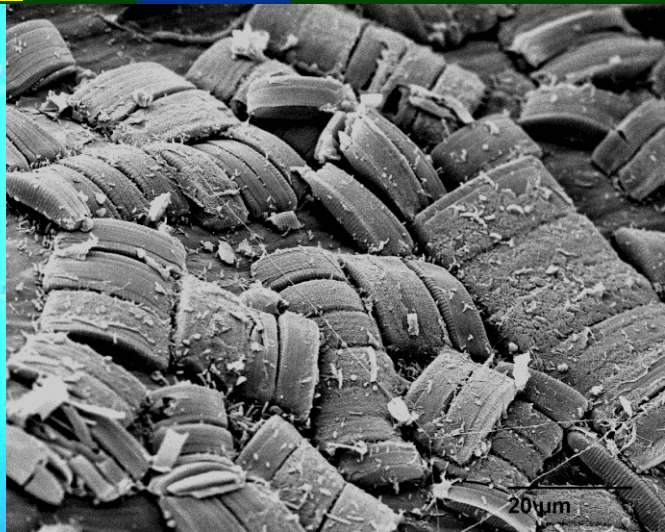
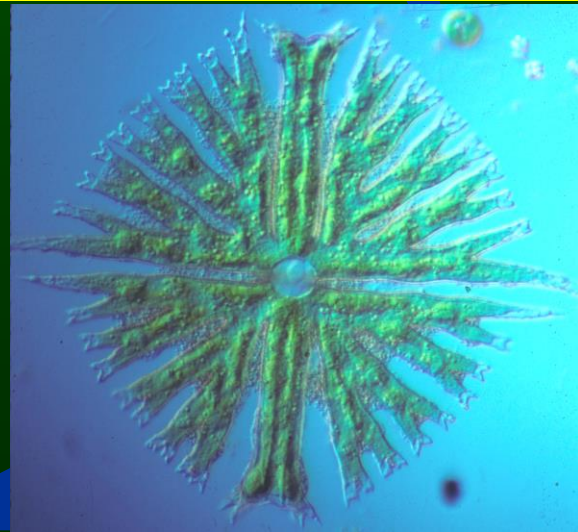


Algal diversity and application.

Rex L. Lowe

Bowling Green State University



Presentation Roadmap

What are these things called algae?

Species diversity & properties

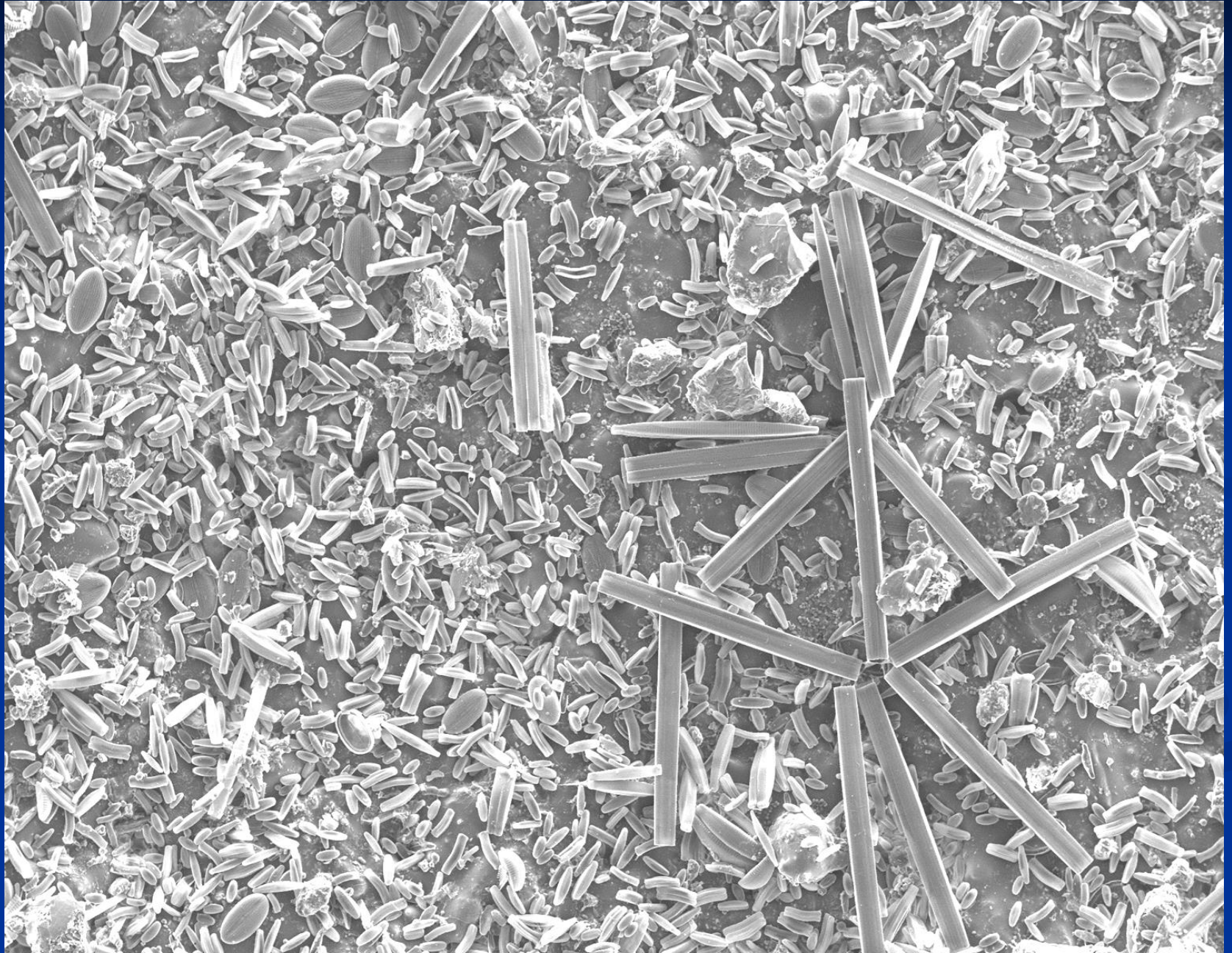
Ecosystem services, Ecosystem hazards

Algal communities might look homogeneous but are very complex

- A stone this size may contain hundreds of species in a very complex community.

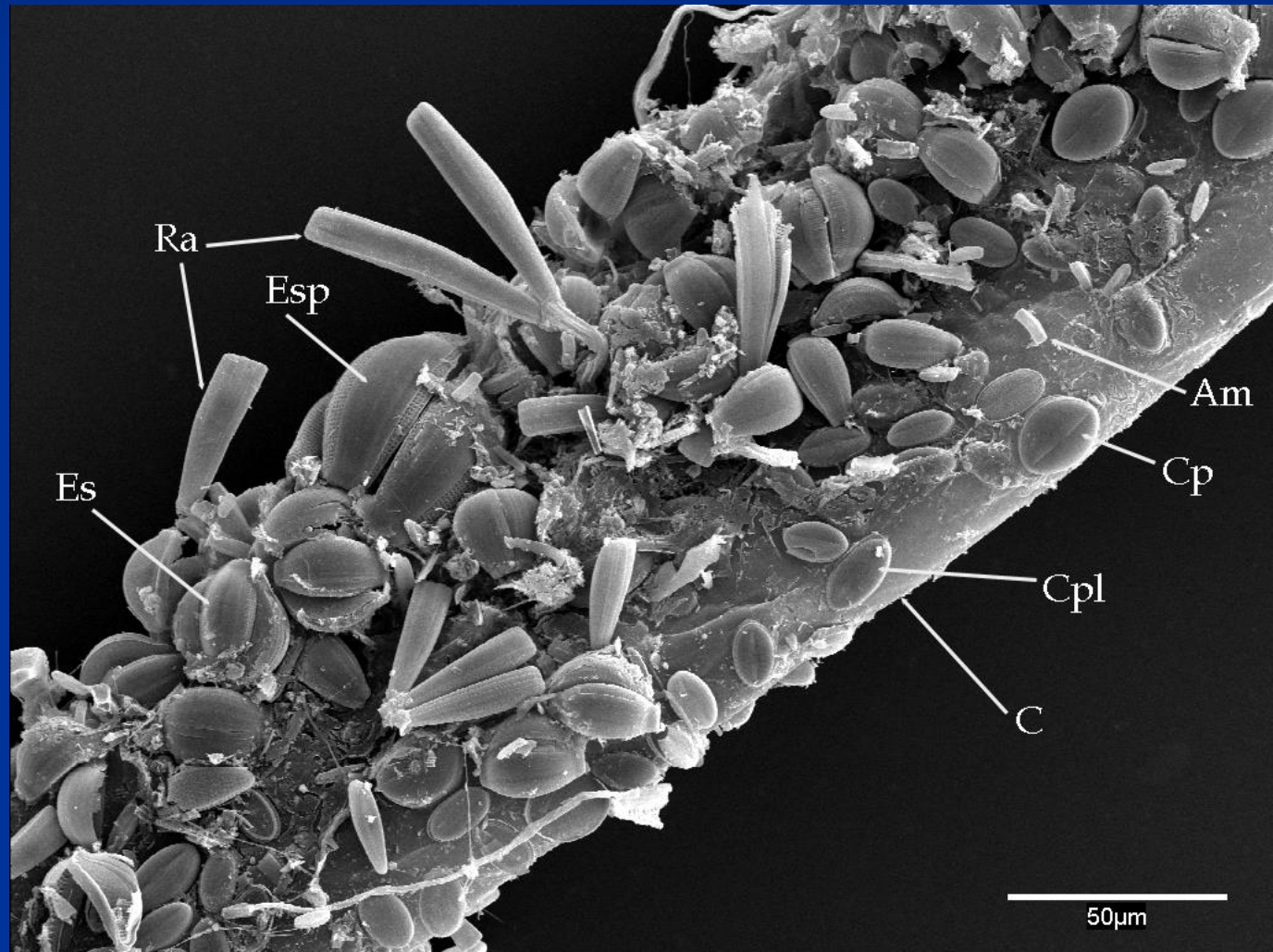


A complex community of epilithic algae



A complex community of epiphytic algae on *Cladophora*

- Ra = *Rhoicosphenia abbreviata*
- Esp = *Epithemia* sp.
- Es = *Epithemia sorex*
- Am = *Achnanthydium minutissimum*
- Cp = *Cocconeis pediculus*
- Cpl = *Cocconeis placentula*
- C = *Cladophora*



What are algae?

Algos = Latin seaweed

Phycos = Greek seaweed

- ◆ Thalloid organisms bearing **chlorophyll a**, lacking multicellular **gametangia** and their **colorless relatives**.
- ◆ Morphologically diverse:
 - ◆ Prokaryotes, mesokaryotes, eukaryotes
 - ◆ Largest to smallest phototrophs (0.5 μ m-220 m)
- ◆ Physiologically diverse: autotrophs, facultative heterotrophs, obligate heterotrophs (molecules or particles), parasites).

“Algae” is not a “taxonomic” group
but a functional group of convenience

Algae should not all be considered plants,
some are, some are also protozoa, many
are unique and belong in other kingdoms.
But they are all part of the eclectic group
called algae that are aquatic and oxygenic.

