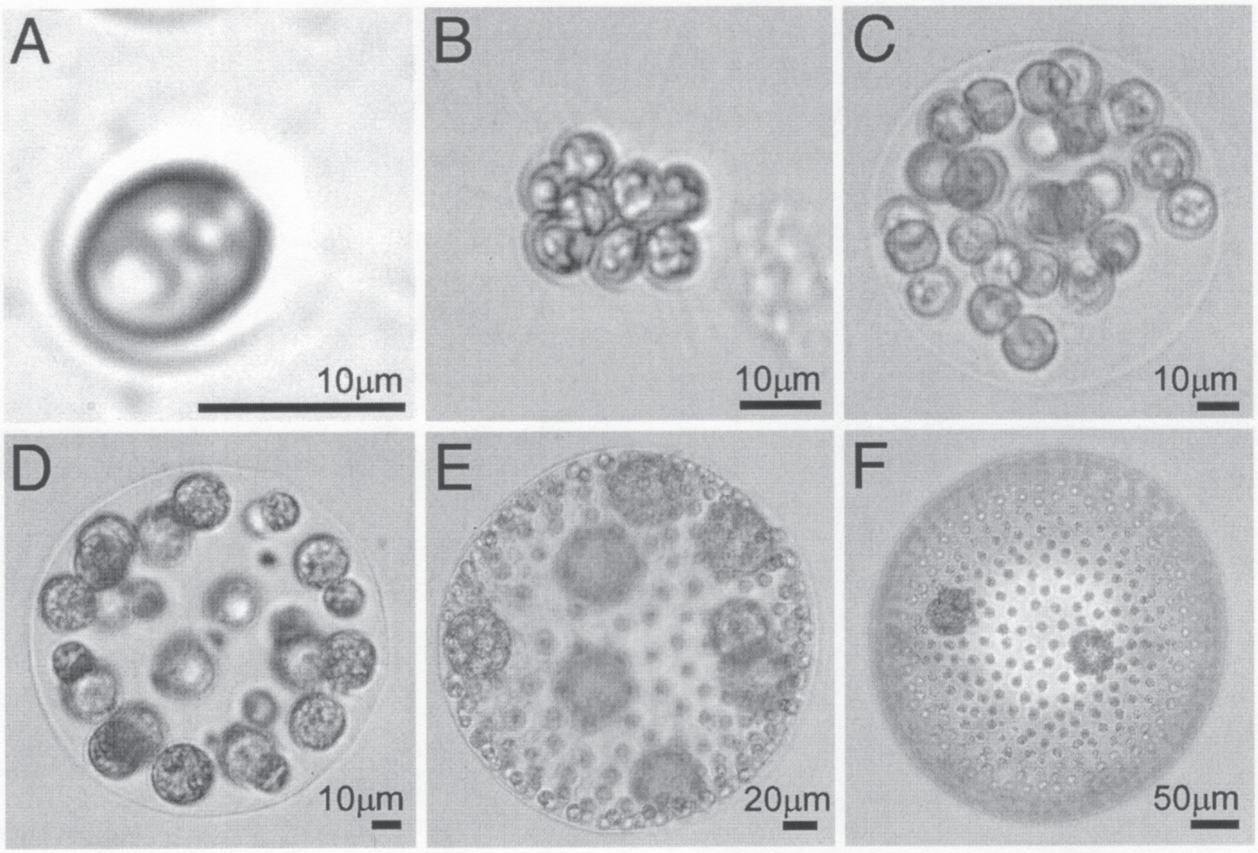


The effect of exchanging nuclei between two species of Acetabularia.
Nuclei were transplanted into enucleated rhizoid fragments



Regeneration Ability of different fragments of Acetabularia mediterranea.

Species of volvocalean green algae spanning a large range in size. Shown are the single-cell *C. reinhardtii* (A), undifferentiated colonies *Gonium pectorale* (8 cells) (B) and *Eudorina elegans* (32 cells) (C), and those with germ-soma differentiation *Pleodorina californica* (64 cells) (D), *V. carteri* ({approx}1,000 cells) (E), and *Volvox aureus* ({approx}2,000 cells) (F).



Cristian A. Solari, Sujoy Ganguly, John O. Kessler, Richard E. Michod, and Raymond E. Goldstein (2006) Multicellularity and the functional interdependence of motility and molecular transport. Proc/ Natl/ Acad. Sci *USA* 203(5):1353–1358.

