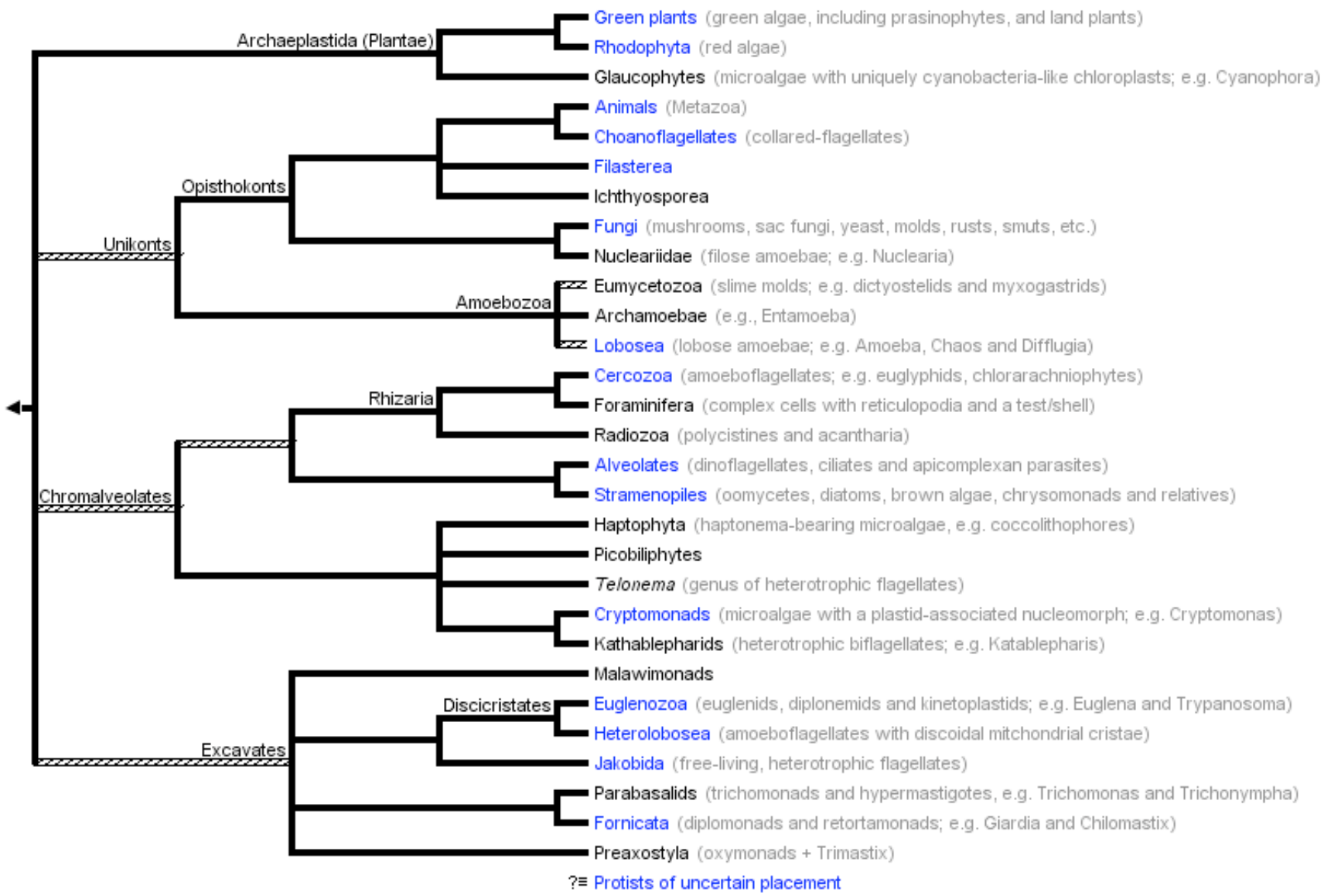


What are algae?

