

Corso di Biologia delle Alghe

3 CFU

Mercoledì e Venerdì

14:00-16:00

Aula 8

fino al 19 dicembre

Patrizia Albertano

Introduction to Phycology

- *phycology* (Greek) vs *algology* (Latin)--both mean study of algae
- What are the algae?
 - pond scum, red tides, seaweeds, etc.
 - thallophytes (not embryophytes)
 - lacking roots, stems, and leaves
 - no protective layer around reproductive cells
 - oxygenic photosynthetic organisms: definition includes chlorophyll *a*

Historical background

- ancient Chinese classics refer to algae as food and medicine
- Greeks refer to phykos (seaweed) -- later becomes fucus
- gradually grouped into: *Fucus*, *Corallina*, *Ulva*, *Conferva*
 - names lasted from 1620 to well into the 1700's
 - Linnaeus recognized five genera: *Tremella*, *Fucus*, *Ulva*, *Conferva*, *Corallina*, plus *Chara* and *Volvox*
- **The Golden Age of Plant Taxonomy in 19th century**
 - huge interest in naming plants of all sorts from a scientific viewpoint
 - recognition of the importance of life-histories and, especially, of flagellate stages (but some thought indicated metamorphosis into animals)
 - Light microscope (LM) and first microalgal cultures
 - a few names still recognized today:
Vaucher, Hedwig, Roth, Trentepohl, C. A. Agardh, J. G. Agardh, Kützinger, Rabenhorst, Pringsheim, Bornet and Flahault, Gomont, Borzi, and De Toni

Modern phycology

Systematics in 20th century - from LM to TEM to DNA sequences

- based primarily on cell structure:

 - plastid structure,

 - flagellar apparatus,

 - cell wall structure,

 - other cytoplasmic structures (with more and more detail added
as more tools become available)

N.B. value of structure varies from group to group

(diatoms and cell wall, green algae and flagellar apparatus)

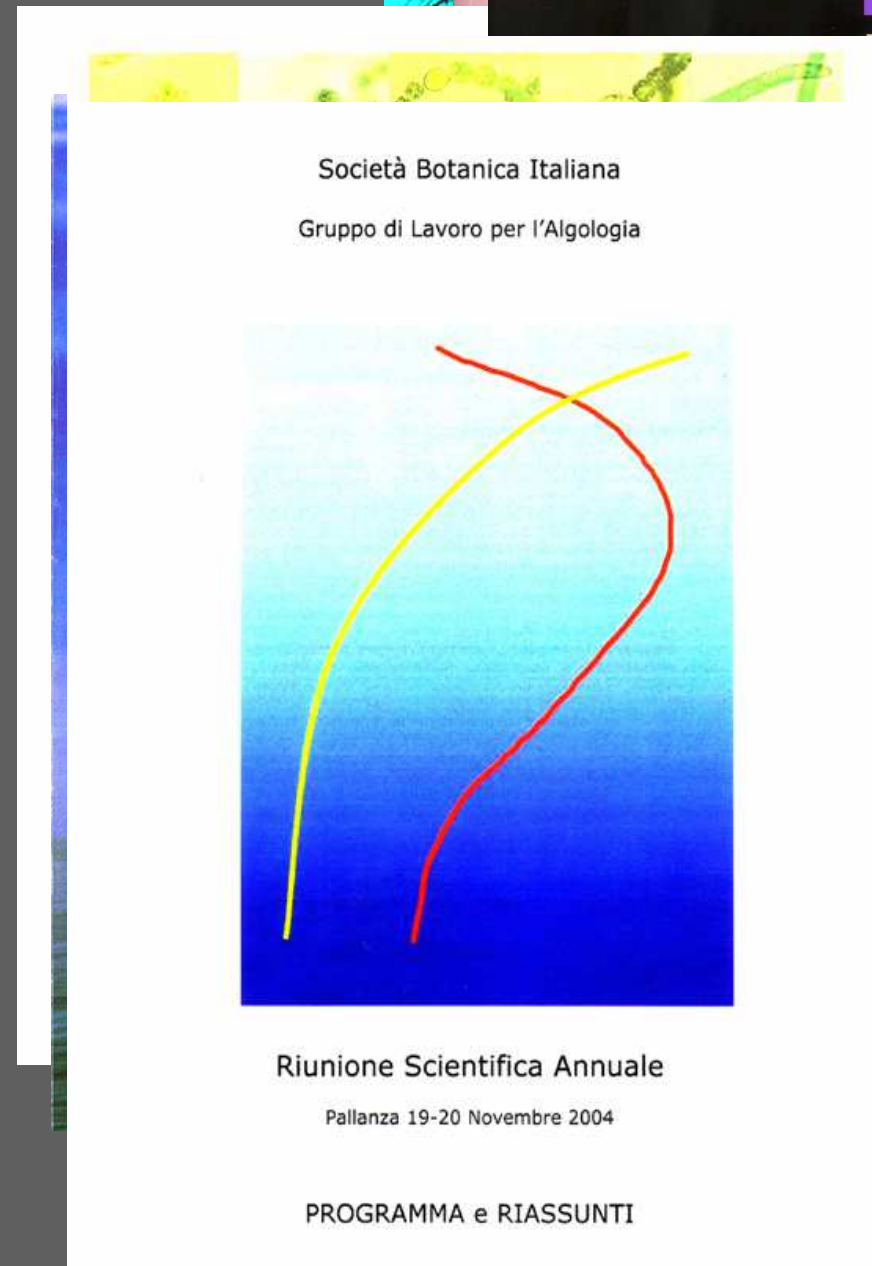
- new phylogenies being developed based on small subunit ribosomal RNA sequences

- a few important figures:

Pascher, Prescott, Geitler, Iyengar, Fritsch, West and West from the early days

Who does study algae? And How?

- Gruppo di Algologia Società Botanica italiana
- International Association for Cyanobacteria/Cyanophyte Research
- Federation of European Phycological Societies – Oviedo, July 2007
- International Phycological Society
- Annual Meetings
- European and International Symposia
- Thematic conferences and workshops
- Scientific journals:
European Journal of Phycology, Phycologia, International Journal of Phycology, Archiv fur Hydrobiologie-Algological Studies, J. Applied Phycology, Cryptogamic Botany, etc.



Diversity of algae

Table 1. The known number and predicted world species totals of extant algal species.

Taxonomic Group	Known species	Estimated species	% known	Source of information on known numbers of species
KINGDOM PLANTAE ¹				
SUBKINGDOM VIRIDIPLANTAE (all green plants)				
Chlorophyta ² (=Green Algae)				
Chlorophyceae	2,500	10,000-100,000	2.5-25	Melkonian 1989a
Prasinophyceae	120	500	24	Melkonian 1989c
Ulvophyceae	1,100	3,000	37	Floyd & O'Kelly 1989a
Charophyceae ³	10,472-12,512	20,500 ⁴	51-61	Hoshaw et al. 1989, Khan & Sarma 1984, Grant 1989, Silva 1982
SUBKINGDOM BILIPHYTA				
Rhodophyceae	2,500-6,000	5,500-20,000	12.5-100+	Woelkerling 1991
Glaucophycocystophyceae	13	50	26	Kies & Kremer 1989
KINGDOM CHROMISTA ⁵				
Chromophyta <i>sensu lato</i> ⁶				
Bacillariophyceae	10,000+	100,000 ⁷	10	Round & Crawford 1989
Bicossecophyceae ⁸	45	1,000	4.5	Dyer 1989
Chrysophyceae ⁹	1,000	2,400	42	Kristiansen 1989
Cryptophyceae ⁶	200	1,200	17	Norris 1982
Eustigmatophyceae	12	1,000-10,000	0.1-1	Hibberd 1989a
Fucophyceae (Phaeophyceae)	900-1,500+	2,000	45-75	Clayton 1989, Wynne 1982
Haptophyceae (Prymnesiophyceae)	500	2,000	25	Green et al. 1989
Raphidophyceae	27 ¹⁰	100	27	Norris 1982
Synurophyceae	135-250	1,000	13.5-25	Andersen 1992
Tribophyceae (Xanthophyceae)	600	2,000	30	Hibberd 1989b
KINGDOM PROTOZOA				
Euglenophyceae	650-1,050	2,000	32.5-52.5	Walne & Kivic 1989
Dinophyceae ¹¹	2,000 ¹²	3,500-11,000	18-57	Taylor 1989
Chlorarchnidaceae ¹³	3-4	20	15-20	Andersen 1992

Table 2. Comparison of the mean estimated numbers of known and predicted world species total: within the major series or lineages of algae. See Table 1 for detailed figures.

Taxonomic Grouping	Known species	Estimated known	Percentage
KINGDOM PLANTAE			
SUBKINGDOM VIRIDIPLANTAE			
Chlorophyta ¹ (4 algal classes)	15,345	79,000	19
SUBKINGDOM BILIPHYTA (2 algal classes)	4,263	12,800	33
KINGDOM CHROMISTA			
Chromophyta <i>sensu lato</i> (10 algal classes)	13,776	117,200	12
KINGDOM PROTOZOA (3 algal classes)	2,853	9,270	31
TOTAL FOR ALGAE	36,238	218,270	17

¹ included are 133 species of green algae whose affinities are uncertain (see Table 1, note 10)

Table 3. Comparison of the numbers of known and estimated world species totals of algae with other selected groups of organism Earlier figures for algae cited by Hawksworth (1991, table 6) are given in parenthesis.

