In the beginning…

In Japan, the nori seaweed (*Porphyra*) has been used for 1500 years

In the early days of nori production, Japanese fishermen depended on wild nori, therefore was very valuable, and only higher classes would eat it. It was a luxury item

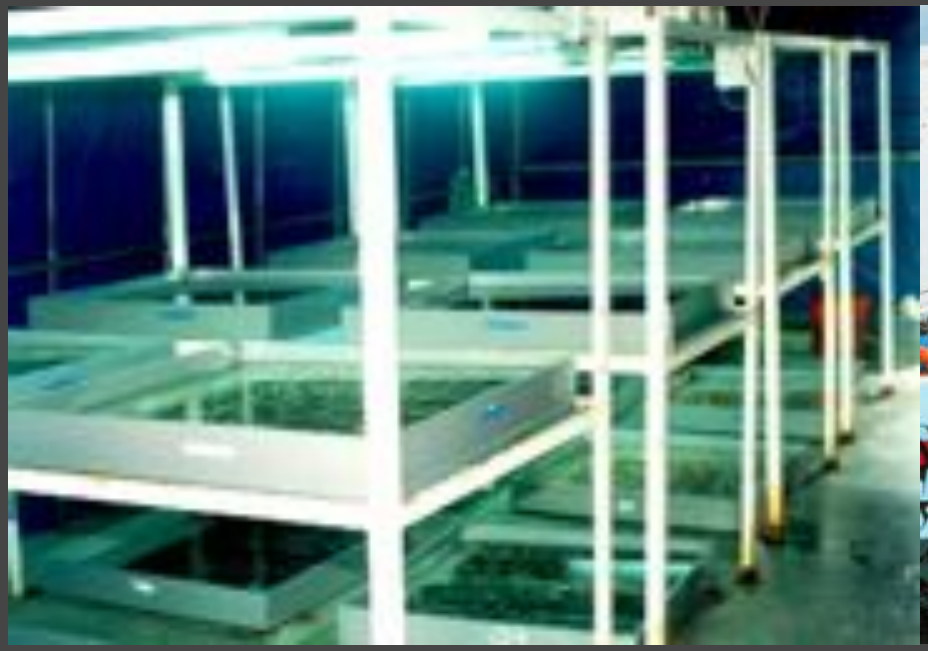
With an increasing population the demand and price were escalating

During the 1930-40s, after years of unreliable nori harvests the seaweed industry in Japan was at the point of collapsing

1947, Dr. Kathleen Mary Drew, a phycologist, found that nori spores grew up IN oyster shells That cryptic (endozoic) red alga was previously known as *Conchocelis*!

It was Dr Drew's work that provided the answers.
Dr Drew's work saved the seaweed industry in Japan. Farmers having suffered years of unreliable harvests.

This discovery made possible the mass production of nori!



Before her discovery, annual production of nori 1925 to 1957: 3-5,000 tons

After her discovery, annual production of nori 1958-1980: 5,000-35,000 tons

In Japan, the total annual production value of nori is: >US$2 billion

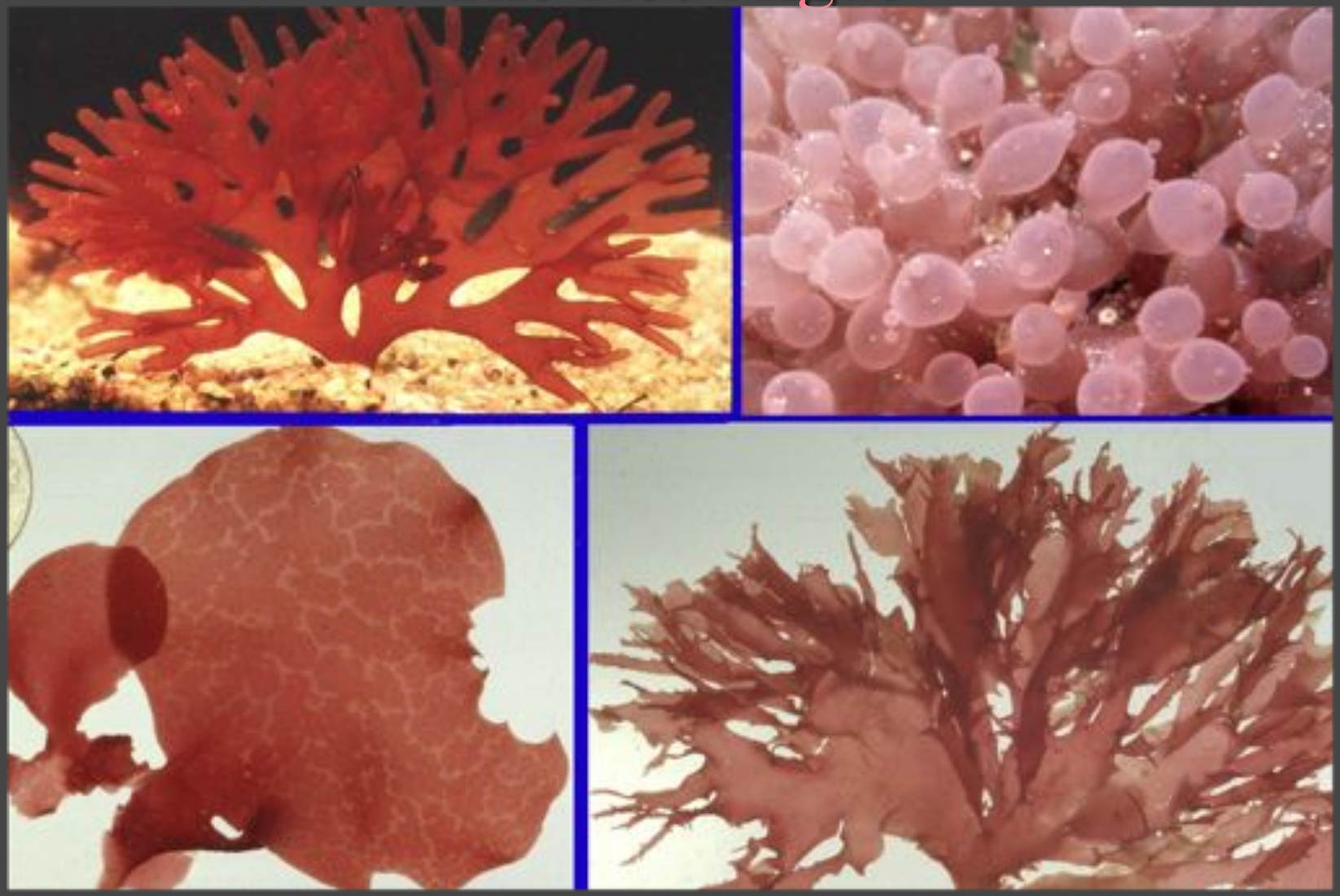
She never went to Japan and she never knew how famous she was in Japan!

"Drew Festival" April 14th

In gratitude: monument in Japan at Sumiyoshi Shrine Park, overlooking the Ariake Sea, at Uto City (Kumamoto)

