Algae

Microbiological Approach

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Introduction

- What are algae definition according to you?
- How were they gain their nutrition?
- Why do we should learn this topic ?
- How do algae can provide benefit to us?

Objective

Algae

- Algae are simple organisms. Many are unicellular, while others are
- multicellular and more complex, but they all have rudimentary conducting tissues. They also exhibit a wide range of variation from a morphological and reproductive point of view. Algae are biochemically and physiologically very similar to the rest of plants: they essentially have the same metabolic pathways, possess chlorophyll, and produce similar proteins and carbohydrates

Objective

Algae

- **Algae also lack true roots, stems, and leaves—features they share with the avascular lower plants (e.g., mosses, liverworts, and hornworts).**

Objective

Algae

- **Beginning in the 1830s, algae were classified into major groups based on colour—e.g., red, brown, and green**
- he colours are a reflection of different chloroplast pigment s, such as chlorophylls, carotenoids, and phycobiliproteins.

Size

Algae

- **Macroalgae**

- **Microalgae**

Objective

Algae

- Many algae consist of only one cell, while the largest have millions of cells. In large, macroscopic algae, groups of cells are specialized for specific functions, such as anchorage, transport, photosynthesis, and reproduction; such specialization indicates a measure of complexity and evolutionary advancement.

Classification

Classification Scheme of the Different Algal Groups

	Kingdom	Subkingdom	Infrakingdom	Phylum	Class	Representative	Image
Prokaryota	Bacteria	Negibacteria		Cyanobacteria	Cyanophyceae	*Arthrospira*	1.1a
Eukaryota	Plantae	Biliphyta		Glaucophyta	Glaucophyceae	*Cyanophora*	1.1b
				Rhodophyta	Bangiophyceae	*Porphyra*	1.1c
					Compsopogonophyceae	*Erythrocladia*	1.1d
					Cyanidiophyceae	*Cyanodioschyzon*	1.1e
					Florideophyceae	*Phyllophora*	1.1f
					Porphyridiophyceae	*Porphyridium*	1.1g
					Rhodellophyceae	*Glaucosphaera*	1.1h
					Stylonematophyceae	*Stylonema*	1.1i
		Viridiplantae	Chlorophyta	Chlorophyta	Prasinophytes	*Pyramimonas*	1.1l
					Mamiellophyceae	*Crustomastix*	1.1m
					Nephroselmidophyceae	*Nephroselmis*	1.1n
					Pedinophyceae	*Pedinomonas*	1.1o
					Chlorodendrophyceae	*Tetraselmis*	1.1p
					Chlorophyceae	*Scenedesmus*	1.1q
					Ulvophyceae	*Ulva*	1.1r
					Trebouxiophyceae	*Chlorella*	1.1s
					Dasycladophyceae	*Acetabularia*	1.1t
					Palmophyllales	*Palmophyllum*	1.1u
			Streptophyta	Charophyta	Mesostigmatophyceae	*Mesostigma*	1.1v
					Chlorokybophyceae	*Chlorokybus*	1.1z
					Klebsormidiophyceae	*Klebsormidium*	1.1aa
					Charophyceae	*Nitella*	1.1ab
					Coleochaetophyceae	*Coleochaete*	1.1ac
					Zygnematophyceae	*Cosmarium*	1.1ad
	Chromista	Hacrobia		Haptophyta	Coccolithophyceae (Prymnesiophyceae)	*Umbellosphaera*	1.1ae
					Haptophyta incertae sedis	*Coronocyclus*	1.1af
					Pavlovophyceae	*Pavlova*	1.1ag

