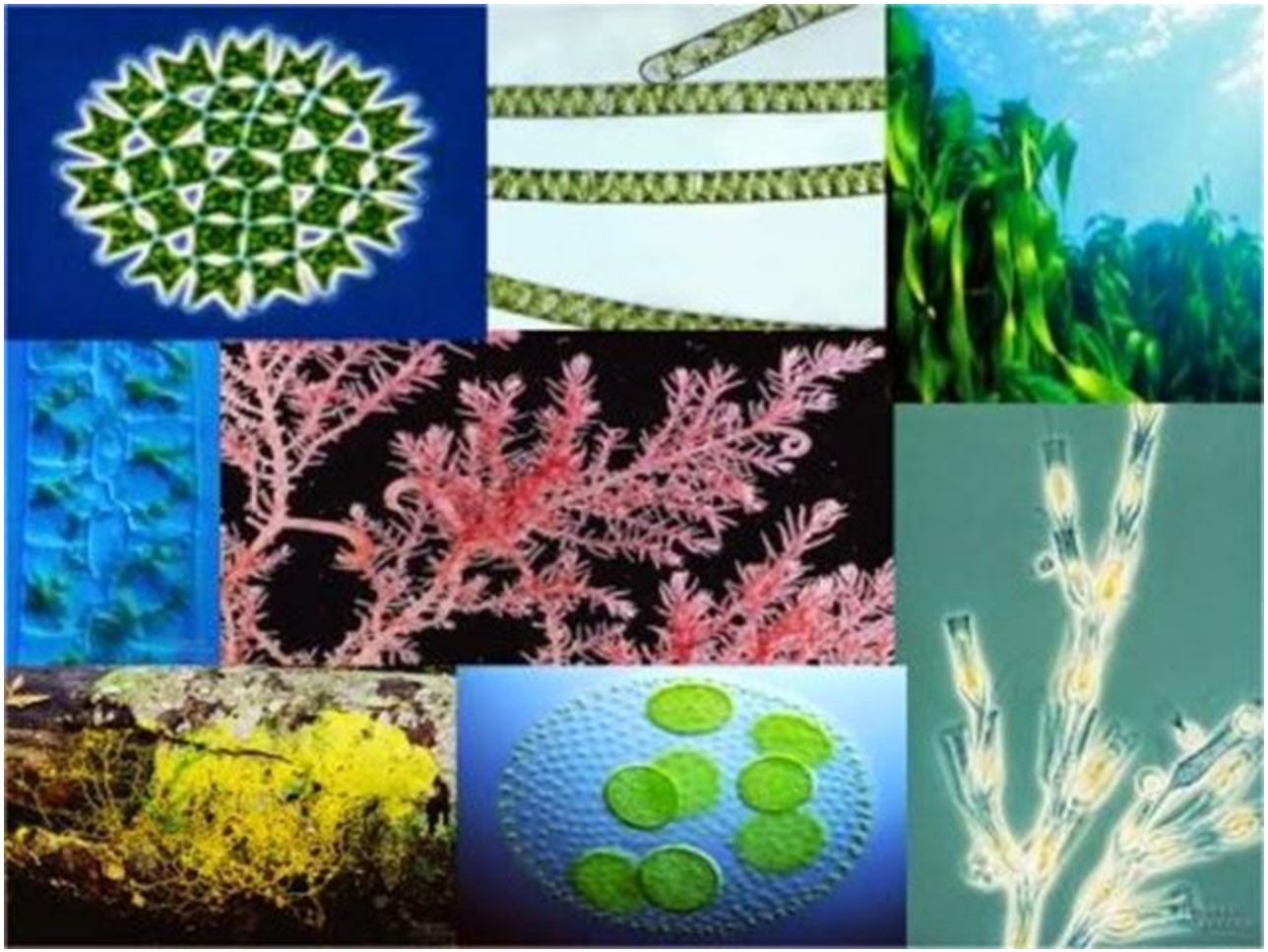
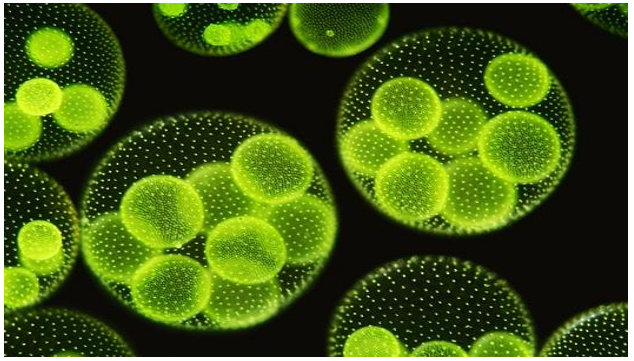


# Classification

Dr. Urmi Roy

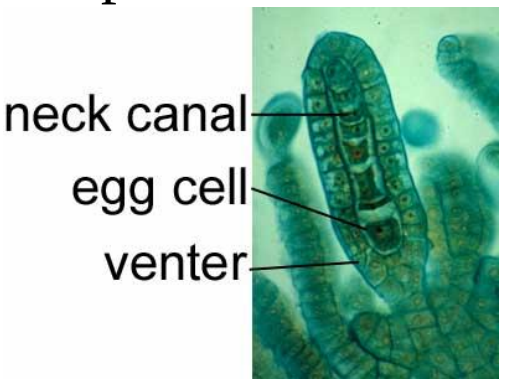
# Phycology

- Phycology, is the study of algae.
- Greek
  - φῦκος, phykos means "seaweed";
  - λογία, -logia means is the scientific study.
  - Also known as algology.
  - Phycology is a branch of life science.
  - The algae are thallophytes
    - Plants lacking roots, stems, and leaves
    - They have chlorophyll a as their primary photosynthetic pigment and
    - They lack a sterile covering of cells around the reproductive cells.
    - Algae most commonly occur in water,
      - Fresh water,
      - Marine, or
      - Brackish (নোনা).