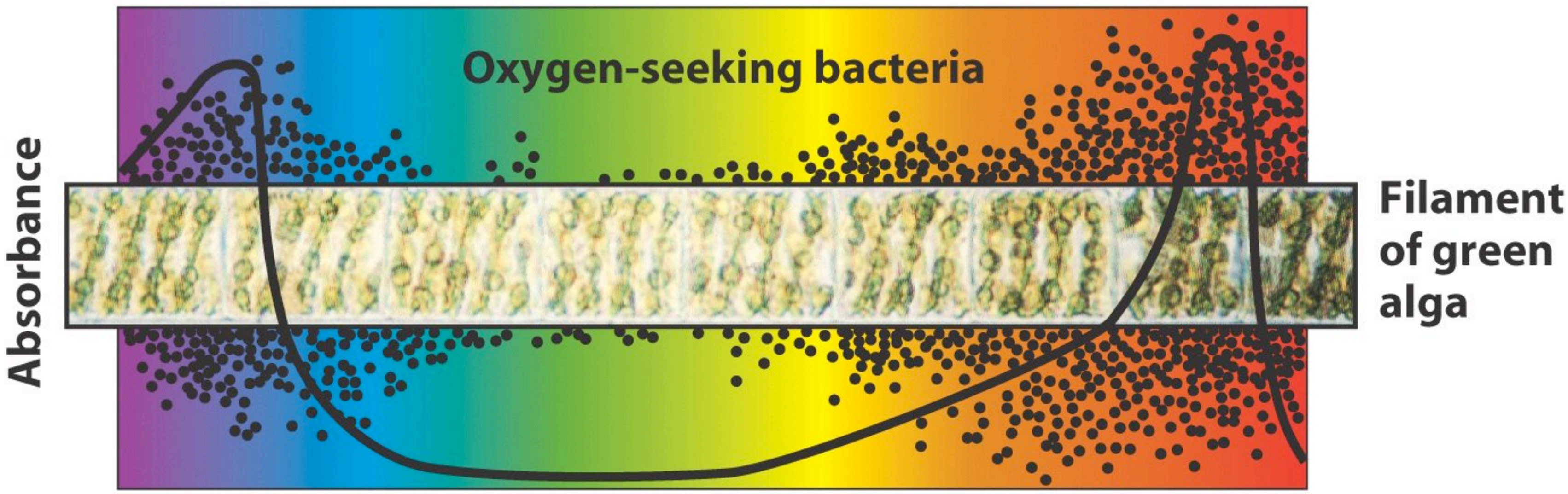


Figure 7-6
Biology of Plants, Seventh Edition

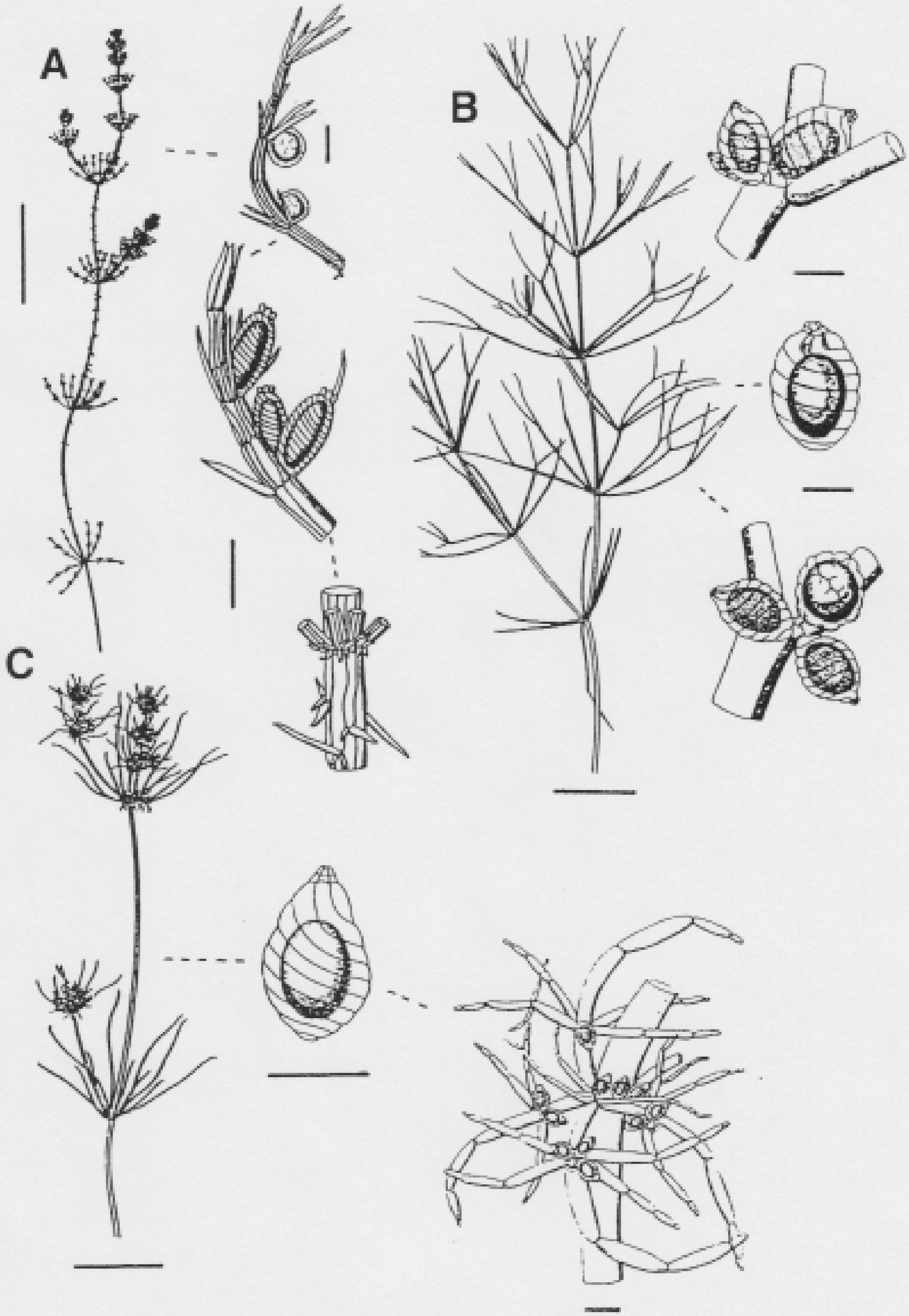
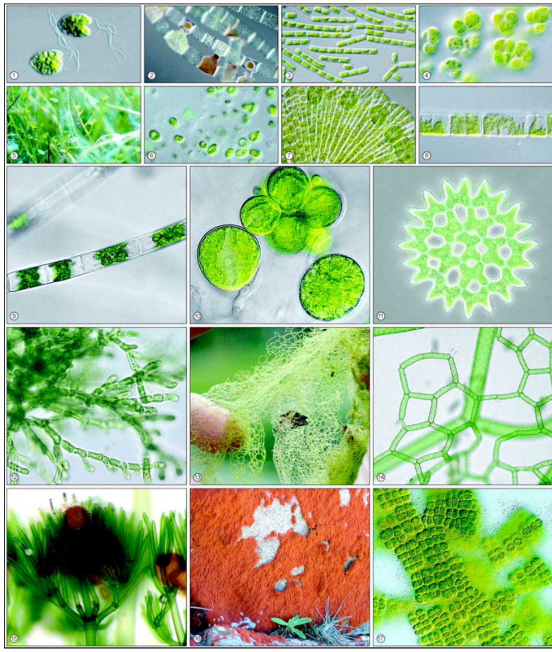


FIGURE 9 (A) *Chara canescens*, habit of alga, branchlet of a male and a female individual, and a node showing the corticated main axis with its bract cells and stipulodes arranged in 2 rows (after Wood and Imahori, 1964). (B) *Nitella flexilis*, habit of alga, branchlets with clustered oogonia or conjoined oogonia and antheridia, and an oogonium with a 2-tiered corona (after Wood and Imahori, 1964). (C) *Tolypella nidifica*, habit, portion of node with fertile branchlets, and an oogonium with a 2-tiered corona (Wood and Imahori, 1964).