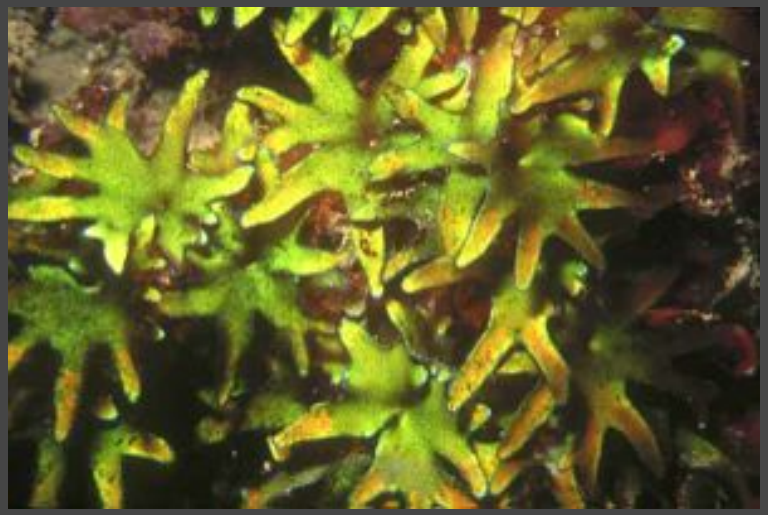
RHODOPHYTA

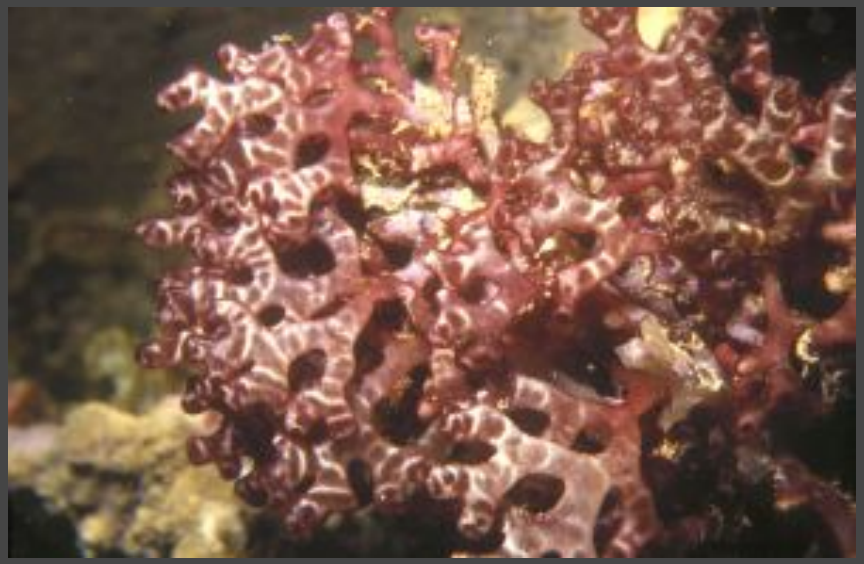
The Red Algae



- Mostly marine species and 3% are freshwater
- More than 10,000 species described worldwide
- Chlorophyll *a* and phycobilisomes
- Chloroplasts with separated thylakoids never forming grana
- Carbohydrate reserve as Floridean starch
- Lack of flagella

- Cell wall with a fibrous cellulose and a matrix of phycocolloids agar and carrageenan
- Pit connections and plugs between cells





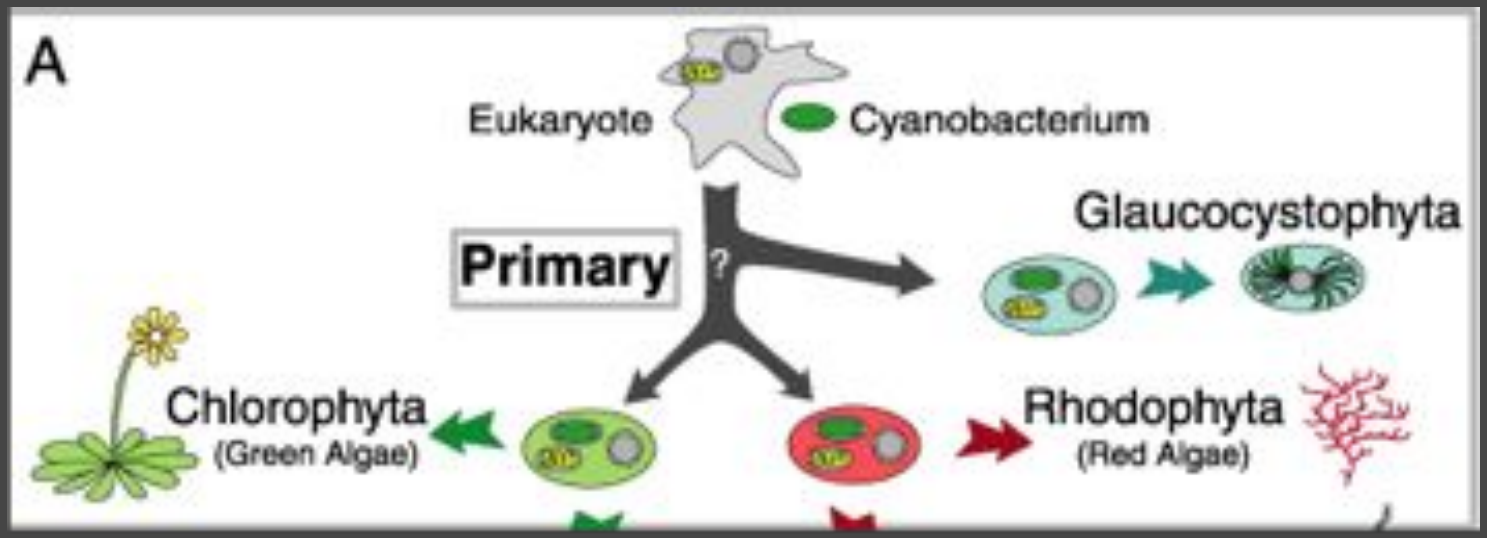
- Most red algae are filamentous in nature forming pseudoparenchymatic thalli

- Life cycles complex, with a specialized oogamy and consisting of an alternation of three generations: the gametophyte, the tetrasporophyte, and the carposporophyte

General Features of Rhodophyta

Red algae are the descendents of a primary endosymbiotic event, and with the previous green algae and glaucophytes they share a common ancestry

Evidence: Primary plastids with two membranes and ultrastructural similarities with the cyanobacteria cell organization

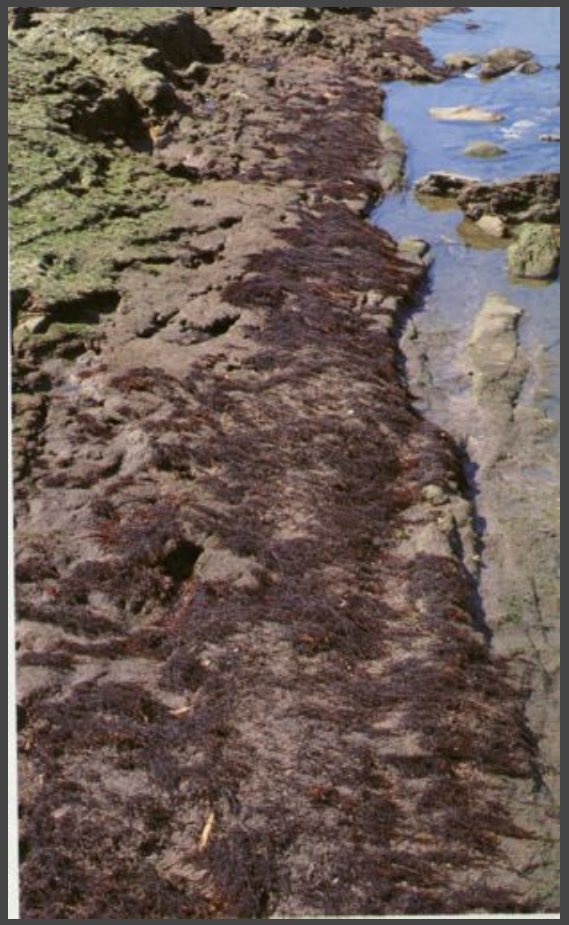


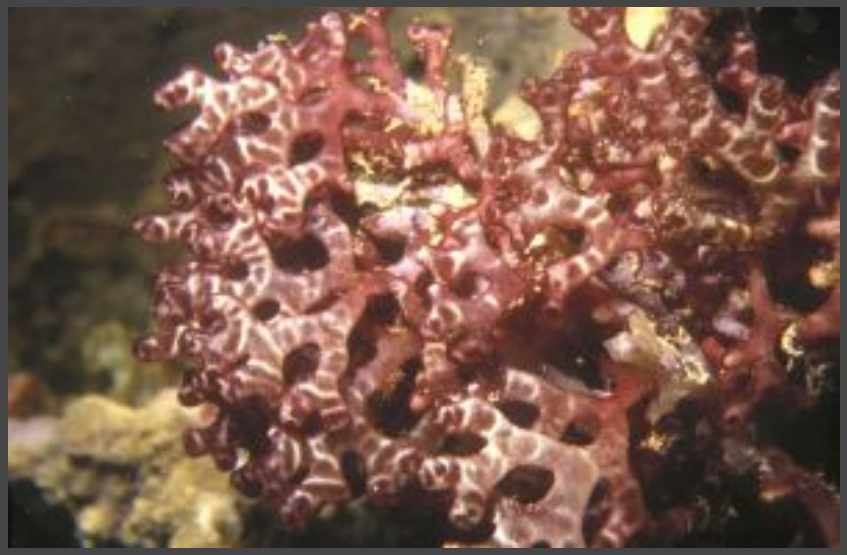
There is no significant fossil record of the evolutionary history of the marine red algae, except for the order Corallinales which extends back as far as the Jurassic (Johansen, 1981)

The oldest taxonomically resolved eukaryote on record, @1,200 mya from arctic Canada, is identified as a bangiophyte red alga, *Bangiomorpha pubescens*, on the basis of diagnostic cell division patterns in its multicellular filaments. This marks the onset of a major protistan radiation near the Middle proterozoic/Late proterozoic boundary (Butterfield, 2000)

