Pond Adventures

Issue #1: Why is my pond green?

What are algae?
Why is there algae in my pond?

Algae is a term used to describe all photosynthetic bacteria and protest that produce oxygen.

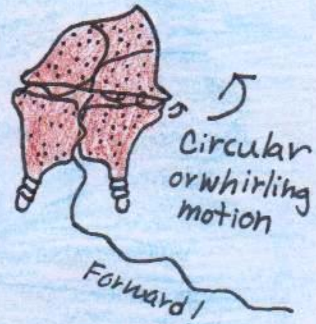
Your pond is providing the algae with everything they require to grow and thrive.

Like what?

Light

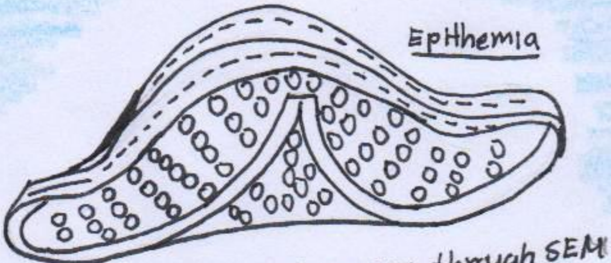
Most algae require light to photosynthesize, just like plants

Some algae have special structures called flagella that allow them to swim to adjust their position in the water column for optimal light levels.

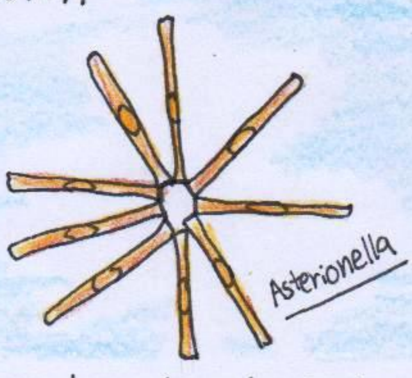


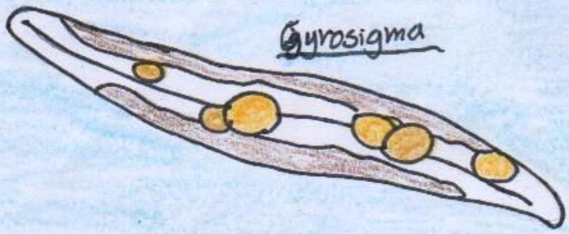
Other types of algae do not have flagella but their cells depart from a spherical shape to slow their sinking rate. This is called Form Resistance.

An example is diatoms, which have heavy silica frustules, would normally sink very fast. These frustules are not solid cups of glass but are modified with pits, pores, and ornamentation that helps decrease sinking rates.



Pores and ornamentation seen through SEM



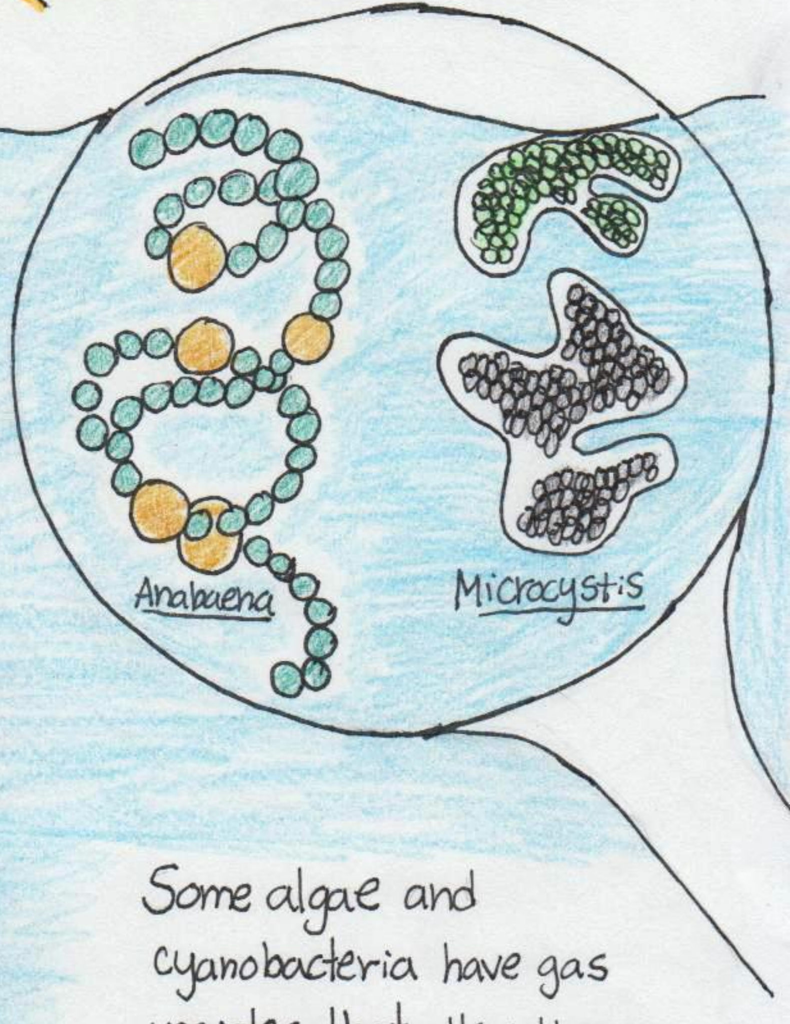


Diatoms can also produce lipids to help them float and some types, as well as other algae, form colonies to slow sinking rates.