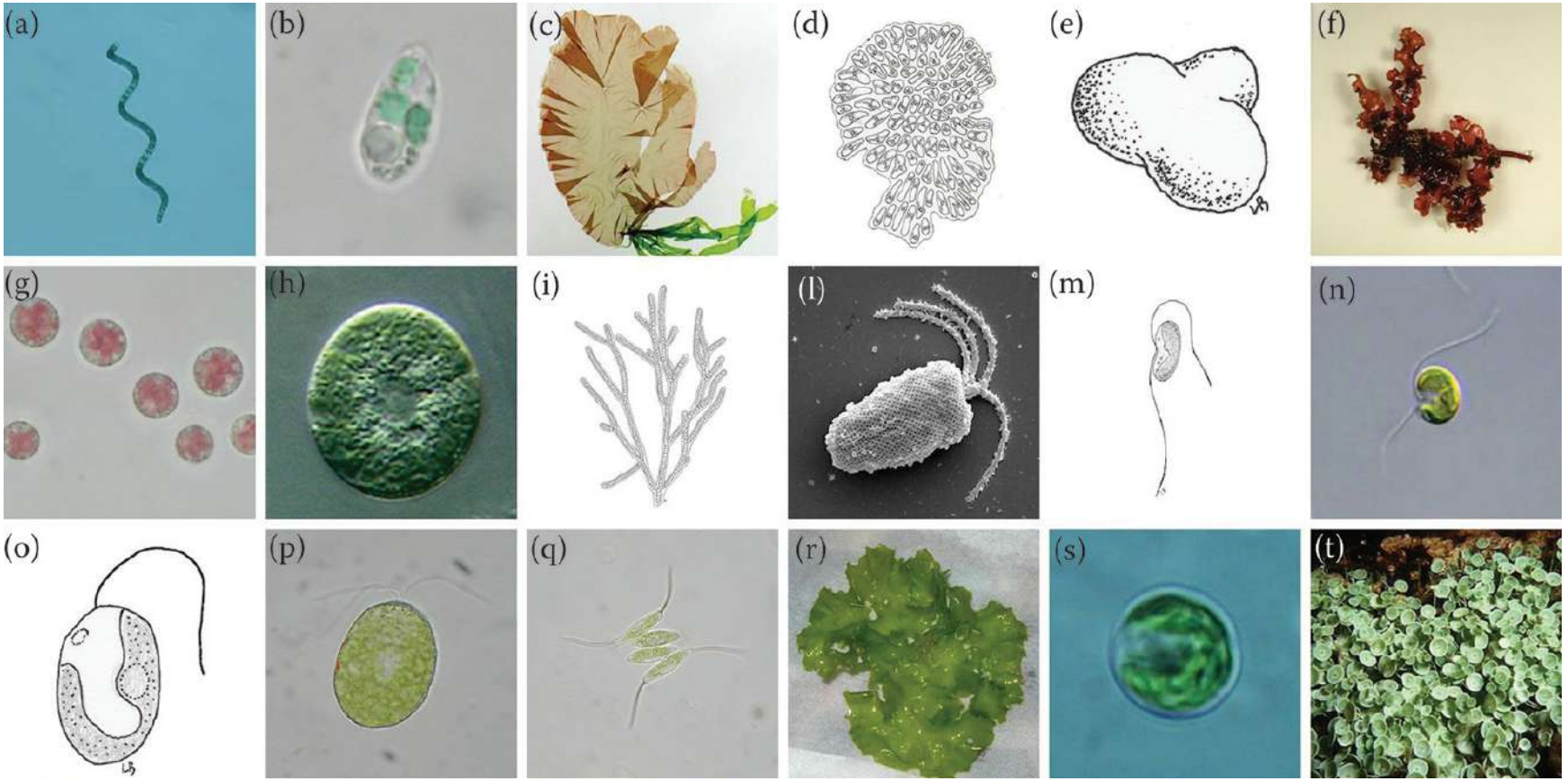
continued

Classification

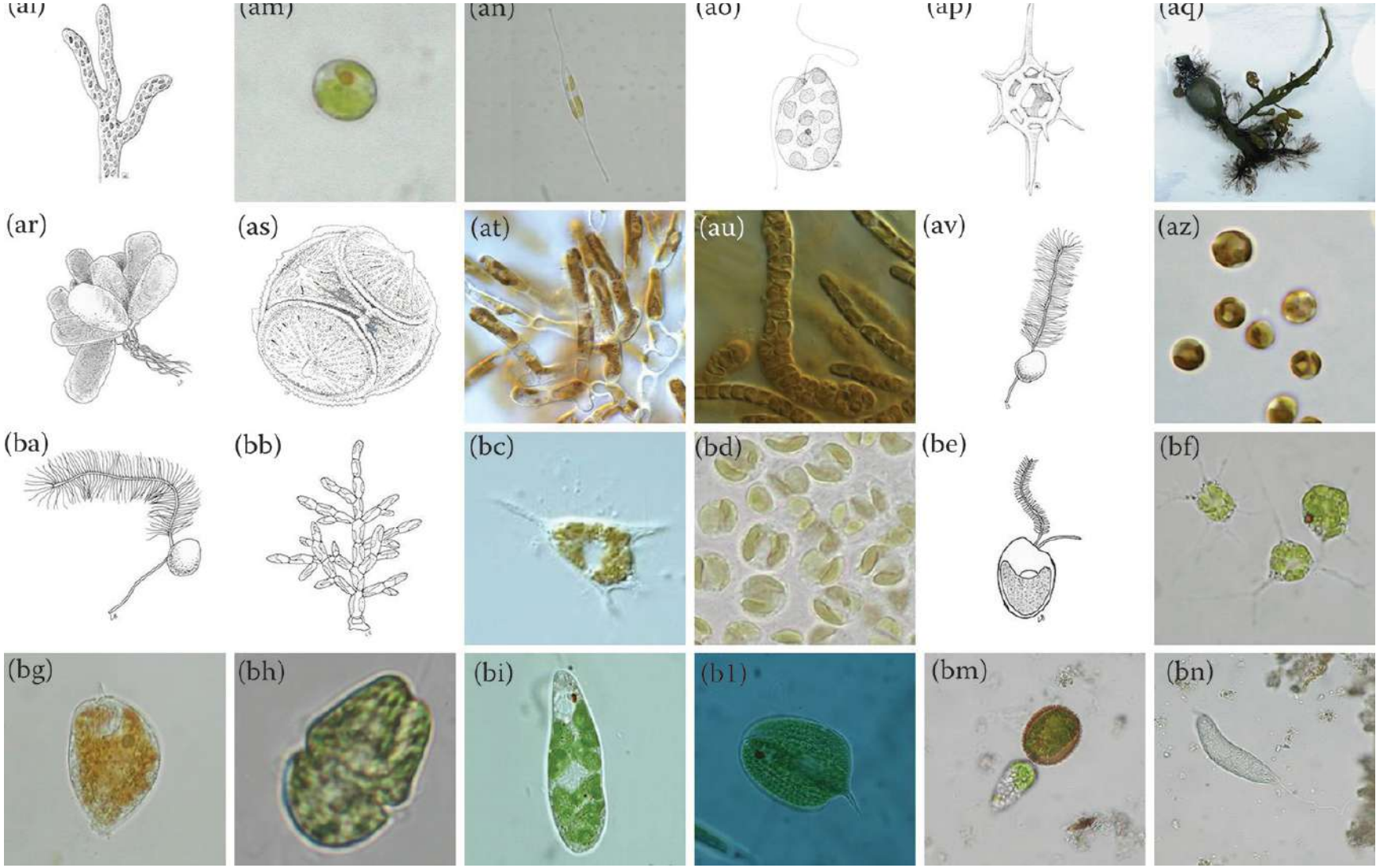
Classification Scheme of the Different Algal Groups

Kingdom	Subkingdom	Infrakingdom	Phylum	Class	Representative	Image
			Cryptophyta	Cryptophyceae	*Rhodomonas*	1.1ah
	Harosa	Heterokonta	Ochrophyta	Chrysophyceae	*Ochromonas*	1.1ai
				Xanthophyceae	*Vaucheria*	1.1al
				Eustigmatophyceae	*Nannochloropsis*	1.1am
				Bacillariophyceae	*Cylindrotheca*	1.1an
				Raphidophyceae	*Heterosigma*	1.1ao
				Dictyochophyceae	*Distephanus*	1.1ap
				Phaeophyceae	*Ascophyllum*	1.1aq
				Pelagophyceae	*Chrysophaeum*	1.1ar
				Bolidophyceae	*Tetraparma*	1.1as
				Schizocladiophyceae	*Schizocladia*	1.1at
				Chrysomerophyceae	*Gyraudiopsis*	1.1au
				Picophagophyceae	*Picophagus*	1.1av
				Pinguiophyceae	*Pinguiococcus*	1.1az
				Placidiophyceae	*Placidia*	1.1ba
				Phaeothamniophyceae	*Phaeothamnion*	1.1bb
				Synchromophyceae	*Synchroma*	1.1bc
				Synurophyceae	*Synura*	1.1bd
				Aurearenophyceae	*Aurearena*	1.1be
			Cercozoa	Chlorarachniophyceae	*Gymnochlora*	1.1bf
Protozoa	Biciliata	Alveolata	Myzozoa	Dinophyceae	*Prorocentrum*	1.1bg
					Lepidodinium	1.1bh
	Eozoa	Euglenozoa	Euglenozoa	Euglenophyceae	*Euglena*	1.1bi
					Phacus	1.1bl
					Trachelomonas	1.1bm
					Peranema	1.1bn

Shapes diversity



Shapes diversity



Distribution of Algal Divisions

Phylum	Common Name	Habitat			
		Marine	Freshwater	Terrestrial	Symbiotic
Cyanobacteria	Blue-green algae	Yes	Yes	Yes	Yes
Glaucophyta	n.a.	n.d.	Yes	Yes	Yes
Rhodophyta	Red algae	Yes	Yes	Yes	Yes
Chlorophyta	Green algae	Yes	Yes	Yes	Yes
Charophyta	n.a.	Yes	Yes	Yes	n.d.
Haptophyta	Coccolithophorids	Yes	Yes	Yes	Yes
Cryptophyta	Cryptomonads	Yes	Yes	n.d.	Yes
Ochrophyta	Golden algae Yellow-green algae Diatoms Brown algae	Yes	Yes	Yes	Yes
Cercozoa (Chlorarachniophyceae)	n.a.	Yes	n.d.	n.d.	Yes
Myzozoa (Dynophyceae)	Dinoflagellates	Yes	Yes	n.d.	Yes
Euglenozoa (Euglenophyceae)	Euglenoids	Yes	Yes	Yes	Yes

Note: n.a., not available; n.d., not detected.

Thallus Morphology in the Different Algal Divisions

Phylum	Unicellular and Nonmotile	Unicellular and Motile	Colonial and Nonmotile	Colonial and Motile	Filamentous	Siphonous	Parenchimatous
Cyanobacteria	*Synechococcus* *Prochloron*	n.d.	*Anacystis*	n.d.	*Calothrix* *Prochlorothrix*	n.d.	*Pleurocapsa*
Glaucophyta	*Glaucocystis*	*Cyanophora*	n.d.	n.d.	n.d.	n.d.	n.d.
Rhodophyta	*Phorphyridium*	n.d.	*Cyanoderma*	n.d.	*Goniotricum*	n.d.	*Palmaria*
Chlorophyta Charophyta	*Chlorella*	*Dunaliella*	*Pseudo-sphaerocystis*	*Volvox*	*Ulothrix*	*Bryopsis*	*Ulva*
Haptophyta	n.d.	*Chrysochromulina*	n.d.	*Corymbellus*	n.d.	n.d.	n.d.
Cryptophyta	n.d.	*Cryptomonas*	n.d.	n.d.	*Bjornbergiella*	n.d.	n.d.
Ochrophyta	*Triceratium*	*Ochromonas*	*Chlorobotrys*	*Synura*	*Ectocarpus*	*Vaucheria*	*Fucus*
Cercozoa (Chlorarachniophyceae)	n.d.	*Chlorarachnion*	n.d.	n.d.	n.d.	n.d.	n.d.
Myzozoa (Dynophyceae)	*Dinococcus*	*Gonyaulax*	*Gloeodinium*	n.d.	*Dinoclonium*	n.d.	n.d.
Euglenozoa (Euglenophyceae)	*Ascoglena*	*Phacus*	*Colacium*	n.d.	n.d.	n.d.	n.d.

Note: n.d., not detected.