Taxonomic Grouping	Known species	Total unknown	Percentage known	
Vascular plants ¹	220,000	270,000	81	
Bryophytes ¹	17,000	25,000	68	
Fungi ¹	69,000	1,500,000	5	} 52 phyla out of 95
Protoctista ² (protozoa, excludes algae and fungal protoctists)	30,000	130,000	31	
Eukaryotic Algae	36,238 (40,000)	218,270 (60,000)	17 (67)	
Bacteria ^{1,2} (including Cyanobacteria)	3,000	30,000	10	
Viruses ^{1,2} (including plasmids and phages)	5,000	130,000	4	

¹ from Hawksworth, 1991, table 6.

² from Di Cast.

1.4 -1.8 M species out of 2-30 M

Culturable *versus* Non-Culturable microorganisms

Number of seaweed species in different geographical areas

Table 2. Species diversity of seaweeds (Chlorophyta, Phaeophyta, and Rhodophyta) in different regions

	C	P	R	Total	Source
Pacific—Americas					
Arctic Pacific	12	30	38	80	Kjellman 1883
S. Alaska—Oregon	117	143	373	633	Seagei <i>et al.</i> 1989
California	72	137	459	668	Abbott & Hollenberg 1976
Mexico	107	113	623	843	Dawson 1952, 1953, 1954, 1960, 1961a, 1961b, 1962, 1963, 1964; Dawson <i>et al.</i> 1960
Peru	31	20	105	156	Dawson <i>et al.</i> 1964
Chile				550	Santelices 1989
Tierra del Fuego				334	John <i>et al.</i> 1994
Pacific—Asia & Australasia					
Kurile Islands	31	71	33	185	Nagai 1940
Japan	235	376	899	1510	Yoshida <i>et al.</i> 1990
Korea	81	135	357	573	Lee & Kang 1986
Taiwan				490	Lewis & Norris 1987; Wang <i>et al.</i> 1993
Vietnam	115	86	223	424	Tittley, personal communication
Philippines	215	125	475	818	Silva <i>et al.</i> 1987
Northern Australia	189	149	374	713	Lewis 1984, 1985, 1987
Southern Australia	120	231	>357 ¹	708+	Womersley 1978, 1979, 1984, 1987, 1994; Womersley & Shepley 1982; Baldock 1976; Saito & Womersley 1974; Wollaston 1968
New Zealand	96	138	383	617	Adams 1994
Arctic Ocean	59	89	104	252	Kjellman 1883
Antarctic Ocean				550	Papenfuss 1964
Atlantic—Americas					
Arctic Canada & W. Greenland	61	74	66	201	South & Tittley 1986
Newfoundland—N. Carolina	97	127	130	354	South & Tittley 1986
Cape Hatteras—Cape Canaveral	65	59	104	228	Schneider & Searles 1991
Florida & Dry Tortugas	133	61	227	354	Taylor 1928; Humm & Taylor 1961; Humm 1963
Caribbean & adjacent waters	253	150	655	1058	Wynne 1986
Brazil	129	76	355	560	Oliveira Filho 1977; Yoneshigue 1985; M. de O. Figueiredo, unpublished
Argentina				c. 400	Kühnemann 1972
Atlantic—Europe & Africa					
N. Norway, Iceland, Spitzbergen, E. Greenland	67	101	112	280	South & Tittley 1986
W. Norway—Portugal	208	281	509	998	South & Tittley 1986
Mediterranean	214	265	c. 550	c. 830	Ribera <i>et al.</i> 1992; Prud'homme van Reine & van den Hoek 1988
Portugal—Morocco	91	114	355	560	Prud'homme van Reine & van den Hoek 1988
Subtropical W. Africa: Senegal—Mauretania	48	51	197	296	Prud'homme van Reine & van den Hoek 1988
Tropical W. Africa: Gambia—the equator	65	46	213	324	Lawson & John 1982
South Africa				c. 700	Simons 1976

¹ Does not include Gracilariales, Bonnemaisoniales, Corallinales, and Rhodomeniales.

