… of algae and seaweeds …
an introduction

January 2016

Durban

Olivier De Clerck

John J Bolton

Robert J Anderson

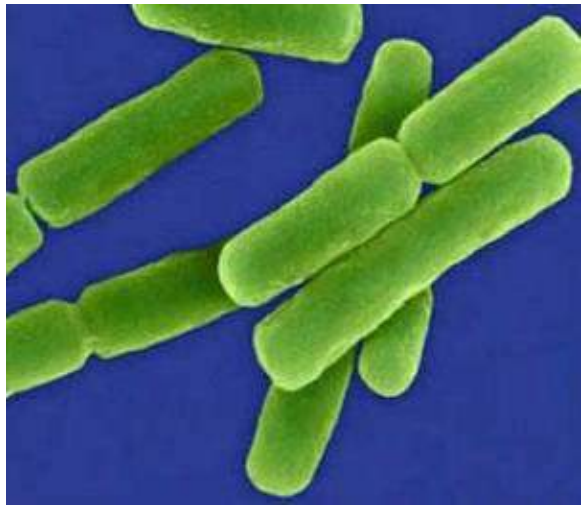
Content

- Algae – what's in the name
- How to collect and study them
- Algal diversity in Kwazulu-Natal
  - Green algae - Chlorophyta
  - Brown algae - Phaeophyta
  - Red algae - Rhodophyta

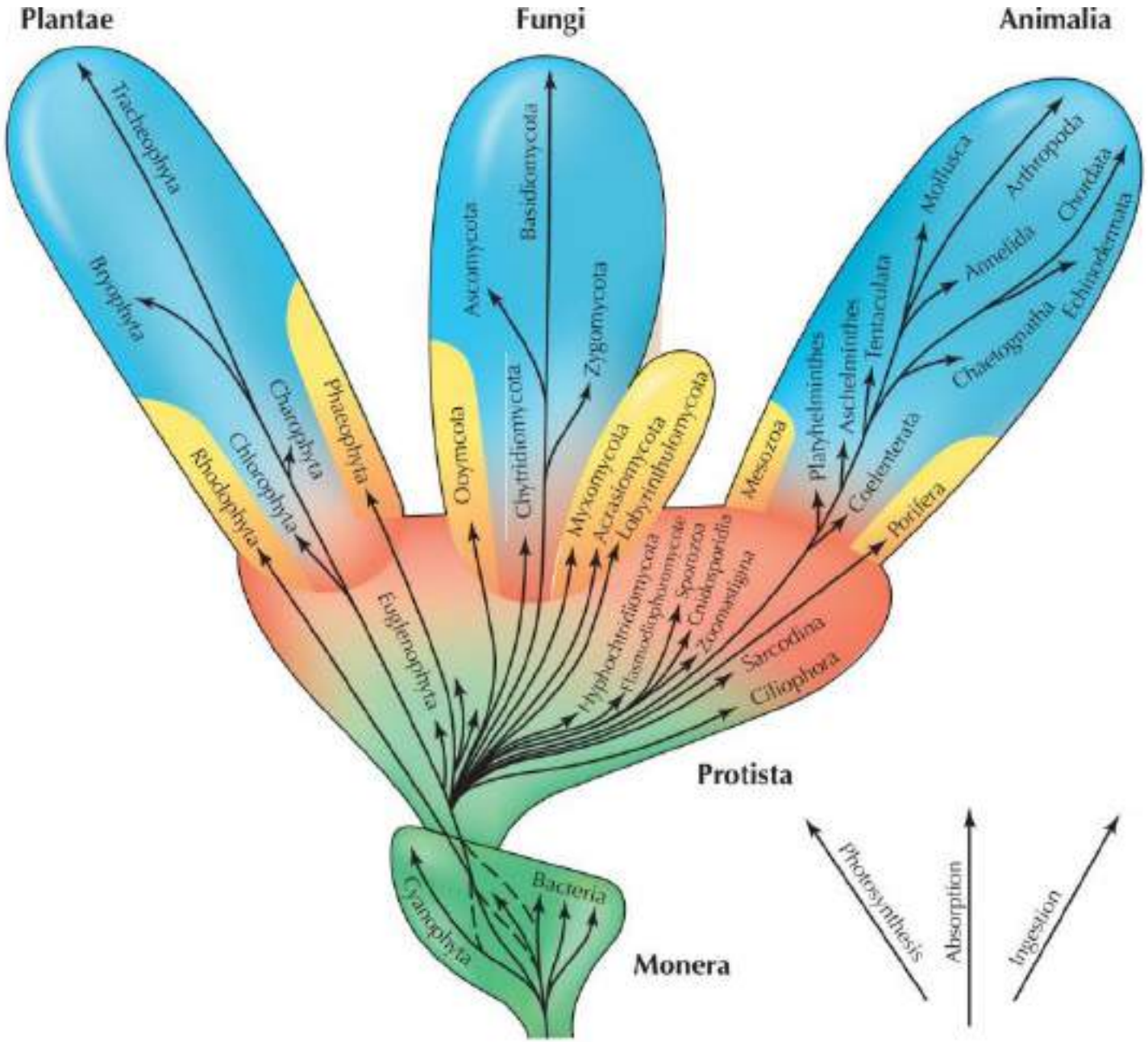
Algae – what’s in the name

Biodiversty

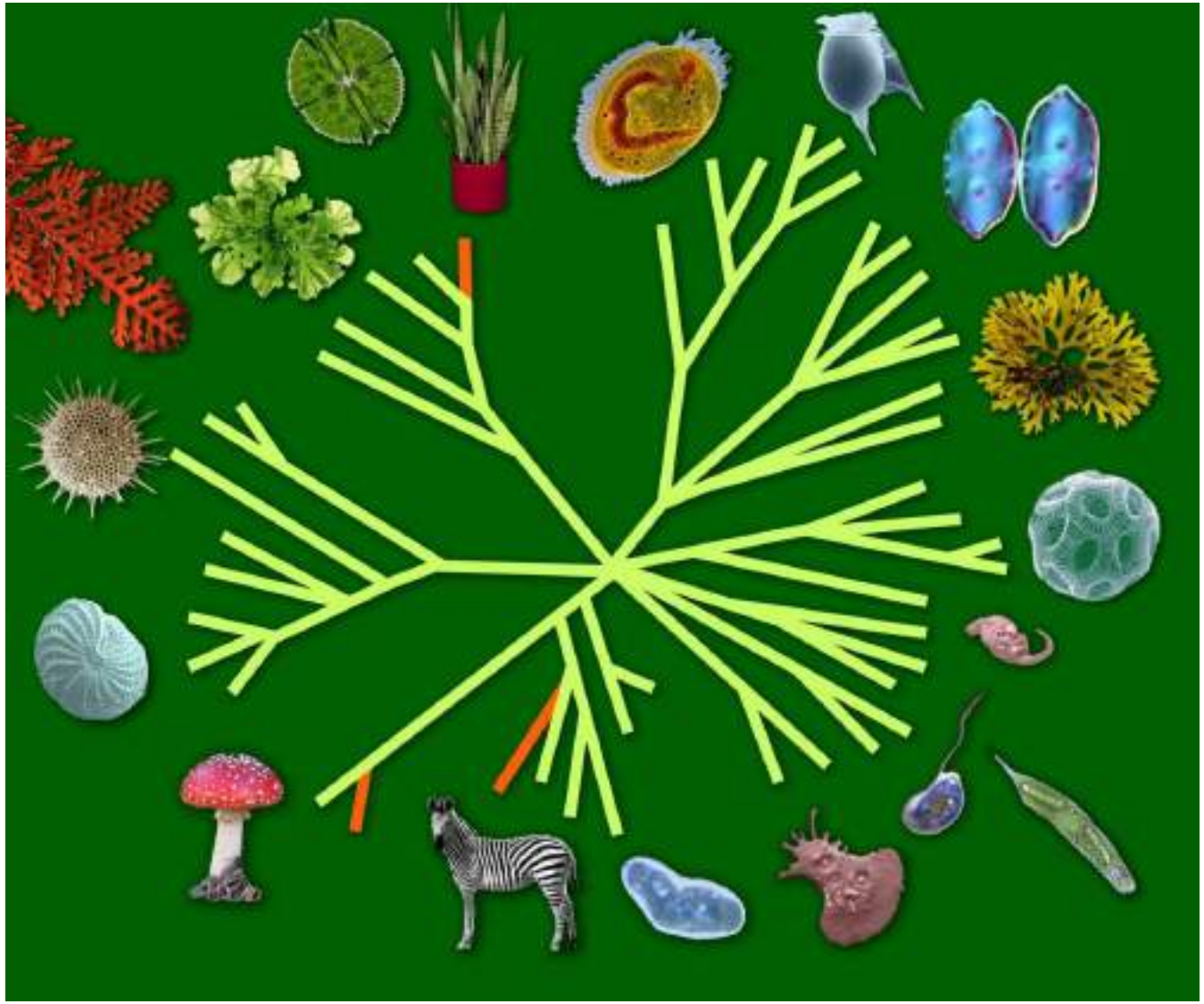
The things we see



Robert Whittakker's Five kingdom classification (1969)



Protozoa and algae comprise an **enormous evolutionary diversity** and dominate the eukaryotic ‘tree of life’ (all groups below except the red ones)



Protists = unicellular eukaryotes

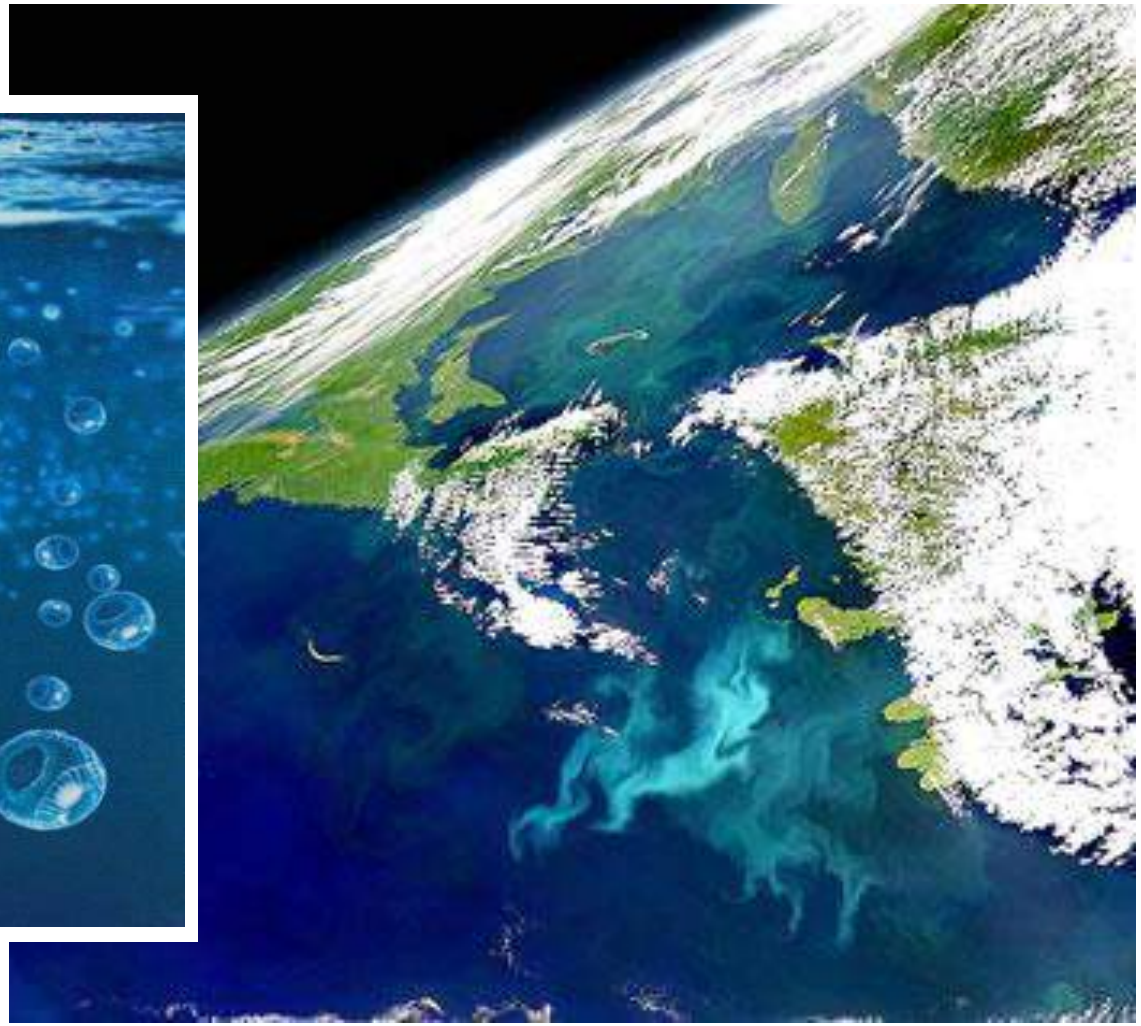
Micro-algae = unicellular photosynthetic eukaryotes

Macro-algae (seaweeds) = multicellular photosynthetic eukaryotes, ≠ vascular plants

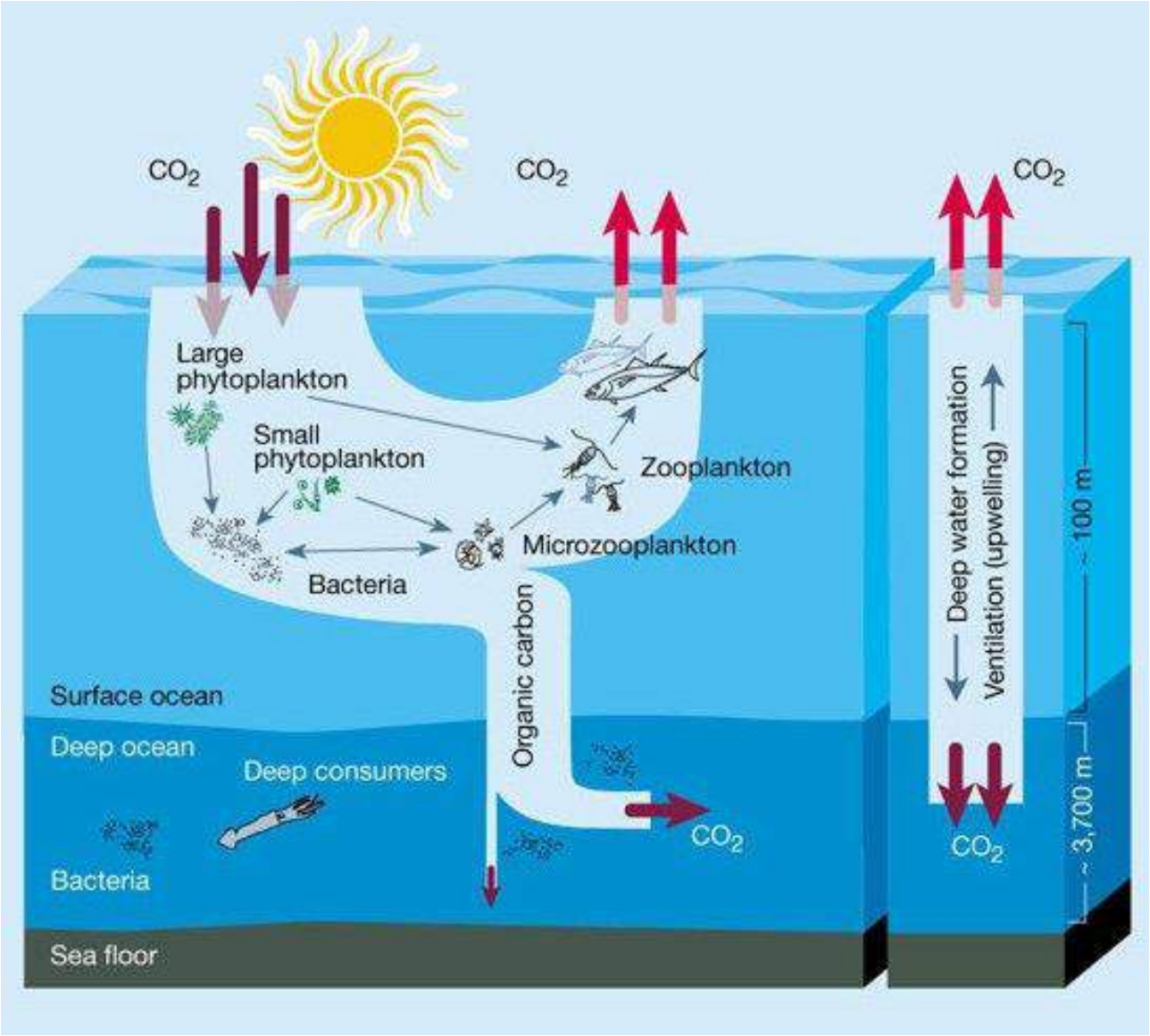
Protozoa = unicellular heterotrophic eukaryotes

Protoctista = protists and their direct multicellular descendants (macro-algae)

Emiliana huxleyi



phytoplankton < 1 % of biomass on Earth but responsible for ~ 50 % of total primary production, enormous importance in food chains, cycling of matter and energy, ...

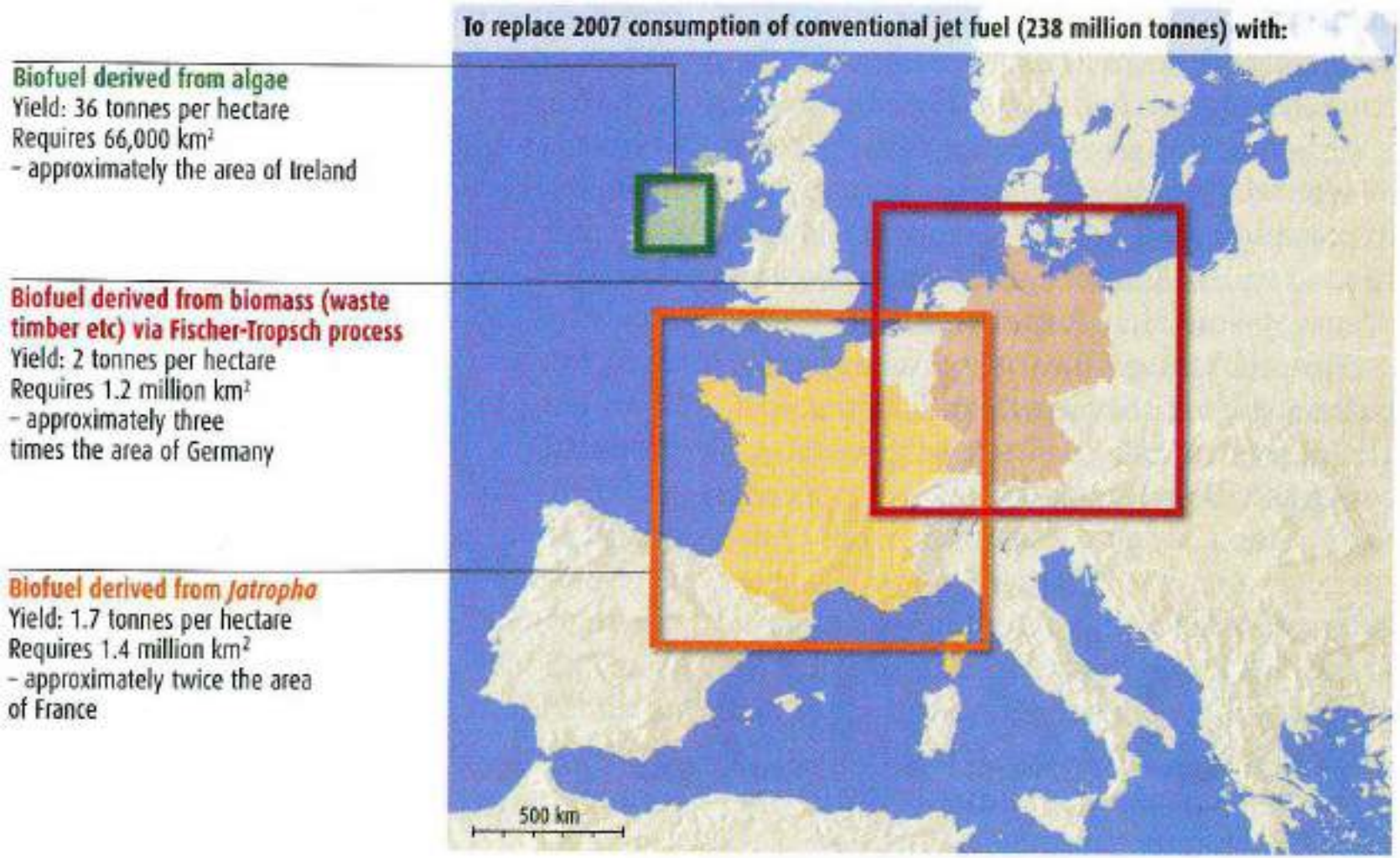


Drawdown of atmospheric CO_2 by the biological pump

mariculture macroalgae

Food, alginates, carragenes and agar, fertilizers, etc.

