

Kingdom Protista

Anton van Leeuwenhoek provided the first descriptions of what he called “animacules” in 1683. Today we recognize this broad group as the Protists.

This kingdom constitutes the most diverse life forms on earth. Members of this kingdom are all eukaryotic but that’s pretty much where their commonality ends. They may be unicellular, colonial or multicellular. Perhaps the safest thing to say about these organisms is they are not plants, not animals, and not fungi.

The kingdom is represented by over 200,000 species with more being discovered. Some of these gave rise to higher plants. Some are the forerunners of animals. Probably after the bacteria and cyanobacteria, they are the oldest of life forms.

In summation, we put everything here in this kingdom we can’t figure out where to put in the other five. However, perhaps order will arise from chaos. Molecular biology is beginning to make sense of some of these diverse organisms and in the future, you may see a much clearer evolutionary hierarchy.

Raven and others (2005) groups the Protists into six subgroups: Euglenozoa, Alveolata, Stramenopila, Rhodophyta, Chlorophyta, and Choanoflagellida. It’s as good as a grouping as any and we will follow that scheme here.

The Euglenozoa

The Euglenozoa are composed of two major groups: the euglenoids and the kinetoplastids.

Euglenoids

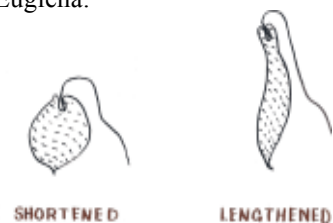
According to Raven and others (2005) the euglenoid line of evolution was the first free-living eukaryotes to possess mitochondria (prokaryotes living in a mutualistic relationship with eukaryotes). Members of this group exhibit both plant and animal-like characteristics. Many contain chloroplasts and are photosynthetic while others are achlorophyllous and heterotrophic. We’ll study a representative genus, *Euglena*.

Euglena (Gr. *eu* = good + *glene* = eyeball)

These are predominantly fresh water in distribution and over 800 species have been described. They can undergo such rapid asexual reproduction as to literally color the water green and form blooms.

□ Make a wet mount of living *Euglena* and cover with a coverslip. Observe the swimming motion. *Euglena* are capable of moving by two methods: by the flagella of the organism and by euglenoid motion. The flagella most often whirl to (1) either push or (2) pull the organism through the water. There are two present, but one is so short it does not appear except through electron microscopy. Euglenoid motion is a method where *Euglena* contracts and relaxes to give a inch worm-like motion. Euglenoid motion is due to the semi-rigid wall material of *Euglena* called the **pellicle**. The pellicle is *not* composed of cellulose like many wall materials of protists.

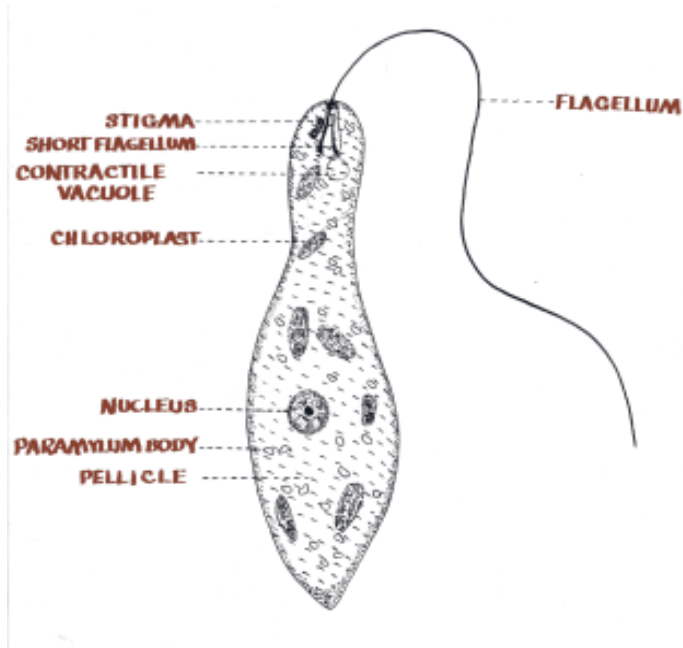
Figure 1. Euglenoid motion in *Euglena*.



□ Make another wet mount as before but before placing the culture on the slide, make a ring in the center of the slide with methyl cellulose or Protoslo©. Place a drop of *Euglena* culture in the center of this “doughnut.” Cover with a coverslip. This material is like syrup and the organism will have difficulty swimming through the material. You will better be able to view the organism. Look for the **flagella**, the numerous **chloroplasts**, the **nucleus**, the **reservoir**, and the **eyespot (stigma)**. The eyespot will appear either orange or red, or some shade between these two due to color aberration in your lenses.

□ Obtain a prepared slide of *Euglena* stained to enhance the flagella. Next observe the nucleus. You will probably not see the eyespot or chloroplasts as the stain often masks these organelles. *Euglena* stores starch in the form of paramylon granules, a β -1,4 glucose polymer. Paramylon starch is nonreactive with IK_2I but will react with safranin.

Figure 2. *Euglena gracilis*.



Kinetoplastids

This group gets its name from the unique, single mitochondrion in each cell. These organisms lack chromatophores and are thus colorless. There is no cell wall or pellicle in these organisms and thus no cellulose. They are holozoic or saprozoic in nutrition. Most are symbiotic and many are pathogens in animals and humans. We will look at two genera: *Trypanosoma* and *Trichomonas*.

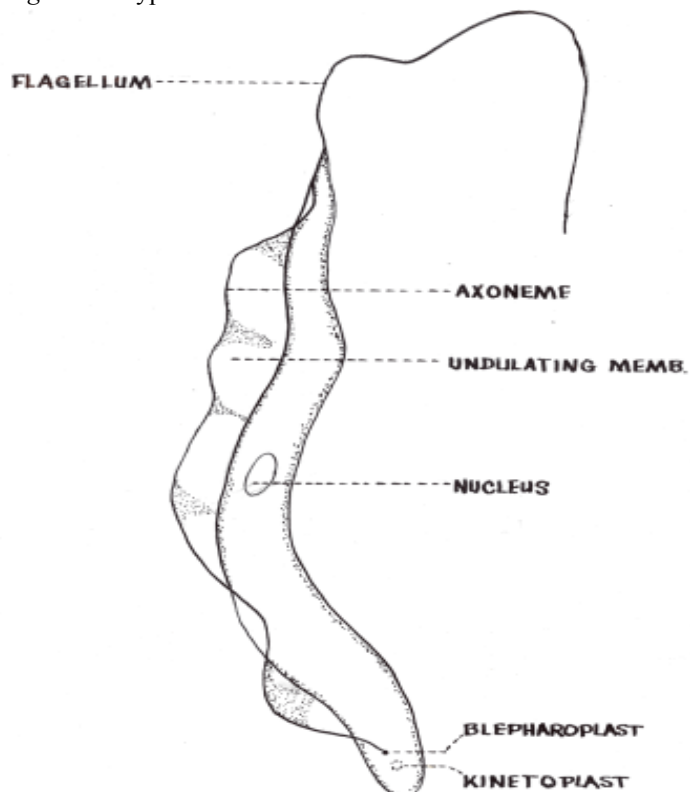
Trypanosoma

This genus is a parasitic one that is of great medical and economic importance. Species of this genus can be found in the blood of all vertebrates including humans. Transmission to the vertebrate host is by invertebrates, particularly of the class Insecta.

There are three major diseases we are concerned with:

- *Trypanosoma gambiense* or *T. rhodesiense*, the causative agent of African sleeping sickness;

Figure 3. *Trypanosoma*



- *Trypanosoma brucei*, a disease of cattle called nagana; and
- *Trypanosoma cruzi*, a disease of South and Central America, called Chagas' disease.

To study the organism, blood of frogs or reptiles are good sources since most vertebrates carry the organism. The size range of *Trypanosoma* is 15 to 60 microns. The general shape is that of a curved flattened blade: one side convex and the other concave. The convex side is thrown into folds of a rippling membrane.

□ Obtain a prepared slide of the genus *Trypanosoma*. You may have any one of the three species. Try to locate the following structures. The organism is uninucleate and has a single **flagellum**. The **nucleus** has a dense, staining region called the **endosome** that probably has concentrated areas of DNA. **Volutin granules** apparently are nucleic acid reserves.

The flagellum is continuous with the outer fold of the **rippling membrane** for a part of its length. Where the flagellum is joined to the membrane, it is referred to as the axoneme. The axoneme is anchored to the posterior area of the body called the **blepharoplast**. The blepharoplast is formed by a structure just posterior to it called the **kinetoplast**. Movement in some appears to be a sluggish wiggling and in others, a torpedolike action.

The organism lives in an isotonic environment and thus osmoregulation is minimal. The greatest change is going from the blood of an invertebrate host to a vertebrate host's blood. There is no structure for intake of food, so food is absorbed by the cell membrane. This is very easily accomplished since the host's blood has dissolved food in it and intake often is by simple diffusion.

There are various changes of form in the life cycle of *Trypanosoma*. Two other stages are known; (a) Crithidial stage: a prenuclear stage that maintains the undulating membrane; and (b) Leptomonad stage: undulating membrane replaced by typical flagellum. The stage or form the organism is in depends on the host infested.

Pathogenesis

African Sleeping Sickness

This disease was recognized in two distinct geographical regions and was thought to be extinct at one time. *Trypanosoma gambiense*, the causative agent of Gambian trypanosomiasis, was reported first. Eight years later, in 1908, *T. rhodesiense*, the causative agent in Rhodesian trypanosomiasis was isolated. *T. gambiense* is widely distributed through the western and central regions of Africa, and *T. rhodesiense* is restricted to the southeastern regions of Africa. Do not confuse this with virus induced sleeping sicknesses of Eastern and Western Equine Encephalitis. Gambian trypanosomiasis is contracted by humans from the bite of the tsetse fly, *Glossina palpalis*. The vectors for *T. rhodesiense* are closely related species of *Glossina*. The fly takes the protozoan up during a blood meal from infected hosts (any vertebrate). The parasite passes into the insect's intestine where it matures and changes into an infective stage. The fly then bites a susceptible host and the cycle is maintained. The major difference in the species of parasites is that *T. rhodesiense* has a shorter incubation time, a more rapid course, and death occurring within a year's time.

Characteristics of the Disease

The first sign of infection is inflammation at the site of the bite, usually within 48 hours. Within several weeks, the parasite invades the blood and lymph system. Symptoms include:

- intermittent fever,
- rapid heart beat,
- enlargement of lymph nodes and spleen,

Advanced stages include:

- personality changes,
- apathy,
- sleepiness,
- disturbances of speech and gait, and
- severe emaciation.

Nagana

The causative agent is *T. brucei*. It causes a fatal disease in cattle. It is not to be confused with brucellosis in cattle, caused by a bacterium *Brucella*.