Number of seaweed species in the Mediterranean region

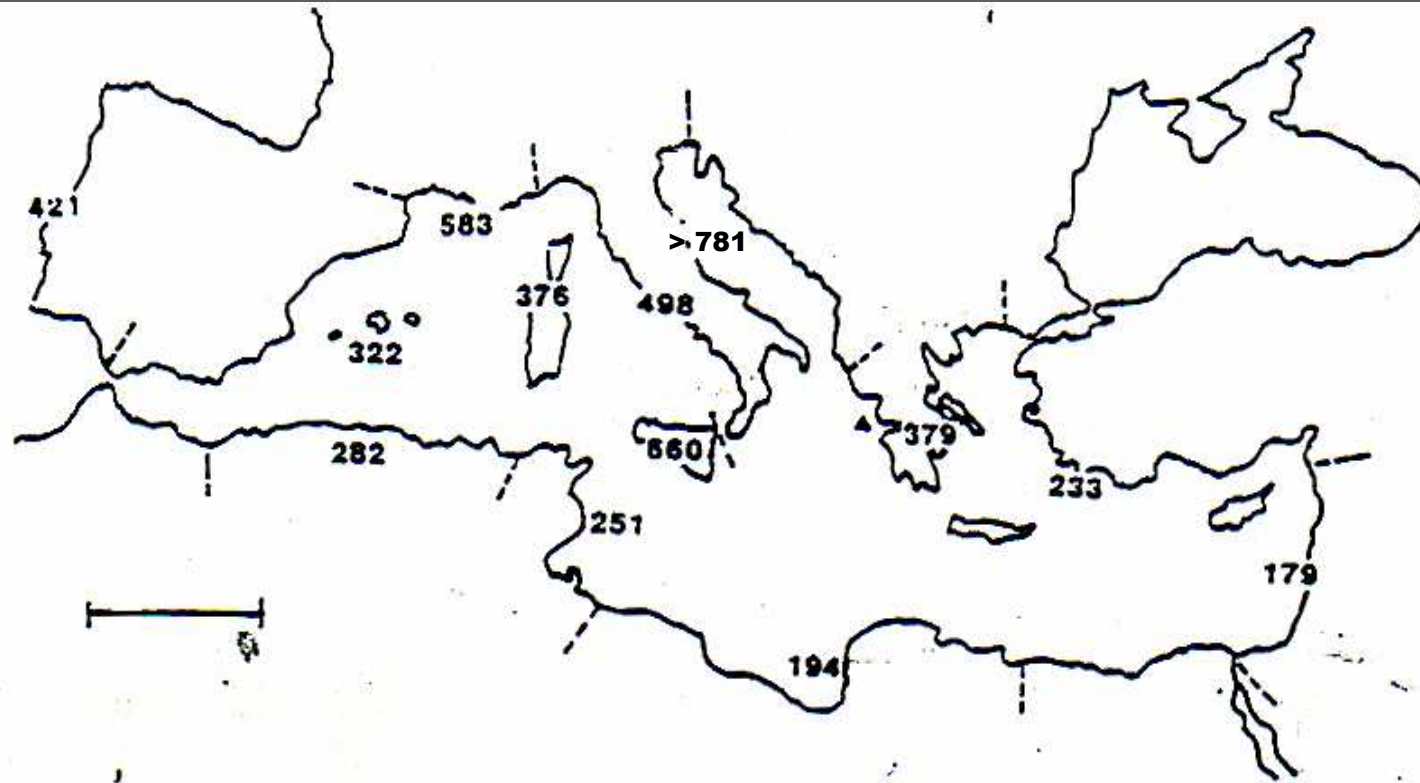


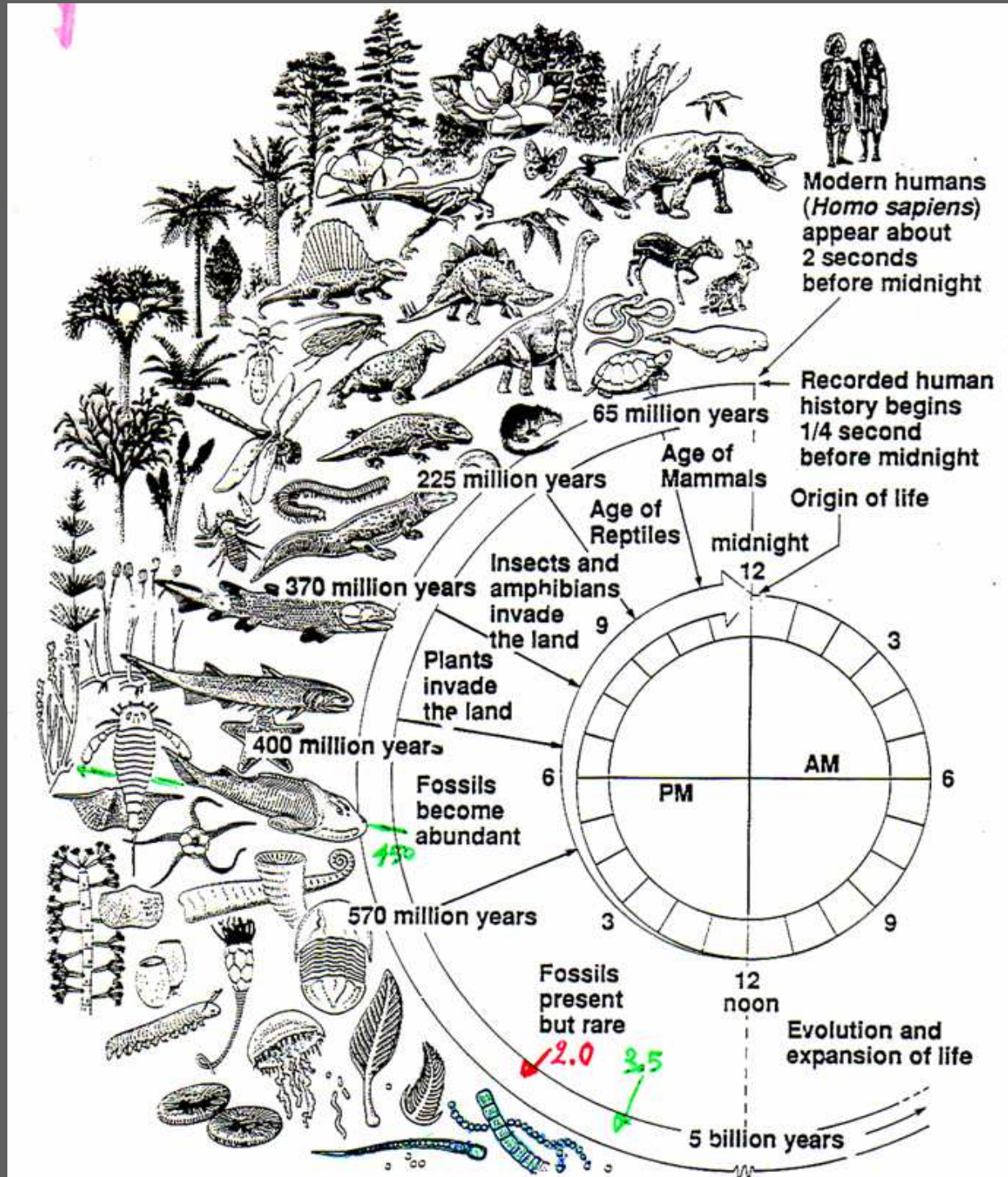
Fig. 1. The total number of seaweeds (greens, browns and reds) from different regions of the Mediterranean and adjacent coasts of the Atlantic. The limits of each region are indicated by dashed lines. (Based on data compiled by Scoane-Camba 1969; Gerloff & Geissler 1971; Gülven & Örtzig 1971; Nizamuddin *et al.* 1979; Menez & Mathieson 1981; Boudouresque *et al.* 1984; Giacconi *et al.* 1985; Maiz 1985; South & Tittley 1986; Boudouresque & Perret-Boudouresque 1987; Diapoulis & Haritonidis 1987; Perret-Boudouresque & Seridi 1989; Verlaque 1990; Ribera *et al.* 1992; Gallardo *et al.* 1993).

Table 3. The estimated endemism of seaweed species (Chlorophyta, Phaeophyta, and Rhodophyta) in different regions

	Percentage endemic	Source
Pacific Ocean		
Kurile Islands	8.6	Nagai 1940
Galapagos Islands	36	Silva 1966
Juan Fernandez Island	32	Santelices 1989
Isla de Pascau	13.9	Santelices 1989
Southern Australia	57 (Browns only)	Womersley 1987
New Zealand	47 (Greens only)	Chapman 1956
	12.2 to N. Island (Browns only)	Lindauer <i>et al.</i> 1961
	9.2 to S. Island (Browns only)	Lindauer <i>et al.</i> 1961
Islands around New Zealand	0-1.3	Nelson 1994
Atlantic Ocean		
Greenland	15 to Arctic	Lund 1959
USA, Cape Hatteras-Cape Canaveral	7	Schneider & Searles 1991
NE Spain, N. France, British Isles	9	Prud'homme van Reine and van den Hoek 1988
Baltic Sea	3.8	South & Tittley 1986
Portugal-Morocco	4.8	Prud'homme van Reine & van den Hoek 1988
Western Mediterranean	27.2	Prud'homme van Reine & van den Hoek 1988
Azores	5.3	Prud'homme van Reine & van den Hoek 1988
Canaries, Madeira, Salvage Islands	4.3	Prud'homme van Reine & van den Hoek 1988
Subtropical Africa, N.		
Senegal-Mauretania	12.5	Prud'homme van Reine & van den Hoek 1988
Angola	0	Lawson <i>et al.</i> 1975
Gough Island, Tristan da Cunha group	6	Chamberlain 1965
Arctic Ocean		
'Ice-bound Arctic Ocean proper'	12.3	Kjellman 1883
'Arctic sea-general'	24.9	Kjellman 1883
Antarctic Ocean		
Antarctic & sub-Antarctic islands	45.5	Papenfuss 1964
Macquarie Island	11 to island	Ricker 1897
	41 to sub-Antarctic zone	
Caribbean		
Caribbean general	28	Taylor 1960
	15.7	Diaz-Piferrer 1969
Jamaica	46.8 to Caribbean	Chapman 1961
Indian Ocean		
Mauritius	16	Silva 1966

Endemic seaweed species

Simplified history of evolution



origins of oxygenic photosynthesis (cyanobacteria) and increasing oxygen in the environment

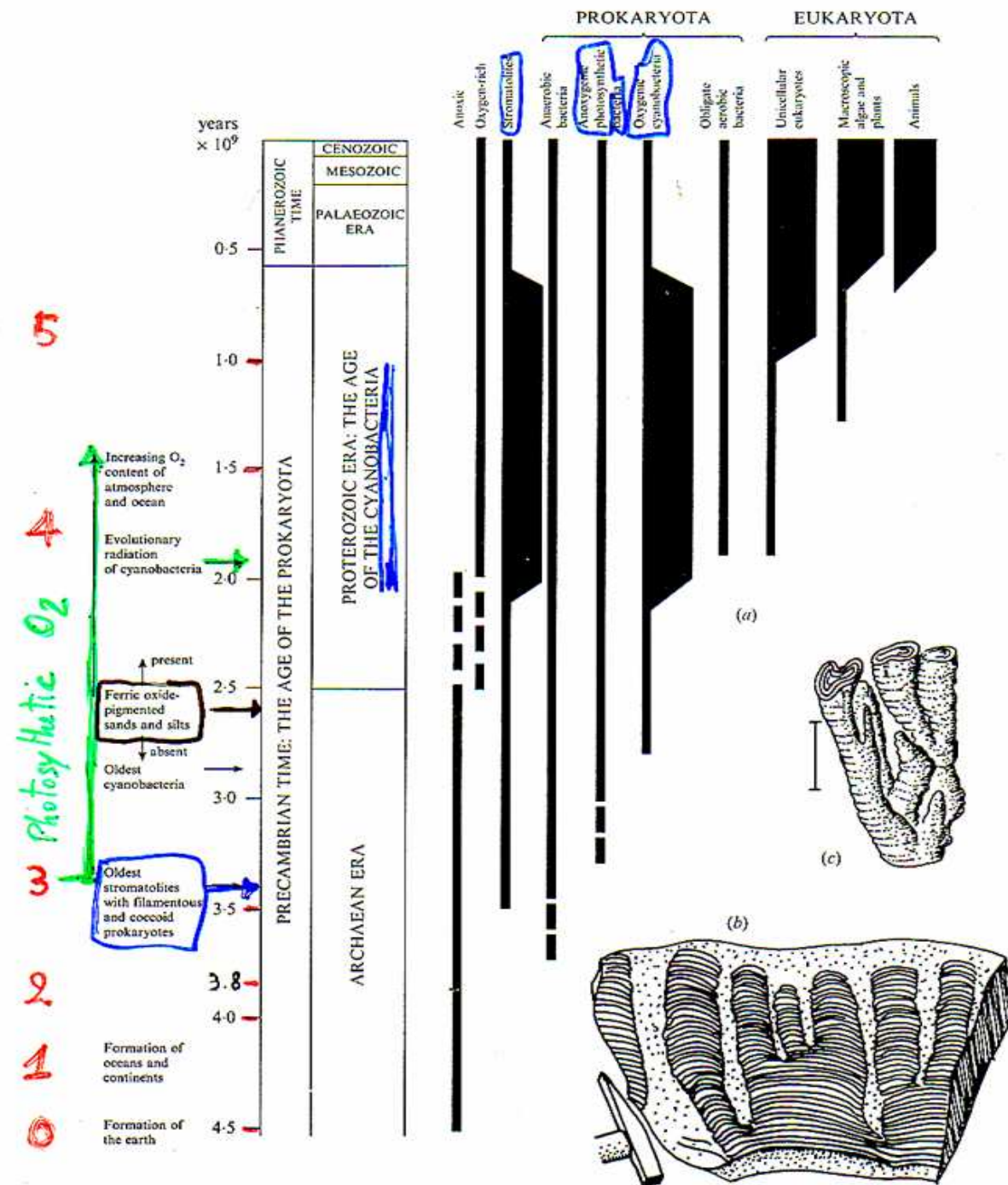
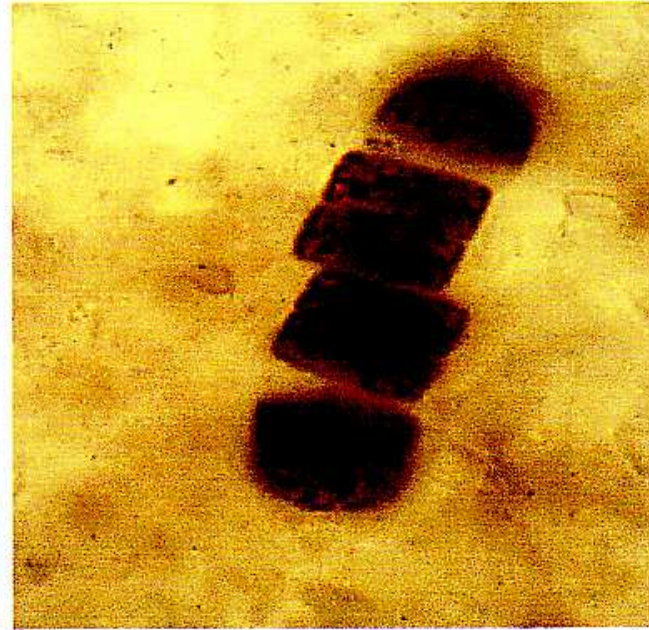
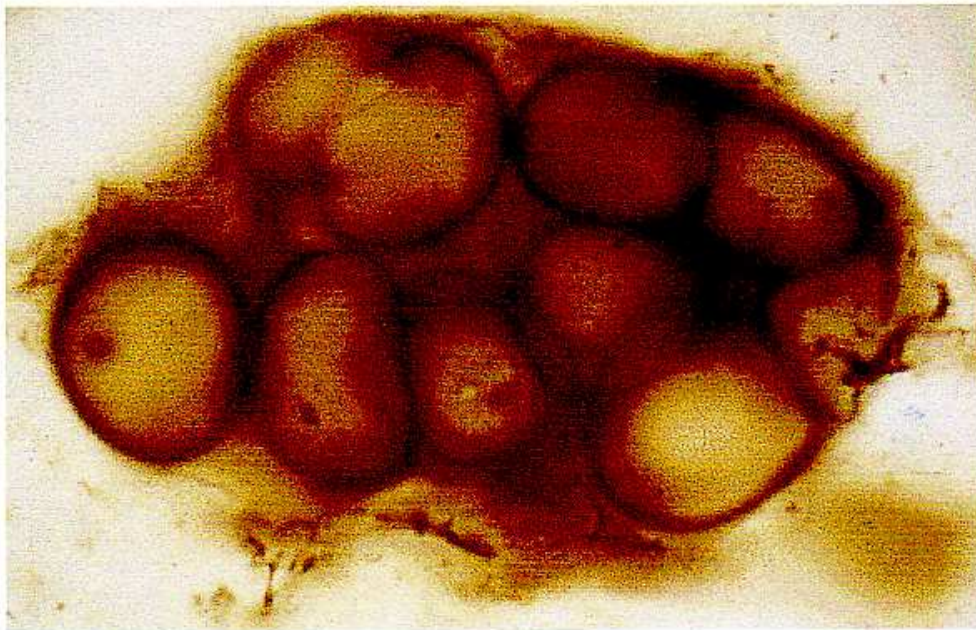