Microalgal biofuels?



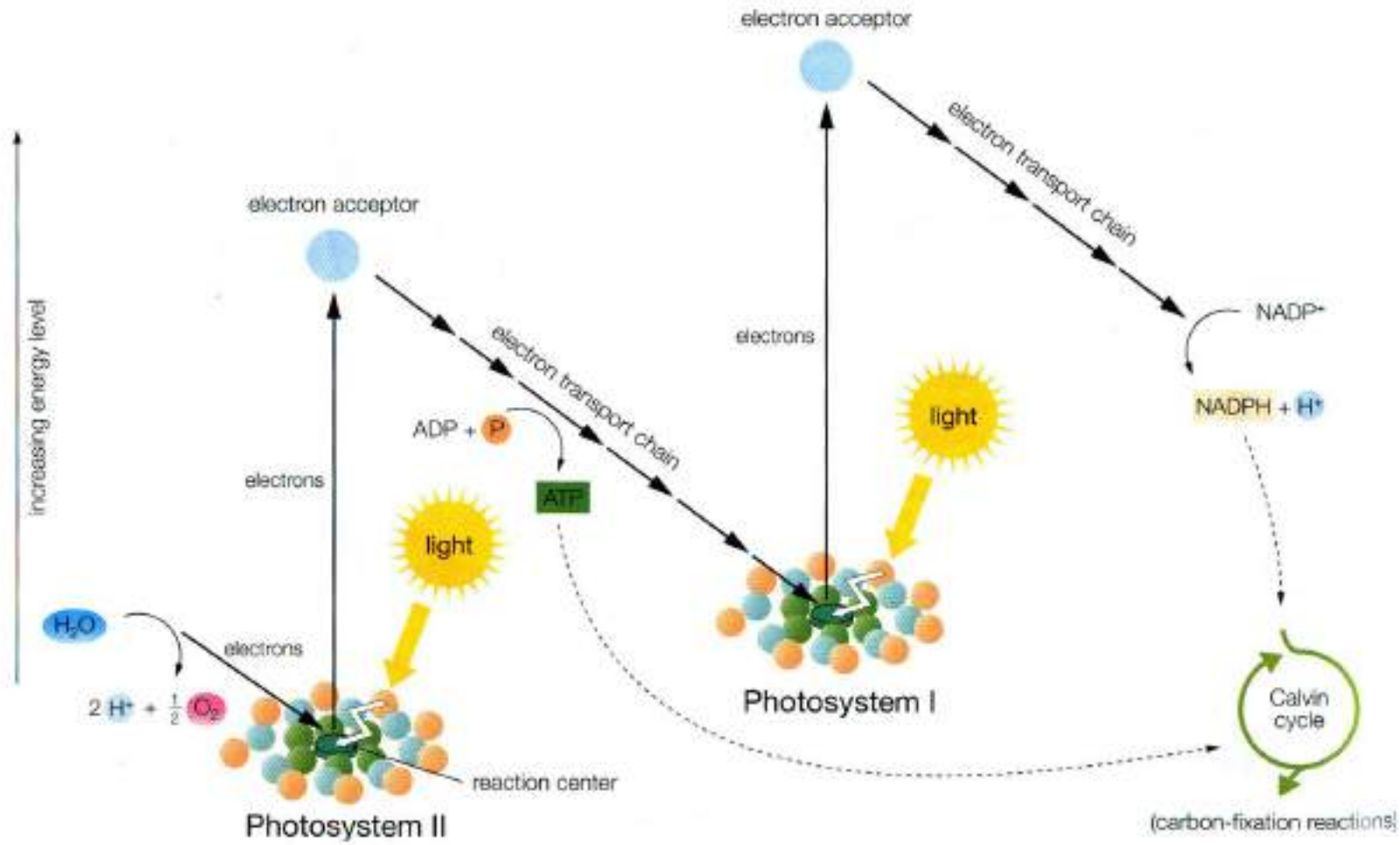
(New Scientist 16 Aug 2008)

The origin in a nutshell

Stromatolites – origin of photosynthesis in Cyanobacteria

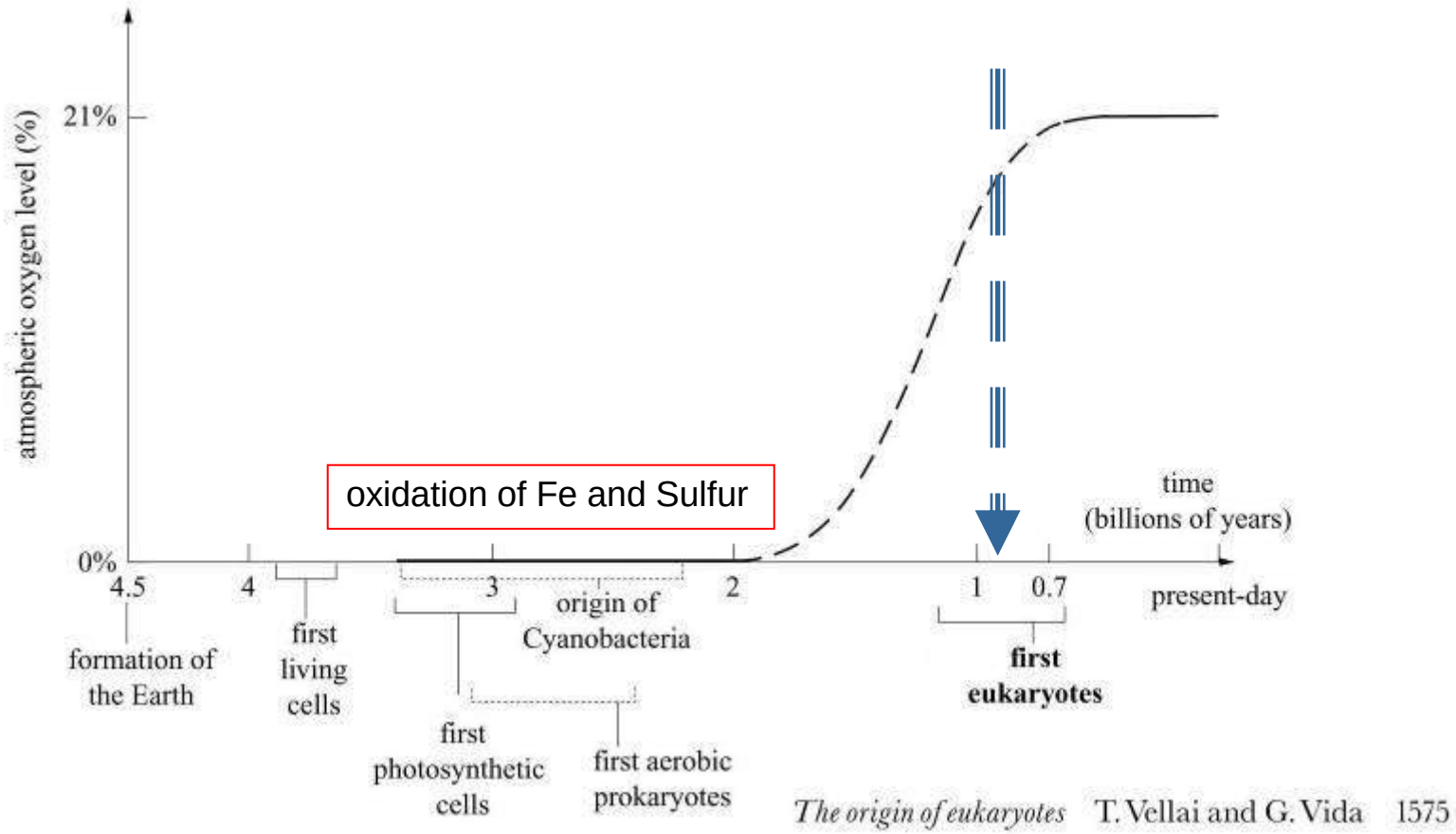
Oxygenic photosynthesis

- Unique origin – 2.5 billion years ago
  - $n\ CO_2 + 2n\ H_2O + ATP + NADPH \rightarrow (CH_2O)_n + n\ O_2 + n\ H_2O$



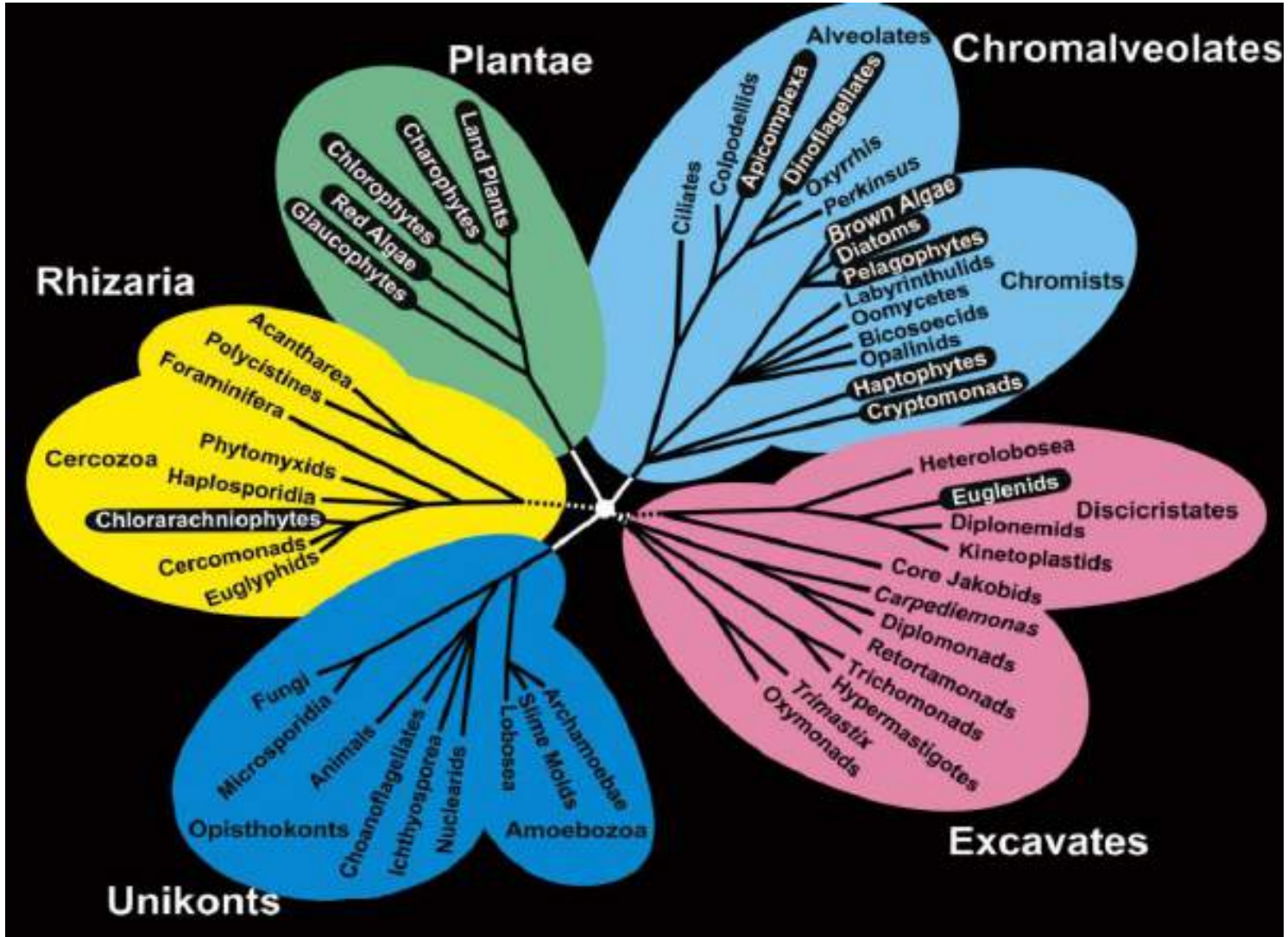
Oxygenic photosynthesis

- Stromatolites and the oxygenation of the atmosphere



The origin of eukaryotes T. Vellai and G. Vida 1575

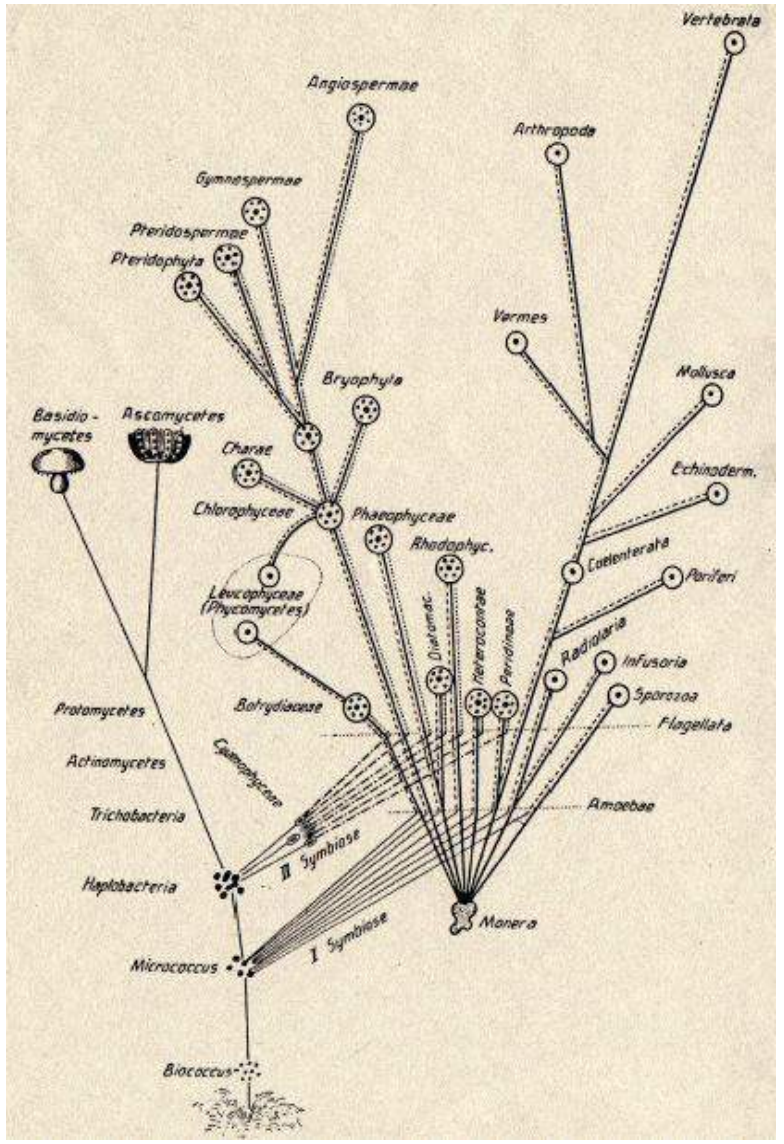
Eukaryotes and the spread of photosynthesis



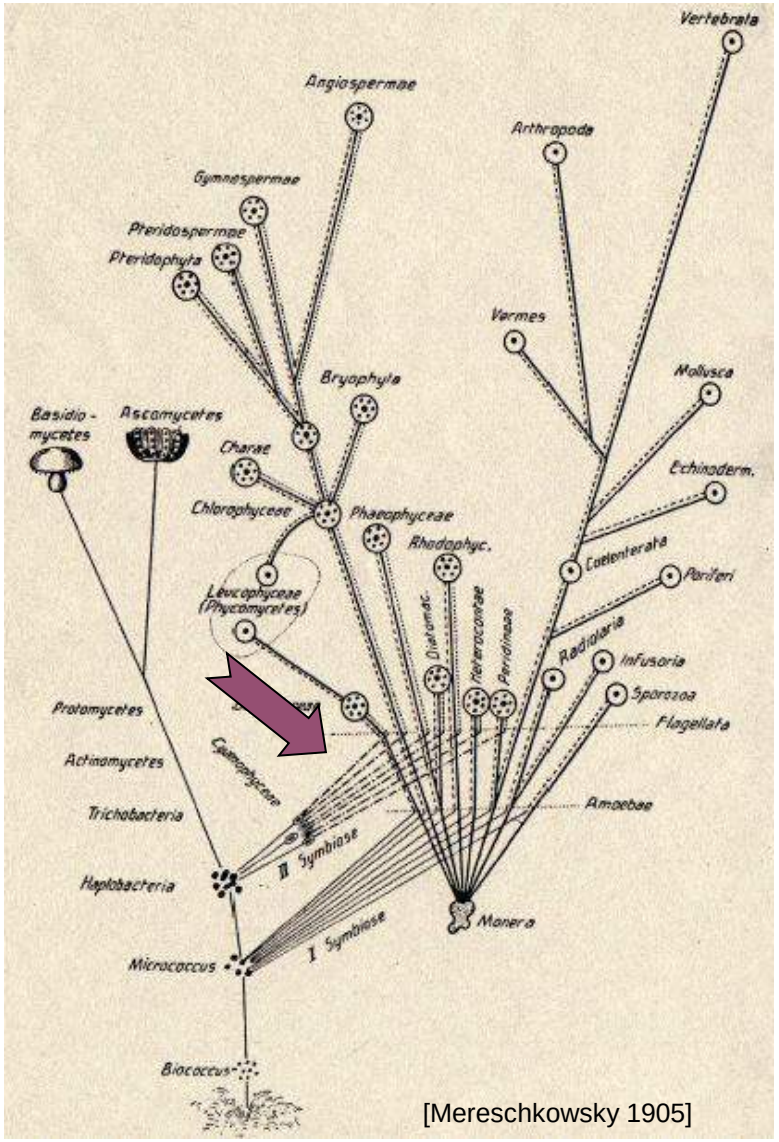
Endosymbioses (ES)

- mitochondria and plastids evolved from ES bacteria and cyanobacteria.