Algal Diversity

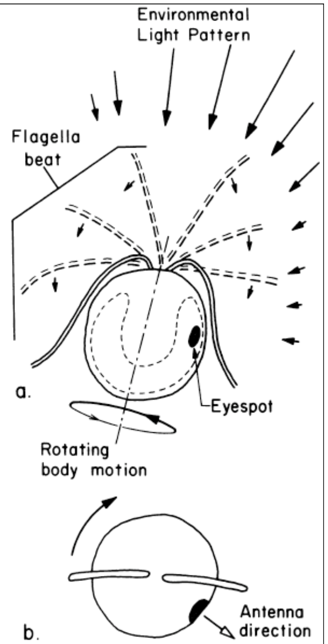
(photo by V. Flechtner)

Representative green algae. 1. *Halosphaera* cf. *minor*; prasinophyte (photo by C. O'Kelly). 2. Two conjugating filaments of *Spirogyra maxima*; charophyte (photo by C. Drummond). 3. *Klebsormidium flaccidum*; charophyte (photos 3–9 by C. F. Delwiche). 4. *Chlorokybus* sp.; charophyte. 5. Marine macro-alga, *Caulerpa*; an ulvophyte. 6. *Mesostigma*; flagellate charophyte. 7. View of part of a *Coleochaete orbicularis* thallus, with eggs, charophyte. 8. *Entransia fimbriata*; charophyte. 9. *Ulothrix* sp.; ulvophyte. 10. *Myrmecia* sp.; trebouxiophyte (photo by V. Flechtner). 11. Colonial planktonic alga, *Pediastrum duplex*; chlorophyte. 12. *Microthamnion* sp.; trebouxiophyte. Figs. 13 and 14. Macroscopic and microscopic view of the water net, *Hydrodictyon reticulatum* from a pond in Connecticut; chlorophyte. 15. *Nitella hyalina* with orange sex organs; charophyte (photo by K. Karol). 16. *Trentepohlia* sp., with abundant orange secondary pigments forming a shaggy coat on rocks at Point Reyes, California; ulvophyte. 17. *Chlorosarcinopsis* sp.; chlorophyte .


Dinoflagellate containing ingested diatoms.
Image: Harvey Marchant
http://www.aad.gov.au/default.asp?casid=3433

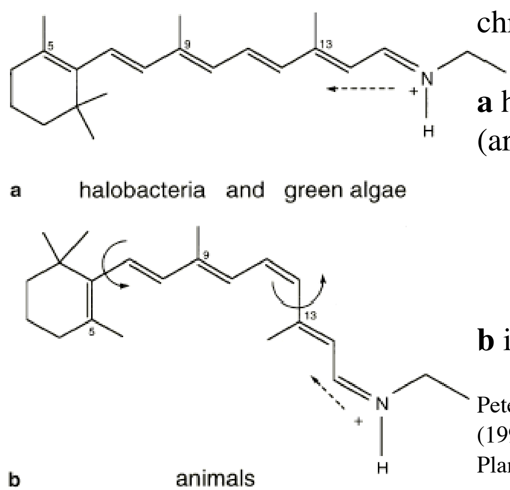

Movement by deformation. Euglenoid.
Image: Harvey Marchant
http://www.aad.gov.au/default.asp?casid=3432

FIG. 2. *Design principles of phototaxis in Chlamydomonas. (a) Side view of cell; (b) end view. The incident light pattern is indicated by solid arrows. The eyespot, which lies inside the chloroplast (dashed line), forms part of the antenna. Rotation of the cell causes the antenna to scan the incident light. This produces a signal that controls the flagellar beat (see Fig. 3). The antenna direction (open arrow) is normal to the cell surface. The antenna is most sensitive to light coming from this direction. Successive positions of the flagella during the power stroke are shown. Flagellar motion causes the cell to translate with the flagellar end forward and to rotate in the left-hand sense.*



Foster KW, and RD Smyth (1980) Light antennas in phototactic algae. Microbiol. Rev. 44:572–630.

Rhodopsins are found in all kingdoms: prokaryote and eukaryote.



Structure of rhodopsin chromophores in

a halobacteria (archaea) and algae (plants)

b in metazoan (animals).

Peter Hegemann (1997) Vision in microalgae. Planta 203:265–274.

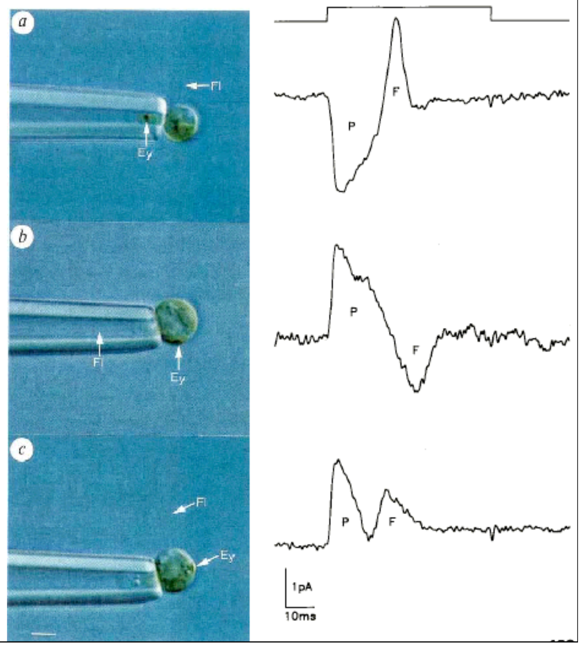
Light-induced photoreceptor (P) and flagellar (F) currents, whose sign depends on the orientation of the cell in the pipette.

a. The eyespot (Ey) is inside the pipette.

b. The flagella (Fl) is inside the pipette, and

c. Eyespot and flagella are outside the pipette. Scale bar 10 μm.

Harz H, and P Hegemann (1991) Rhodopsin–regulated calcium currents in *Chamydomonas*. Nature 351:489–491.



“Vision” in Single-Celled Algae

Suneel Kateriya,[1] Georg Nagel,[2] Ernst Bamberg,[2] and Peter Hegemann[1]

[1]Institut für Biochemie, Universität Regensburg, 93040 Regensburg; and [2]Max-Planck-Institut für Biophysik, 60439 Frankfurt am Main, Germany

Photosynthetic unicellular algae have a unique visual system. In Chlamydomonas reinhardtii, the pigmented eye comprises the optical system and at least five different rhodopsin photoreceptors. Two of them, the channelrhodopsins, are rhodopsin-ion channel hybrids switched between closed and open states by photoisomerization of the attached retinal chromophore. They promise to become a useful tool for noninvasive control of membrane potential and intracellular ion concentrations.