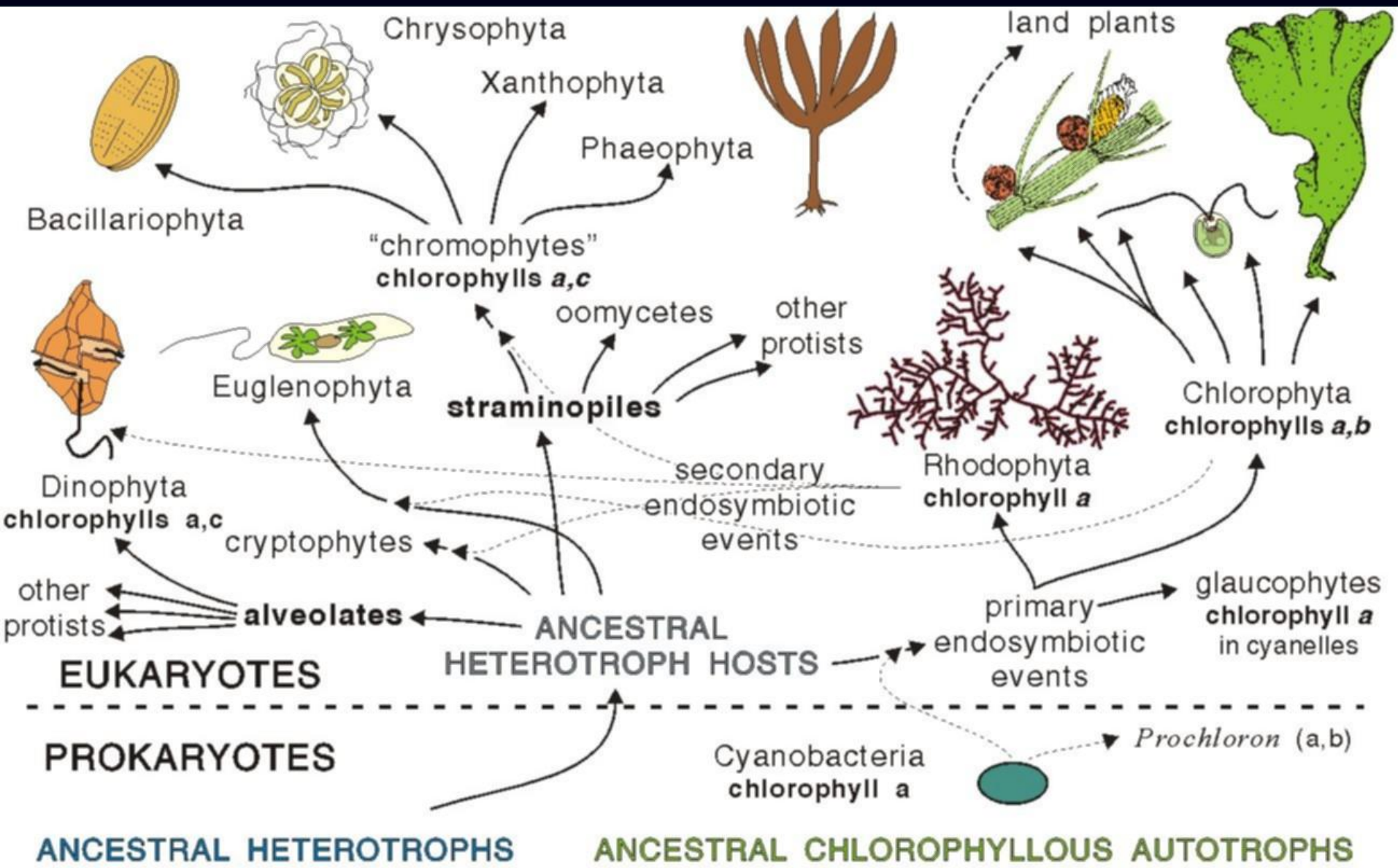


FIG. 9.1 HYPOTHETICAL ENDSYMBIOTIC ORIGINS OF PLASTIDS IN ALGAE AND PLANTS. This figure should be compared with the phylogeny of the host cells shown in Fig. 1.1. Cavalier-Smith (2000) hypothesizes a single primary capture event and a number of secondary capture events along with losses of pigments and membranes.

Major groups of algae

■ <u>Common Name</u>	<u>Phylum</u>	<u>Kingdom</u>
■ Green Algae	Chlorophyta	Plantae
■ Diatoms	Bacillariophyta	Stramenopila
■ Chrysophytes	Chrysophyta	Stramenopila
■ Brown Algae	Phaeophyta	Stramenopila
■ Blue Green Algae	Cyanophyta	Monera
■ Red Algae	Rhodophyta	Rhodophyta
■ Dinoflagellates	Pyrrhophyta	Alveolata
■ Euglenoids	Euglenophyta	Euglenozoa

Algal Divisions (Phyla)

How do the phyla differ from each other?

We employ 4 main criteria

**Pigmentation, storage products,
cell wall, flagella**

Overview of common phyla

- Green Algae
- Diatoms
- Cyanobacteria
- Brown Algae
- Red Algae

GREEN ALGAE

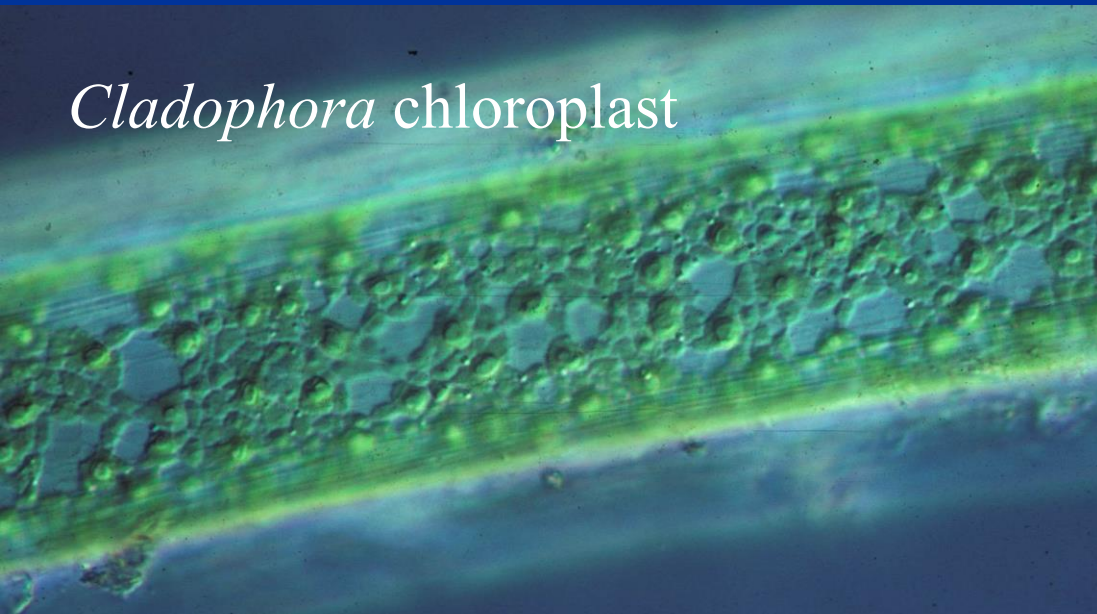
- Usually green in color
- Cellulose cell walls
- Store starch
- Ancestors of plants
 - Chlorophylls a & b dominate
 - Also rich in beta carotene

