Biology 2015 – Evolution and Diversity
Lab 3: Protista, part II – Algae

The term "algae" refers to eukaryotic, photosynthetic organisms that are mostly aquatic and lack the characters that are found in plants. Most algae are photoautotrophic organisms while others, including some members of *Euglena* and the dinoflagellates, use both photosynthesis and phagocytosis. "Algae" do not constitute a monophyletic group. Algal life cycles can be complex. Sexual reproduction is common in most groups but absent in Euglenoids. The occurrence and form of the haploid and diploid phases of the sexual life cycles of algae vary considerably.

In today's lab you will have the opportunity to observe the following examples of the algae: ***Euglena*** (Euglenophycota); ***Peridinium*** (Pyrrophycophyta); ***Synedra*** and ***Thalassiosira*** (Ochrophyta); ***Volvox*** (Chlorophyta); ***Spirogyra, Coleochaete, Nitella, Cosmarium,*** *and* ***Micrasterais*** (Charophytes), ***Polysiphonia*** (Rhodophyta); and ***Ectocarpus*** (Phaeophyta);

EUGLENOPHYCOTA

Euglenids are unicellular organisms. Some are photosynthetic, others are heterotrophic, and some of the photosynthetic members are also heterotrophs. Most are motile and have flagella and they reproduce asexually.

The photosynthetic Euglenids have chlorophyll a and b, have apical flagella, and store their carbohydrates as paramylon bodies. Euglenids obtained chloroplasts from unicellular green algae by way of **secondary endosymbiosis.** They do not have cell walls. Instead, they have a covering of proteinaceous material called a pellicle.

Euglena

Prepare a slide of some living *Euglena*. Use some "Detain" to slow them down a bit. Observe the overall shape of the cells. Notice that that shape can change quite a bit as they move around, especially when they make sharp turns. It's the presence of a pellicle, instead of a cell wall, that provides them with their shape-changing ability.

Observe the chloroplasts and try to find the nucleus. You should be able to observe the stigma, the red spot near the anterior end that is light sensitive. There is also a contractile vacuole near the anterior end but this may be difficult to see by light microscopy. *Euglena* reproduces asexually. See if you can find cells reproducing.

Figure 1. *Euglena gracilis.* Notice the red spot, called the stigma, and the green chloroplasts. There are two flagella but one is short and is typically hard to see.

PYRROPHYCOPHYTA (DINOFLAGELLATES)

Dinoflagellates are unicellular, with most being motile and having flagella. There are both photosynthetic and heterotrophic organisms in this group. Dinoflagellates have plates of cellulose enclosed within continuous inner and outer membranes therefore some can perform phagocytosis. They have a distinctive appearance with characteristic transverse and vertical grooves, called the cingulum and sulcus, respectively. Dinoflagellates have two flagella. One trails behind the cell and the other lies within the cingulum.

Photosynthetic dinoflagellates obtained their chloroplasts through secondary or tertiary endosymbiosis. They have chlorophylls a and c, along with carotenoids. So, en masse, they usually have a somewhat brownish color.

Peridinium

Prepare a slide of *Peridinium* cells using a little "Detain" to slow them down. Describe the movements of the cells. Look for the cingulum, the transverse groove, and sulcus, the vertical groove, and find the trailing flagellum. You may be able to find empty valve remnants in the culture material.

Figure 2. *Peridinium*. The cingulum, the groove between the epitheca and hypotheca, is visible in the more magnified specimens.

Next, you should prepare a slide of *Peridinium* and *Euglena* together **but do not use the same pipette**. Then add a drop of the stain 1-KI. This is a stain for starch. (It will also kill the cells.) The type of food reserve is an important character distinguishing different groups of algae, which in this case can be determined by using a simple stain. Can you distinguish between the food reserves of *Peridinium* and *Euglena* based on this stain?

OCHROPHYTA (DIATOMS)

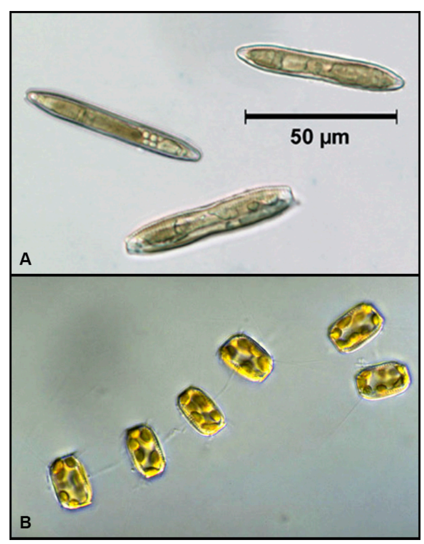

Figure 3. Diatoms. A) *Synedra* and B) *Thalassiosira*.