# Definition

- **Smith**: Simple plants with autotrophic mode of nutrition.
- **Sharma(1987):**
  - Assemblage of chlorophyll bearing autotrophic thallophytes
  - Bounded by a cell wall made up of pure or mixed carbohydrate.
- Algae can be unicellular or multicellular
- They bear uni/multicellular sex organs which are not protected in sterile jacket cells.



# Basis for Classification of Algae

- The primary classification is based on the following *five* criteria:
  - Photosynthetic apparatus and pigments
  - Nature of reserve food
  - Nature of cell wall components
  - Type, number and attachment of flagella
  - Cell structure

# Basic Classifications of algae

1. F.E. Fritsch's Classification (1935)
2. G.M. Smith's Classification (1950)
3. Round's Classification (1973)
4. Bold and Wynne's Classification (1985)
5. Robert Edward Lee's Classification (1989)

# Classification of algae proposed by F. E. Fritsch (1935)

- It is the most comprehensive and authorative classification of algae.
- His book '*The Structure and Reproduction of the Algae*'.
- His classification was based on criteria such as
  - Pigmentation,
  - Types of flagella,
  - Assimilatory products,
  - Thallus structure
  - Methods of reproduction.

# F.E. Fritsch (1935, 1948): Algal Classification

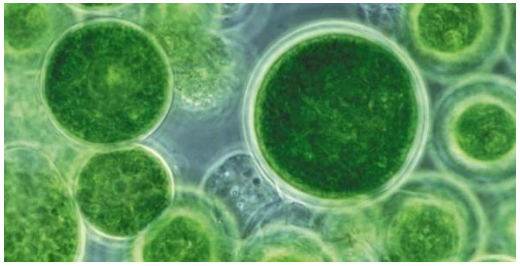
- He divided algae into 11 classes on following basis:
  1. Chlorophyceae
  2. Xanthophyceae
  3. Chrysophyceae
  4. Bacillariophyceae
  5. Cryptophyceae
  6. Dinophyceae
  7. Chloromonadineae
  8. Euglenineae
  9. Phaeophyceae
  10. Rhodophyceae
  11. Myxophyceae.

# Robert Edward Lee's Classification

- R.E. Lee (1989) divided the algae based on *evolution*
- He formed *4 evolutionary groups* of algae
- These groups are divided into 15 phyta (divisions).

1. *Prokaryotic algae* (Cyanophyta and Prochlorophyta)
2. *Eukaryotic algae* with chloroplast surrounded *only by the two membranes of the chloroplast envelope* (Glaucophyta, Rhodophyta and Chlorophyta)
3. *Eukaryotic algae* with chloroplast surrounded *only by one embrane of chloroplast endoplasmic reticulum* (Euglenophyta and Dinophyta)
4. *Eukaryotic algae* which have *two membranes of chloroplast endoplasmic reticulum* (Cryptophyta & Heterokontophyta)

# Classification by R.E Lee



**Group 1.** – It contains the only prokaryotic algae known as

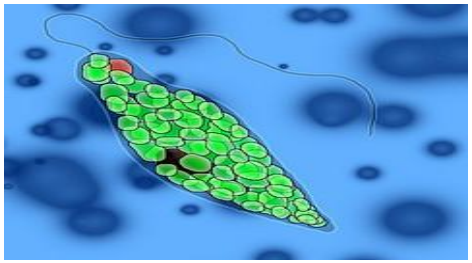
- Cyanophyta or blue-green algae.
- Prochlorophyta

**Group 2. -** Chloroplasts surrounded by 2 membranes of the CHLOROPLAST ENVELOPE (CEnv) consists of

- Glaucophyta,
- Rhodophyta, and
- Chlorophyta.

**Group 3.** One membrane of chloroplast endoplasmic reticulum (CER) consists of

- Euglenophyta and
- Dinophyta.