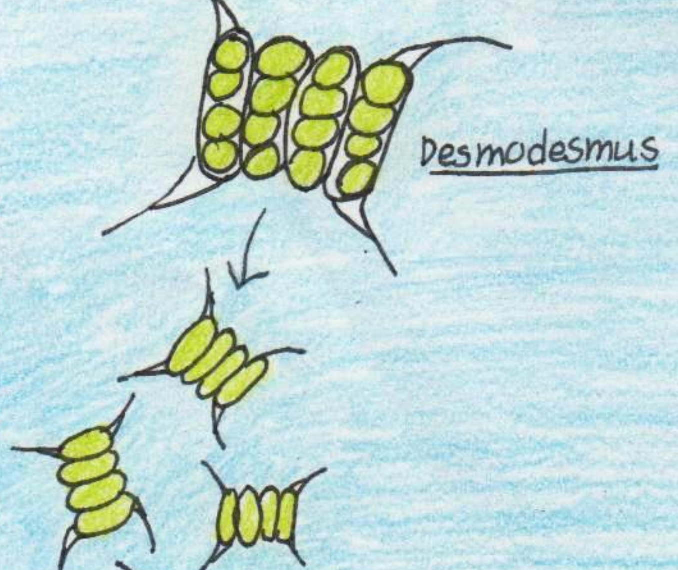
Light

Coenobiums are algal colonies where the number of cells and their arrangement is under genetic controll.

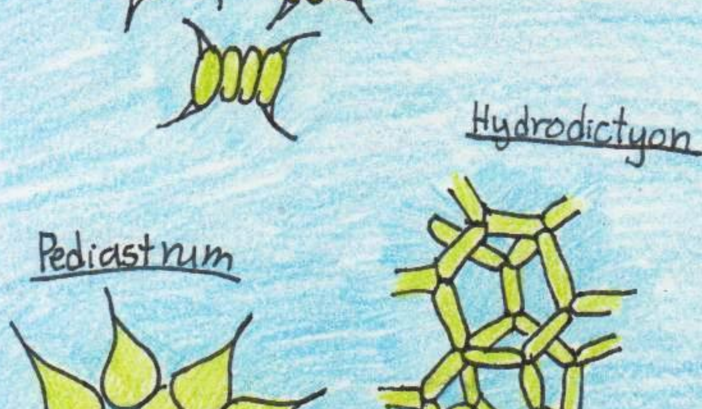
Daughter cells are produced within the parent cell with the specified number of the parent colony and these arrange within the parent cell or just after release to the same arrangement of the parent colony.

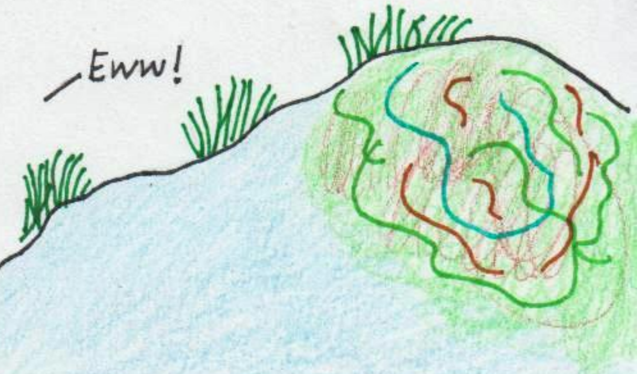


Some algae and cyanobacteria have gas vesicles that allow them to float to the top of the water column.



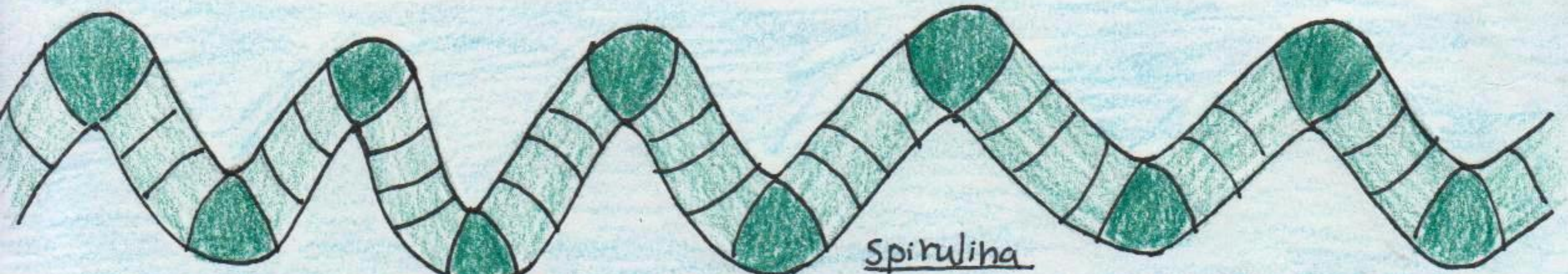
However, sometimes the gas vesicles can't becollapsed and such algae die, forming scum on the pond surface





