What are algae?

Are they a monophyletic group?
Archaeplastida (Plantae)
  └── Green plants (green algae, including prasinophytes, and land plants)
      └── Rhodophyta (red algae)

Glaucophytes (microalgae with uniquely cyanobacteria-like chloroplasts; e.g. Cyanophora)
      └── Animals (Metazoa)
           └── Choanoflagellates (collared-flagellates)

Filasterea
  └── Ichthyosporea

Unikonta
  └── Fungi (mushrooms, sac fungi, yeast, molds, rusts, smuts, etc.)
      └── Nucleariidae (filose amoebae; e.g. Nuclearia)

Amoebozoa
  └── Eumycetozoa (slime molds; e.g. dictyostelids and myxogastirids)
      └── Archamoebae (e.g., Ertaamoeba)
           └── Lobosea (lobose amoebae; e.g. Amoeba, Chaos and Diffugia)

Cercozoa (amoeboflagellates; e.g. euglyphids, chlorarachiophytes)
  └── Foraminifera (complex cells with reticulopodia and a test/shell)
      └── Radiolarians (polycistines and acantharia)

Rhizaria
  └── Alveolates (dinoflagellates, ciliates and apicomplexan parasites)
      └── Stramenopiles (oomycetes, diatoms, brown algae, chrysomonads and relatives)

Picobiliphytes
  └── Telonema (genus of heterotrophic flagellates)
      └── Cryptomonads (microalgae with a plastid-associated nucleomorph; e.g. Cryptomonas)
          └── Kathablepharids (heterotrophic biflagellates; e.g. Katablepharis)

Malawimonads
  └── Discicristates
      └── Euglenozoa (euglenids, diplonemids and kinetoplastids; e.g. Euglena and Trypanosoma)
          └── Heterolobosea (amoeboflagellates with discoidal mitochondrial cristae)
              └── Jakobida (free-living, heterotrophic flagellates)

Parabasalids (trichomonads and hypermastigotes, e.g. Trichomonas and Trichonympha)
  └── Fornicata (diplomonads and retortamonads; e.g. Giardia and Chilomastix)
      └── Preaxostyla (oxymonads + Trimastix)

?≡ Protists of uncertain placement
How did chloroplasts arise?

1. Cyanobacteria: photosynthetic bacteria
2. Endosymbiosis: engulfing of cyanobacterium by early eukaryotic cell (primary endosymbiosis)
3. Primary endosymbiosis: red and green algae
4. Secondary endosymbiosis: engulfing eukaryotic cell that contains photosynthetic plastid; capturing a red or green alga
5. Brown algae such as kelp got their chloroplasts via secondary endosymbiosis
Primary endosymbiosis

Secondary endosymbiosis

Cyanobacterium

Green & Red algae

Brown algae
Primary endosymbiosis

Glaucoiphytes

Red algae

Chlorophytes

Land plants

Charophytes

Green algae
Secondary endosymbiosis

- Apicomplexans
- Dinoflagellates
- Ciliates
- Brown algae
- Diatoms
- Oomycetes
- Haptophytes

- Alveolates
- Stramenopiles
Consumption/use of cyanobacteria

- **Spirulina** (*Arthrospira* sp.)
- Occurs naturally in tropical/subtropical lakes
- Food source for Aztecs: cultivation of bacterial mats
- Chad—dried cakes called Dihé
- High amount of protein, essential fatty acids, vitamins & minerals
- Suggestion of medicinal/health benefits including anti-HIV
- Source of blue dye for new (2008) naturally-dyed Smarties in UK
- Used as animal feed additive

Artificial dye → **Spirulina clip**

Spirulina dye →
100 species of marine algae consumed, especially in Asia

- Domestication of macroalgae recent compared to terrestrial plants
- <20 species domesticated in last 200 years, seven within last 10 years
- Important to understand and control reproduction and propagation
- Seaweed aquaculture in Asia, Chile for food and colloid production
- High protein content, vitamins and minerals
- Main farmed species: brown kelps *Laminaria* sp. (Kombu) and *Undaria pinnatifida* (Wakame); red algae *Porphyra* sp. (Nori) and *Gracilaria* sp.
Brown algae

*Laminaria* sp. (Kombu)

- Used for centuries in Japan, with majority cultivated in Hokkaido (cultivated since 1730)
- Often boiled with aniline dye malachite green
- Main ingredient for soup stock *dashi*, also source of glutamic acid (umami taste); brewed with tea (kombucha)
Brown algae

*Undaria pinnatifida* (Wakame)

- Often cultivated with *Laminaria*
- Cultivated in Japan and Korea, invasive in New Zealand
- Eaten as “wakame chips”, coated with sugar, or mixed with rice
- Used in soups (Miso) & salads, side dishes
Primary endosymbiosis

- Glaucophytes
- Red algae
- Chlorophytes
  - Land plants
  - Charophytes
What is the most commonly consumed red alga?
Red algae

Nori (*Porphyra* sp.)