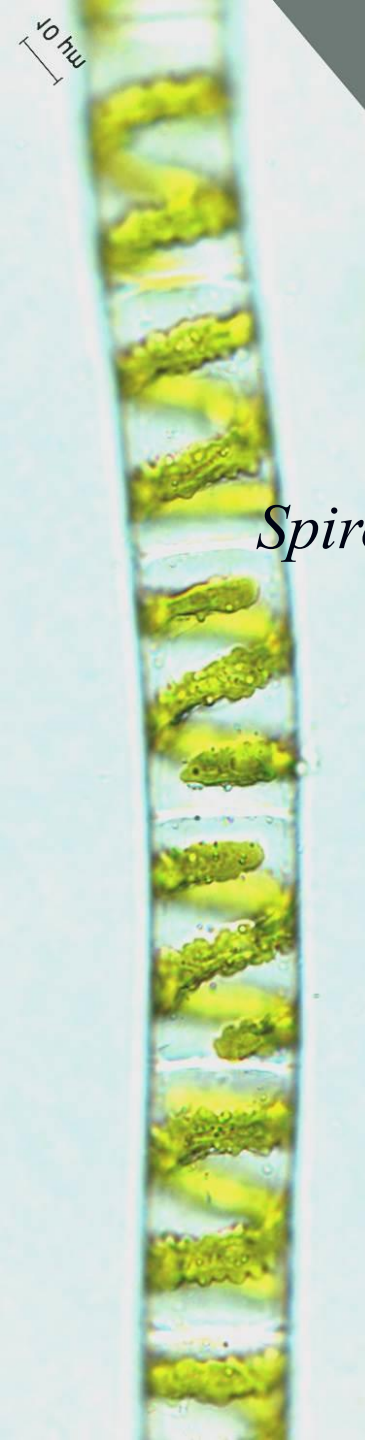
Cladophora



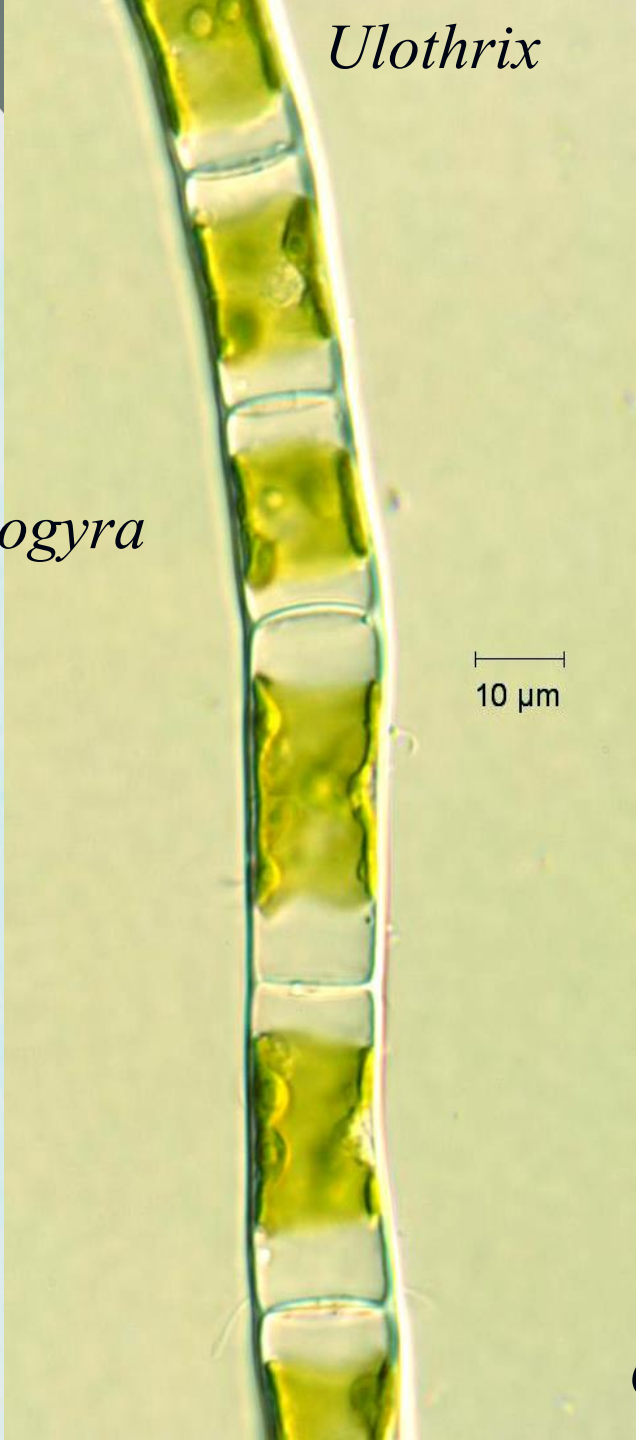
Cladophora epiphytes

Cladophora chloroplast

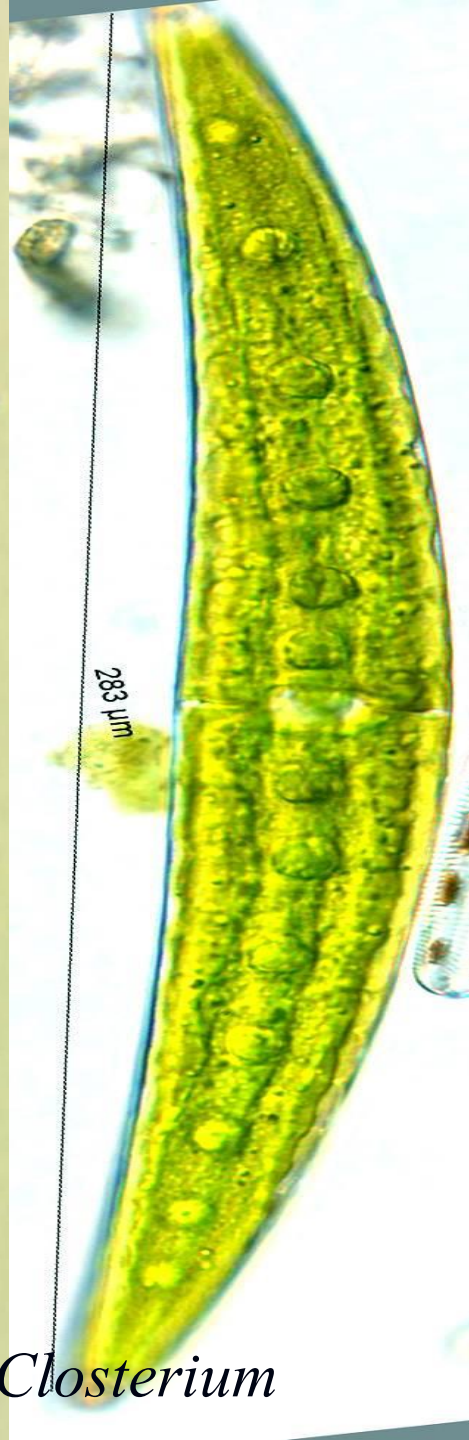




Spirogyra



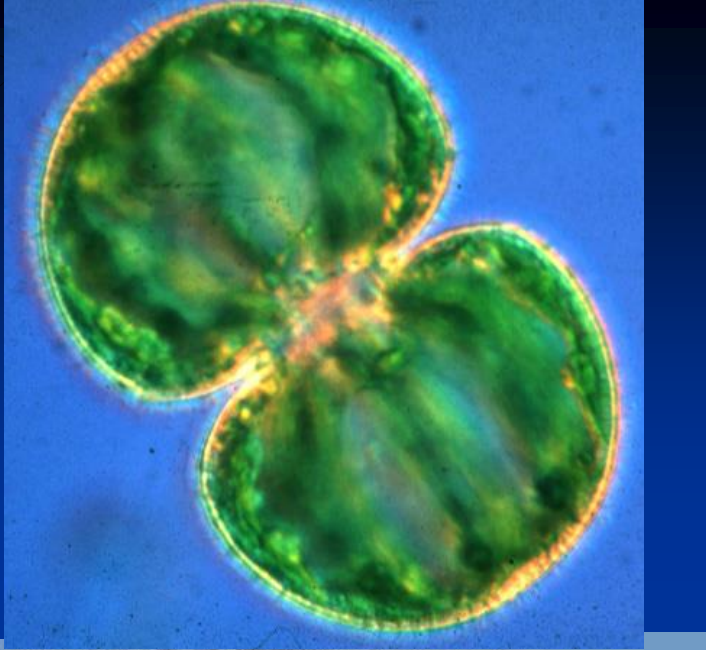
Ulothrix



Closterium

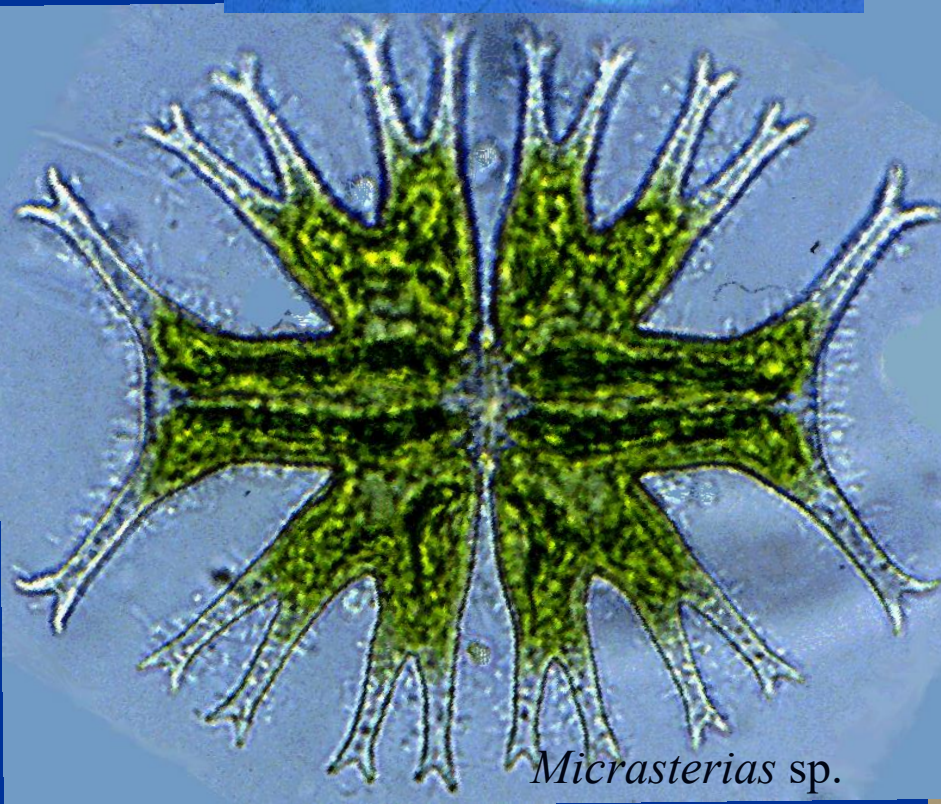


Spirotaenium



Ulothrix zonata

10 μm

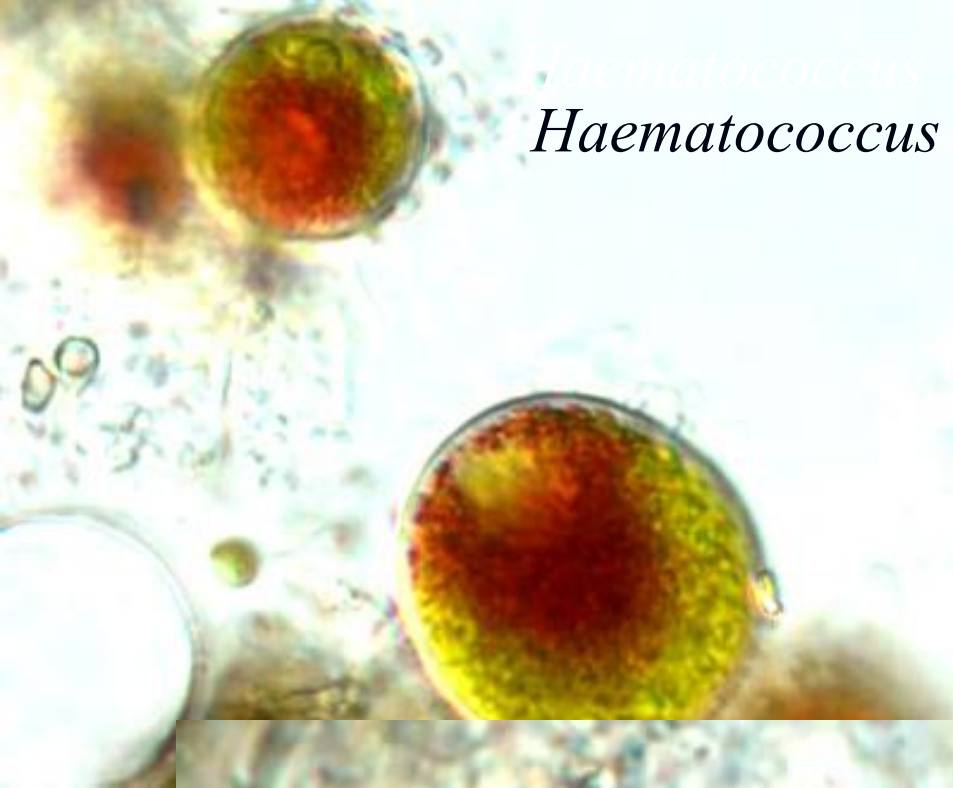


Micrasterias sp.

