Rhodophyta are cosmopolitan, found from the arctic to the tropics. Although they grow in both marine and fresh water, 98% of the 7,117 species of red algae are marine. Most of these species occur in the tropics and sub-tropics, though the greatest number of species is temperate. Along the California coast, the species of red algae far outnumber the species of green and brown algae.

In temperate regions such as California, red algae are common in the intertidal zone. In the tropics, however, they are mostly subtidal, growing as epiphytes on seagrasses, within the crevices of rock and coral reefs, or occasionally on dead coral or sand. In some tropical waters, red algae can be found as deep as 200 meters. Because of their unique accessory pigments (phycobiliproteins), the red algae are able to harvest the blue light that reaches deeper waters.

Red algae are important economically in many parts of the world. For example, in Japan, the cultivation of *Pyropia* is a multibillion-dollar industry, used for *nori* and other algal products. Rhodophyta also provide valuable “gums” or colloidal agents for industrial and food applications. Two extremely important phycocolloids are agar (and the derivative agarose) and carrageenan.

The Rhodophyta are the only algae which have "pit plugs" between cells in multicellular thalli. Though their true function is debated, pit plugs are thought to provide stability to the thallus. Also, the red algae are unique in that they have no flagellated stages, which enhance reproduction in other algae. Instead, red algae has a complex life cycle, with three distinct stages. Study the life cycle diagram at the end of this lab to understand the stages and their sequence.

**Morphology**

As in the green algae, thallus structures in the Rhodophyta range from simple to complex. Unicellular forms, of course, have the simplest structure. There are few unicellular red algae, but *Porphyridium* is a common unicellular species found in many freshwater pools.

Higher in complexity than single cells are the simple filaments, branched or unbranched. Simple filaments are abundant among the red algae. In some cases, these filaments are alternate life history stages of an alga of more complex thallus form. The simplest filaments are uniseriate, forming a single line of connected cells. Multiple cells in each segment defines a multiseriate filament, while even more complex forms are organized into corticated or polysiphonous thalli.

To understand the more complex multicellular thallus forms, it helps to examine growth patterns and cell divisions. Diffuse growth occurs via random cell divisions that are not localized or coordinated in one area. The foliose thallus of *Pyropia* illustrates this type of random growth. On the other hand, localized cell division can be apical, basal, intercalary, or can occur along an axis.

Complex multicellular thallus forms may be parenchymatous or pseudoparenchymatous. In parenchymatous thalli (e.g. *Pyropia*), adjacent cells are related, whether the divisions are diffuse or localized. Pseudoparenchymatous plants, however, are made up of masses of filaments, in which adjacent cells are unlikely to be the products of a common cell division. Typically, apical cell divisions and coordinated development in the filaments produce a characteristic morphology in the pseudoparenchymatous plant.
Taxonomy

The Rhodophyta are divided into 8 classes. We will focus on three classes in lab. An important distinction is that most Porphyridiophyceae are unicells, Bangiophyceae are filamentous or parenchymatous, while the Florideophyceae are pseudoparenchymatous. The table below illustrates the main differences between the classes.

<table>
<thead>
<tr>
<th></th>
<th>Porphyridiophyceae</th>
<th>Bangiophyceae</th>
<th>Florideophyceae</th>
</tr>
</thead>
<tbody>
<tr>
<td>Macroscopic Phase</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Thallus form</td>
<td>unicells</td>
<td>filamentous,</td>
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<tr>
<td></td>
<td></td>
<td>foliose,</td>
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<td></td>
<td></td>
<td>(unicellular)</td>
<td>parenchymatous</td>
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<td></td>
<td></td>
<td></td>
<td>filamentous,</td>
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<td></td>
<td></td>
<td></td>
<td>pseudoparenchymatous</td>
</tr>
<tr>
<td>Growth</td>
<td>diffuse or</td>
<td>apical,</td>
<td>Apical</td>
</tr>
<tr>
<td></td>
<td>intercalary</td>
<td>intercalary</td>
<td></td>
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<tr>
<td>Chloroplasts</td>
<td>1 per cell, stellate</td>
<td>1 per cell,</td>
<td>1 or more,</td>
</tr>
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<td></td>
<td></td>
<td>stellate</td>
<td>ribbonlike</td>
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<tr>
<td>Central vacuole</td>
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<td>absent</td>
<td>Present</td>
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<td></td>
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<td>absent</td>
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<td></td>
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<td>Primary &amp;</td>
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<td></td>
<td></td>
<td></td>
<td>secondary</td>
</tr>
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<td>Present</td>
</tr>
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<td></td>
<td></td>
<td>usually absent</td>
</tr>
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<td>uni- and</td>
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<td></td>
<td></td>
<td></td>
<td>multinucleate</td>
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<td>Life history</td>
<td>Cell division,</td>
<td>Biphasic</td>
<td>Triphasic</td>
</tr>
<tr>
<td></td>
<td>release of</td>
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<td></td>
<td>endo spores</td>
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<td>mostly marine,</td>
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<tr>
<td></td>
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</tr>
<tr>
<td></td>
<td>brackish, marine</td>
<td>terrestrial</td>
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</table>

after Cole and Conway (1975)

Objective

In the following exercises, you will learn to observe features of the red algae and to identify characteristics unique to orders and species of the Rhodophyta.