Kingdom	Phylum	Subphylum	Class
Prokaryota eubacteria	Cyanophyta		Cyanophyceae
Eukaryota	Glaucophyta		Glaucophyceae
	Rhodophyta	Cyanidiophytina	Cyanidiophyceae
		Eurhodophytina	Compsopogonophyceae
			Porphyridophyceae
			Rhodellophyceae
			Stylonematophyceae
			Bangiophyceae
			Florideophyceae
	Cryptophyta		Cryptophyceae
	Dinophyta		Dinophyceae
	Haptophyta		Haptophyceae
	Ochrophyta	Khakista	Bacillariophyceae
			Bolidophyceae
		Phaeista	Chrysophyceae
			Synurophyceae
			Eustigmatophyceae
			Raphidophyceae
			Dictyochophyceae
			Pelagophyceae
			Pinguiophyceae
			Phaeothamniophyceae
			Chrysomerophyceae
			Xanthophyceae
			Phaeophyceae
	Euglenophyta		Euglenophyceae
	Chlorarachniophyta		Chlorarachniphyceae
	Chlorophyta	Prasinophytina	Prasinophyceae
		Tetraphytina	Chlorophyceae
			Chlorodendrophyceae
			Trebouxyophyceae
			Ulvophyceae
			Dasycladophyceae
	Charophyta (Streptophyta *p. p.*)		Coleochaetophyceae
			Conjugatophyceae
			Mesotigmatophyceae
			Klebsormidiophyceae
			Charophyceae

Main Pigments, Storage Products, and Cell Coverings of the Algal Divisions

Phylum	Pigments (See Figures 3.5–3.9)				Storage Products
	Chlorophylls	Phycobilins	Main Carotenoids	Main Xantophylls	
Cyanobacteria	*a*, *b*	C-phycoerythrin C-phycocyanin Allophycocyanin	β-carotene	Myxoxanthin Zeaxanthin	Cyanophycin (arginine and aspartic acid) Cyanophycean starch (α-1,4-glucan)
Glaucophyta	*a*	Phycoerythrocyanin C-phycocyanin Allophycocyanin	β-carotene	Zeaxanthin	Starch (α-1,4-glucan)
Rhodophyta	*a*	B-phycoerythrin R-phycoerythrin R-phycocyanin Allophycocyanin	α- and β-carotene	Lutein	Floridean starch (α-1,4-glucan)
Chlorophyta	*a*, *b*	Absent	α-, β-, and γ-carotene	Lutein Prasinoxanthin	Starch (α-1,4-glucan)
Charophyta	*a*, *b*	Absent	α-, β-, and γ-carotene	Lutein Prasinoxanthin	Starch (α-1,4-glucan)
Haptophyta	*a*, c_1, c_2	Absent	α- and β-carotene	Fucoxanthin	Chrysolaminaran (β-1,3-glucan)
Cryptophyta	*a*, c_2	B-phycoerytrin (545) R-phycocyanin Allophycocyanin	α-, β-, and ε-carotene	Alloxanthin	Starch (α-1,4-glucan)
Ochrophyta	*a*, c_1, c_2, c_3	Absent	α-, β-, and ε-carotene	Fucoxanthin, violaxanthin	Chrysolaminaran (β-1,3-glucan)
Cercozoa (Chlorarachniophyceae)	*a*, *b*	Absent	Absent	Lutein, neoxanthin, violaxanthin	Paramylon (β-1,3-glucan)
Myzozoa (Dynophyceae)	*a*, c_1, c_2	Absent	β-carotene	Peridinin Fucoxanthin Diadinoxanthin Dinoxanthin Gyroxanthin	Starch (α-1,4-glucan)
Euglenozoa (Euglenophyceae)	*a*, *b*	Absent	β- and γ-carotene	Diadinoxanthin	Paramylon (β-1,3-glucan)

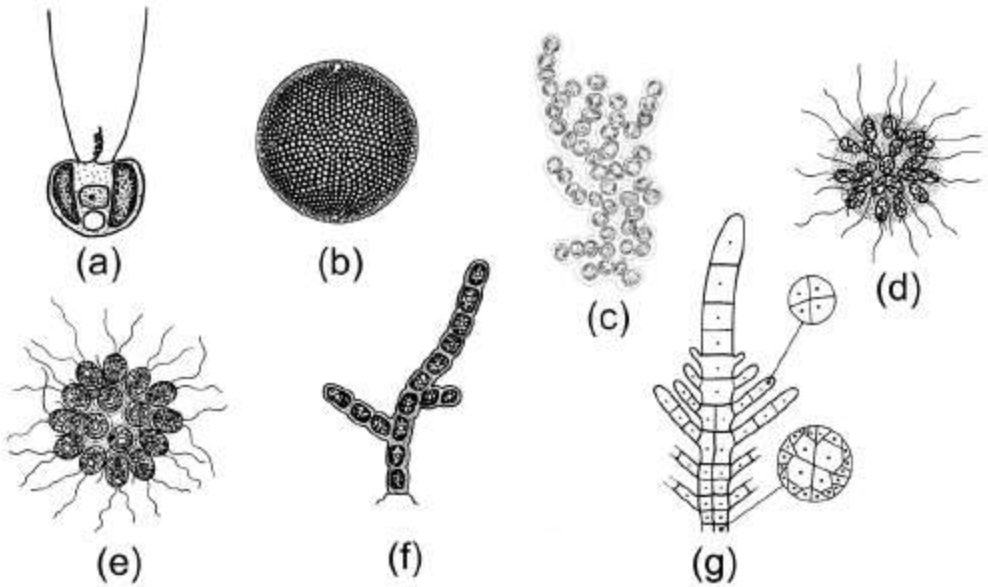
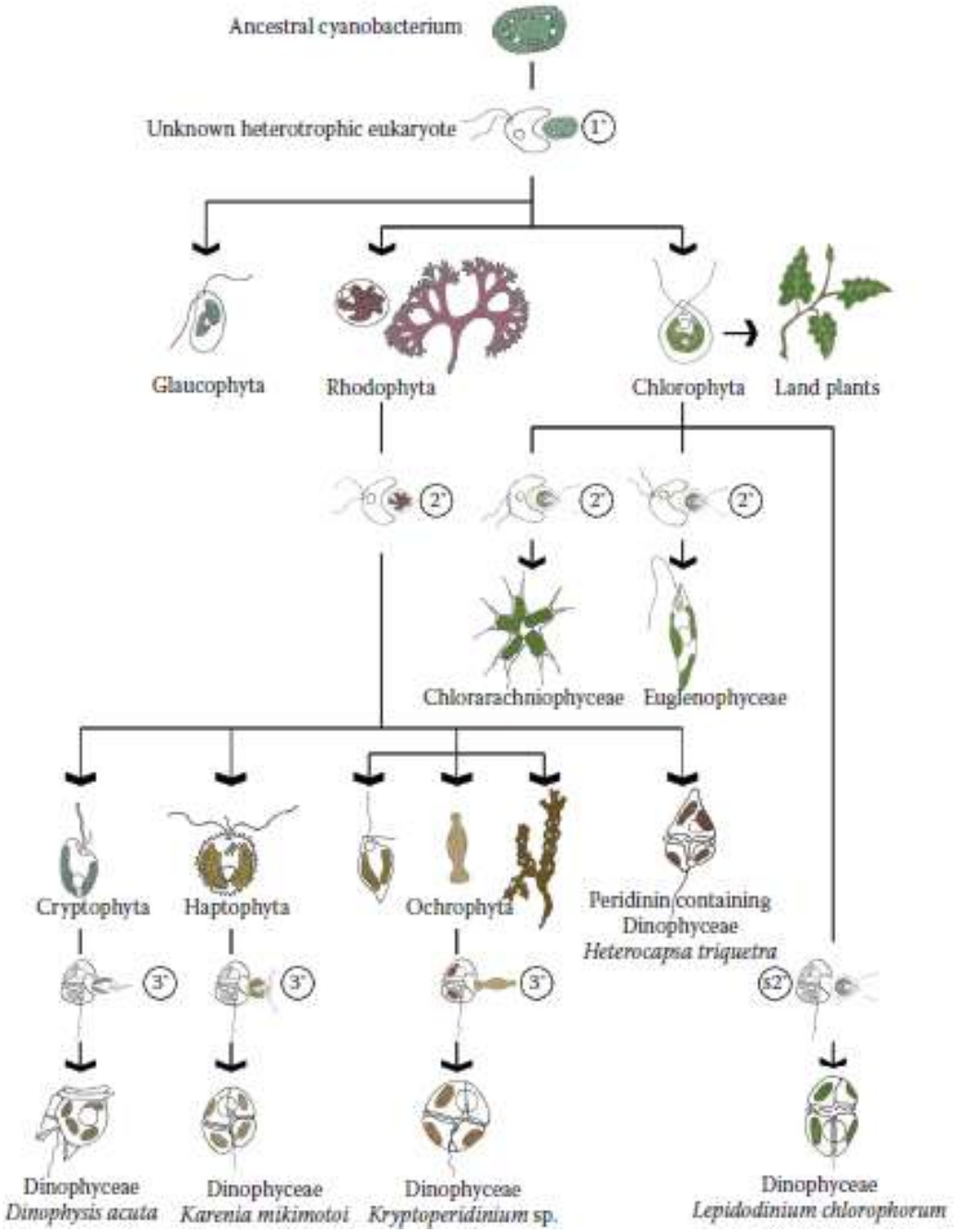