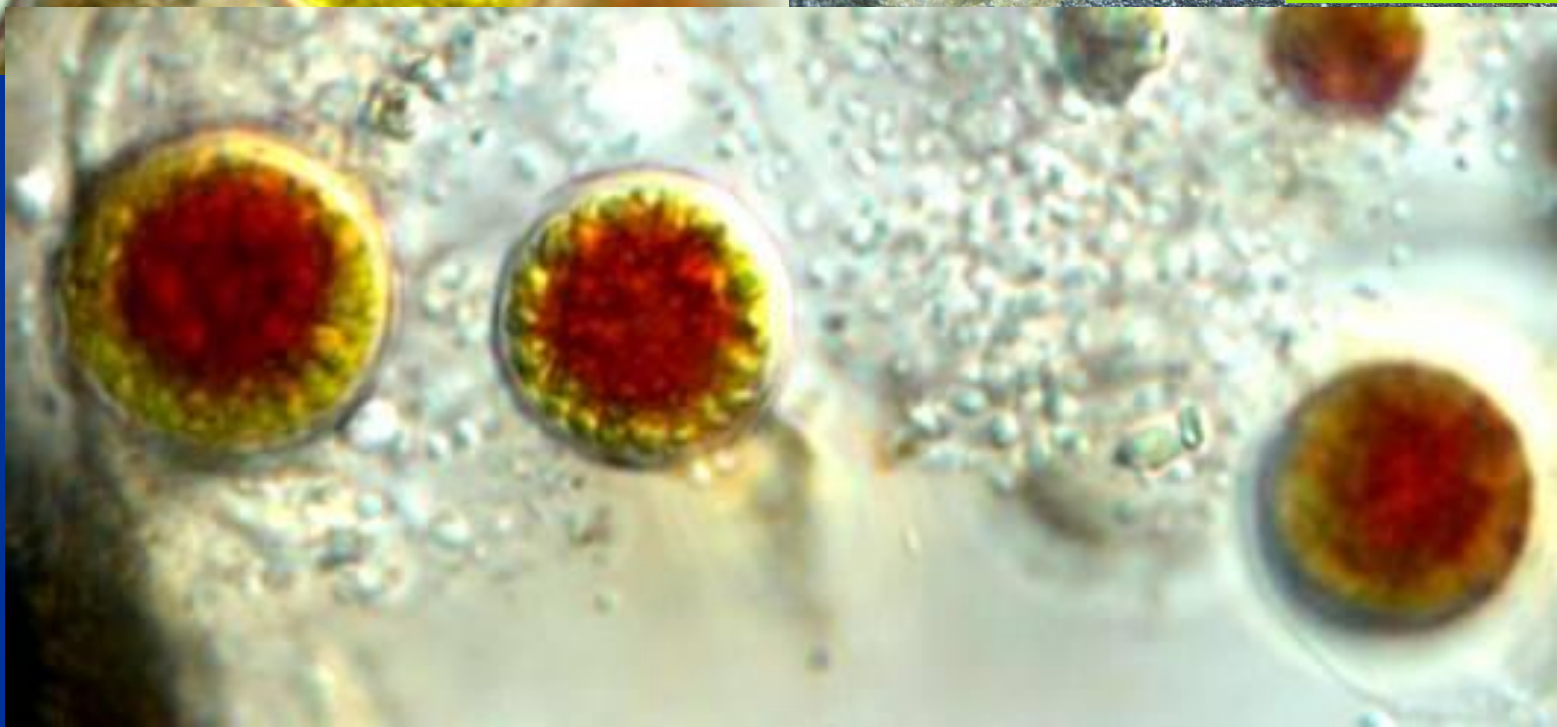


Staurastrum sp.

Haematococcus
Haematococcus



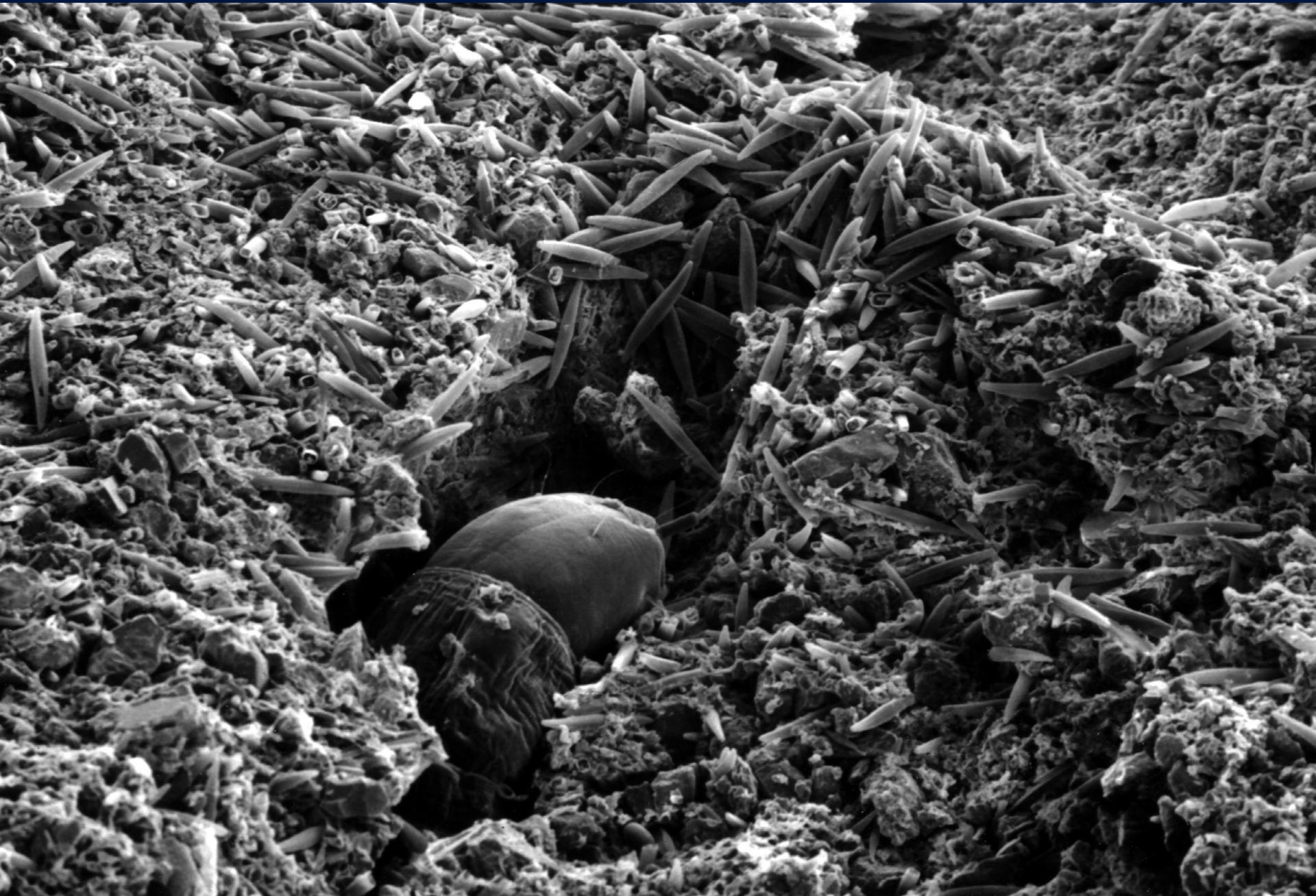
Not all green
Algae are
Green in color

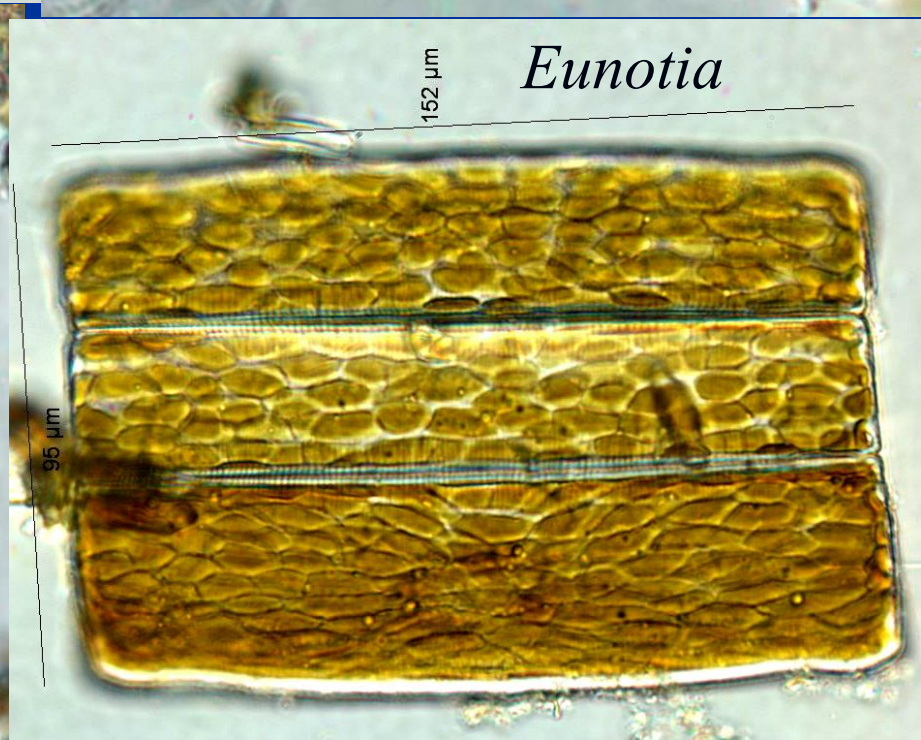
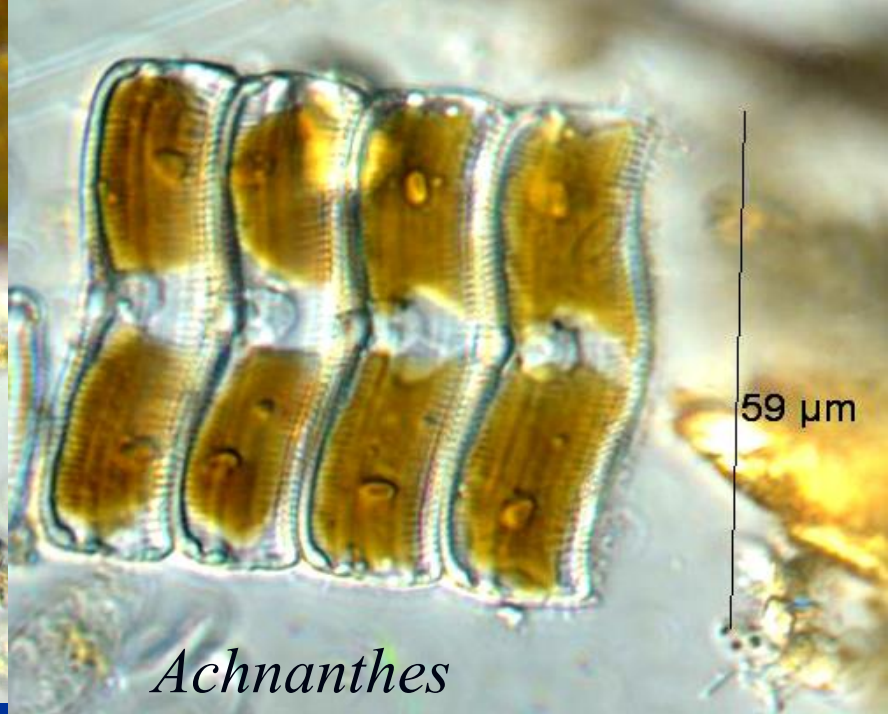


Bacillariophyta Diatoms

- Chlorophylls a & c but carotenoids dominate
- Golden-brown in color
- Silica cell walls
- Store oil as food reserve
- Very nutritious for grazers
- Rich in omega-3 oils