News Physiol. Sci. 19:133–137 [2004]

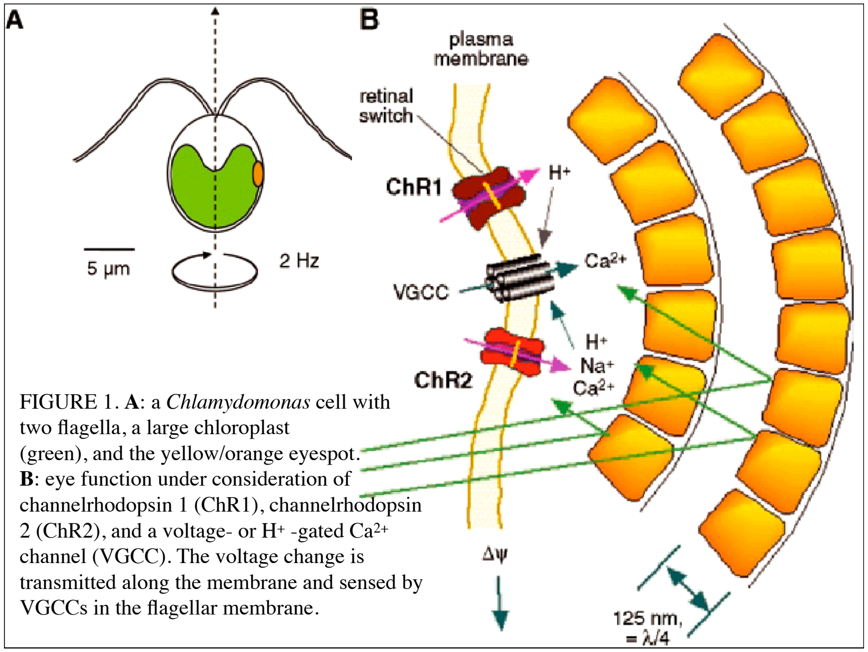
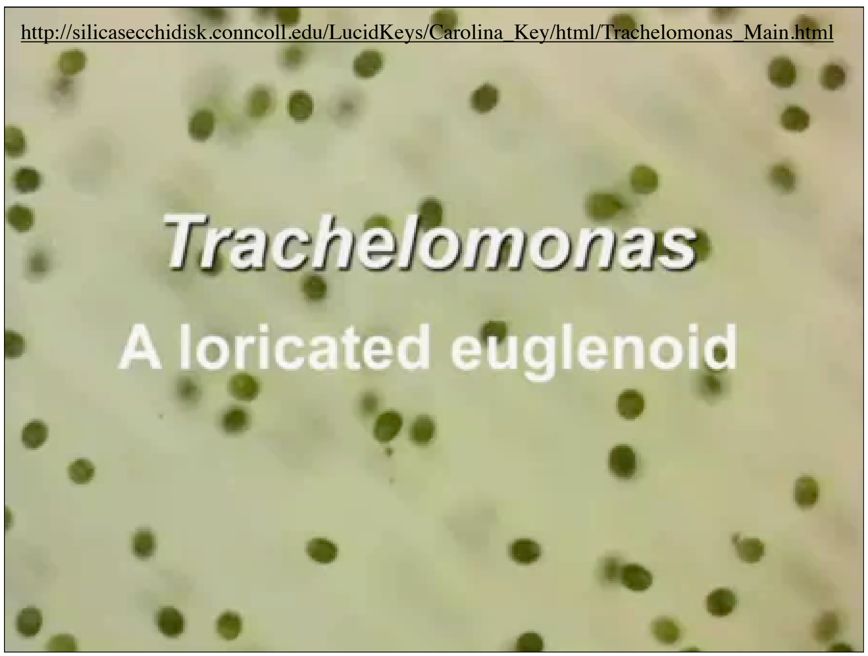
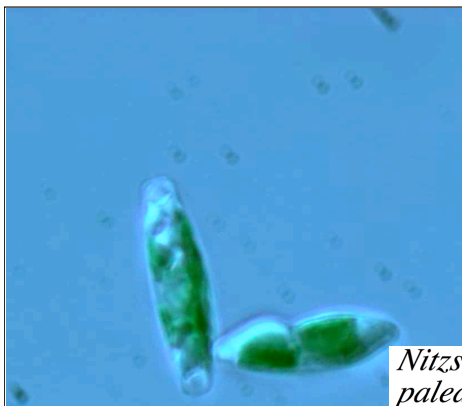


FIGURE 1. **A**: a *Chlamydomonas* cell with two flagella, a large chloroplast (green), and the yellow/orange eyespot. **B**: eye function under consideration of channelrhodopsin 1 (ChR1), channelrhodopsin 2 (ChR2), and a voltage- or H^+ -gated Ca^{2+} channel (VGCC). The voltage change is transmitted along the membrane and sensed by VGCCs in the flagellar membrane.

http://silicasecchidisk.conncoll.edu/LucidKeys/Carolina_Key/html/Trachelomonas_Main.html



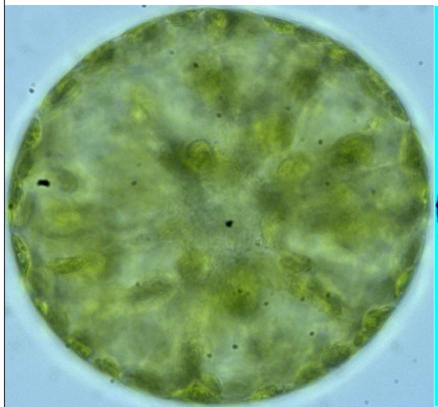


Diatom motility: Observed in pennate forms. The mechanism remains controversial but may involved actin and myosin.