- Schimper (1883),
- Mereschkowsky '*Uber Natur und Ursprung der Chromatophoren …*' (1905)



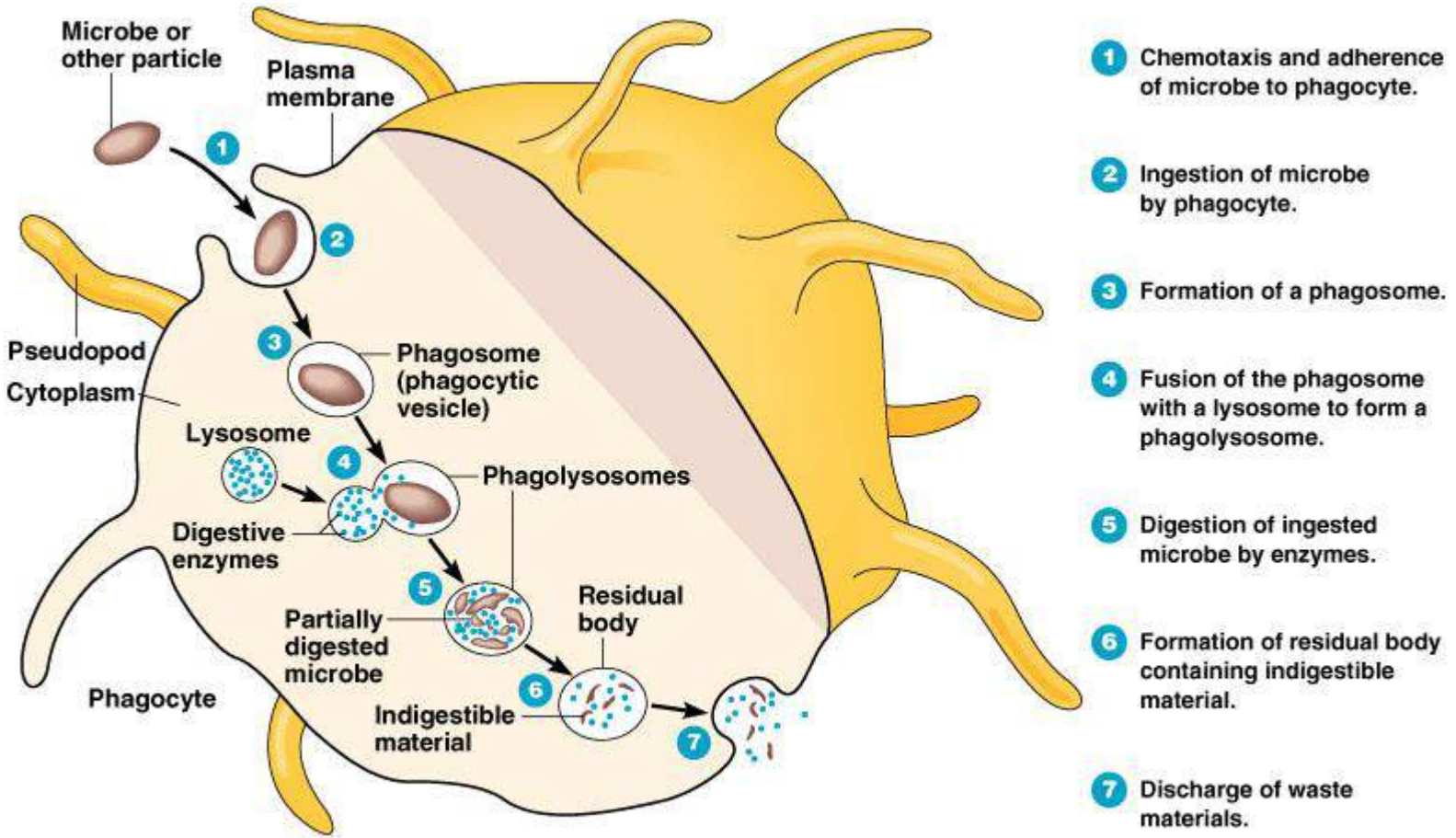
Endosymbioses (ES)



[Mereschkowsky 1905]

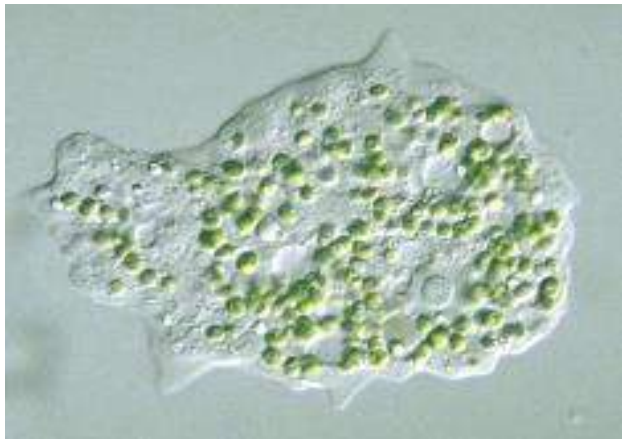
Endosymbioses (ES)

- How ?
- Phagocytosis

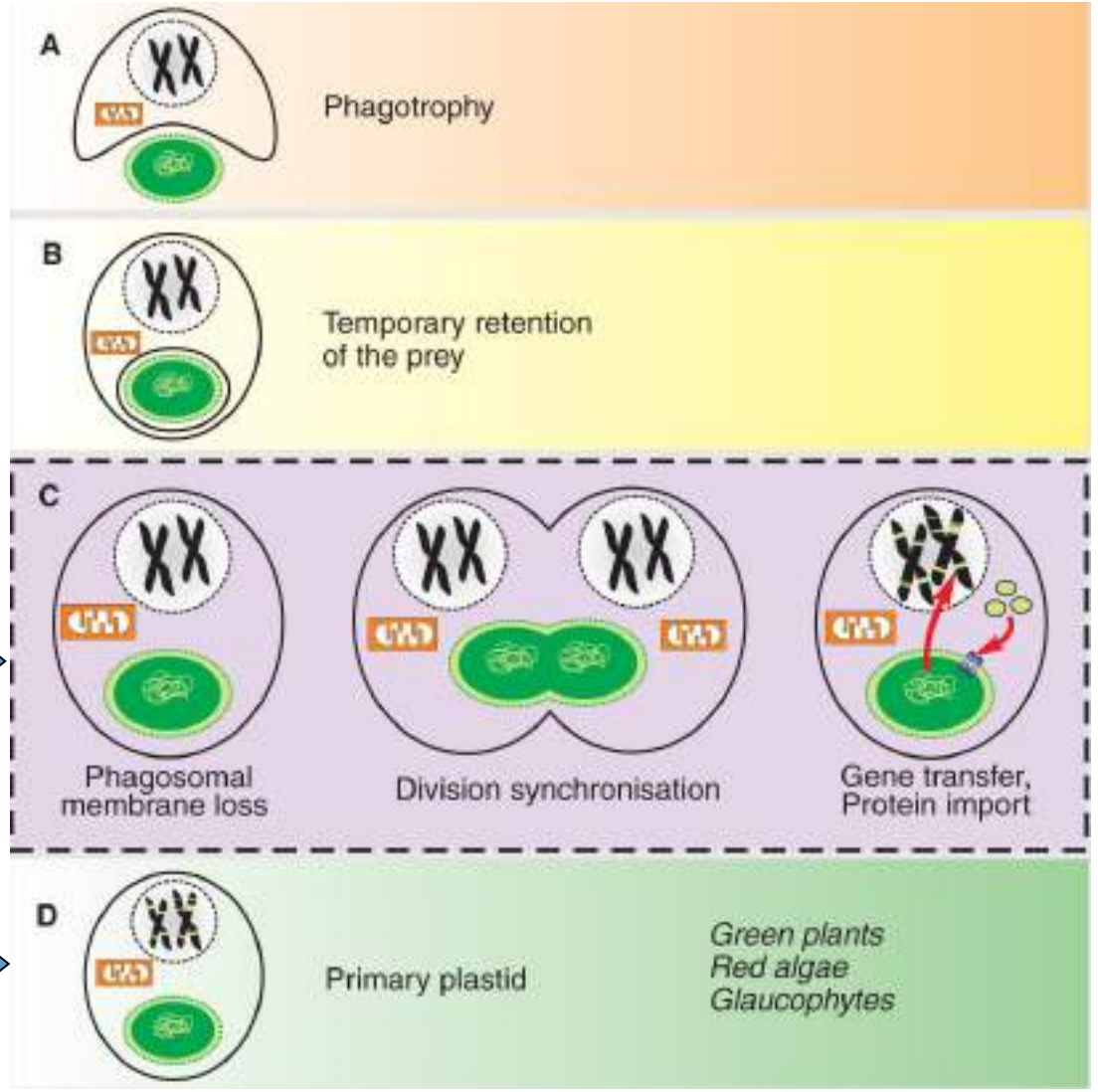


(a) Phases of phagocytosis

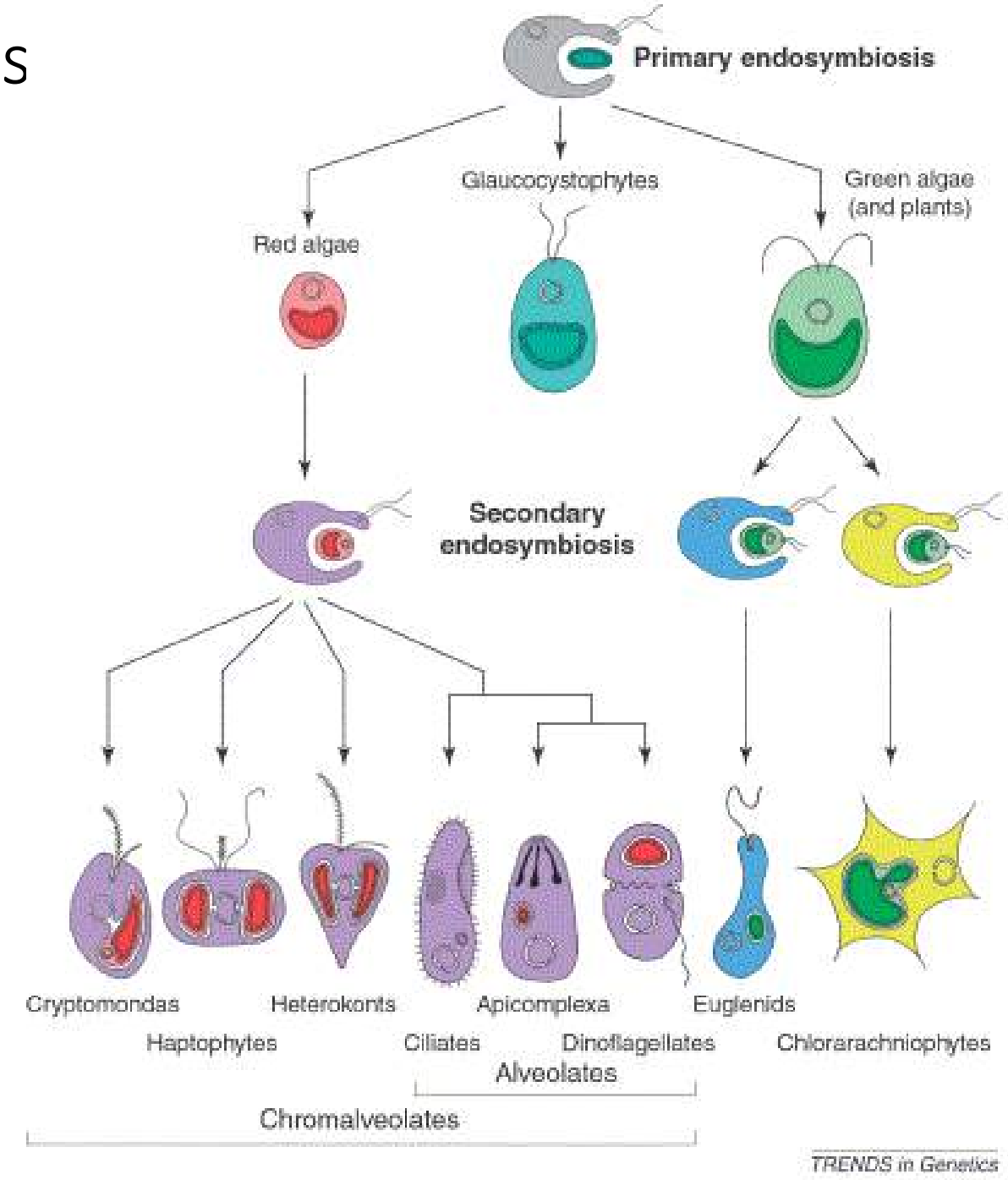
Endosymbioses versus symbiogenesis



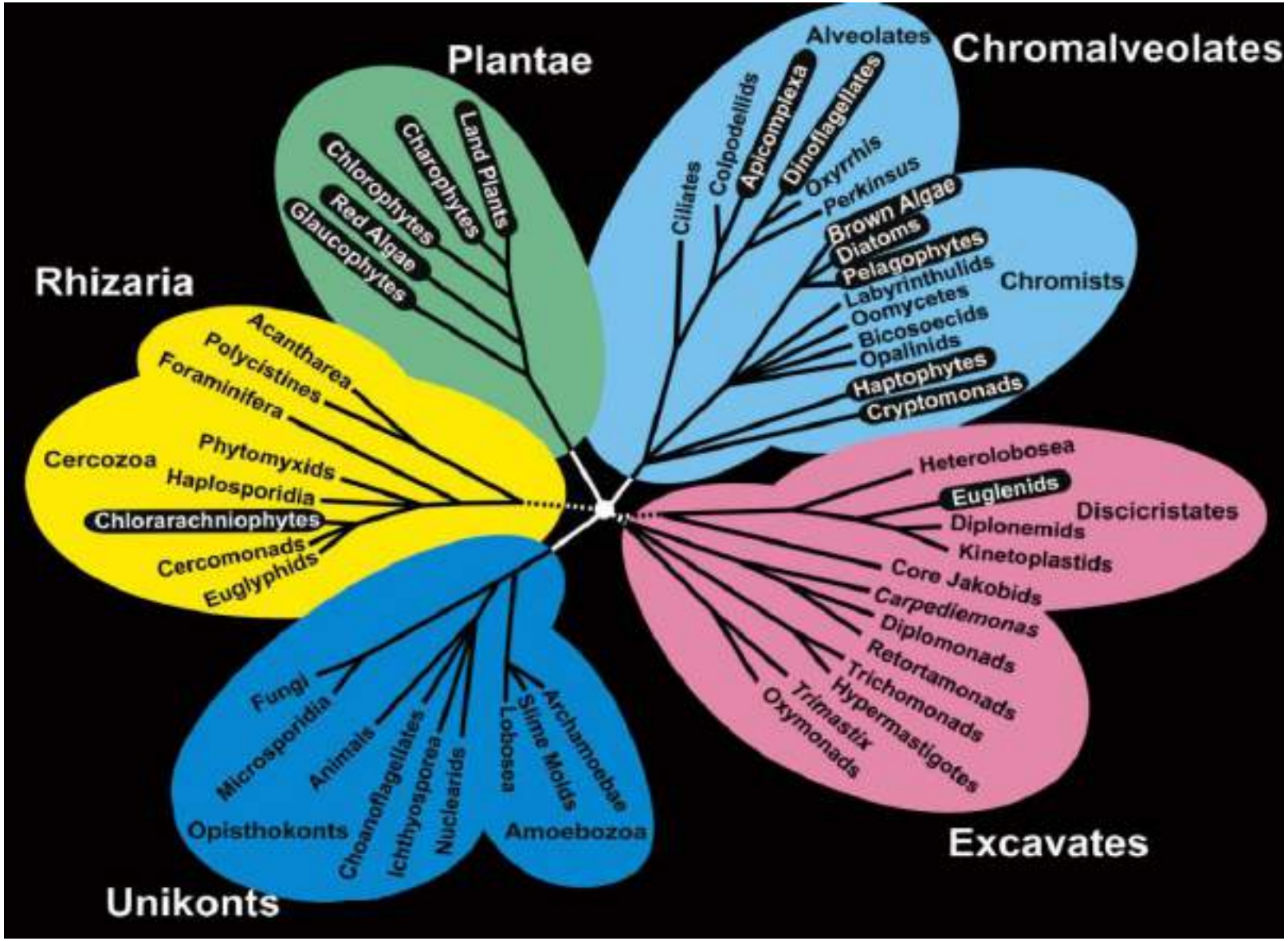
Symbiogenesis:
- the fusion of 2 organisms resulting in one new organism
- rare phenomenon (6-7 times independently)