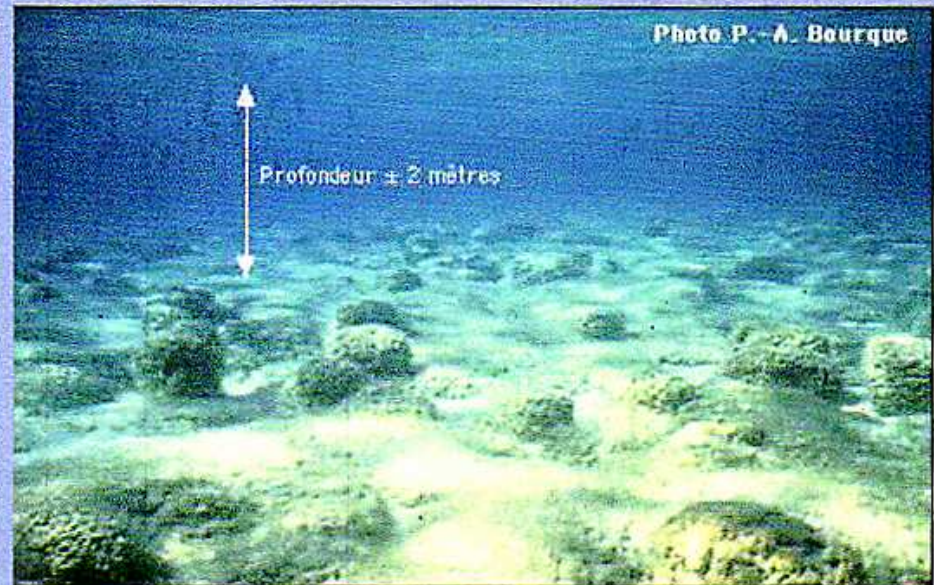
Figure 2.7. (a) The geological occurrence of what are presumed to be blue-green algae (cyanobacteria) and other prokaryotes, compared with eukaryotes.

(b, c) Field sketch and reconstruction of proterozoic stromatolites. (a based on 715, 1585, 1586, 1751, 1827; b, c on 1197.)

Fossil stromatolites and cyanobacteria



Living stromatolites



Colonnes stromatolitiques en construction dans la zone infratidale supérieure, Shark Bay, nord-ouest de l'Australie.

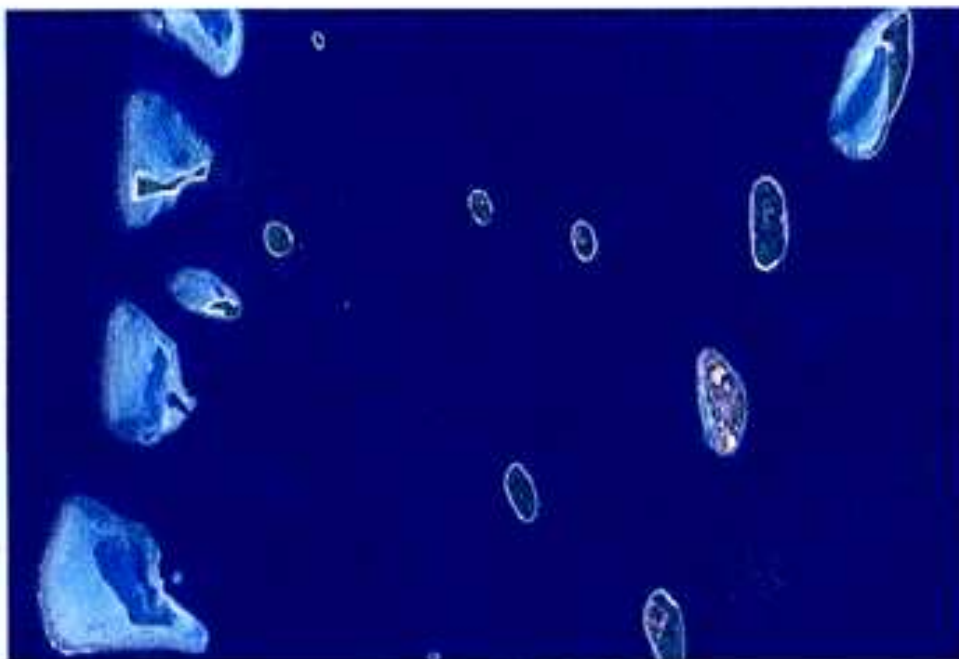
Ecology of algae

Algae are important components of aquatic systems as phytoplankton and benthic growths

- » kelp forests
- » corals and coral reefs

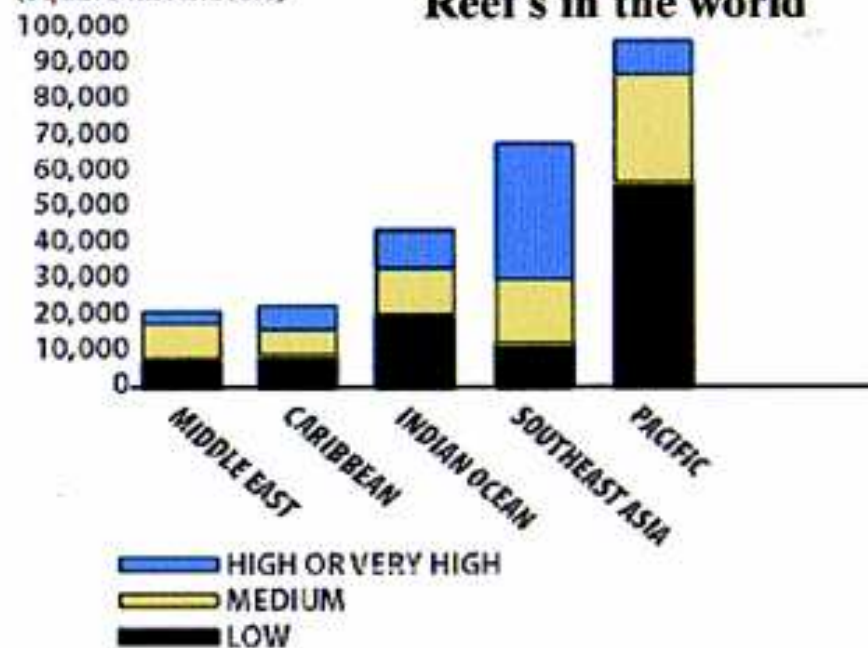
- phytoplankton and periphyton in rivers, streams, ponds, and lakes
- terrestrial algae (soils, rocks, plants, animals)
- extreme environments (low and high solar radiation, hot and cold deserts, hot waters, snow, ice, low and high pH)
- occurrences of harmful algal blooms HABs
- biological indicators of water quality
- paleoclimate reconstruction (diatoms, coccoliths)

Coral atolls



(square kilometers)