Diatoms are unicellular photoautotrophs are found in almost every aquatic environment as well as moist soils. Because they are photoautotrophs they are restricted to water depths that permit the penetration of light. Unlike other phototrophic algae diatoms store oils rather than starches and possess a bipartite (two-part) outer cell wall made of silica. They can be cell solitary or colonial, forming long chains of cells attached by mucous filaments, as seen in *Thalassiosira*. They may occur in such large numbers that they are capable of forming sediments composed almost entirely of diatom silica walls. Diatoms are used commercially variety of different ways. They are used in filters (for solvents, chemicals, and alcohol), as fillers (in paints, detergents, paper), and as abrasive agents (in various types of polishes), they were even used in toothpastes!
Diatoms have chlorophylls a and c and obtained chloroplasts by secondary or tertiary endosymbiosis. In addition to storing oils, diatoms also store various polysaccharides, like laminarin and chrysolaminarin. The silica skeleton of the diatom is called a frustule and is composed of two thecae, the epitheca (the larger valve), and a hypotheca (the smaller valve). The lip

or rim of the epitheca slightly overlaps the rim of the hypotheca. The way these valves overlap is similar to the way the two parts of a Petri dish fit together. The place where the epitheca overlaps the hypotheca is called the girdle. They may be radially symmetrical ("centric" diatoms) or bilaterally symmetrical ("pennate" diatoms). Some diatoms are capable of limited mobility by secreting a mucilaginous substance through a central groove called a "raphe" and creating a type of propulsion while others are non-motile.

Synedra and Thalassiosira

Prepare a slide each of these specimens (you won't need "Detain" for these). How would you classify each of these diatoms (either centric or pennate)? After you've let them settle a bit, do you see any movement? Compare the color of their chloroplasts to the chloroplasts of *Euglena.* Draw top and side views for each of the species, and try to focus carefully to see if you can observe any of the surface details on their walls.

CHLOROPHYTA

Volvox globator

Members of the order Vovocales are green algae in which the chloroplasts are cup-shaped and contain chlorophylls a and b. The pyrenoid of the chloroplast synthesizes starch as a food storage product. Each cell has two, four, and occasionally eight flagella. Cells are enclosed in a gel-like matrix of glycoproteins and glycosaminoglycan that are interconnected by cytoplasmic bridges. Some genera exist as solitary species, such as *Chlamydomonas,* while other genera are colonial and can take the shape of a flat plate of 32 to 40 cells, as seen in *Gonium*, or as hollow spheres, as seen in *Pandorina* (16 to 32 cells), *Eudorina* (32 cells), and *Volvox* (2000 to 6000 cells). Solitary species reproduce by longitudinal binary fission. In *Volvox*, the large, aflagellate cells, called **gonidia**, are capable of both asexual and sexual reproduction. During asexual reproduction gonidia undergo multiple fission, forming a hollow sphere within the parent colony. These daughter colonies then rupture through the wall of the parent colony. During sexual reproduction the gonidia form true eggs and sperm, which are located at the posterior of the colony. The egg remains stationary and is fertilized by a sperm packet released by another colony. Colonies can be hermaphroditic or male and female.

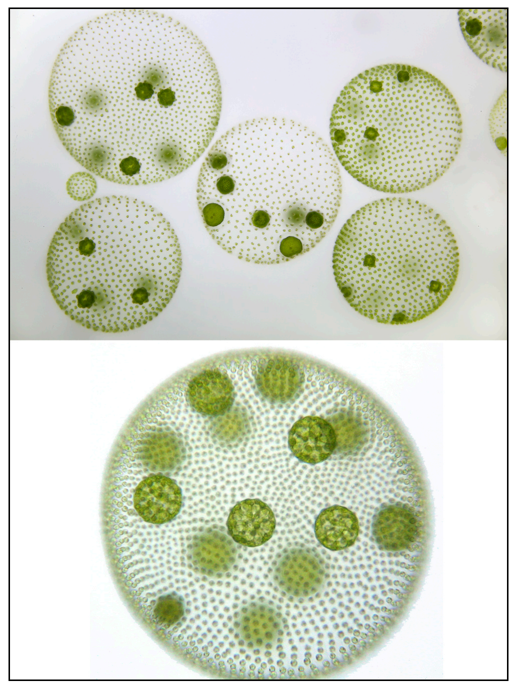

Figure 4. Volvox, parent colonies containing gonidia and daughter colonines.

