Division: Ochrophyta
Or (Heterokontophyta, Chromophyta, Phaeophyta)

~ 16,999 species
99% marine

Algal Evolution:

3.9 bya = Cyanobacteria appear and introduce photosynthesis
2.5 bya = Eukaryotes appeared (nuclear envelope and ER thought to come from invagination of plasma membrane)
1.6 bya = Multicellular algae - Rhodophyta (Red algae) & Chlorophyta (Green algae)
900 mya = Dinoflagellates & Invertebrates appear
490 mya = Phaeophyceae (Brown algae) & land plants & coralline algae & crustaceans & mussels
408 mya = Insects & Fish
362 mya = Coccolithophores & Amphibians & Reptiles
290 mya = Gymnosperms
145 mya = Diatoms & Angiosperms

Algae

1. Alveolates- dinoflagellates, coccolithophore
2. Stramenopiles- diatoms, ochrophyta
3. Rhizaria- unicellular amoeboids
4. Excavates- unicellular flagellates
5. Plantae- rhodophyta, chlorophyta, seagrasses
6. Amoebozoans- slimemolds
7. Fungi- heterotrophs with extracellular digestion
8. Choanoflagellates- unicellular
9. Animals- multicellular heterotrophs

Chromista

1. Alveolates- dinoflagellates
2. Stramenopiles- diatoms, ochrophyta
3. Rhizaria- unicellular amoeboids
4. Excavates- unicellular flagellates
5. Plantae- rhodophyta, chlorophyta, seagrasses
6. Amoebozoans- slimemolds
7. Fungi- heterotrophs with extracellular digestion
8. Choanoflagellates- unicellular
9. Animals- multicellular heterotrophs
DOMAINEukaryotes
Chromista = 17,500 spp. chloroplasts derived from red algae contains Alveolates & Stramenopiles according to Algaebase

Group Stramenopiles- 13,500 spp two unequal flagella, chloroplasts 4 membranes

Division Ochrophyta- 13,235 spp. - many classes unicellular
  - class: Aurearenophyceae- 32
  - class: Bacillariophyceae- 9657 pennate diatoms
  - class: Bellidophyceae- 14
  - class: Chrysophyceae- 595
  - class: Coscinodiscophyceae- 2199 centric diatoms
  - class: Dictyochophyceae- 106
  - class: Eustigmatophyceae- 36
  - class: Fragilariophyceae- 785
  - class: Pelagophyceae- 16
  - class: Phaeophyceae- 2059 brown algae
  - class: Phaeophyceae- 2059
  - class: Picophagophyceae- 4
  - class: Placidiophyceae- 2
  - class: Raphidophyceae- 28
  - class: Synurophyceae- 314
  - class: Xanthophyceae- 557

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Algal taxonomy
Hierarchical system of classification:

<table>
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<th>Level:</th>
<th>suffix:</th>
<th>example:</th>
</tr>
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<tr>
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<td>Chromista</td>
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<td>Phaeophyceae</td>
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<td>Division</td>
<td>Ochrophyta</td>
<td>Laminariales</td>
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<tr>
<td>species</td>
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</tbody>
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Ochrophyta Characteristics:

1) Pigments?
2) Chloroplast structure?
3) Storage product?
4) Flagella?
Phaeophyceae Storage Products:

- laminaran and mannitol are most abundant
- Always sugars, never starch
- Storage products found in pyrenoids

Seawater is hypotonic (less saline) than most algal cells

Phaeophyceae Storage Products:

- Mannitol function
  - important in osmoregulation - algae make more mannitol to use up ions -> algal salinity decreases
  - transporting organic material to different parts of the thallus in large species
  - lowers freezing point

Phaeophyceae Flagella:

- Heterokont flagella:
  - Anterior "flimmer flagellum"
    - used for movement
    - long flagellum with two rows of stiff hairs ("mastigoneme")
    - directed forward
  - Posterior "whiplash flagellum"
    - used for steering
    - short, smooth flagellum
    - directed backward
    - contains flavin which functions as a photoreceptor
    - an eyespot acts a shading structure or light reflector

Flagella attached laterally not apically

Phaeophyceae Metabolites:

- Tannins - polyphenolic compounds
- Terpenes - aromatic hydrocarbons
- Anti-endophyte, -epiphyte, and anti-herbivory
- Stored in special vesicles called physodes in the cytoplasm
- May strengthen cell walls by interacting with alginates
- Block UVB protecting algae from radiation damage
Phaeophyceae Thallus Morphology:
- Advanced forms: complex multicellular thalli
- Not unicellular (except gametes and spores)
- Simplest forms are branching filaments
- More complex forms are parenchymatous and pseudoparenchymatous
- Differentiation of cortex (outer pigmented cells) and medulla (inner non-pigmented cells)
- Medullary cells → primarily for storage or transport
- Some brown quite large → over 40 meters long

Phaeophyceae Morphology of Cell Walls
Two main components:
1. Cellulose → microfibrils (1-10% of thallus dry weight)
   Function: structural support
2. Alginic acid → surrounds the microfibrills (35% of thallus dry weight)
   Function: elasticity; flexibility; prevent desiccation; and osmoregulation (ion exchange)

Phaeophyceae Alginates:
Alginates = salt form of alginic acid; primarily in intercellular matrix
- Alginates = Alginic acid + an Ion
- Details of how alginates are used in helping ion exchange are not well understood.
- One proposed mechanism is that preferentially using some ions and not others helps to balance overall ion levels.
- Common ions that are used to make alginates are Ca, Na and Mg

Phaeophyceae Alginates:
Human uses for alginates →
- Ice-cream → prevents ice crystal formation
- Frosting → water retaining properties; prevent drying
- Paints → emulsifying agent; keeps pigments suspended and prevents brush streaking
- Pharmaceuticals
- Food → "kombu" in Japan; dried and shredded laminarians
**Algal life histories: Terminology**

Sporophyte: diploid, 2n, multicellular → release spores

Sporangia = structure where spores are formed

Sporangia: structure where spores are formed

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Gametophyte: haploid, 1n, multicellular → release gametes

Gametangia = structure where gametes are formed

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**Phaeophyceae Reproduction:**

Functional Anisogamy = look the same but have different behaviors

How do the male gametes find the female ones?

Pheromones = chemicals produced to elicit a specific behavioral or physiological response from another individual.

Many Phaeophyceans produce sexual pheromones, all are chemically similar (unsaturated hydrocarbons). Similarity → high cross-reactivity

Male gametes are VERY sensitive to pheromones: very low concentration will elicit a response

Phaeophyceae Reproduction:

Female gamete

Male gamete

Functional Anisogamy = look the same but have different behaviors

Phaeophyceae Reproduction:

Unilocular = all spores/gametes are produced in a single compartment

"unangia"

Plurilocular = divided into many small chambers (locules), one spore/gamete per chamber

"plurangia"
Phaeophyceae habitat:

- Mostly marine (or at least brackish water)
- Intertidal and subtidal
- Dominate colder waters

→ Northern hemisphere:

# of red species > # of brown species

# of red individuals << # of brown individuals

Browns are less diverse but more abundant

Division: Ochrophyta - 16,999 species
Class: Phaeophyceae - 2,060 species
Order: 19 orders but we will focus on 6
1. Fucales - 591 species
2. Ectocarpales - 787 species
3. Dictyotales - 272 species
4. Ralfsiales - 35 species
5. Desmerestales - 29 species
6. Laminaricales - 148 species

Distinguishing among orders based on:

1. Life History and Reproduction
   - Isomorphic/heteromorphic alt. of gen.; diplontic
   - Isogamous, anisogamous, oogamous

2. Macrothallus Construction:
   - Filamentous
   - Parenchymatous
   - Pseudoparenchymatous

3. Growth
   - Diffuse
   - Apical
   - Intercalary
   - Trichothallic
   - Meristodermal-a surface layer of cells (epidermis) that is capable of dividing (is meristematic)

Division: Ochrophyta - 16,999 species
Class: Phaeophyceae - 2,060 species
Order: 19 orders but we will focus on 6
1. Fucales - 591 species
   - Usually saxicolous
   - Unattached in some cases
   - Unilocular gametangia