Reef s in the world



Calcium communities in coral reefs

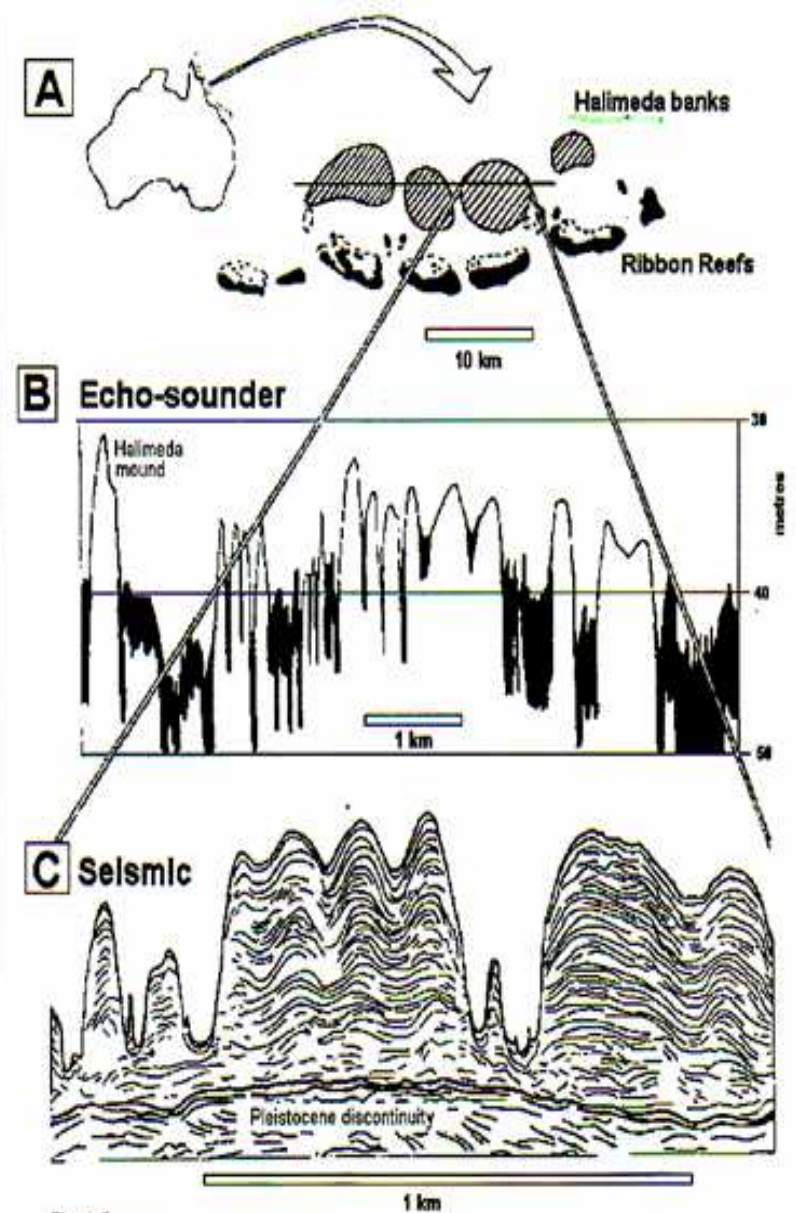


Figure 3
The structure of *Halimeda* gravel deposits
A *Halimeda* banks associated with ribbon reefs off Cookdown
B Echo-sounder profile across a *Halimeda* bank
C Seismic profile across the same bank (courtesy of P.J.Davies)

Algal contribution to primary production

Oxygen derives
4/5 from marine
1/5 from terrestrial

MARINE PRODUCERS

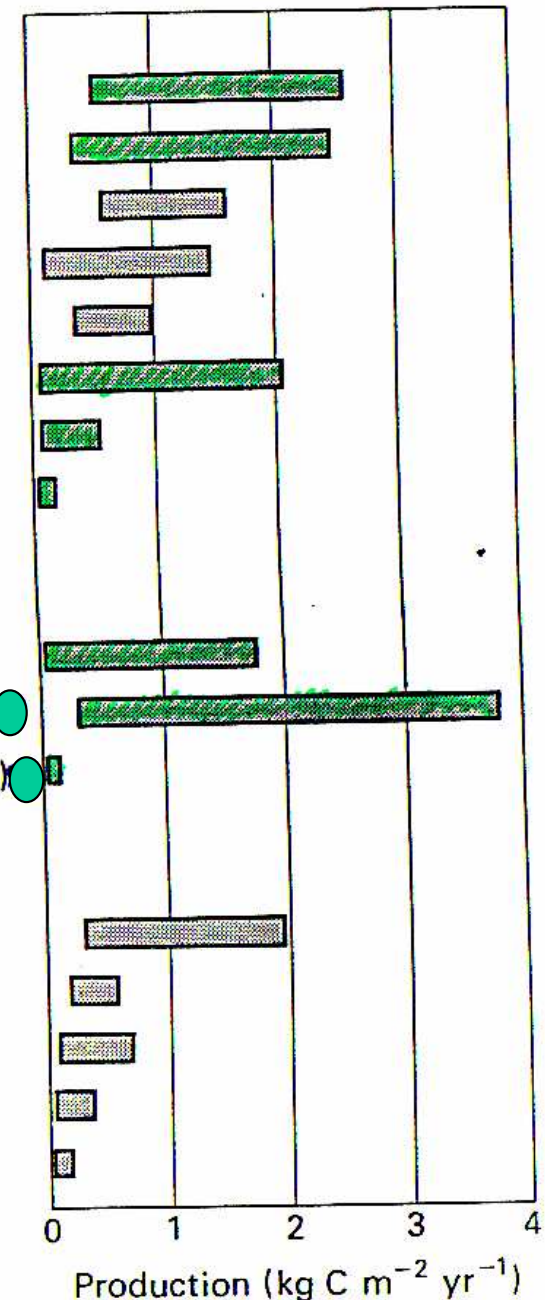
- Corals ●
- Kelp and rockweeds ●
- Salt marsh grasses
- Sea grasses
- Mangroves
- Benthic microalgae ●
- Coastal phytoplankton ●
- Open sea phytoplankton: ●

FRESHWATER PRODUCERS

- Macrophytes ●
- Phytoplankton (nutrient-rich) ●
- Phytoplankton (nutrient-poor) ●

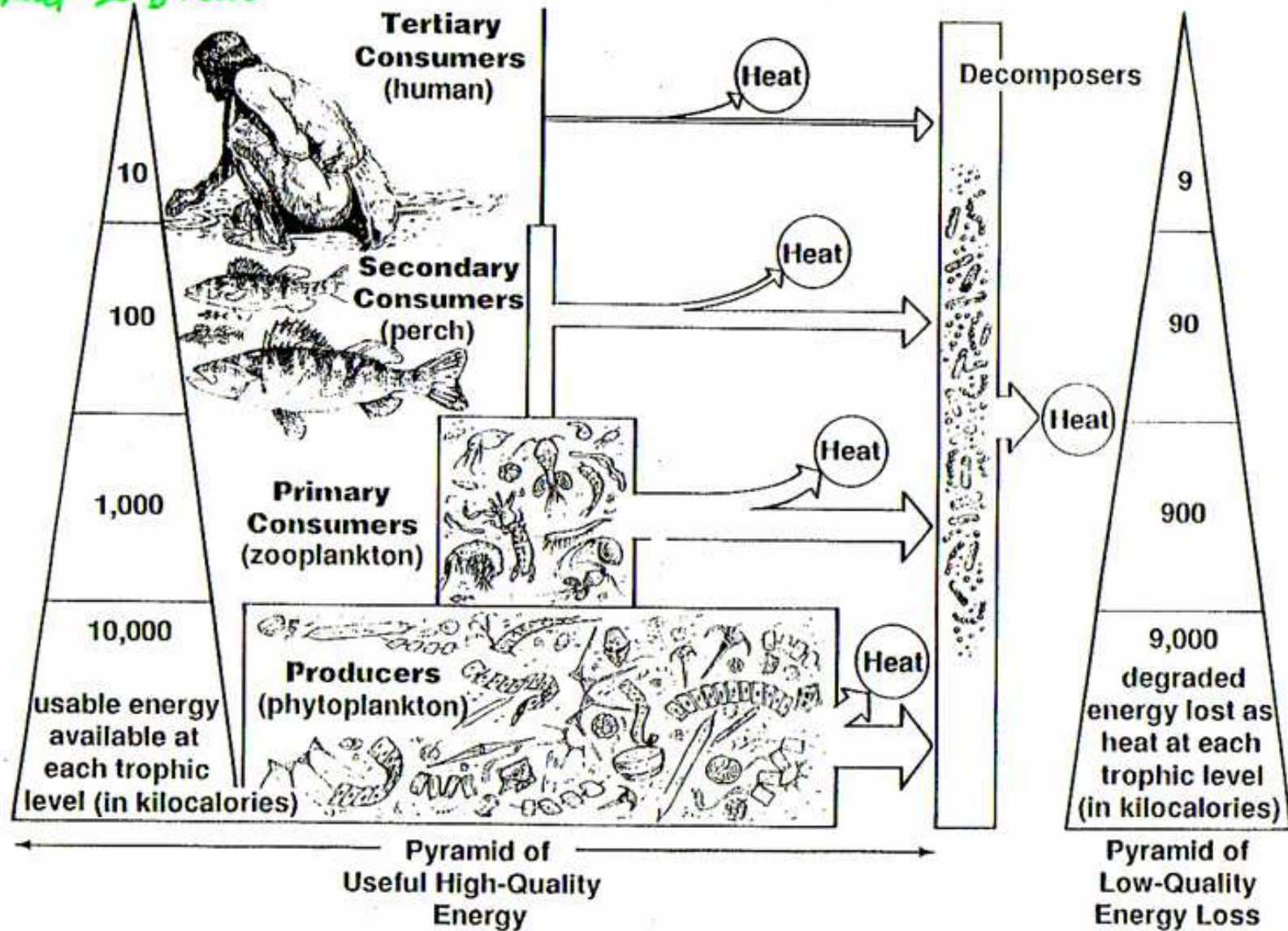
TERRESTRIAL PRODUCERS

- Rain forests
- Temperate forests
- Grasses, forbs
- Prairies, steppes
- Deserts, tundra