Light

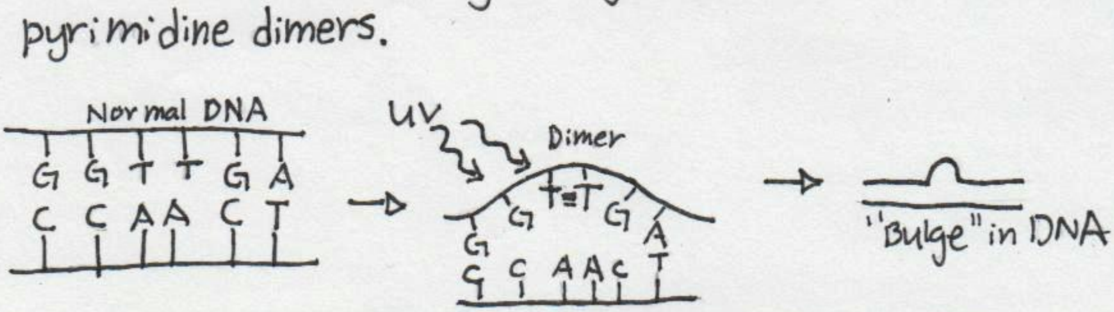
Algae that can grow at greater depths, or with disturbances leading to turbid water, use accessory pigments that absorb light outside the range of Chlorophyll a to gather more light energy. Accessory pigments include chlorophyll b, phycobiliproteins, and carotenoids and can cause color variation in algae such as a blue color in cyanobacteria from phaycocyanin.



Spirulina

Too much light can also be a problem leading to DNA damage. Some protective compounds are produced by algae and act as a natural sunscreen. Such compounds include carotenoids, which can absorb excess light energy and dissipate it as heat. Some cyanobacteria produce sectonemin in their sheaths to protect against UV irradiation giving the filament a yellow-brown color.

Many algae, along with humans, have DNA repair mechanisms for removing damaged areas of DNA such as pyrimidine dimers.

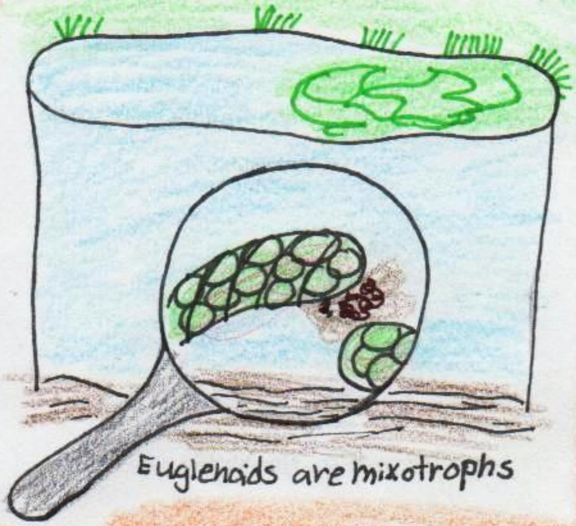


FOOD

Algae require nutrients, some in large (macro) quantities and others in very small (micro) quantities. If all required nutrients are not present in the necessary amounts, then algae will not grow.

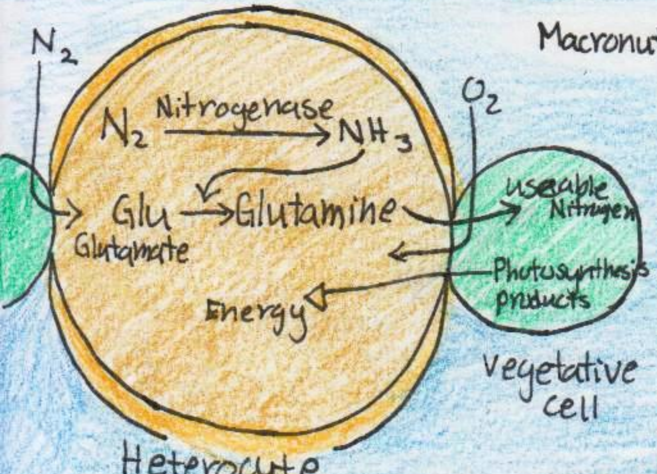
Macronutrient CARBON

Most algae use inorganic carbon to form organic molecules through carbon fixation. Inorganic sources of carbon include dissolved CO_2, which in water is converted to carbonate except in acidic conditions. Many algae can use carbonate and convert it back to CO_2 inside their cell for use in carbon fixation. Some algae can take up dissolved organic carbon compounds by osmotrophy just like humans. Other algae can alternate between osmotrophy and photosynthesis and are called mixotrophic.



Euglenoids are mixotrophs

Macronutrient NITROGEN



Has thick layers to protect Nitrogenase from oxygen inhibition

Algae also require combined nitrogen and typically take up ammonium or nitrate ions directly from water. Algae can obtain ammonium by extracellular enzyme cleavage of dissolved compounds. A few types of cyanobacteria are known to fix atmospheric nitrogen (N_2) to useable forms.

Macronutrient PHOSPHORUS

Algae require phosphrous, in the form of phosphate ion ($H_2PO_4^-$). The ion binds to Al^{3+}, Fe^{3+}, and Ca^{2+} along with carbonate in high pH waters to form highly insoluble complexes in lake sediments.

In lakes with minimal human influence there are generally no algal blooms due to phosphorus limitations.

FOOD

A few algal micronutrients, though many are important.