Ecology

Red algae are common on hard-bottom habitats, as *epiphytes* on other algae, seagrass or mangrove roots, *epizooic* on animals, *epilithic* on pebbles & rocks, or *psammophilic*





They occur at all latitudes from the Arctic to the Antarctic

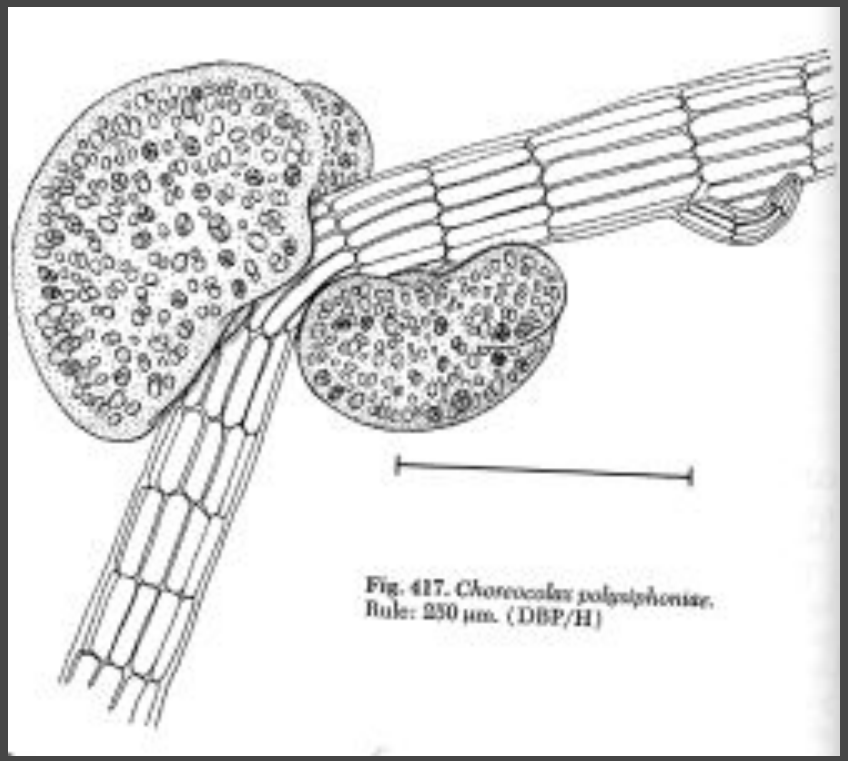
They occupy the entire range of depths inhabitable by photosynthetic organisms, from high intertidal regions to subtidal depths as great as 268 m (San Salvador I, Bahamas is the greatest depth for known plant life) (Littler *et al*., 1985)

Some red algae, the corallines, are important in the formation of tropical reefs

Red algal parasites

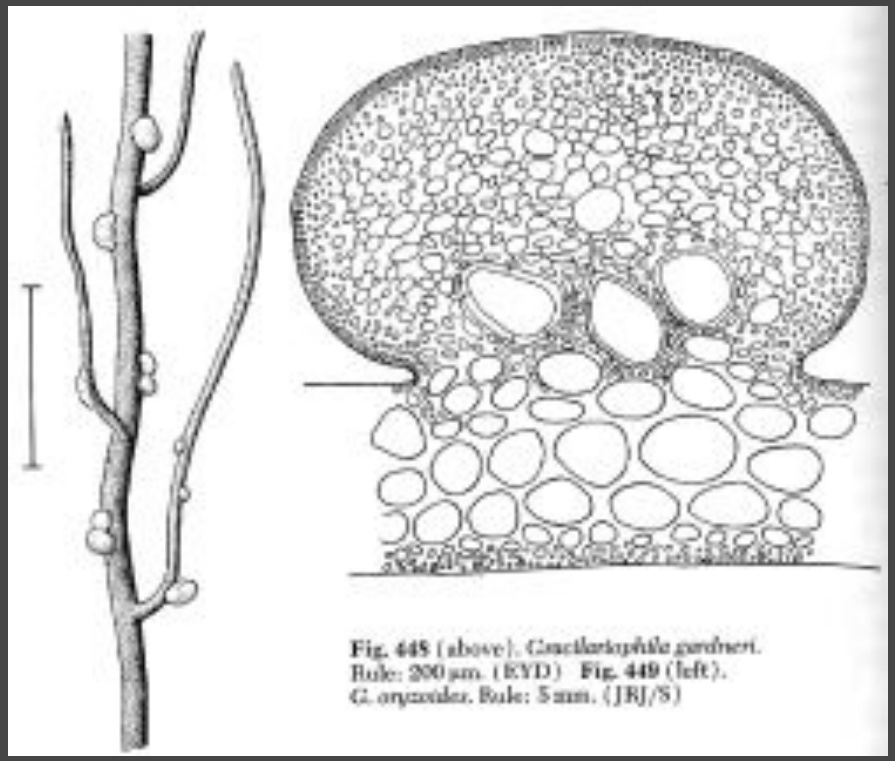
Some red algae are parasites of other red algal hosts

Alloparasite if the two taxa are unrelated



Choreocolax (Cryptonemiales) on *Polysiphonia* (Ceramiales)

Adelphoparasite if growing on a closely related form (same family)

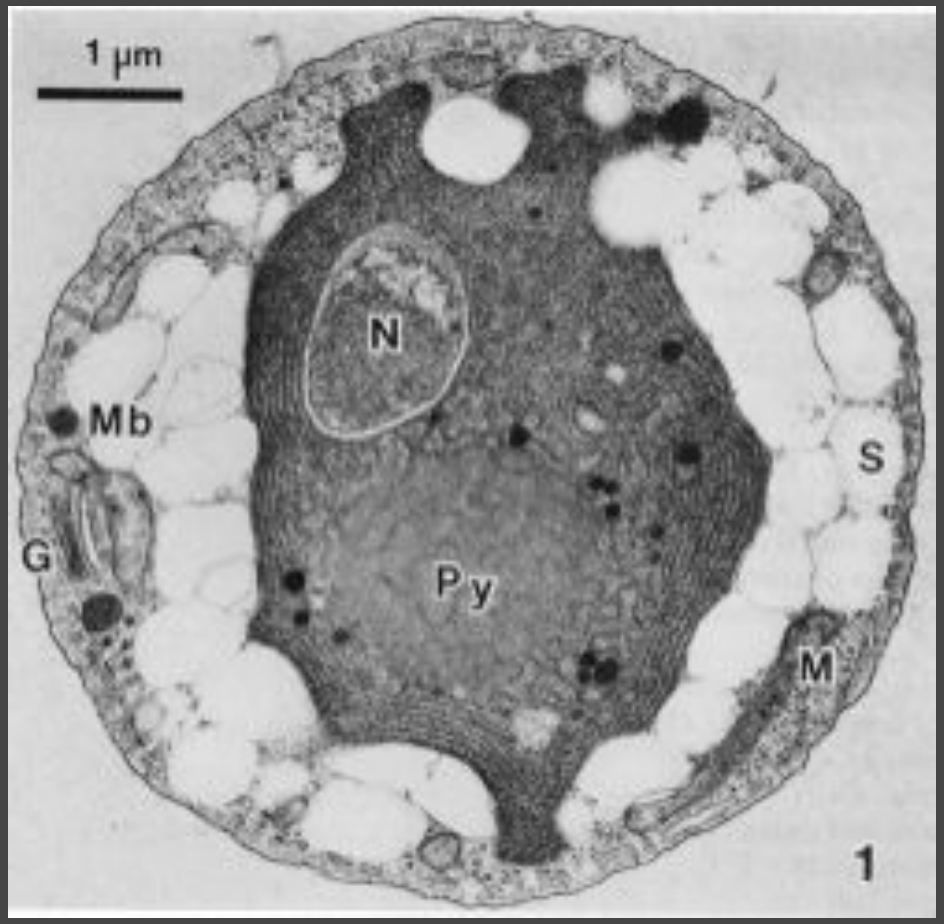


Gracilariophylla on *Gracilariopsis*, both Gracilariaceae

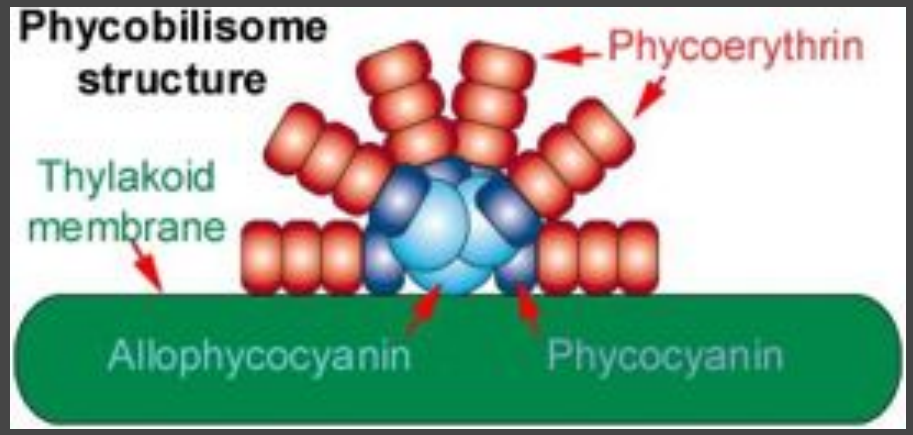
Pigments and plastids

Chlorophyll *a*, R-Phycoerytrhin, R-Phycocyanin, R-allophycocyanin, and Carotenoids (protection for excessive sunlight)