Chagas Disease

The causative agent of Chagas disease, *T. cruzi*, was first isolated by Carlos Chagas in 1908. The parasite was found in the intestine of a small, blood-sucking reduviid bug (a type of hemipteran, like stink bugs, chinch bugs, etc.). The distribution of the disease is:

- southern United States;
- Mexico;
- Central America;
- South America to Argentina.

In addition to the reduviid bug, rodents, opossums, and armadillos can harbor the protozoan. It is spread through the feces of the bug.

Characteristics of the Disease:

- inflammation
- swelling of eyelids and formation of a hard, painful nodule on skin
- enlargement of lymph nodes, liver, and spleen
- inflammation of the heart
- psychic changes
- general disability.

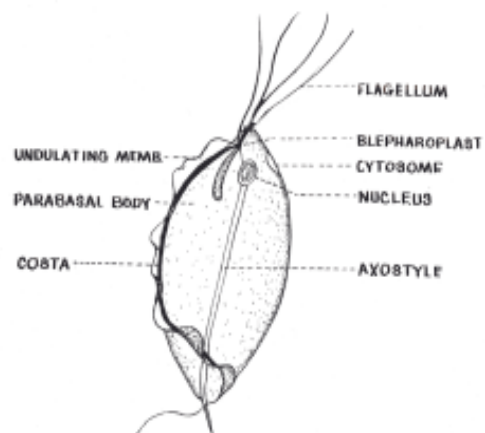
The symptoms are very similar to heart disease. The acute form often attacks children.

Trichomonas

These are parasitic organisms of vertebrates and invertebrates, most often found in the digestive system of the host. Somewhere around 75 species have been described, with three of these present in humans. They are found in humans in the: (1) buccal cavity, (2) large intestine, and (3) urogenital system. In humans, they may be transmitted sexually and are therefore considered a venereal disease.

□ Obtain a prepared slide of *Trichomonas*. Look for various structures detailed below. The organism is pear-shaped and there is a single nucleus. Depending on the species, the chromatin is either condensed or dispersed. A rodlike structure, termed the costa, runs the

Figure 4. *Trichomonas*.



length of the undulating membrane at its base. It is the line of attachment of the membrane to the body of the organism. Another rod, this one semirigid, runs the length of the organism and usually presents as a spike at the posterior end. It is called the axostyle. It obviously lends support, but also stains with iodine to represent glycogen. A parabasal body is present. It extends from the blepharoplast, but its function is not clear.

There are three to eight anteriorly directed flagella. When in motion, the area closest to the organism (proximal) often become entangled and intertwined. There is a trailing flagellum running along the border of the undulating membrane. Both flagella and membrane are utilized in locomotion. As the organism moves, it rotates longitudinally and moves forward in a rather jerky motion.

Its environment is isotonic, and so most regulation occurs at the cell membrane. A cytosome is present in the anterior region and nutrition is primarily holozoic. Reproduction is asexual by longitudinal binary fission. There is no known sexual reproduction and cysts have never been reported.

No sexual reproduction is known.

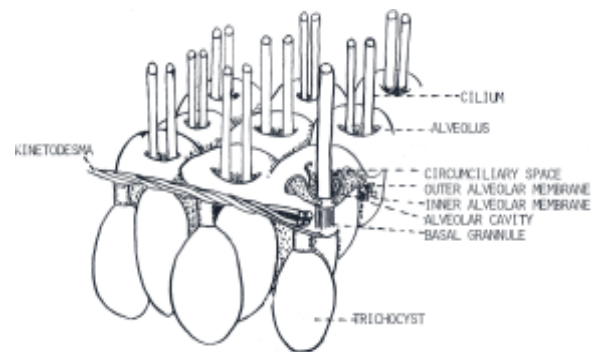
Pathenogenesis

A condition known as Trichomiasis occurs in human females in the vagina and bladder. In males, it usually is restricted to the urinary system. The organism is first diagnosed in the human female when she complains of profuse discharge of a greenish white, foul-smelling foam, along with irritation.

The Alveolata

The unifying feature of this group is the presence of an alveolus below their cell membrane. The alveolus perhaps has its greatest complexity in the ciliates. Three subgroups are found in the Alveolata: dinoflagellates, apicomplexas and ciliates. Although all three have alveoli associated with their cell membranes, each has a different form of locomotion. Dinoflagellates by a pair of flagella, apicomplexas by a sliding or gliding motion and ciliates, as their name implies, by cilia.

Figure 5. Alveoli of Paramecium with cilia and trichocysts in between each alveolus.



The Dinoflagellates (*dino* = whirling, Gk.)

This group is composed primarily of unicellular biflagellate organisms that are predominantly marine even though some freshwater species do occur. Over 1000 species are known and they are either directly or indirectly important to humans. This group includes species that are **bioluminescent** and also species that are responsible for **red tides**.

These are uninucleate organisms. Many species have cell walls of cellulose arranged as plates so as to give an appearance of being armored. Other species appear “naked” but in reality have very thin cellulose plates. The dinoflagellates contain chlorophylls *a* and *c*, but these are masked by abundant **chromatophores** containing **carotenoids**. Oil droplets may be found in the cytoplasm, and starch is the typical starch found in green plants.

Most dinoflagellates are biflagellate. The organism is divided into two planes - longitudinal and transverse - by the cellulose plates. Where these plates come together they form grooves: an **annulus** (transverse plane) and a **sulcus** (longitudinal plane). The flagella are found in the grooves. The

annular flagellum is ribbon shaped and the sulcal flagellum is whiplike.

Some species may be found in both fresh water and salt water and thus are euryhaline. Those species that do not contain chlorophyll are heterotrophic, but even chlorophyllous species exhibit a requirement for Vitamin B₁₂. Reproduction is by means of binary fission and a few species exhibit sexual reproduction by the production of gametes. Most species are able to form cysts which may remain viable for years.

Red Tides

One direct influence dinoflagellates have on humans is red tides. Species of the genus *Gonyaulax* often undergo **blooms** where the species proliferate so quickly that they literally color the water. The Red Sea is so named due to blooms of *Gonyaulax*. The concept of the biblical story of Moses turning the Red Sea red is probably based on a red tide. *Gymnodinium* is a genus in Florida responsible for red tides.

Red tides can be extremely dangerous. In the winter and spring of 1974 on the west coast of Florida, there occurred the 25th red tide since 1844. Thousands of dead fish littered the beaches and millions of tourist dollars were lost.

Dinoflagellates form part of the food chain, and fish and shell fish (such as oysters, mussels, and clams) ingest them. Fish are killed by the toxin present in the dinoflagellates but shellfish are unharmed. The danger comes in eating the contaminated shellfish. In the fall of 1972, twenty-six people were killed by red tide poisoning in New England. It so destroyed public confidence in the Massachusetts shellfish industry that four years later, business had recovered only 2/3 of its previous business.

The toxin of *Gonyaulax* is **saxitoxin**. It is a neurotoxin that interferes with the transmembrane movement of Na⁺ in nerve cells by binding to the nerve cell membrane. It is said to be 100,000 times more potent than cocaine.

The chemical nature and biological activity of the toxin is well understood, but the cause of blooms is less known. Factors include:

- 1) levels of nutrients,
- 2) presence of certain trace metals,
- 3) sewage runoff,
- 4) ocean salinity,
- 5) temperature,
- 6) winds and
- 7) light.

Bioluminescence

You are probably familiar with fireflies' bioluminescence, but many aquatic organisms also exhibit this trait of being able to provide "cool" light or light by chemical reactions. Often times at night, a ship's wake is very vivid and glowing due to bioluminescence of marine organisms. Some dinoflagellates give off this type of light. A compound called **luciferin** interacts with an enzyme **luciferase** in the presence of oxygen and inorganic ions, high energy

Figure 6. Chemical structure of saxitoxin.

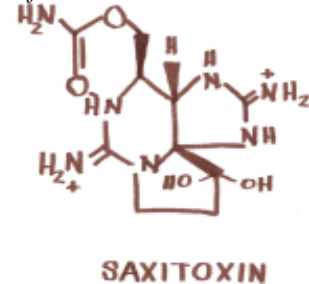
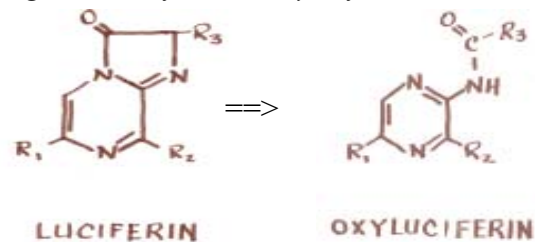


Figure 7. Luciferin and oxyluciferin.



phosphates such as ATP, etc., to produce light in the resulting oxidation process. Luciferins vary with the species involved. The compounds can be synthesized in the laboratory and the “cool” light can be produced in a test tube.

Ciguatera Poisoning

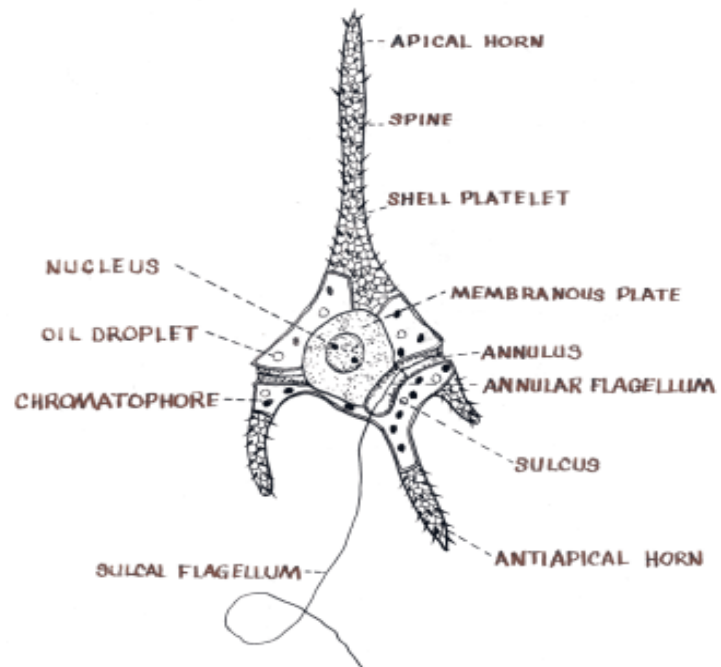
Another danger from dinoflagellates is ciguatera poisoning due to a mutualistic dinoflagellate associated with the polyps of corals in coral reefs. These dinoflagellates contain the toxin, brevetoxin. Reef fish often feed on the coral polyps and thus inadvertently ingest brevetoxin. Other fish such as grouper, snapper, and barracuda feed on these reef fish, concentrating the toxin. When humans eat large specimens of grouper, snapper, and barracuda (and others), they may become poisoned.