Endosymbioses

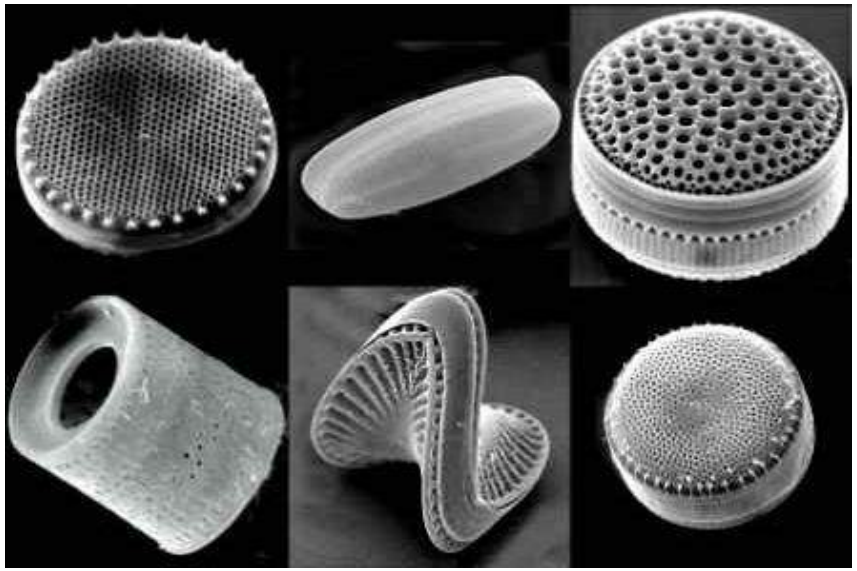


Eukaryotes and the spread of photosynthesis

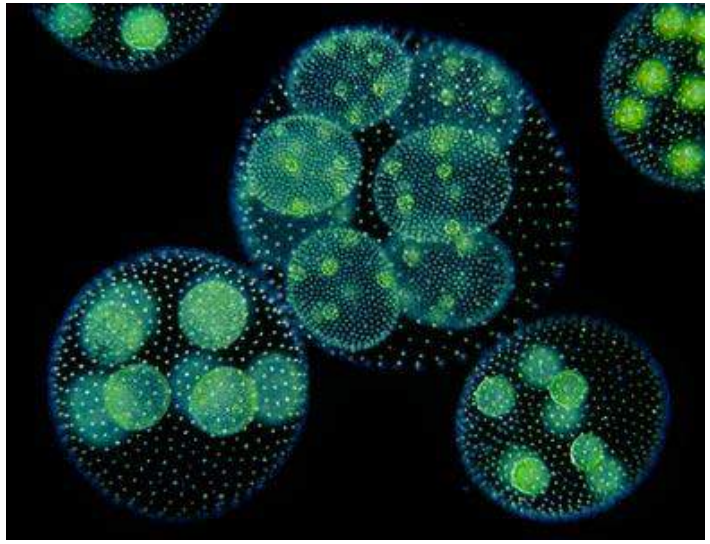


small

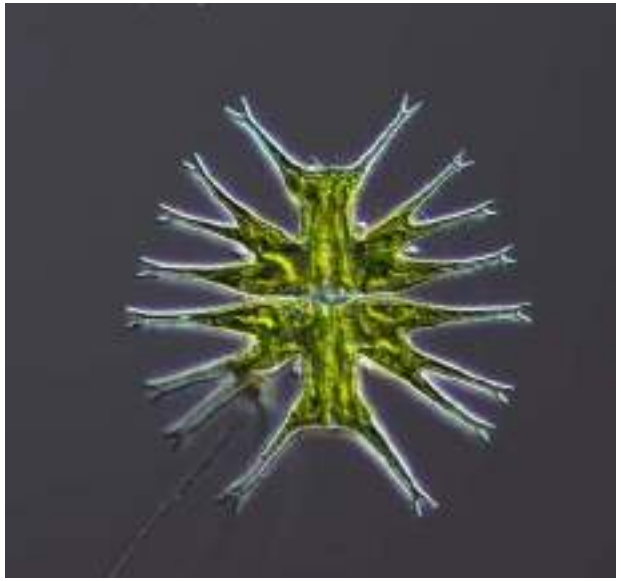
In all shapes and colors



diatoms



Volvox

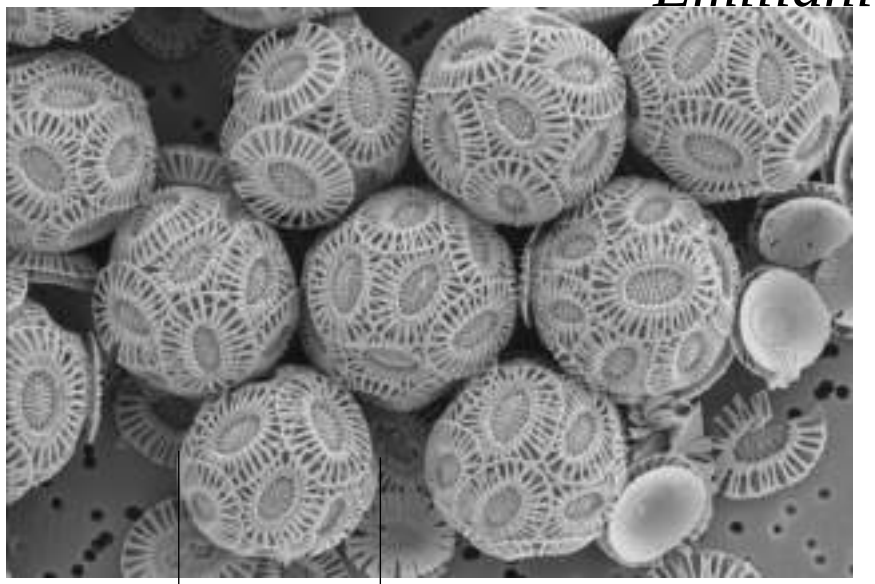


desmids

small

In all shapes and colors

Emiliania



60 m

4 µm

1000 µm = 1 mm

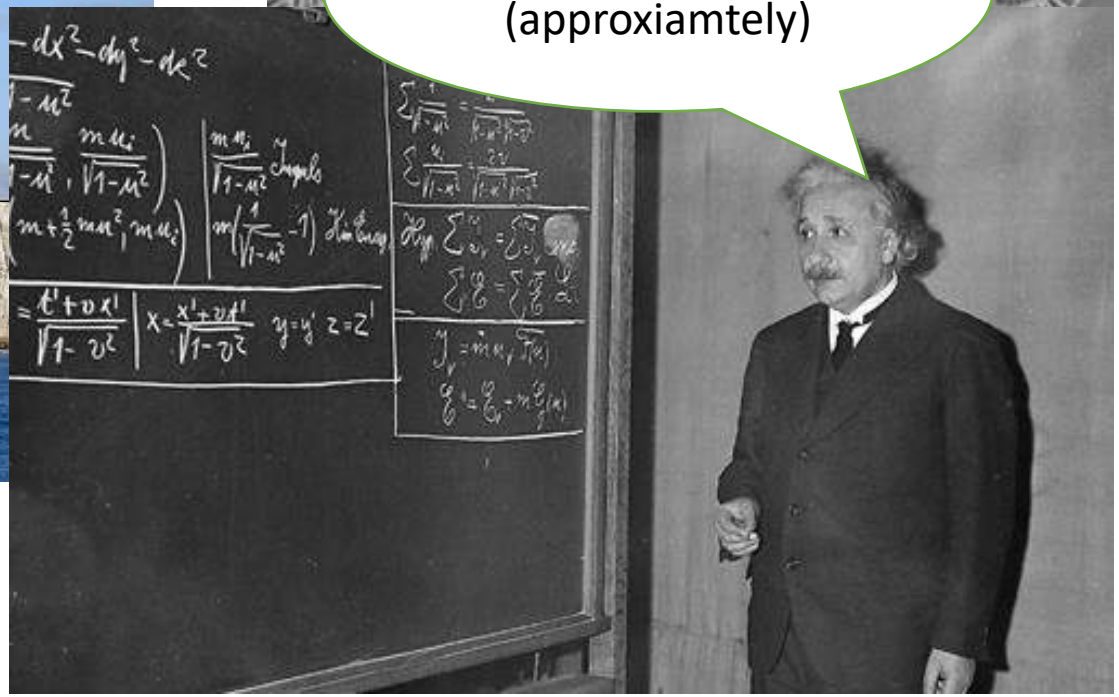
The white cliffs of Dover

small

In all shapes and colors

Emiliania

15.000.000.000
(approxiamtely)



kliffen in Dover

In all shapes and colors

brown

green

In all shapes and colors

In all shapes and colors

kelp

In all shapes and colors

In all shapes and colors

red

How to collect and study seaweeds

Fieldwork - collecting

GPS
Collecting bag
Plastic bags
Bucket

Fieldwork – sorting and preserving

Trays
Bristol paper
Cork sheet

Fieldwork – herbarium specimen

Plant press
Bristol paper
Newspaper
Fleece / nappy liner / cloth
Cardboard
Straps

External links:
1, 2

Fieldwork – herbarium specimens

Herbarium GENT

Number: HEC11206

Date: 11 – 1 – 1996
Collector(s): Coppejans E., De Clerck O.

Locality: Mafia: Chole Bay: Juani Island
Country: Tanzania
Ocean: Indian Ocean
Locality note: Indian Ocean, Tanzania

Ecology: horizontal rock surfaces, mainly well developed (and locally dominant in the lower intertidal area); exposed at low tide

Morphology: thalli gregarious, forming dense, stiff cushions; each specimen with a recurved main axis covered by short branchlets in all directions, but mainly upwardly; ± supple but extremely tough and very well attached to the substrate; from dark purplish to orangy
Note:

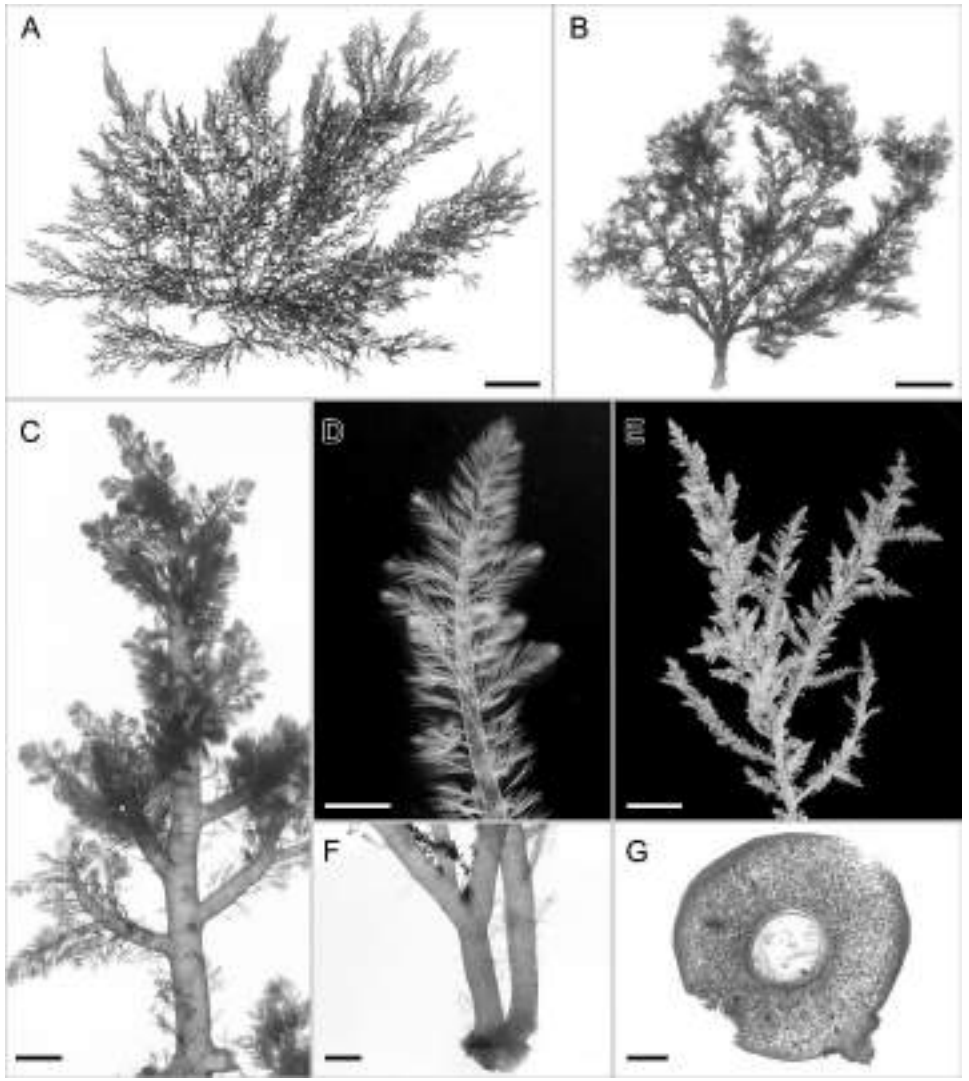
Depth (m):
☐ silica ☐ Sheet ☐ Formalin ☐ Ethanol

Field ID: *Gelidiella acerosa*

Fieldwork – formalin preserved specimens

5% formalin in seawater
Gloves

Formaldehyde is toxic !!!

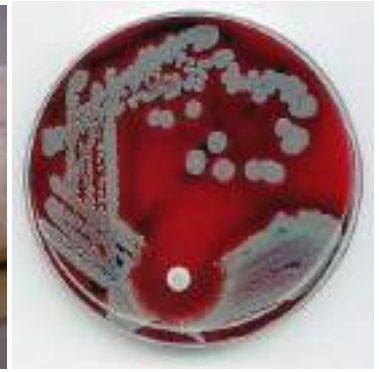


Fieldwork – DNA preservation

Fieldwork – DNA

- DNA is a fairly stable molecule
  - living material (cultures, collections)



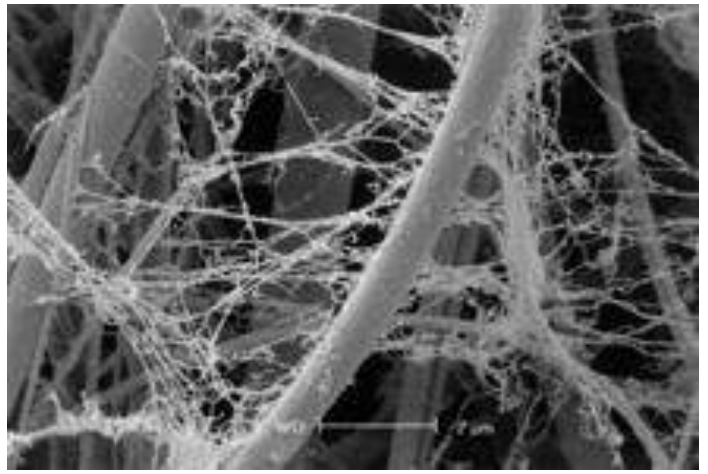
  - preserved material
    - EtOH, liquid N2 (-196°C), silica gel, storage cards

- DNA is a fairly stable molecule
  - preserved material
    - flash freezing in Liquid N_2 (-196°C) => subsequent storage in -80°C
    - advantage: perfect storage
    - disadvantage: containers are heavy, liquid nitrogen is often not available, and evaporates, restriction on airplanes,

- DNA is a fairly stable molecule
  - preserved material
    - silica gel, storage cards , EtOH

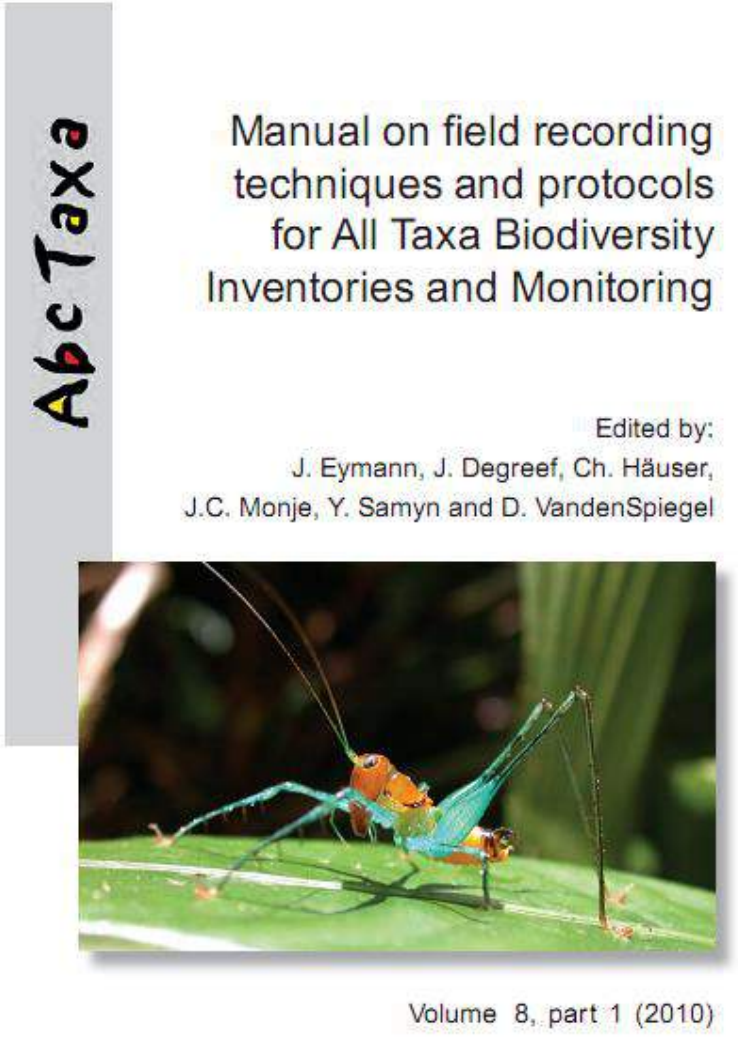
Fig. 50. Silicagel dried specimens. A. Putting a specimen in a labeled Eppendorf; B. Closing the Eppendorf; C. Indicating that the Eppendorf has been used.

- DNA is a fairly stable molecule
  - preserved material
    - storage cards (e.g. *Whatman FTA devices format*)



Intermezzo : collecting & tissue storage

- www.abctaxa.be



Chapter 11 - Sampling the Marine Realm
J. Templado, G. Paulay, A. Gittenberger and Ch. Meyer

Fig. 7. Tissue subsampling for molecular work. A. Sorted micromollusks relaxing prior to tissue sampling; B. Tissue subsampling straight into digestion buffer for DNA extraction

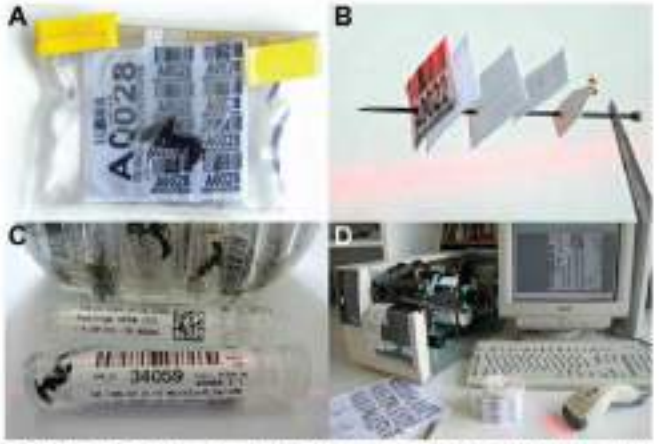
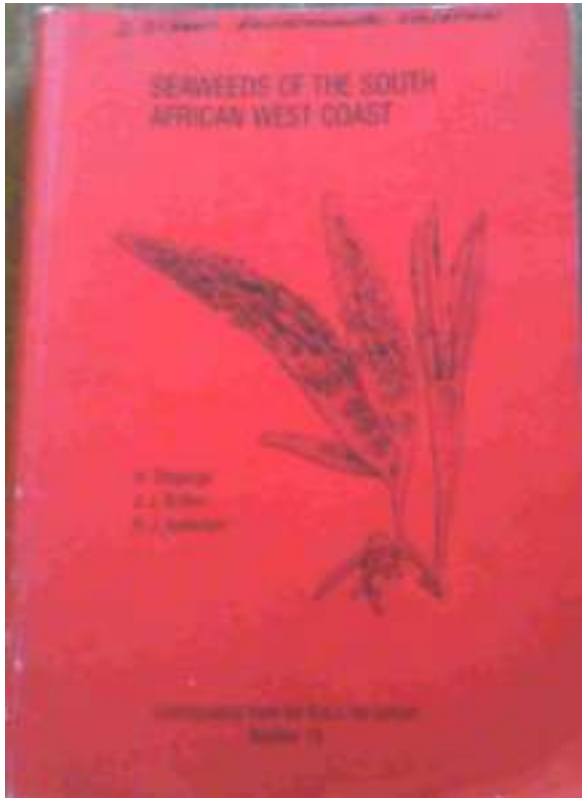
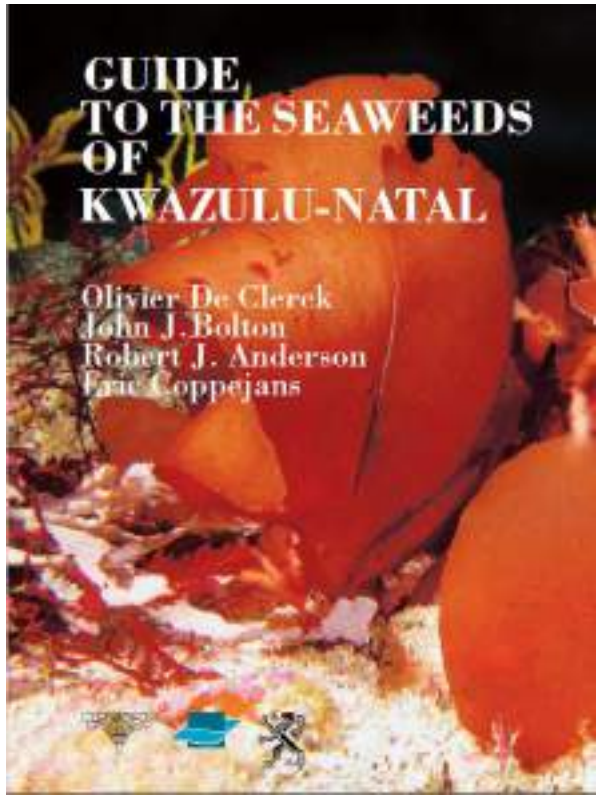


Fig. 5. Labeling of specimens with optical barcodes facilitates specimen management. A. Sampling bag (whirlpak) containing a series of identical labels. When sorting the sample it is then easy to add a label to each subsample stored in dry (B) or wet (C) condition. Two