R-Phycoerytrhin is very efficient collecting blue+green light in subtidal habitats and very abundant in the plastid

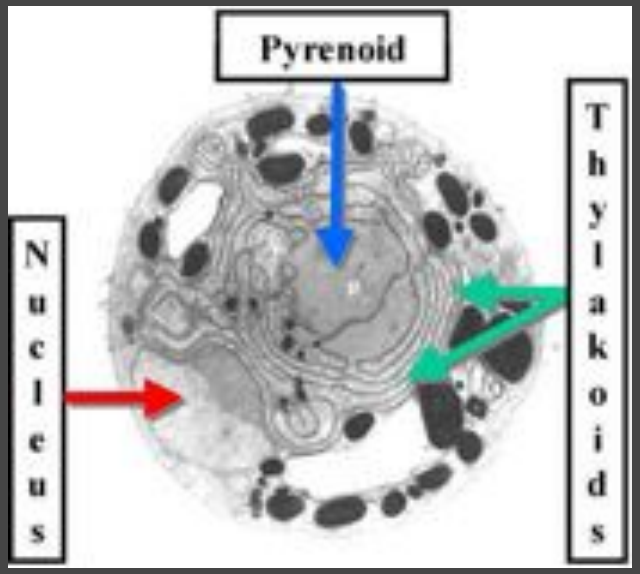


Phycobilins are located in Phycobilisomes on the surface of the Unstacked thylakoids

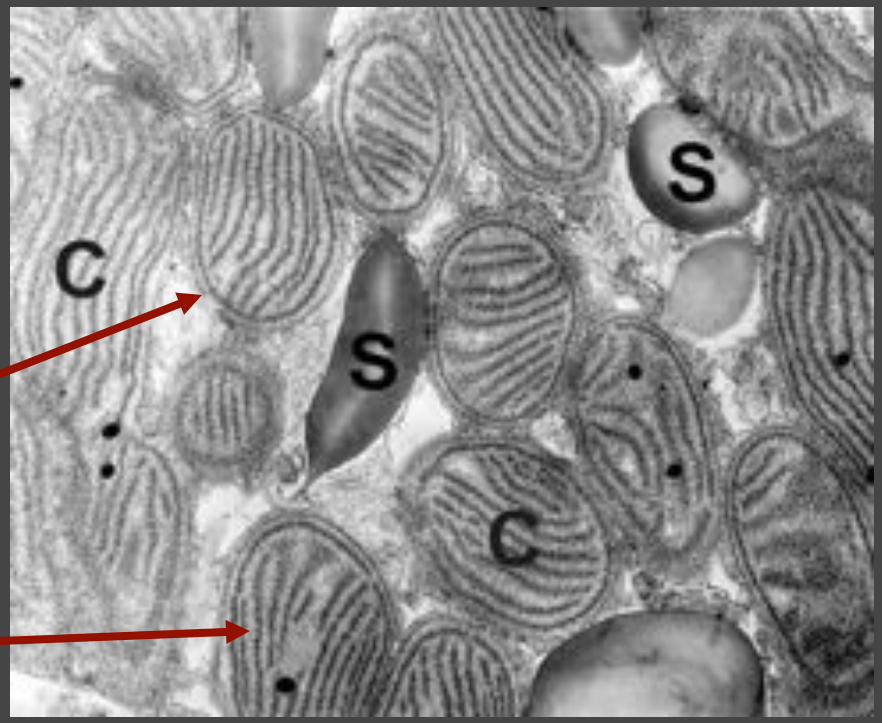


Pigments and plastids

- The plastids of red algae have originated from cyanobacteria by primary endosymbiosis, therefore they are <u>Primary Plastids</u>



- Only a few red algae contain pyrenoids in the center of the chloroplast, but because reserve floridean starch is produced in the cytoplasm, the exact function is not known



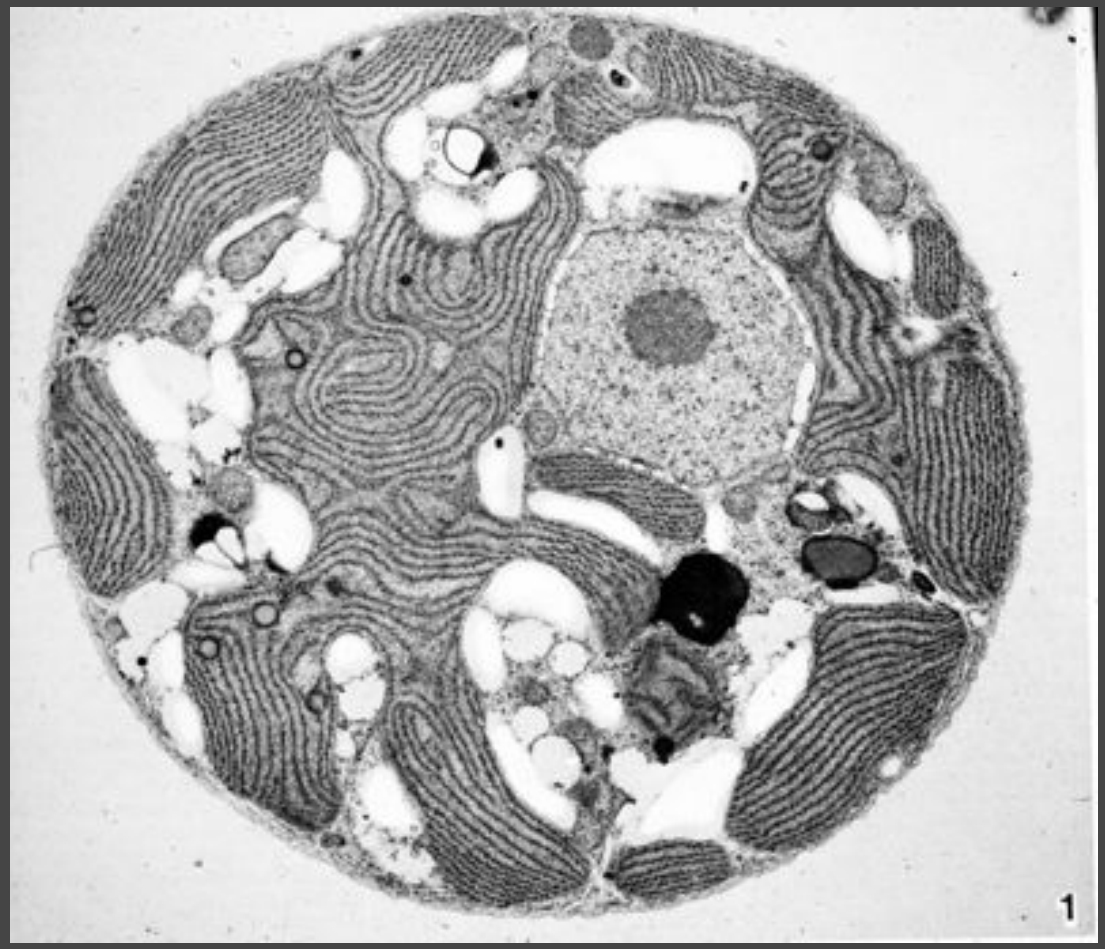
- Plastids have only <u>2 plastid membranes</u>

- <u>Thylakoids are singly</u>, never forming grana

Reserve

•The most important food reserve is Floridean starch, a polysaccharide consisting of units of glucose, is similar to glycogen or the branched amylopectin fraction of green algal & higher plant starch, but lacks amylose, the unbranched fraction of green algal starch