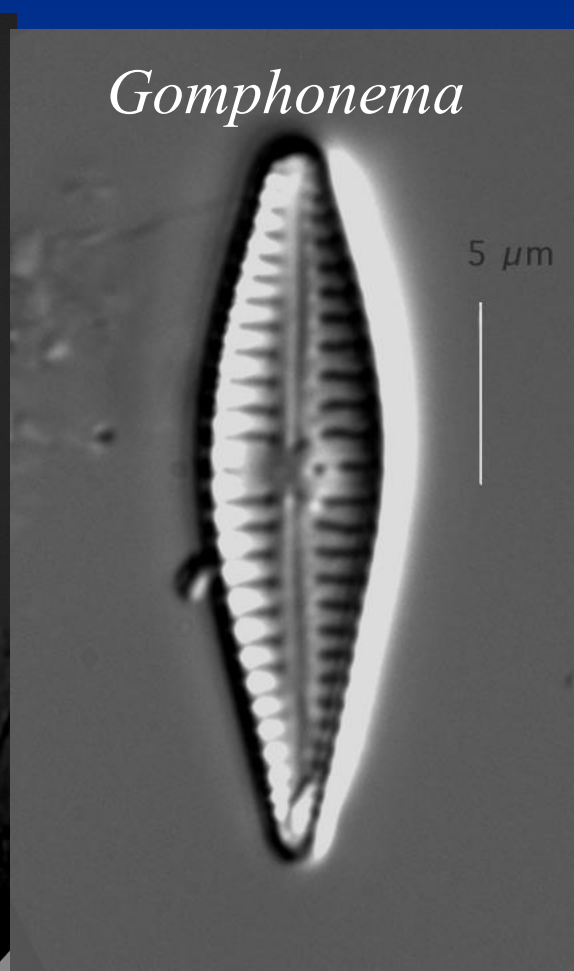
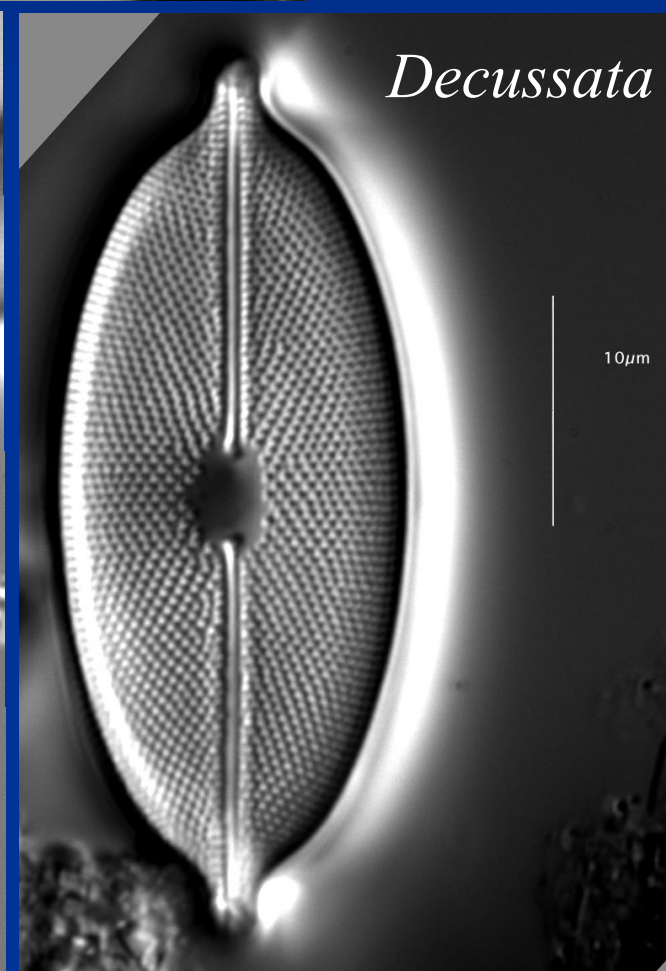
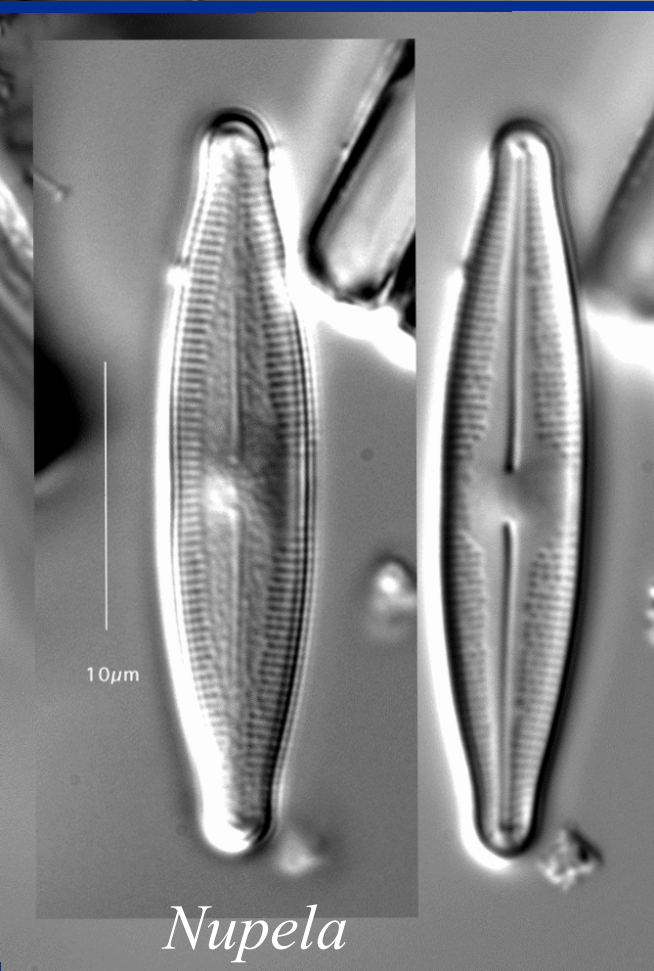
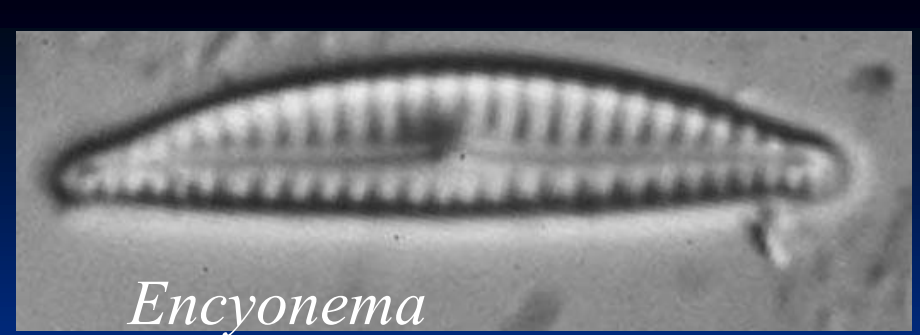
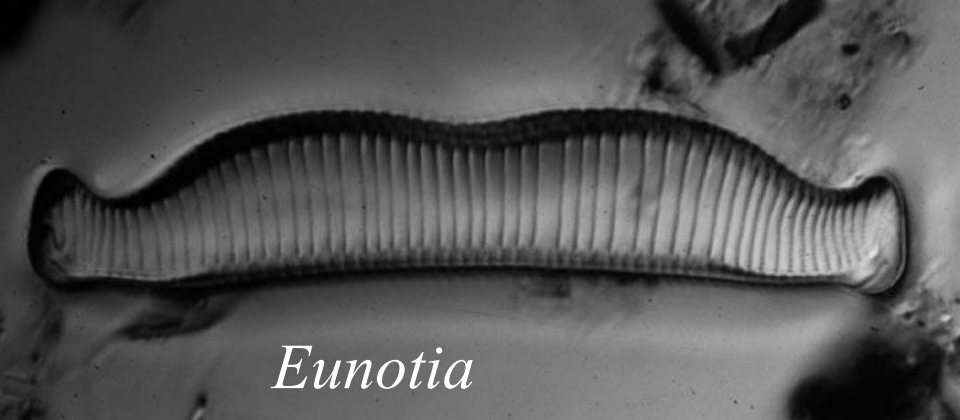
Chironomid consuming “french fry-like” diatoms, *Gyrosigma*

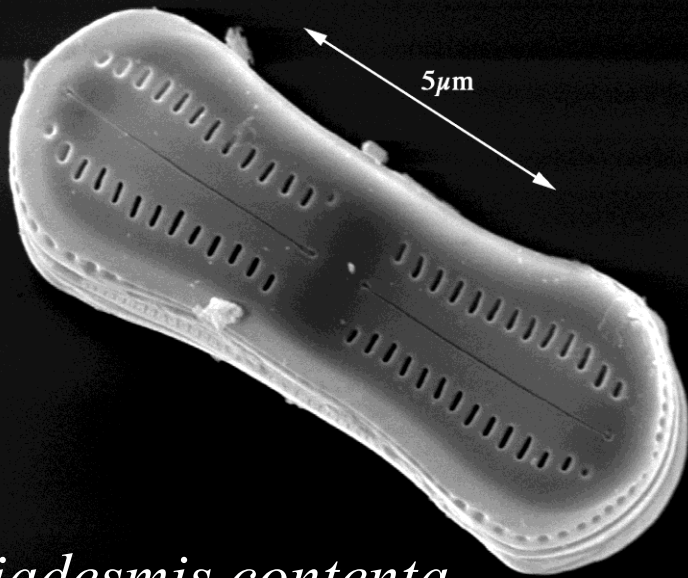




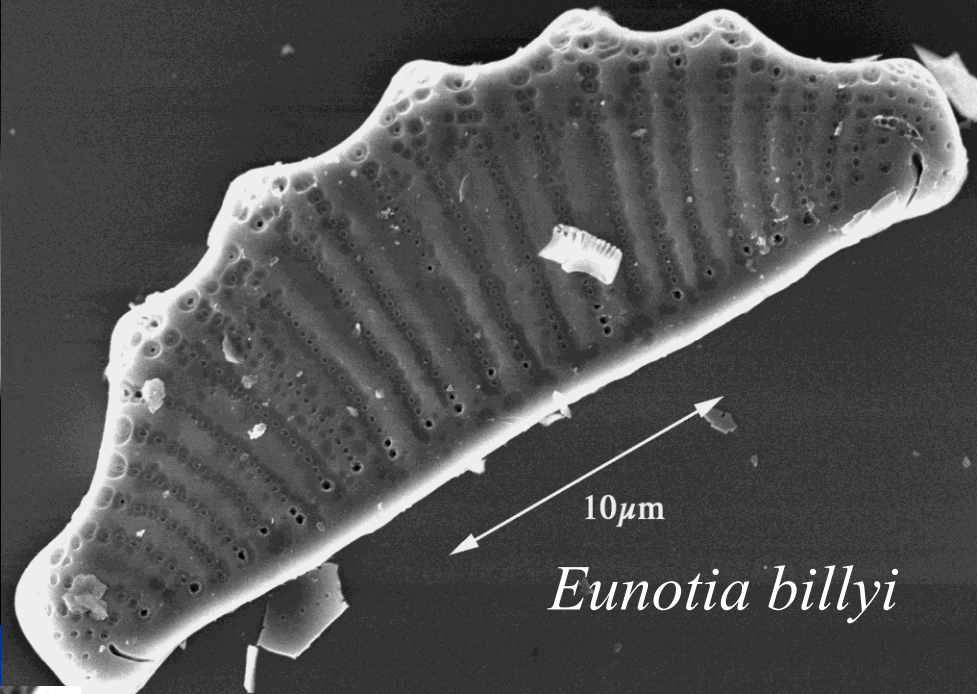
Diatoms normally need to be “cleaned” to identify them to species

