October 18 - Algae

Protist: Any eukaryote not a plant (Kingdom Plantae), animal (Kingdom Animalia), or fungus (Kingdom Fungi). Algae, for now, are in the Kingdom Protista.

Algae: I wish I could provide you with a concise and encapsulating definition…alas …none exists…☹…why not?

The group of organisms referred to as 'algae' includes many different evolutionary lineages. That is to say, the algae do not all arise from a single common ancestor. (To find the most recent common ancestor for the algae, one must view a phylogenetic tree that includes lineages of organisms that are NOT algae…)

Because they are not all directly related to each other, the algae have many different forms, colors and biological attributes. Therefore, they defy tidy definition. We will NOT focus on the CHAOS! Instead – we will select five groups that have traditionally been defined as algae, and we will study them. Our five groups, which are listed below with attributes I expect you to know, are as follows: 1) green algae, 2) red algae, 3) brown algae, 4) diatoms, 5) dinoflagellates.

<u>In lieu of a unifying definition, let's identify some common attributes of the algae we'll study</u>:

1) They are protists (Kingdom Protista)
2) Aquatic (live in water: either marine or freshwater). Beware, however (!), that a minority of species live on land – for example, we discussed *Chlorella* on a tree branch in lab)
3) Ecologically, algae are like plants – they are photoautotrophs, and they are important producers (sources of carbon fixation) in aquatic ecosystems
4) Structurally, they are UNLIKE plants in that they lack true organs such as roots, leaves, and stems. Diverse in form. Some are unicellular. Those that are multicellular are unlike plants.

So, why study algae in a botany class? There are two important reasons:

1) As mentioned above, they are ecologically similar to plants because they are photoautotrophs (and thus, **producers** in aquatic ecosystems).
2) Certain multicellular green algae are the **ancestors of all land plants**. We'll discuss this more in coming weeks…

Following is a list of characteristics for each of the five groups, and an example of an important representative from each group. You need to know this info for exams and quizzes:

1) Green algae

- Unicellular and multicellular – very diverse
- Marine, freshwater, terrestrial (land)
- Ancestors of the four land plant lineages (we'll meet these over the next three weeks)
- Multicullular marine forms = "sea lettuce" or "seaweed"

As we saw in lab, green algae can be unicellular, filamentous, and thallus-forming ("sheet-like").

Unicellular example: *Chlorella*. Not to be confused with *Spirulina* – which is actually a bacterium (prokaryote!) but is referred to as “blue-green algae” – in the case of *Spirulina* the term “algae” is a complete misnomer!

Spirulina and *Chlorella* are touted as “superfoods” because they contain high amounts (by dry weight) of protein and/or lipids, carbohydrates, and some vitamins. Their nutritional value is probably overstated by the supplement industry, and many experts point out that there isn’t much in either that can’t be obtained through a well-balanced (and much more affordable) diet.

Filamentous forms can form films on the surface of fresh water known as “pond scum”. Representatives include *Spirogyra*, *Oedogonium*, and *Cladophora* (you don’t need to know).

Multicellular and thallus-forming (“sheet-like”) green algae include the genus *Ulva*, which very common in cold-water coastlines and is known as “sea lettuce”. The term “seaweed” applies to green, red, and brown algae:

“Seaweed”: a colloquial term for multicellular marine algae that are macroscopic (visible to the naked eye). Includes brown, red, and green algae.

Green algae, as well as other algae (and cyanobacteria), can increase their population size rapidly when nutrients (mostly nitrogen and phosphorus) increase in water. Such rapid increases are referred to as **algal blooms.**

Algal bloom: rapid increase or accumulation of algae in an aquatic ecosystem.
Harmful algal bloom (HAB): algal bloom with harmful impact(s).

Three primary harmful impacts of HABs are:
a) Nuisance to humans – diminishes quality of life for communities affected (Ex: Qingdao during Beijing Olympics).
b) Hypoxia (low oxygen) in water – this results from bacteria that decompose algae after they die – the bacteria consume oxygen as they conduct cellular respiration. Low O_2 levels can make life impossible or intolerable for other heterotrophs, such that they migrate away or die. Low O_2 can also result in subsequent blooms of anaerobic bacteria - which can also cause foul odors that are annoying to humans! (see item “a”). (This happens every year in Santa Barbara’s Andree Clark Bird Refuge (in spring/summer after days get long…and algae bloom).
c) Toxins produced by some algae – can be harmful to marine life and humans (more below).