First signs of poisoning is a tingling sensation around the lips and fingertips. Later nausea and diarrhea occur, hot food and liquids give the sensation of cold and *vice versa*. If the victim recovers, there may be neurological damage; flashbacks of symptoms have been reported 10 years later. Cooking or freezing of the fish does not destroy the toxin.

Ceratium is a shelled, freshwater diatom that can be found in our lakes and streams.

☐ Make a wet mount of living *Ceratium*, if available. Try to find the features illustrated in *figure 8*. You will not be able to discern the flagella but look for the **annulus** and **sulcus**, **apical** and **antipical horns**, the **cellulose plates**. Compare your wet mount with a prepared slide of *Ceratium*.

Figure 8. The fresh water genus *Ceratium*.



The Apicomplexas

This is a parasitic, spore forming group. Movement is often by body flexion, gliding or undulation. Flagella are found in some gamete stages. If pseudopods are present in some species, they are not utilized for locomotion.

Life cycles are complex and often involve several stages. A typical life cycle begins with the infection of a host by a **sporozoite** stage. The sporozoite often lodges in the gut of the host and transforms to a **trophozoite**. This stage will undergo multiple fission to form the **schizont** stage. The schizont stage remains in the host to form a resting stage, the **merozoite**. Merozoites continue to infect the host and spread to other parts of tissue. Merozoites will eventually mature and form either **microgametes** (male) or **macrogametes** (female). Fertilization results in the formation of a **zygote** which will undergo **sporogony** to form more sporozoites.

The most pathogenic species of sporozoan in humans is *Plasmodium vivax*, the causative agent of **malaria**. Over 100 million cases occur every year and the disease is endemic to parts of Africa, Asia, Central and South America. Symptoms of the disease are periodic chills and fevers. It can be

effectively treated and death is seldom the outcome except in underdeveloped countries. After recovery, relapses do occur.

The disease is caused by the protozoa *Plasmodium*, but the disease is transmitted by the female *Anopholes* mosquito. Why do you think only the female *Anopholes* transmits the disease?

When the mosquito bites, it injects saliva into the victim. The saliva contains an anticlotting agent to prevent the hosts's blood from clotting. It then sucks up the blood of the host. Since one of the stages of *Plasmodium* lives in the salivary glands of the mosquito, the person bitten by the mosquito often becomes infected. The mosquito has stages of the life cycle called **gametocytes** composed of **microgametes** and **macrogametes**. These undergo fertilization in the stomach lining of the mosquito and form an **oöcyst**. The oöcyst undergoes **sporogony** to form **sporozoites** that migrate to the salivary gland of the mosquito and thus to humans.

Sporozoites in the human infect liver cells and undergo **schizogony** to form **merozoites**. Merozoites may also infect the liver but eventually they will infect red blood cells. Once in the red blood cells, the merozoites will undergo schizogony to produce macro- and microgametes which the mosquito will take up when it bites an infected human.

Table 1: Life cycle times for Plasmodium.

Species	Life Cycle in Hours
<i>Plasmodium vivax</i>	48
<i>Plasmodium malariae</i>	72
<i>Plasmodium falciparum</i>	36-48

Figure 9. Plasmodium life cycle shown with female Anopholes mosquito. Notice the slant position of the female mosquito, characteristic of how Anopholes lands on its victim.

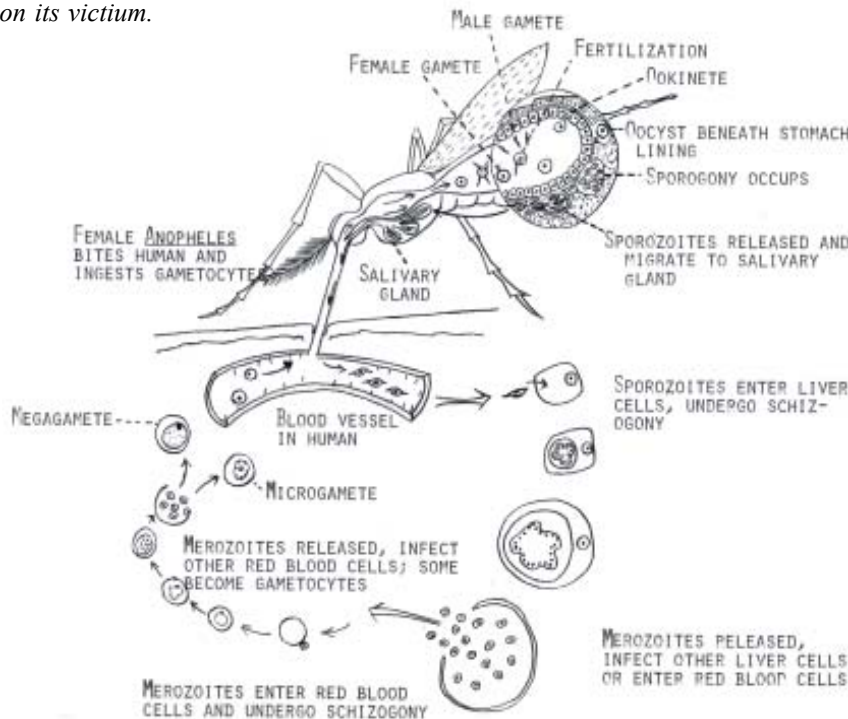


Figure 10. Plasmodium vivax ring stage in human red blood cells.



There are three species of *Plasmodium* which cause malaria and each species has a different time frame for its life cycle. Usually there are no symptoms of malaria until several cycles take place. At a critical point, the red blood cells in the host rupture and cause chills followed by fever. Temperature of the host

may reach 105° F. When the fever breaks, a tremendous amount of sweating occurs. Other symptoms include headache, nausea, body pain, and exhaustion. The symptoms persist for 4 to 6 hours

and reoccur at regular intervals depending upon the species.

Tertian malaria results in attacks every other day and Quartan malaria every three days. Both last for 1 to 4 weeks with 2 weeks the most common duration.

□ Observe the prepared slide of human whole blood. Look for red blood cells and look for a little dot inside some of the red blood cells. These are the merozoites of *Plasmodium*. They give the red blood cell a peculiar appearance. Some suggest it looks somewhat like a single stone in a ring and call this stage the ring stage of infection.

Gregarines

Gregarines are parasitic species mostly of invertebrates as earthworms and insects. For example, *Gregarina blattarum* infects cockroaches, mealworms, and termites. They differ slightly from other apicomplexans in they have no schizogony. They infect the gut and are spread in feces.

□ You have been provided some mealworms to dissect. The intestines of these often have *Gregarina*. Take a clean slide and coverslip. Cut off the head of the mealworm with a razor blade or scalpel and slit the body longways. Using a probe, pull out the intestines and macerate on the slide. Place a drop of insect Ringer's solution on the slide and cover with a coverslip. Try to find the trophozoite stage which is easily differentiated into a posterior and anterior end. Sometimes, you may find two stuck together in the **gamont** stage.

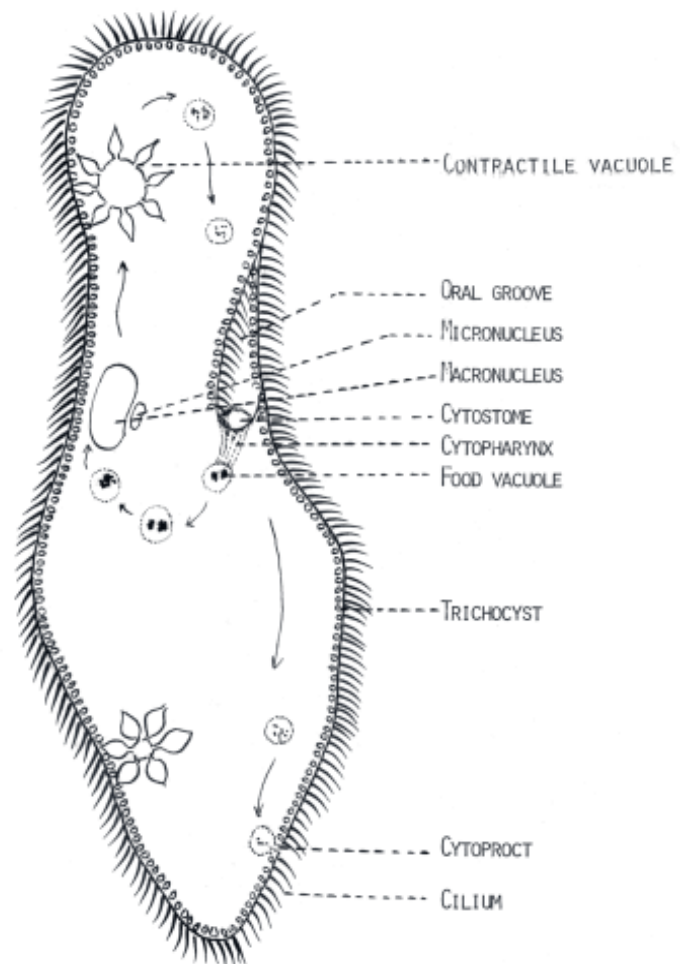
The Ciliates (*L. cilium* = eyelash)

There are more than 6,000 species of this group making it the largest group of the protists. Characteristic is the presence of cilia or ciliary structures at some stage of their life cycle. These are used for locomotion and/or food gathering. Most have two nuclei: a macronucleus and a micronucleus. The macronucleus controls metabolic processes and the micronucleus is involved in reproduction. Reproduction, in this group, does not involve the production of free ga-

Figure 11. *Gregarina* in mealworm intestines, 100X.



Figure 12. *Paramecium caudatum*.



metes. Both fresh and salt water species exist and may be either commensal or parasitic.

Paramecium caudatum

Paramecium caudatum is the typical ciliate studied in laboratories due to its large size and easy cultivation in hay infusions. It is found in isolated bodies of fresh water. No cyst formation is known. As a result, the method of dispersal to other bodies of water is considered to be on the feet of aquatic birds.

□ Place a drop of *Paramecium* culture on a clean slide prepared previously with a circle of Protoslo© or methyl cellulose. The best place to find *Paramecium* in your culture dish is around the seeds at the bottom of the dish. Bacteria feed on the seeds and *Paramecium* feed on the bacteria. Cover with a coverslip and observe.

Some describe the overall shape as “slipper shaped.” Note the swimming movements caused by the cilia and especially note the forward and backward motion used in feeding. Locate **food vacuoles** forming at the base of the mouth (**cytosome**) called the **cytopharynx**. Both at the anterior and posterior end of the organism you should be able to see a **contractile vacuole** used in water regulation.