- Boiled in nitric acid
- Mounted in Naphrax (a mounting medium of high refractive index)
 - For LM (light microscopy)
- Cleaned specimens are mounted onto specimen stubs for SEM (scanning electron microscopy)

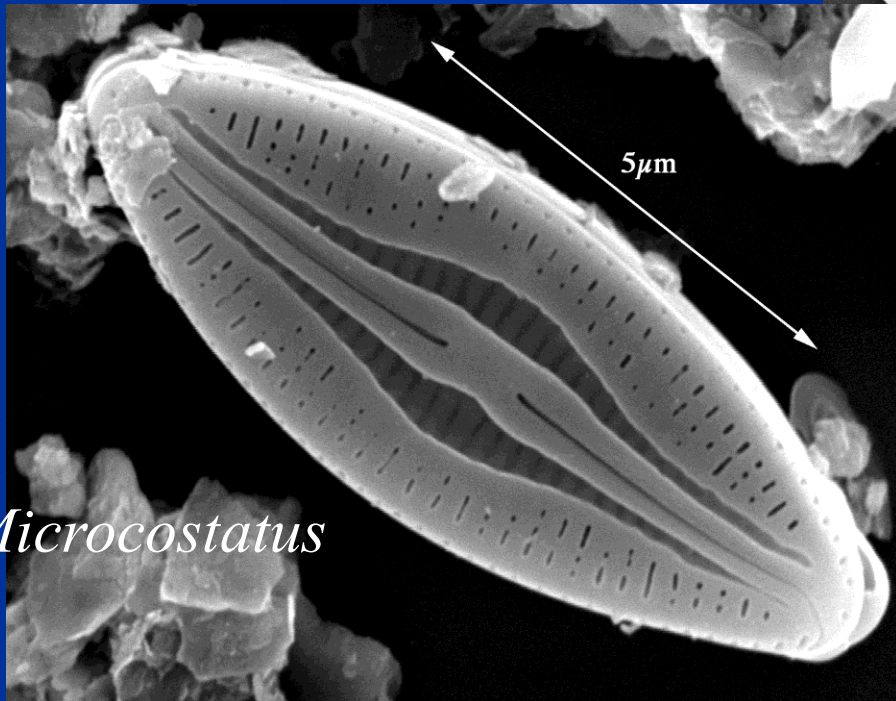




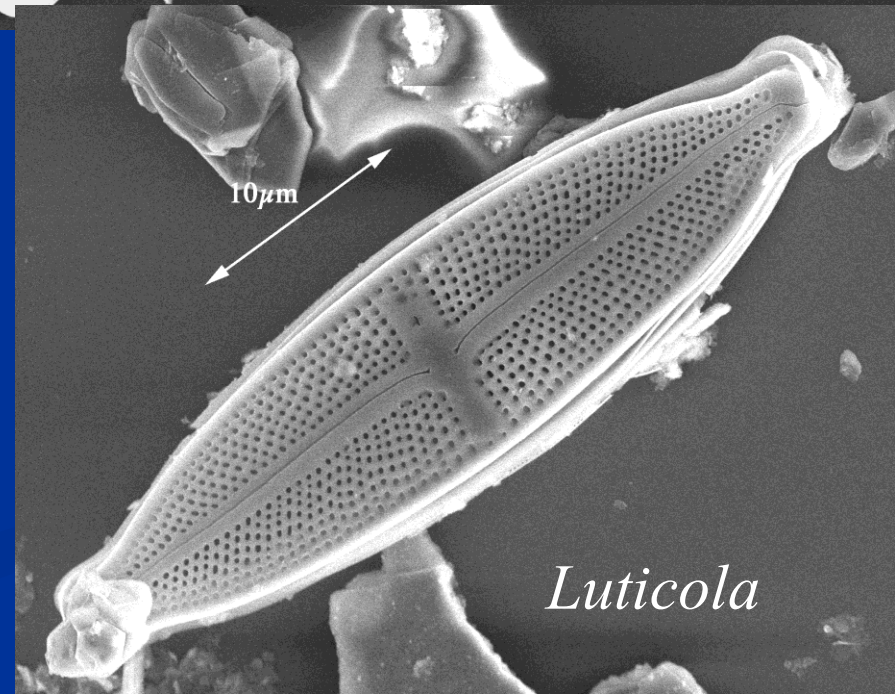
Diadesmis contenta



Eunotia billyi



Microcostatus



Luticola

Ecosystem services, Ecosystem hazards

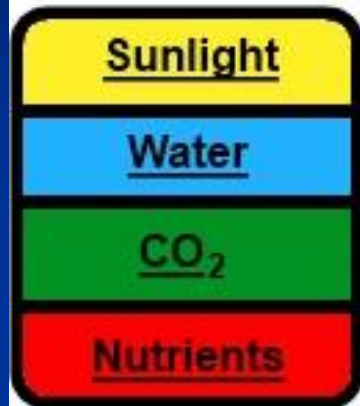
Services

Carbon fixation, about $\frac{1}{2}$ is from algae

Oxygen!

Aquatic food webs

Useful Products



Soil Conditioners & Agrochemicals

- > Fertilizers
- > Proteins

Fine Chemicals & Bioactive substances

- > Carotenoids
- > Phycobilliproteins
- > Omega 3 & Omega 6 fatty acids
- > Polysaccharides
- > Antioxidants
- > Bactericides
- > Plant growth promoters
- > Proteins and enzymes
- > Medical treatment & Pharmaceuticals

Energy Carriers

- > Biodiesel
- > Hydrocarbons
- > Ethanol
- > Gasoline
- > Methane & Hydrogen

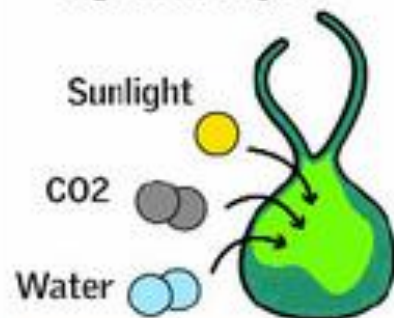
Algae bioproducts example

Biodiesel from algae

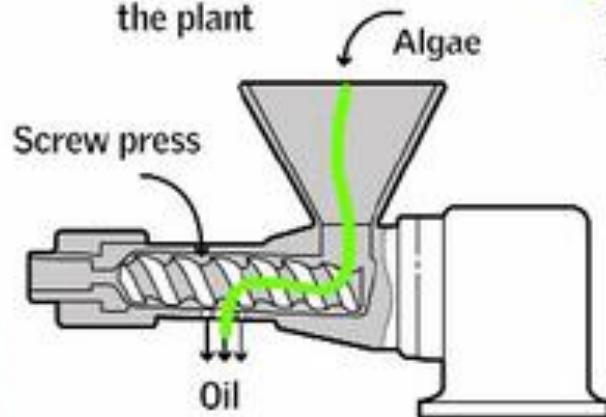
High oil prices and advances in biotech over the past decade have refueled the algae biofuel race.

The process

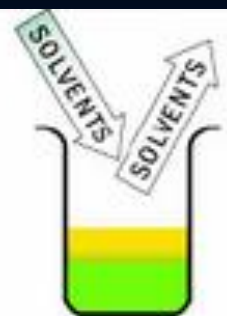
1 After initial growth, algae is deprived of nutrients to produce a greater oil yield



2 Extraction of oil
A press produces 70-75% of the oils from the plant



3 Solvents used to separate sugar from oil; solvents then evaporate



4 Oil is ready
Can be used as oil directly in diesel engines or refined further into fuel



Yield of various plant oils

(Gallons per hectare)

Soy	118
Safflower	206
Sunflower	251
Castor	373
Coconut	605
Palm	1,572
Algae	26,417



About algae

- Among the fastest growing plants; about 50% of their weight is oil
- Contains no sulfur; non toxic; highly biodegradable
- Algae fuel is also known as algal fuel or oilgae

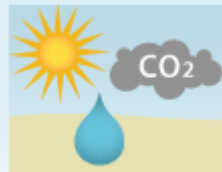
26,417

[Why Algae?](#)[How Does it Work?](#)[Why Does it Matter?](#)[FAQ](#)[Learn](#)

What is Green Crude

Green Crude is renewable crude oil that is a result of our proprietary process of turning sunlight, CO₂, and algae into green oils to be refined into fuel. Our approach leverages the same industrial refining processes as current crude oil, yielding "drop-in" replacement transportation fuels that meet ASTM standards for gasoline, jet fuel, and diesel and that are environmentally sound, cost effective, and scalable.

First- and second-generation biofuels are not compatible with the petroleum infrastructure while Green Crude fits within the existing infrastructure – from refinement through distribution, including the retail supply chain for cars, trucks, and airplanes.

[Why Algae?](#)[How it Works](#)[Why it Matters](#)

"The process for making algae into fuel at a very base level is this: Sunlight and CO₂ are the source of energy and carbon dioxide, rather than sugar or other organic material."

Want more information? Try the tabs in the column to your left or visit allaboutalgae.com

[Print](#) [Email](#) [Share](#)

RESOURCES

[Fast Facts](#)[Sapphire FAQ](#)