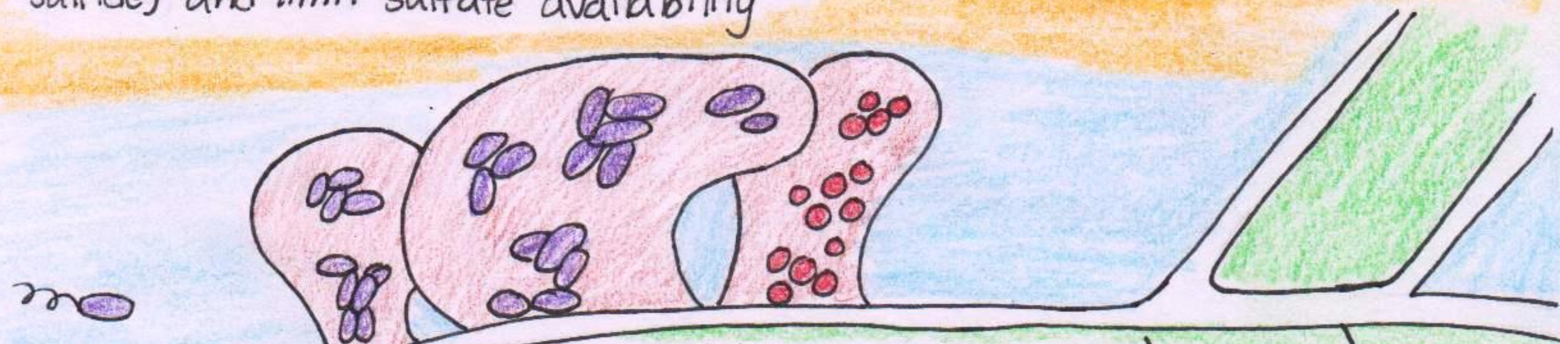
Micronutrient IRON

Algal cells use iron as a cofactor for many enzymes including nitrogenase in nitrogen-fixing cells and for photosystem reaction centers. Iron can be limiting in environments containing sulfides, which precipitate dissolved iron.

When iron is abundant, some algae can store it in protein aggregations known as ferritin. Some cyanobacteria, dinoflagellates, and certain diatoms are known to harvest iron from low-content waters by producing surface iron-binding organic molecules known as siderophores.

Micronutrient SULFUR

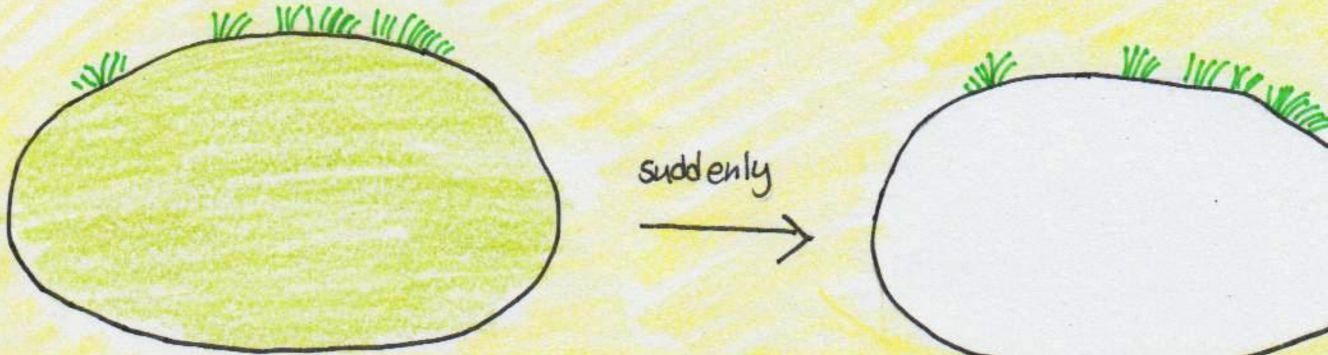
Algae use sulfur in biosynthesis of the amino acids cysteine and methionine as well as in some thylakoid lipids. Sulfate is abundant in marine waters but in freshwater systems anaerobic bacteria convert sulfate to H_2S (hydrogen sulfide) and limit sulfate availability



Micronutrient Cobalamin (vitamin B_{12})

The vitamin cobalamin is required by most eukaryotic algae and is produced by some bacteria and archaea generally found as epiphytes on larger algal cells.

Predation!

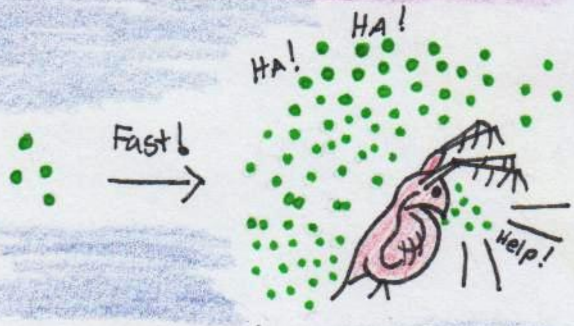


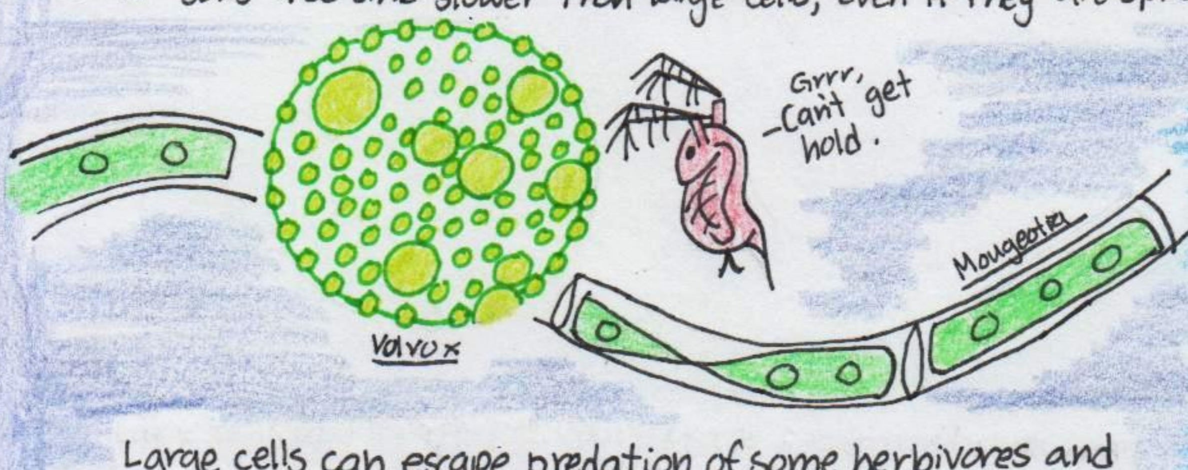
Predation limits algal densities and can cause "clear water phase" in ponds with planktonic algal blooms. This occurs in late spring or early summer where crustacean densities accumulated to a point that they filter all the small algae out of a pond.