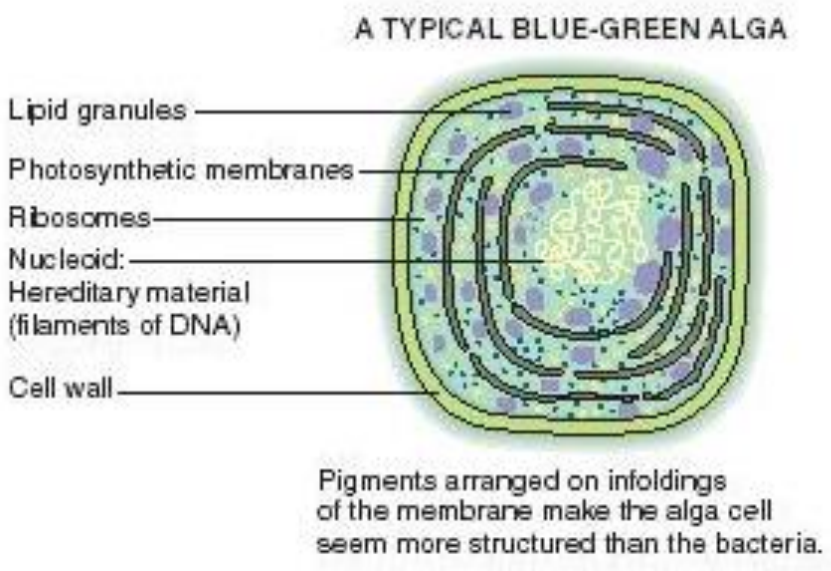


**Group 4.** Consists of algae which have two membranes of chloroplast endoplasmic reticulum. Contains

- Cryptophyta
- Heterokontophyta

# Group 1

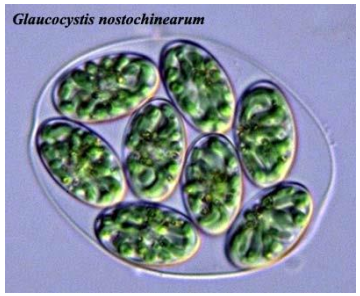
- It contains the only prokaryotic algae, the Cyanophyta or blue-green algae.
- It forms a natural group of the only prokaryotic algae.
- Prokaryotic algae have
  - An outer plasma membrane enclosing protoplasm containing photosynthetic thylakoids,
  - 70S ribosomes and
  - DNA fibrils not enclosed within a separate membrane.
- Chlorophyll a is the main photosynthetic pigment and oxygen is evolved during photosynthesis.




**Cyanophyta, Prochlorophyta**

**Group 2** – It contains

1) Glaucophyta 2) Rhodophyta 3) Chlorophyta.




- These form a natural group of algae in that they have **chloroplasts** surrounded by only the 2 membranes of the chloroplast envelope.

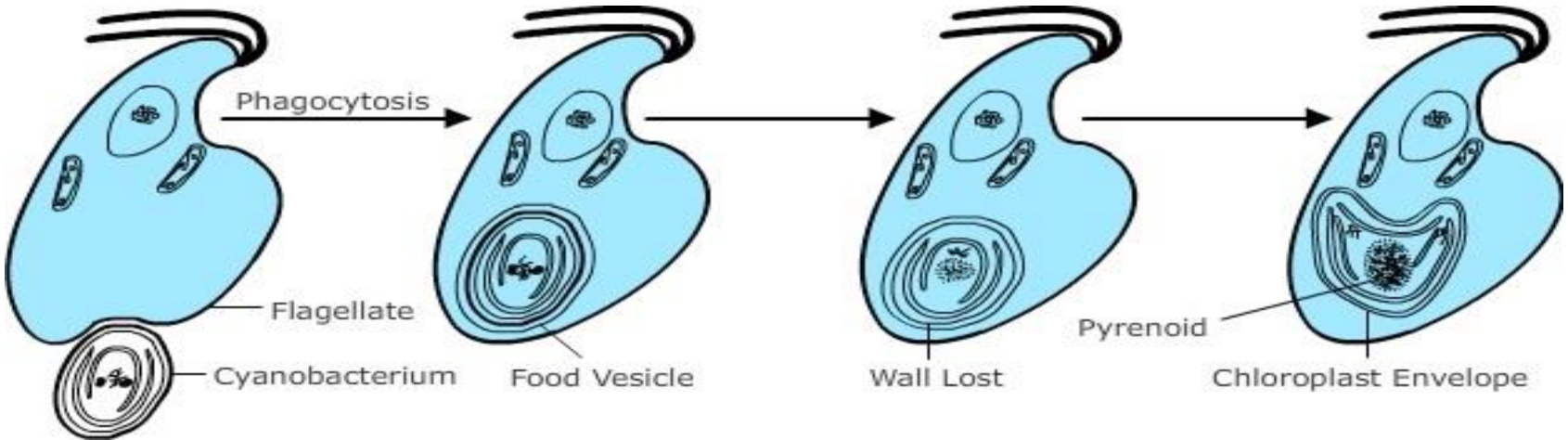
# Endosymbiotic Theory

- Early 1880s, German botanist Andreas **Schimper** (1856–1901):
  - First to describe the chloroplasts of plant cells,
  - Identified their role in starch formation during photosynthesis and
  - Noted that they divided independent of the nucleus.
- Based upon the chloroplasts' ability to reproduce independently, Russian botanist Konstantin **Mereschkowski** (1855–1921) suggested that
  - Chloroplasts may have originated from ancestral photosynthetic bacteria living symbiotically inside a eukaryotic cell.
  - He proposed a similar origin for the nucleus of plant cells.
  - This was the first articulation of the **endosymbiotic hypothesis**, and
  - This would explain how eukaryotic cells evolved from ancestral bacteria.
- American anatomist **Ivan Wallin** (1883–1969), began to experimentally examine the similarities between mitochondria, chloroplasts, and bacteria.
  - Wallin's ideas regarding the endosymbiotic hypothesis were largely ignored for the next 50 years because scientists were unaware that these organelles contained their own DNA.
- Lynn **Margulis** (1938–2011), an American geneticist, published her ideas regarding the endosymbiotic hypothesis of the origins of **mitochondria** and **chloroplasts** in 1967.