CONTACT SAPPHIRE

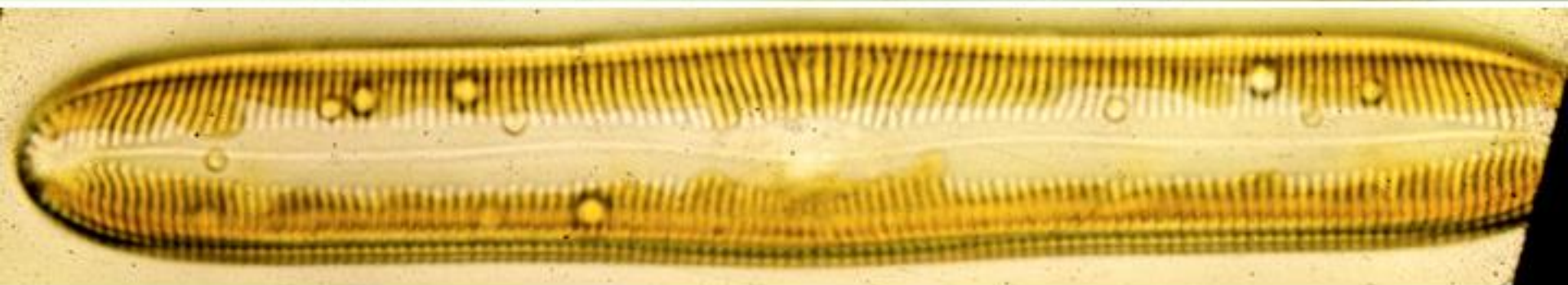
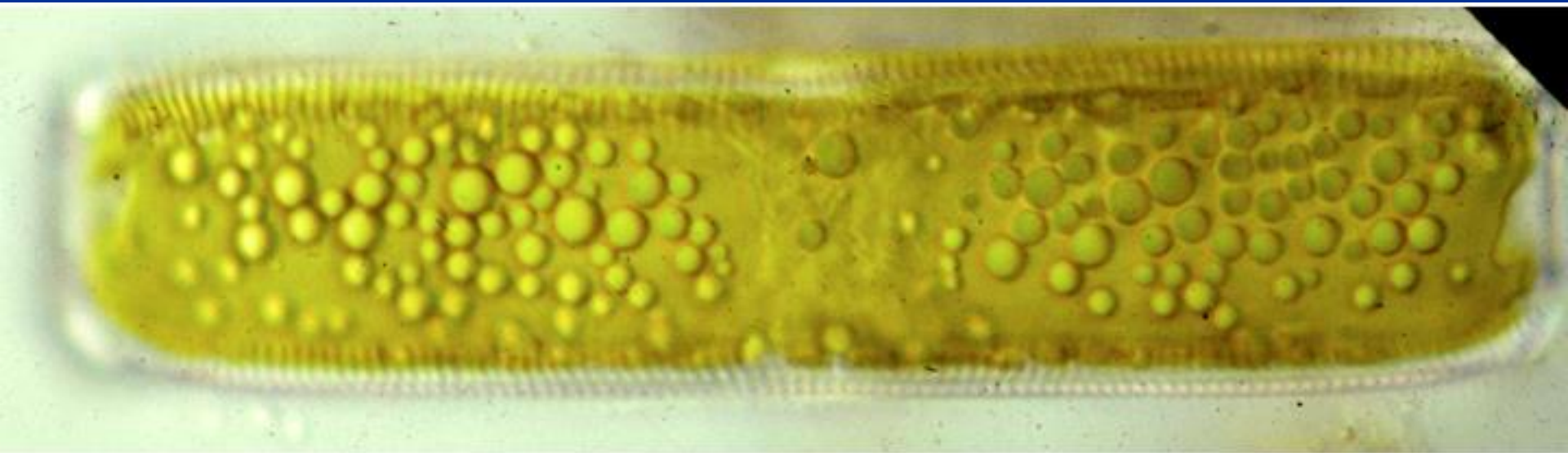
For media and analyst inquiries, please click:

[Media and analyst inquiry](#)

For general corporate inquiries contact Sapphire Energy by:

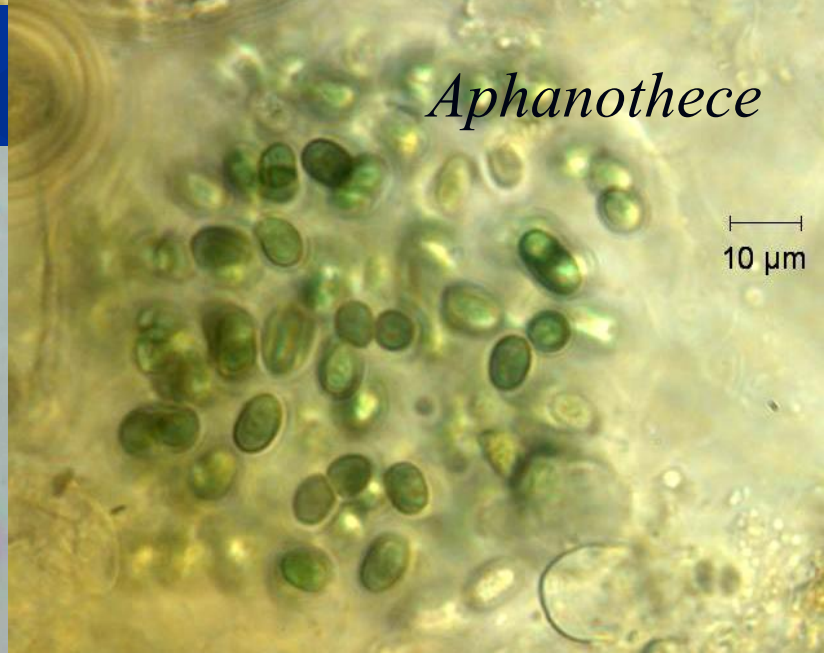
email:
info@sapphireenergy.com

More diatoms
Please.



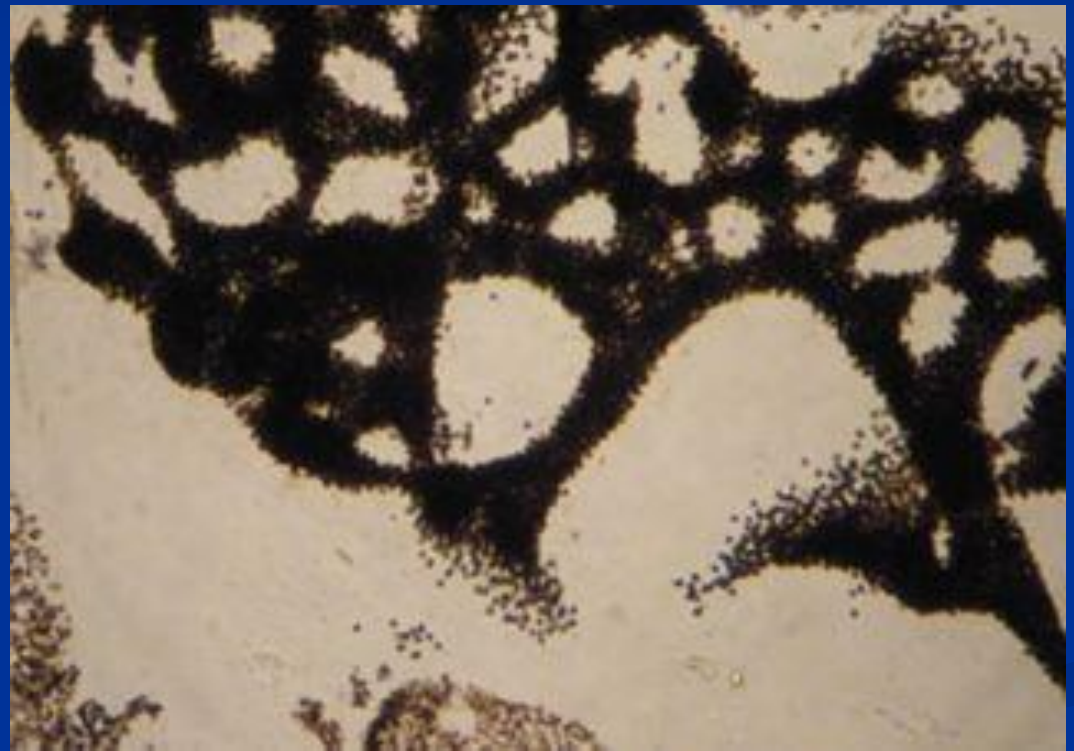
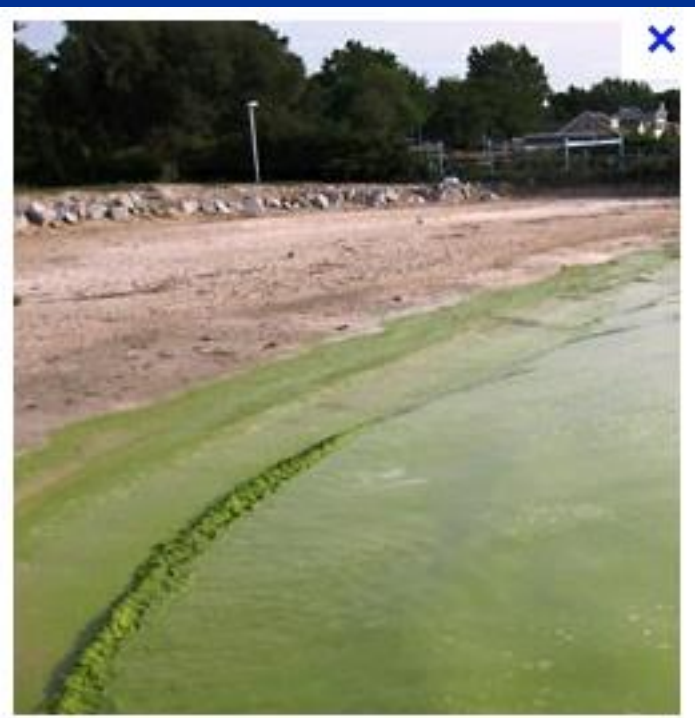
Blue Green Algae

- Cyanobacteria
- Prokaryotic
- Chlorophyll a
- Phycobilins present
- Store glycogen
- Heterocytes on some species (N-fixation)
- Some species are toxic



Hazards

Toxic Algae (Cyanobacteria, Dinoflagellates)



Microcystis

Toxins

- Blue-green algae produce two toxins, each with different symptoms. Signs of neurotoxin poisoning usually appear within 15 to 20 minutes after ingestion. In animals, symptoms include weakness, staggering, difficulty in breathing, convulsions and ultimately death. In humans, symptoms may include numbness of the lips, tingling in fingers and toes, and dizziness.
- Signs of liver poisoning may take hours or days to appear. Liver toxins can cause abdominal pain, diarrhea and vomiting in humans and death in animals.

Toxin and Taste-and-Odor Producing Cyanobacteria (list is not exhaustive)

(LYN, lyngbyatoxin-a; APL, aplysiatoxins; LPS, lipopolysaccharides; CYL, cylindrospermopsins; MC, μ -anatoxins; BMAA, β -N-methylamino-L-alanine; NEO, neosaxitoxins; SAX, saxitoxins; GEOS, geosmin;

	Dermatotoxins			Hepatotoxins			Neurotoxins				Tastes and Odors	
	LYN	APL	LPS	CYL	MC	NOD	ANA	BMAA	NEO	SAX	GEOS	MIB
Cyanobacterial Genera												
Colonial/Filamentous												
<i>Anabaena</i>			X	X	X		X	X	X	X	X	
<i>Anabaenopsis</i>			X		X							
<i>Aphanizomenon</i>			X	X			X	X	X	X	X	
<i>Aphanocapsa</i>			X		X							
<i>Cylindrospermopsis</i>			X	X				X		X		
<i>Fischerella</i>			X					X			X	
<i>Haplosiphon</i>			X		X							
<i>Hyella</i>			X								X	X
<i>Lyngbya (Plectonema)</i>	X	X	X	X				X		X	X	X
<i>Microcystis</i>			X		X			X				
<i>Nodularia</i>			X			X		X				
<i>Nostoc</i>			X		X			X			X	X
<i>Oscillatoria (Planktothrix)</i>	X	X	X		X		X	X		X	X	X
<i>Phormidium</i>			X				X	X			X	X
<i>Pseudanabaena</i>			X		X							X
<i>Raphidiopsis</i>			X	X			X					
<i>Schizothrix</i>	X	X	X									
<i>Umezakia</i>			X	X								
Unicellular												
<i>Synechococcus</i>			X		X			X			X	X
<i>Synechocystis</i>			X		X			X				

Table courtesy of Jennifer Graham, USGS

Red Algae/Rhodophyta

- Chlorophylls a, d; phycobilins (phycoerythrin)
- Store Floridean Starch
- Flagella: ABSENT. Only major eukaryotic division without flagella in some stage
- Cell Wall: Cellulose w/mucopolysaccharides
- The source of agar

Red Algae Products

- Most are from the complex cell wall
- Carrageenan (stabilizer and thickener)
 - Salad dressing, soft serve ice cream, puddings, icings, sauces, creamed soups, laxatives, lotions, creams, etc.