- Consumed by many cultures; long history of use (533 A.D.)
- Cultivation began ca. 1625 in Japan (*Porphyra yezoensis*), bamboo twigs were placed in intertidal zones and algae grew on bamboo
- In mid-1900’s, with understanding of life-cycle, commercial cultivation possible
- Cultivated in shallow bays with nets seeded with propagules
- Washed, chopped, poured onto frames (similar to paper making), dried, toasted
Porphyra used wherever it grows: laver in England and US, slack in Scotland, sloke in Ireland, karengo by the Maori in New Zealand, luche in Chile.
Sea lettuce (*Ulva lactuca*) consumed in various places including the UK, Scandinavia, China and Japan

- Eaten raw in salads or cooked in soup
- Various microalgae used/investigated as biofuels, health food supplements (e.g., beta-carotene, omega-3 fatty acids), aquaculture feeds
Colloid Compounds

• Phycocolloids/Hydrocolloids in cell walls; polysaccharides that are used as emulsifiers, stabilizers, gelling agents

• Also referred to as “gums”, polysaccharide compounds composed of sugars other than glucose (often galactose, xylose…) that are soluble in water or absorb water

• Mixing these compounds with water forms a gel; colloid = substances suspended but not dissolved in water

• Common gels not from algae include gum arabic (exuded from wounded trees of Acacia senegal; Fabaceae)—sticky substance licked on a stamp or envelope; also two other legumes: locust bean gum (seeds of carob, Ceratonia siliqua) and guar gum (ground endosperm of Cyamopsis tetragonolobus)
Phycocolloids from red algae

Carrageenan: a sulfated polysaccharide composed of galactose derivatives

- Whole plants of Irish moss (*Chondrus crispus*) used for centuries in jellies and puddings
- Added for creamy texture, thickening, gelling
- Component of de-icing fluid for airplanes
- May have some anti-viral properties, anti-coagulant
- First extracted from Irish moss (in North Atlantic), now also extracted from *Euchema* and *Kappaphycus* (Phillipines and Indonesia)
- Irish moss usually collected from wild by hand along beaches, *Eucheuma* cultivated on lines attached to poles.
Phycocolloids from red algae

**Agar:** mixture of *agarosepectin* and *agarose*

*Agarose* is a polysaccharide like carrageenan but no sulfates; *agarosepectin* is also composed of galactose, but with sulfates and other side groups

- Ingredient in Japanese desserts
- Use as laxative, vegetarian gelatin, thickener, clarifier (aggregate with proteins that “cloud” products such as juices, vinegar), binder for medicines
- Agar as culture medium in laboratory (ease of transition between liquid and gel states through heating and cooling)
- Agarose does not bind to proteins, DNA; very useful for gel separation of these large molecules
- *Gracilaria, Gelidium* are the main genera used for these products
Phycocolloids from brown algae

Alginic acid: gummy substance in cell walls; used as glue to stick holdfast to substrate

• Polymer with sugar acids, mannnuronic and guluronic acids

• Alginates very important for colloidal properties--stabilize emulsions. Used in pharmaceuticals, foods (emulsifier in ice cream), cosmetics, treatment of latex during manufacture, dental impressions

• Absorbs water quickly (gelatinous substance can absorb 200-300 times its weight in water)—used as appetite suppressant

• Active ingredient in heartburn/acid-reflux medication Gaviscon: works with bicarbonate to create a barrier preventing stomach acid from going up esophagus

• Extracted commercially from giant kelp (Macrocystis pyriforma), Ascophyllum nodosum, Laminaria sp.
Laminaria

Giant kelp
Algae and medicine: Red algae

- Anti-viral activity of polysaccharides from red algae
- *Digenea simplex* used for internal parasites (properties suggested by dugong, which eats both sea grasses and *Digenea*); kainic acid is active compound that acts as vermifuge, also found to be central nervous system stimulant
Algae and medicine: Brown algae

• Fibers from alginate to make calcium alginate fabrics that can be used as absorbent wound dressings
• Chelating agents for treatment of heavy metal or radioactive poisoning
• *Laminaria* prescribed for goiter (insufficient iodine)
• *Laminaria* stipes used for dilation in obstetrics/gynecology
Algae and medicine: Brown algae

- Fucoidan is a sulfated polysaccharide (galactose, xylose and fucose sugars) from various brown algae including kombu
- Medicinal uses under investigation: anti-coagulant and anti-tumor properties