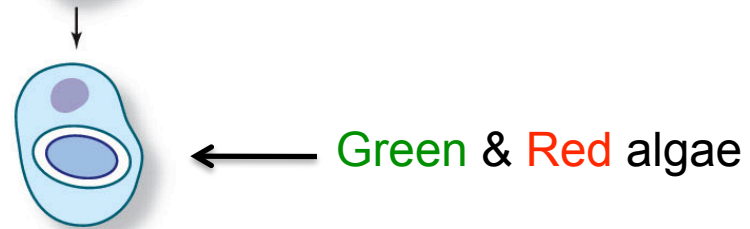
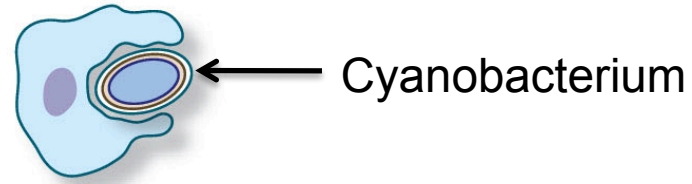
Are they a monophyletic group?



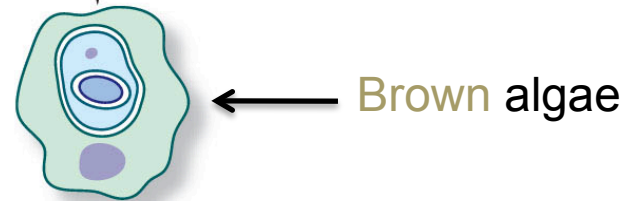
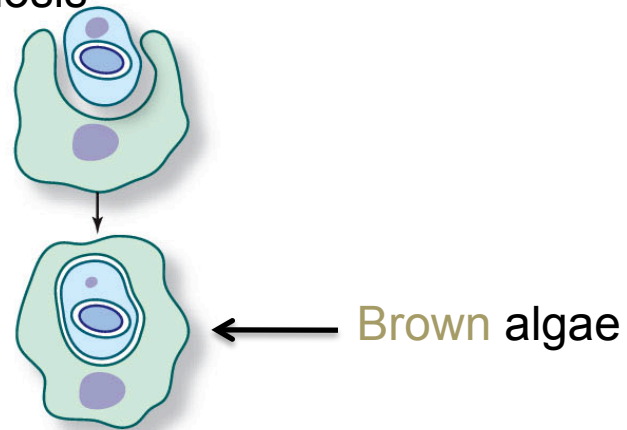
# How did chloroplasts arise?