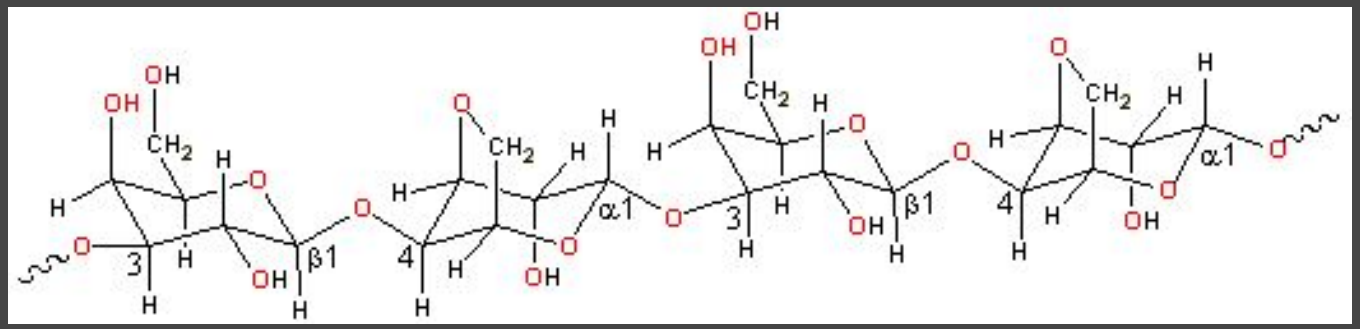
The low-molecular mass carbohydrate floridoside has an osmoregulatory function



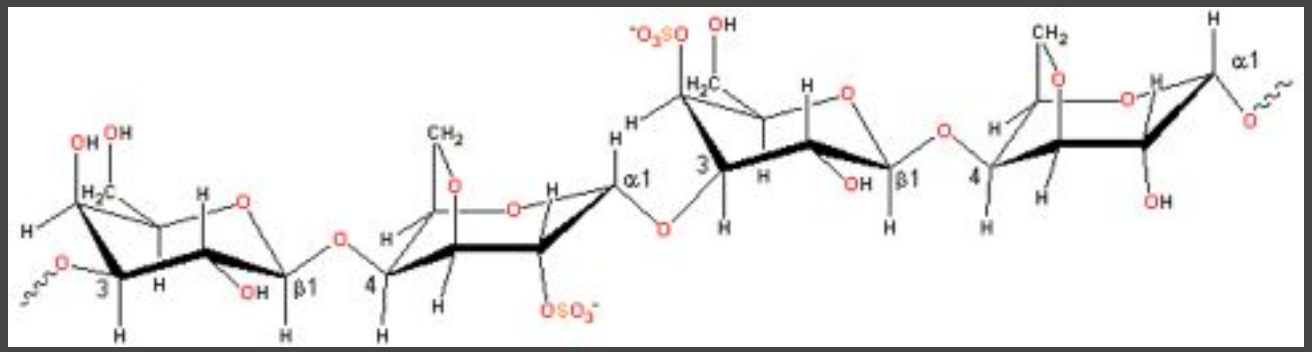
Cell walls

•The cell walls of red algae consist of cellulose fibers embedded in a matrix of non-fibrillar materials, the phycocolloids. The most abundant of these polysaccharides are referred to either as *agars* and *carrageenans*, and are of great economic importance

•Agar is used as a nutrient medium for growing bacteria and fungi & also in the food and drug industries

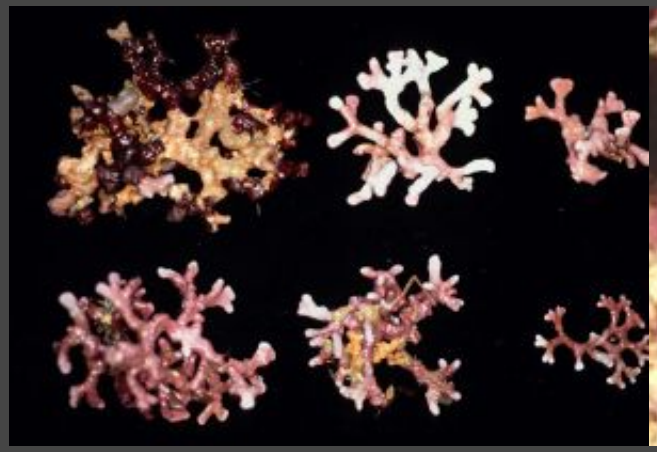


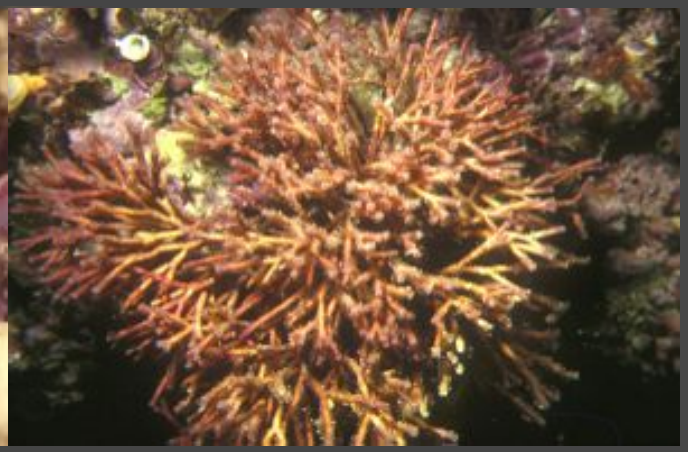
•Carrageenan is used as a substitute for gelatin, or as food in Japan & the Philippines



Cell walls

Many red algae, in particular the coralline algae (order Corallinales) have heavily calcified cell walls