Algae deal with predation in several ways

Cell size

Small cells can be easily eaten but have a high surface to volume ratio that allows them to quickly gather nutrients and quick cell division. In nutrient-rich environments they can reach population levels too large for filter-feeders to eliminate from a system. Small cells also sink slower than large cells, even if they are spherical.

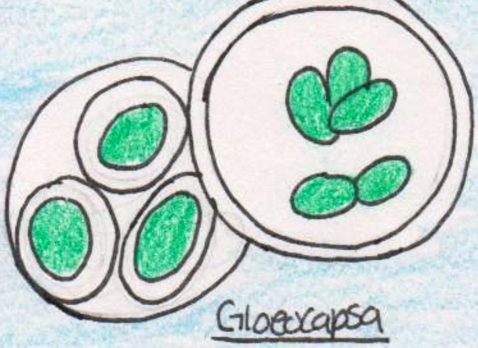




Large cells can escape predation of some herbivores and can store more nutrients than smaller cells, but take a long time to grow. Filaments can gather and store more nutrients under low nutrient conditions and are usually too large for most grazers to consume.

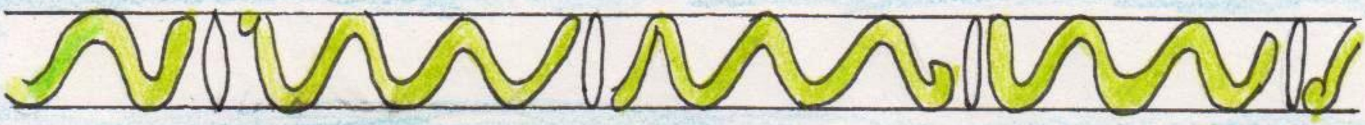
But, sometimes the predators just get bigger.

Mucilage and Sheaths



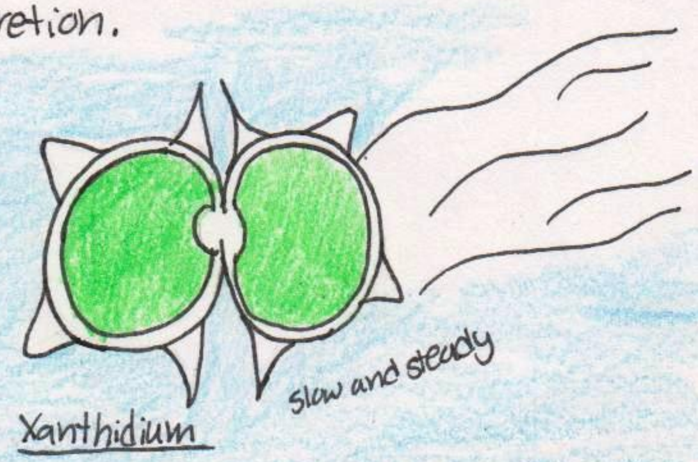
Gelatinous envelopes and mucilage can increase cell size, colony formation, add to buoyancy up to a point, and make it hard for herbivores to chomp onto.

Some mucilage, such as the pectin-like mucilage of *Microcystis*, has the capacity to capture scarce iron and other micronutrients enhancing algal growth.

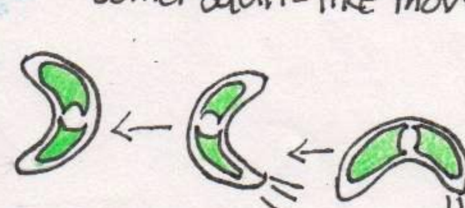


Some Zygnemataleans (*Spirogyra*, *Zyngema*, *Mougeota*, and Saccoderm desmids) secrete an outer mucoid layer of calcium pectate and hemicellulose surrounding a thin fibrillar primary wall and thicker fribrillar secondary wall. The mucilage helps in water retention, nutrient trapping, and absorbing UV irradiation.

Many desmids extrude mucilage to achieve gliding motility. The resulting movement is quite slow and requires continuous secretion.