□ Make another slide of living culture as before and this time add some yeast stained with Congo red. Congo red is a red dye indicator that changes color to blue in the presence of an acid. Observe the flow of food vacuoles inside the animal. What’s happening to the red stained yeast cells over time and why?

□ Make a third slide, this time without the methyl cellulose (Protoslo©). Stain with acetoorcein to see the nucleus. Can you make out both the macro- and micronucleus? It depends upon the angle of the cell to you.

The Stramenophila

This grouping includes the brown algae, diatoms, and the water molds. As you go through these groups, see if you can determine what unites this diverse assemblage.

The Brown Algae

These are exclusively marine with the exception of four genera. They may be found in the open ocean, along estuaries, or in salt marshes. Many grow attached to all kinds of things in the intertidal zone. Estimates as to the number of species are 1500 with 250 genera (Bold 1973). The majority are temperate species but there are some tropical forms. Most grow in shallow waters of intertidal and sublittoral zones (Bold 1973).

The general color of this group is due to the abundance of the xanthophyll, **fucoxanthin**. It masks chlorophylls *a* and *c*. There are other xanthophylls present in addition to β -carotene.

There is no starch in the brown algae; instead, the storage product is the carbohydrate **laminarin**. Additional food is stored as the alcoholic sugar called **mannitol** (Bold 1973).

The cell walls are connected to each other by a middle lamella which is composed of a gummy material called alginic acid. The dry weight of a plant may be up to 25% alginic acid (Bold 1973) and this material is commercially used as a stabilizer, emulsifier, and a coating for papers, as on this paper.

The typical number of flagella is two. They are not inserted apically as they are in other organisms but rather laterally. They are unequal in length and in form. The longer flagellum is of the tinsel type and the shorter one is whiplash. A tinsel flagellum is one that looks like a tree with branches coming from a central column and the whiplash is very much like a whip.

The Rockweed *Fucus* (L. *fucus* from Gr. *phykos* = seaweed)

Fucus grows in relatively cold waters at the intertidal zone. The organism is exposed at high tides and it makes use of this in its reproductive cycle. The body may reach a length of two meters. It is very leathery, flattened and dichotomously branched. At the tips are found swellings called **receptacles**. A **holdfast** attaches it to the rock and there is a short **stipe** which becomes flattened into forking branches. **Air bladders** are found along the length of the blades. Tiny dots are found along the receptacles. These are the openings to **conceptacles**. The opening is called an ostiole.

□ Observe the preserved specimen of *Fucus* and try to identify **holdfast, dichotomous branching, conceptacles, receptacles, and ostia**.

The anatomy of the body is complex. It is separated into an **epidermis** and **cortex**. The cortex has a slimy material making up its interior. The plant body is diploid.

Sexual reproduction is oogamous. The ostia open into the conceptacles where you find male and/or female reproductive structures. This means *Fucus*, depending on the species, may be either monoecious (both sexes in one receptacle) or dioecious (male receptacles on one plant, female conceptacles on another).

Sexual reproduction involves the production of numerous sperm in cells called antheridia and the production of 4-8 egg cells in structures called oögonia. At low tide, the receptacles turn inside out exposing antheridia and oögonia to the incoming tide. Water releases the sperm and they swim to the oögonia which have been exposed to the water currents. Sterile hairs called paraphyses guide the sperm to the eggs to facilitate fertilization. Meiosis is prezygotic so the eggs and sperms are haploid. This difference in diploid body of the plant and haploid gametes is called **alternation of generations** and is common in life forms on earth. The amount of time spent as diploid as opposed to haploid varies from kingdom to kingdom and phylum to phylum.

Figure 13. *Fucus* rockweed. From Bold HC. 1973. Page 80 in *Morphology of plants*, 3rd ed. New York:

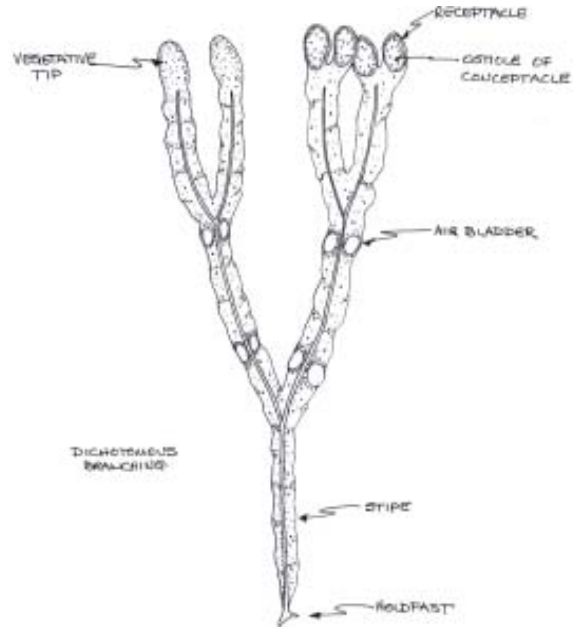


Figure 14. *Fucus* male receptacle. From Bold HC. 1973. Page 81 in *Morphology of plants*, 3rd ed. New York: Harper & Row.

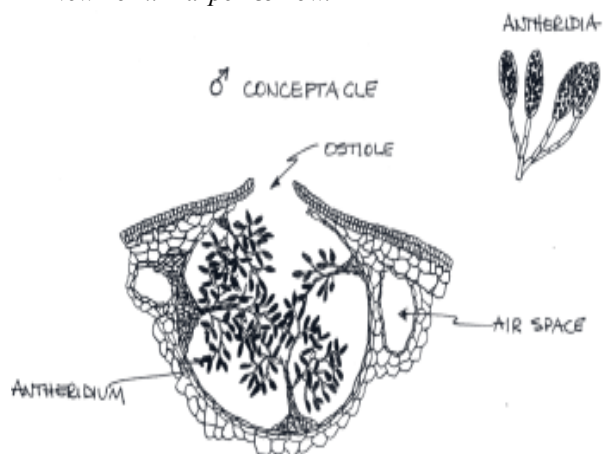
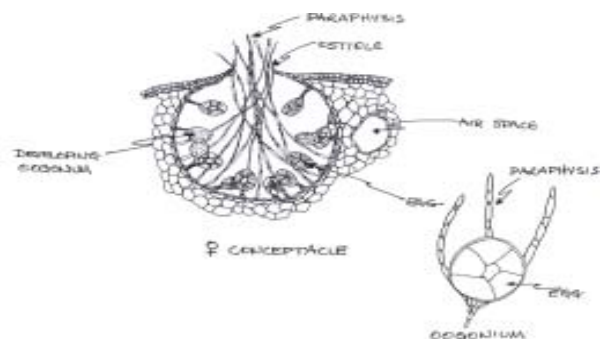


Figure 15. *Fucus* female receptacle. From Bold HC. 1973. Page 81 in *Morphology of Plants*, 3rd ed. New York: Harper & Row.



The male produces laterally biflagellate sperm and the female produces large, nonmotile eggs. Asexual reproduction is by the production of zoöspores that form clusters called sori. They form as superficial cells along the blade.

Obtain a prepared slide of *Fucus* conceptacles and look at the individual receptacles found within. Try to identify **ostiole**, **oögonia**, **antheridia**, and **paraphyses**.

The genus *Sargassum*

Gulfweed, or *Sargassum*, is probably the most often encountered algae on the Florida coast. There are at least 15 species common to our waters and they may grow either pelagic (free-floating) or attached. Two species, *Sargassum fluitans* and *Sargassum natans* make up 90% of the bulk of the Sargasso Sea which frightened Columbus' sailors on their way to the New World. Both these species are sterile and reproduce only by fragmentation.

□ Observe the preserved specimen of *Sargassum*. Try to identify the **air bladders** and **leaf-like branches**. The free-floating species found along our coasts are homes to numerous sea creatures including the Sargasso crab, the Sargasso shrimp and the Sargasso fish. Next time you are at the beach, go into the water and pick up a handful of *Sargassum* and hold it out of the water. The inhabitants panic and begin to drop out of the bundle into your hand, trying to get back into the ocean.

The Diatoms and Yellow-Green Algae

This group is related to both the brown algae and the upcoming green algae. The carotenes and xanthophylls are more dominant than the chlorophylls, thus giving rise to the common name of the group - the yellow-green algae.

These contain the same chlorophylls as the brown algae: chlorophylls *a* and *c*. Excess food is never stored as starch, but like the browns, as another form of

Figure 16. *Sargassum* or Gulf Weed. From Bold HC. 1973. Page 84 in *Morphology of Plants*, 3rd ed. New York: Harper & Row.

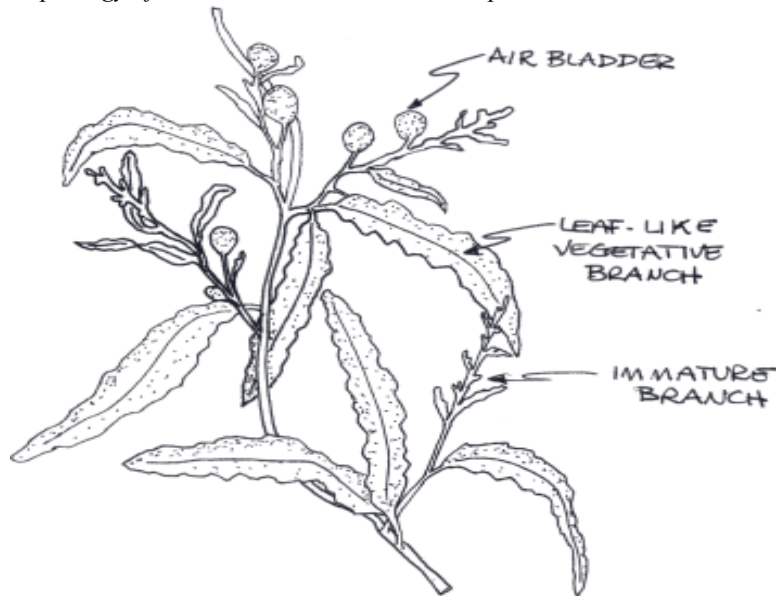
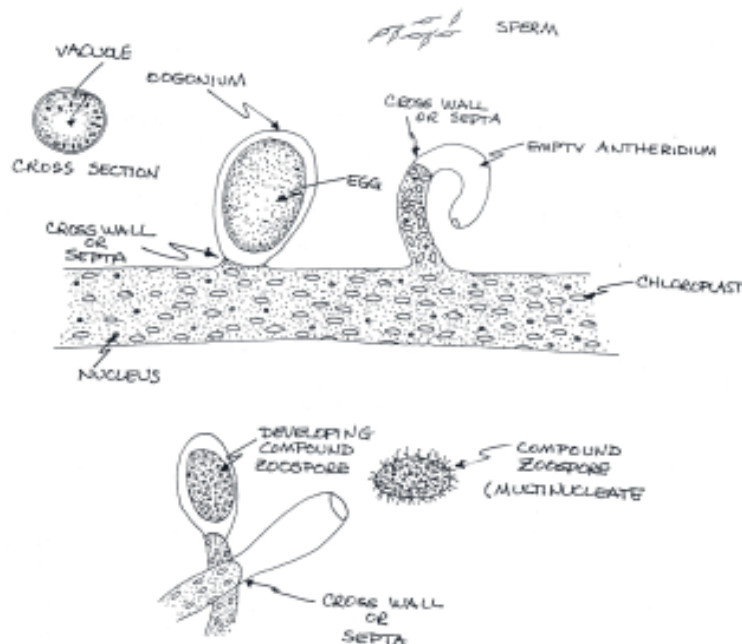


Figure 17. *Vaucheria* or water felt. From Bold HC. 1973. Page 90-91 in *Morphology of Plants*, 3rd ed. New York: Harper & Row.



carbohydrate. In this case, it is **chrysolaminarin**. Oil is also a storage product. The cell walls are often silicified and are formed from two portions which fit together. More than 325 genera and 6000 species have been described.

