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ECO-ACADEMY for Youth and Parent Educators

Marine algae, more commonly known as seaweeds, come in all shapes and sizes. Algae are not plants, even though they sometimes look like them. The classification system of algae can be confusing, as the classification schemes change as we learn more about them. Interestingly, although they are all referred to as algae, the red, green and brown algae are classified into three different kingdoms: the protists, chromists and Plantae, respectively. The algae all have cell wall structures and are capable of photosynthesis like our plants on land.
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Module: Marine Biology

Algae

Sunshine State Standards:

SC.2.L.17.2, SC.1.L.14.1, SC.4.L.17.4, SC.5.L.15.1, SC.912.E.6.6, SC.912.L.16.10, SC.912.L.17.3, SC.912.L.17.2

Objectives

- Understand the difference between algae and seaweed
- Understand the difference between algae and plants
- Learn about the different types of algae
- Learn about the economic uses of algae
- Learn collection and preservation techniques for algae

Vocabulary

Algae- are a large and diverse group of simple, typically autotrophic organisms, ranging from unicellular to multicellular forms, such as the giant kelps that grow to 65 meters in length. The US Algal Collection is represented by almost 300,000 accessioned and inventoried herbarium specimens. The largest and most complex marine forms are called seaweeds. They are photosynthetic, like plants, and "simple" because they lack the many distinct organs found in land plants.

A**utotroph -**also called a producer is an organism that produces complex organic compounds (such as carbohydrates, fats, and proteins) from simple inorganic molecules using energy from light (by photosynthesis) or inorganic chemical reactions (chemosynthesis).

Budding- is a form of asexual reproduction in which a new organism grows on another one. The new organism remains attached as it grows, separating from the parent organism only when it is mature. Since the reproduction is asexual, the newly created organism is a clone and is genetically identical to the parent organism.

Kelp- are large seaweeds (algae) belonging to the brown algae. There are about 30 different genera. Kelps grow in underwater "forests" (kelp forests) in shallow oceans. The plants requires nutrient-rich water with temperatures below about 20 °C (68 °F). They are known for their high growth rate - can grow as fast as half a meter a day, ultimately reaching 30 to 80 m.

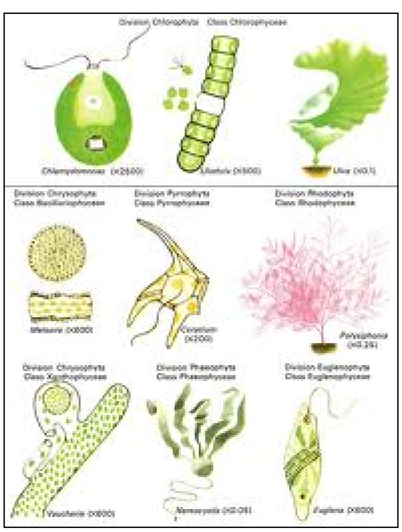
Photosynthesis- is a process that converts carbon dioxide into organic compounds, especially sugars, using the energy from sunlight

Seedweed- is a loose, colloquial term encompassing macroscopic, multicellular, benthic marine algae. The term includes some members of the red, brown and green algae. Seaweeds can also be classified by use (as food, medicine, fertilizer, industrial, etc.).

Symbiosis- is close and often long-term interactions between different biological species**.**

Background

Introduction

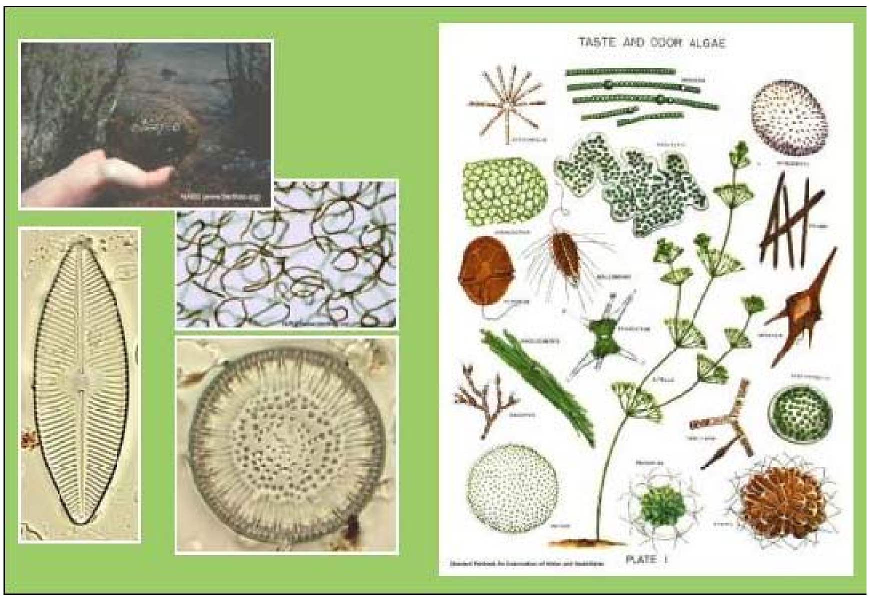


Algae are photosynthetic organisms that occur in most habitats, ranging from marine and freshwater to desert sands and from hot boiling springs to snow and ice. They vary from small, single-celled forms to complex multicellular forms, such as the giant kelps of the eastern Pacific that grow to more than 60 meters in length and form dense marine forests. Algae are found in the fossil record dating back to approximately 3 billion years in the Precambrian. They exhibit a wide range of reproductive strategies, from simple, asexual cell division to complex forms of sexual reproduction.

Algae are important as primary producers of organic matter at the base of the food chain. They also provide oxygen for other aquatic life. Algae may contribute to mass mortality of other organisms, in cases of algal blooms, but they also contribute to economic well- being in the form of food, medicine and other products. In tropical regions, coralline algae can be as important as corals in the formation of reefs.

Seaweeds are larger algae that live in the marine (salt or brackish water) environment. Kelps are large brown seaweeds. In the Pacific, individual kelp plants may reach 65 meters in length.

Algae



Algae are a diverse group of simple, plant-like organisms. Like plants, most algae use the energy of sunlight to make their own food, a process called photosynthesis. However, algae lack the roots, leaves, and other structures typical of true plants. Algae are the most important photosynthesizing organisms on Earth. They capture more of the sun's energy and produce more oxygen (a by product of photosynthesis) than all plants combined. Algae form the foundation of most aquatic food webs, which support an abundance of animals. Algae vary greatly in size and grow in many diverse habitats. Microscopic algae, called phytoplankton, float or swim in lakes and oceans. Phytoplankton are so small that 1000 individuals could fit on the head of a pin. The largest forms of algae are seaweeds that stretch 100 m (300 ft) from the ocean bottom to the water's surface. Although most algae grow in fresh water or seawater, they also grow on soil, trees, and animals, and even under or inside porous rocks, such as sandstone and limestone. Algae tolerate a wide range of temperatures and can be found growing in hot springs, on snow banks, or deep within polar ice.

Algae also form mutually beneficial partnerships with other organisms. For example, algae live with fungi to form lichens--plant-like or branching growths that form on boulders, cliffs, and tree trunks. Algae called zooxanthellae live inside the cells of reef-building coral. In both cases, the algae provide oxygen and complex nutrients to their partner, and in return they receive protection and simple nutrients. This arrangement enables both partners to survive in conditions that they could not endure alone. The earliest life-forms on this planet are thought to be early ancestors of cyanobacteria, a type of algae formerly called blue-green algae. Fossilized cyanobacteria have been found in rocks more than 3 billion years old. These early algae formed when there was no oxygen in the atmosphere, and scientists theorize that as the algae photosynthesized, they released oxygen as a by product, which eventually accumulated in the atmosphere. Algae were probably the first organisms capable of photosynthesis and, until the appearance of plants on earth, the only photosynthesizers for billions of years.

Seaweeds

Seaweeds are marine algae, saltwater dwelling, and simple organisms that fall into the rather outdated general category of "plants." Most of them are red (6000 species), brown (2000 species) or green (1200 species) kinds, and most are attached. These plant-like organisms are found throughout the world's oceans and seas and none is known to be poisonous. Many are in fact eaten and considered to be a great delicacy. Seaweed, any of the larger, multicellular forms of algae living in fresh and salt water, especially along marine coastlines. The three main phyla, or divisions, are the brown algae, such as the kelps; the red algae, such as Irish moss; and the green algae, such as the sea lettuces, all of which are commonly seen at low tide along rocky shores of northern seas. Seaweeds differ from plants in that they lack the true stems, leaves, roots, and vascular systems of higher plants. Instead, they anchor themselves to solid objects by holdfasts and absorb nutrients directly from the water, manufacturing their food by photosynthesis. The pigments of red and brown algae mask the predominant green photosynthetic pigment, chlorophyll, and probably aid in photosynthetic metabolism by absorbing and transferring light energy to the chlorophyll.

Seaweeds abound in shallow waters from the midtide line down to depths of 50 m (165 ft). Along damp cold-water shores, they are able to withstand several hours of exposure to the sun, and they cover rocks high into the intertidal zone. In the Tropics, seaweeds are confined to the zone between the low-tide line and a depth of about 200 m (about 660 ft); red algae predominate, especially in lagoons and around coral reefs. The brown algae, commonly called kelp, comprise the largest seaweeds. Pacific species can reach 65 m (213 ft) in length and have structures that superficially resemble leaves and stems, as well as large air-filled bladders and strong holdfasts that anchor them against heavy surf. Other brown algae are the common rockweed and the gulfweed, which floats in great masses in the Gulf Stream and the Sargasso Sea. Among the red algae are several species of Irish moss, which is commonly seen along northern Atlantic coasts as a matted carpet in the sublittoral zone. Red algae are abundant in clear tropical waters, where their red pigment, phycoerythrin, enables them to carry on photosynthesis at deeper levels than is possible for ordinary green algae.