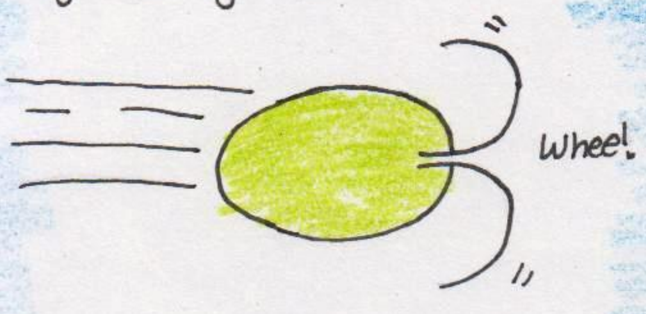


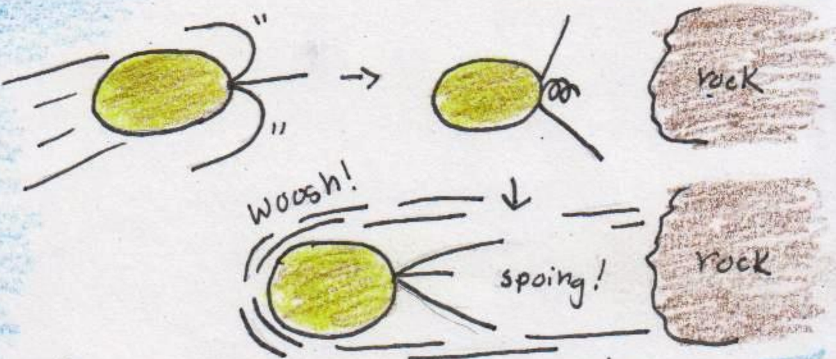
Closterium and some other desmids secrete mucilage only from opposing cell tips resulting in a somersault-like movement



Predation!

Motility is a good defense against predation but it may work better if the algae can go faster.



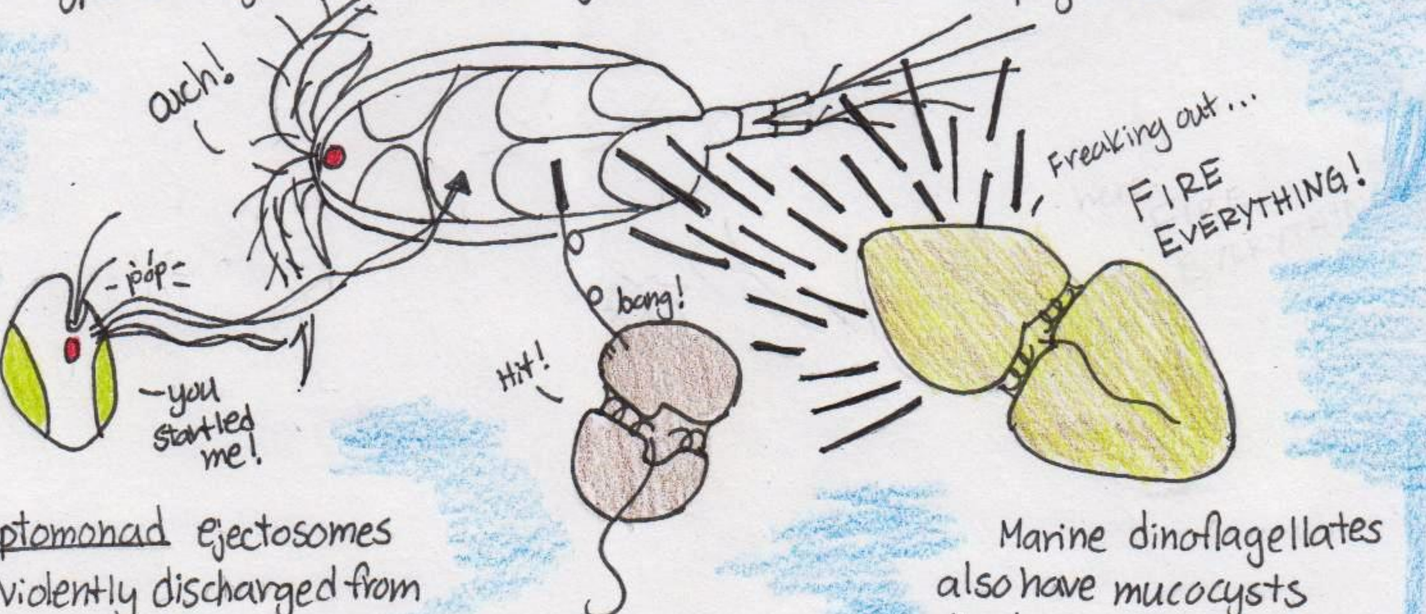


some algae have flagella that help them to swim very fast.

A few algae called haptophytes also have a haptonema that can be coiled to stop or slow down the algae so the flagella can change direction and send the cell backward.

Ejectable components

Some types of algae have the ability to deter herbivores with projectiles



Cryptomonad ejectosomes can be violently discharged from cells in 2 coiled ribbons (one smaller than the other). When discharged, both unfurl and form a narrow kinked barb

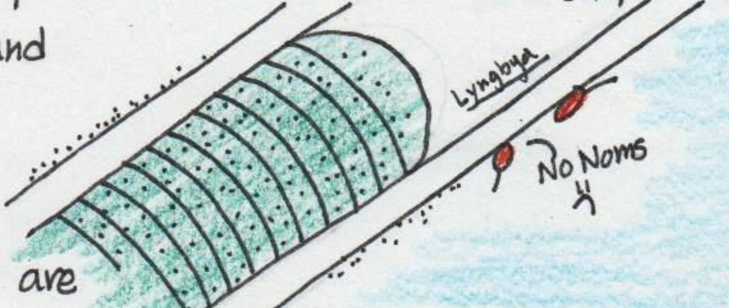
Trichocysts are ejective rods of marine dinoflagellates. These are peripheral structures that are located beneath pores in the thecal plates of armored species. They explode from the cell and a rod is at the end of twisted fibers.

Marine dinoflagellates also have mucocysts that are relatively simple sacks that release mucilage to the cell exterior as thick rod-shaped bodies.