There are three classes to the division (phylum):

1. Class Xanthophyceae - the yellow-greens
2. Class Chrysophyceae - the golden-browns, and
3. Class Bacillariophyceae - the diatoms.

We'll concentrate on the Xanthophyceae and Bacillariophyceae.

Class Xanthophyceae

Genus *Vaucheria* (in honor of Vaucher, a Swiss phycologist)

The common name of the organism is water felt. The genus is considered amphibious in that some flourish as dark mats in running water *or* on moist, undisturbed soil. The body is tube-like or coenocytic. True septa in the body only occur at reproductive structures. Since it is coenocytic, it is multinucleate.

Make a wet mount and observe the coenocytic nature of the organism. Look for septa or cross-walls.

Asexual reproduction is by the production of large, motile, compound zoöspores. Sexual reproduction is via the production of a large, nonmotile egg and small, biflagellate sperm (oögamous). The egg is contained in an oögonium and the sperm contained within an antheridium. Usually the antheridia are located close to the oögonia. A tube from the antheridium often connects the two. Fertilization results in a zygote and meiosis is postzygotic.

Obtain a prepared slide of *Vaucheria* and try to identify: **coenocytic filament, oögonium, antheridium, and septa (cross-walls)**.

The Diatoms

These are the best known and most numerous of species of the group. There are approximately 200 genera and 5000 species of diatoms. They form the very first part of the food chain and serve as producers. Although they may be benthic and epiphytes in both salt and fresh water, most are planktonic. They have been dated to the Jurassic period of the Mesozoic era. The silicon walls allow for fossil evidence.

Diatoms may be either unicellular, colonial, or filamentous. They are basically divided into two types patterned after their symmetry:

1. pennate diatoms which have bilateral symmetry and
2. centric diatoms with radial symmetry.

Centric diatoms are almost exclusively marine.

The cell walls of diatoms are composed of two overlapping portions, the **valves**. One is usually slightly larger than the other and forms the cover or **epitheca**. The smaller or insert is called the **hypotheca**. They fit together much in the way that a Petri dish works.

Note the Petri dish made to look like a centric diatom. A prominent line called the **raphe** runs along the middle of each valve. Rib-like lines run along the edges. These are pores that enter to the interior of the cell and are called **costae**.

Asexual reproduction is by mitosis. Sexual reproduction in pennate diatoms results in the formation of **auxospores** (so named because they are naked protoplasts). The most distinguishing feature here is that meiosis is prezygotic. Here, meiosis occurs and then sex cells fuse to form the gamete, thus pennate diatoms are diploid in the vegetative state. Centric forms are haploid in the

vegetative state.

As individual diatoms die, they sink to the bottom where the protoplast disintegrates. The deposits of silicious skeletons produce vast deposits of diatomaceous earth. There are many industrial and technical processes which use this substance, among those are swimming pool filtering systems.

□ Make a wet mount of a small amount of diatomaceous earth by placing a drop of distilled water on a clean, dry blank slide. Moisten the tip of a sharp probe in the water droplet and stick the probe tip into the sample of diatomaceous earth. Simply add the material on the tip of the probe to your drop of water on the slide. Cover with a coverslip. Note the various forms and sculpturing associated with the silicon walls. Compare this with a prepared slide of mixed diatoms.

The Oömycetes

These are parasitic or saprobic organisms. Most are aquatic but there are some terrestrial forms. One member, *Phytophthora infestans*, causes late blight of potatoes and is of historical significance. This organism is the cause of the Irish Potato famine of 1845 and 1847. Historians say over 400,000 deaths can be attributed to the famine. The overall effect was millions of Irish immigrated to the United States and wrote a significant chapter in American history.

□ Observe the prepared slide of *Phytophthora infestans*. Note the organism has permeated most of the potato leaf and the reproductive structures are found extruded through the stomata.

The spore producing structures and filaments overwinter in the potato tuber during winter. In spring, the entire plant is infected. Zoöspores enter the plant through the stomata of the leaves. Optimum infection is 18-22°C with 100% humidity.

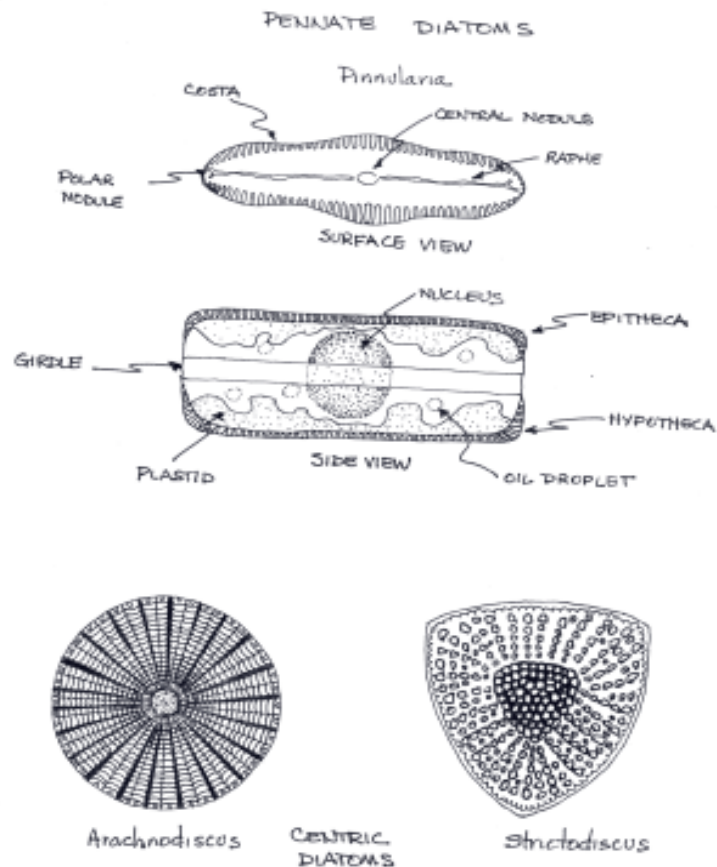
Achlya or *Saprolegnia*

Achlya is sometimes referred to as “ick” a parasitic infection of fish. You see this on aquarium fish as a patch of whitish filaments growing out of the side of the fish. Both *Achlya* and *Saprolegnia* are referred to as water molds. Cells are considered to be coenocytic with walls composed of chitin. Since they are coenocytic, they are considered multicellular.

In this exercise, you will grow either *Achlya* or *Saprolegnia* for observation in the next lab. Both can grow on any number of substrates including cockroaches, but we'll be a little neater here and grow them on sterile hemp seed.

First, carefully split three sterile marijuana seeds lengthwise and place the six halves in a plastic, sterile Petri dish. Cover the seeds with distilled water. Using a pair of forceps, pull away some of the filaments of *Achlya* or *Saprolegnia* from the culture provided. Place the filaments in your Petri

Figure 18. Diatoms. From Bold HC. 1973. Pages 97, 99 in



dish and cover. Seal with parafilm and write your name on the dish. Place the dish were instructed for incubation. You will need to change the water after two days and replace with more distilled water and for every day after that. You will then study your culture in the following lab. What unifying features do you find in the Stramenopila? Why do we put such a diverse group of organisms under one category? _____

The Rhodophyta (Red Algae)

(Gr. *rhodon*, rose + Gr. *phykos*, seaweed + Gr. *phyton*, plant)

There are approximately 400 general and 3900 species of red algae. These are predominately marine but there are a few fresh water species. The marine species are found in both the littoral and sublittoral zones. Many of the species precipitate calcium carbonate on their cell surface and they are very important in reef formation.

The red algae contain chlorophylls *a* and *d*. There are carotenoids present but they are often masked by the red pigment phycoerythrin and sometimes the blue-green pigments phycocyanin and allophycocyanin. What other organisms have you studied that contained these pigments?

Food is stored in the form of **floridean starch** which is approximately 15 glucose units strung together. Regular plant starch (amylose) is composed of hundreds of glucose units. In addition to floridean starch, glycogen may also be present.

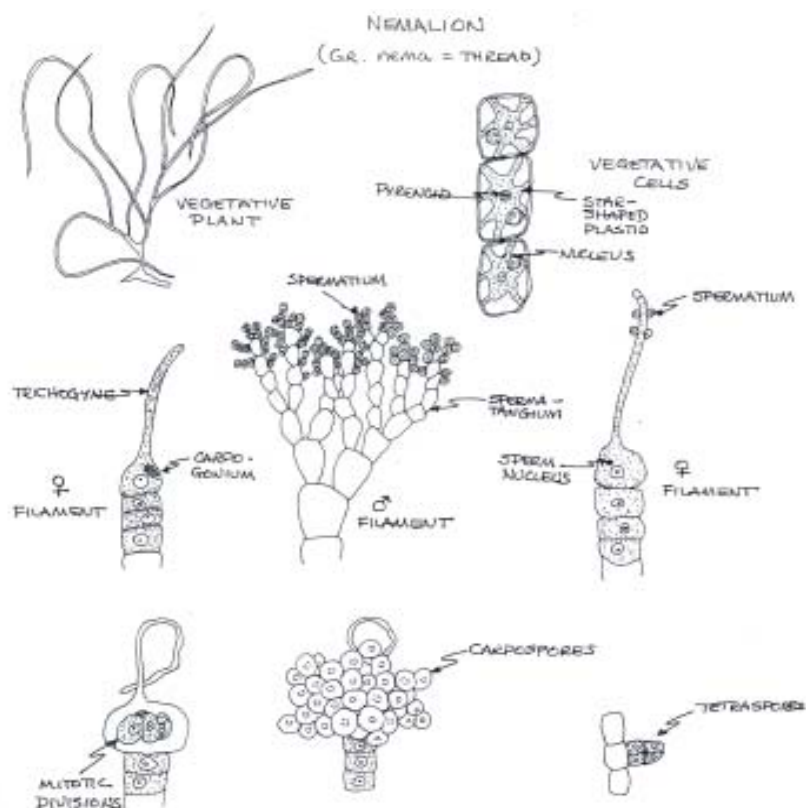
The cell wall is composed of cellulose but is often surrounded by a slimy layer. In some other forms, the slimy area may be further added to by a gelatinous layer. The additional gelatinous layer is called a **hydrocolloid**. Hydrocolloids of the red algae have been classified as:

1. agars - used in microbiology to grow bacteria;
2. carrageenans - used as stabilizers in food products; and
3. gelans - as jello.