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

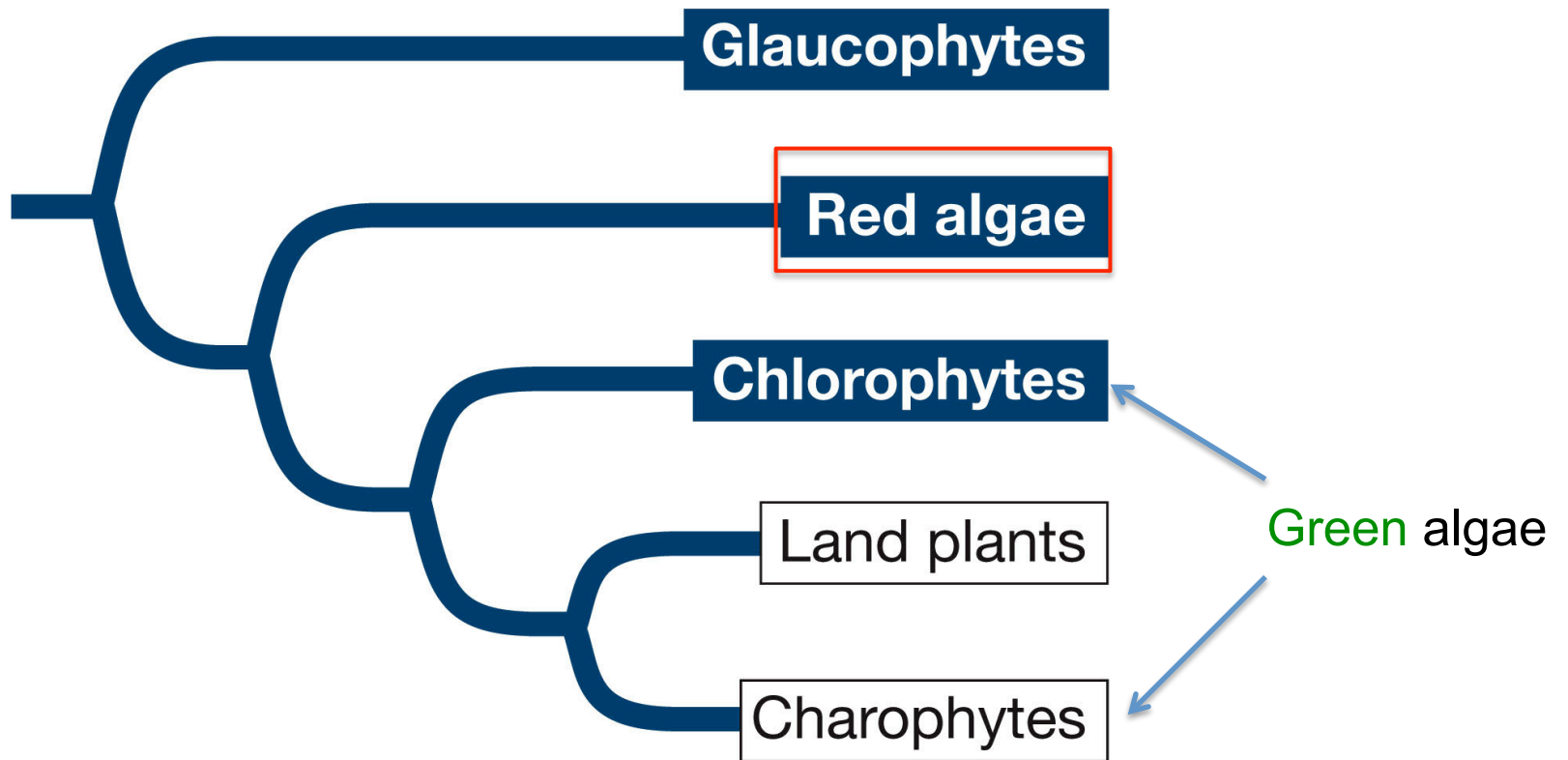


Secondary endosymbiosis

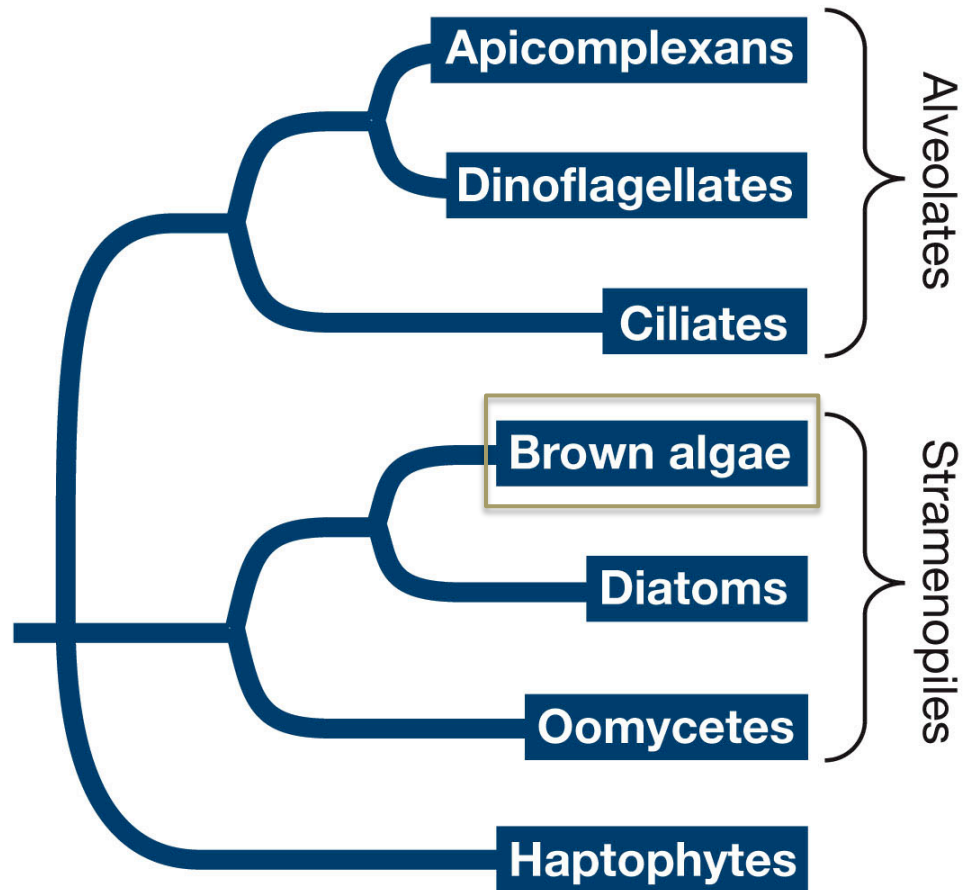




# Primary endosymbiosis

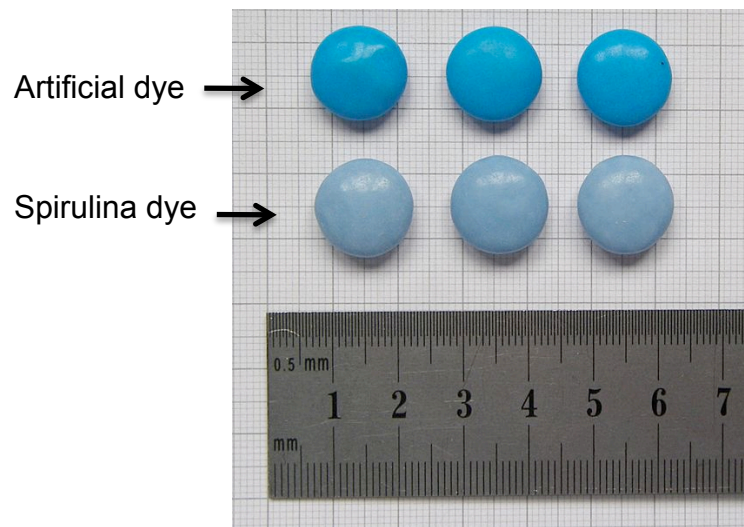


# Secondary endosymbiosis



# Consumption/use of cyanobacteria

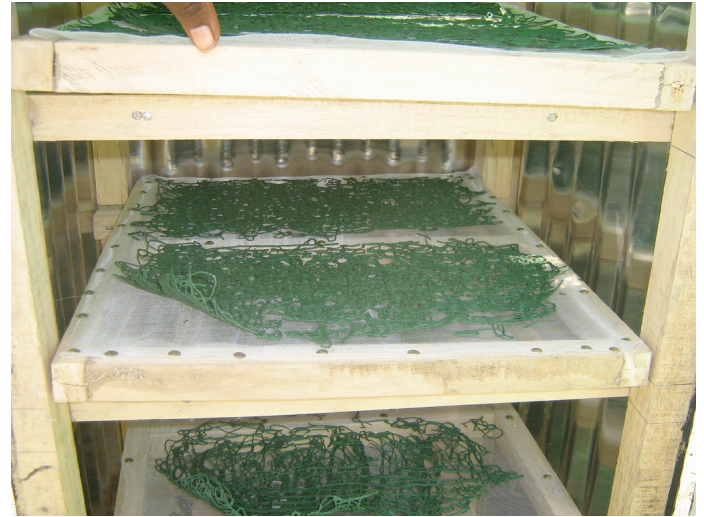
- Spirulina (*Arthrospira* sp.)
- Occurs naturally in tropical/subtropical lakes
- Food source for Aztecs: cultivation of bacterial mats
- Chad—dried cakes called Dihé
- High amount of protein, essential fatty acids, vitamins & minerals
- Suggestion of medicinal/health benefits including anti-HIV
- Source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



[Spirulina clip](#)