Red Algae Products

- Most are from the complex cell wall
- Agar (suspending agent, stabilizer and thickener)
 - Frozen foods, dessert gels, candies, cheeses, electrophoretic media, castings and impressions, radiology suspending agents, etc.

Carrageenan is a generic term for compounds extracted from species of red algae.

Carrageenans are used in stabilizing and gelling foods, cosmetics, pharmaceuticals, and industrial products.

Brownie mix, Chocolate milk, Coffee creamer, Cottage cheese, Evaporated milk, Frozen yogurt, Ice cream, Infant formula, Pet food, Pudding, Relishes, Salad dressing, Sauces and gravies, Sour cream, Toothpaste, Whipped topping, Whipping cream, Yogurt

Brown Algae

- Mostly large leathery seaweeds
- Cellulose wall with alginic acid and the polysaccharide fucoidan

Brown Algae





Brown Algae Products

- Most are from the complex cell wall
- Alginic acid (alginate) (suspending agent, emulsifying, gel-forming and film-forming)
 - Frozen foods, dessert gels, candies, cheeses, electrophoretic media, castings and impressions, radiology suspending agents, etc.

Algal species to consider

- This the list provided to me partitioned into major algal divisions.
- Mostly Red Green and Brown algae which are widely used as food and for other useful products. I would guess all are safe.

Agarum Cribrosum Extract

2. Ahnfeltia Concinna Extract

3. Alaria Esculenta Extract

4. Algae Extract (this ingredient name is slated to be retired due to the vagueness of the name and definition)

5. Aphanizomenon Flos-Aquae Powder

6. Ascophyllum Nodosum Extract

7. Ascophyllum Nodosum Powder

8. Asparagopsis Armata Extract

9. Betaphycus Gelatinum Extract

10. Botryocladia Occidentalis Extract

11. Calliblepharis Ciliata Extract

12. Capsosiphon Fulvescens Extract

13. Caulerpa Lentillifera Extract

14. Caulerpa Okamurai Extract

15. Caulerpa Racemosa Extract

16. Caulerpa Taxifolia Extract

17. Ceramium Kondoii Extract

18. Ceramium Rubrum

19. Chlamydocapsa Extract

20. Chlamydomonas

Algal Groups

Unknown

Blue Green

Brown

Red

Green

Euglenoid

Diatom

Haptophyte

21. Chlorella Ellipsoidea Extract	Algal Groups
22. Chlorella Emersonii Extract	Unknown
23. Chlorella Minutissima Extract	Blue Green
24. Chlorella Pyrenoidosa Extract	Brown
25. Chlorella Pyrenoidosa Powder	Red
26. Chlorella Variabilis Extract	Green
27. Chlorella Vulgaris Extract	Euglenoid
28. Chlorella Vulgaris Powder	Diatom
29. Chondracanthus Teedii Powder	Haptophyte
30. Chondrus Crispus	
31. Chondrus Crispus Extract	
32. Chondrus Crispus Powder	
33. Cistus Monspeliensis Extract (Cistus monspeliensis is a species of rockrose)	
34. Cladosiphon Novae-Caledoniae Extract	
35. Cladosiphon Okamuranus Extract	
36. Codium Fragile Extract	
37. Codium Tomentosum Extract	
38. Codium Tomentosum Powder	
39. Corallina Officinalis Extract	
40. Corallina Officinalis Powder	

41. **Cyanidium Caldarium Extract**
42. **Cystoseira Amentacea/Caespitosa Branchycarpa Extract**
43. **Cystoseira Baccata Extract**
44. **Cystoseira Compressa Extract**
45. **Cystoseira Compressa Powder**
46. **Cystoseira Tamariscifolia Extract**
47. **Delesseria Sanguinea Extract**
48. **Dictyopteris Membranacea Extract**
49. **Dictyota Coriacea Extract**
50. **Digenea Simplex Extract**
51. **Dilsea Carnosa Extract**
52. **Dunaliella Bardawil Extract**
53. **Dunaliella Bardawil Powder**
54. **Dunaliella Salina Extract**
55. **Durvillea Antartica Extract bull kelp**
56. **Ecklonia Cava Extract**
57. **Ecklonia Kurome Extract**
58. **Ecklonia Kurome Powder**
59. **Ecklonia Laminaria Extract**
60. **Ecklonia Maxima Extract**

Algal Groups

Unknown

Blue Green

Brown

Red

Green

Euglenoid

Diatom

Haptophyte

61. **Ecklonia Maxima Powder**
62. **Ecklonia Radiata Extract**
63. **Eisenia Arborea Extract**
64. **Emiliana Huxleyi Extract (haptophyte)**
65. **Enteromorpha Compressa Extract**
66. **Enteromorpha Compressa Powder**
67. **Enteromorpha Flexuosa Extract**
68. **Euglena Gracilis Extract**
69. **Fucoxanthin**
70. **Fucus Serratus Extract**
71. **Fucus Vesiculosus Extract**
72. **Fucus Vesiculosus Powder**
73. **Furcellaria Lumbricalis Extract**
74. **Gelidium Amansii Extract**
75. **Gelidium Cartilagineum Extract**
76. **Gelidium Pulchrum Protein**
77. **Gelidium Sesquipedale Extract**
78. **Gellidiela Acerosa Extract**
79. **Gigartina Skottsbergii Extract**
80. **Gigartina Stellata Extract**

Algal Groups

Unknown

Blue Green

Brown

Red

Green

Euglenoid

Diatom

Haptophyte

- 81. Gloiopeltis Aenax Powder**
- 82. Gracilaria Verrucosa Extract**
- 83. Gracilariopsis Chorda Extract**
- 84. Grateloupia Livida Powder**
- 85. Haematococcus Pluvialis Extract**
- 86. Haematococcus Pluvialis Powder**
- 87. Halimeda Opuntia Extract**
- 88. Halopteris Scoparia Extract**
- 89. Haslea Ostrearia Extract**
- 90. Himanthalia Elongata Extract**
- 91. Himanthalia Elongata Powder**
- 92. Hizikia Fusiforme Extract**
- 93. Hydrolyzed Algae Extract**
- 94. Hydrolyzed Asparagopsis Armata Extract**
- 95. Hydrolyzed Chlorella Vulgaris Extract**
- 96. Hydrolyzed Chlorella Vulgaris Protein**
- 97. Hydrolyzed Chondrus Crispus Extract**
- 98. Hydrolyzed Corallina Officinalis Extract**
- 99. Hydrolyzed Ecklonia Cava Extract**
- 100. Hydrolyzed Enteromorpha Compressa**

Algal Groups

Unknown

Blue Green

Brown

Red

Green

Euglenoid

Diatom

Haptophyte

101. Hydrolyzed Euglena Gracilis Extract
102. Hydrolyzed Fucus Vesiculosus Extract
103. Hydrolyzed Fucus Vesiculosus Protein
104. Hydrolyzed Porphyra Yezoensis
105. Hydrolyzed Rhodophyceae Extract
106. Hypnea Musciformis Extract
107. Kappaphycus Alvarezii Extract
108. Kassou Genaric Japanese name for brown algae
109. Kousou
110. Kousou Ekisu brown algal extract
111. Laminaria Angustata Extract
112. Laminaria Cloustoni Extract
113. Laminaria Digitata Extract
114. Laminaria Hyperborea Extract
115. Laminaria Japonica Extract
116. Laminaria Longissima Extract
117. Laminaria Ochotensis Extract
118. Laminaria Ochroleuca Extract
119. Laminaria Saccharina Extract
120. Lessonia Nigrescens Extract

Algal Groups

Unknown

Blue Green

Brown

Red

Green

Euglenoid

Diatom

Haptophyte

121. **Lessonia Nigrescens Powder**
122. **Lithothamnium Calcarum Extract**
123. **Lithothamnium Calcarum Powder**
124. **Lithothamnium Corallioides Powder**
125. **Macrocystis Pyrifera (Kelp)**
126. **Mesophyllum Lichenoides Extract**
127. **Monostroma Obscurum Extract**
128. **Nereocystis Leutkeana Extract**
129. **Odontella Aurita Oil**
130. **Palmaria Palmata Extract**
131. **Palmaria Palmata Powder**
132. **Pelvetia Canaliculata Extract**
133. **Pelvetia Siliquosa Extract**
134. **Phaeodactylum Tricornutum Extract**
135. **Phyllacantha Fibrosa Extract**
136. **Phymatolithon Calcareum Extract**
137. **Pikea Robusta Extract**
138. **Pleurochrysis Carterae Extract** haptophyte
139. **Polysiphonia Lanosa Extract**
140. **Porphyra Linearis Powder**

Algal Groups

Unknown

Blue Green

Brown

Red

Green

Euglenoid

Diatom

Haptophyte

141. **Porphyra Tenera Extract**
142. **Porphyra Umbilicalis Extract**
143. **Porphyra Umbilicalis Powder**
144. **Porphyra Yezoensis Extract**
145. **Porphyra Yezoensis Powder**
146. **Porphyridium Cruentum Extract**
147. **Porphyridium Purpureum Extract**
148. **Pyrocystis Noctiluca Extract dinoflagellate**
149. **Pytocystis Noctiluca Lysate**
150. **Ransou Ekisu blue green algae skin conditioner**
151. **Rhodymenia Palmata Extract**
152. **Rissoella Verruculosa Extract**
153. **Sahel Scenedesmus Extract**
154. **Sarcodiotheca Gaudichaudii Extract**
155. **Sargachromanol D**
156. **Sargachromanol E**
157. **Sargachromanol F**
158. **Sargassum Filipendula Extract**
159. **Sargassum Fulvellum Extract**
160. **Sargassum Fusiforme Extract**

Algal Groups

Unknown

Blue Green

Brown

Red

Green

Euglenoid

Diatom

Haptophyte

- 161. Sargassum Horneri Extract**
- 162. Sargassum Muticum Extract**
- 163. Sargassum Vulgare Extract**
- 164. Sphacelaria Scoparia Extract**
- 165. Spirulina Maxima Powder**
- 166. Spirulina Platensis Extract**
- 167. Spirulina Platensis Powder**
- 168. Spirulina Subsalsa Extract**
- 169. Thalassiosira Pseudonana Extract**
- 170. Ulva Lactuca Extract**
- 171. Ulva Lactuca Powder**
- 172. Ulva Pertusa Extract**
- 173. Undaria Pinnatifida Extract**

Algal Groups

Unknown

Blue Green

Brown

Red

Green

Euglenoid

Diatom

Haptophyte