Another unusual feature of the red algae is the presence of pit connections between adjacent cells. Biologists are unsure as to the nature of these connections, but many theorize they are a means of protoplasmic continuity between cells for transport and communication.

There are two theories as to the origin of the red algae. One, based on the chloroplasts' DNA suggest a

Figure 19. Nematocyst. From Bold HC. 1973. Pages 112-115 in *Morphology*



very early eukaryotic origin. Another, based on the DNA code for RNA polymerase II suggests a lineage with the green algae (Raven and others 2005).

The Genus *Nemalion* (Gr. *nema*, thread)

This is a marine species found growing attached to rocks at the tidal zone. The organism looks like a wormlike, branching strand. There is a set of central filaments with lateral photosynthetic filaments arising as whorls from the central ones. The cells are beadlike in appearance and there is a single, star-shaped chloroplast in each cell. A pyrenoid is embedded in the chloroplast and its function is to produce floridean starch.

Sexual reproduction in *Nemalion* is both complex and interesting. The plant does not reproduce as most other algae. *Nemalion* is bisexual. The female reproductive structure is called a **carpogonium**. This structure contains an oögonium that ends with a well-developed, hair-like structure called a **trichogyne**.

The male plant produces male reproductive structures called **spermatia**. Each **spermatangium** (structure that holds spermatia) holds a single spermatium or male gamete. The spermatia are released at maturity and since there are no flagellated cells in the red algae, the spermatia swim to the female by **ameboid** motion. The spermatia attach to the trichogyne and moves down the filament to the oögonium and egg.

After fertilization, the trichogyne withers and a series of mitoses and cell division follow which produces a tuft of short filaments. These become **carpospores**. There is evidence these carpospores disseminate and grow into a body which produces an additional set of spores which must germinate before you obtain the original organism. This additional set of spores is called **tetraspores**.

Observe the preserved specimen of *Nemalion* and notice the thread-like filaments.

Obtain a prepared slide of *Nemalion* and try to identify as many features as possible. The slide will contain all the stages mentioned above but on different regions of the slide so be sure to scan the entire slide.

Other Red Algae

Observe the various herbarium specimens of different red algae, including those that produce calcium carbonate secretions.

The Green Algae (Chlorophyta)

The Chlorophyta (Gr. *chloros*, green + *phyton*, plant) are the most similar to the present-day land plants and many biologist believe the green algae were the evolutionary forbearers of today's plants. Among evidence which supports this are the following:

1. they have the same form of starch as land plants;
2. the nuclei are similar down to the pores in the nucleus;
3. cell walls are mostly cellulose; and
4. the cells have a large, central vacuole.

This division is considered ubiquitous - found in both fresh and marine waters, in the soil, and even in the air. There are some 450 genera and 7500 species. They range in size from the microscopic to large, multicellular forms. They may be both epiphytic or endophytic as well as planktonic.

There are five types of cellular organization in the green algae:

1. motile, unicellular and colonial;
2. nonmotile, unicellular and colonial;
3. filamentous;

4. membranous; and
5. coenocytic and tubular.

The green algae contain several pigments, most of which are water insoluble. They include chlorophylls *a* and *b*; α , β , γ carotenes; and several xanthophylls. The chloroplasts vary greatly in form and are often used to determine the species of the plant. Some of the shapes include urn-like, twisted ribbons, lens-shaped, and even star-shaped. Pyrenoids are present in the chloroplasts of most and represent centers of formation of the enzyme amylose synthetase. What do you think is the function of this enzyme?

***Chlamydomonas* (Gr. *chlamys*, mantle + Gr. *monas*, single organism)**

This genus is widely distributed in aquatic and soil habitats and even in airborne dusts.

Make a wet mount of the living culture. You'll want to make the ring of Protoslo© or methyl cellulose to slow the creature down. Try to identify the following structures: eyespot or stigma, contractile vacuoles, nucleus, pyrenoid, and chloroplast. Also observe the water currents created by the beating of the flagella. Once you have viewed the organism under these conditions, stain with iodine and observe.

There are no males or females in *Chlamydomonas*. Instead, we designate them as positive or negative strains. The individual cells serve as isogametes which undergo fusion (syngamy) to form a resting zygote called the **zygospore**. Meiosis is postzygotic, therefore the zygospore is diploid and the meiospores that result are haploid. Asexual reproduction may occur by longitudinal fission.

***Volvox* (L. *volvere*, to roll)**

Volvox is a motile, colonial form that may contain thousands of colonies arranged around the edge of a gelatinous matrix. It is an inhabitant of small, fresh water ponds and lakes. There are some 18 species, only two, *V. aureus* and *V. globator*, which are common. Many biologists consider *Volvox* to be the evolutionary step up from *Chlamydomonas*.

Make a wet mount of *Volvox*. Be especially careful when placing the coverslip on the slide since it may crush the colony. *Volvox* colonies are large enough to be viewed with the unaided eye so you

Figure 20. *Chlamydomonas*.

Adapted from: Bold, Harold C. 1973. Page 19 in *Morphology of plants*, 3rd. ed. New York, Harper & Row.

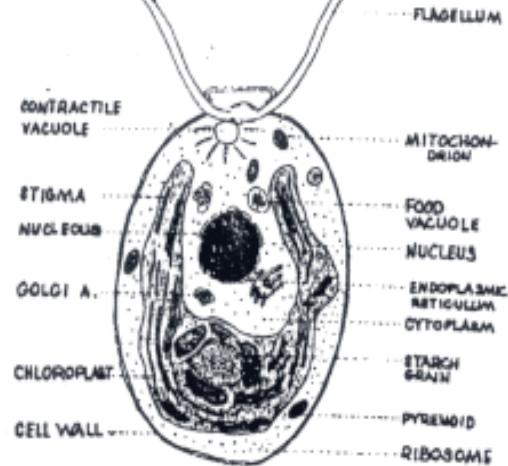
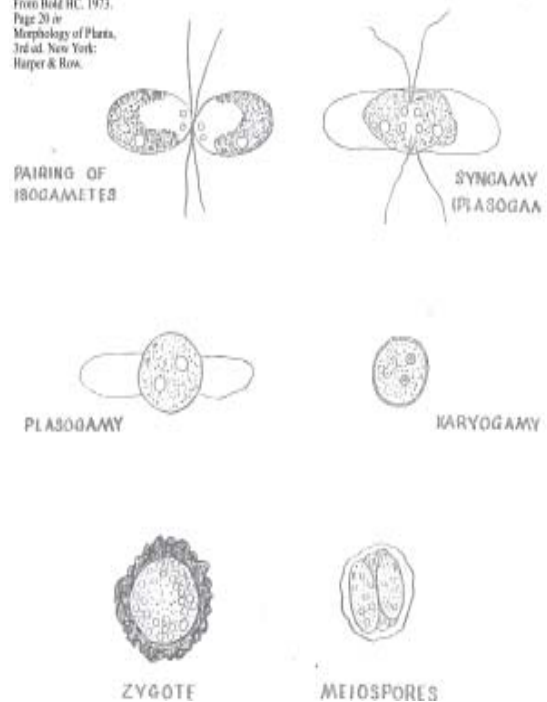


Figure 21. *Chlamydomonas isogametes*.

From Bold H.C. 1973. Page 20 in *Morphology of Plants*, 3rd ed. New York: Harper & Row.



should have no trouble pulling up a colony with the pipette. Note the method of locomotion. Can you see **daughter colonies** in your specimen?

□ Compare the live culture with the prepared slide of *Volvox*. *Volvox* reproduces asexually by the formation of daughter colonies inside the parent colony. Daughter colonies begin as a single totipotent cell which is extruded to the interior and undergoes repeated mitosis. How do you think daughter colonies escape the parent colony?

Sperm are produced in packets of multiples of 16, usually 64 in number. The sperm are biflagellate. See if you can identify a sperm packet in your prepared slide. Reproduction in *Volvox* is said to be **protandrous** which means sperm mature before eggs. Again, sperm packets begin with a single, extruded totipotent cell.

Volvox undergoes sexual reproduction by the production of oögametes. Look for a large, nucleated egg cell. After fertilization, the egg becomes a spiny **zygote** what will undergo meiosis to produce meiospores. These meiospores develop into new colonies.

Spirogyra (Gr *speira*, a coil + *gyros*, curved)

Spirogyra (or pond scum) is one of the most studied green algae in biology labs. It is an unbranched filament, free-floating, and slimy to the touch - hence the common name pond scum. The slimy feel is due to watery sheaths visible under India ink or Methylene Blue. *Spirogyra* is easily identified by the spiral nature of the chloroplast in each cell.

Make a wet mount of *Spirogyra*. Look for the spiral shaped chloroplast, the nucleus, and pyrenoids. Once you have viewed these on scanning, low, and high, **have your instructor guide you through oil immersion**. Look for protoplasmic streaming.

Reproduction is isogamous. There are plus and minus strains which lie side by side. This is called **conjugation**. A protoplasmic bridge forms between the two strands called the conjugation tube. One protoplast from the plus strain migrates through the tube into the minus strain. The

Figure 22. *Volvox*.