Seaweed is a commercially important food, especially in Japan, where it is called nori and is harvested mainly from red algae, extensively cultivated on bamboo screens submerged in estuaries. Agar, also derived from red algae, is consumed as a delicacy in Asia and is used as a laboratory medium for culturing microorganisms. Red algae are probably of little nutritive value to humans, however, other than for their limited protein, vitamin, and mineral (especially iodine) content. Brown algae are used as fertilizer and as an ingredient for livestock meal. Alginic acid, found in kelp, has wide industrial uses. It can be made into a silk-like thread or a plastic material, insoluble in water, that is used to make films, gels, rubber, and linoleum, and as a colloid in cosmetics, car polishes, and paints. Organic derivatives of alginates are used as food gums in making ice cream, puddings, and processed cheeses. Scientific classification: Brown algae make up the phylum Phaeophyta, red algae the phylum Rhodophyta, and green algae the phylum Chlorophyta. Large Pacific brown algae include those species classified in the genera Macrocystis and Nereocystis. Rockweed makes up the genus Fucus, and gulfweed the genus Sargassum. Irish moss makes up the genus Chondrus. The species most commonly cultivated for food in Japan is Porphyra tenera.

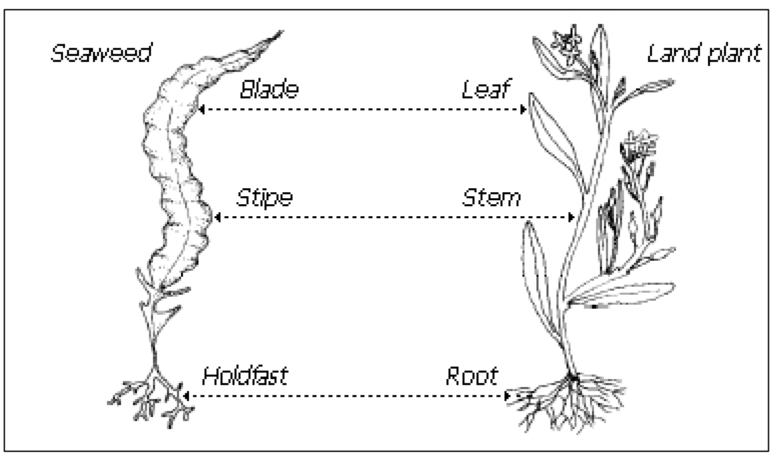
Snow Algae

Snow algae describes cold-tolerant algae and cyanobacteria that grow on snow and ice during alpine and polar summers. Visible algae blooms may be called red snow or watermelon snow. These extremophilic organisms are studied to understand the glacial ecosystem.

Snow algae have been described in the Arctic, on Arctic sea ice, and in Greenland, the Antarctic, Alaska, the west coast, east coast, and continental divide of North America, the Himalayas, Japan, New Guinea, Europe (Alps, Scandinavia and Carpathians), China, Patagonia, Chile, and the South Orkney Islands.

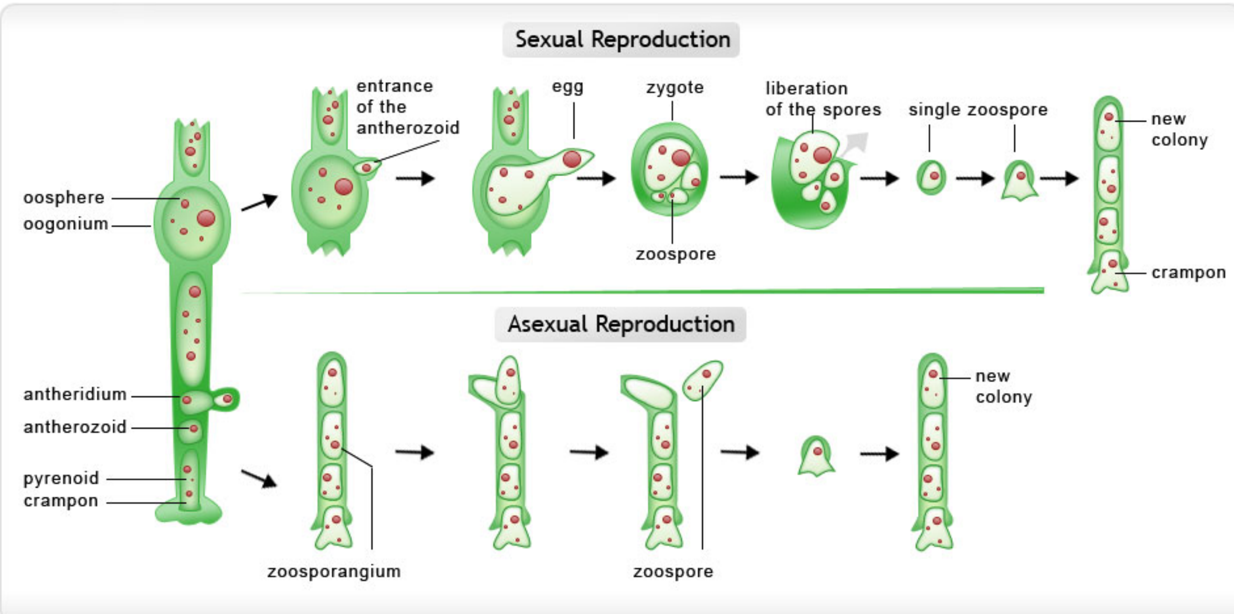
Physical Characteristics

With the exception of the cyanobacteria, algae are eukaryotes--that is, the insides of their cells are organized into separate membrane-wrapped organelles, including a nucleus and mitochondria. An important organelle found in eukaryotic algae is the chloroplast, which contains the light-absorbing pigments responsible for capturing the energy in sunlight during photosynthesis. In most algae the primary pigment is chlorophyll, the same green pigment used in plants. Many algae also contain secondary pigments, including the carotenoids, which are brown or yellow, and the phycobilins, which are red or blue. Secondary pigments give algae their colorful hues. The cyanobacteria are prokaryotes--that is, relatively simple unicellular organisms lacking a nucleus and other membrane-bound organelles. As their modern name implies, the cyanobacteria have many characteristics that resemble bacteria. Like plants, most algae have rigid cell walls composed largely of cellulose. An exception is the diatom, whose cell wall is composed primarily of silica, which provides rigidity and also produces elaborately sculpted patterns of grooves that serve as identifying features. Many eukaryotic algae have whiplike appendages called flagella attached to their cell walls. By beating flagella in a rotary movement, these algae are able to move through water with considerable speed. A few algae that are devoid of rigid cell walls are able to protrude one part of the body ahead of the other to crawl on solid surfaces in an amoeba-like fashion.



Algae come in a variety of shapes and forms. The simplest form is the single, self-sufficient cell, such as Euglena, dependent only on sunlight and carbon dioxide and minerals from the water. Numerous one-celled algae may clump together to form a colony. Although these cells are attached to one another, each cell within a colony continues to function independently. Still other algae are multicellular organisms. In the simplest multicellular algae, the cells are joined end to end, forming filaments, both branched and unbranched. More complex structures may be shaped like a small disc, tube, club, or even a tree. The most complex algae have highly specialized cells. Some seaweeds, for instance, have a variety of specialized tissues, including a rootlike holdfast, a stipe, which resembles a plant stalk, and a leaf-like blade. While most algae create their own food through photosynthesis, some are unable to photosynthesize. These algae ingest food from external sources by absorbing simple nutrients through the cell membrane. To absorb more complex nutrients, algae that lack rigid walls are able to engulf food particles and digest them. Some of the algae known as dinoflagellates extend a feeding tube, called a peduncle, to suck in food. Other dinoflagellates use special harpoonlike structures to snare their food. Some algae are parasites, living in or on another organism from which they get their food. Some parasitic red algae live off other red algae, and parasitic dinoflagellates live in the intestines of some marine animals, such as copepods and annelids.