Identification – the hard bit

Regional floras
Fieldguides
Scientific papers





Algal diversity in Kwazulu-Natal

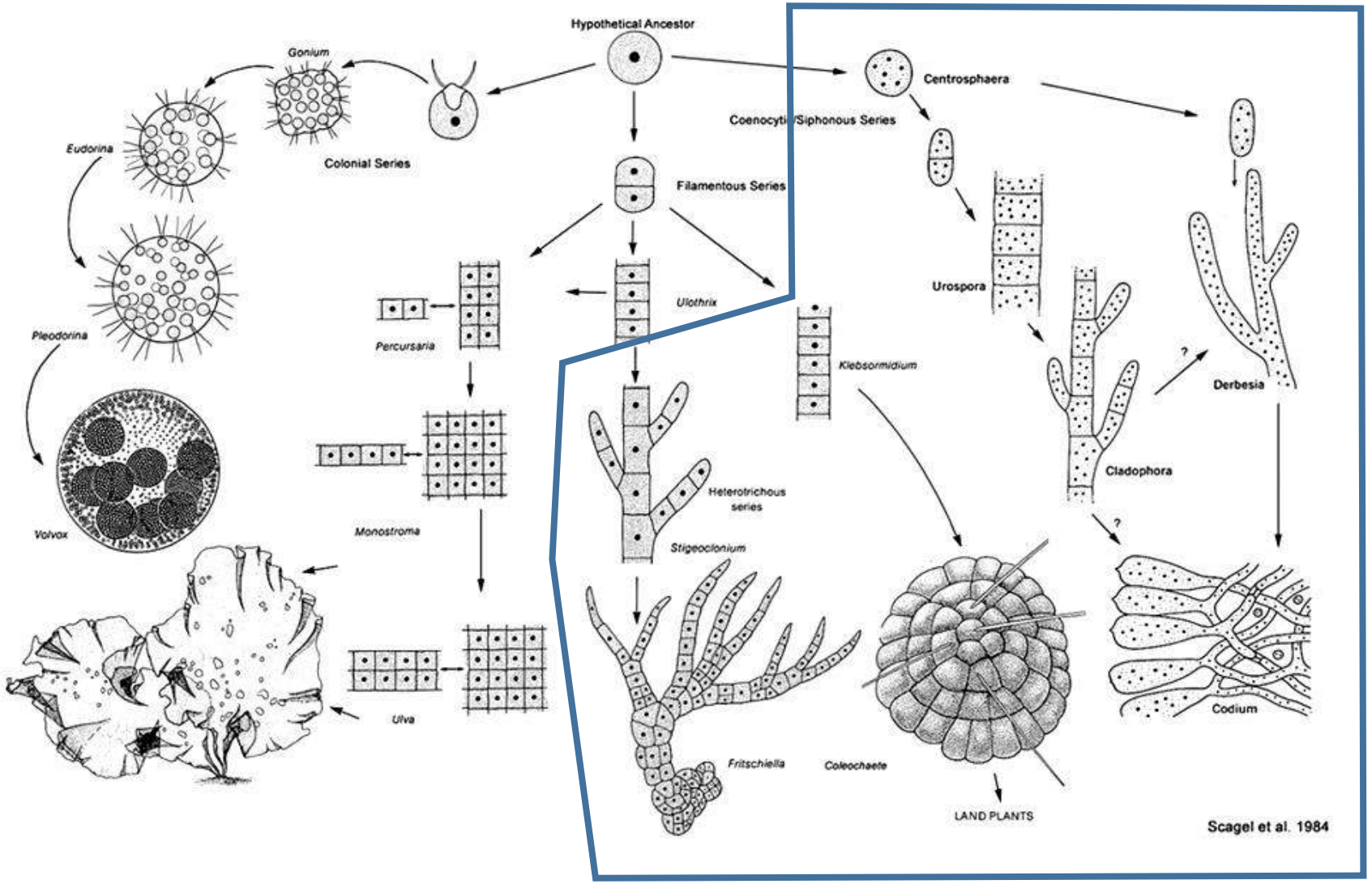
- Green algae - Chlorophyta








- Green algae – gigantic morphological diversity

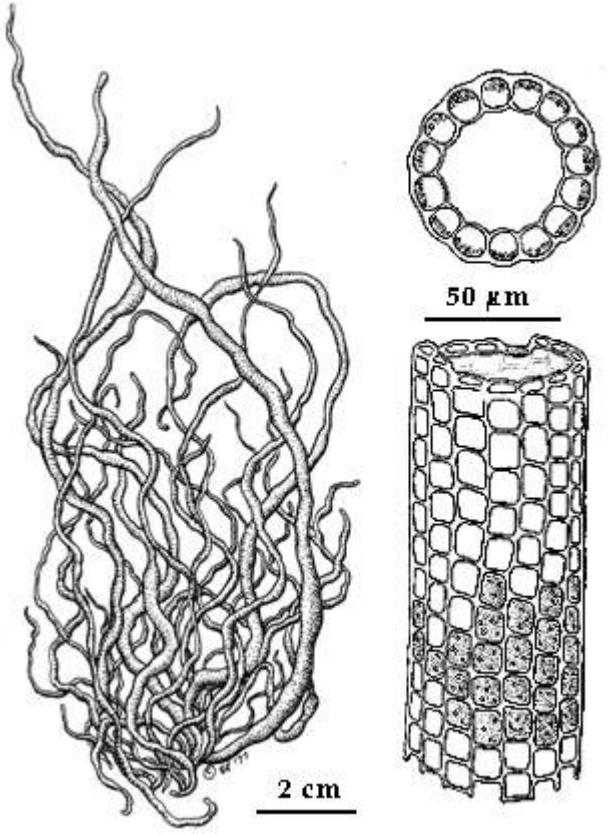


Leafy (foliose) thalli
Example : *Ulva*

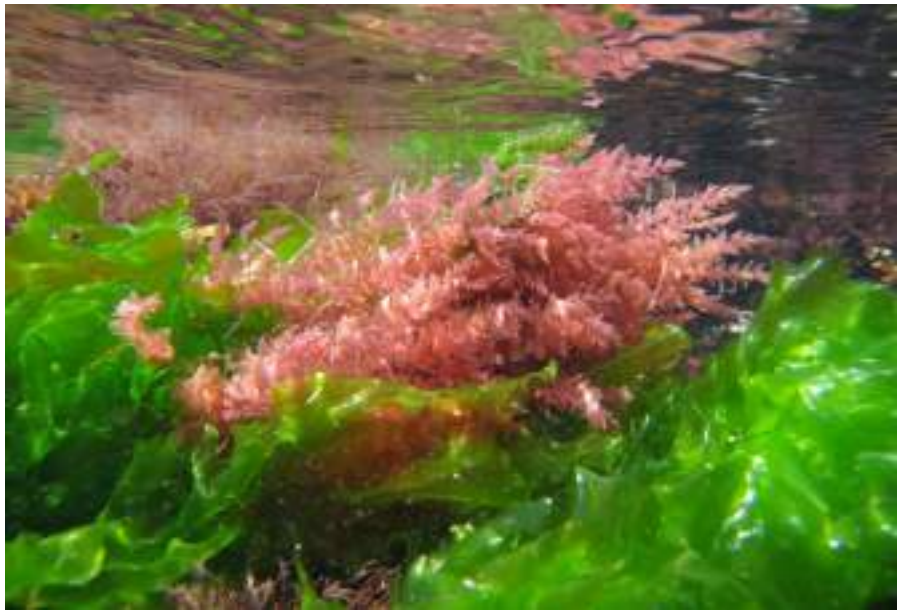
- A variety of leafy green seaweeds – the best known is *Ulva*.
- Juveniles begin life as a SMALL TUBE ONE-CELL THICK.
- In the typical ‘sea lettuce’ form, the tube flattens, and the adult thallus is TWO CELLS THICK
- In other species (previously know as the genus *Enteromorpha*) the adult thallus stays as a tube, one cell thick

Ulva: the ‘sea lettuce’

[*Enteromorpha*]

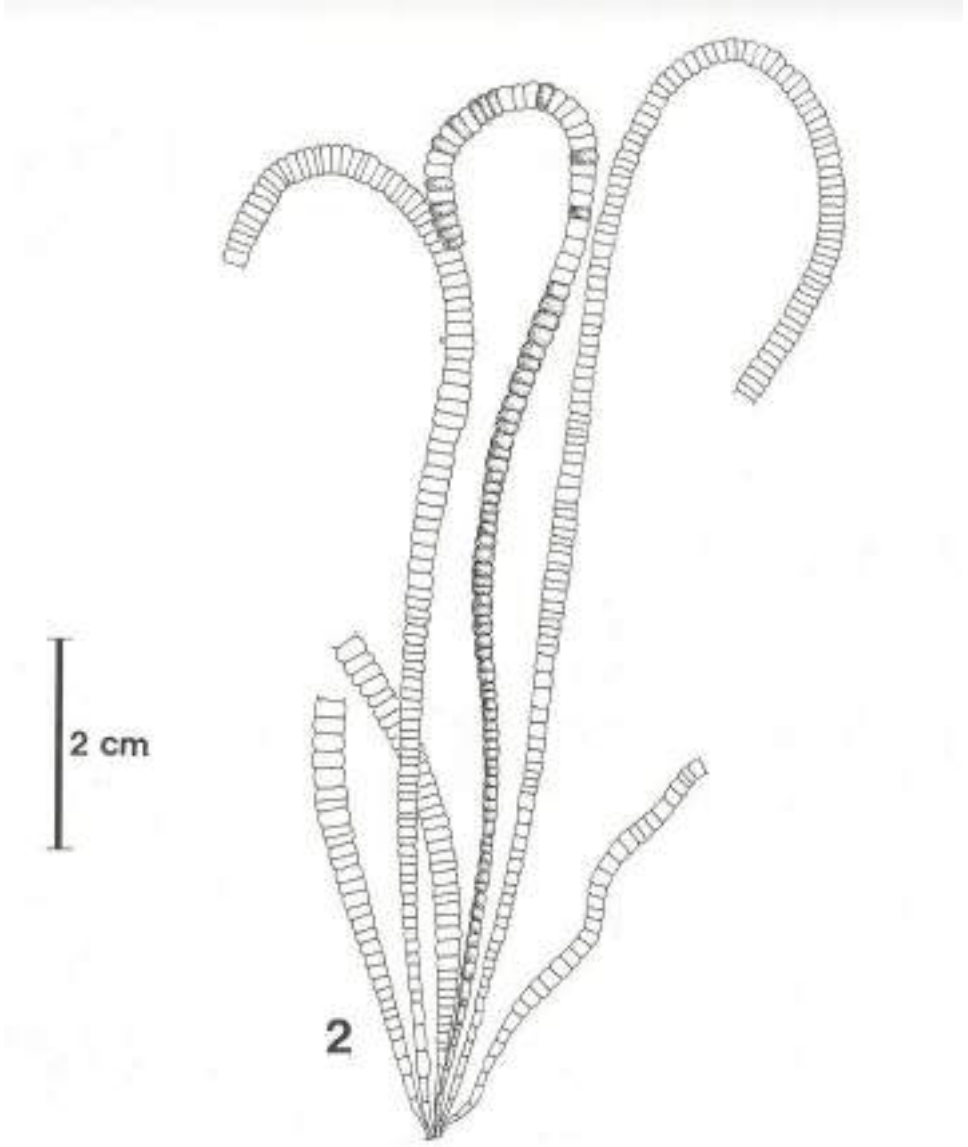


Welkom to now ...



Filamentous greens

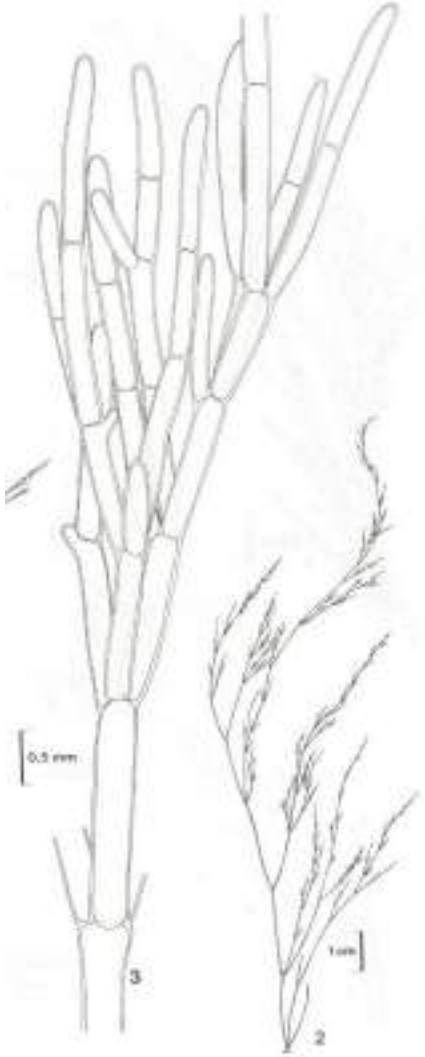
- Uniseriate (one-cell wide) unbranched *Chaetomorpha*
- Uniseriate, branched *Cladophora*



Chaetomorpha

- A number of species of seaweeds (and common in estuaries).
- Unbranched filament with DIFFUSE GROWTH. Lots of individuals often from a single fused base.
- Spores and gametes produced APICALLY (often leave a white length of empty cell wall).

- *Cladophora*
- Very common seaweeds (more than a dozen species in SA)
- Also in freshwater – *C. glomerata* – great pest species, block canals and lakes.



SIPHONOUS green algae

- Most complex morphologies in the green algae are the siphonous forms in the: CAULERPALES (Ulvophyceae)
- No cross walls – therefore no cells (COENOCYTIC). Thousands of nuclei and chloroplasts in the siphon. Biggest are a few metres long.
- Only form cross walls when separating off reproductive cells.
- 3 examples

Examples of siphonous construction

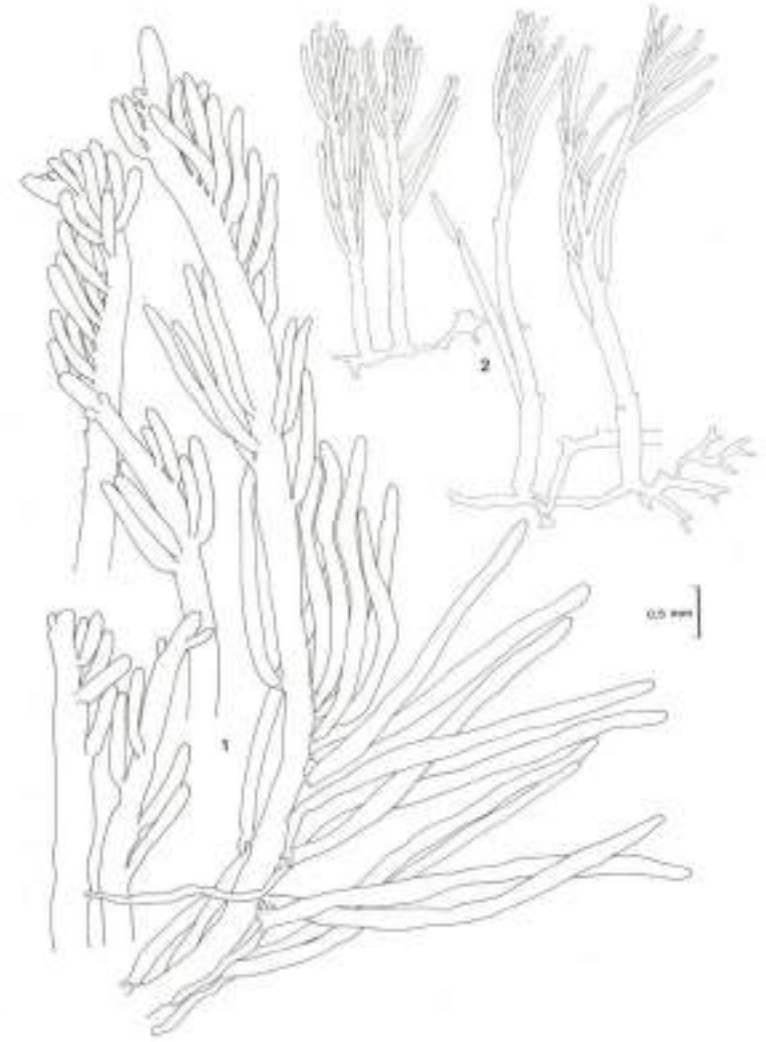
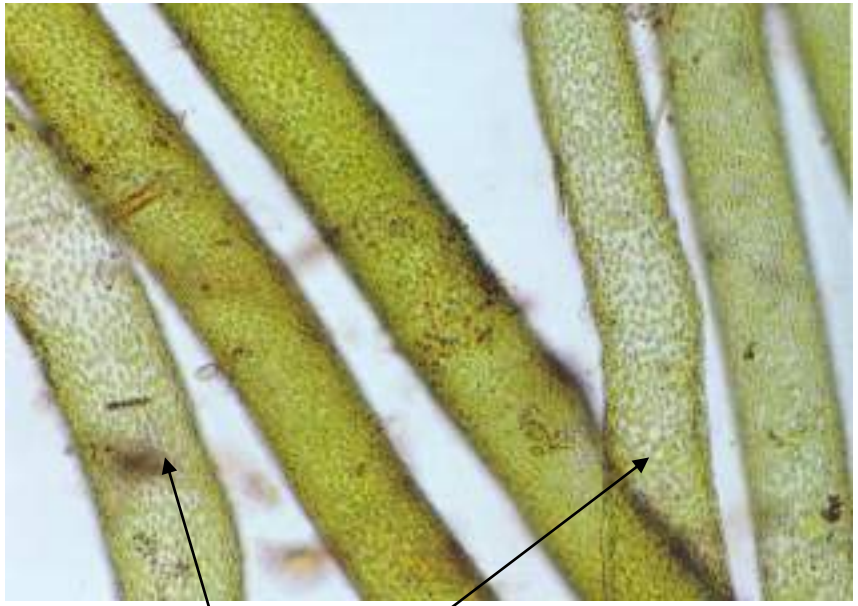


Plate 29. 1. *Bryopsis africana*, apices of erect filaments; 2, *B. ecklioniae*, microscopic habit.



chloroplasts

Bryopsis

- Seaweeds
- Name means ‘moss-like’
- Single branched siphon – often PINNATE branching (looks like a feather).
- Often in a mossy tuft packed with sand.

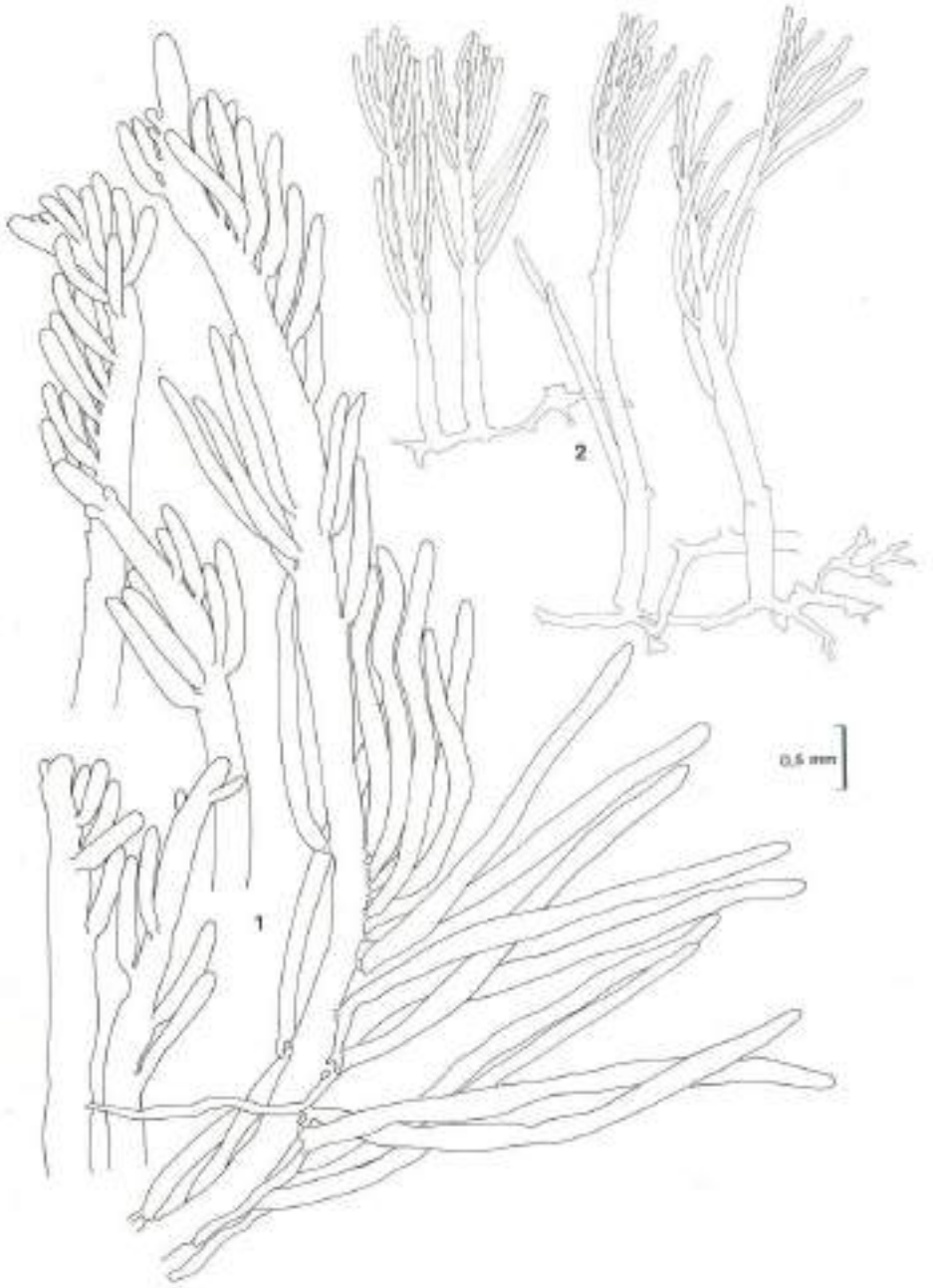


Plate 29. 1, *Bryopsis africana*, apices of erect filaments; 2, *B. ecklioniae*, microscopic habit.