Figure 3. Diversity of algal body type. (a) Motile unicellular (*Chrysochromulina* sp., Haptophyceae). (b) Coccoid unicellular (*Cerataulus smithii*, Bacillariophyceae). (c) Colony of coccoid cells (*Sphaeridiothrix compressa*, Chrysophyceae). (d) Motile colony (*Uroglena volvox*, Chrysophyceae). (e) Coenobium (*Gonium pectorale*, Chlorophyceae). (f) Branched filament (*Asterocystis smaragdigna*, Bangiophyceae). (g) Parenchymatous thallus (*Sphacelaria plumula*, Phaeophyceae).


Ancestral cyanobacterium
Unknown heterotrophic eukaryote
1°
Glaucophyta
Rhodophyta
Chlorophyta
Land plants
2°
2°
2°
Chlorarachniophyceae
Euglenophyceae
Cryptophyta
Haptophyta
Ochrophyta
Peridinin containing Dinophyceae
Heterocapsa triquetra
3°
3°
3°
s2°
Dinophyceae
Dinophysis acuta
Dinophyceae
Karenia mikimotoi
Dinophyceae
Kryptoperidinium sp.
Dinophyceae
Lepidodinium chlorophorum

Nutritional strategies

- *Obligate heterotrophic algae*: they are primarily heterotrophic, but are capable of sustaining themselves by phototropy when prey concentrations limit heterotrophic growth (e.g., *Gymnodium gracilentum*, Myzozoa);
- *Obligate phototrophic algae*: their primary mode of nutrition is phototrophy, but they can supplement growth by phagotrophy and/or osmotrophy when light is limiting (e.g., *Dinobryon divergens*, Ochrophyta);
- *Facultative mixotrophic algae*: they can grow equally well as photoautotrophs and as heterotrophs (e.g., *Fragilidium subglobosum*, Myzozoa);
- *Obligate mixotrophic algae*: their primary mode of nutrition is phototrophy, but phagotrophy and/or osmotrophy provide substances essential for growth (in this group, we can include photoautoxotrophic algae) (e.g., *Euglena gracilis*, Euglenozoa).

Reproduction

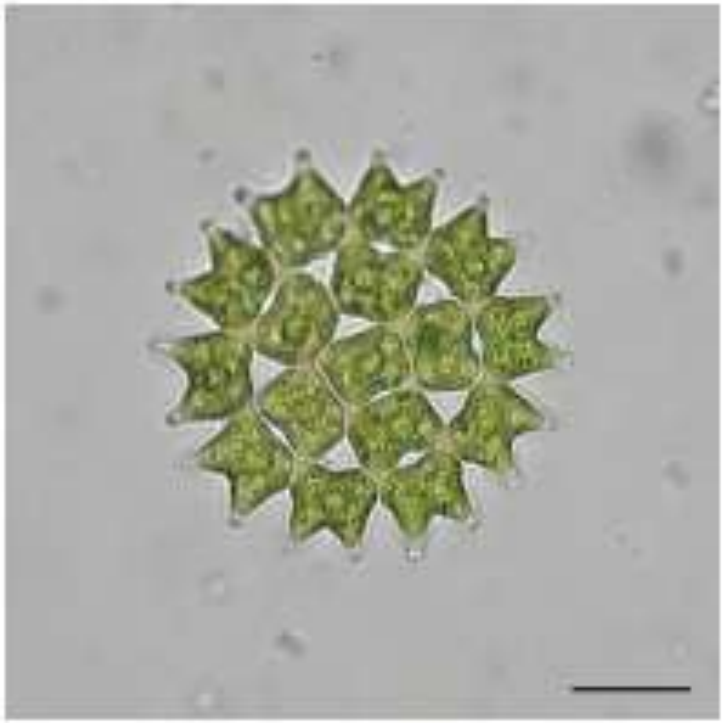
- **Binary Fission or Cellular Bisection**

Cell division in *Euglena* sp. Scale bar: 5 µm.

- **Zoospore, Aplanospore, and Autospore**

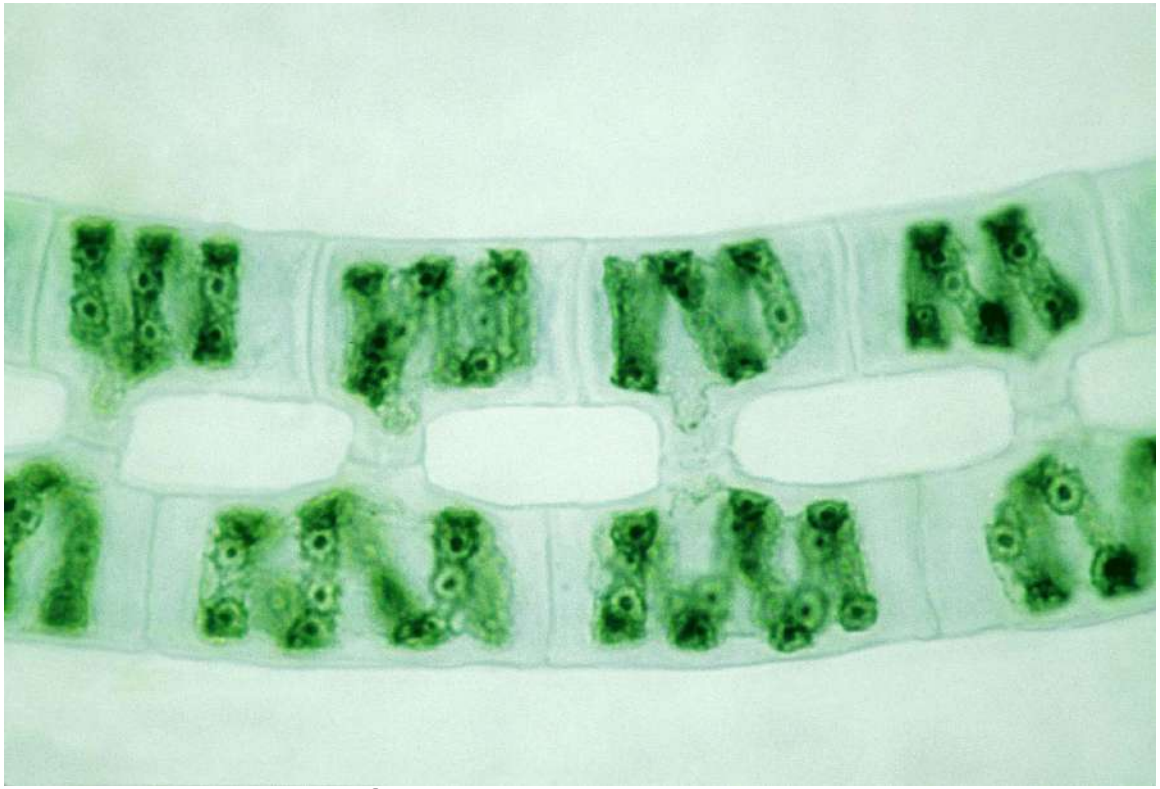
Zoospores of *Tetraselmis* sp. within the parental cell wall. Scale bar: 5 µm.