## **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)



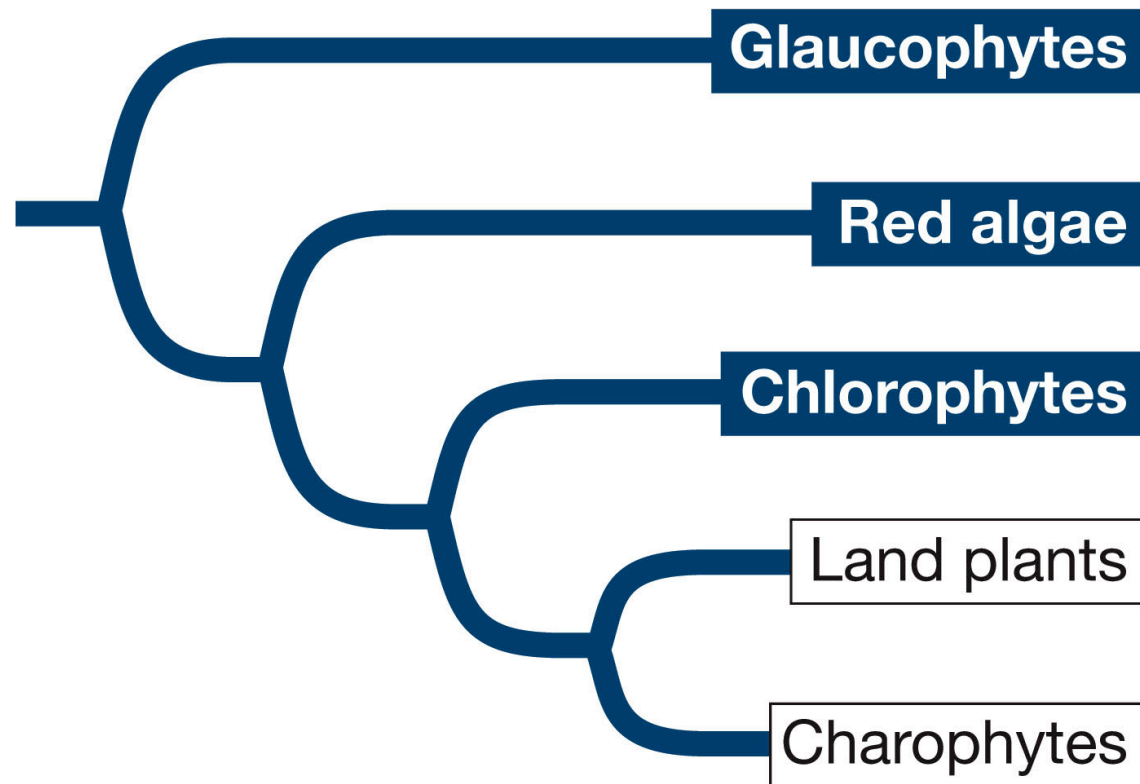
# Brown algae

## *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



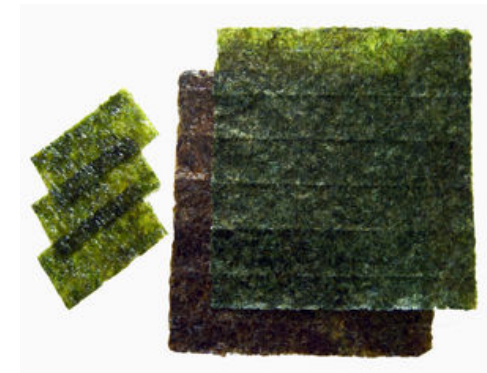


What is the most commonly consumed red alga?

# 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





# Green algae



- **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

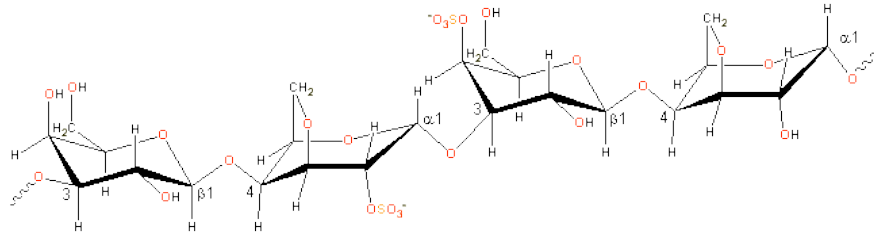
- Phycocolloids/Hydrocolloids in cell walls; polysaccharides that are used as emulsifiers, stabilizers, gelling agents
- Also referred to as “gums”, polysaccharide compounds composed of sugars other than glucose (often galactose, xylose...) that are soluble in water or absorb water
- Mixing these compounds 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 *Eucheuma* and *Kappaphycus* (Phillipines and Indonesia)
- Irish moss usually collected from wild by hand along beaches, *Eucheuma* cultivated on lines attached to poles.