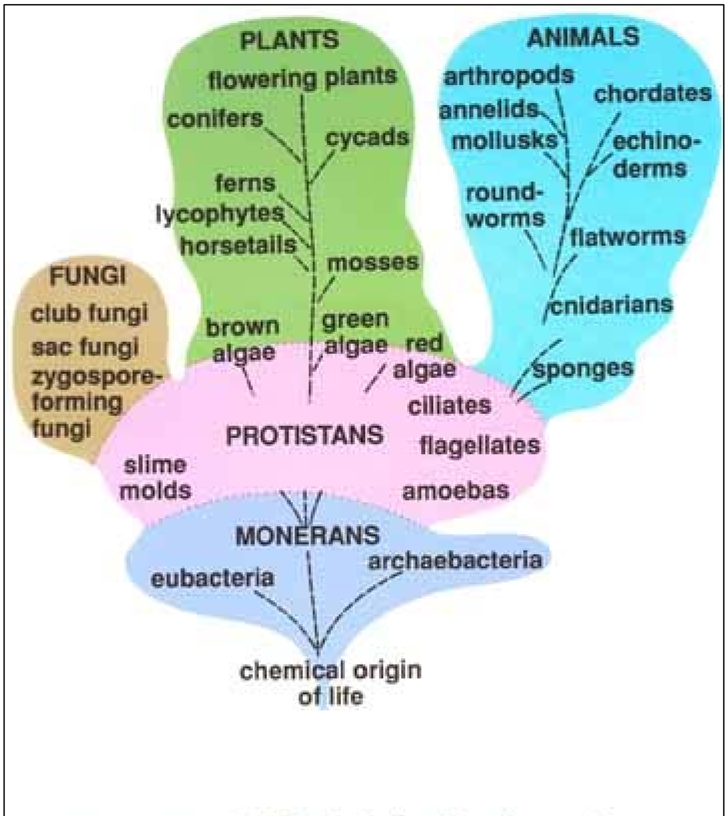
Reproduction



Algae reproduce in astoundingly diverse ways. Some reproduce asexually, others use sexual reproduction, and many use both. In asexual reproduction an individual reproduces without combining its genetic material with that from another individual. The simplest form of asexual reproduction is binary fission, in which a unicellular organism simply divides into two new individuals. Some multicellular algae, including Sargassum, reproduce asexually through fragmentation, in which fragments of the parent develop into new individuals. In a similar process called budding, special buds detach from multicellular algae and develop into new individuals, commonly found in Sphacelaria. Many algae produce special cells called spores that are capable of growing into new individuals. If these spores move about using flagella, they are known as zoospores. In sexual reproduction, genetic material from two individuals is combined. The simplest form of sexual reproduction in algae is conjugation, in which two similar organisms fuse, exchange genetic material, and then break apart. For example, in Spirogyra, which produces both asexually and sexually, two long, unbranched filaments join via conjugation tubes, through which genetic material is exchanged between cells.

Most multicellular algae undergo a more complex form of sexual reproduction involving the union of special reproductive cells, called gametes, to form a single cell, known as a zygote. Many algae incorporate both sexual and asexual modes of reproduction. This is well demonstrated in the life cycle of the alga Chlamydomonas. The mature alga is a single haploid cell--that is, it contains only one set of chromosomes. During asexual reproduction the cell undergoes mitosis, a type of cell division that produces genetically identical offspring. Four daughter cells are created that emerge from the enclosing parent cell as spores. The spores develop into mature haploid cells that are genetically identical to the parent cell. Certain environmental conditions, such as lack of nutrients or moisture, may trigger the haploid daughter cells to undergo sexual reproduction. Instead of forming into spores, the haploid daughter cells form gametes that have two different mating strains. These two strains are structurally similar and are called plus and minus strains. Opposite mating strains fuse in a process known as isogamy to form a diploid zygote, which contains two sets of chromosomes. After a period of dormancy, the zygote undergoes meiosis, a type of cell division that reduces the genetic content of a cell by half.

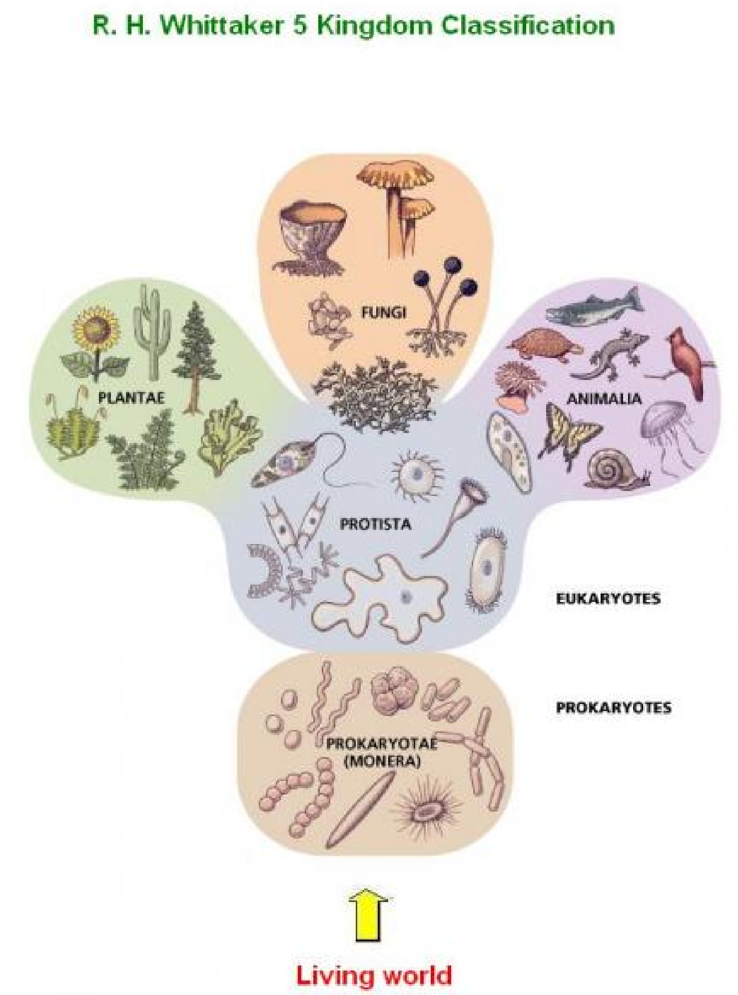
This cell division produces four genetically unique haploid cells that eventually grow into mature cells. Some multicellular green algae, such as Ulva, follow a distinct pattern of reproduction called alternation of generations, in which it takes two generations--one that reproduces sexually and one that reproduces asexually--to complete the life cycle. The two mature forms of the algae, alternating between diploid and haploid individuals, are identical in appearance, or isomorphic. The haploid form, called a gametophyte, undergoes mitosis to produce haploid gametes. These gametes unite to form a diploid zygote, which develops into the diploid form called a sporophyte. The sporophyte undergoes meiosis to form haploid spores that, in turn, form gametophytes. Not all algae that undergo alternation of generations have haploid and diploid forms that look alike. In the life cycle of the seaweed Laminaria, the gametophyte and the sporophyte are distinct in appearance, or heteromorphic. The Laminaria sporophyte appears as long, bladelike structures that grow on rocks just below the water in intertidal zones. The gametophyte is short, with branched filaments.



Modified version of Whittaker's five-kingdom system of classification.

Types of Algae

The most common classification system distributes algae in more than one kingdom. Most algae are classified in the Kingdom Protista, along with other eukaryotic organisms that lack true specialized tissues. The cyanobacteria, however, are classified with the bacteria in the Kingdom Prokaryotae, which consists of prokaryotic organisms. This classification system continues to be intensely debated as new research increases our understanding of the way that these organisms are related.



BACILLARIOPHYTA (Diatoms)

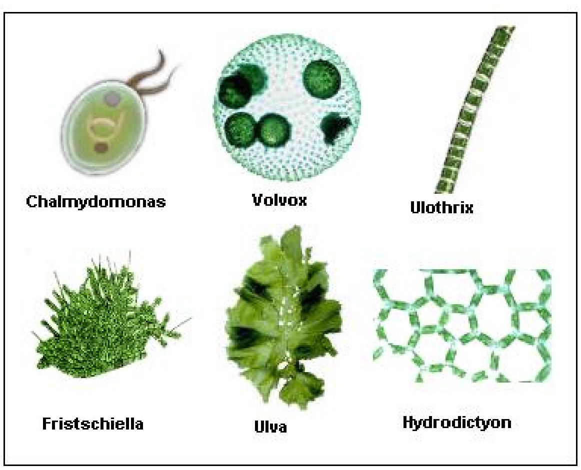
Bacillariophyta are unicellular organisms that are important components of phytoplankton as primary sources of food for zooplankton in both marine and freshwater habitats. Most diatoms are planktonic, but some are bottom dwellers or grow on other algae or plants.

Except for their male gametes, diatoms lack flagella. Instead many diatoms achieve locomotion from controlled secretions in response to outside physical and chemical stimuli. Diatoms have unique shells, which serve as their cell wall. The overlapping shells, or frustules that surround the diatom protoplasm are made of polymerized, opaline silica. Identification of diatom species is based on the delicate markings on their frustules, comprising a large number of tiny, intricately-shaped depressions, pores and passageways that bring the diatom's cell membrane in contact with the environment. Diatom frustules have accumulated over millions of years to form the fine, crumbly substance known as diatomaceous earth, which has a variety of uses (e.g. for filtration and insulation). Diatom remains in both marine and freshwater sediments are also important as indicators of paleo-environmental conditions at the time the sediments were formed.

Bacillariophytes have brownish plastids containing chlorophylls a and c and fucoxanthin. The primary means of reproduction is asexual, by cell division. Most diatoms are autotrophic, but a few are obligate heterotrophs (they must absorb organic carbon) because they lack chlorophyll altogether. Some diatoms even lack their distinctive frustules and live symbiotically in large marine protozoa, providing organic carbon for their hosts.

CHAROPHYTA (Stoneworts)

Charophyta are freshwater plants and generally grow anchored to the substratum by rhizoids with a shoot extending upward. The shoot then divides and forms nodes from which a whorl of side filaments projects. Charophyta reproductive structures develop at these nodes and are, along with the biflagellate sperm produced in the male gametangium, quite similar to those of mosses. These similarities have led some scientists to identify the charophytes as ancestors of the mosses. Their green color comes from chlorphylls a and b.