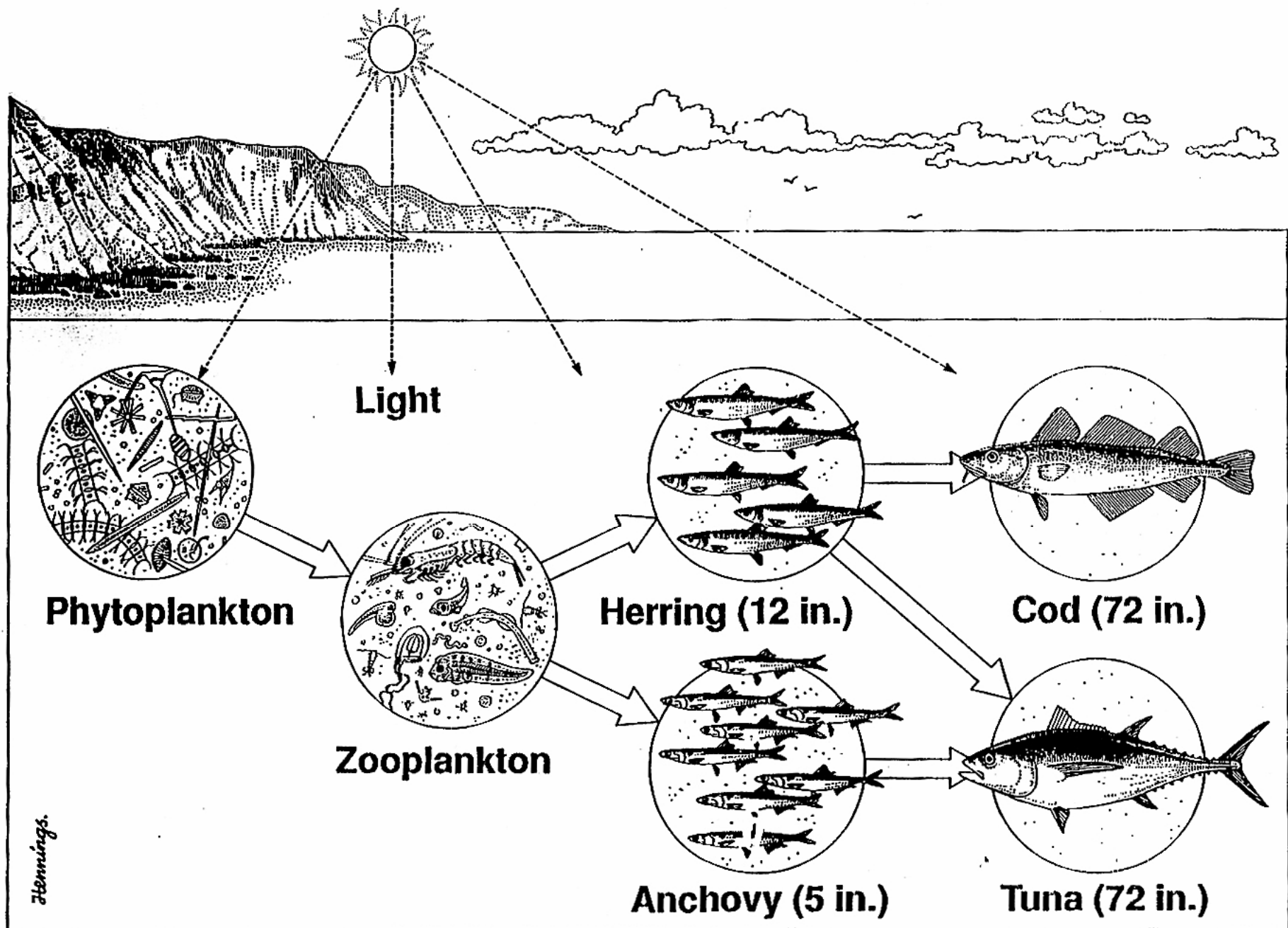


● + picoplankton

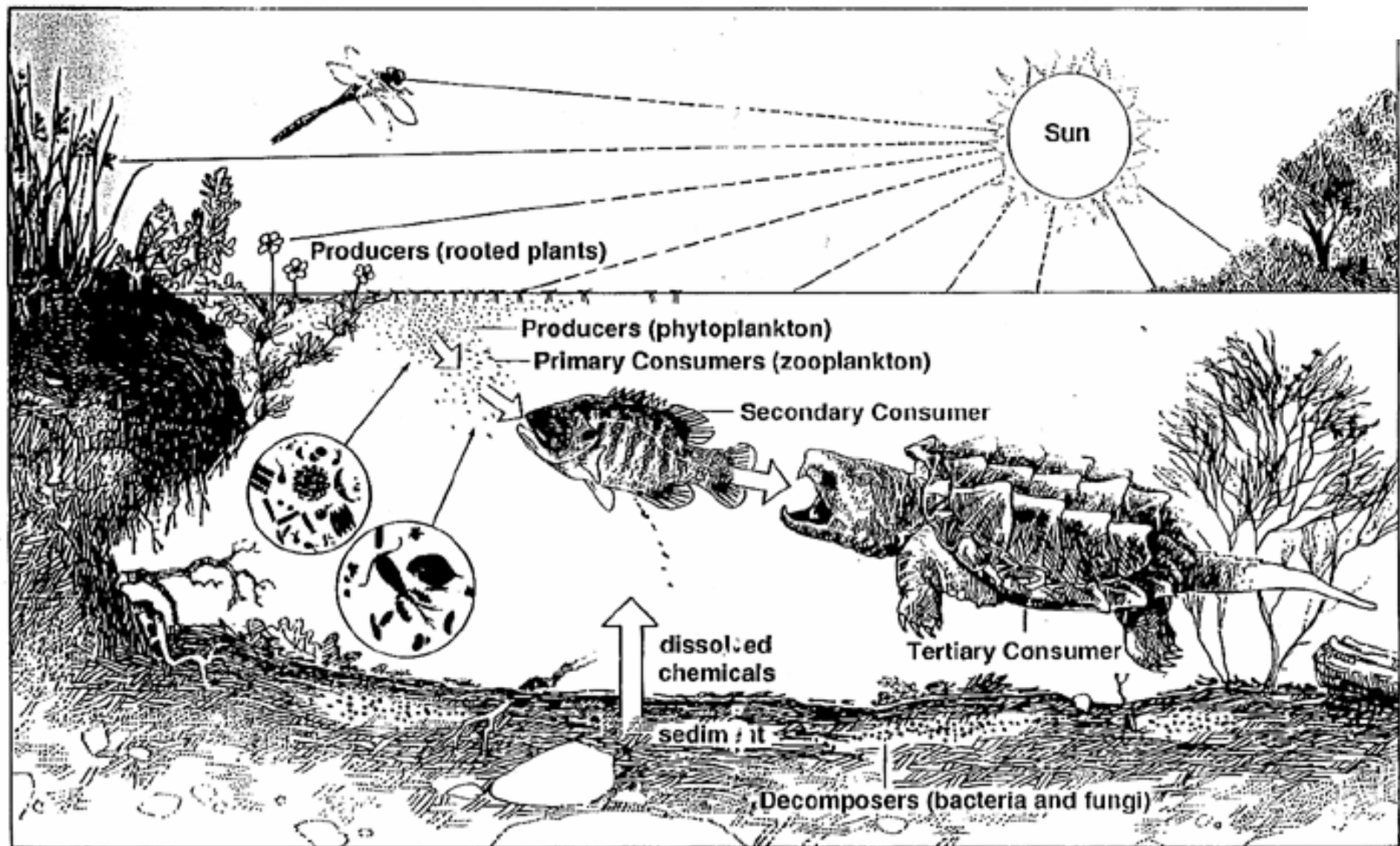
FP — marine 150 b tons
 — terrestrial 50 b tons



Hypothetical energy flow pyramids for each trophic level in a food chain or food web.