Green algae constitute a large and very diverse group that is abundant in both marine and fresh water habitats. Some are unicellular, others are colonial and many are filamentous. Some species are quite large and some have complex branching patterns. Green algae obtained chloroplasts by primary endosymbiosis and contain chlorophylls a and b. They have cell walls of cellulose or glycoprotein and store starch in their chloroplasts. Plants evolved from within a sub-group of the green algae known as the Charophytes. You'll see many example of this group in today's lab, including *Coleochaete,* thought to be the sister group to land plants.

CHAROPHYTA

Spirogyra

Spirogyra is a filamentous green alga that gets its name from the spiral arrangement of its chloroplasts. Mount some in a drop of water on a microscope slide. Notice that the chloroplasts contain small, but conspicuous, structures within them. They often appear gold-colored under phase contrast microscopy. These structures are called pyrenoids, which are concentrations of the carbon-fixing enzyme Rubisco (ribulose bisphosphate carboxylase).

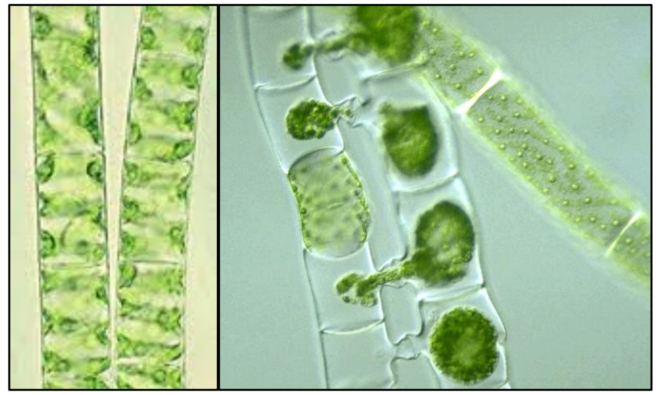

Figure 4. *Spirogyra.* Vegetative filament (left). Zygotes formed in left-hand filament (right). Notice unpaired cells in the right-hand filament that have formed conjugation tubes.

Spirogyra filaments are haploid. The alga reproduces asexually by fragmentation and continued growth of the filament fragments. But *Spirogyra* also reproduces sexually in a process called **conjugation**. The individual cells in a filament are capable of becoming gametes and fuse with cells in another filament of the opposite mating type. When compatible filaments come close to one another small conjugation tubes can form between the individual cells that comprise each filament. The cytoplasm from the cells in one of the filaments will move through the conjugation tube into the cell to it's counterpart on the compatible filament.

Find and examine prepared slide labeled *"Spirogyra* Vegetative and Zygotes w.m."

Coleochaete

The Charophyte genus *Coleochaeta* is regarded as the sister group of all land plants and there is strong evidence supporting this idea. Among the evidence is a fossil record of the appropriate age, with some species exhibiting parenchymatous growth and nurturing of the zygote. *Coleochaetes* can reproduce sexually and asexually. There are both monoecious (parent is able to produce both gametes) and dioecious (parent can only produce one type of gamete) species. When reproducing sexually they are oogamous, meaning that the oogonium (female gamete) remain with parent organism while the antherozoids (male gametes) become motile and leave the parent organism. When reproducing asexually the organism produces zoosporangia, each of which produce a single zoospore. Amazingly, every cell is capable of functioning like a zoosporangium. Prepare a microscope slide and examine the *Coleochaete* we have on hand today.

Figure 5. *Coleochaete*

Nitella

The other proposed sister group of land plants are the Characales, represented here by *Nitella*. Note the orange-brown spheres on *Nitella* in figure 7. These are called globules and are the male reproductive structures that enclose the antherozoids.

Find and examine one of the prepared slides labeled *"Nitella"*.

Figure 7. ***Nitella.***

Cosmarium

Cosmarium are deeply divided in the middle, which holds the nucleus. The two semi cells are rounded when views from the front and flattened, oval, or elliptic when viewed from the side. The older half of the cell wall secretes mucilage. The mucilage swells as it absorbs water and propels the cell forward. The cell wall may be smooth with pores or ornamented with granules, pits, or warts. The vegetative cells usually do not have spines. Each semi cell has at least one central chloroplast. They sometimes produce thick-walled resting cells

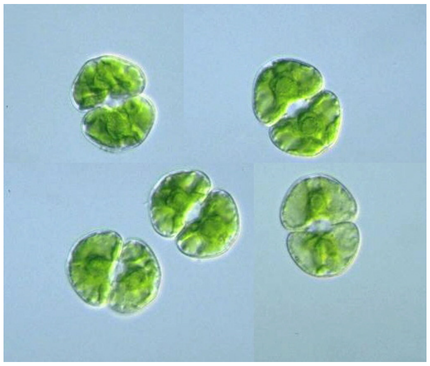
Figure 8. ***Cosmarium.***

Micrasterias

Micrasterias is a genus whose members are considered placoderm desmids, those that feature a cell wall composed of two sections that attach in the mid-region. This type of desmid is also characteristically furnished with pores, spines, granules, or other protuberances. Contrariwise, saccoderm desmids typically possess a smooth, unornamented cell wall that consists of a single piece. *Micrasterias* exhibit a substantial amount of diversity in the adornment of their lobed, disc-like shapes, and many are among the most picturesque microscopic life forms in the world. Most often found in acidic waters and bogs, the organisms may grow between 80 to 200 micrometers in diameter.