Even prasinophytes, early divergent green algae, have extrusomes that can be ejected as coiled ribbons.

Cell wall Structure

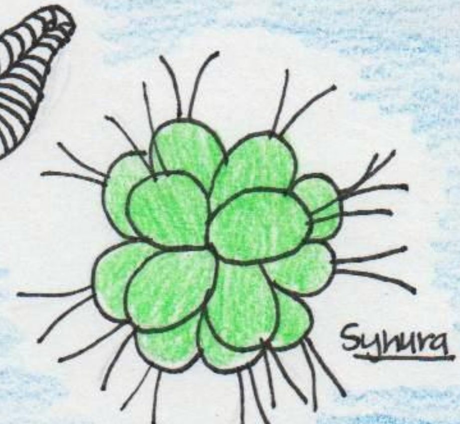
Some algae have refractory carbon compounds in their cell walls. Such compounds are resistant to chemical breakdown and microbial decay that occurs in mucilage sheaths or cell walls. Some examples include scytonemin in cyanobacterial sheaths, algaens in green algae that are cross-linked by hydrocarbons, and sporopollenin, which is present in the zygote cell walls of some green algae.

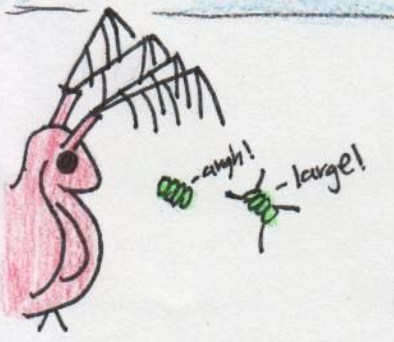


Cysts of dinoflagellates have dinosporin just beneath the outer cell wall of resting cysts or zygotes.

Cellulose, when organized in ridged, crystalline sheaths of microfibriles, can be very stable and resist microbial enzymatic attacks.

Silica in diatom frustules is also innert to enzyme attack. Silica scales on some Synurophycean (a stramenopile) cells can be overlapping or perforated to reduce weight and allow contact with the environment.





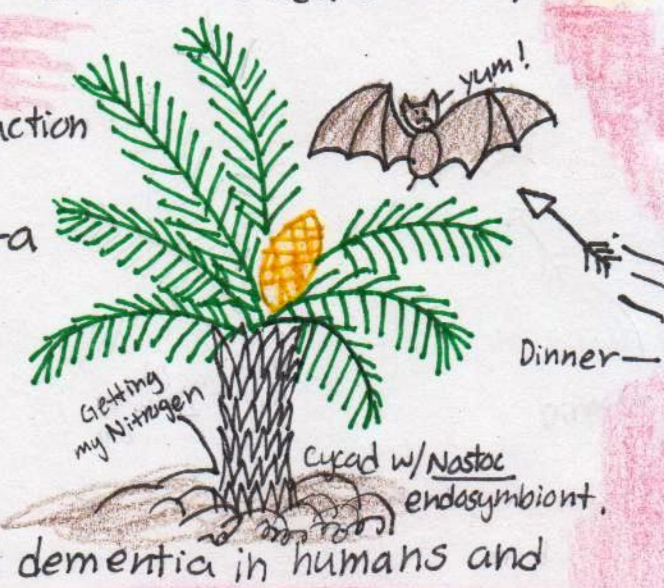
Other cell wall modifications include horns or spines. Desmodesmus can make spines when Daphnea or other herbivores are present.

Some marine algae, like the red rhodoliths, calcify their body to prevent herbivore or wave damage. However, this leads to extremely slow growth rates.

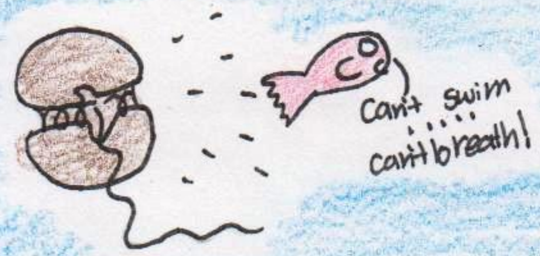
Predation!

Toxins

Some algae secrete toxic compounds that can prove hazardous to wildlife and humans. A few toxins of major concern are neurotoxins, saxitoxin, and hepata toxins.



Neural toxins can interfere with muscle contraction and cause nervous system dysfunction. Cyanobacterial anatoxin-a and homoanatoxin-a are produced in freshwater by many genus such as Anabaena and Planktothrix. Another toxin called β-N-methylamino-L-alanine (BMAA) is produced by all cyanobacteria. This toxin is known to cause dementia in humans and can be concentrated up the food chain.

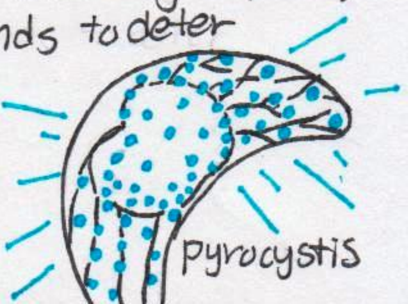


Saxitoxin blocks plasma membrane sodium channels and causes paralysis. It can be produced by some cyanobacteria and dyinoflagellates.

Hepata toxins cause irreversible inhibition of liver-cell protein phosphatases and can lead to liver failure. It is produced by cyanobacteria such as Microcystis, Nodularia, Planktothrix, and Anabaena.