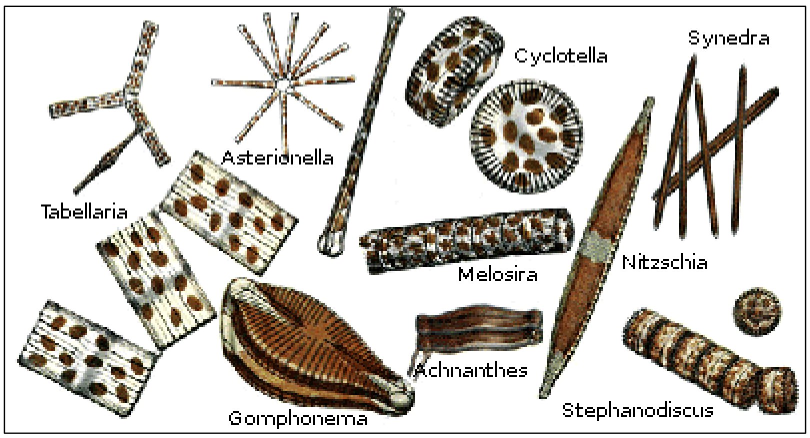
CHLOROPHYTA (green algae)

Most chlorophytes are aquatic, but some green algae can live on the surface of snow, on tree trunks, in soils, or symbiotically with protozoans, hydras or lichen-forming fungi. Numbering about 8,000 species, the chlorophytes range in size from microscopic to quite large. The typical color of plants in the Chlorophyta, resulting from the dominant chlorophyll pigments, is some shade of apple or grass green, although certain species may appear yellow-green or blackish-green due to the presence of carotenoid pigments or high concentrations of chlorophyll. Chlorophytes appear more than a billion years ago in the fossil record.

Calcified green algae, particularly Halimeda spp., are especially important as major contributors of marine sediments. The sparkling white sand beaches of the Caribbean and many other areas in the world are largely the sun-bleached and eroded calcium-carbonate remains of green algae. The deepest occurring, fleshy, erect alga Johnson-sea-linkia profunda found attached to bedrock at a depth of 157 meters off the Bahamas and is a member of this group.

Green algae have chlorophylls a and b and store starch as a food reserve inside their plastids. Most green algae have firm cell walls composed of cellulose along with other polysaccharides and proteins.

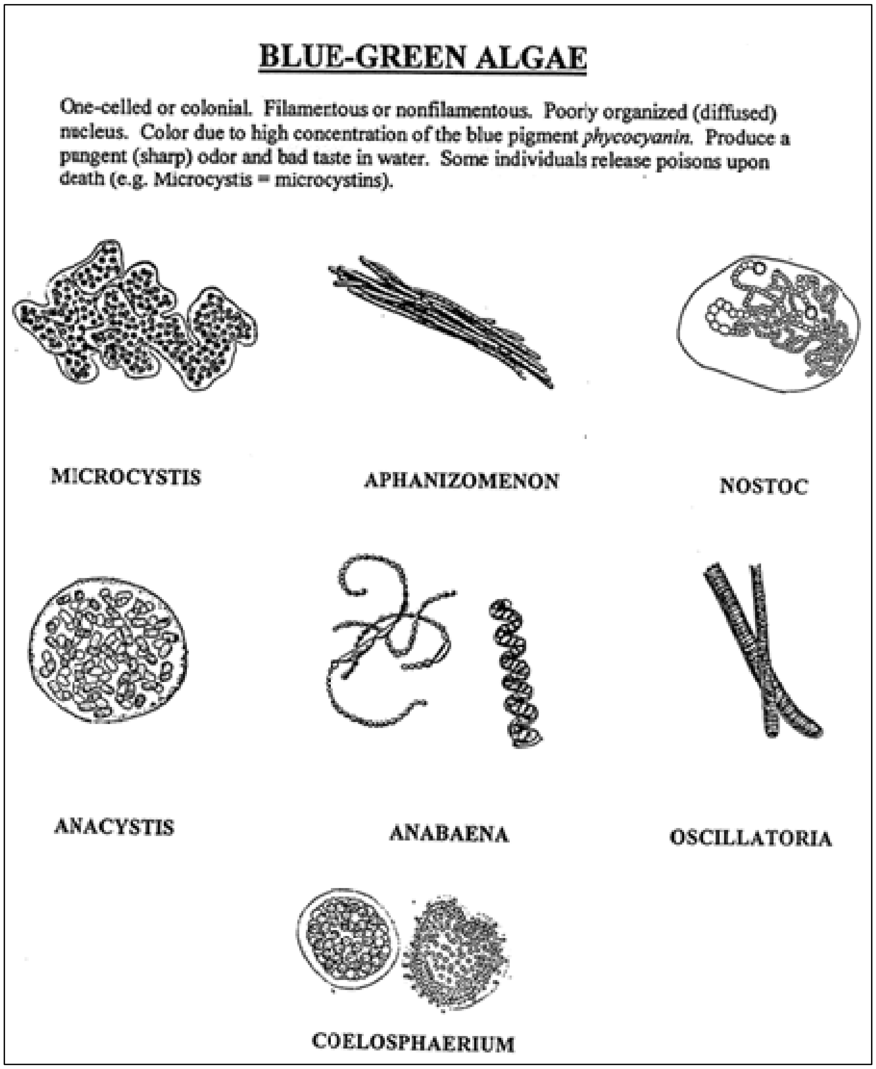
CHRYSOPHYTA (golden algae)



Chrysophytes are photosynthetic, unicellular organisms that are abundant in freshwater and marine environments. Chrysophytes contain chlorophylls a and c, which are masked by the accessory pigment fucoxanthin, a carotenoid. In many ways, golden algae are, biochemically and structurally similar to brown algae. Both golden algae and brown algae store food outside of the chloroplast in the form of polysaccharide laminarin, or chrysolaminarin. In both groups, motile cells have unequal flagella of similar structure.

CYANOBACTERIA (Blue-Green Algae)

Even though the Cyanobacteria are classified as bacteria (lacking a membrane-bounded nucleus) they are photosynthetic and are included among our algal collections. Cyanobacteria played a decisive role in elevating the level of free oxygen in the atmosphere of the early Earth. Cyanobacteria can change remarkably in appearance, depending on the environmental conditions. Blue-green algae are common in soil, in both salt and fresh water, and can grow over a wide range of temperatures. They have been found to form mats in Antarctic lakes under several meters of ice and are responsible for the beautiful colors of the hot springs at Yellowstone and elsewhere. Cyanobacteria can also occur as symbionts of protozoans, diatoms and lichen-forming fungi, and vascular plants. Some blue-greens can fix nitrogen as well as photosynthesize, allowing them to grow with only light, water, a few minerals, and the nitrogen and carbon dioxide in the atmosphere.



Cyanobacteria are different in many important ways from other photosynthetic prokaryotes. Instead of the bacteriochlorophylls found in purple and green bacteria, blue-greens contain chlorophyll a, as in eucaryotic phototrophs, and, produce free oxygen as a byproduct of photosynthesis. Cyanobacteria, however, lack the organized chloroplasts of eukaryotes and have their photosynthetic apparatus distributed peripherally in the cytoplasm.

The variety of striking colors exhibited by Cyanobacteria are a result of their major light-gathering pigments, the phycobilins, that are bound to protein granules, (phycobilisomes), that are attached to the photosynthetic membranes.

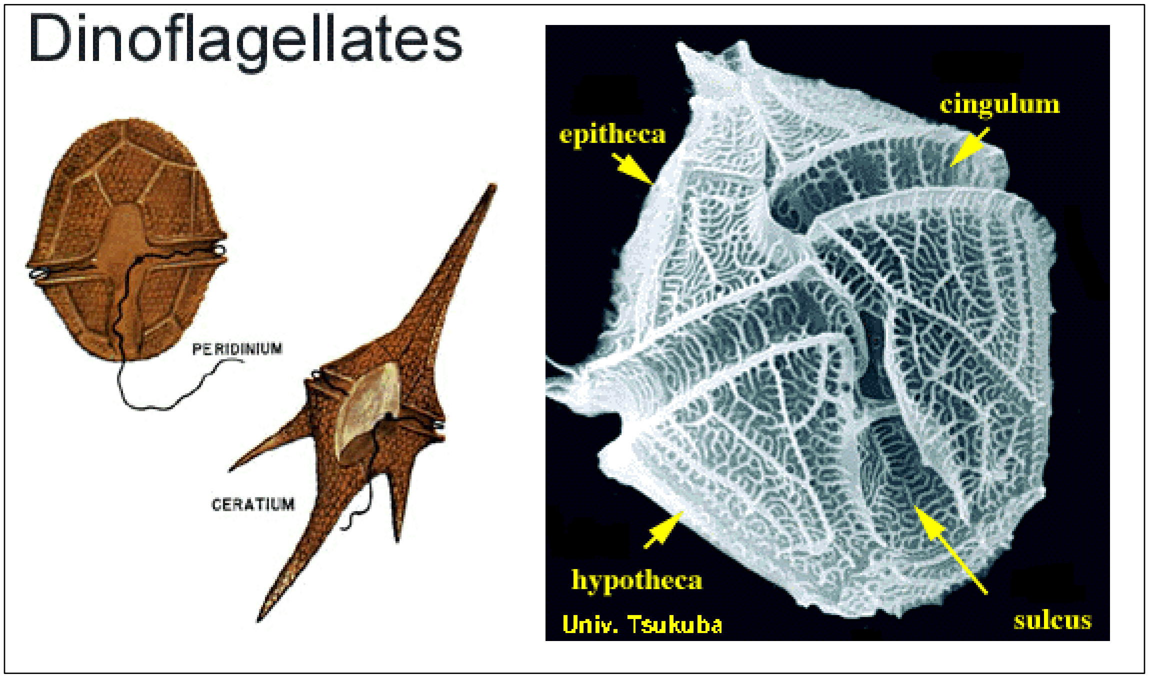
Large blooms of freshwater Cyanobacteria may produce toxins that can kill livestock. Other forms (Spirulina) are grown commercially and marketed as a high-protein dietary supplement.