- **Autocolony Formation**



Nonmotile coenobium of *Pediastrum* sp. Scale bar: 100 µm.

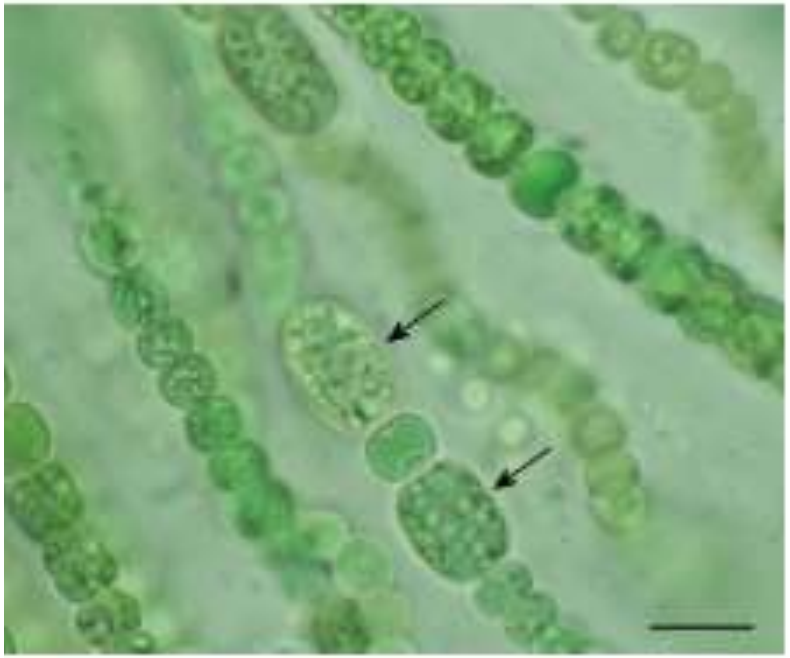
- **Fragmentation**



Spirogyra sp.

- **Resting Stages**

Dinoflagellate hypnozygote. Scale bar: 10 µm.



Akinetes (arrows) of *Anabaena* sp. Scale bar: 10 µm.

Haplontic or Zygotic Life Cycle

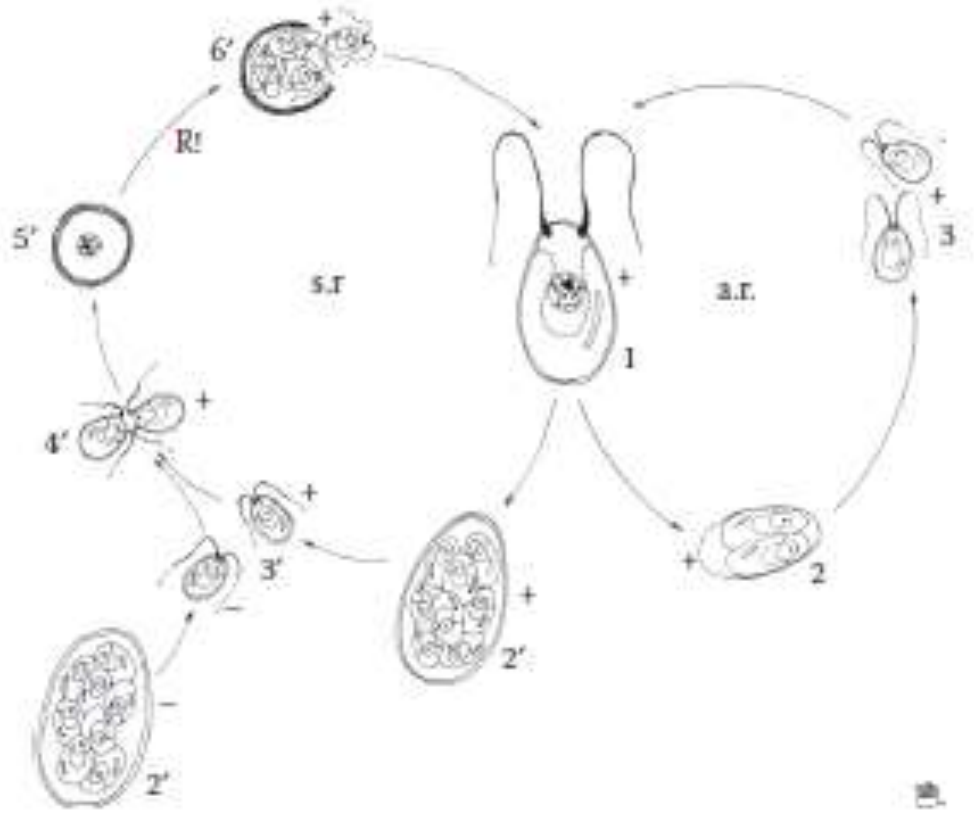


FIGURE 1.28 Life cycle of *Chlamydomonas* sp.: 1, mature cell; 2, cell-producing zoospores; 2′, cell-producing gametes (strain + and strain –); 3, zoospores; 3′, gametes; 4′, fertilization; 5′, zygote; 6′, release of daughter cells. R!: meiosis; a.r.: asexual reproduction; s.r.: sexual reproduction.

Diplontic or Gametic Life Cycle

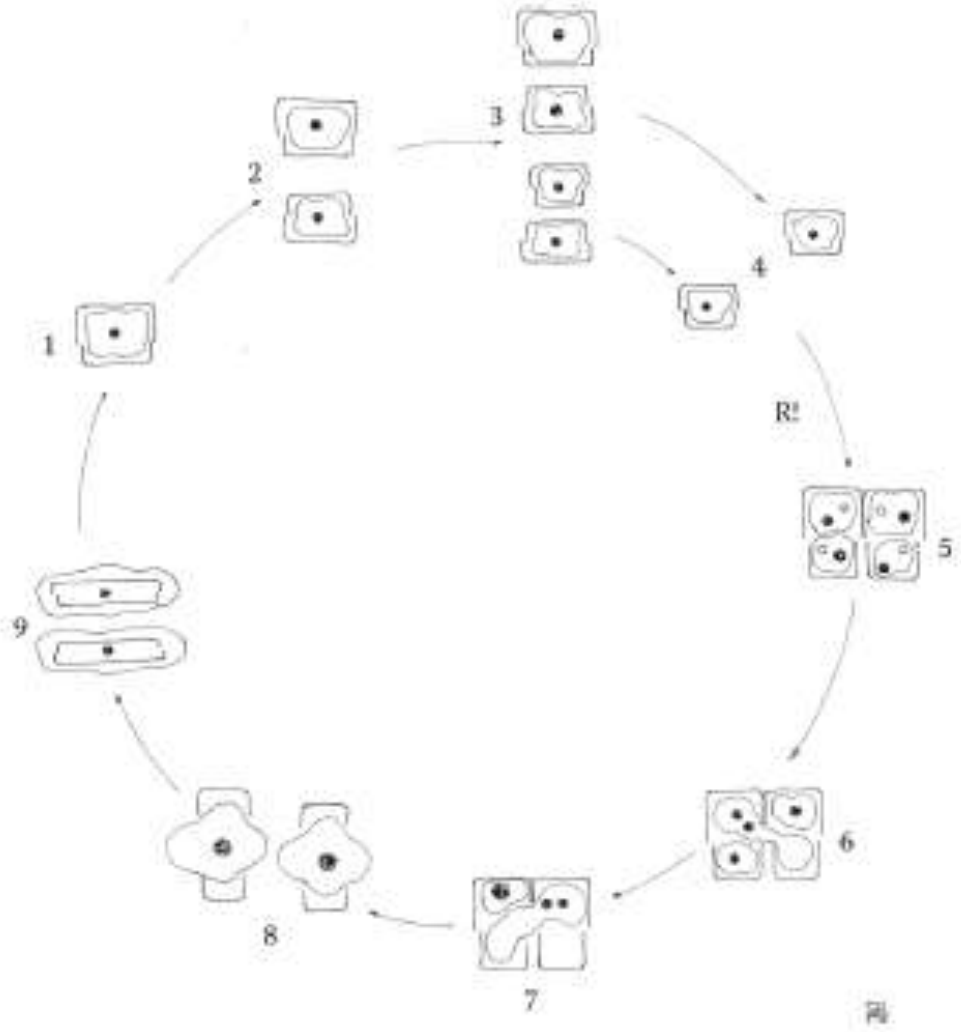


FIGURE 1.29 Life cycle of a diatom: 1, vegetative cell; 2–3, vegetative cell division; 4, minimum cell size; 5, gametogenesis; 6–7, fertilization; 8, auxospores; 9, initial cells. R!: meiosis.