Some marine red algae have specialized gland cells that secrete various compounds including halogenated terpenoids and alkaloids. Other marine macroalgae produce defensive compounds including terpenes, acetogenins, alkaloids, and halogenated phenolic compounds to deter amphipods, copepodes, polychaetes, urchins and fish.

Bioluminescence, the production and emission of light by a living organism, may startle predators and facilitate escape.



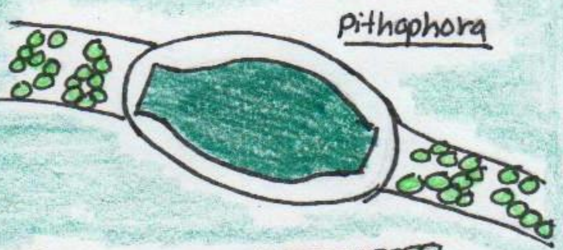
The Environment

Prennation, the formation of resting stages that allows algal species to avoid a period of adverse conditions, is important in the persistance and repeated development of algal blooms in a pond. Unfavorable conditions include low nutrients, irradiance levels, changes in photoperiod, and too high or too low temperature.

Resting structures

These cells are packed with high-energy storage compounds such as lipids and carbohydrates.

Akinetes are a form of asexual resting cells that develop from actively growing cells. They are produced by some cyanobacteria and green algae. Akinetes have lower metabolism and thicker cell walls than vegetative cells.



Pithophora

Aphanizomenon

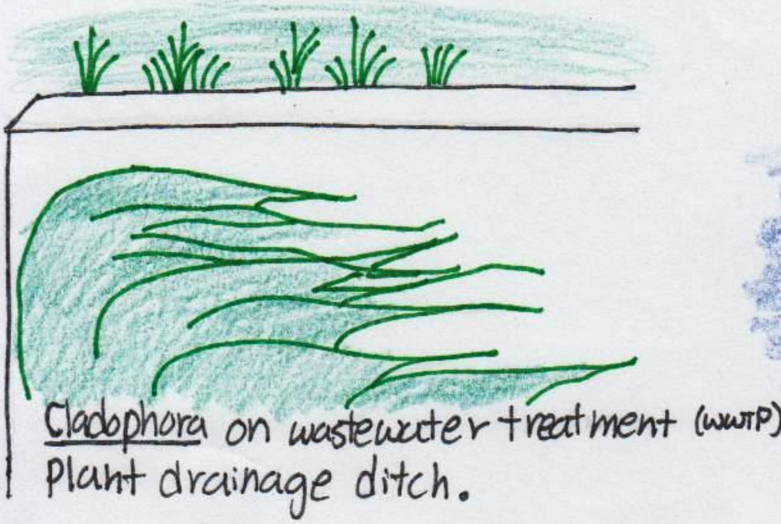
Gomphorema

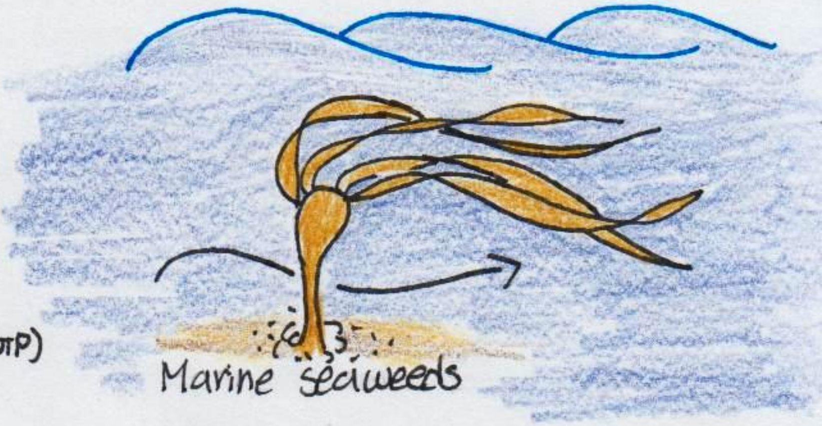
Spores and resting vegetative cells produced by diatoms have microscopically noticeable changes in their cell frustules, which become very thick and more round in shape. Such structures may also lose ornamentation and the cell cytoplasm is usually condensed into a brown mass with lipids and polyphosphate granules present.

Other structures include dinoflagellate cysts, which form after sexual reproduction, and zygotes.

Some zygotes contain highly resistant phenolic compounds in their cell wall.

Shear stress





Algae, especially marine seaweeds, handle shear stress through physical adaptations in strechiness, flexibility, twisting, and structural strength. Other adaptations include algae that grow flat to a substrate, such as marine corallines, or in short turfs, like Cladophora.

Pollution

Different types of pollution can hurt or help the growth of algae. Some chemical pollution such as chlorinated hydrocarbons, oil, herbicides, insecticides or heavy metals can damage algae along with other organisms.

Runoff from nearby agricultural lands, fertilized lawns, leaky septic systems, WWTP effluent, and industry can cause buildup of organic sludge at the bottom of a lake or pond. The nutrients in the sludge can be remineralized and used by incoming or resting algal structures.

High incoming nutrients such as phosphate, nitrate, and some micronutrients promote large persistant populations of algae, with low diversity, which may include toxin-producing cyanobacteria.

Some marine algae have adapted to areas with higher salt content due to industrial waste or runoff from de-iced roads and may eventually adapt to freshwater (just like Cladophora).

END

Graham, Linda E., Graham, James M., and Wilcox, Lee W.
Content from: Algae Second edition. San Francisco: Pearson Education, 2009

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AQUAFIX

Pond Adventures

Issue #2: I put stuff in my pond, why is it still green?