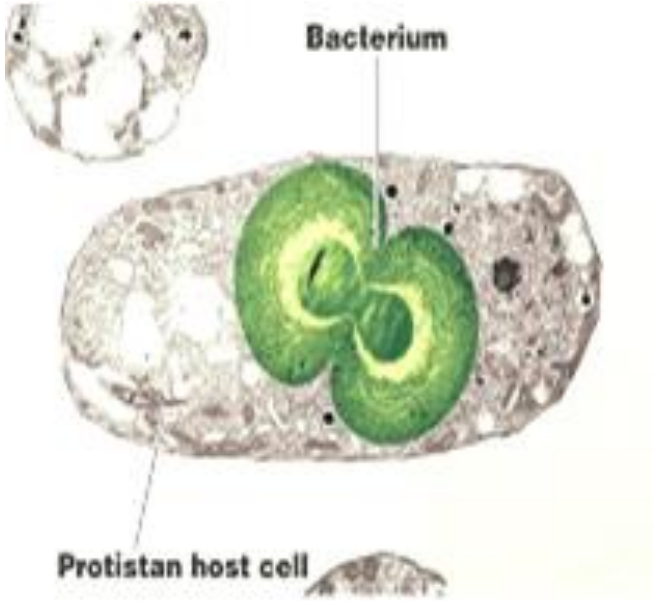
# Endosymbiotic Theory: The evolutionary event

• The uptake of a ***cyanobacterium*** by a protozoan into a food vesicle.
• This resulted in the establishment of an endosymbiosis between the cyanobacterium and the protozoan.
• Through evolution, the endosymbiotic cyanobacterium evolved into a chloroplast surrounded **by two membranes of the chloroplast envelope**. During evolution the wall of the endosymbiotic cyanobacterium was lost to facilitate the transfer of compounds between the host and the endosymbiont.
• The food vesicle membrane of the phagocytotic host became the outer membrane of the chloroplast envelope.
• The plasma membrane of the cyanobacterium symbiont became the inner membrane of the chloroplast envelope.
• Rearrangement of the thylakoid membranes and evolution of polyhedral bodies into a pyrenoid completed the transition to a true chloroplast such as it occurs in green algae.

Primary endosymbiosis



• Glaucophyta represents an intermediate stage where they have endosymbiotic cyanobacteria  in the cytoplasm instead of chloroplast.
•The host is called cyanome, the blue green alga is called cyanelle and the association between the two a syncyanosis.




*Cyanophora paradoxa* a fresh water algae belonging to Glaucophyta has two cyanelles (endosymbiont cyanobacteria) where nitrogen fixation occurs along with photosynthesis.

## Group 3 -

• They are the only algal groups to have **ONE MEMBRANE** of **CHLOROPLAST ENDOPLASMIC RETICULUM**.

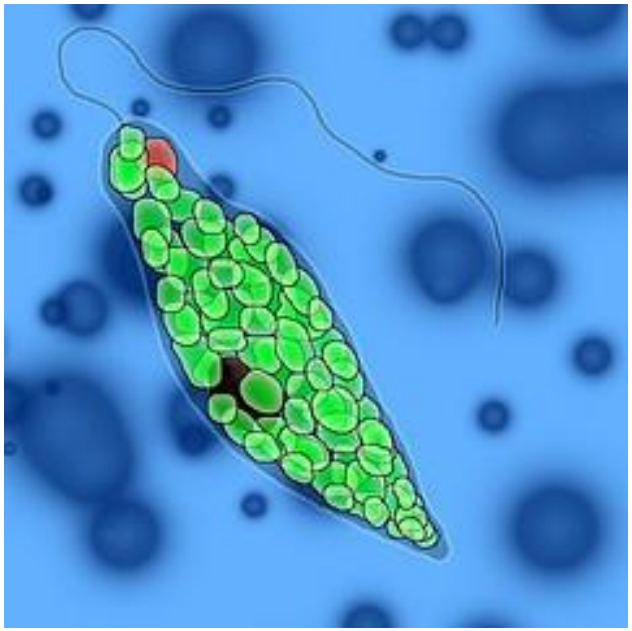
• Groups:

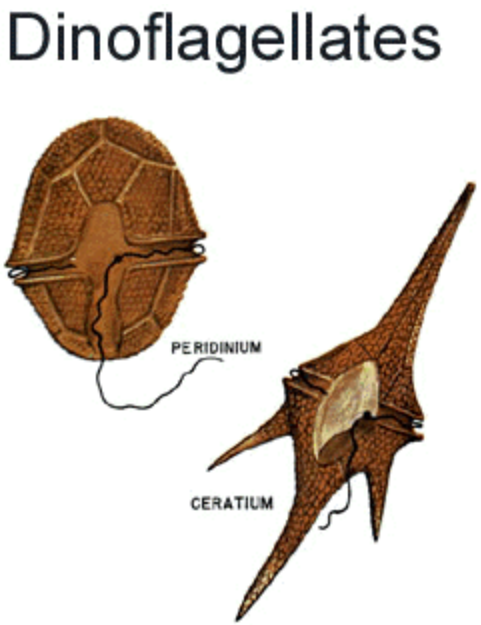
- •The Euglenophyta and
- •Dinophyta

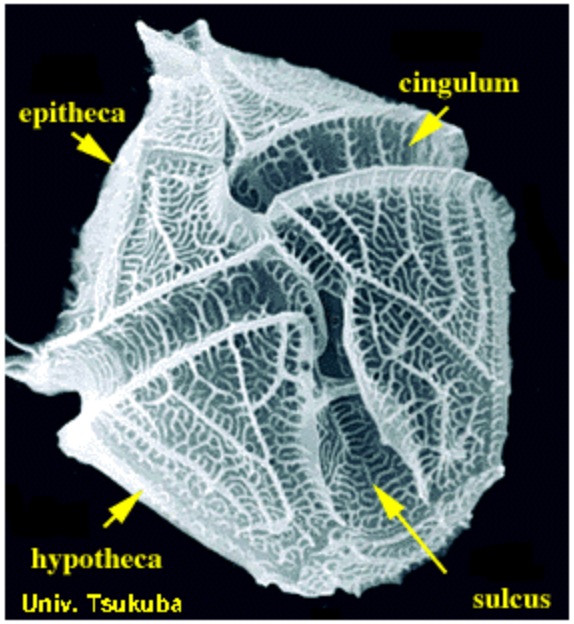
• Chloroplast endoplasmic reticulum resulted when a chloroplast from a eukaryotic alga was taken up to as a food vesicle by a phagocytotic protozoan into a food vesicle.

• The food vesicle membrane eventually evolving a single membrane of chloroplast endoplasmic reticulum surrounding the chloroplast.

Euglenophyta



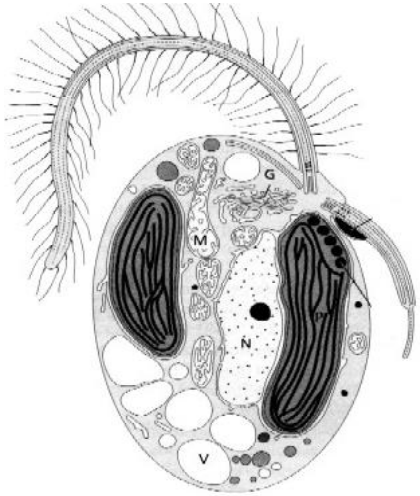


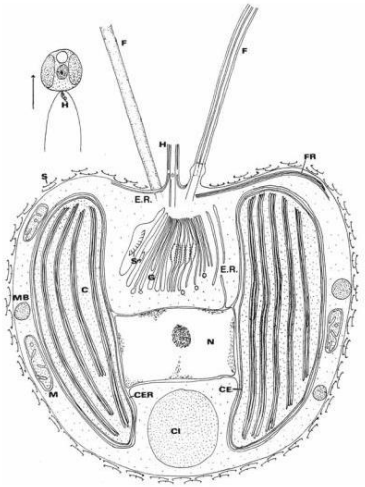
## Group 4

- Algae with **TWO MEMBRANES** of **CHLOROPLAST ENDOPLASMIC RETICULUM** (chloroplast ER)
- The inner membrane of chloroplast E.R. surrounding the chloroplast envelope.
- The other membrane of chloroplast ER is continuous with the outer membrane of the nuclear envelope and has ribosomes on the outer surface.
- Groups:
  - Cryptophyta
  - Heterokontophyta
  - Prymenophyta