Siphonous greens: Example 2

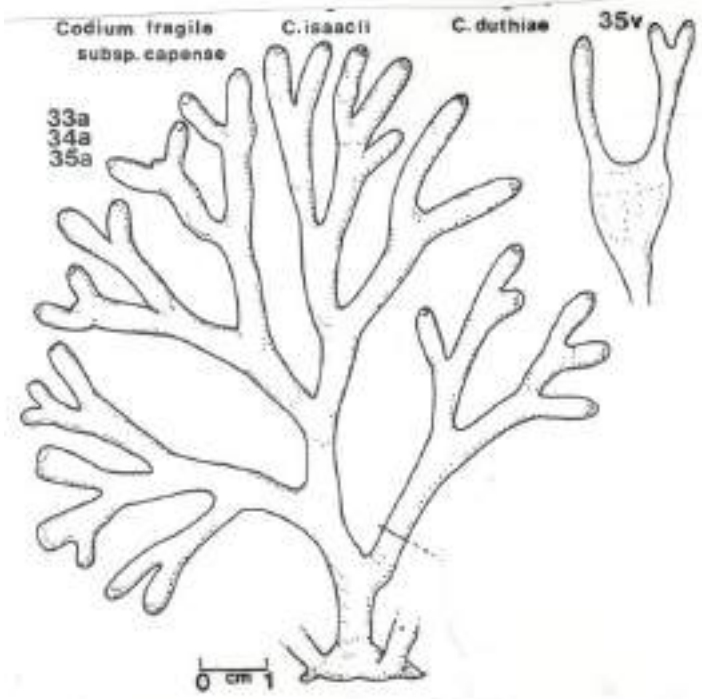
Codium

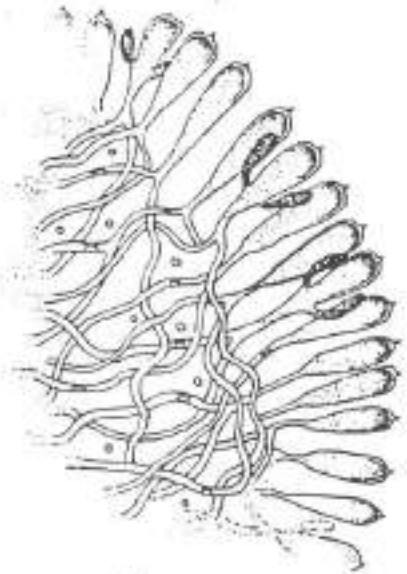
- Very common dark green seaweeds. All are very SPONGY to the touch. Best known forms are made up of spongy cylindrical branches, but can be flat blades, spherical balls etc. All have same structure.
- Complex structure.

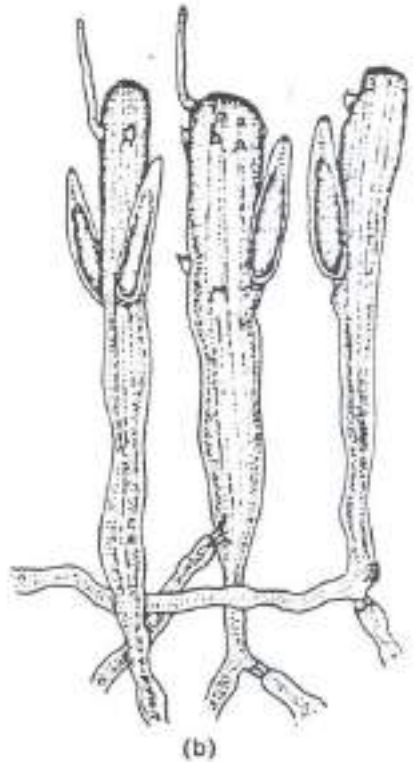
Species of *Codium*: different morphologies, same anatomy

Structure of all *Codium* species (no cells!)

- Consists of closely-packed SIPHONOUS FILAMENTS.
- The thalli are MULTIAXIAL (lots of branched filamentous axes make up a single branch of the seaweed).
- Fine filaments make up the central MEDULLA.
- These filaments have branches on the outside, with large swelling, which make up the outside CORTEX.
  These swellings are called UTRICLES.







Codium. (*a*) *C. fragile* (Suring.) Har., diagrammatic transverse section of a thallus branch. (*b*) *C. prostratum* Levr., utricles bearing gametangia and hairs. (*a*) × 20; (*b*) × 53. [(*a*) after Smith; (*b*) after Silva.]

Fig. 39 Codium papenfussii

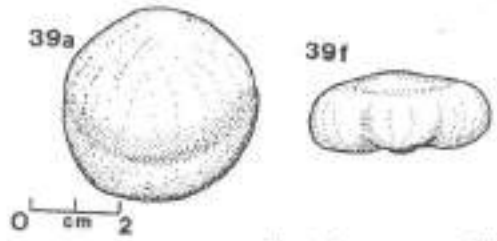


Fig. 40
Codium megalophysum

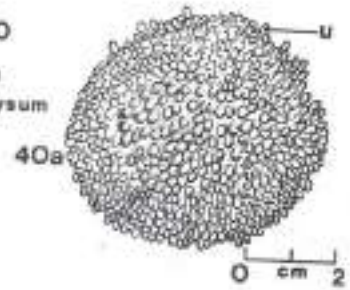
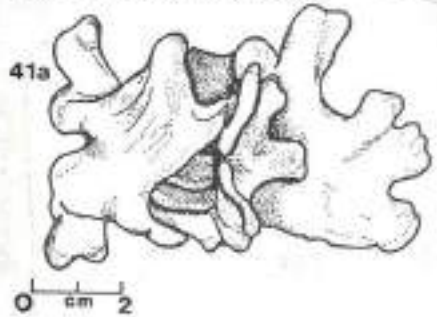


Fig. 41 Codium stephensiae



Siphonous chlorophytes 3: *Caulerpa*

- The most complex morphology among the green algae.
- Tube-like STOLONS, anchored by bundles of RHIZOIDS. Tend to grow attached to rocks buried in sand.
- Produce upright photosynthetic ‘SHOOTS’, with very different shapes in different species.
- A simple siphon – no cross walls.
- Strengthening provided by ingrowths of the outside cell walls – little bushes of TRABECULAE.

Caulerpa species

Halimeda

- One of the most important seaweeds on coral reefs – we have one common species on the south coast *H. cuneata*. Lots of species in the tropics – lagoons and deeper more sheltered water.
- How does *Halimeda* survive the very high grazing pressures in these sheltered tropical habitats?

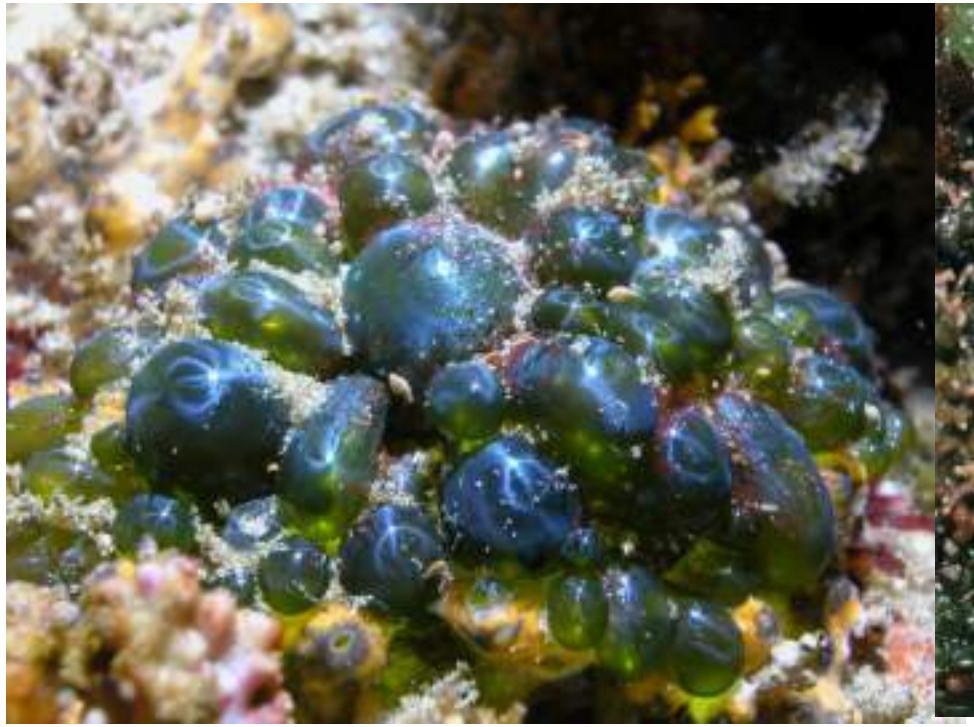
Halimeda defences

- Calcified segments. Not so palatable (but – lots of calcified seaweeds still eaten).
- Produces a terpenoid called HALIMEDATRIAL.

Halimeda defences

- New growth (new segment) has no pigment or $CaCO_3$. PRODUCED AT NIGHT – high concentrations of toxin. Calcification begins. Remains white throughout next day.
- At second dawn new surface turns green – migration of chloroplasts
- 48h later – new segment is calcified – toxin levels decrease.

There are lots of other siphonous greens on tropical reefs



Valonia

Dictyosphaeria

Algal diversity in Kwazulu-Natal

- Brown algae - Phaeophyta

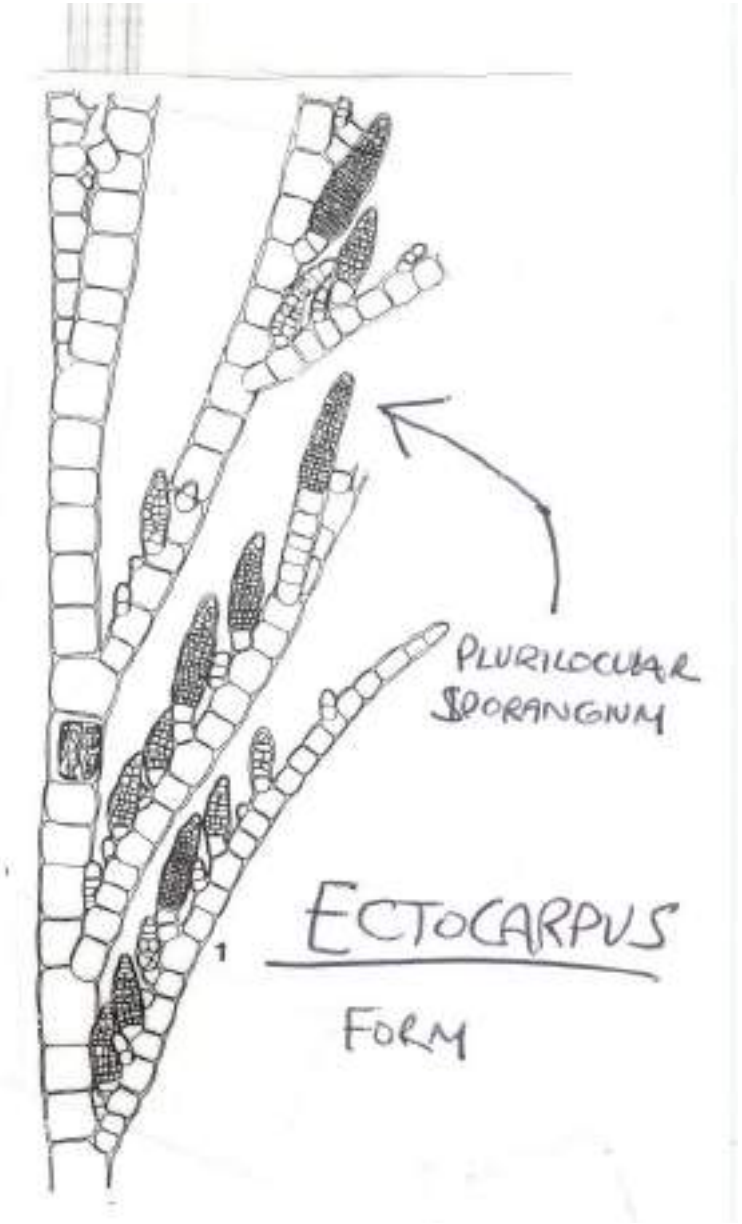
Class: PHAEOPHYCEAE (Heterokontophyta)

The brown algae.

- Mostly all seaweeds (265 genera) with just a few in freshwater (5 genera).
- Include the largest marine plants – the giant kelps up to 70m long.
- All species are MULTICELLULAR.
- Most look a sort of yellow-brown (fucoxanthin)

Ectocarpus

- **Filamentous**
- Among the simplest brown algae.
- Fine, uniseriate branched filaments, form a ‘fur’ on rocks or other seaweeds



Lots of other genera in Ectocarpales

- Not usually ecologically important (except sometimes *Ectocarpus* in sheltered lagoons and estuaries)
- Identified by cell structure and shape of reproductive structures
- Many different genera

Brown crust: e.g. *Ralfsia*

This, fleshy crusts, often circular in outline, closely adhering to rocks in intertidal region. Thallus structure: closely coherent filaments – grow horizontally at first, then upwards to form layer of vertical rows.

Ralfsia: Pseudoparenchymatous crust

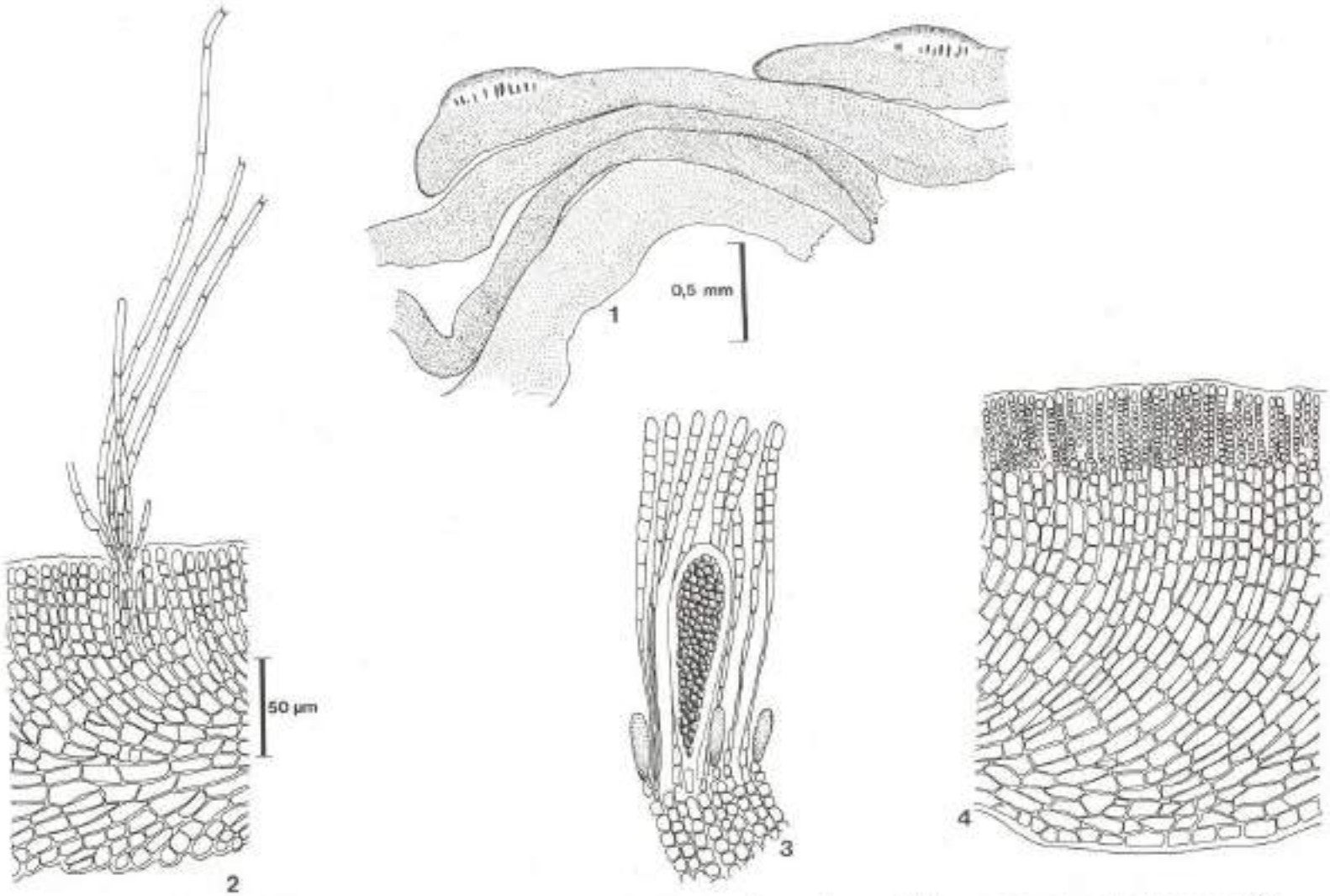


Plate 37. *Ralfsia verrucosa*; **1**, Radial vertical section of thallus with several superimposed lobes and raised unilocular sporangial sori; **2**, Radial section showing median primary cell rows and hair bundle; **3**, Unilocular sporangia and associated paraphyses; **4**, Radial section of thallus showing terminal plurilocular sporangia.

- **Order Dictyotales, e.g. *Dictyota***
- Order is most abundant in warmer waters. Common in Tropics.
- Thallus a branched, flat sheet of cells, 3 or more cells thick.