PYRROPHYTA/DINOPHYTA (Dinoflagellates)

[Dinoflagellata - Pyrrophyta - Pyrrhophyta] * (Current names in use by various authorities)

The division Pyrrophyta (from the Greek "pyrrhos" meaning flame-colored) comprises a large number of unusual algal species of many shapes and sizes. There are about 130 genera in this group of unicellular microorganims, with about 2000 living and 2000 fossil species described so far.

The name "dinoflagellate" refers to the forward- spiraling swimming motion of these organisms. They are free-swimming protists (unicellular eukaryotic microorganisms) with two flagella, a nucleus with condensed chromosomes, chloroplasts, mitochondria, and Golgi bodies. Biochemically, photosynthetic species possess green pigments, chlorophylls a and c, and golden brown pigments, including peridinin. Dinoflagellates primarily exhibit asexual cell division, some species reproduce sexually, while others have unusual life cycles. Their nutrition varies from autotrophy (photosynthesis; in-nearly 50% of the known species) to heterotrophy (absorption of organic matter) to mixotrophy (autotrophic cells engulf other organisms, including other dinoflagellates).



Free-living dinoflagellates are an ancient and successful group of aquatic organisms. They have adapted to pelagic (free-floating) and benthic (attached) habitats from arctic to tropical seas, and to salinities ranging from freshwater, to estuaries, to hypersaline waters. Many species are found in numerous habitats, living in the plankton or attached to sediments, sand, corals, or to macroalgal surfaces or to other aquatic plants. Some species are present as parasites in marine invertebrates and fish. Some even serve as symbionts, known as zooxanthellae, providing organic carbon to their hosts: reef-building corals, sponges, clams, jellyfish, anemones and squid.

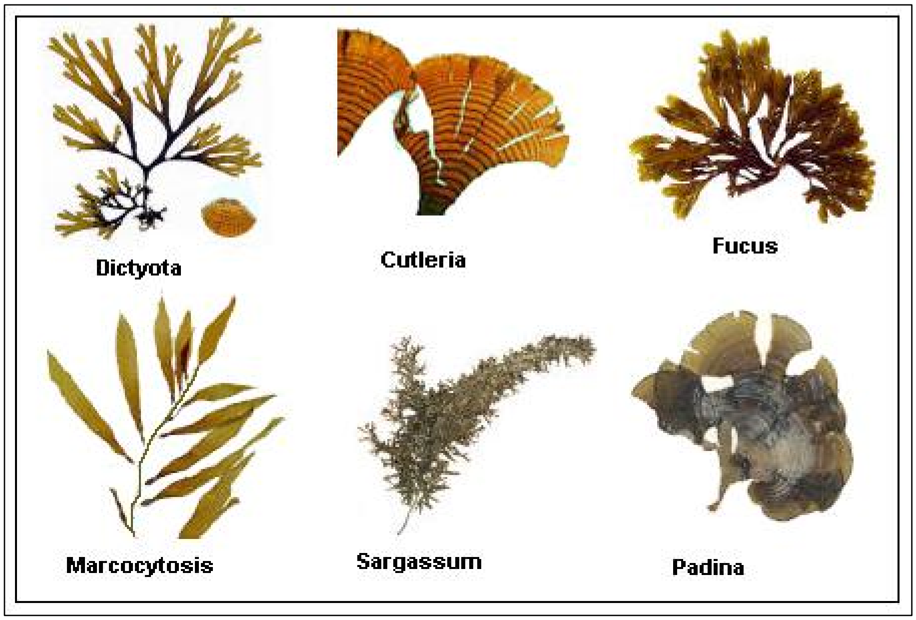
Dinoflagellates exhibit a wide variety in morphology and size (from 0.01 to 2.0 mm). They commonly have a cell covering structure (theca) that differentiates them from other algal groups. Cells are either armored or unarmored. Armored species have thecae divided into plates composed of cellulose or polysaccharides which are key features used in their identification. The cell covering of unarmored species is comprised of a membrane complex. The theca can be smooth and simple or laced with spines, pores and/or grooves and can be highly ornamented.

In systematics, dinoflagellates have been claimed by both botanists and zoologists.

Dinoflagellates share features common to both plants and animals: they can swim, many have cell walls, and both photosynthetic and nonphotosynthetic species are known. Botanists have grouped them with the "microalgae" and zoologists have grouped them with the protozoa, and both have produced classification schemes for this diverse and confusing group.

Dinoflagellates have attracted a lot of negative attention from the general public in recent times. For example, blooms (population explosions) of dinoflagellates can cause the water to turn a reddish-brown color known as "red tide". Red tides can have harmful effects on the surrounding sea-life and their consumers. Additionally, certain species of dinoflagellates produce neurotoxins. These toxins are carried up the food chain, ultimately to humans and can, sometimes result in permanent neurological damage or even death. Yet dinoflagellates are important members of the phytoplankton in marine and freshwater ecosystems.

PHAEOPHYTA (Brown Algae)

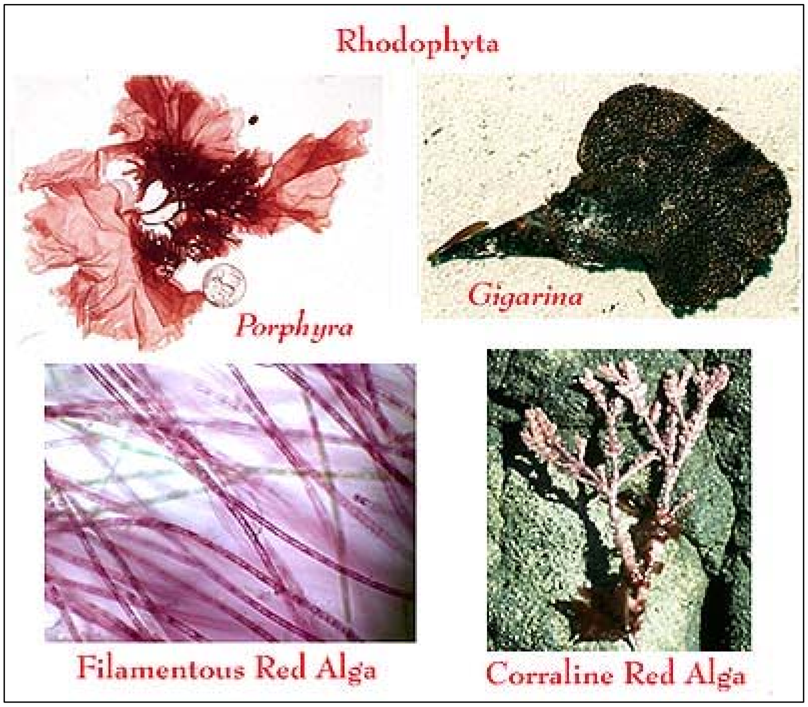


The Phaeophyta are almost entirely marine, frequently dominating rocky shores in cold and temperate waters throughout the world. The giant kelp, Macrocystis pyrifera , forms expansive seaweed forests off the west coast of North America and provides habitat and shelter for many other organisms. Tropical waters have fewer species of brown algae, although genera such as Sargassum and Turbinaria can dominate in some areas to form small-scale forests. Sargassum is also unique among macroalgal genera in that it contains totally free-floating species with no requirement for attachment to the bottom, as in the Sargasso Sea.

The colors of brown algae (predominantly due to the brown accessory pigment fucoxanthin) cover a spectrum from pale beige to yellow-brown to almost black. In tropical seas, they range in size from microscopic filaments to several meters in length.

The large kelps are harvested for use as an emulsion stabilizer, in products such as ice cream. They are also used as fertilizer and as a vitamin rich food source.

RHODOPHYTA (Red Algae)



Of the approximately 6000 species, most red algae are marine; only a few occur in freshwater. Rhodophytes are usually multicellular and grow attached to rocks or other algae, but there are some unicellular or colonial forms. They do not have flagellated cells, are structurally complex, and have complex life cycles divided into three phases. Many red algae feature pit connections between the cells, and their cell walls include a rigid component composed of microfibrils and a mucilaginous matrix. Agar and carrageenin are two red algal mucilages that are widely used for gelling and thickening purposes in the food and pharmaceutical industries.

Rhodophytes contain chlorophyll a which is masked by phycobilin pigments bound to proteins. The chloroplasts in red algae resemble Cyanobacteria both biochemically and structurally. Food reserves are stored outside of the chloroplasts as Floridean starch.

The coralline red algae deposit calcium carbonate in their cell walls, making them particularly tough and stony. They are often abundant, ecologically important, and widespread from the arctic regions to the tropics and play an important role in building tropical reef communities. Coralline red algae can form an algal ridge that absorbs wave energy and thereby protects the more delicate organisms that inhabit the sheltered lagoons and back-reef habitats.

Symbiotic algae

Some species of algae form symbiotic relationships with other organisms. In these symbioses, the algae supply photosynthates (organic substances) to the host organism providing protection to the algal cells. The host organism derives some or all of its energy requirements from the algae. Examples are as follows.