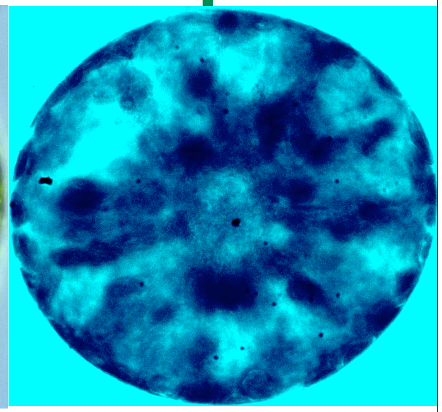
Nitzschia palea



Cells and Chloroplasts



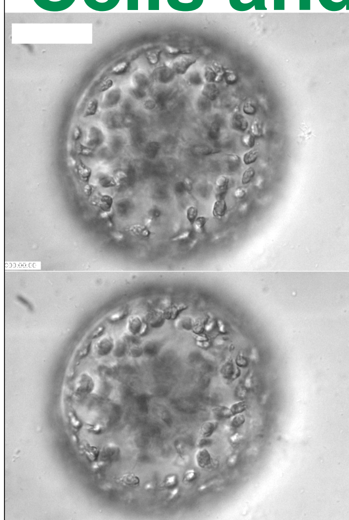
Brightfield

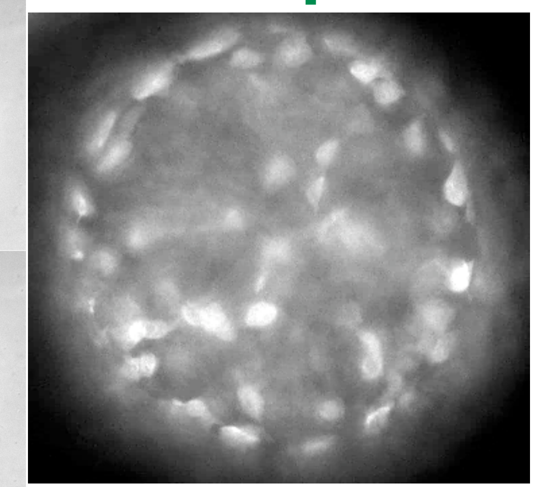


467 nm (blue)
(to highlight chloroplasts)

Eremosphaera viridis

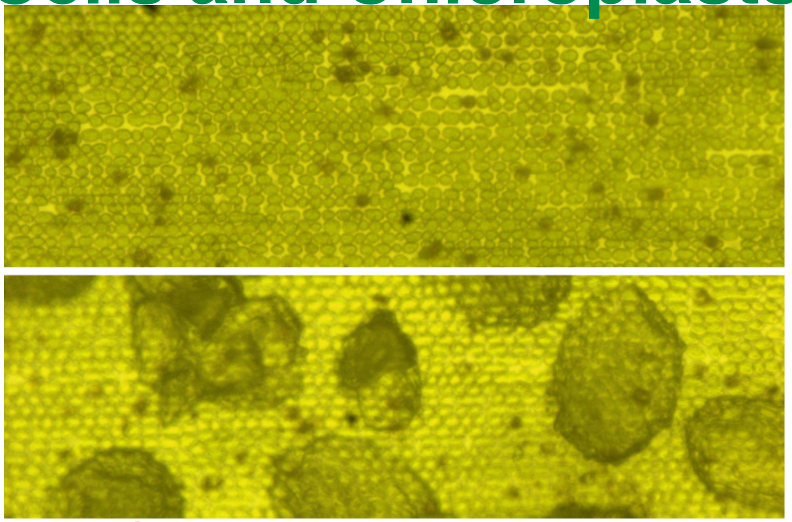
Cells and Chloroplasts



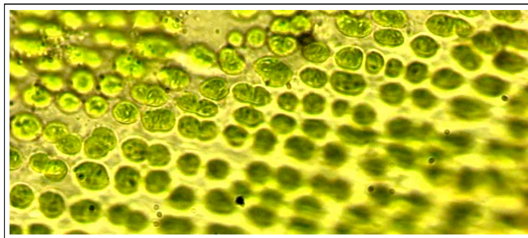


Eremosphaera viridis

Cells and Chloroplasts

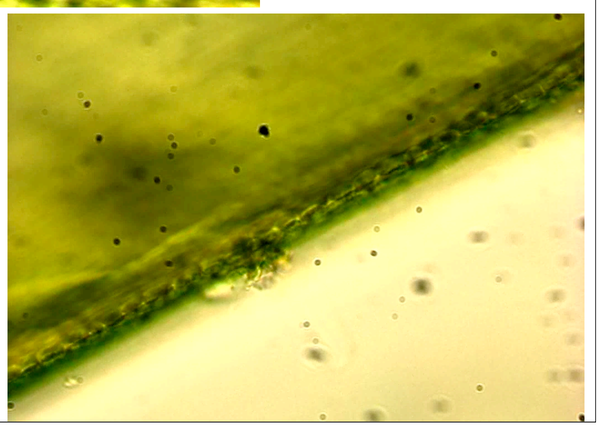


Chara australis

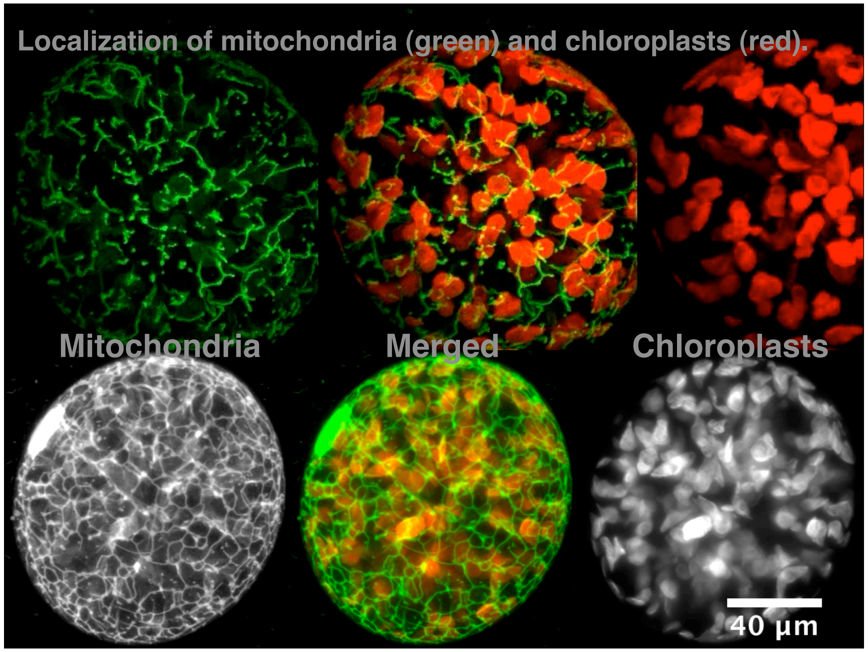


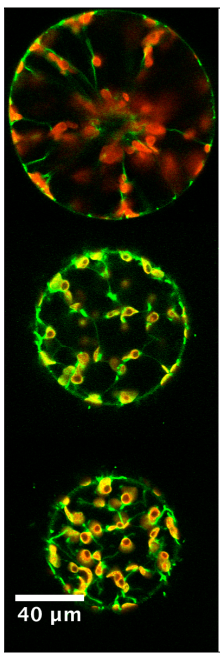
Cells and Chloroplasts

Cytoplasmic movement behind the peripheral sheath of chloroplasts probably serves to move photosynthate products throughout the cell.