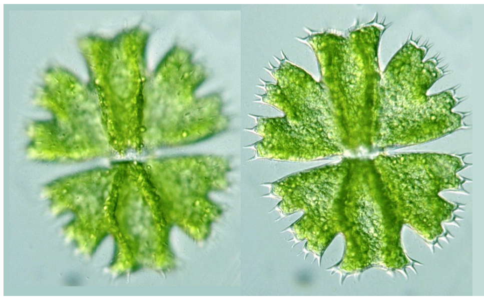
Figure 9. ***Micrasterias.***

RHODOPHYTA

The red algae are mostly marine and typically multicellular. They have chlorophyll a and carotenoids in their chloroplasts. They also contain phycobilin pigments (phycoerythrin and phycocyanin), which contribute to their color. When phycoerythrin is predominant, the alga will tend to be reddish, but when phycocyanin is predominant the alga may have a blue-green coloration. Red algae store a glycogen-like polysaccharide molecule outside their chloroplasts that is often referred to as "Floridian starch".

Polysiphonia

We have live red algae available in the lab. We will have a demonstration slide showing the thallus filaments of *Polysiphonia.* Thallus filaments are composed of multiple uniseriate filaments packed together. The growth of this alga is called "pseudo-parenchymatous". True **parenchymatous** growth occurs when a three-dimensional tissue develops by cell division in all planes. Land plants and most complex algae are characterized by true parenchymatous growth.

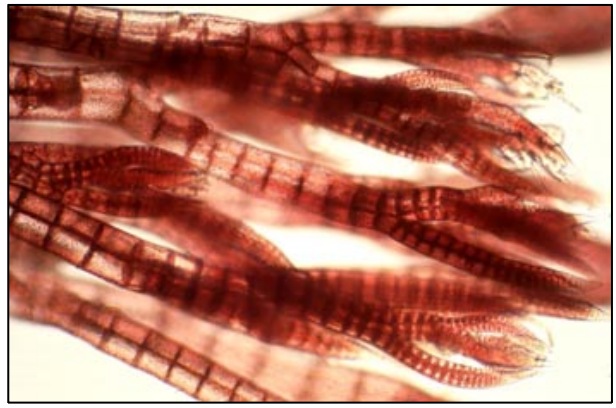

Figure 10. *Polysiphonia*. Notice the pseudo-parenchymatous growth.

Find and observe the living specimens of *Polysiphonia* at a dissection scope.

PHAEOPHYTA

The brown algae are nearly all marine and multicellular. Most are fairly large, with some of the giant Kelps reaching lengths of up to 50-60 meters. Their chloroplasts contain chlorophylls a and c along with carotenoids. They store a polysaccharide called laminarin and have cell walls of cellulose. While most of the brown algae do have a very brownish look, they may vary from quite green to nearly black in color.

Ectocarpus

Ectocarpus is a filamentous brown alga that is common on rocks in pools along the shoreline or growing on larger seaweeds. It is also an important ship-fouling organism. The genome of *Ectocarpus siliculosus* recently became the first brown algal genome to be sequenced. We include *Ectocarpus* in this lab so you'll have the opportunity to see a brown alga that's much smaller than giant Kelps.

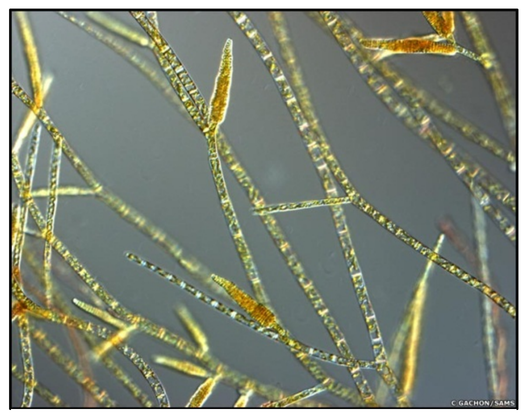

Figure 11. *Ectocarpus*.

Find and observe the living specimen of *Ectocarpus* at a dissection scope.