Lichens

Lichen is a symbiosis. That means that it is two or more organisms living together such that both are more successful within the partnership than they would have been if they were living on their own. With lichens the basic components of this partnership are 1) a fungus called the 'mycobiont' and 2) one or more algae and/or a cyanobacteria called the 'photobiont'.

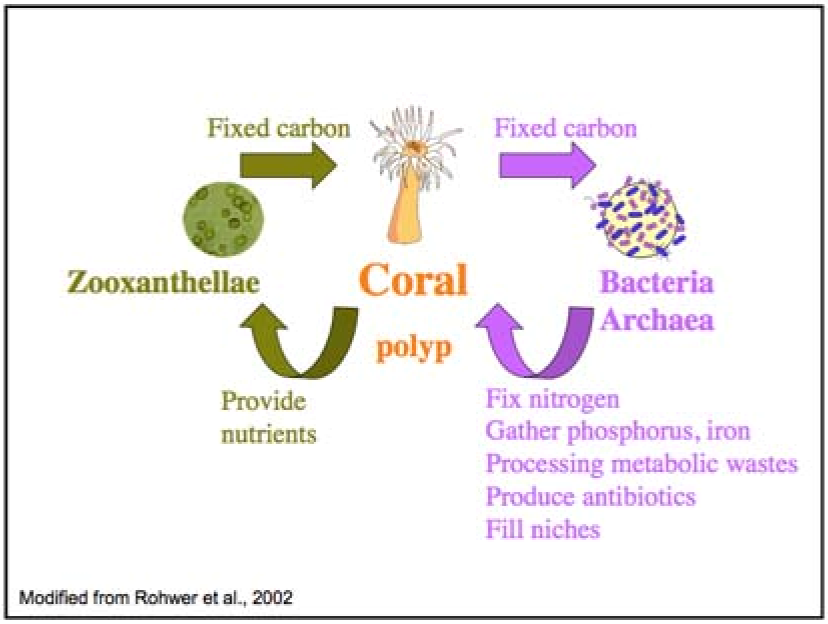
The true nature of the symbiosis between this two partners is still being debated by scientists and some would maintain that the fungus is a parasite on the photobiont. However, in many cases, the algae in question cannot survive alone in the habitat occupied by the lichen any more than the unattached fungi can, so it is not realistic to use the term parasite.

The fungal partners are mostly (over 95%) Ascomycetes. Most of the rest are Basidiomycetes. As far as science has been able to discover few if any of the fungi involved can survive and reproduce in the wild on their own. Each lichen species contains a different species of fungi and so it is according to the species of fungi that lichens are classified. This classification is generally based on characteristics of the thallus and reproductive organs. There are between 13500 and 17000 species of lichen depending on whose classification you believe. About 20% of fungal species are involved in lichen partnerships.

The algal partners are far less numerous than fungal partners. In other words any given species of algae will probably form part of several if not many different lichens. Many, if not all the algal partners can exist on their own in some habitats, however, normally when part of a lichen they have a much greater distribution.

Zooxanthellae

Tiny plant cells called zooxanthellae live within most types of coral polyps. They provide the coral with foods resulting from photosynthesis. Click the image for a larger view of these cells.



Most reef-building corals contain photosynthetic algae, called zooxanthellae, that live in their tissues. The corals and algae have a mutualistic relationship. The coral provides the algae with a protected environment and compounds they need for photosynthesis. In return, the algae produce oxygen and help the coral to remove wastes. Most importantly, zooxanthellae supply the coral with glucose, glycerol, and amino acids, which are the products of photosynthesis. The coral uses these products to make proteins, fats, and carbohydrates, and produce calcium carbonate. The relationship between the algae and coral polyp facilitates a tight recycling of nutrients in nutrient-poor tropical waters. In fact, as much as 90 percent of the organic material photosynthetically produced by the zooxanthellae is transferred to the host coral tissue. This is the driving force behind the growth and productivity of coral reefs.

Coral polyps, which are animals, and zooxanthellae, the plant cells that live within them, have a mutualistic relationship.

In addition to providing corals with essential nutrients, zooxanthellae are responsible for the unique and beautiful colors of many stony corals. Sometimes when corals become physically stressed, the polyps expel their algal cells and the colony takes on a stark white appearance. This is commonly described as “coral bleaching”. If the polyps go for too long without zooxanthellae, coral bleaching can result in the coral's death.

Because of their intimate relationship with zooxanthellae, reef-building corals respond to the environment like plants. Because their algal cells need light for photosynthesis, reef corals require clear water. For this reason they are generally found only in waters with small amounts of suspended material, i.e., in water of low turbidity and low productivity. This leads to an interesting paradox—coral reefs require clear, nutrient-poor water, but they are among the most productive and diverse marine environments.

Zooxanthellae cells provide corals with pigmentation. On the left is a healthy stony coral. On the right is a stony coral that has lost its zooxanthellae cells and bleached.

Sea sponges

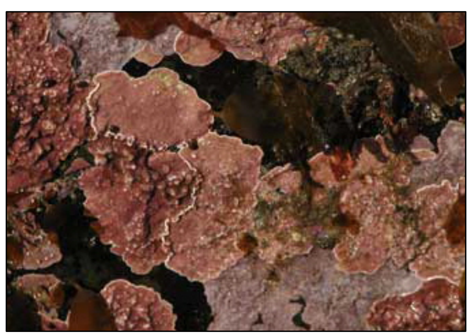
Some of the many faces of “Breadcrumb Sponge”

Green Algae live close to the surface of some sponges, for example, breadcrumb sponge (Halichondria panicea). The alga is thus protected from predators; the sponge is provided with oxygen and sugars which can account for 50 to 80% of sponge growth in some species.

Tropical Coralline Algae

Functional algal groups

Tropical reef algae can be divided into three key functional algal groups: crustose coralline algae, algal turfs, and macroalgae. Using a functional grouping approach is useful for understanding broader generalizations on the ecology of algae as well as predicting changes in algal community structure. Crustose coralline algae are often calcified, usually pink in color and adhere to the substrate; although some species have different characteristics. Algal turfs consist mostly of tiny filaments with canopy heights of less than 10 mm. Macroalgae are usually larger, canopy-formers, including brown algae (Dictyota, Sargassum), red algae (Gracilaria, Laurencia); green algae (Caulerpa, Microdictyon) and can be either fleshy (e.g., Lobophora) or calcareous (e.g., Halimeda).



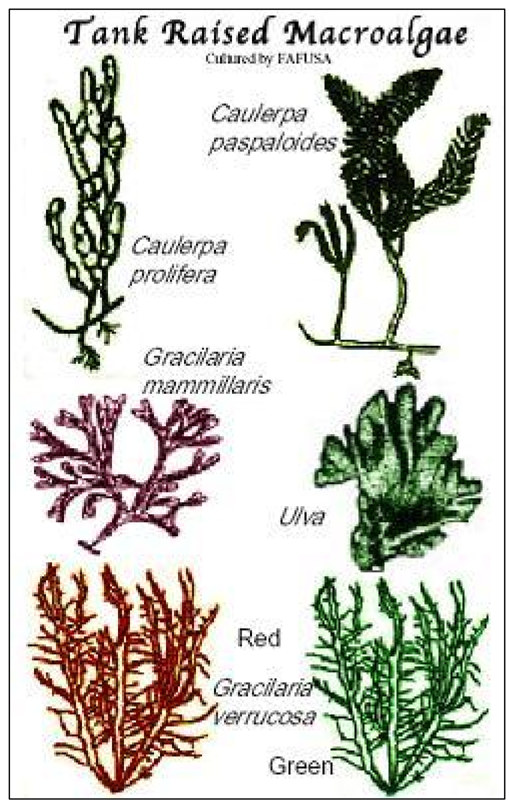
Crustose coralline

Crustose corallines are calcified, often encrusting algae usually pink to dark burgundy in color (e.g., Porolithon, Peyssonnelia, Lithophyllum). Crustose coralline algae play two important roles in the coral reef community, first by contributing calcium carbonate to reef structure and second by possibly facilitating settlement of coral recruits. The ecology of crustose corallines is complex often interrelated with the presence of macro and turf algae, grazing intensity by herbivores, and productivity.

Turf algae

Turf algae are a multispecific assemblage of diminutive, often filamentous, algae that attain a canopy height of only 1 to 10 mm (see Steneck 1988 for review). These microalgal species have a high diversity (>100 species in western Atlantic), although only 30 to 50 species commonly occur at one time. There is a high turnover of individual turf algal species seasonally and only a few species are able to persist or remain abundant throughout the year. But turf algae, when observed as a functional group, remain relatively stable year round (Steneck and Dethier 1994). They are often able to recovery rapidly after being partially consumed by herbivores. Turfs are capable of trapping ambient sediment and kill corals by gradual encroachment.