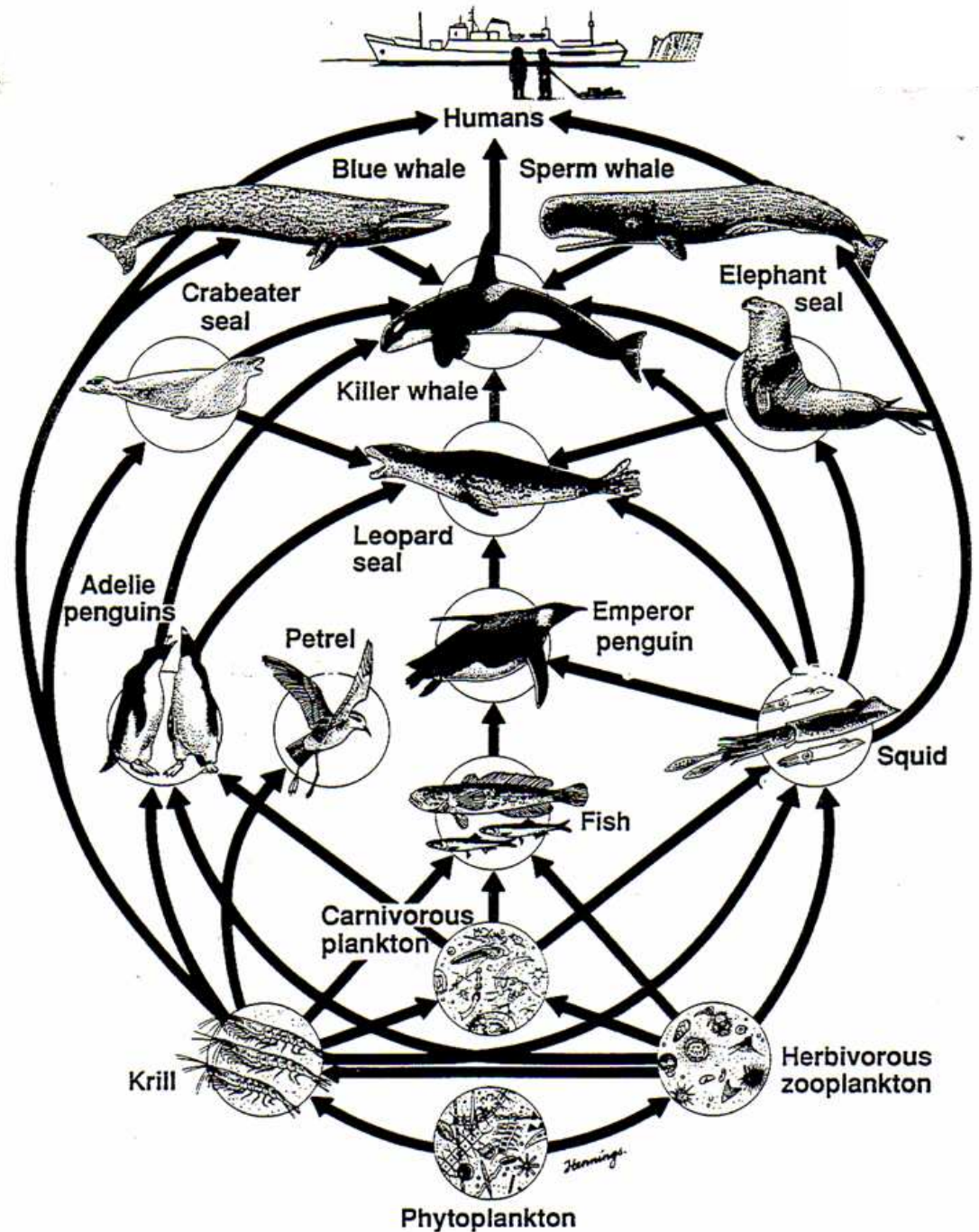


Greatly simplified ocean food web.

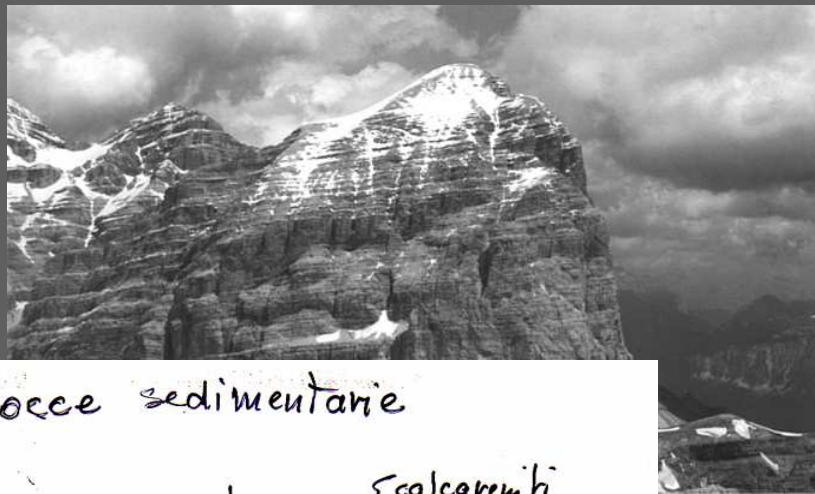


Major components of a freshwater pond ecosystem.

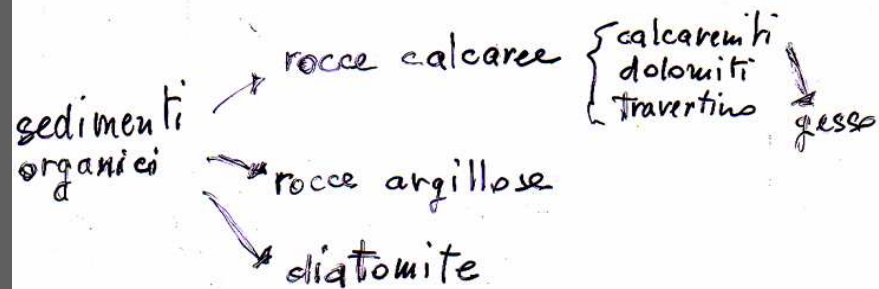
Food web in Extreme Environments



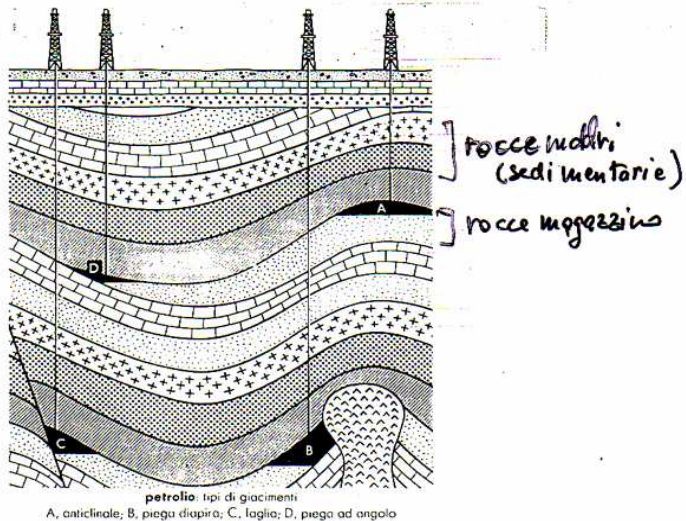
Simplified Antarctic food web.



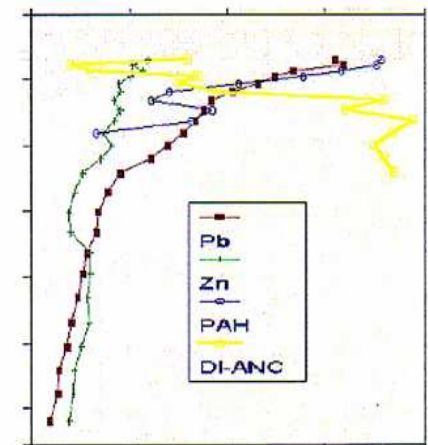
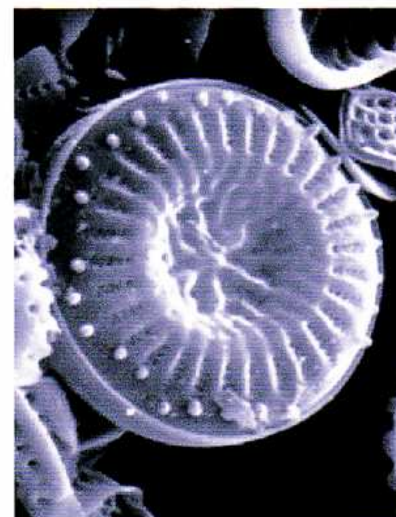
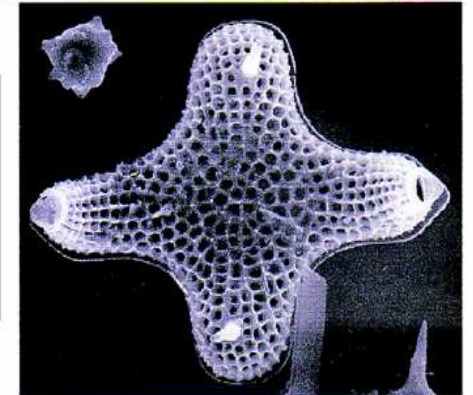
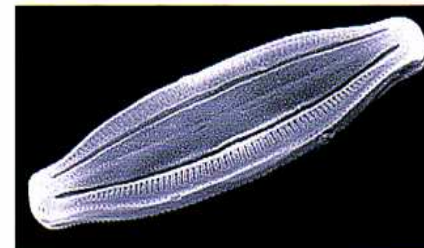
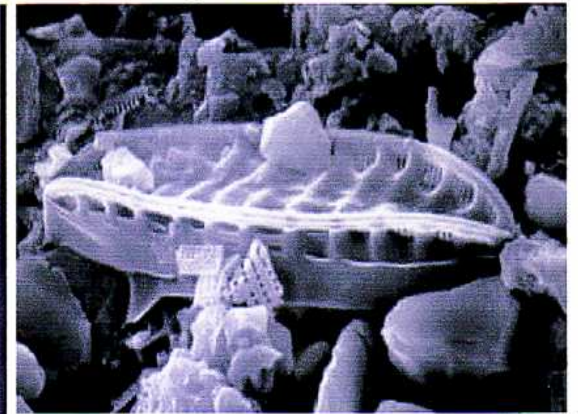
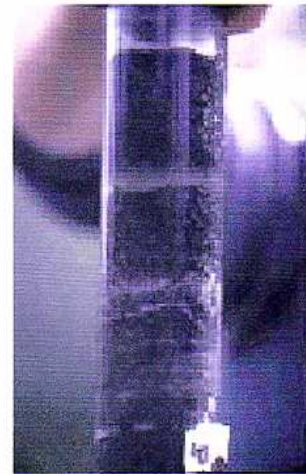
Rocce sedimentarie



Origine biogenica del petrolio e metano



Diatom fossils and paleoclimate



The most popular photo of a HAB event



What are the Economic Effects of HABs on the U.S. Economy?