Simple parenchyma: *Dictyota*

- APICAL GROWTH from a prominent apical cell.
- Apical cell divides into two producing -TRUE DICHOTOMOUS BRANCHING.
- Thallus is 3-CELLS THICK.
- Upper and lower small cells: Photosynthetic CORTEX
- Middle layer: Large-celled MEDULLA (no chloroplasts)

Dictyota:

Growth from division of apical cells

Dichotomous branching (equally into two)

Three cells thick

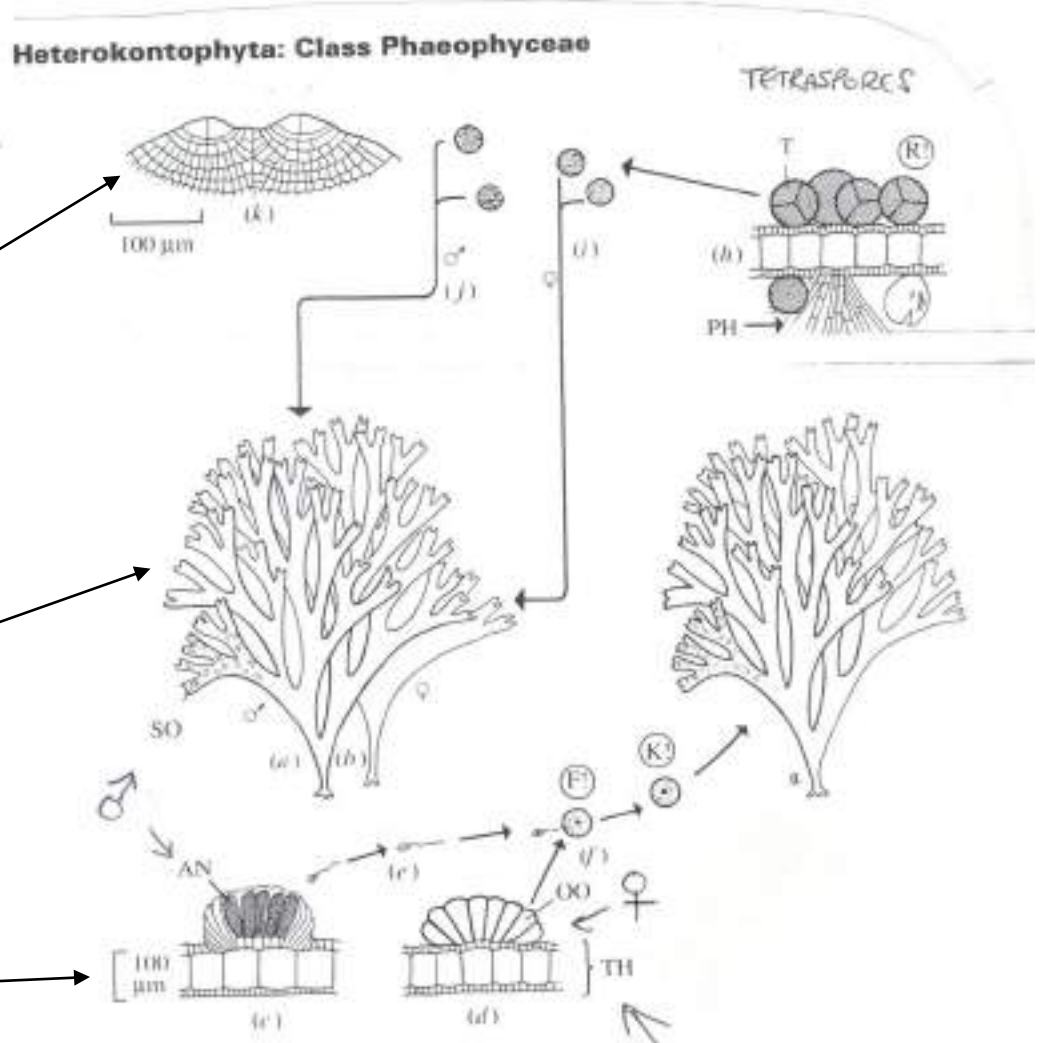


Figure 12.12. *Dictyota dichotoma:* life cycle. (*a, b*) Male and female gametophytes (haploid). (*c*) Transverse section through a gametophyte with a male sorus. (*d*) Transverse section through a gametophyte with a female sorus. (*e, f*) Spermatozoid and egg cell. (*g*) Sporophyte (diploid). (*h*) Transverse section through a sporophyte with tetrasporangia. (*i, j*) Tetraspores. (*k*) Apical cells. AN = antheridium; F! = fertilization; K! = karyogamy; OO = oogonium; PH = phaeophycean hairs; R! = meiosis; SO = sori; T = tetrasporangium; TH = thallus.

Dictyota species

Some species refract light when under water: IRIDESCENCE

Dictyopteris: Looks similar but has midrib (middle vein)

Other genera have a row of apical cells at the tip (*Padina, Zonaria, Lobophora*)

Lobophora variegata.

A. Erect plant from shallow lagoon;
B. Prostrate plant from deepwater boulders (20 m depth);
C. Sori of tetrasporangia (reproductive structures)
D. Transverse section.

Padina: Row of apical cells/ slightly calcifed

FUCOIDS (Order Fucales).

Receptacles (reproductive structures)

Sargassum

Turbinaria

And a few other genera ….

Algal diversity in Kwazulu-Natal

- Red algae - Rhodophyta

RHODOPHYTA – THE RED ALGAE

- Mostly marine group, and most species of seaweeds belong to this group (about 70% of SA flora).
- There are a few freshwater red algae also.

- Can be quite large (**to ca. 2m**), but not as large as browns.

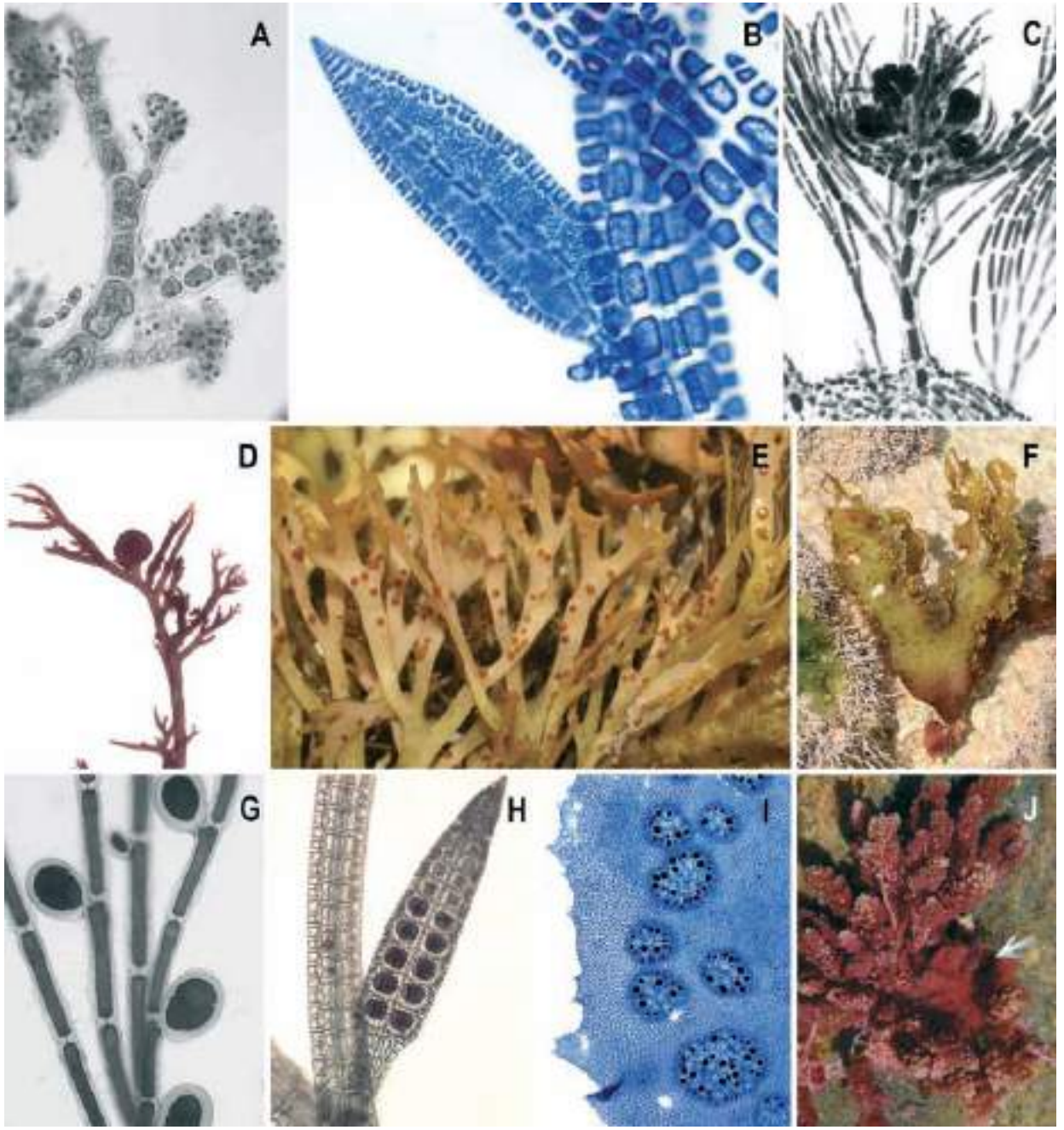
Rhodophyta: chemistry

- A number are ECONOMICALLY IMPORTANT because of the cell walls, which contain PHYCOCOLLOIDS – jellies which are used in food and many other industry.
  Two main types of jellies from red algae – AGARS AND CARRAGEENANS.
- SULPHATED POLYSACCHARIDES SOLUBLE IN WATER
- Rhodophyta store FLORIDEAN STARCH

Red algae:

Complicated life histories and reproductive structures

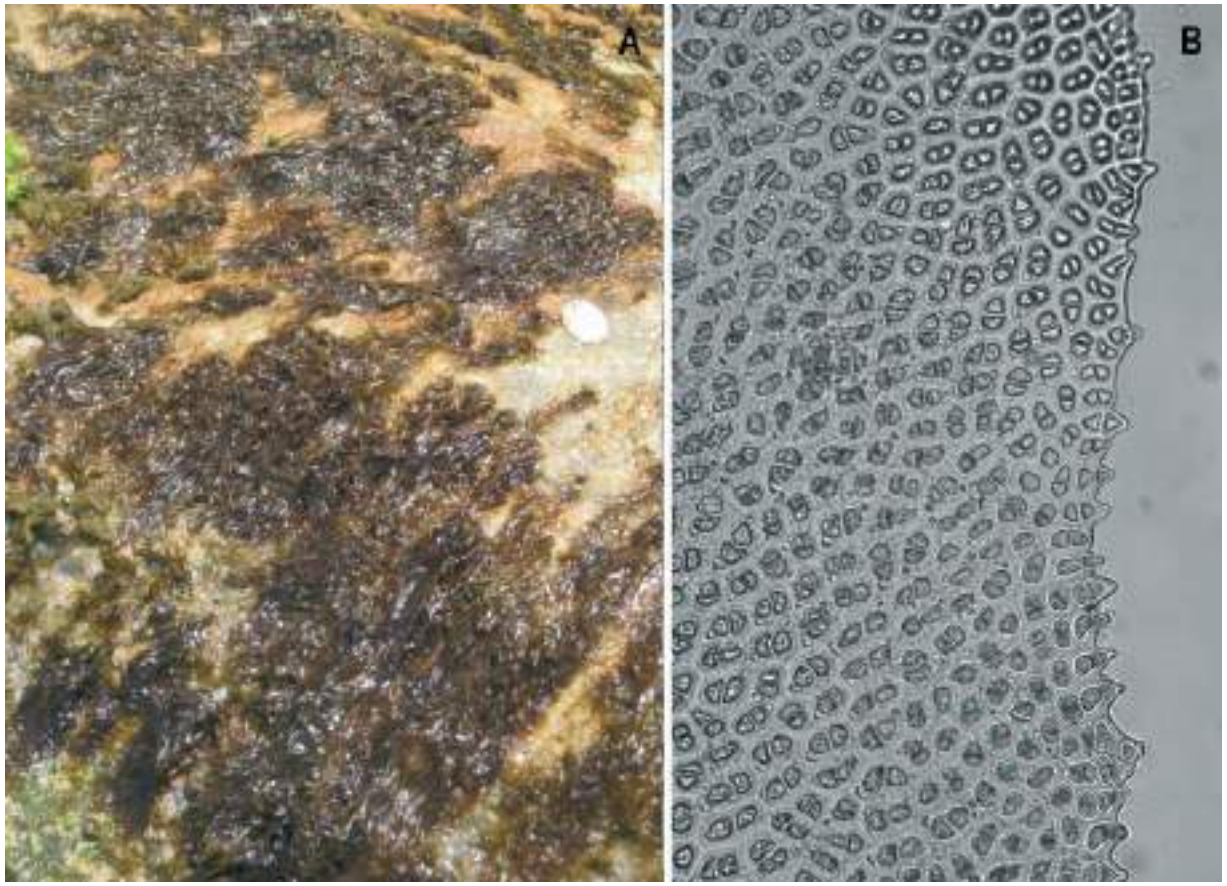
Three types of plant: MALES, FEMALES and TETRASPOROPHYTES



Reproduction structures in red algae (mainly shown by African examples).
A. Spermatangia in *Sciurothamnion stegengae*; B. A sorus of spermatangia in *Platysiphonia delicata*; C. Gonimoblasts (groups of diploid carpospores) in *Sciurothamnion stegengae*; D. A cystocarp on *Rhodomelopsis africana*; E. Cystocarps as wart-like protrusions on *Gracilaria corticata*; F. Cystocarps (mainly) on the margin of the female blade of *Sarcodia montagneana*; G. Tetraspores in *Sciurothamnion stegengae*, produced after meiosis in tetrasorangia on the diploid sporophyte; H. Tetrasporangia in a stichidium of *Platysiphonia delicata*; I. Sori of tetrasporangia in *Augophyllum marginifructum*; J. *Asparagopsis taxiformis*: the large gametophyte with cystocarps and the filamentous tetrasporophyte (*Falkenbergia hildenbrandii*) in the centre (arrow).
Reproductive structures, or even the presence of a particular life

Porphyra (not common in tropics)

- Flat, blade-like. Similar in form to *Ulva*, appears brownish/blackish.
- Very top of the seashore.
- Blade is 1 OR 2 CELLS THICK



Porphyra

- Enormous economic use in the Far East, for NORI

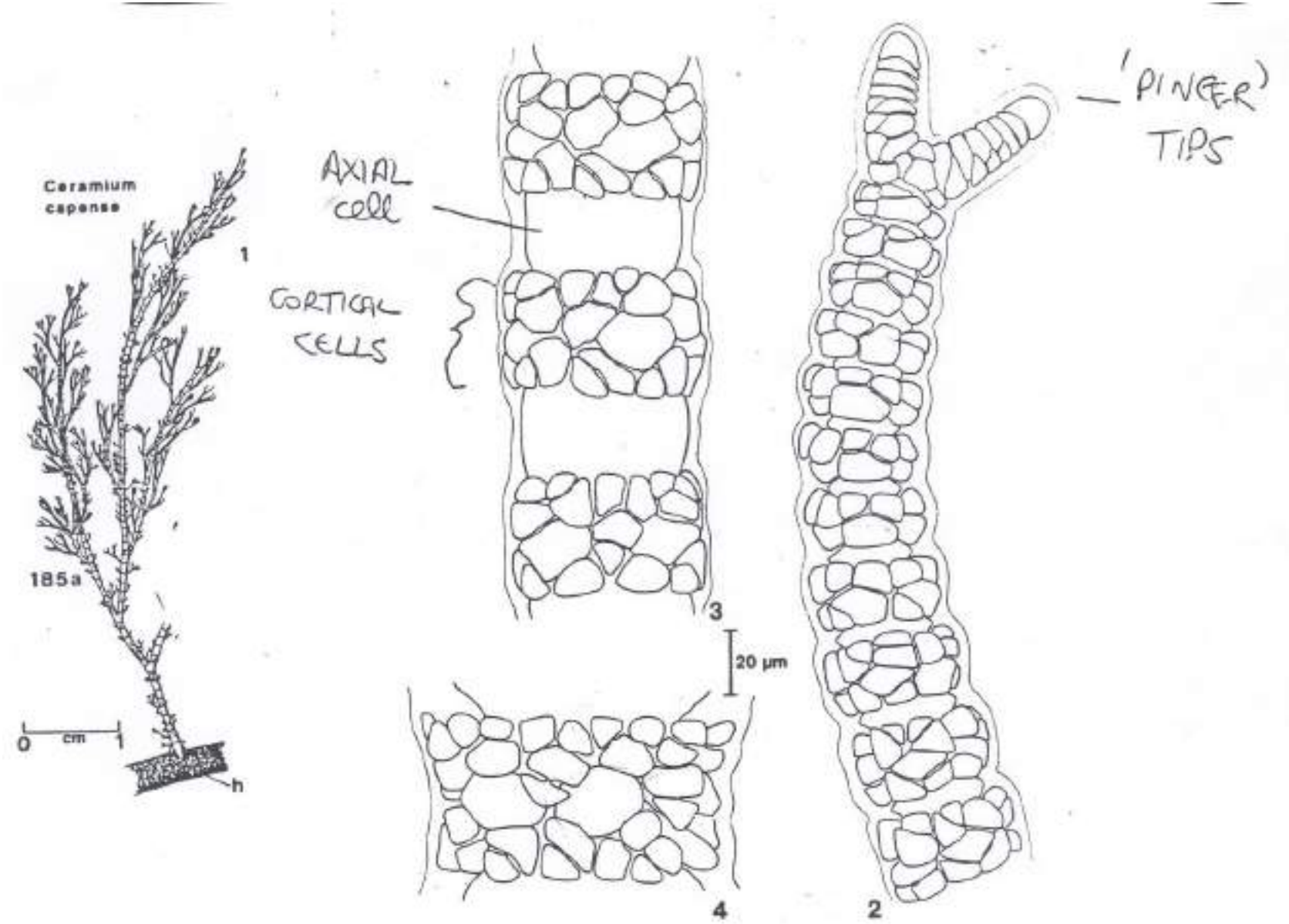
Rhodophyta

- TAXONOMY of red algae is complicated. Higher groups (orders and families) are traditionally based on the female reproductive development before fertilisation)….
- IDENTIFICATION in practice often needs to look at structure (e.g. cross-section) and form and position of reproductive structures

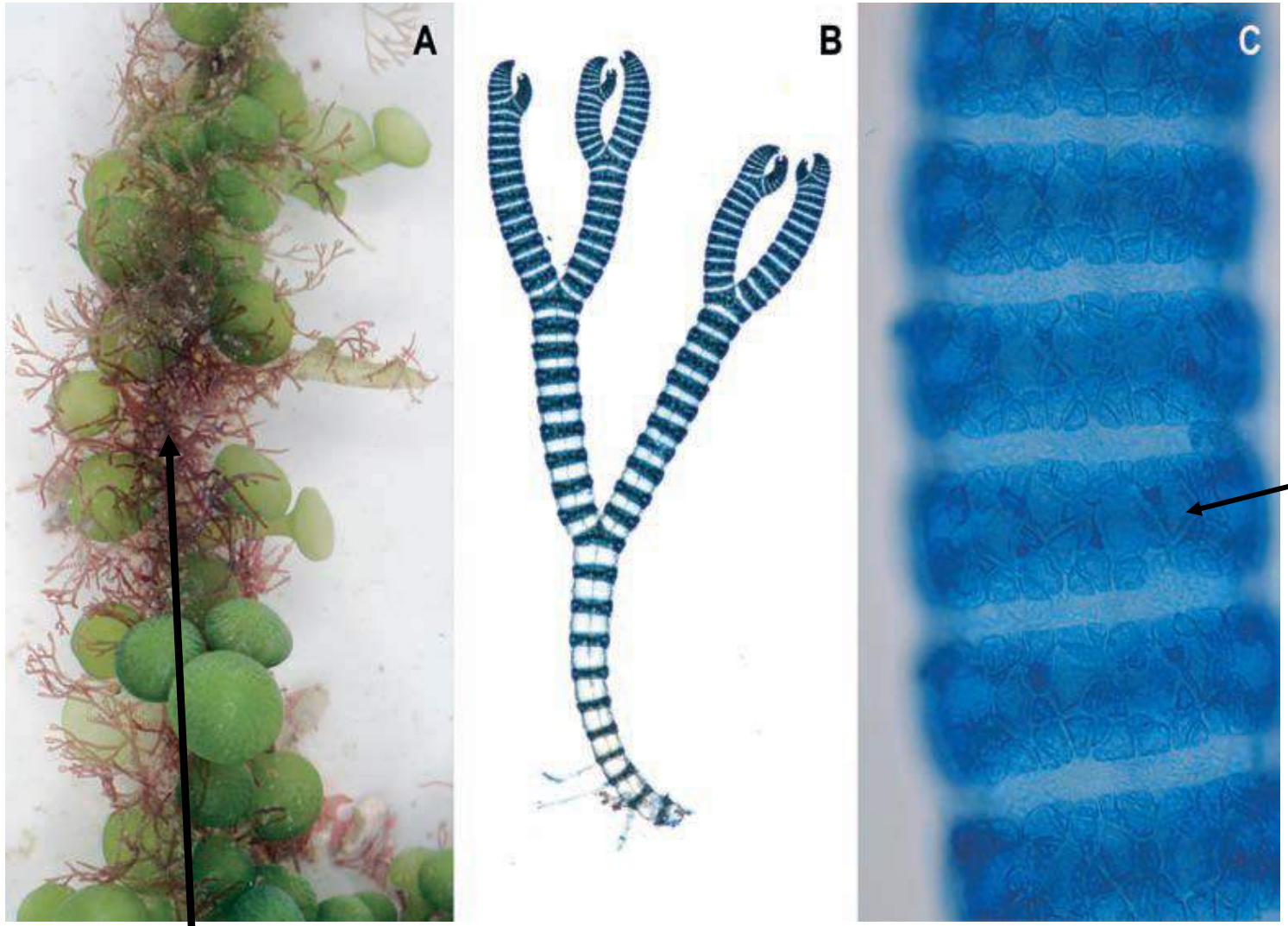
Ceramium: Ceramiaceae

- FILAMENTS
- Single row of cells in the main axis.
- Where cells meet – at the NODES – rows of small cells which partially cover the central cells, making the thallus seem BANDED. This is the formation of a CORTEX – and is known as CORTICATION.
- PINCER-LIKE TIPS (APICAL GROWTH)