Macroalgae



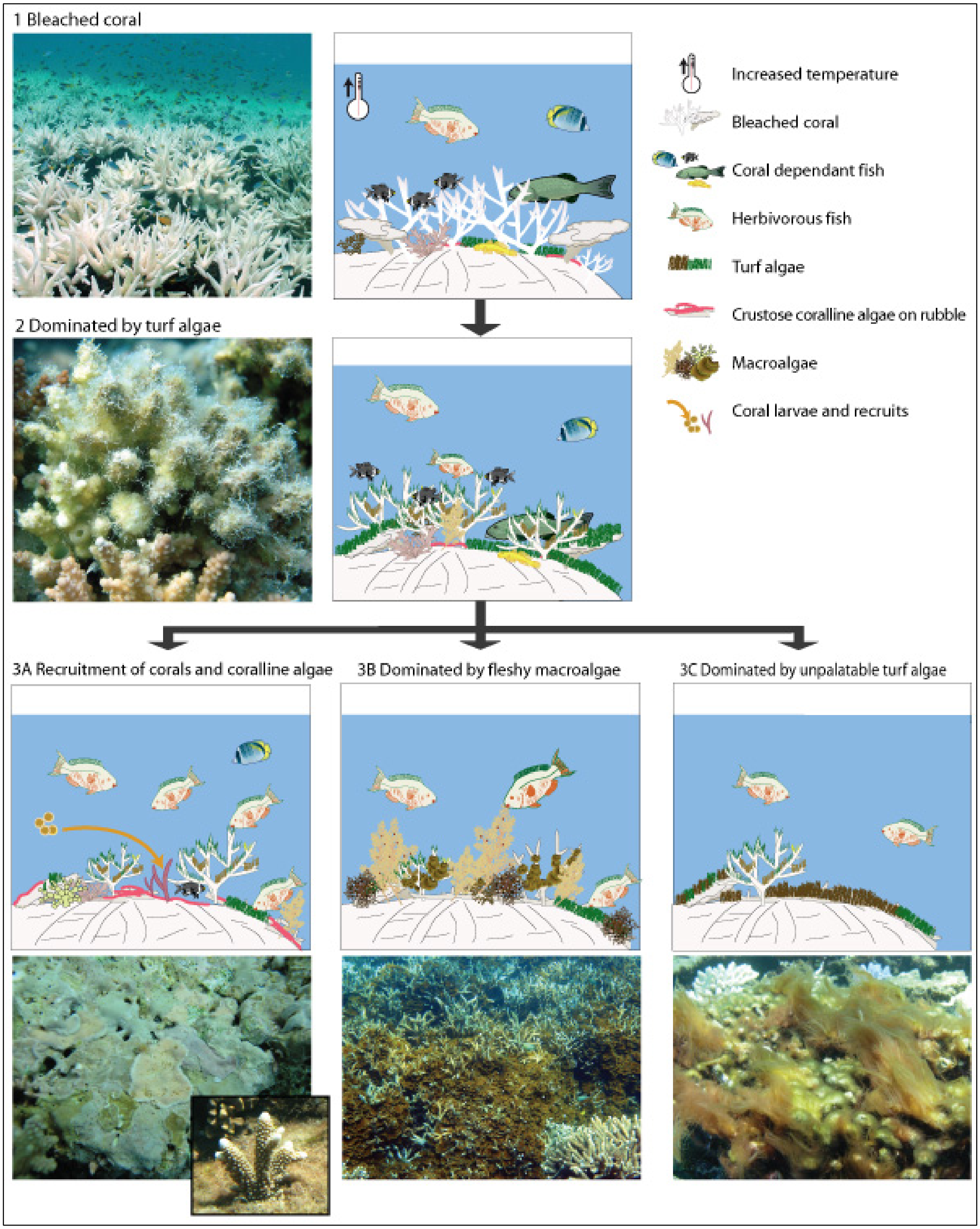
Macroalgae are larger (canopy height usually >10mm) erect algae often with anatomically complex forms. Most macroalgae possess some from of deterrent against herbivory, either through chemical deterrents or structural resistance. Although macroalgae are often more resistant to physical and biological disturbances than corallines and turfs, grazing by certain herbivores and high wave action can inhibit macroalgal growth. High macroalgal biomass can interfere with coral recruitment and reduce coral survival.

Community structure

Algal community structure is complex often interrelated with the presence of or competition with other algae, intensity of herbivory, and productivity (and productivity-related environmental factors such as light, nutrients, and water motion). Most herbivore groups are able to feed on turfs, while fewer feed on macroalgae and even fewer on corallines. Crustose corallines are able to withstand or resist most intensive grazing due to the mechanical properties of their calcified thallus; many macroalgae have structural or chemical defenses to deter grazing; but turf algae are not as effective in resisting or deterring herbivory, although they are capable of rapid growth and regeneration. Increased herbivory reduces algal biomass and shifts algal community dominance from macroalgae to turf algae and eventually to encrusting corallines.

Crustose corallines are usually abundant on shallow reefs with high coral cover, abundant herbivores and low levels of fleshy algae . In shallow waters, herbivory has been found to facilitate the survival of some corallines and is often required in areas where sediment-trapping turf algae dominate. In deeper waters, crustose corallines often exist as an understory beneath a canopy of macroalgae and herbivory is not required to promote growth among those corallines in that microhabitat. Corallines have a self-cleaning mechanism (epithallium sloughing) to remove a small amount of fouling fleshy algae and possibly low levels of sedimentation. Corallines growing underneath a canopy of macroalgae are often different species and have a different morphology. When herbivory is reduced or removed, turf algae are able to colonize on and around corallines and once established, they begin to trap sediment and kill underlying corallines. When grazing intensity increases, turf and macroalgal biomass usually will decrease. In general, certain corallines can co-exist with macroalgae; for a limited time under sparse non-sediment trapping turfs; but not with densely-spaced sediment-trapping turf algae.

After the mass mortality of the herbivorous sea urchin, Diadema antillarum, in 1983 a shift was observed from coralline to macroalgal dominance in shallow reefs and from turf to macroalgae in deep forereefs of Jamaica and St. Croix. Similar declines of corallines have been observed after the reduction of other herbivores such as fish, limpets, and sea urchins. Generally, when macroalgal biomass is high, coral recruitment declines and coral abundance declines as well.


1 Bleached coral
Increased temperature
Bleached coral
Coral dependant fish
Herbivorous fish
Turf algae
Crustose coralline algae on rubble
Macroalgae
Coral larvae and recruits
2 Dominated by turf algae
3A Recruitment of corals and coralline algae
3B Dominated by fleshy macroalgae
3C Dominated by unpalatable turf algae

Economic Uses of Algae

Marine algae, as primary producers, are ecologically important, and economically have been used as food and medicines for centuries. Today, various species of marine algae provide not only food but also produce extracts such as agar, carrageenans, and alginates. These extracts are used in numerous food, pharmaceutical, cosmetic, and industrial applications.

Algae as the entrée

•Kombu, nori and wakame (Japan)
    Kombu = Laminaria
    Nori = Porphyra
    Wakame = Undaria stipes and blades
•Hai dai - (China)
    Laminaria
•Limu (Hawaii) - [Miscellaneous algal species]
    Limu kohu = Asparagopsis taxiformis
    Limu wawaeiole = Codium
    Limu huluhuluwaena = Grateloupia filicina
    Limu palahalaha = Ulva
•Dulse (Scotland); Dillisk - (Ireland); Sol - (Iceland)
    Rhodymenia palmata
•Irish moss or Carraghean (Europe)
    Chondrus crispus
•Nori or Amanori (Japan); Zicai (China)
    Porphyra

Secondary Products of Brown Algae

Brown algae (Phaeophyta) includes Kelps (Macrocystis, Laminaria) and A scophyllum, Fucus, and Sargassum.

Alginic Acid (Alginate) is a colloidal product used for thickening, suspending, stabilizing, emulsifying, gel-forming, or film-forming, as required.

About half of the alginate produced is used for making ice cream and other dairy products, the rest is used in other products, including shaving cream, rubber, or paint. In textiles, alginates are used to thicken fiber-reactive dye pastes, which facilitates sharpeness in printed lines and conserves dyes.

Dentists use alginates to make dental impressions of teeth.
Applications using Alginates

FOOD (Nondairy): Frozen foods, Pastry fillings, Syrups, Bakery icings, Relishes, Cooked/ instant puddings, Meringues, Chiffons, Dessert gels, Candies, Fruit juices, Jams & Jellies, Sauces and gravies, Pimiento strips, Salad dressings

FOOD (Dairy): Whipped toppings, Milk shakes, Cheeses, Flans and custards, Instant breakfasts, Ice Cream

INDUSTRIAL: Paper sizing / coatings, Adhesives, Textile printing / dyeing Air freshener gels, Explosives, Boiler compounds, Polishes Antifoaming agents, Ceramics, Welding rods, Cleaners, Castings and impressions, Enzyme immobilization

MEDICAL & PHARMACEUTICAL: Baulking agents, Capsules and tablets, Lotions and creams, Ulcer products

Secondary Products of Red Algae

Red algae (Rhodophyta) Carrageenan is made from Gigartina stellata, Chondrus crispus and Eucheuma.

Carrageenan (carrageenin, carragheen) is similar to agar, but requires higher concentrations to form gels.

Carrageenan is used for stabilizing chocolate, milk, egg nog, ice cream, sherbets, instant puddings, frostings, creamed soups, etc.

Red algae (Rhodophyta) Agar is made from Gelidium, Gracilaria, Pterocladia and Ahnfeltia.

Agar is another colloidal agent used for thickening, suspending, and stabilizing. However, it is best noted for its unique ability to form thermally reversible gels at low temperatures.

The greatest use of agar is in association with food preparation and in the pharmaceutical industry (as a laxative, or as an inert carrier for drug products where slow release of the drug is required).

Agar is used in bacteriology and mycology as a stiffening agent in growth media.
Agar is used as a stabilizer for emulsions, and as a constituent of cosmetic skin preparations, ointments, and lotions. It is used in photographic film, shoe polish, dental impression molds, shaving soaps, hand lotions, and in the tanning industry.
In food, agar is used as a substitute for gelatin, as an antidrying agent in breads and pastry, and also for gelling and thickening purposes. It is used in the manufacture of processed cheese, mayonnaise, puddings, creams, and jellies and in the manufacture of frozen dairy products.