Diplohaplontic or Sporic Life Cycles

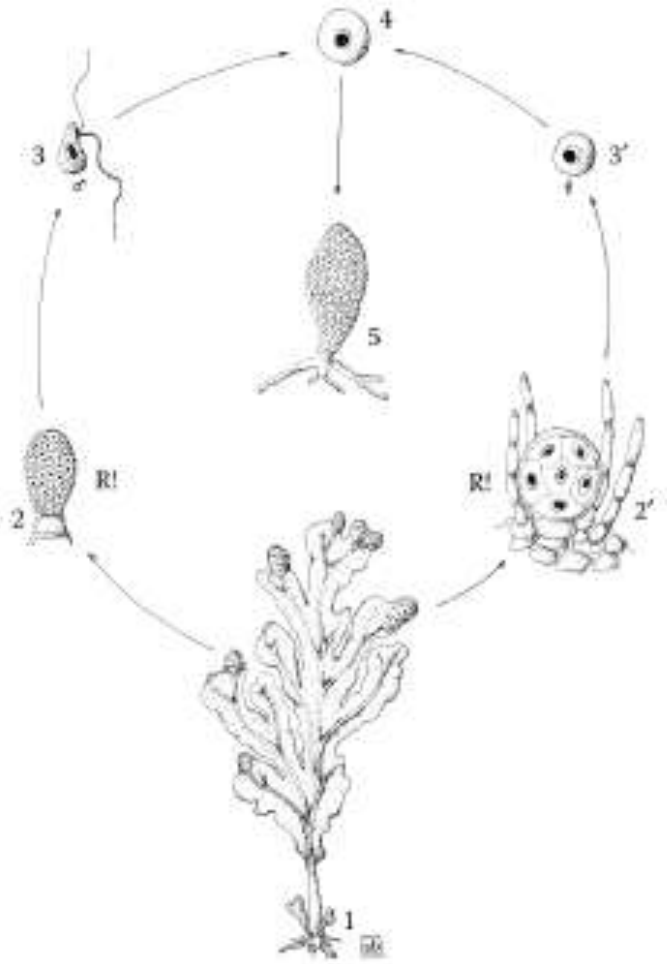
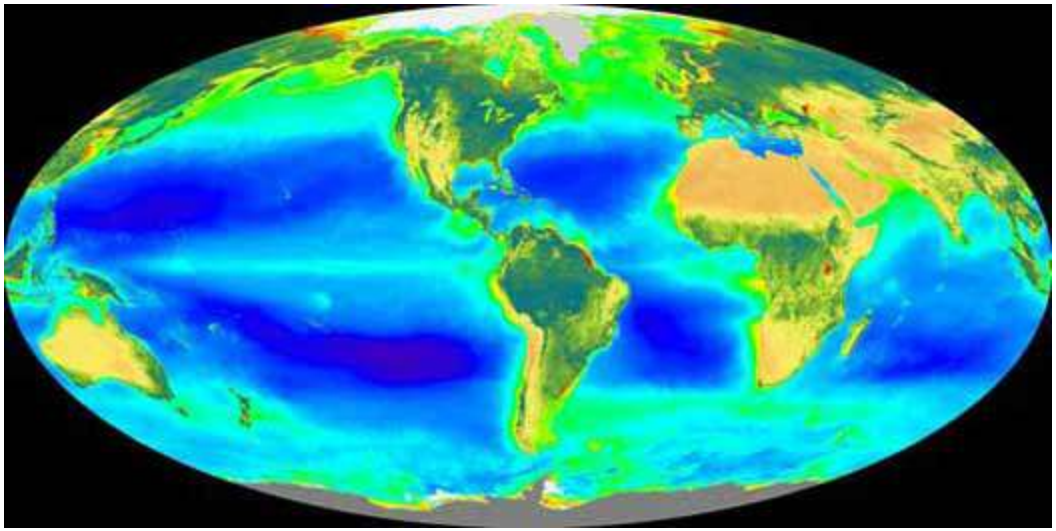
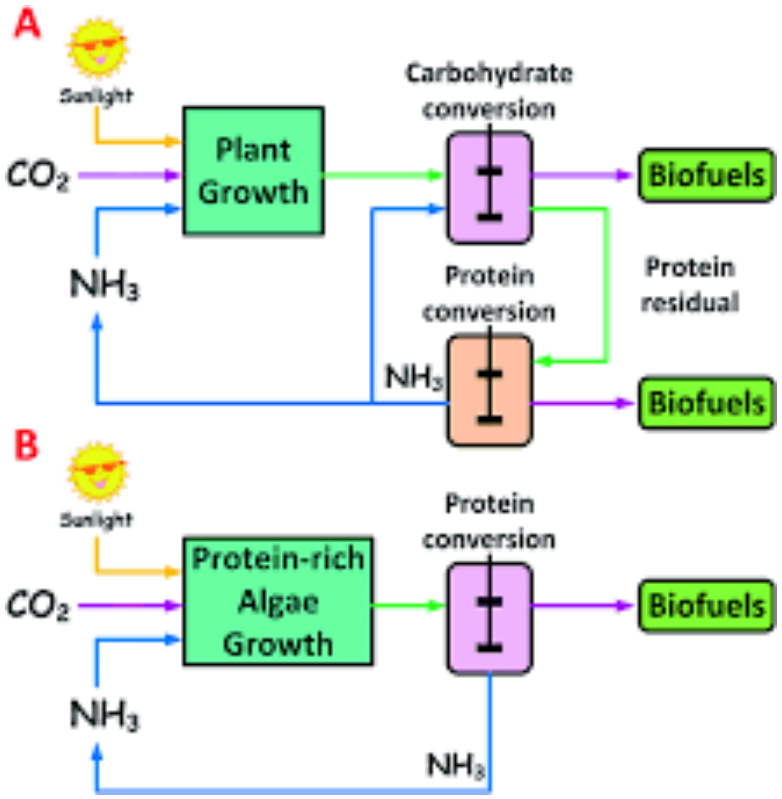


FIGURE 1.30 Life cycle of *Fucus* sp.: 1, sporophyte; 2, anteridium; 2′, oogonium; 3, sperm; 3′, egg; 4, zygote; 5, young sporophyte. R!: meiosis.