Ceramium: structure



Ceramium



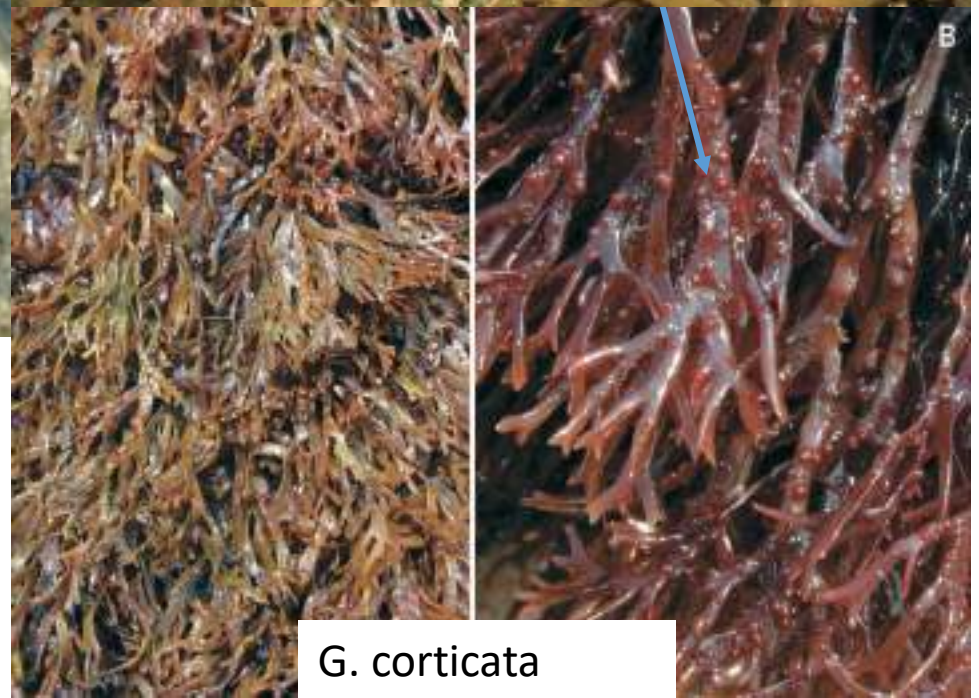
Cortex of small cells overgrowing the larger cells

Ceramium growing on a green seaweed (*Caulerpa*)

Some other important genera: *Graciliaria*. Very cartilaginous

G. canaliculata

G. salicornia



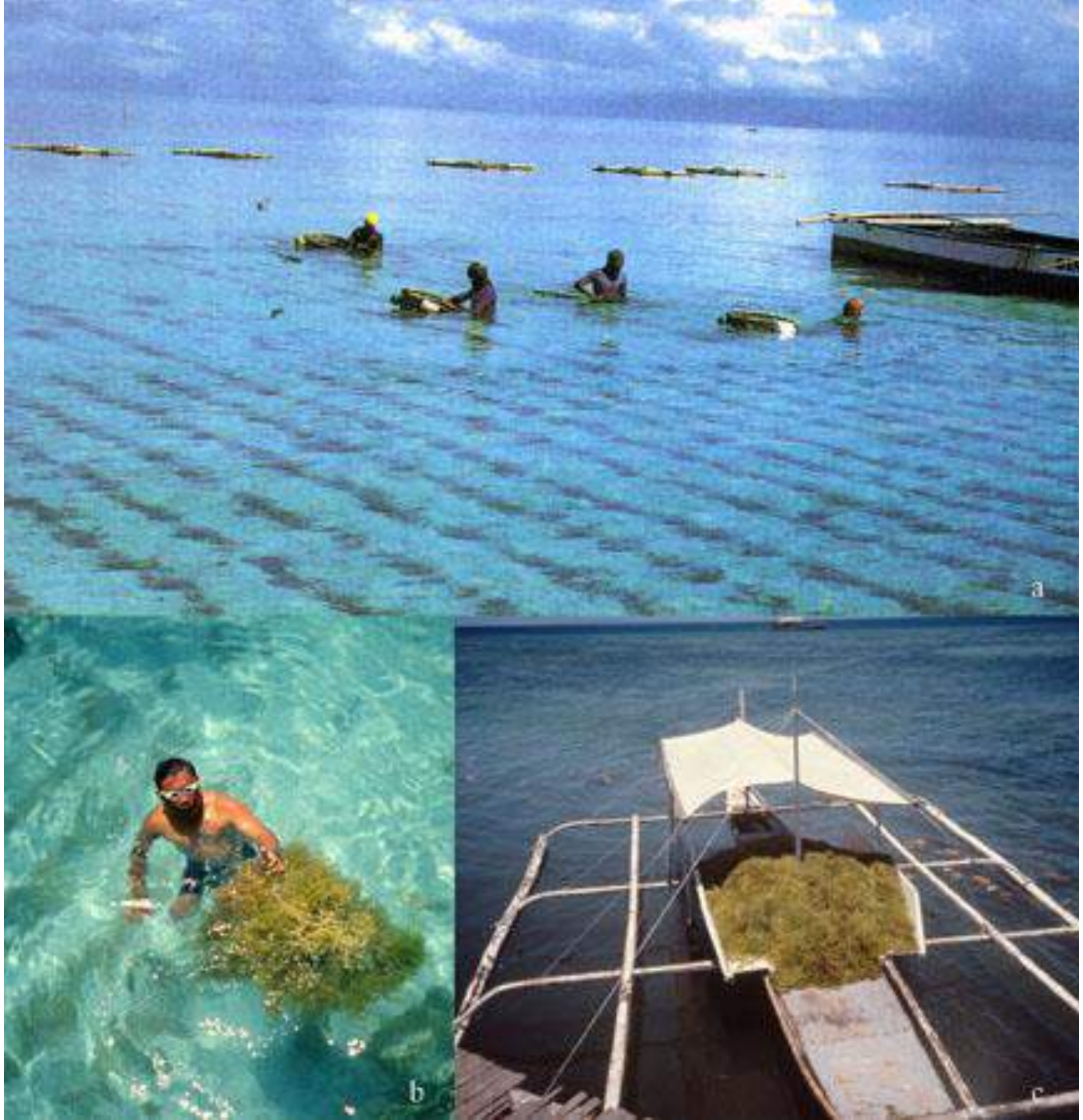
G. corticata

Economically important: produce AGAR

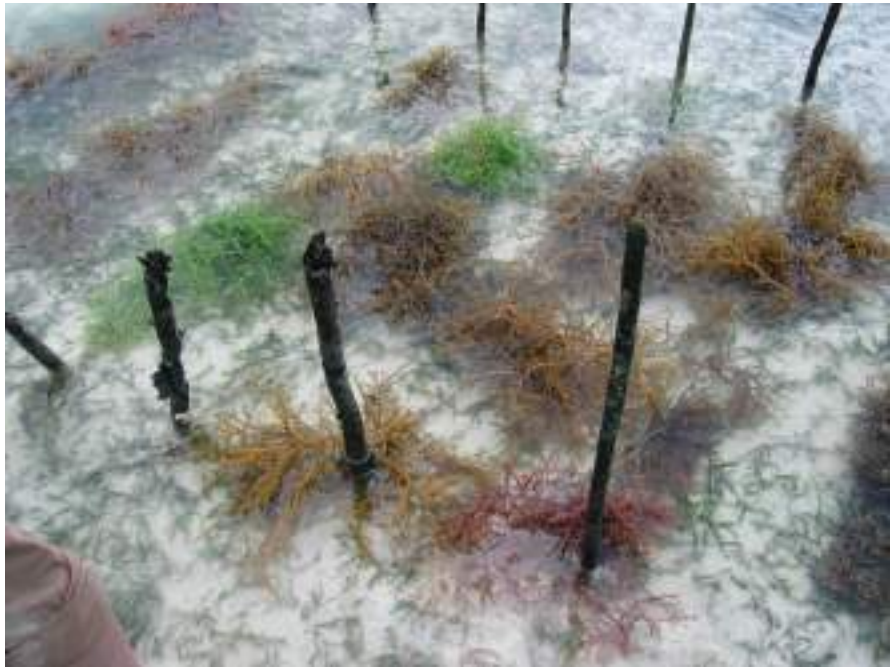
Eucheuma denticulatum

Eucheuma farming in Bali (Indonesia)

For CARRAGEENAN



Eucheuma farming in Zanzibar



Gelidium harvesting in South Africa

Harvesting (by plucking) for agar on open rocky shores on the South African south coast.

Hypnea

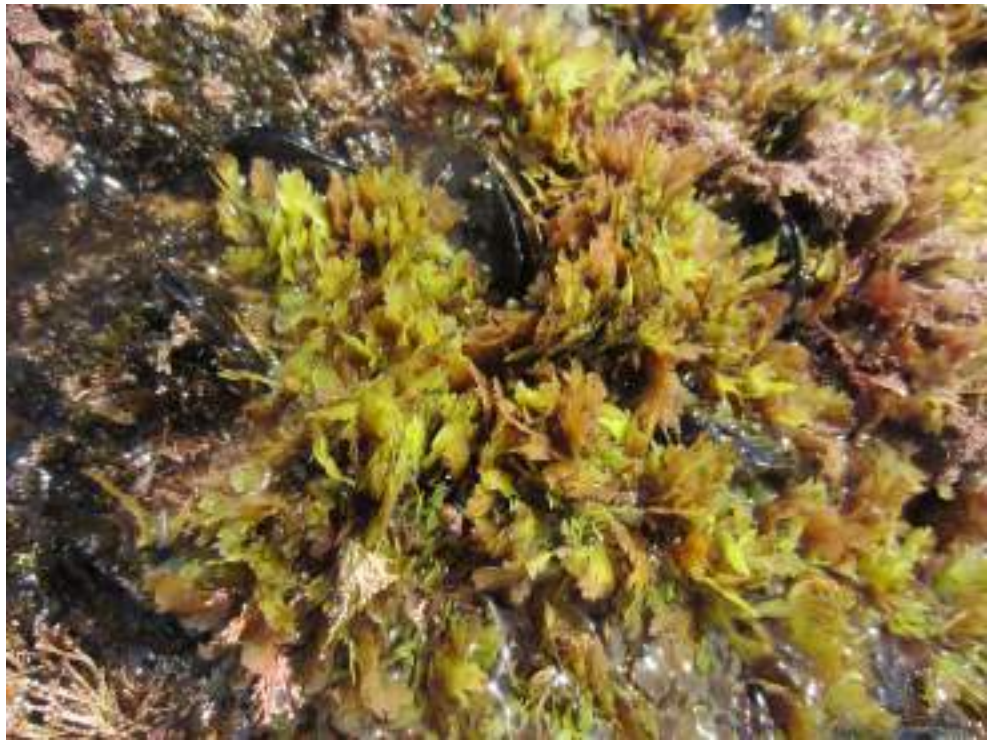
H. spicifera

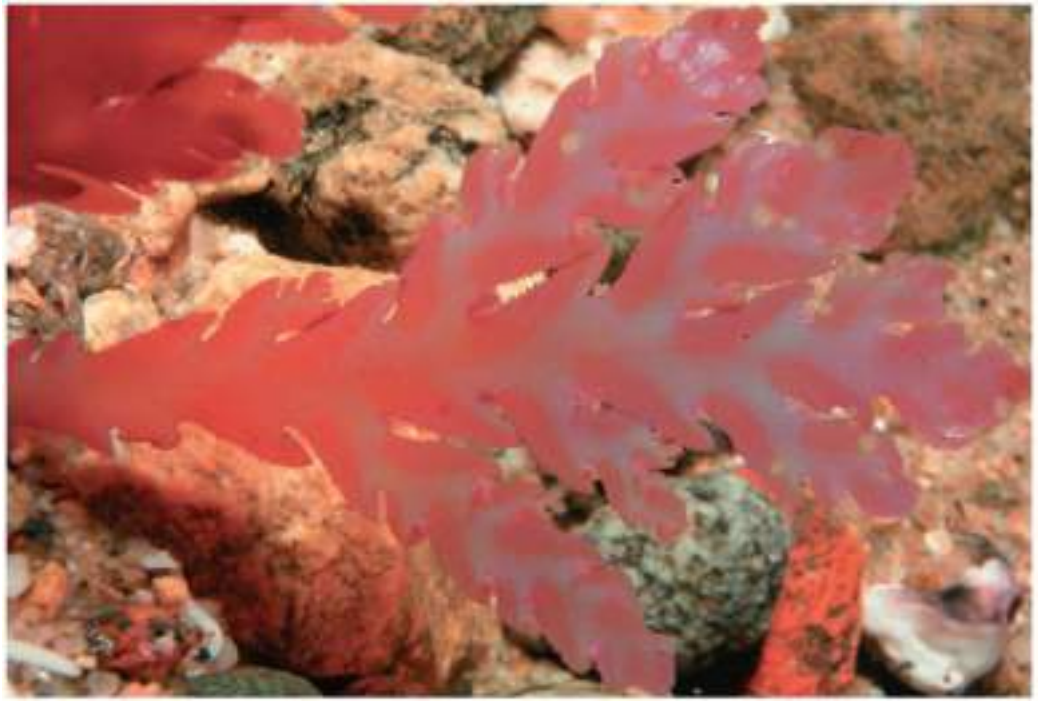
H. rosea

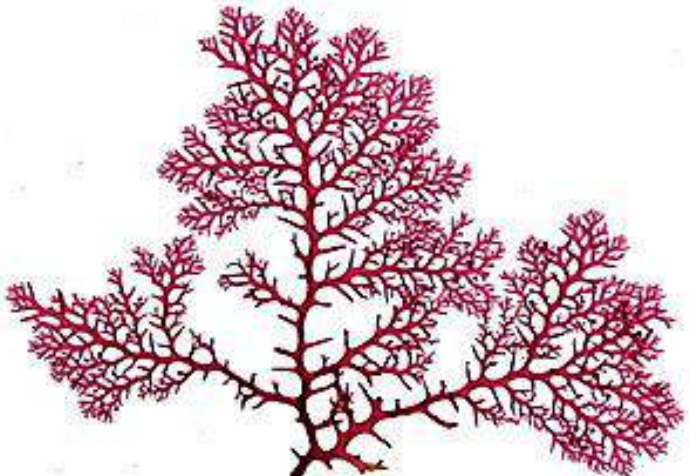
Lower intertidal diversity

Plocamium

P. corallorhiza



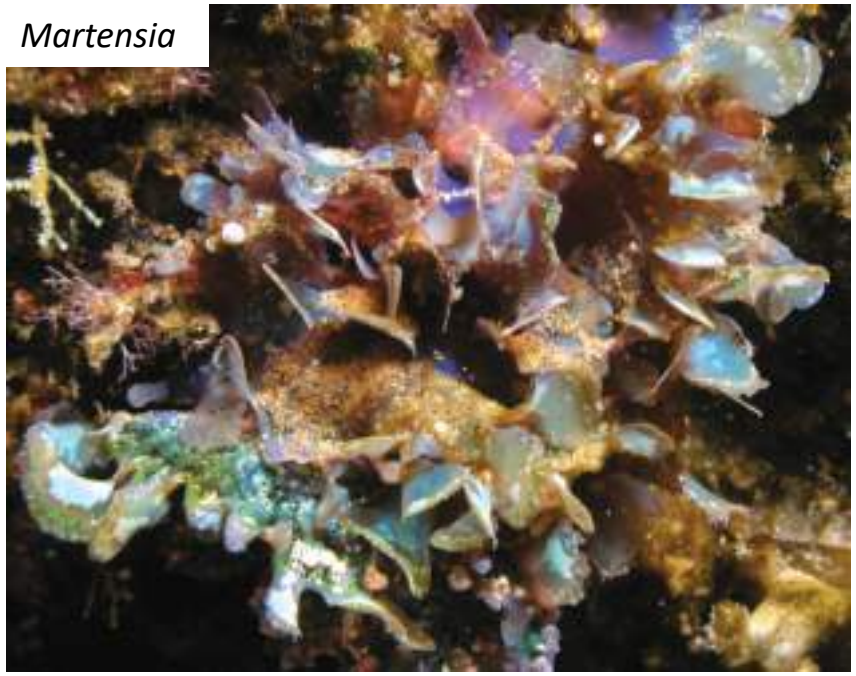




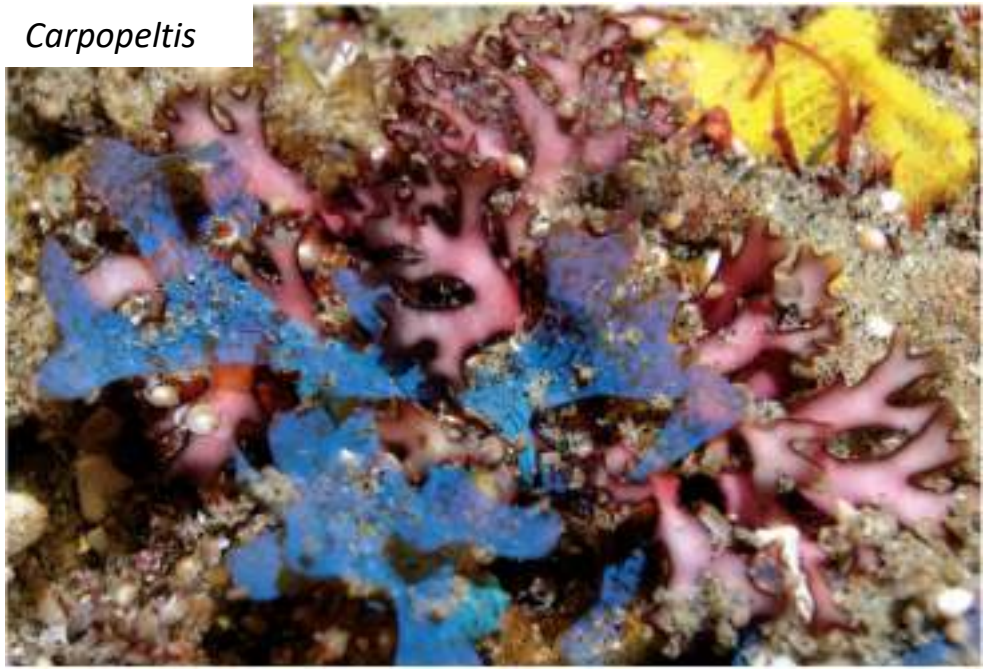
Beauty is not in the eye of the beholder

Dichotomaria

Martensia



Carpopeltis



CORALLINE RED ALGAE

- **Family Corallinaceae**
- All members of this family deposit CALCIUM CARBONATE ($Ca\ CO_3$) in their cell walls.
- Hard and brittle to the touch.
- Reproductive structures are found in CAVITIES CALLED CONCEPTACLES.

Coralline red algae

- Two groups:

1. Articulated (jointed corallines).

- Heavily calcified except at the joints between the calcified segments.
- Flexible at the joints.

2. Crustose corallines

- Many areas of the seashore, and rock under kelp beds covered with a pinkish, calcareous crust. Composed of a variety of crustose corallines

Jania & Arthrocardia : common and widespread articulated corallines

Joint

Amphiroa sp.

Reproductive structures

Amphiroa fragilissima

Jania cultrata

Reproductive conceptacles

- Conceptacles are cavities containing the reproductive structures.
- Spores and male gametes exit through a pore on the surface – the OSTIOLE
- Same life history as most red algae (isomorphic)
- Conceptacles contain **spermatangia, carposporangia, or tetrasporangia**

Crustose corallines


a friend of
the algae is a
friend of
mine !