TOTAL (\$ 82 million per year)

Based on subset of outbreaks in 1987-2000

Does not include freshwater outbreaks

Public Health Costs of Illness (\$37 million per year) 45%

Medical treatment, lost productivity, transportation, causal investigations

Ciguatera poisoning responsible for majority of costs

Commercial Fisheries Impacts (\$38 million per year) 46%

Includes lost revenue due to closed fisheries, mortalities of shellfish and fish, some untapped fisheries (surf clams in Alaska and on Georges Bank)

Does NOT include cost of delayed harvesting or changes in economic value (i.e., surplus losses)

Local Recreation and Tourism Impacts (\$4 million per year) 5%

Data is lacking for good estimates Based on 1987 bloom in North Carolina and estimates of reduced spending on razor clam harvesting in Washington State

Coastal Monitoring and Management (\$3 million per year) 4%

Based on data obtained from state governments

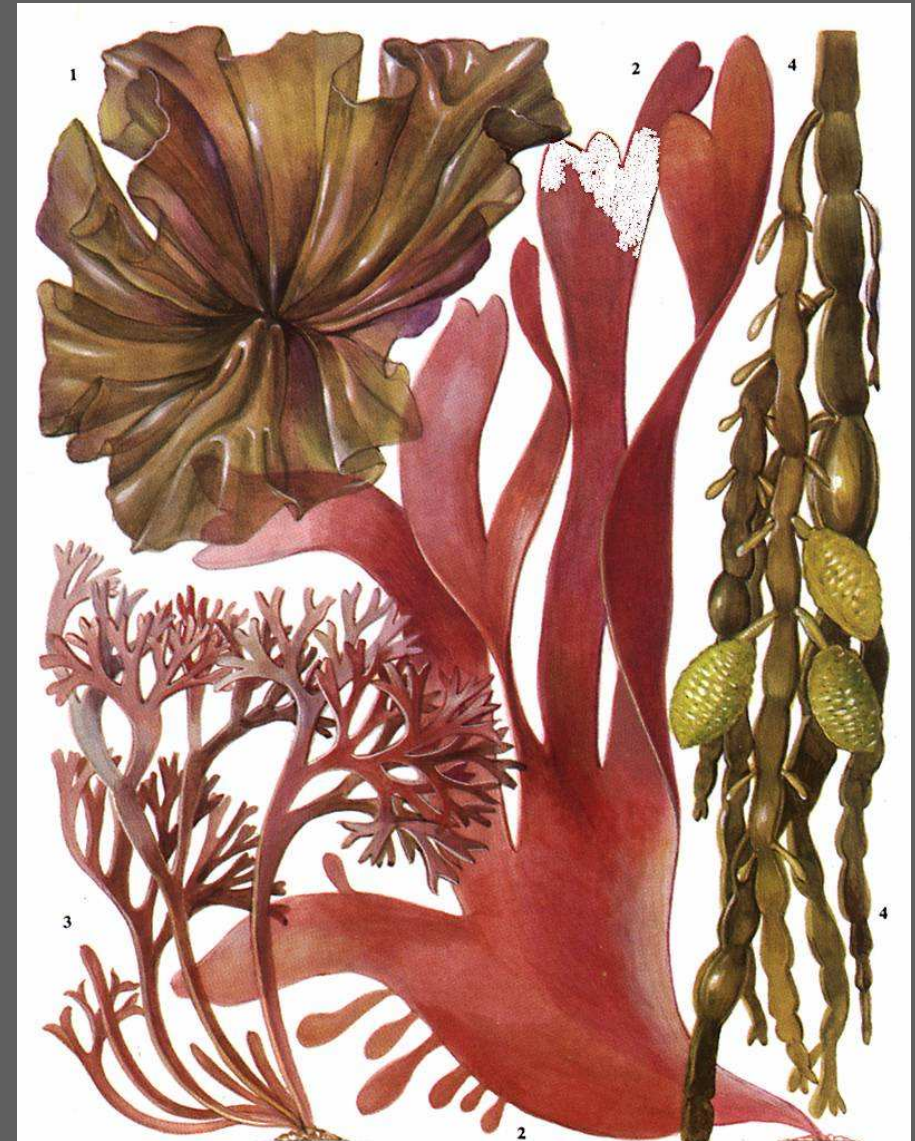
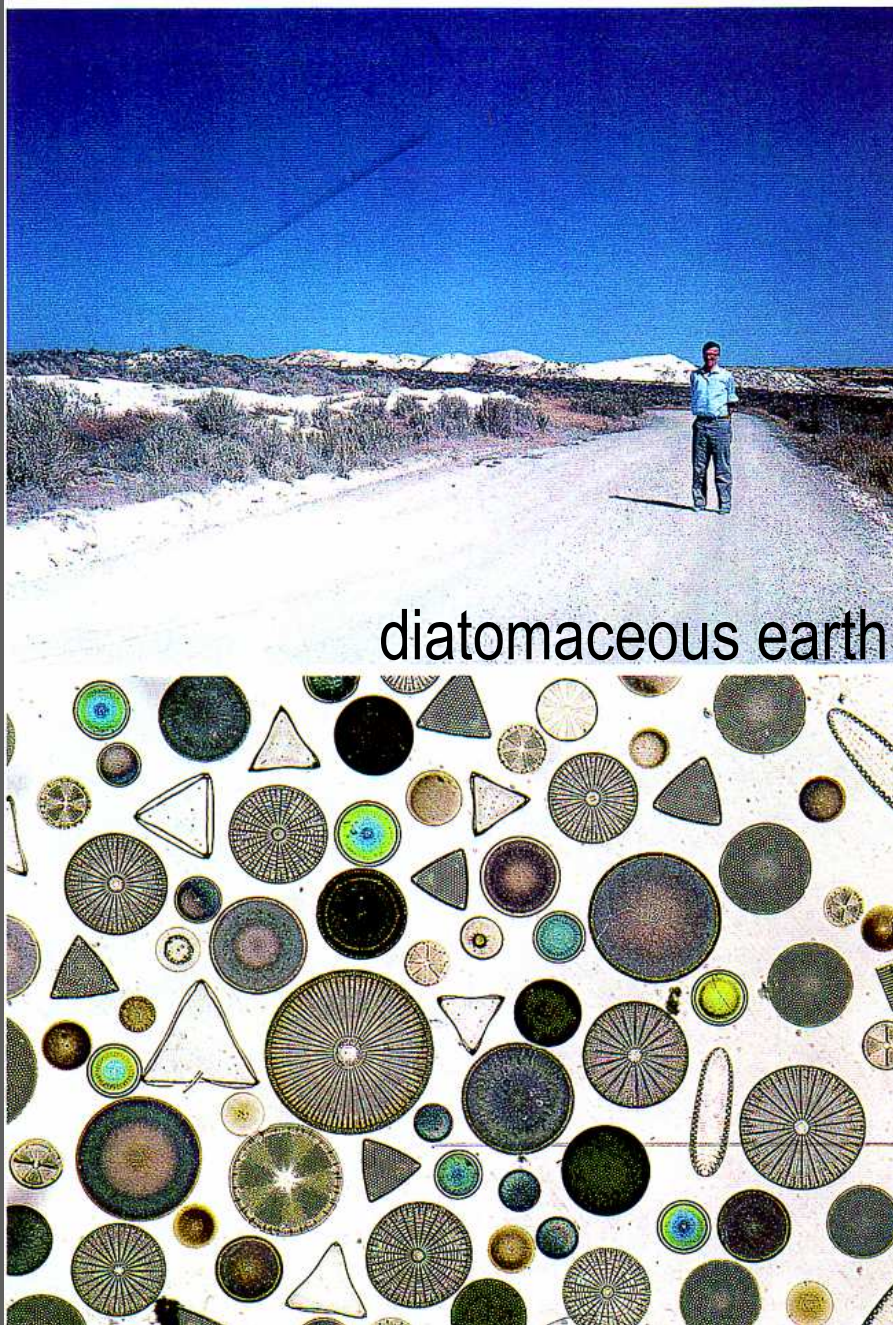
Helps reduce costs in other sectors

[U.S. Interagency Report I, 2007]

Economic interest of Algae

- food for man and animals
- waste water recovery
- soil biofertilizers and stabilisation
- contaminated soil remediation
- polysaccharide extraction
- salt production
- diatomaceous earth
- Biomass
 - new biomolecules for pharmaceuticals and health products
 - biofuels

food for animal and man, fertilizers
extraction of agar, carrageen, alginates,
iodine and potassium salts



mariculture

LIFE SIZE
1 LAVER 2 DULSE 3 CARRAGEEN
4 KNOTTED WRACK



**Coltivazioni su larga scala
per produzione di
biomasse algali**

*Sistemi aperti
(vasche)*

*Fotobioreattori
tubulari ,*

a pannelli



Materials

- all slides and short notes at Didattica Web
www.uniroma2.it/didattica/

Books

- Christofer S. Lobban & Paul J. Harrison, 2008. **Seaweed Ecology and Physiology**, Cambridge University Press
- Robert E. Lee 2008. **Phycology**, Cambridge University Press
- Matt. J. Dring, 2008. **The Biology of Marine Plants**, Cambridge University Press