Notebook Requirements (21 drawings)
1) Porphyridium- 1 drawing (thallus under compound scope)
2) Bangia fusco-purpurea- 2 drawings (thallus under compound scope and thallus under dissecting scope)
3) Pyropia spp- 3 drawings (thallus, surface view (squash) and cross section)
4) Ceramium spp.- 2 drawings (thallus under compound scope and thallus under dissecting scope)
5) Polysiphonia spp. or Pterosiphonia spp.- 6 drawings (thallus under compound scope, thallus under dissecting scope,cross section, antheridia, carposporophyte, and tetrasporangia)
6) Microcladia spp- 2 drawings (thallus and cross section)
7) Cumagloia andersonii- 2 drawings (thallus and cross section)
8) Cryptopleuraspp- 2 drawings (thallus and cross section)
9) Unknowns- 2 drawing & steps to key out
Class Porphyridiophyceae - 12 species

A. Order Porphyridiales
Unicellular with stellate chloroplast. Reproduction by cell division, release of vegetative cells or endospores.
Species: Porphyridium
1. Draw under compound scope label chloroplast and any other organelles that you can see.

Class Bangiophyceae-197 species

B. Order Bangiales
Thalli filamentous, discoid or bladelike; walls gelatinous; no cells with flagella; asexual reproduction by monospores; some sexual reproduction reported, but not certain.
Species: Bangia fusco-purpurea
In compound scope and dissecting scope, look at whole filament and observe:

1. Thallus construction. Look at multiseriate tip (parenchymatous) and compare to the structure of the thallus near the base (See MAC Figure 222, pg. 281. Image on left shows same cell types in a different genus.)

2. Attachment. Look for basal cell filaments, rhizoidal cell extensions (See MAC Figure 237, pg. 295.)

3. Draw the entire thallus including transition from filament to parenchymatous thallus construction and the modified basal cells involved in attachment.

Species: Pyropia sp.
Prepare a cross section and surface view, and observe under compound scope:

1. Thallus construction. In surface view, observe parenchymatous structure, draw cell orientation. In cross section, how many cells thick is the thallus?

2. Stain with analine blue or malachite green and look for stellate chloroplasts and pit plugs (See MAC Figure 237, page 295 for stellate chloroplasts)

Q: What stage is this in the life history of Pyropia? Is it haploid or diploid?

Class Florideophyceae-6767 species

C. Order Nemaliales-273 species
Thalli multiaxial, pseudopaenchymatous, tetrasporangia unknown; alga is monoecious or dioecious
Species: Cumagloia andersonii
1. Sketch the thallus under the dissecting scope.
2. Prepare a cross section and draw under compound scope.
   Q: What type of chloroplast does this alga have?
Q: Do you see any reproductive structures, where are they located?
Q: What stage is this in the life history of Cumagloia?

D. Order Ceramiales - 2662 species
Thalli uniaxial, filamentous, erect; apical growth; zero to complete cortication; tetrasporangia cruciate or tetrahedral.

Species: Ceramium sp.
1. Sketch the thallus under the dissecting scope.
2. Make a squash of thallus material and draw:
   Note the banding pattern.
   Q: Is the cortication throughout or only at the nodes?

Species: Polysiphania sp. Or Pterosiphania bipinnata
1. Sketch the thallus under the dissecting scope.
2. Make a squash of fresh material and draw:
   Q: How many pericentral cells are there? (Hint: if you can see 4 in front, there are at least 4 in the back as well.)
   Q: Are the tricoblasts branched or unbranched? These are non-pigmented, tapering, hair-like cells at the apices.
   Q: What is the purpose of the tricoblasts?
2. Make a cross-section, draw and label the axial and pericentral cells.

On permanent slides of the reproductive regions of Polysiphania, observe and draw:
3. Antheridia (on male gametophyte)
4. Carposporophyte. The carposporophyte is pedicillate, on a stalk. Label the pericarp, carposporangia and cystocarp.
5. Tetrasporangia, embedded in the thallus.
   Q: How many tetrasporangia are there per segment?