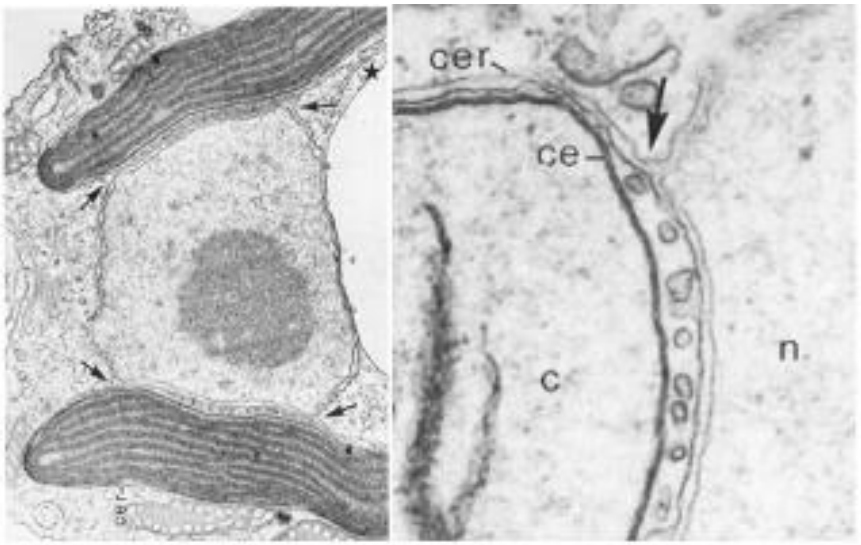
Cryptophyta




Heterokontophyta



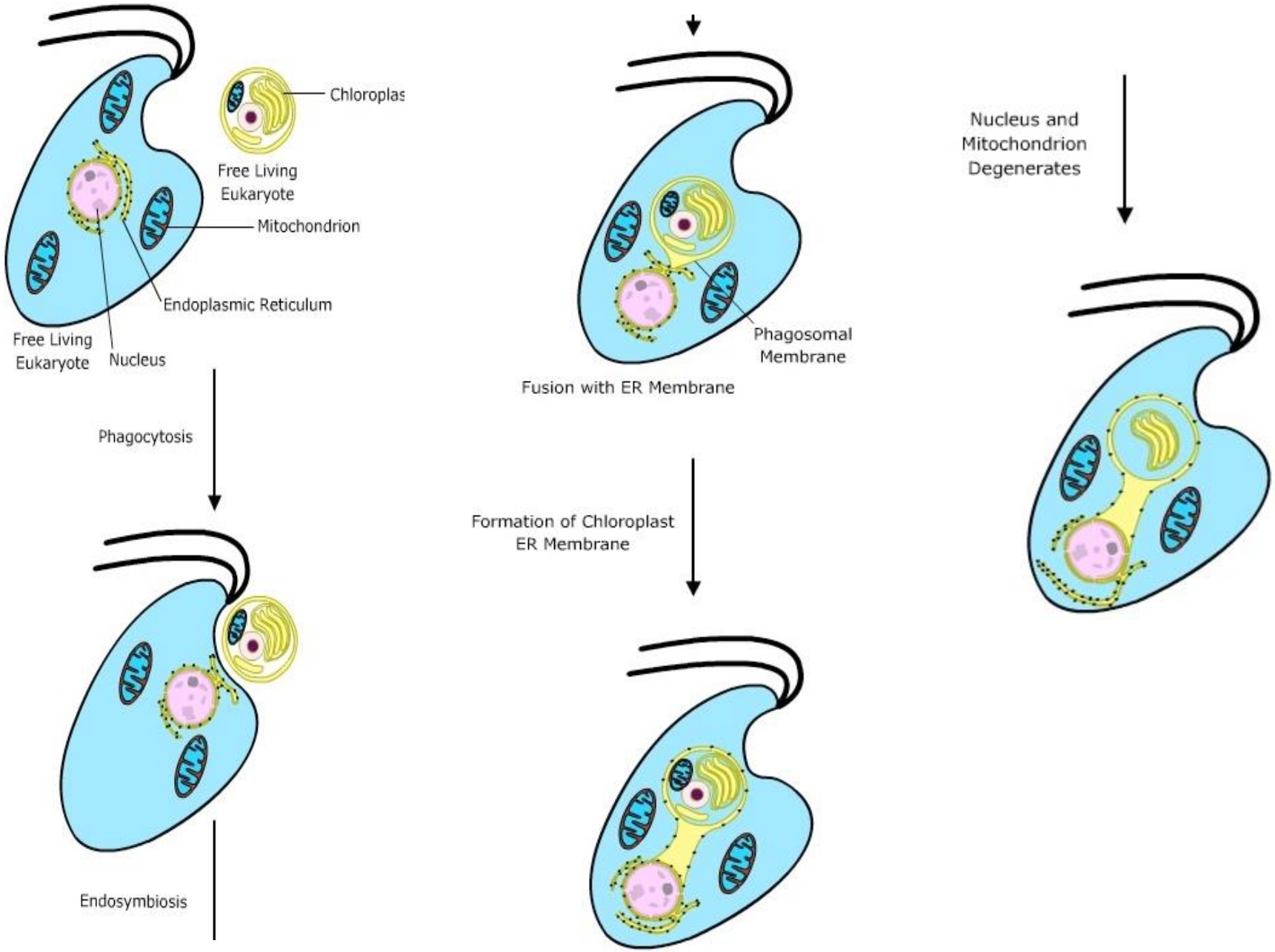

Prymnesiophyta




Section through the nucleus and adjacent chloroplast (c) of *Ochromonas danica* showing the continuity of the chloroplast ER (cer) with the nuclear envelope (arrow).

- Two membranes of chloroplast ER evolved by a ***secondary endosymbiosis***.

- A phagocytic protozoan took up a ***eukaryotic photosynthetic alga*** into a food vesicle.
- Instead of being phagocytosed by the protozoa, the photosynthetic alga became established as an endosymbiotc within the food vesicle of the protozoa.
- The endosymbiotic photosynthetic alga benefitted from the acidic environment in the food vesicle that kept much of the inorganic carbon in the form of $CO_2$ i.e. the form needed by ribulose biphosphate/ carboxylase for Carbon fixation.
- The host benefitted from receiving some of the photosynthate from the endosymbiotic alga.
- The ***food vesicle membrane*** eventually fused with the ER of the host protozoa, resulting in ribosomes on the ***outer surface*** of the membrane which became the ***outer membrane of chloroplast ER***.




**Evolution of the two membranes of the chloroplast endoplasmic reticulum**

- Through evolution, ATP production and other functions of the endosymbiont's mitochondria of the endosymbiont were lost.

- The host nucleus also took over some of the genetic control of the endosymbiont.

- The resulting cytology is characteristic of the extant cryptophytes which have a nucleomorph representing the degraded endosymbiont nucleus, as well as starch produced in what remains the endosymbiont cytoplasm.

- The type of chloroplast ER that exists in the Heterokontophyta and the Prymnesiophyta resulted from further reduction.

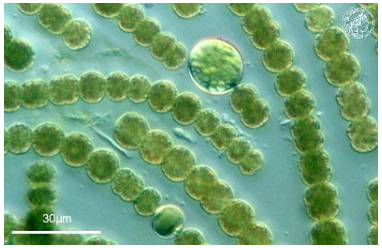
- The nucleomorph was completely lost and storage product formation was taken over by the host.