2) Red algae

- Multicellular (very few exceptions)
- Marine (very few freshwater species)
- Most are thus “seaweeds” (multicellular + marine)

Example: *Porphyra* spp., nori
Red algae in the genus *Porphyra* have been used for centuries as an important food item, especially in Asian countries (mostly Japan) where it is used in sushi (and other foods). As a food, *Porphyra* is most commonly known as nori (laver in the UK). It is harvested from the wild and grown in aquaculture. Sheets of noir are prepared by shredding individual “plants”, then pressing and drying the fragments in a process not unlike paper making.

3) Brown algae

- Multicellular
- Marine (a very few freshwater species), dominate rocky coastlines and reefs in non-tropical oceans, there **many of these algae are known as "kelps",** "seaweed", or "rockweeds"

Important species are the "**kelps**" and "rockweeds", which form conspicuous and ecologically important canopies of growth on rocky coastlines and nearshore reefs (to water depths of ~60 - 90 feet, or 20-30 meters) in non-tropical oceans.

Example: *Macrocystis pyrifera*

***Macrocystis pyrifera* (giant kelp)** – in California this is an ecologically and economically important species that forms the giant **kelp forests** (underwater areas with high densities of kelp) found off of our coastline. Kelp forest ecosystems are diverse (contain many individual animals and many species) and they form the basis for many fisheries in Santa Barbara. Organisms associated with kelp forests include abalone, lobster, sea urchin, and many fishes.

Macrocystis pyrifera is notably fast-growing alga that can grow up to 2 feet per day (~60cm), and reach a maximum length of ~150 feet (~48 meters). The many **pneumatocysts** at the base of each **blade** (aka frond) float the long **stipes** and blades towards the sunlit sea surface. Individuals are tethered to the seafloor by the **holdfast**.

Macrocystis pyrifera is the largest and fastest-growing alga.

{VIDEO: Planet Earth "Shallow seas" 24:10}

Macrocystis pyrifera is harvested commercially as feed for aquaculture (especially abalone), for dietary supplements (it is high in iodine, potassium, and other vitamins), but is harvested most intensely for **alginate** (aka, algin). The boats that harvest *Macrocystis pyrifera* cut the stipes just below the canopy ~2-3 feet below the surface, thus these boats are known as "kelp cutters".

Alginate (algin): A polysaccharide in cell walls of brown algae. When mixed with water it forms viscous fluids that are used industrially as **thickeners** and **emulsifiers** (emulsifiers keep ingredients mixed together). Alginate is used in cosmetics, ice cream, toothpaste, and many food products that require thickening and emulsification.

4) Diatoms

- Unicellular
- Outer covering made of silica called "frustule". As diatoms live in great abundance and die in the seas/oceans, accumulations of these frustules form "diatomaceous earth"
- Marine (mostly) and some freshwater species

Diatom frustules are intricate and are well described microscopically due to their charismatic and photogenic architecture. We looked at a number of images in lab and lecture.

Diatoms are important members of marine (and freshwater) phytoplankton.

Plankton: any organisms that live suspended in water and that are unable to swim against currents. (**Phytoplankton** are photosynthetic plankton, and there are many animals that are planktonic, at least in early life stages – you saw them in lab under your microscope!). (BTW: planktonic animals are called <u>zooplankton</u>).

Photosynthesis in the world's oceans contributes to **~50% of global carbon fixation**. The vast majority of this 50% is conducted by phytoplankton, not the thin band of seaweed that grows along coastlines. Of the photosynthesis conducted by phytoplankton, much is conducted by diatoms.

What is meant by the phrase: "give me a half a tanker of iron and I will give you an ice age"

As phytoplankton populations grow in rapid response to some environmental change (typically longer days of the spring and early summer, and/or increased nutrient availability) they form **algal blooms**. Phytoplankton blooms may contain one or many species, and they are visible and are often what causes our ocean water to appear green and have low visibility.

As diatom blooms die off, the frustules sink to the seafloor and form **diatomaceous earth**. Diatomaceous earth is white/gray and is comprised of diatom frustules. It is has many industrial applications, including filtering agent (swimming pool and large aquarium filters) and mild abrasives (toothpaste, polishing agents), and is quarried large pits/mines – there is a large quarry near Lompoc, CA – just north of Santa Barbara.

<u>Domoic acid poisoning and diatom HABs</u>

Diatoms in the genus ***Pseudo-nitzschia*** produce **domoic acid** – which is a neurotoxin that affects the health of animals in a number of ways, perhaps most notably by impairing the alertness, coordination, and physical performance in animals that consume large amounts of domoic acid. In severe cases, seizures and death can result. **Algal blooms of *Pseudo-nitzschia* can be harmful (i.e., become HABs)** because marine birds and mammals that accumulate the toxin and can become sick and/or die. {VIDEO: http://whalerescueteam.org/rescue-stories/domoic-acid-poisoning-rescues/}

The odd behavior of seabirds in the coastal towns Capitola and Santa Cruz, California in 1961 was thought to be caused by domoic acid poisoning and was the inspiration for Alfred Hitchcock's classic movie "The Birds". After some diatom HABs, we get large numbers of dead and stranded sea lions, dolphins and whales along our beaches in Santa Barbara. This typically occurs in springtime/early summer – have you noticed such events?