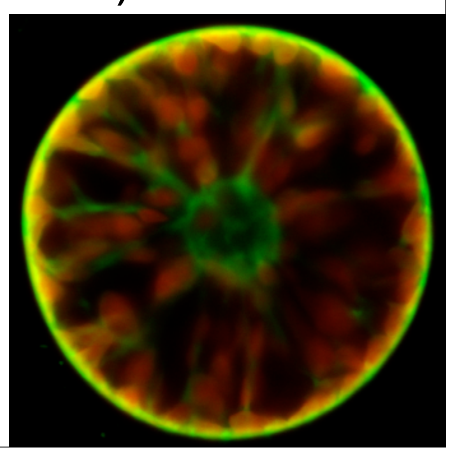


Chara australis





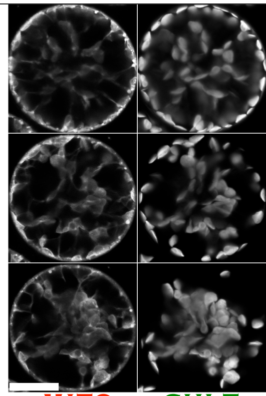
Chloroplasts do not exist in isolation within the cell. In *Eremosphaera viridis*, chloroplasts (red) are often closely associated with mitochondria (imaged with MitoFluorGreen).



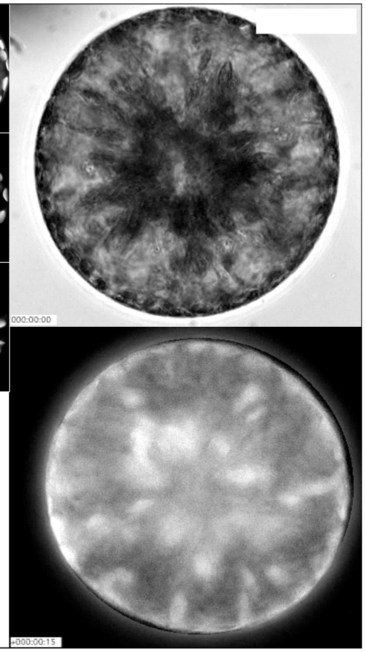
0 MIN

11 MIN

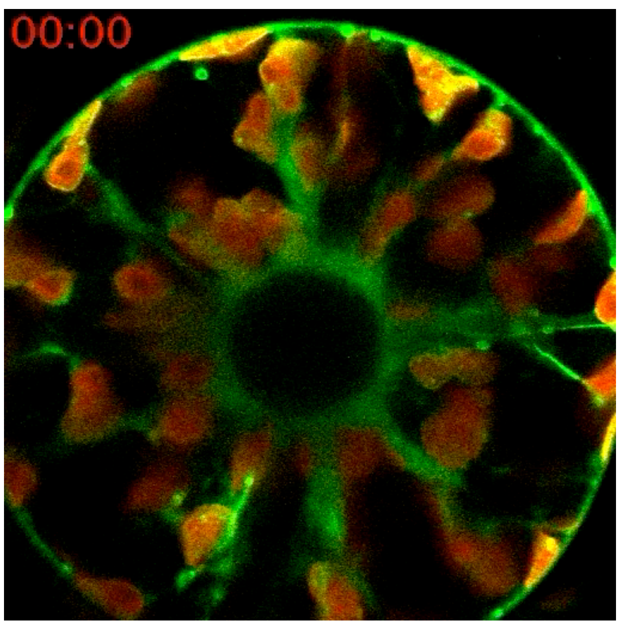
16 MIN



MITO CHLT



HIGH LIGHT INTENSITIES CAUSE THE CHLOROPLASTS TO MOVE TO THE CENTER OF THE CELL TO PROTECT THE NUCLEUS. MITOCHONDRIA STAY AT THE CELL PERIPHERY.

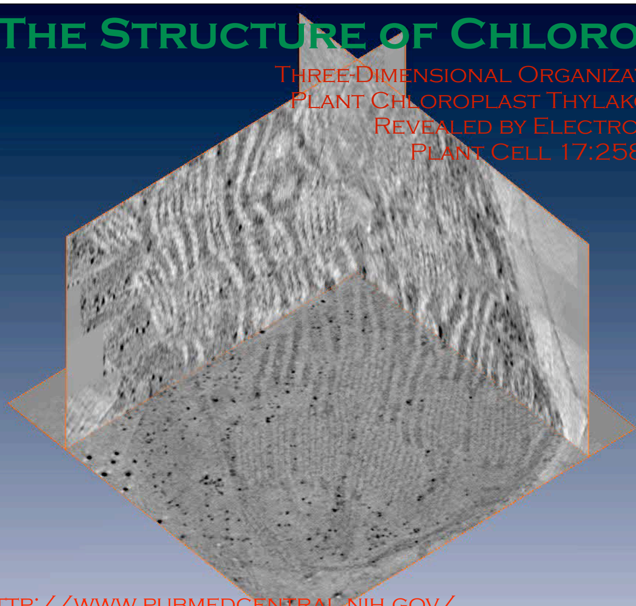


Chloroplasts and mitochondria in *Eremosphaera viridis*.

During high light-induced chloroplast movements to the center of the cell, mitochondria remain at the periphery. So, the two organelles are not co-localized in an obligatory fashion in *Eremosphaera viridis*.

The Structure of Chloroplasts

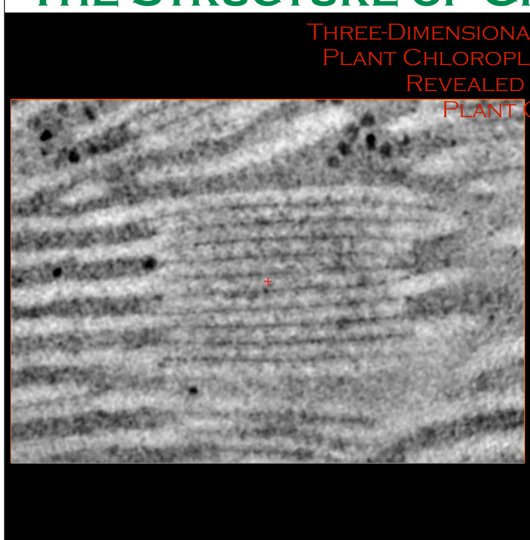
Three-Dimensional Organization of Higher-Plant Chloroplast Thylakoid Membranes Revealed by Electron Tomography. Plant Cell 17:2580-2586 (2005)



http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=1197436

The Structure of Chloroplasts

Three-Dimensional Organization of Higher-Plant Chloroplast Thylakoid Membranes Revealed by Electron Tomography. Plant Cell 17:2580-2586 (2005)