- The resulting cell had two membranes of chloroplast envelope surrounding the chloroplast. Outside of this was the inner membrane of chloroplast ER that was the remains of the plasma membrane of the endosymbiont.

- Outside of this was the outer membrane of chloroplast ER which was the remains of the food vesicle membrane of the host.

Group I: Prokaryotic algae

1. **Cyanophyta** (cyanobacteria) : Blue green algae
   a) Chlorophyll a;
   b) Phycobiliproteins
   c) Example: *Anabaena*, *Gleotrichia*
2. **Prochlorophyta**:
   a) Chlorophyll a and b
   b) No phycobiliproteins
   c) Example: *Prochloron*

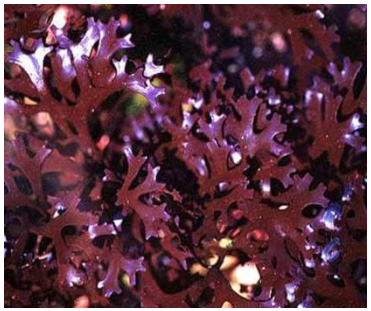


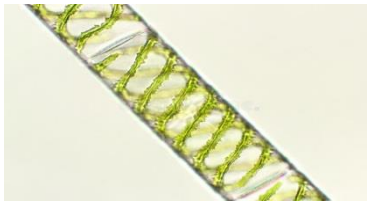
*Anabaena*


*Glaucocystis*

Group II: Eukaryotic algae with chloroplasts surrounded only by the two membranes of the chloroplast envelope.

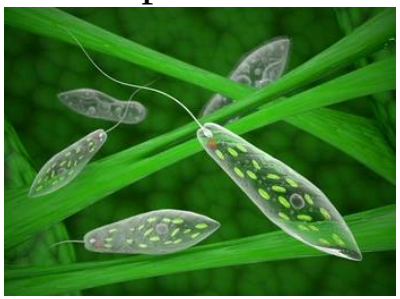
1. **Glaucophyta**:
   a) Intermediate in the evolution of chlorophyll.
   b) Photosynthesis is carried out by modified endosymbiotic cyanobacteria.
   c) Example: *Cyanophora paradosa*, *Glaucocystis*.
2. **Rhodophyta** (red algae): Red algae
   a) Chlorophyll a and d.
   b) Phycobiliproteins.
   c) No flagellated cells.
   d) Storage product is floridean starch.
   e) Example: *Prophyra*, *Chondrus*.
3. **Chlorophyta** (green algae): Green algae
   a) Chlorophyll a and b;
   b) Storage product: starch (found inside the chloroplast).
   c) Example: *Spirogyra*, *Chara*.


*Chondrus*


*Spirogyra*

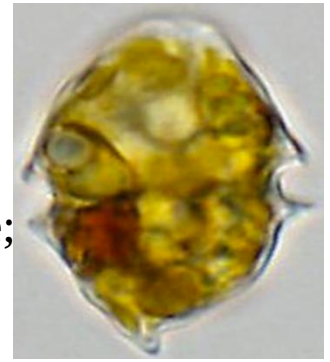
Group III Eukaryotic algae with chloroplasts surrounded by one membrane of chloroplast endoplasmic reticulum.

1. Euglenophyta (euglenoids):
   a) Chlorophylls a and b;
   b) One flagellum with a spiraled row of fibrillar hairs;
   c) Proteinaceous pellicle in strips under the plasma membrane;
   d) Storage product is paramylon starch;
   e) Example: *Euglena*.



*Euglena*

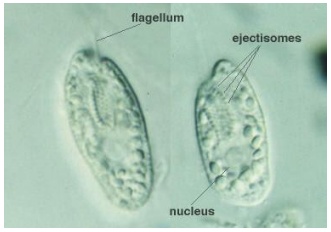
2. Dinophyta (dinoflagellates):
   a) Mesokaryotic nucleus;
   b) Chlorophylls a and c1;
   c) Cell commonly divided into an epicone and a hypocone by a girdle;
   d) Helical transverse flagellum
   e) Example: *Heterocapsa*, *Peridium*.



*Heterocapsa*

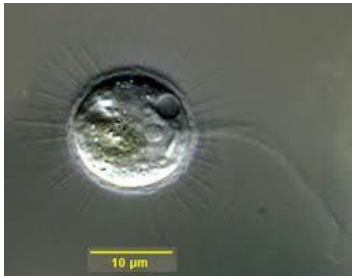
Group IV Eukaryotic algae with chloroplasts surrounded by two membranes of chloroplast endoplasmic reticulum.

1. Cryptophyta (cryptophytes):
   a) Nucleomorph present between inner and outer membrane of chloroplast endoplasmic reticulum;
   b) Starch formed as grains between inner membrane of chloroplast endoplasmic reticulum and chloroplast envelope
   c) Chlorophyll a and c
   d) Phycobiliproteins
   e) Periplast inside plasma membrane.
   f) Example: *Chilomonas*