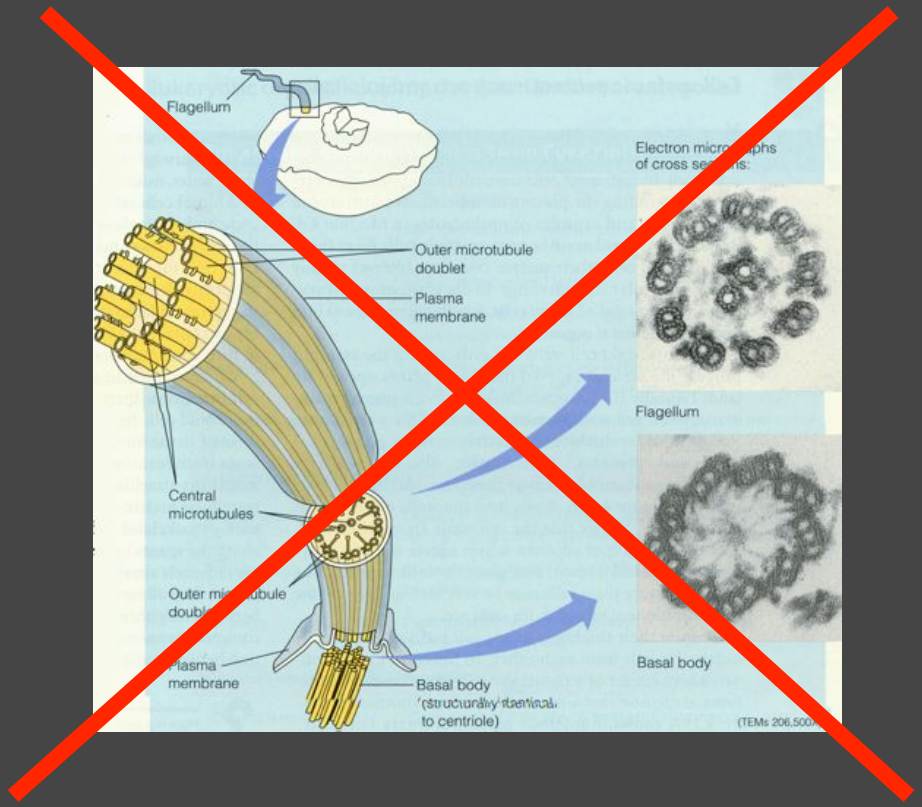




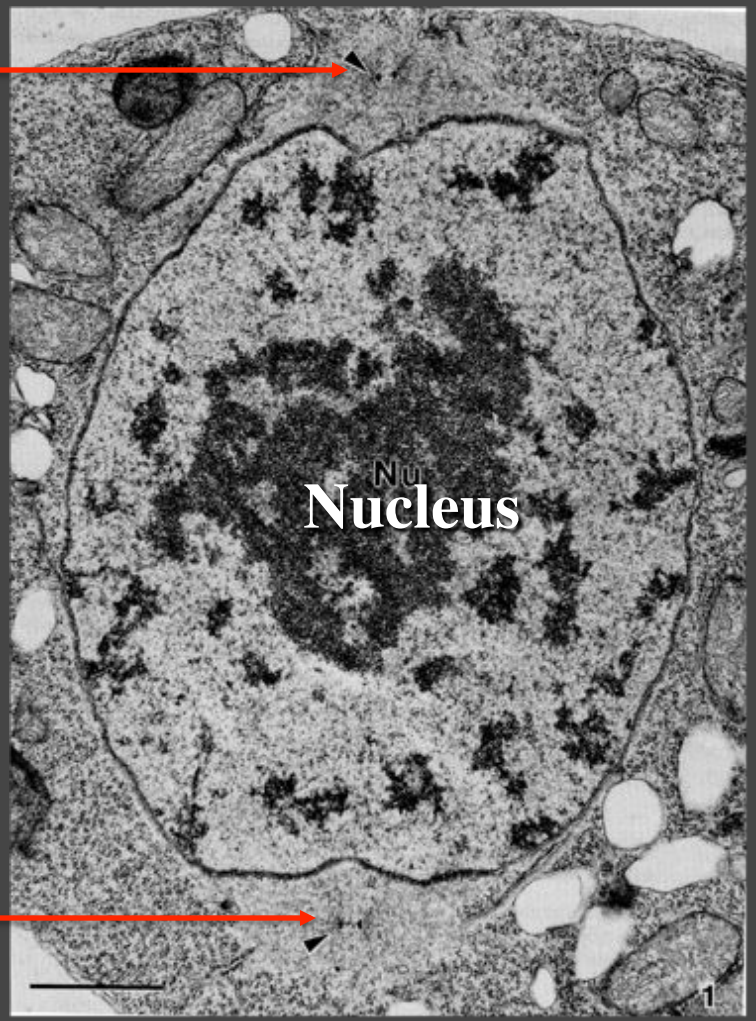
Some algae have a continuous "Cuticle" of protein covering of the algal thallus. This cuticle is responsible for their iridescent appearance

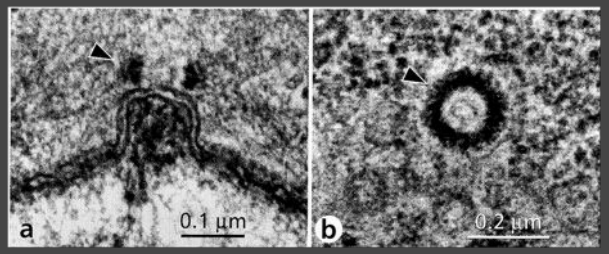
Abscences

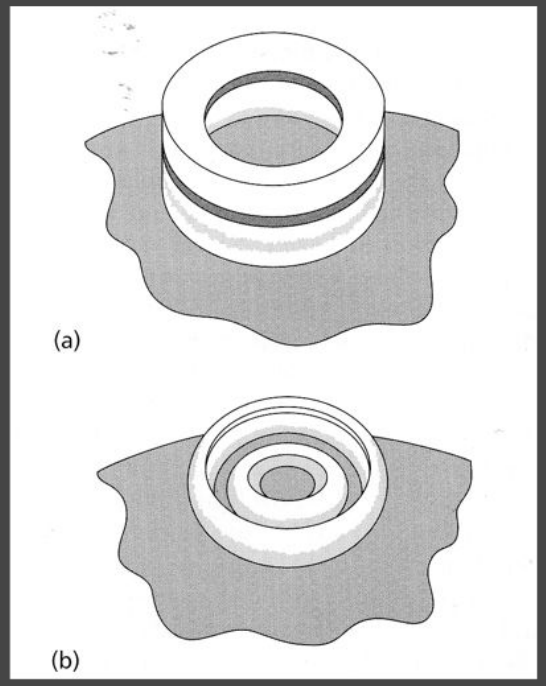
Rhodophyta is unique by a complete lacking of flagellated stages including flagella, centrioles, flagellar basal bodies, or other 9+2 structures



The presence of polar rings or Nuclear Associated Organelles (NAO) instead of centrioles at the poles of the mitotic spindle is another reflection of the complete absence of flagella & related structures, and is a fundamental difference between the Rhodophyta and other groups of algae

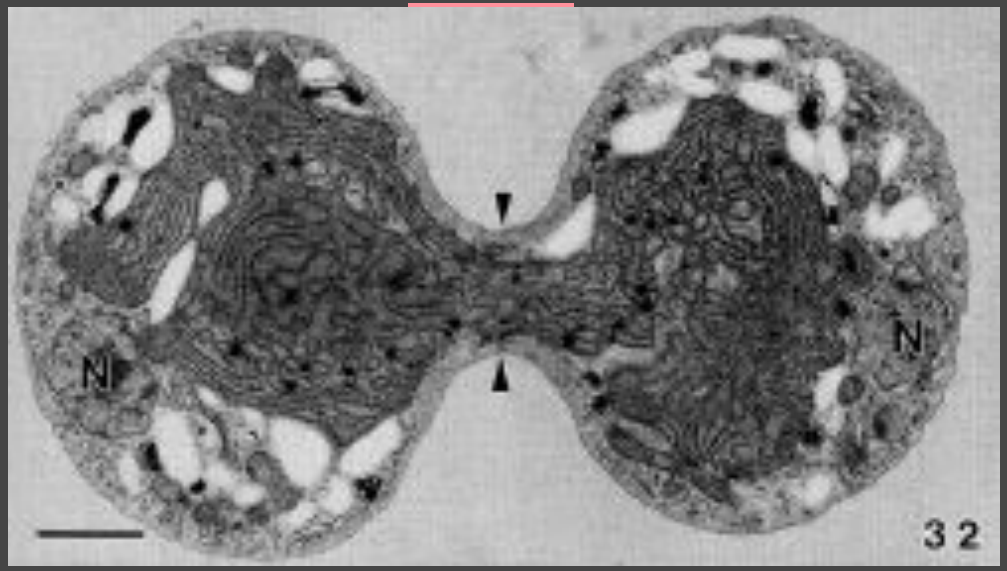






Cell division in Red Algae

During mitosis, the nuclear envelope, although perforated by holes, persist and mitosis is therefore closed



Cell division is by an ingrowing furrow of the plasmalemma, which is filled with cell wall polysaccharides

Cleavage is incomplete, leading to the formation of an open protoplasmic connection between the daughter cells, which becomes closed by a protein stopper, the pit plug (Pueschel, 1990)

Pit plugs

Pit plugs are a highly characteristic feature of Rhodophyta & various different kinds can be distinguished on the basis of their ultrastructure, providing an important character for distinguishing among the orders (Pueschel, 1989)

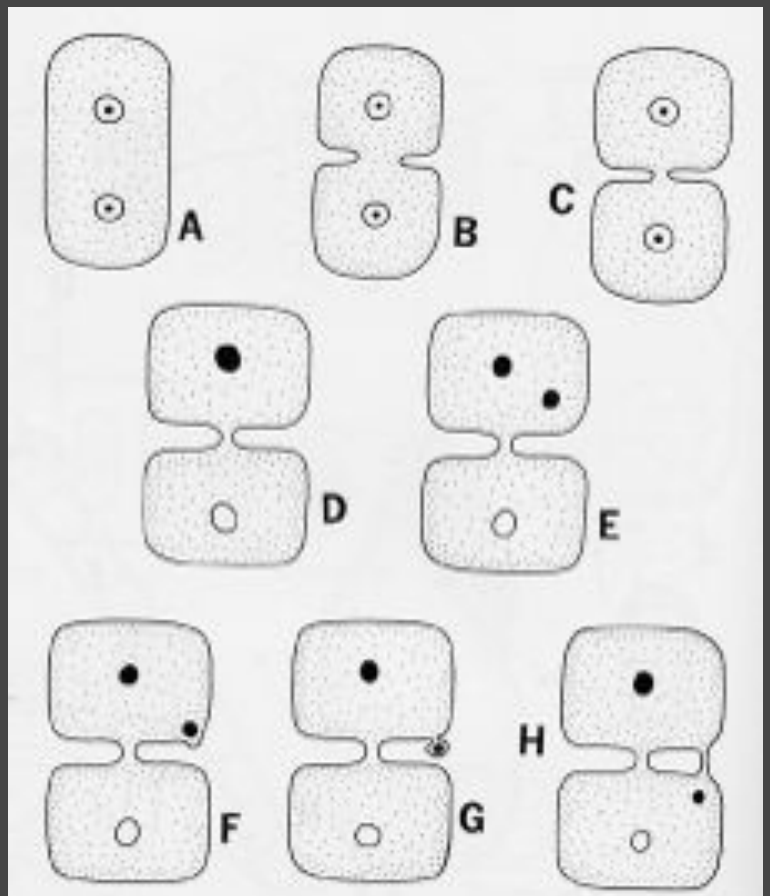


FIGURE 12–7 Formation of pit connections in Florideophycidae. A–C, formation of primary pit connection; D–H, formation of secondary pit connection.