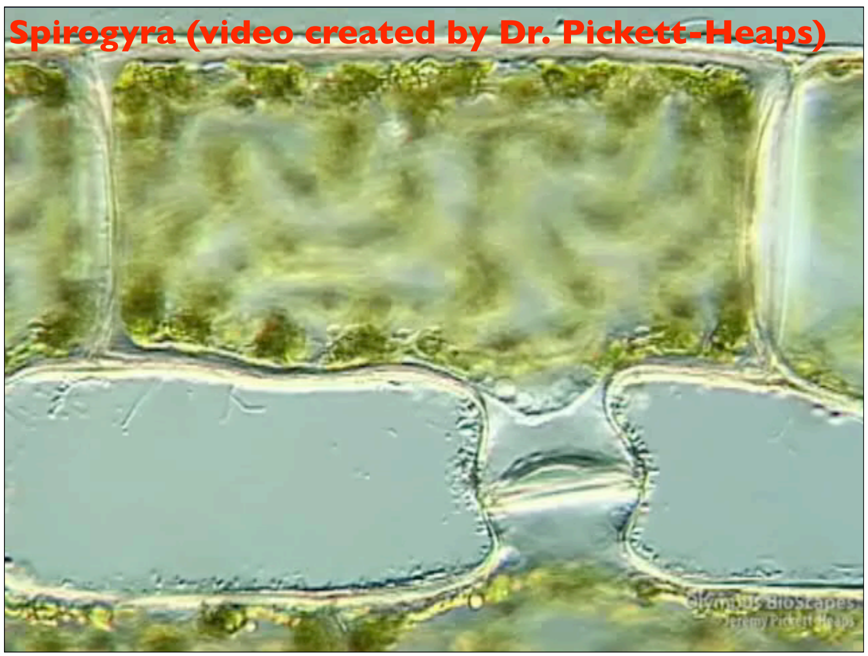


http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=1197436

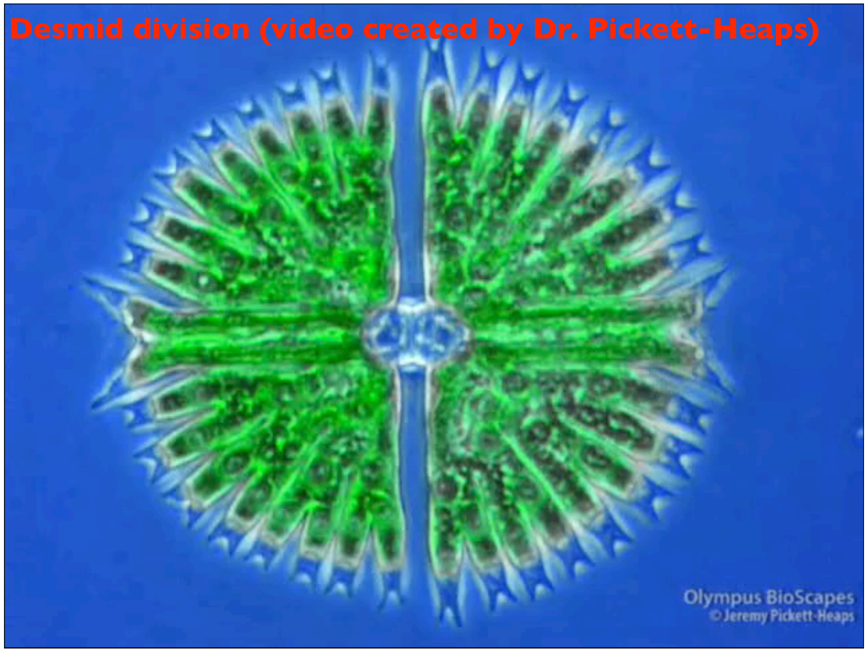
Warning: The following movies may not be suitable for all audiences due to depiction of graphic algal sex and cell division.

Parental Guidance is advised

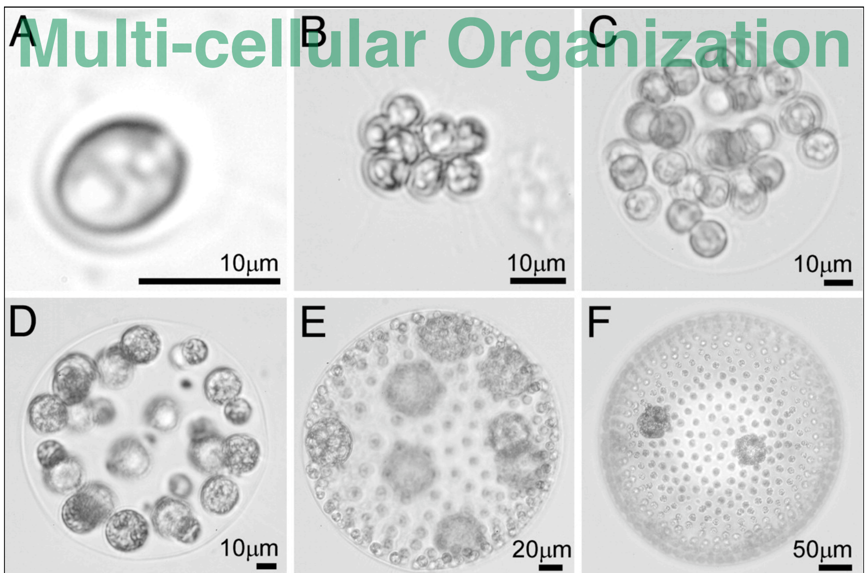
Spirogyra (video created by Dr. Pickett-Heaps)



Desmid division (video created by Dr. Pickett-Heaps)