Species: Microcladia
1. Draw the external morphology under the dissecting scope.
   Q: What type of branching does this alga exhibit?
2. Cross section and draw.
   Q: Is this alga uniaxial or multiaxial?
Species: Cryptopleura

1. **Draw** the external morphology.

   **Q:** What type of branching does this alga exhibit?

2. Prepare a cross section and draw under compound scope.

   **Q:** What type of chloroplast does this alga have?
   
   **Q:** Do you see any reproductive structures, where are they located?
   
   **Q:** What stage is this in the life history of Cryptopleura?

**Key Out 2 Unknowns. Write out the steps and draw a picture of the thallus and cross section if necessary.**

**Vocabulary:**

**generalized red algal life history**

**Spermatium** Non-flagellated male gamete

**Carpogonium** Female gamete = egg (oogamous life cycle only)

**Trichogyne** Extension of egg to which spermatium attaches

**Carpospore** 2N spore resulting from fertilization

**Carposporophyte** 2N generation—this is where the 2N zygote is cloned to form the carpospores

**Pericarp** 1N vegetative tissue surrounding the carposporophyte

**Cystocarp** Pericarp (1N) + carposporophyte (2N)

**Tetrasporophyte** 2N generation from germinating carpospore

**Tetraspore** Meiospore formed by meiosis from 2N tetrasporophyte cell

**Tetrasporangium** 2N cell which undergoes meiosis to form 4 tetraspores

**Connecting filament (ooblastema)** Cell that carries the zygote nucleus from fertilized egg to internal auxiliary cell where it is cloned and differentiates into carpospores

**Gonimoblast** One or all filaments supporting carpospores, in a mass called the carposporophyte

**Auxiliary cell** Vegetative cell which receives the 2N zygote nucleus after fertilization

**Trichoblast** Usually a uniseriate filament of cells with little pigmentation; either remains sterile or undergoes division to form spermatangia or caropogonia
Life Cycle of the Bangiales
Haplo-diplontic
e.g. *Porphyra gardneri*

- syngamy
- spermatium
- carpogonium
- meiosis occurs in conchosporangium
- microfilamentous 2N conchocelis stage
- plantlet
- haploid
- diploid
- 2N carpospores
- monospore
- 1N conchospore
- 1N gametophytic macrothalli
- monospore
- 1N conchocelis stage
- 2N carpospores
- plantlet
- monospore
Floridean Life Cycle

Triphasic
e.g. Mazzaella splendens

2N tetrasporophyte

four 1N tetraspores released by each tetrasporangium

1N gametophytes

spermatia on spermatangial branch

spermatium released from spermatangium

syngamy

carpogonium on carpogonial branch

multiple 2N carpospores produced through mitosis in gonimoblast filaments of carposporophyte

2N zygote develops into carposporophyte on 1N female gametophyte

2N carposporophytes on 1N female gametophyte
Summary of Class and Order Characteristics of Division Rhodophyta

Class Bangiophyceae:
Order Bangiales

Class Florideophyceae:
Order Nemaliales
Order Gigartinales (includes former Cryptonemiales)
Order Rhodymeniales
Order Ceramiales
Order Corallinales (includes former Cryptonemiales)

KEY:
- **C**: Carpogonium
- **A**: Auxiliary cell
- **S**: Supporting cell
- **O.F.**: Ooblast filament
- **G**: Gonimoblast

NOTE: Fertilization and development of carposporophyte occur between steps in diagrams.

Class Bangiophyceae
Order Bangiales
- plastids mostly stellate
- intercalary cell divisions
- pit connections rare, primary, simple
- carpogonium divides to form "carpospores" (no gonimoblasts)

e.g. *Bangia*, *Pyropia*
Class Florideophyceae

- plastids not stellate (mostly bandshaped or discoid)
- apical growth
- pit connections common, primary and secondary, complex—concave
- carpospores from gonimoblasts

Order Nemaliales
- gonimoblasts initiated from carpogonium
- usually no auxiliary cell; carpogonium may fuse with nutritive cells *

Order Gigartinales (includes former Cryptonemiales)
- auxiliary cell in various locations—but not as in Rhodymeniales or Ceramiales

Order Rhodymeniales
- auxiliary cell filament born on a supporting cell of carpogonial filament
- auxiliary cell formed before fertilization
- fusion of carpogonium and auxiliary cell to form gonimoblast

* e.g. Nemalion, Cumagloia

* e.g. Gigartina

* e.g. Rhodymenia
**Order Ceramiales**
- auxiliary cell develops from supporting cell of carpogonial branch after fertilization (supporting cell is a pericentral cell)

  ![](image1)

  e.g. *Polysiphonia*

**Order Corallinales**
- carpogonial branches in conceptacles
- post-fertilization fusion of cells in carpogonial branch

  ![](image2)

  e.g. *Calliarthron, Bosiella*