Genus: Fucus
   - Silvetia
   - Pelvetiopsis
   - Sargassum
   - Stephanocystis
Order: Fucales

1. Life History and Reproduction

2. Macrothallus Construction:

3. Growth
Oogonia- female reproductive cell containing one or more egg (gamete)

Antheridia- a male reproductive structure producing motile male gametes

Fucus
Silvetia
Pelvetiopsis

Mid
Mid-high
High

Midrib
Playdough stipe
Flattened stipe

8 eggs per oogonium
2 eggs per oogonium
1 egg per oogonium

Sargassum: Sargasso Sea in the Atlantic

Stephanocystis

Sargassum

Unattached Sargassum spp. rafts
Pneumatocysts—
a large float containing gas found in Ochrophyta
provide buoyancy to lift the blades toward the surface,
allowing them to receive more sunlight for Ps
- can hold O₂, CO₂, CO

Division: Ochrophyta- 16,999 species
Class: Phaeophyceae - 2,060 species
Order: 19 orders but we will focus on 6
2. Ectocarpales-787 species
   - Saxicolous or epiphytic
   - Uniseriate filaments
   - Opportunistic spp, excellent colonizers
   - Female gametes releases pheromone ectocarpene

Genus: Ectocarpus
Haplogloia

Order: Ectocarpales:
1. Life History and Reproduction:

2. Macrothallus Construction:

3. Growth:
Division: Ochrophyta- 16,999 species
Class: Phaeophyceae - 2,060 species
Order: 19 orders but we will focus on 6
3. Dictyotales- 272 species
   - Saxicolous
   - Common in tropical waters; also found locally subtidal
   - Pheromone= dictyotene
Genus Dictyota
Padina

Order: Dictyotales

1. Life History and Reproduction:

2. Macrothallus Construction:

3. Growth:

Life history of Dictyota

- Reproductive structures in "sori" = cluster of gametangia or sporangia
- Tetraspores (non-flagellated) released by 2N sporophyte
- Gametophyte dioecious
- Large egg \( \rightarrow \) one per "oogonium" = female reproductive structure containing one or more eggs
- Sperm \( \rightarrow \) single hairy flagella but has second basal body
**Life History of Dictyota:**
Isomorphic Alternation of Generations

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**A Dictyota Story:**
(Stachowicz and Hay 2000)

Local adaptation
Associational defences

**Southern Sites**
+ *Libinia dubia*, the decorator crab
+ *Dictyota menstrualis*, the chemically defended brown alga (diterpenes)
+ Omnivorous fishes
+ Crabs are specialists in decoration preference

**Northern Sites**
+ *Libinia dubia*, the decorator crab
+ No chemically noxious algae
+ Carnivorous fishes
+ Crabs are generalists in decoration preference

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**The only calcified Phaeophycean:** *Padina*

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**Division: Ochrophyta- 16,999 species**

**Class:** Phaeophyceae - 2,060 species

**Order:** 19 orders but we will focus on 6
4. Ralfsiales- 35 species
   - Saxicolous or epiphytic
   - Common intertidally, tropics to poles
   - Crustose in at least one life history stage

**Genus:** *Ralfsia*  
**Analipus**
Order: Ralfsiales

1. Life History and Reproduction:

2. Macrothallus Construction:

3. Growth:

Division: Ochrophyta- 16,999 species
Class: Phaeophyceae - 2,060 species

Order: 19 orders but we will focus on 6
5. Desmerestiales- 29 species
   - Saxicolous
   - Low intertidal to subtidal
   - "Acid weed"

Genus Desmarestia

Order: Desmerestiales

1. Life History and Reproduction:

2. Macrothallus Construction:

3. Growth
Life History of Desmarestiales

- Morphology variable within the genus
- Subtidal, but grows well in high light (very abundant if disturbance has removed other plants or canopy, e.g. El Nino, or urchin grazing)
- Disappears with kelp growth due to canopy cover; shading
- "Acid weed": cells accumulate sulfate ions from seawater which reacts with water to produce sulfuric acid or malic acid, stored in vacuoles
  - ANTIHERBIVORY, pH 0.8-1.8, bleaches other algae