Humans are not immune from *Pseudo-nitzschia* HABs: Shellfish such as mussels, clams, and scallops eat by filtering phytoplankton out of the ocean. Shellfish accumulate domoic acid in their flesh (mostly the viscera), and the toxin can cause illness in humans that eat the contaminated shellfish (a condition called **amnesic shellfish poisoning**). Domoic acid is heat-stable and does not break down under the heat of cooking. It is for this reason that recreational mussel quarantines are in place in California coastal waters from ~May 1 – October of every year. When I was a kid, warning posters were posted along beaches in Santa Barbara…now they are shark warnings!!

Although birds and mammals do not eat diatoms directly, domoic acid becomes concentrated in the tissues of birds and mammals through the process of biomagnification.

Bioaccumulation*: The biological sequestering of a substance (here, domoic acid) in an organism's tissues at a [higher] than the surrounding environment.

*Many sources (e.g., textbooks, websites) consider bioaccumulation to be part of, and not necessarily distinct from, biomagnification. I find this lack of distinction annoying and lazy.

Biomagnification (biological magnification): process by which the [] of a substance increases at successively higher levels of a food chain.

Biomagnification occurs when organisms are unable, for one reason or another, to excrete or chemically dismantle molecules (e.g., domoic acid, DDT, mercury) encountered in their environment (usually in their diet). As these toxins are ingested/absorbed, they accumulate in the tissue of individual organims (**bioaccumulation**). This process is accelerated when larger animals (i.e., those near the top of a food chain) prey upon smaller animals that have already experienced toxin accumulation via **biomagnification**. This is why larger marine animals that eat smaller fish experience worse effects of biomagnification. Examples of animals we discussed were pelicans, dolphins, sea lions, and toxins mentioned were mercury and domoic acid.

5) Dinoflagellates

- Unicellular
- Some are mixotrophic or heterotrophic
- Marine (mostly) and a few freshwater species
- Have two flagella (latin root words are dino = "whirl" + flagellum = "whip")

Dinoflagellates have a structurally complex cell covering comprised of folded membrane, and in some species these membranous foldings are fortified with cellulose plates.

Dinoflagellates are important marine phytoplankton, and large algal blooms of diatoms can cause events known as "**red tides**". (Diatoms also contribute to "red tide" events. But dinoflagellate blooms appear especially red because of the photosynthetic pigments they contain (range from yellowish-red in color).

Red tides can be very harmful algal blooms because dinoflagellates are the primary cause of a type of shellfish poisoning called **paralytic shellfish poisoning**. The toxin produced (**saxitoxin**) prevents impairs nerve function and death can result from paralysis of abdominal muscles (which control breathing).

Bioluminescence: The production and emission of light from a living organism

Dinoflagellates are **bioluminescent**. They produce light via a chemical reaction catalyzed by the enzyme **luciferase**. Why be bioluminescent (i.e., how does it increase survival and reproduction)? Two hypotheses: 1) light startles predators, and 2) light calls attention to predators, which then become illuminated and vulnerable to larger predators. This is the **burglar alarm hypothesis**. *{VIDEO:* http://www.youtube.com/watch?v=vimS0ehuSYA 0:33-3:45}

Some dinoflagellates live symbiotically inside corals, and are called **zooxanthellae**.

Coral reefs and coral bleaching
Symbiosis: a close and long-term physical association between organisms from two different species. In many symbioses, both species benefit – this is known as a **mutualistic symbiosis**.

In the **coral-zooxanthellae mutualistic symbiosis**, the dinoflagellates provide the coral host with sugars from photosynthesis, and the host provides the algae with nitrogen, protection, and CO_2.

When corals become stressed, they evict the algal symbionts (or, it is possible that the zooxanthellae 'flee' the host), and the corals take on the white color of their calcium carbonate ($CaCO_3$) skeletons – this phenomenon is known as **coral bleaching**. Increased ocean temperature is one of the most common causes of coral bleaching. Why stressed corals evict their algal partners is….mysterious, does not obviously improve S&R of the coral, is not currently understood, and is a subject of great research in marine biology! Coral bleaching is natural, but is increasing in frequency and might be yet another consequence of global warming.