Multi-cellular Organization



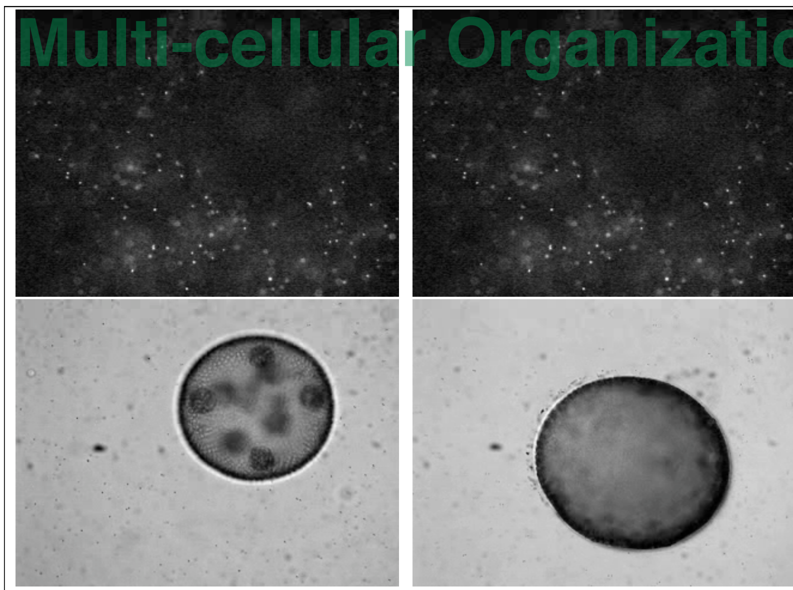
Species of volvocalean green algae spanning a large range in size. Shown are the single-cell *C. reinhardtii* (A), undifferentiated colonies *Gonium pectorale* (8 cells) (B) and *Eudorina elegans* (32 cells) (C), and those with germ-soma differentiation *Pleodorina californica* (64 cells) (D), *Volvox carteri* ({approx}1,000 cells) (E), and *Volvox aureus* ({approx}2,000 cells) (F).

Solari CA, S Ganguly, JO Kessler, RE Michod, RE Goldstein (2006) Multicellularity and the functional interdependence of motility and molecular transport. PNAS 103(5):1353–1358.

Multi-cellular Organization

Movie file of Pleodorina californica (notice increasing flow rate into colony by flagellar beating) and Haematococcus (a bi-flagellated unicellular algae).
(http://eebweb.arizona.edu/Michod/hydrodynamics.htm)
Solari CA, S Ganguly, JO Kessler, RE Michod, RE Goldstein (2006) Multicellularity and the functional interdependence of motility and molecular transport. PNAS 103(5):1353–1358.

Multi-cellular Organization



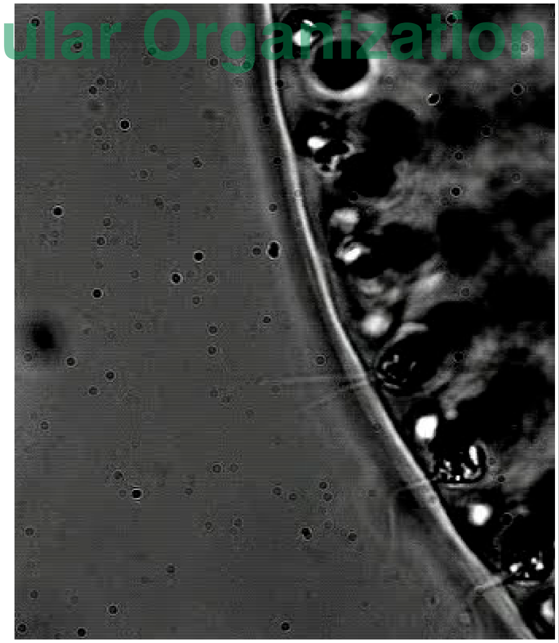
Flagellar feeding of V. carteri (narrow-band laser illumination, bright field) of V. rousseletii.
(http://eebweb.arizona.edu/Michod/hydrodynamics.htm)
Solari CA, S Ganguly, JO Kessler, RE Michod, RE Goldstein (2006) Multicellularity and the functional interdependence of motility and molecular transport. PNAS 103(5):1353–1358.

Multi-cellular Organization

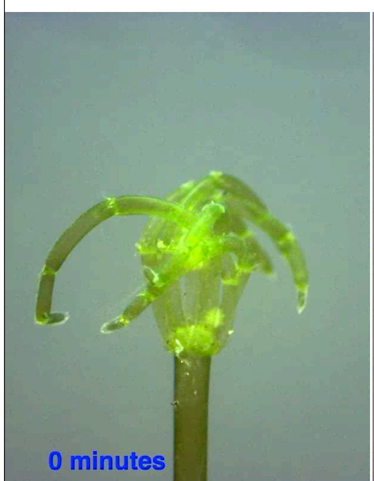
High-speed movie (125 fps) showing flagella (brightfield)

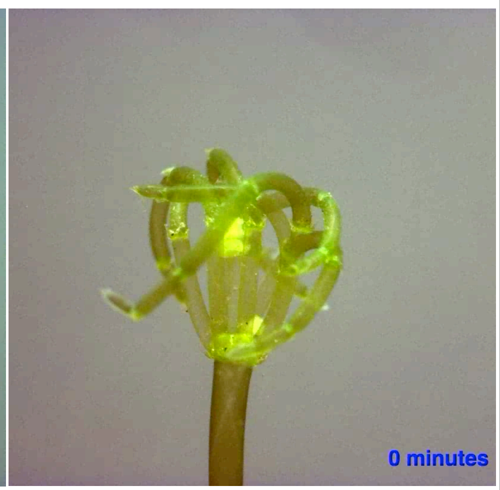
University of Cambridge > DAMTP > Goldstein Lab > Pictures and Movies

http://www.damtp.cam.ac.uk/user/gold/movies.html



Multi-cellular Organization





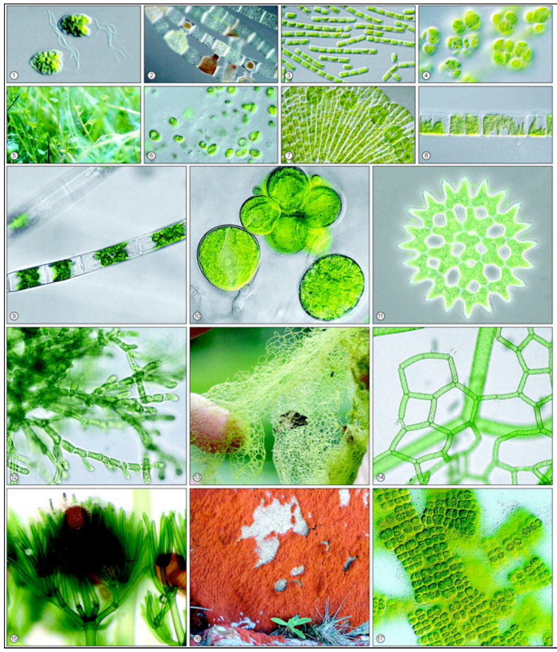
Chara australis

Chara shoot and apex
modified from Smith et al 1953
A Textbook of General Botany

Multi-cellular Organization

Multi-cellular Organization

Bull Kelp (Phaeophyceae)



Algal Diversity

(photo by V. Flechtner)