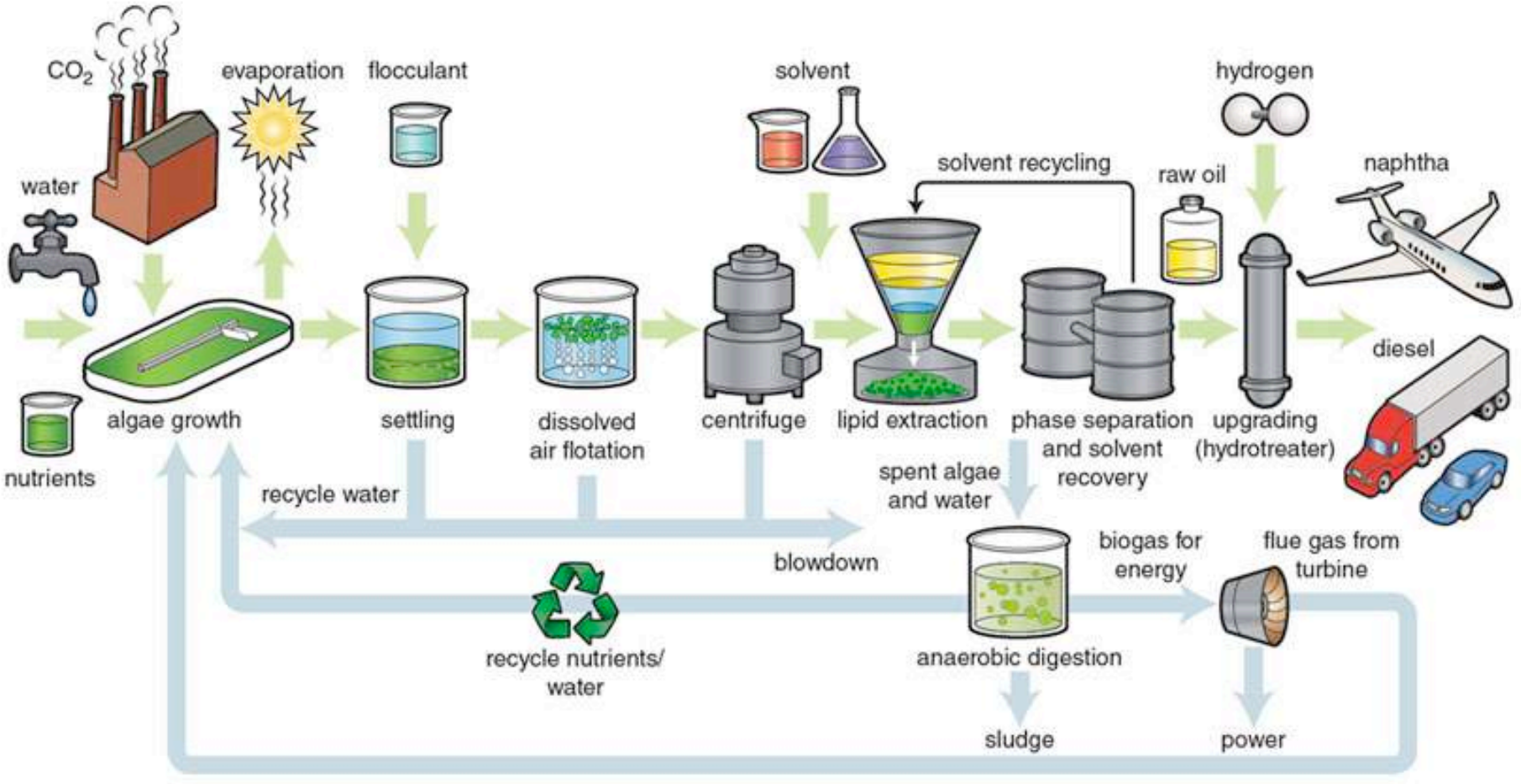
Roles

- Oxygen producer
- Carbon cycle
- Bionergy producer
  - Biorefining
  - Biogas
  - Bioethanol
- Food producer
  - Animal
  - Plant
  - Human
  - Other organisms
- Biofertilizer/Biochar
- Bioremidiation
- Bioindicator

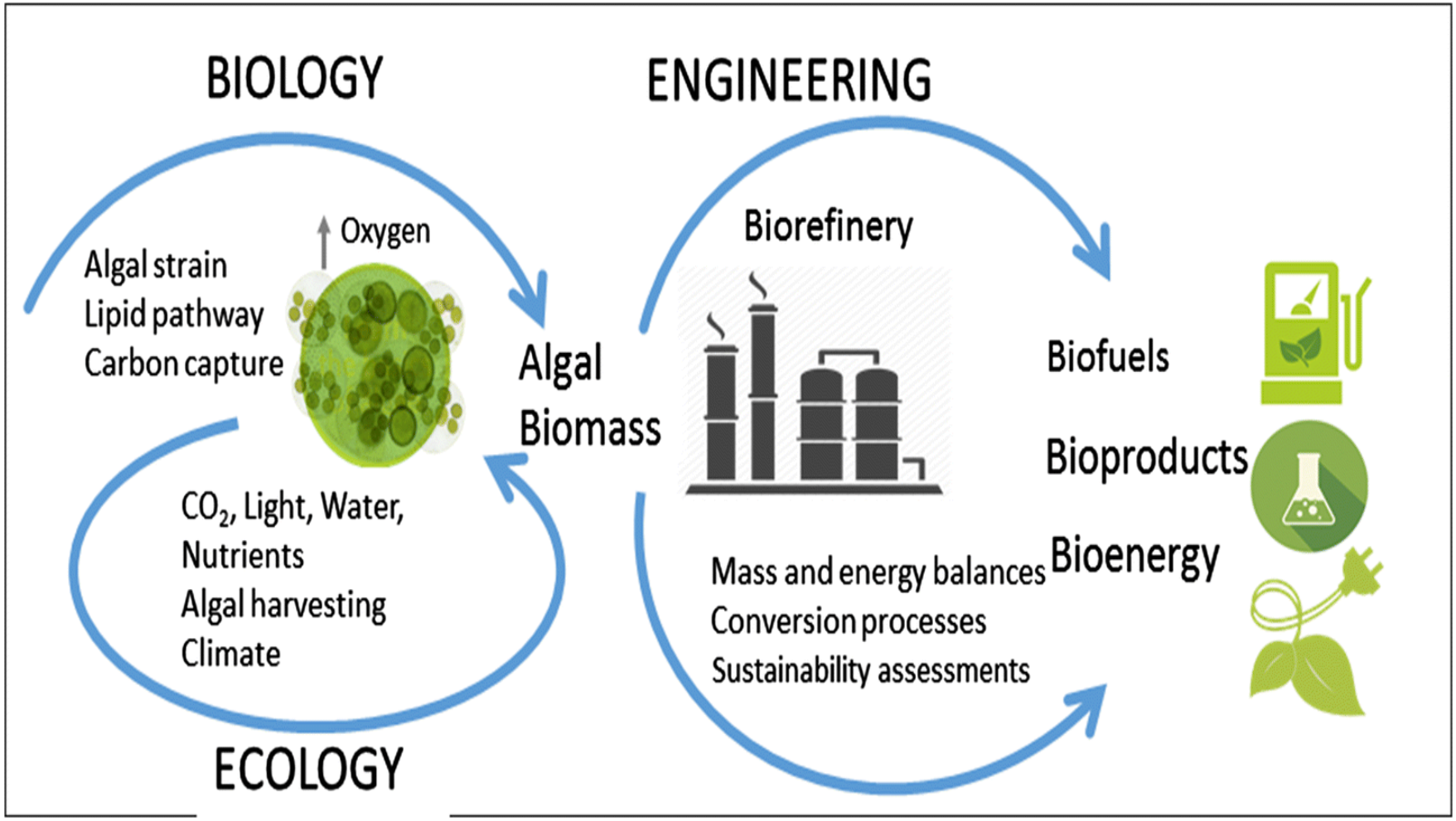



A
Sunlight
CO_2
NH_3
Plant Growth
Carbohydrate conversion
Biofuels
Protein conversion
Protein residual
NH_3
Biofuels
B
Sunlight
CO_2
NH_3
Protein-rich Algae Growth
Protein conversion
Biofuels
NH_3