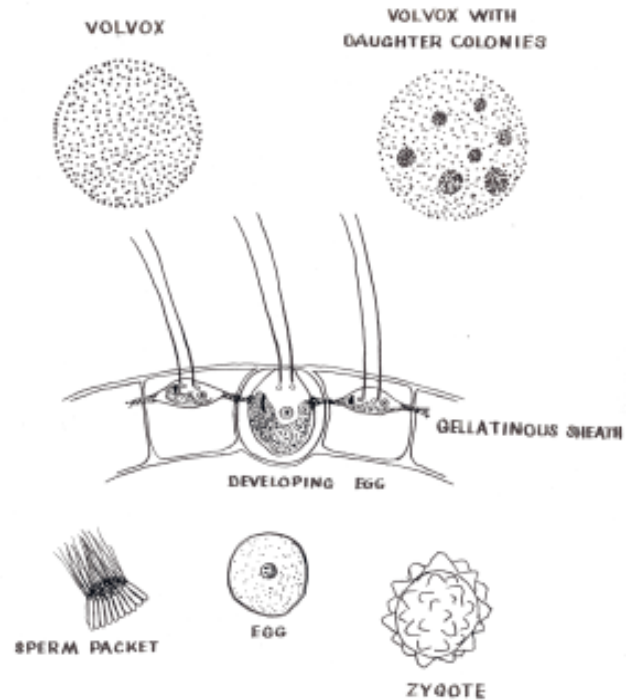
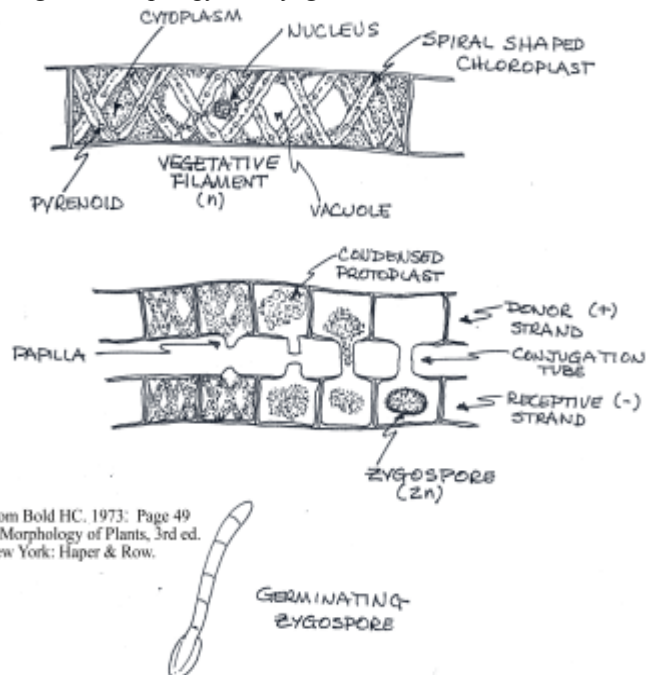


Figure 23. *Spirogyra* conjugation.



From Bold HC, 1973: Page 49 in Morphology of Plants, 3rd ed. New York: Harper & Row.

protoplasts fuse (syngamy) and a zygospore forms. Meiosis is postzygotic with the production of 4 meiospores. However, only two develop. These fall to the bottom of the pond or lake and overwinter and “hatch” in the spring.

□ Observe a prepared slide of *Spirogyra* in conjugation. Identify **plus** and **minus** strands, **conjugation tube**, and **zygospores**.

Desmids

Desmid is the name used to describe several species of unicellular and filamentous algae. The term desmid comes from the Greek word meaning bond. This term derives from the fact a majority of these organisms have two semicells that are mirror images of each other. The region which connects the two semicells is called the **isthmus**. The nucleus lies in the isthmus.

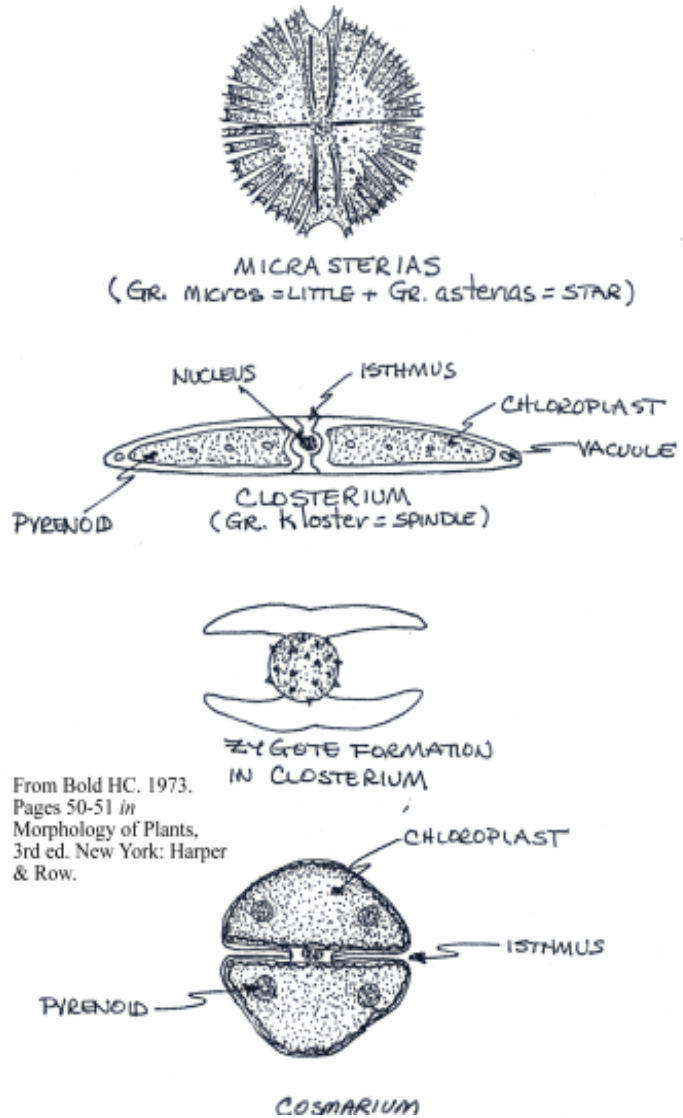
The cell wall may be highly sculptured and is composed of several layers. The outermost layer is pectin-like and the secretion of this material through pores provides movement of the desmid.

□ Make a wet mount of any living desmids. Try to identify **semicells**, **isthmus**, **nucleus**, **pyrenoids** and **chloroplast**. Can you see any movement with individual desmids? Compare this with a prepared slide of desmids.

The only known method of asexual reproduction is via fragmentation of the filament. Sexual reproduction involves the process known as conjugation and isogametes. One filament serves as a positive donor and another as the receptor. The donor protoplast enters the receptor filament through a conjugation tube. A thick-walled zygote is formed and released when the filament decomposes. Meiosis is postzygotic with the production of 4 meiospores, of which only 1 germinates.

□ Compare a slide of desmids with a slide of diatoms. You will be required to distinguish between the two on a lab exam.

Figure 24. Miscellaneous desmids.



Other Green Algae

Note the marine species on display for the green algae. These also may deposit calcium carbonate on their exterior like the red algae.

Choanoflagellida and Other Miscellaneous Protists

The rest of the members of the Protista are even more difficult to categorize. One group included by Raven and others are the slime molds. They have variously been identified as fungi, protists and even Monerans. We'll cover the slime molds with the fungi; however we will look at the choanoflagellates, amebas, radiolarians, and foraminiferans.

Choanoflagellates

These are freshwater zoöflagellates that exist as both unicellular and colonial organisms. They are **sessile**. Attachment is directly to the substrate or by means of a stalk. The flagellum is used to stir water currents and not for locomotion. However, when they detach from their substrate, they can randomly move with the flagellar circulation.

The organism is uninucleate. No unusual structures are found in the cytoplasm. The only real distinction is the **collar** as a modification of the cell membrane. They are hypotonic to their environment.

These are **filter feeders**. The flagellum stirs up water currents, forcing water and suspended nutrients into the posterior portion of the collar. Food is then moved toward the **receiving vacuole**.

Asexual reproduction is by longitudinal binary fission. There is no known sexual reproduction and cysts are also unknown.

Choanoflagellates are rather obscure creatures and probably would not be of any importance to a biology lab except their cellular structure is remarkably similar to the choanocyte cell type found in sponges, suggesting a directly evolutionary relationship.

☐ Make a wet mount of any available choanoflagellates and note their cell structure.

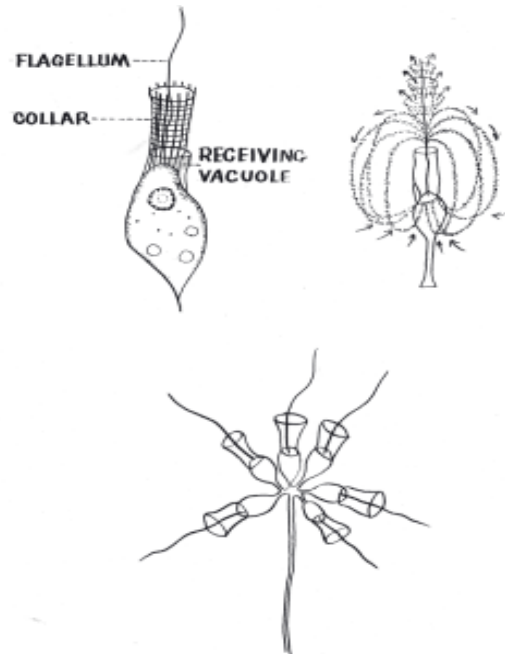
Amebas

The term ameba is a general term associated with organisms which have extensions of protoplasm called pseudopods and feed by phagocytosis. Pseudopods can be used for movement but more commonly are used for food gathering.

These organisms may be either free living or parasitic, with only a few pathogenic to humans. Pseudopodia are typical and flagella may occur in the developmental stages of some. They are typically asymmetrical or with a special type of symmetry. Some genera are naked protoplasm bounded only by a cell membrane while other genera have shells (called tests) of **chitin** or **silicon** and others may pick up other materials and embed it within the cytoplasm. They are primarily fresh water but there are many saltwater species. The cytoplasm is divided into two main regions: (1) **ectoplasm**, and (2) **endoplasm**.

Ectoplasm is the plasmagel state of protoplasm and endoplasm is the plasmasol state. The states

Figure 25. Choanoflagellates.



are interchangeable with one another and this allows for movement in the species. The members of this phylum feed by means of pseudopodia. This structure is also responsible for locomotion. The pseudopodia are of two types:

(1) lobopodia - large, blunt structures composed of both endoplasm and ectoplasm.

(2) filopodia - pseudopodia with tapered ends and composed of ectoplasm only.

Amoeba sp. (amoibe = change, Gk.) - note the spelling “Amoeba” refers to a genus and “ameba” refers to a general class of organisms.

These are found in both fresh and salt water but the most studied in biology laboratory is *Amoeba proteus*, a freshwater species. They are most easily found among decaying pond weeds and may be cultured using boiled-hay infusion that contains flagellates and ciliates.

The size of *A. proteus* is up to 1000 microns (1 mm) and may be seen with the unaided eye. Due to the transparent nature of the organism, to properly view it under a microscope, you must decrease the light intensity. There is a single nucleus that varies in position due to the streaming of cytoplasm. Various organelles can be seen tumbling over one another as the animal moves. The protoplast is surrounded by a cell membrane.

Locomotion is by means of extending the cytoplasm by changes in the gel and sol states. The *Amoeba* extends a pseudopodium and as it extends, the rest of the organism follows.

Freshwater species have contractile vacuoles, while saltwater species have none. The number of contractile vacuoles varies. Excretion occurs by the ameba simply moving away from a particular waste particle.