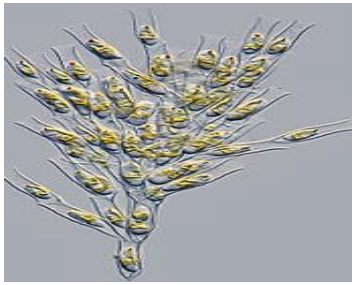


*Chilomonas*

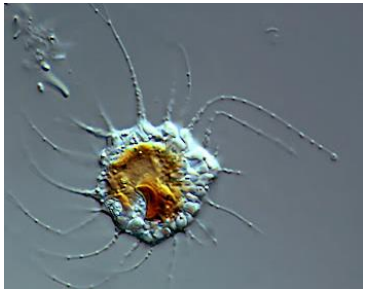
2. Heterokontophyta (heterokonts): anterior tinsel and posterior whiplash flagellum; chlorophyll a and c; fucoxanthin; storage product usually chrysolaminarin occurring in vesicles.
   a) Chrysophyceae:
      i. Chlorophyll a nd c1
      ii. Fucoxanthin
      iii. Anterior tinsel and posterior whiplash flagellum
      iv. Storage product: Chrysolaminarin.
      v. Example: *Paraphysomonas*.
   b) Synurophyceae:
      i. Chlorophyll c1
      ii. Flagella inserted into cell approximately parallel to each other.
      iii. Eye-spot present.
      iv. Example: *Sinura*.



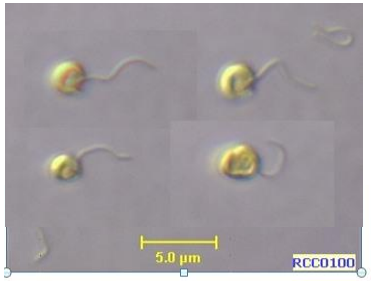
*Paraphysomonas*


*Sinura*

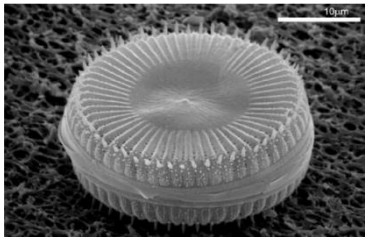
c) Dictyophyceae: Golden brown algae
   i. Have tentacles or rhizopodia on amoeboid vegetative cell.
   ii. Example: *Chrysoamoeba*
d) Pelagophyceae:
   i. Unicellular, chlorophyll a nd $c_1$
   ii. Cells are very small (uktraplankton).
   iii. Example: *Pelagomonas*
e) Bacillarophyceae: Diatom
   i. Silica in cell well.
   ii. Chlorophyll- a, $c_1$ and $c_2$
   iii. Fucoxanthin.
   iv. One anterior tinsel flagellum on sperm cell.
   v. Storage product: Chrosolaminarin.
   vi. Vegetative cell are diploid (2n).
   vii. Example: *Cyclotella*.
f) Xanthophyceae: Yellow green algae
   i. Eye spot in chloroplast.
   ii. Chlorophyll a and c.
   iii. Anterior tinsel and posterior whiplash flagellum
   iv. Example: *Botrydium*, *Vaucheria*.



*Chrysoamoeba*




*Pelagomonas*



*Cyclotella*

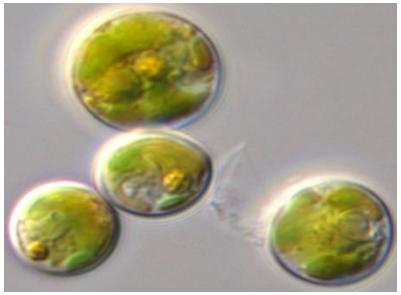
*Vaucheria*

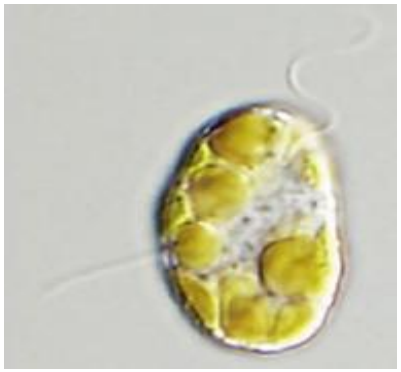
g) Eumastigophyceae
   i. Eyspot large outside chloroplast.
   ii. Chloroplast a and c.
   iii. Anterior tinsel and posterior whiplash flagellum
   iv. Example: *Pleurochloris.*

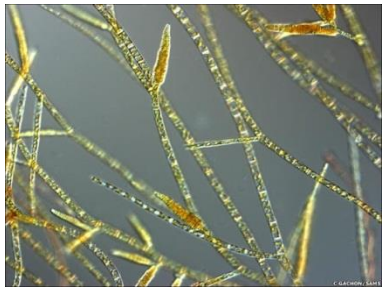
h) Raphidophyceae: Chloromonads
   a) Chlorophyll a nd c
   b) Anterior tinsel and posterior whiplash flagellum
   c) Example: *Heterostigma.*

i) Phaeophyceae: Brown algae
   a) Unicellular and pleurilocular sporangia.
   b) Chlorophyll- a, $c_1$ and $c_2$
   c) Fucoxanthin.
   d) Anterior tinsel and posterior whiplash flagellum.
   e) Storage product: Chrysolaminarin.
   f) Example: *Ectocarpus, Laminarin.*

3. Prymnesiophyta: Haptophytes:
   a) Unicellular, flagellate.
   b) Haptonema present between two smooth flagella.
   c) Chlorophyll a and c.
   d) Fucoxanthin.
   e) Scales common outside cell;
   f) Storage product chrysolaminarin occurring in vesicles.
   g) Example: *Prymnesium.*


*Pleurochloris*


*Heterostigma*


*Ectocarpus*

*Prymnesium*