- A fundamental characteristic shared by all multicellular florideophycean red algae is that the plant body is composed entirely of branched filaments

- Cells within filaments are linked by pit plugs, making it possible to follow each filament cell by cell as seen with light microscopy

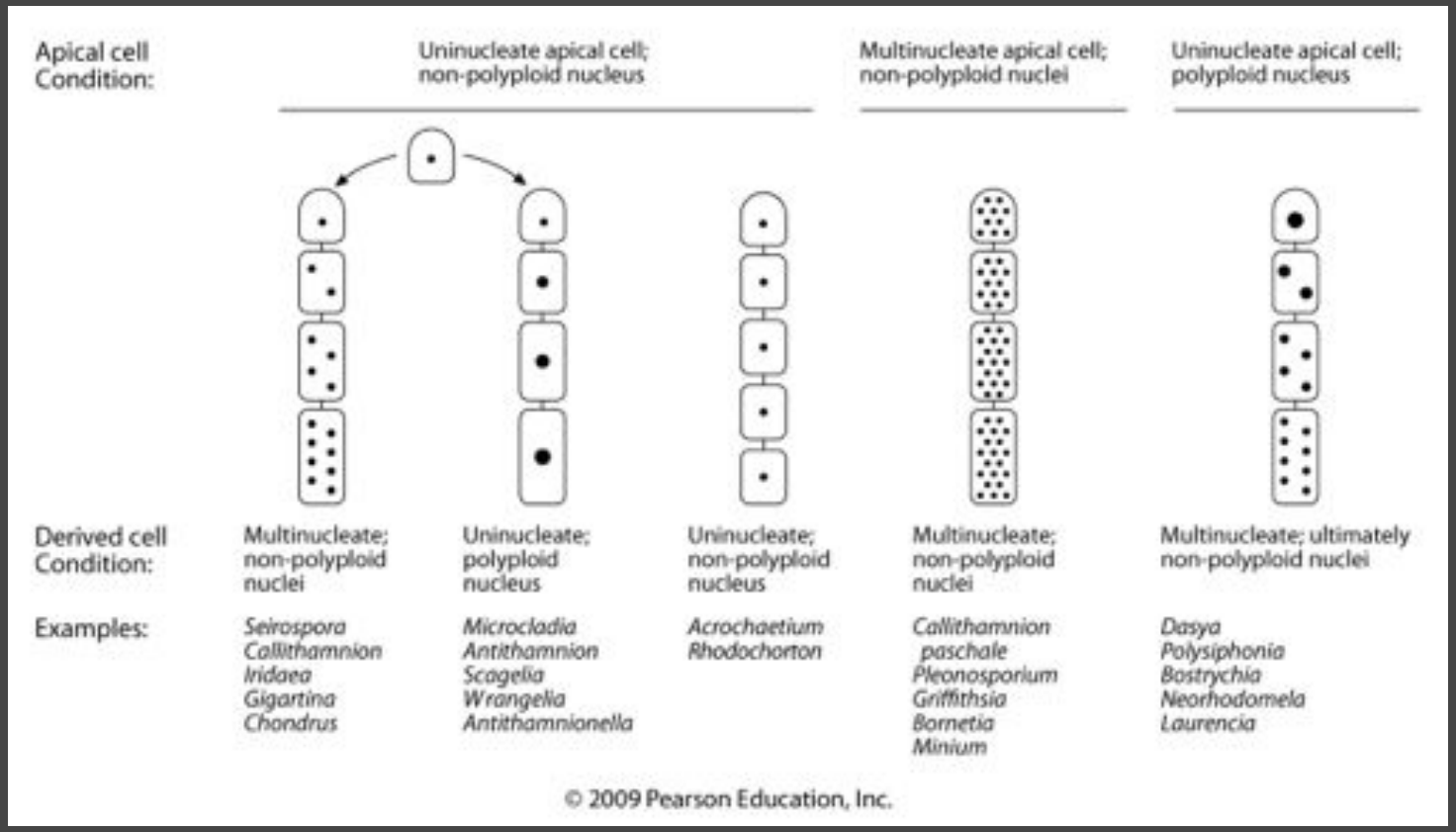
- Cells become differentiated in shape & cytological properties depending on location within filament

- Reveals how cells from different lineages become connected!

Development of multinucleated cells in Rhodophyta

In many rhodophyta, karyokinesis continues without cytokinesis, producing multinucleate cells

Red algal nuclei also endoreduplicate (endopolyploidy) without mitosis to produce a polyploid cell



Morphology

- **Basal red algae** occur as unicellular, colonial, small filaments or blades usually without pit connections

Porphyridium

Rhodosorus

Bangia

- **Advanced red algae** are composed entirely of a *filament* organization which may result in a complex pseudoparenchymatic thallus as a result of predominant apical growth

  They are classified in two growth types:

  a) Uniaxial: composed of a single branched filament; delicate and feathery forms
  b) Multiaxial: composed of multiple filamentous axes, each derived from a terminal apical cell; more robust and fleshy forms

Uniaxial growth

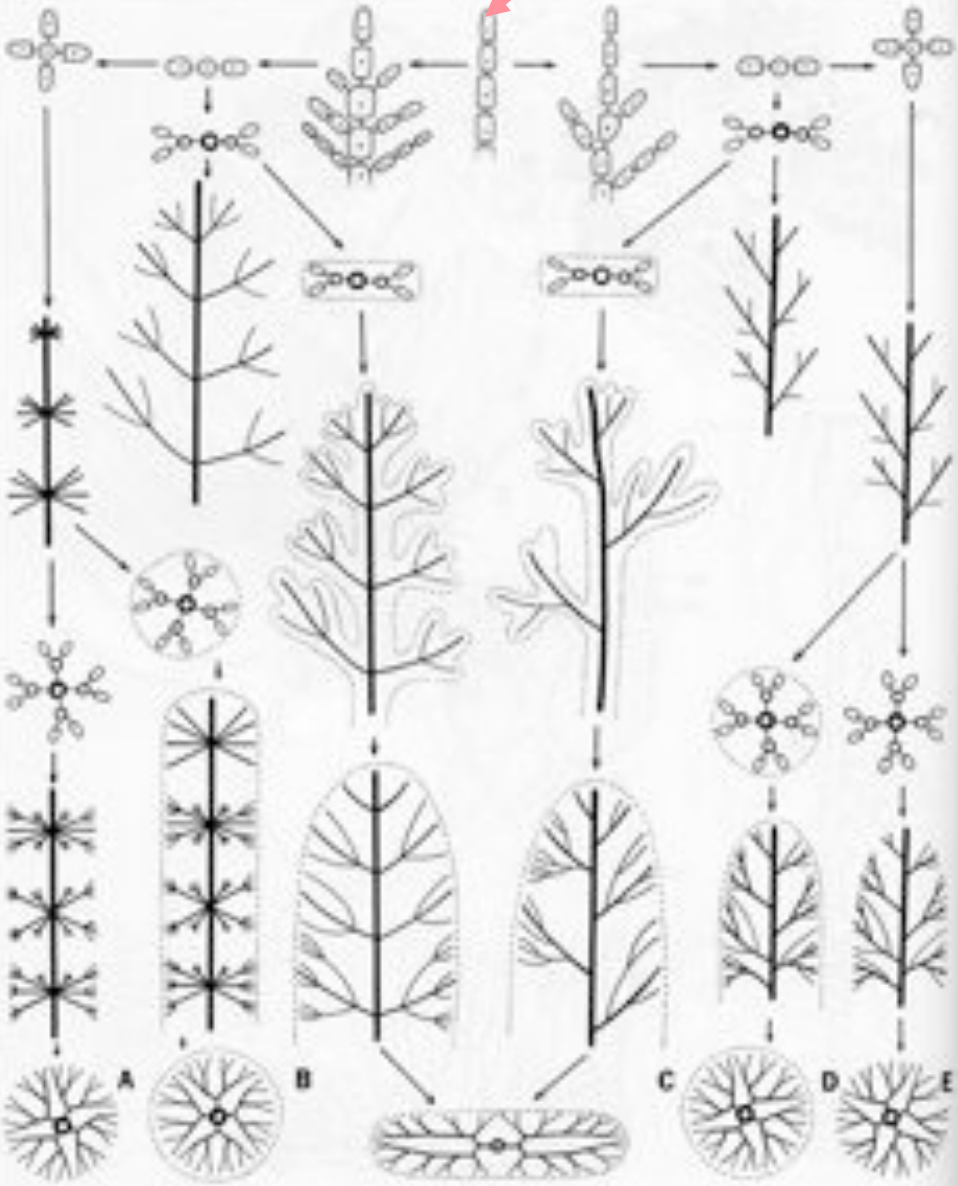


FIGURE 12–13 Growth types in uniaxial Florideophycidae, showing possible evolutionary lines leading to freely branched (A, E) and pseudoparenchymatous (B–D) types with radial (A, B, D, E) and bilateral (C) symmetry.