Amoeba is holozoic with entrapment of food by engulfment with the pseudopodium. The pseudopod, upon contact with food, overruns it and forms a food vacuole around it at the time of engulfment. Death of the prey takes place from three to sixty minutes and death is usually by lack of oxygen. Enzymes are dumped into the vacuole and the pH drops rather quickly for digestion.

Asexual reproduction is by binary fission. Sexual reproduction is by fusion of two protoplasts, each serving as an isogamete. Cyst formation may occur during adverse environmental conditions.

☐ Make a wet mount of living *Amoeba*. (Be sure to start with the iris diaphragm all the way closed. Notice the ameboid motion with the pseudopods. Compare that to the prepared slide of *Amoeba proteus*. Identify as many structures as you can.

Figure 26. *Amoeba proteus*.

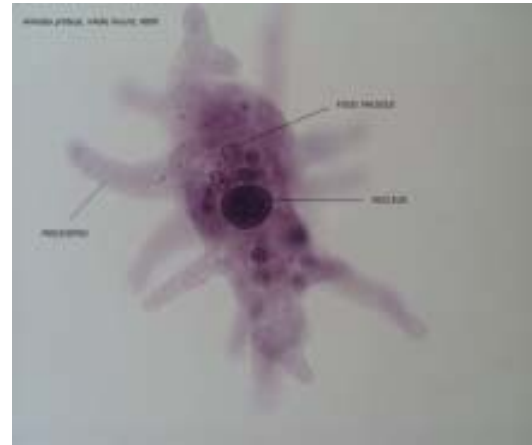


Figure 27. Arcella with test of keratin.

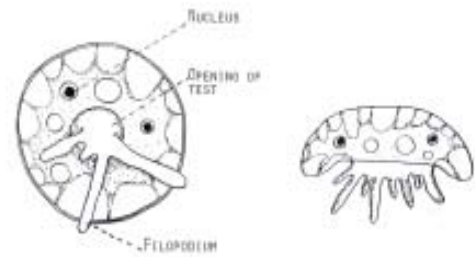


Figure 28. Diffugia.



Other Amebas

Another group of amebas are called the shelled amebas. They generally have radial symmetry and the shell is most often composed of chitin or silica. They always have an opening in the shell from where pseudopodia extend. *Arcella* is one of the most common freshwater shelled amebas and its shell is composed of **keratin**. *Diffugia*, another freshwater ameba, has a shell of mineral particles embedded with the protoplast.

□ Make a wet mount of living *Arcella* and observe.

□ Make a wet mount of living *Diffugia* and observe.

Entamoeba histolytica

This is a pathogenic species in humans. It is widespread and is spread by contaminated water, food, and flies. The organism burrows into the lining of the human intestine and dissolves living tissue. This results in a condition known as **amebic dysentery**. The active stage is known as the **trophozoite stage**; it ranges in diameter from 15 to 25 microns. It is holozoic, even ingesting intestinal bacteria and blood cells. In *E. histolytica*, there is a nucleus with a central endosome with chromatin granules appressed around the nuclear membrane. Cysts form in the intestine and are deposited with fecal matter that may contaminate water and food supplies. Only asexual reproduction is known to occur.

Amebic dysentery results in diarrhea, fatigue, and intestinal bleeding. Complications include liver involvement with liver and pulmonary abscesses.

□ Obtain a prepared slide of *Entamoeba histolytica* and locate the trophozoites in the human intestine.

Heliozoans (*helios* = sun, *zoon* = animal, Gk.)

These are primarily freshwater organisms, either free floating or attached. They may either be naked or shelled. The pseudopodia are very fine, needlelike structures called **axopodia**.

Figure 29. Illustration of *Entamoeba histolytica*.

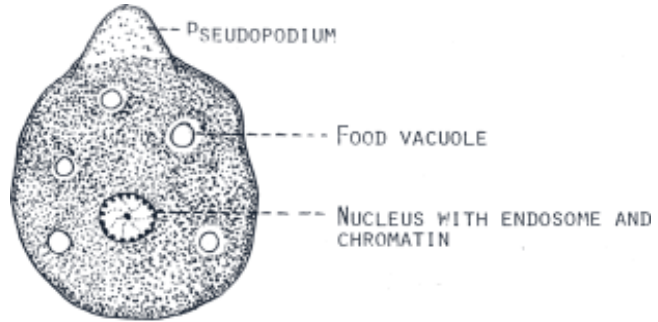


Figure 30. *Entamoeba histolytica* infection of human intestine.

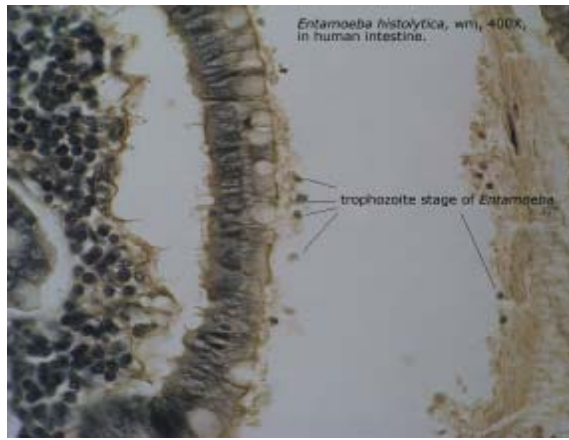
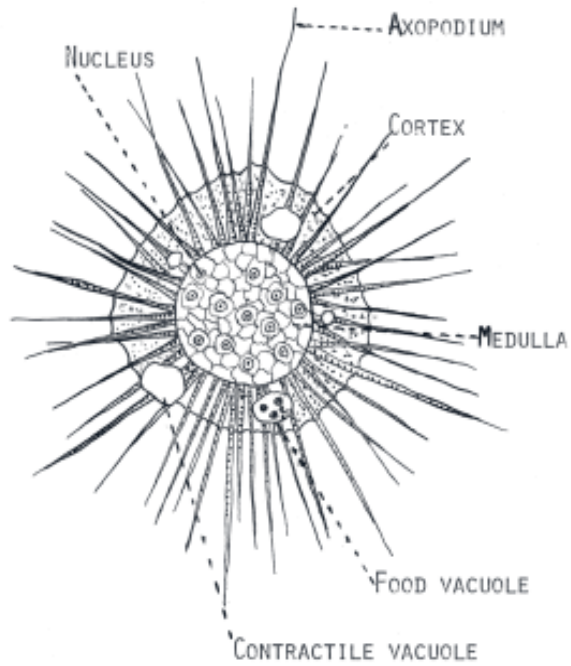


Figure 31. Actinosphaerium, a heliozoan.



Each contains an axial rod covered by ectoplasm only. The axopod does provide support but is not a true skeleton. It can lengthen or shorten and even “melt” into the cytoplasm. They are not used for locomotion.

There is an inner and outer sphere, the **medulla** and the **cortex**, respectively. The cortex is often highly vacuolated. The medulla is composed primarily of endoplasm with many nuclei and the base of axopods. Skeletons are fairly common and may be foreign material as sand grains, living diatoms or of separate siliceous material secreted by the animal. There is an outer gelatinous covering for all skeletons. Locomotion, excretion and osmoregulation, nutrition, and reproduction is as other amebas.

☐ Make a wet mount of any heliozoans provided in lab. See if you can identify any of the structures shown in the illustration.

Radiolarians

These organisms are exclusively marine. As the forams, when they reach 30% or more of sediment, it is called a **radiolarian ooze**. These are both planktonic and benthic but planktonic species by far predominate. They reach several millimeters in diameter and are thus visible to the unaided eye. Colonial forms may reach several centimeters in diameter.

Like heliozoans, the basic body plan is spherical with an inner and outer region. The inner region may be multinucleate and is bounded by a capsule composed of chitin. There may be symbiotic dinoflagellates (**zooxanthellae**) outside the capsule and often the outer region is highly vacuolated as in the heliozoans.

A skeleton is almost always present and is of silica with the exception of one subclass that contains **strontium sulfate**. The skeleton takes two forms: (1) skeletal rods that radiate outward like the sun’s rays, and (2) a spherical skeleton.

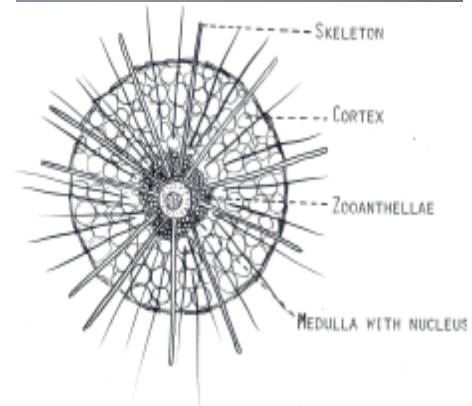
Locomotion, excretion and osmoregulation, nutrition and reproduction is as other amebas.

☐ Observe the prepared slide of radiolarians. Notice the intricate patterns of the tests.

Foraminiferans

These are primarily marine organisms that secrete a shell of **calcium carbonate** with small amounts of other materials as silicas and magnesium sulfate. At one time they were considered amebas but recent evidence seems to indicate they should be a separate group.

Figures 32 and 33. Radiolarians.



Figures 34 and 35. Foraminiferans.



The shells consist of a single chamber and are thus called unilocular, but the majority are **multilocular**. These multilocular forms begin as a single chamber called a **proloculum**. As the animal grows, the organism extends from the chamber and secretes new shell around it, extending the chamber. Chambers may be added in a line, in overlapping scales, or in a spiral manner. Every chamber has protoplasm of the animal in it. The shell is pierced by many small openings and filopodia extend out from these.

Most species are benthic, but there are some plankton forms. Planktonic forms have a more delicate shell than benthic and cold water species (denser water) have smaller, less porous shells than those of tropical waters. You may thus determine climatic changes by observing fossil deposits and observing shells. When foram shells form 30% or more of sediment, the deposit is called **foram ooze**. Due to their shells, forams form an integral part of the fossil record. They are from the Cambrian period of the Paleozoic era. They contribute to the great limestone and chalk deposits of the world.

There are many multinucleate species of forams. The relationship of each nucleus is poorly understood, but often axopodia are associated with each nucleus. They also often contain symbiotic **zoochlorellae** in the interior or the organism called the **calymma**. Free-floating forms can change their depth by increasing or decreasing the vacuolation present in the organism.

Locomotion, excretion and osmoregulation is as other amebas. Nutrition is similar to other amebas but some of these may form symbiotic relationships. Reproduction is as other amebas with exception of multiple fission in multinucleate species.

□ Obtain a prepared slide of forams and notice the markings on the tests. See if you can find the openings for the filipodia.

Questions

How would you be able to separate these individual ameboid groups from each other by slide?

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