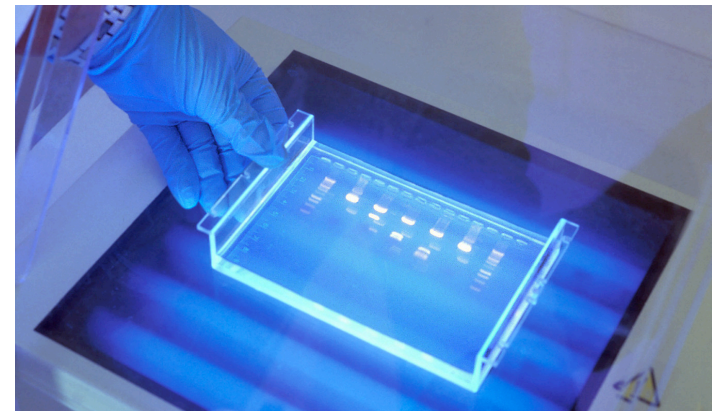
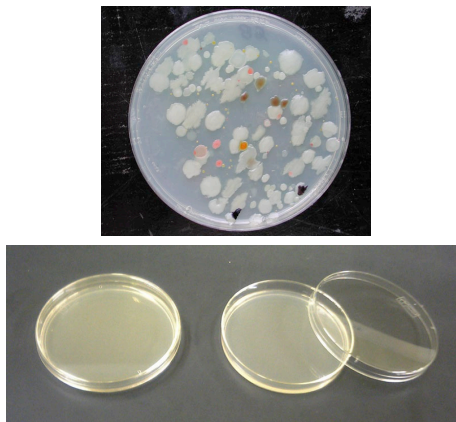
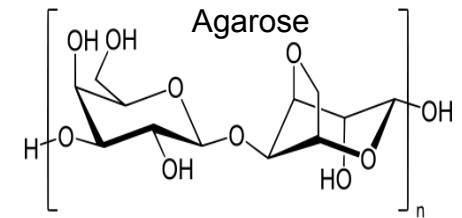


# Phycocolloids from red algae

**Agar:** mixture of **agaropectin** and **agarose**

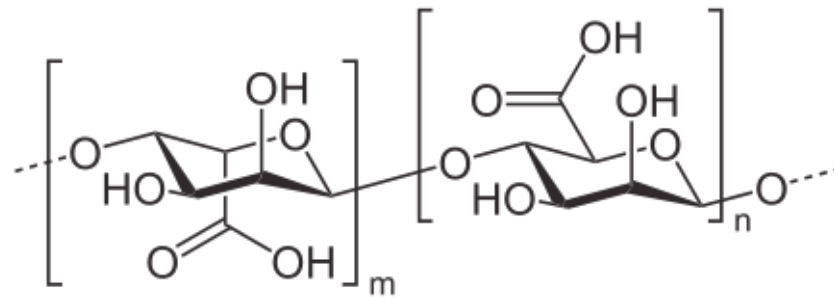
**Agarose** is a polysaccharide like carrageenan but no sulfates; **agaropectin** is also composed of galactose, but with sulfates and other side groups

- 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, mannuronic 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 pyrifera*), *Ascophyllum nodosum*, *Laminaria* sp.



# Laminaria



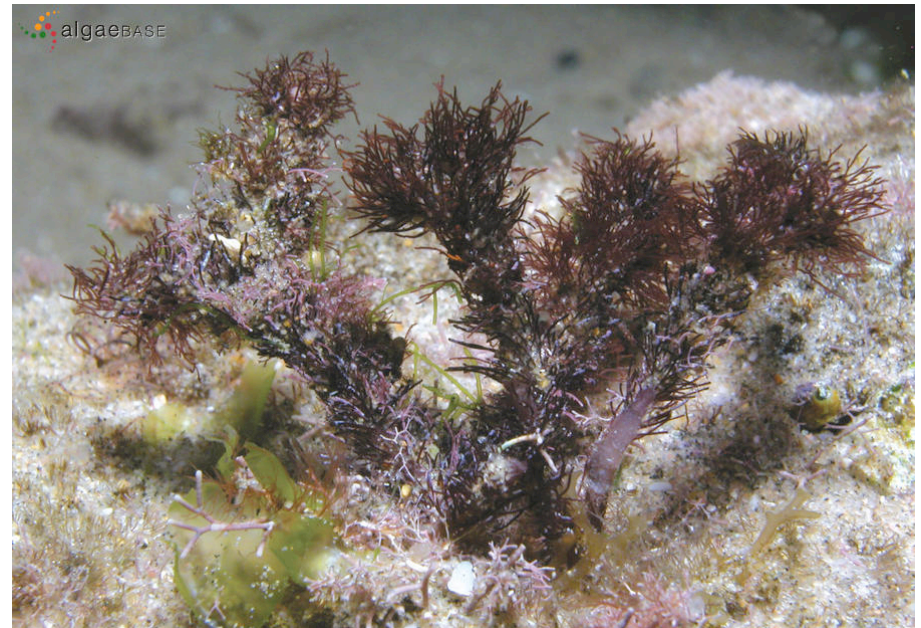
# Giant kelp





## 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