Algae utilization

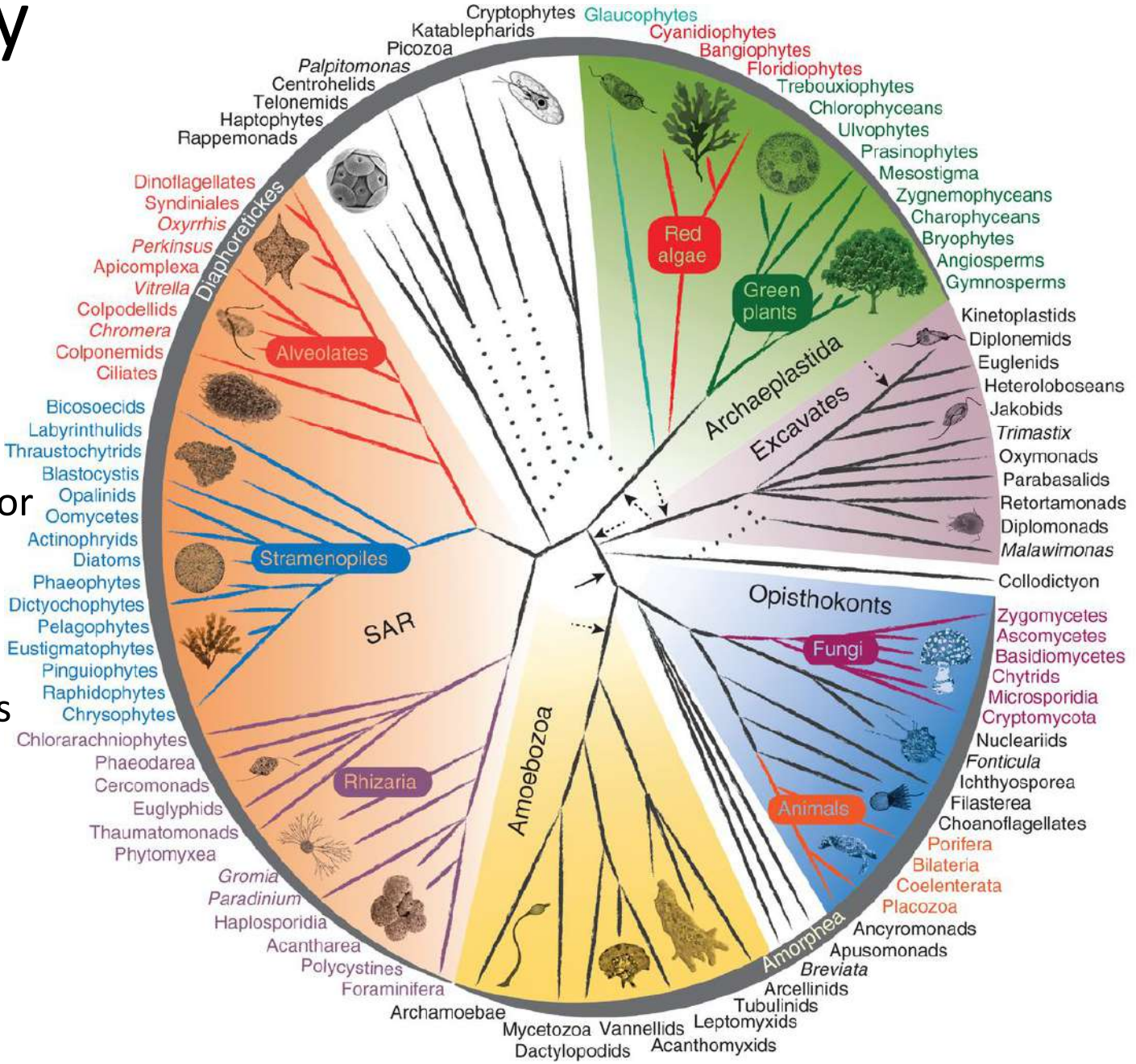


Bioprocess

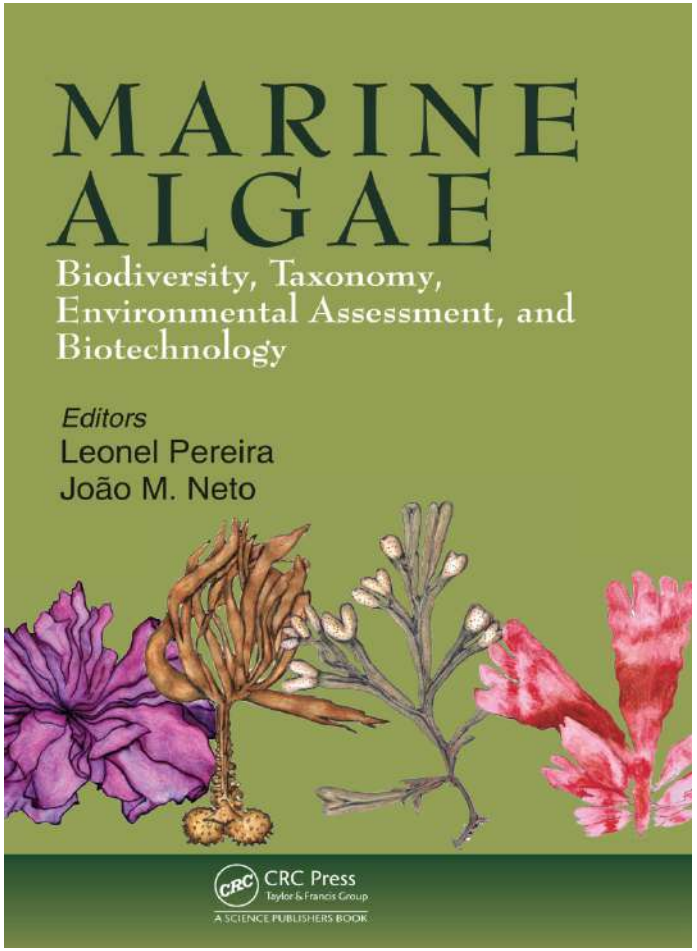

BIOLOGY
ENGINEERING
Oxygen
Algal strain
Lipid pathway
Carbon capture
Biorefinery
Algal
Biomass
Biofuels
Bioproducts
Bioenergy
CO_2, Light, Water,
Nutrients
Algal harvesting
Climate
Mass and energy balances
Conversion processes
Sustainability assessments
ECOLOGY

Summary

- Macro
- Micro
- Freshwater
- Marine
- Roles
  - Bioindicator
  - Toxic
  - Bloom
  - Energy
  - Biosources
    - Oil
    - Protein
    - Carbo
    - Biorem



References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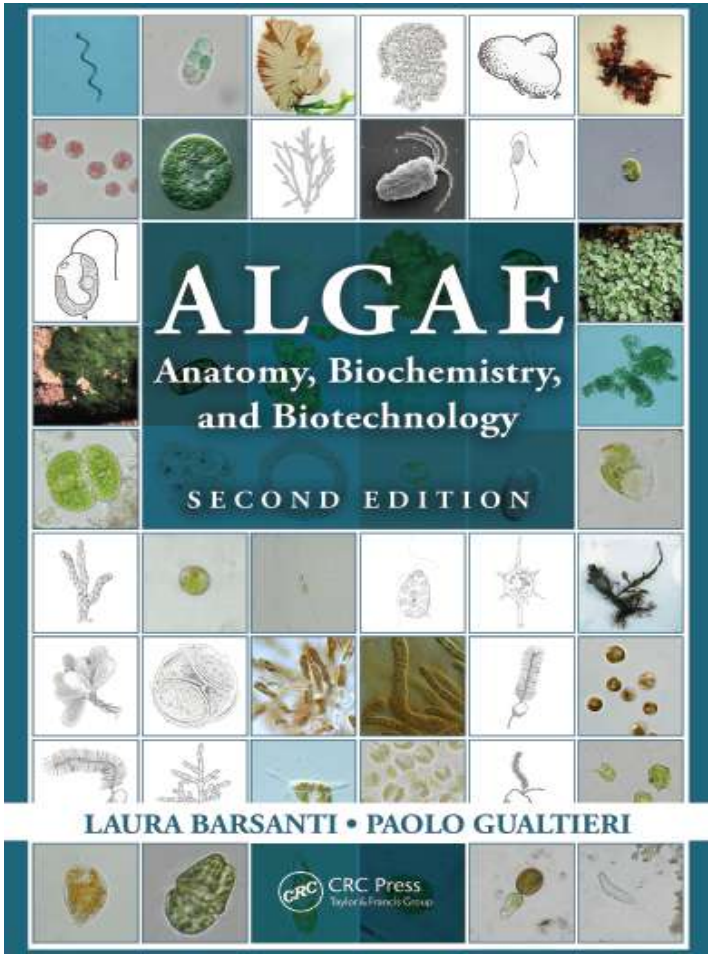
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Vielen Dank

für ihre
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