Multiaxial growth

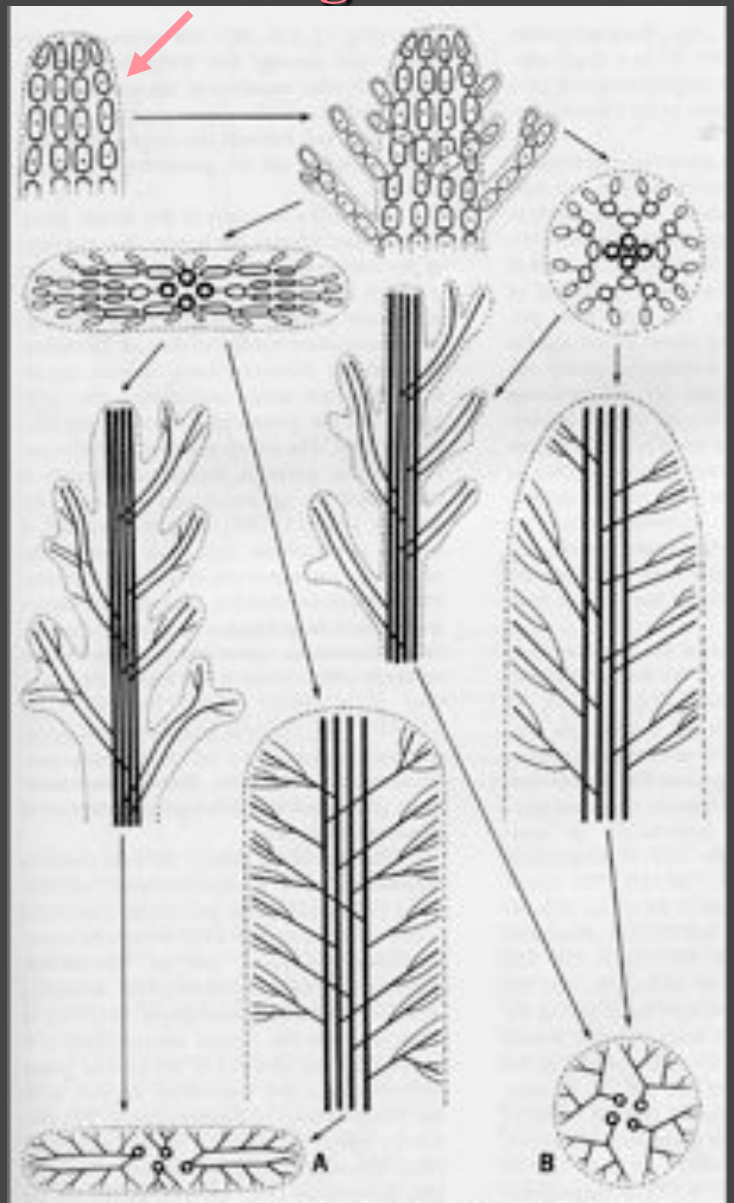
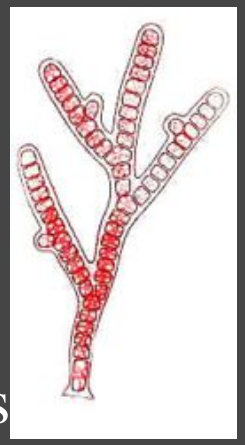


FIGURE 12–14 Growth types of multiaxial Florideophycidae, showing possible evolutionary lines leading to bilaterally (A) and radially (B) symmetrical pseudoparenchymatous forms with varying amounts of fusion of filaments.

Reproduction

Asexual reproduction

- **Monospores** common in primitive Rhodophyta



- **Fragmentation** is common in many red algae such as *Acanthophora* and *Hypnea*
- **Propagules** in *Polysiphonia*
- **Stolons** in *Neorhodomela larix*

Reproduction

Sexual Reproduction

1) Special oogamy: **Trichogamy**

- Male gamete non-flagellated **Spermatium** formed by Spermatangium
- Female gamete **Carpogonium** with an elongated **trichogyne**

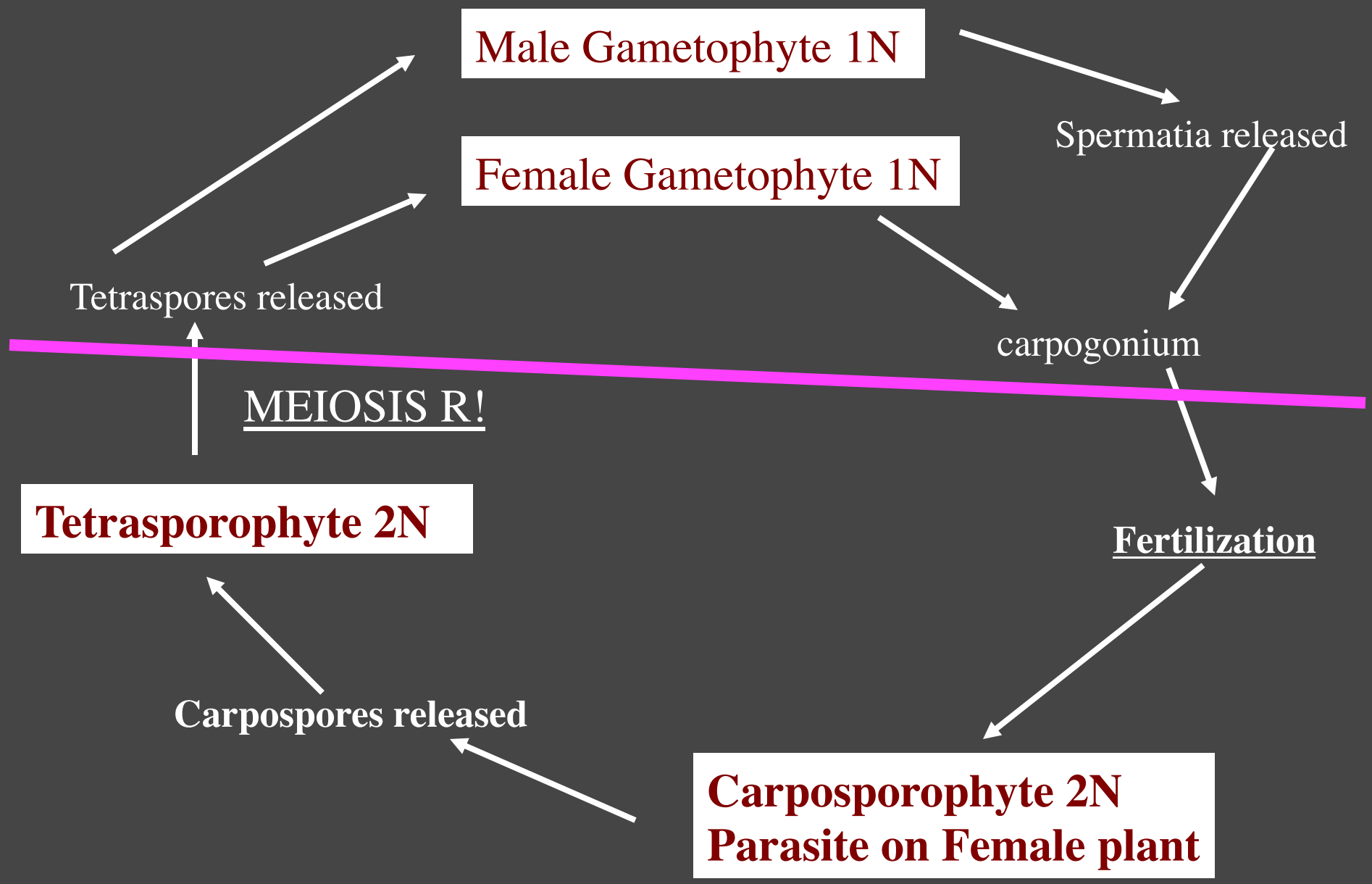
2) Life cycle is a **Sporic meiosis**

3) Alternation of **three** (3) generations or Triphasic:

- **Tetrasporophyte** 2N, producing tetraspores by meiosis
- **Gametophyte** 1N, (male or females) producing gametes
- **Carposporophyte** 2N, living as parasites on female gametophytes and producing carpospores

4) **Isomorphic or Heteromorphic** variations

Typical life cycle of a red alga:



Classification

1. Class Cyanidiophyceae
2. Class Rhodellophyceae
3. Class Porphyridiophyceae
4. Class Compsopogonophyceae
5. Class Stylonematophyceae
6. Class Bangiophyceae
7. Class Florideophyceae
    1. Subclass Hildenbrandiophycidae
    2. Subclass Nemaliophycidae
    3. Subclass Corallinophycidae
    4. Subclass Ahnfeltiophycidae
    5. Subclass Rhodymeniophycidae