Applications using Red Algae

Carrageenan

FOOD (Nondairy): Frozen foods, Dessert gels, Pastry fillings Fruit juices, Syrups, Jams & Jellies, Bakery icings, Sauces and gravies, Relishes, Pimiento strips, Cooked/ instant puddings, Salad dressings, Chiffons

FOOD (Dairy): Whipped toppings, Milk shakes, Skim milk, Evaporated milk, Chocolate milk, Cheeses, Cottage cheese, Infant formulas, Flans and custards, Yogurt, Instant breakfasts, Ice cream

INDUSTRIAL: Air freshener gels, Tertiary oil treatment, Cleaners, Enzyme immobilization, Electrophoretic media, Chromatographic media

MEDICAL & PHARMACEUTICAL: Laxatives, Baulking agents, Capsules and tablets, Lotions and creams, Shampoos, Ulcer products, Toothpastes

Agar
FOOD (Nondairy): Frozen foods, Dessert gels, Bakery icings, Candies, Meringues, Fruit juices

FOOD (Dairy): Cheeses, Yogurt

INDUSTRIAL: Paper sizing / coatings, Microtomy media, Adhesives, Electrophoretic media, Textile printing / dyeing, Chromatographic media, Castings and impressions, Conductivity bridges

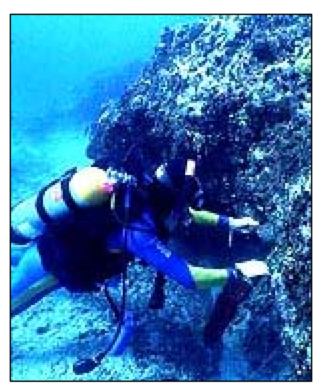
MEDICAL & PHARMACEUTICAL: Laxatives, Capsules and tablets, Baulking agents, Suppositories, Radiology suspending agents, Anticoagulants

Industrial and other uses

Fertilizer / soil amendments
Miscellaneous species of Kelps (Brown algae), e.g. Laminaria, Macrocystis

Filters / Rubbing compounds (polish) / Pest control (fleas)
Diatoms in the form of Diatomaceous earth (diatomite)

Sewage treatment to remove inorganic nutrients and toxins
Unicellular freshwater Chlorophyta and other micro- and macroalgae.



Collection and Preservation of Algae

The objective of taxonomic collections is to represent the natural population in size and form. Therefore, it is important to collect a representative sample of specimens (seasonally), being careful to collect the entire plant (including the holdfast) as well as representative plants from various habitats. Noting information about the habitat for the label may be as important as the specimen itself. The preservation of specimens must be prepared carefully so that important morphological characters are displayed as fully and completely as possible.

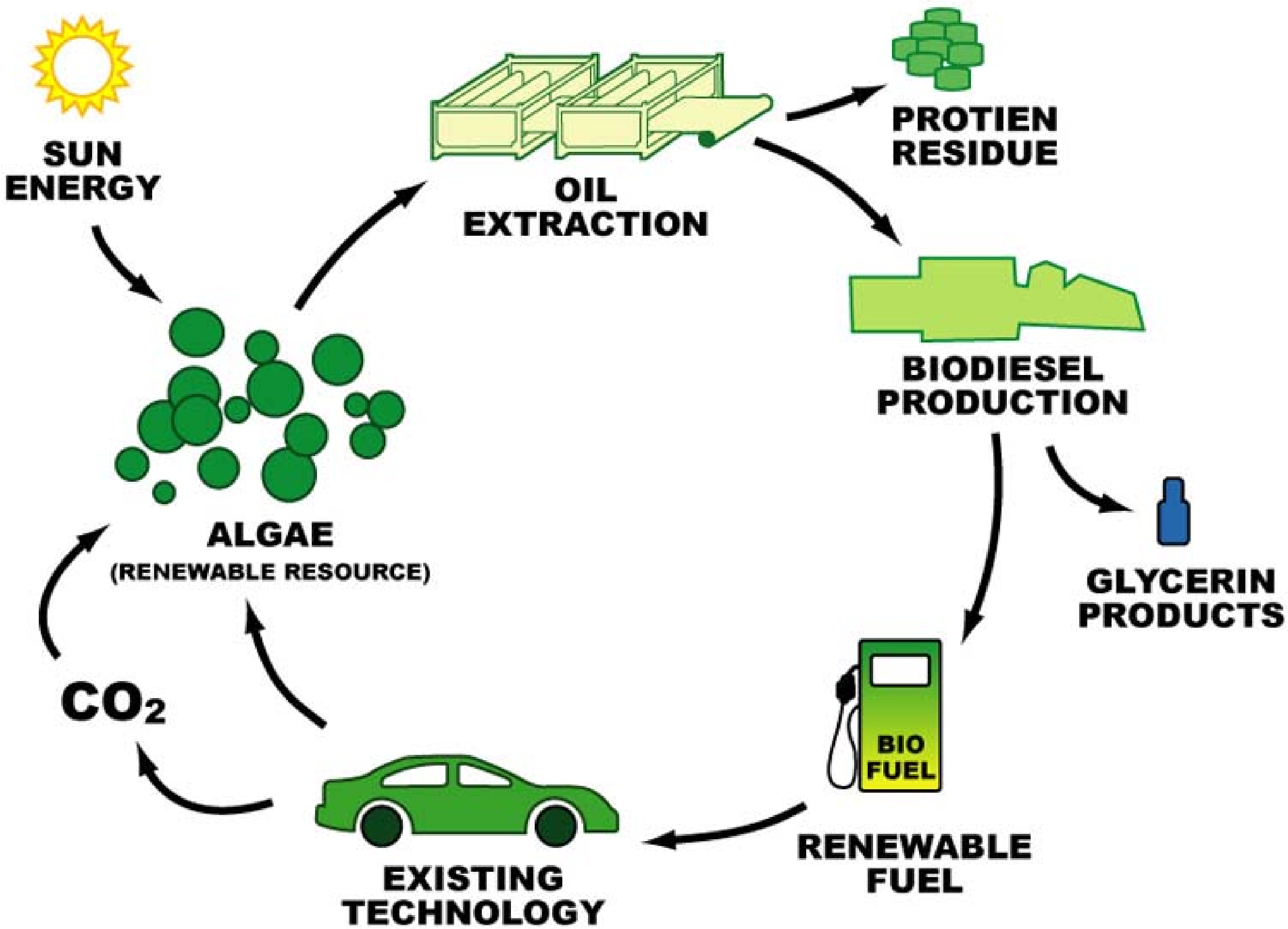
Algae Fuel

Algae fuel, also called **algal fuel**, **algaeoleum** or **third-generation biofuel** is a biofuel which is derived from algae. During photosynthesis, algae and other photosynthetic organisms capture carbon dioxide and sunlight and convert it into oxygen and biomass. Up to 99% of the carbon dioxide in solution can be converted, which was shown by Weissman and Tillett (1992) in large-scale open pond systems.

Several companies and government agencies are funding efforts to reduce capital and operating costs and make algae fuel production commercially viable. The production of biofuels from algae does not reduce atmospheric carbon dioxide (CO_2), because any CO_2 taken out of the atmosphere by the algae is returned when the biofuels are burned. They do however eliminate the introduction of new CO_2 by displacing fossil hydrocarbon fuels.

Crop	Oil Yield Gallons/acre
Corn	**18**
Cotton	**35**
Soybean	**48**
Mustard seed	**61**
Sunflower	**102**
Rapeseed/Canola	**127**
Jatropha	**202**
Oil palm	**635**
Algae (10 g/m^2/day at 15% TAG)	**1,200**
Algae (50 g/m^2/day at 50% TAG)	**10,000**

High oil prices, competing demands between foods and other biofuel sources, and the world food crisis, have ignited interest in algaculture (farming algae) for making vegetable oil, biodiesel, bioethanol, biogasoline, biomethanol, biobutanol and other biofuels, using land that is not suitable for agriculture. Among algal fuels' attractive characteristics: they do not affect fresh water resources, can be produced using ocean and wastewater, and are biodegradable and relatively harmless to the environment if spilled. Algae cost more per unit mass (as of 2010, food grade algae costs ~$5000/tonne), due to high capital and operating costs yet can theoretically yield between 10 and 100 times more energy per unit area than other second-generation biofuel crops. One biofuels company has claimed that algae can produce more oil in an area the size of a two car garage than a football field of soybeans, because almost the entire algal organism can use sunlight to produce lipids, or oil. The United States Department of Energy estimates that if algae fuel replaced all the petroleum fuel in the United States, it would require 15,000 square miles (40,000 km^2). This is less than $\frac{1}{7}$ the area of corn harvested in the United States in 2000. However, these claims remain unrealized, commercially.



Activity: Making Algae (Phytoplankton) Grow

Duration: Several Classes.

Objectives:

- The purpose of this activity is to demonstrate the conditions needed for optimum growth of algae.

Materials:

- algal cultural (can be obtained from a scientific or aquarium supplier or even from a classroom aquarium)
- water (fresh or salt depending on the algae used)
- large (20 – 50 mL capacity) test tubes, baby food jars, or other glass containers and lids, stoppers, or something to seal the containers with. 4 containers will be needed for each group of students.
- aluminum foil
- available light source (sunny window or artificial)
- droppers or pipettes
- liquid fish fertilizer (available from gardening suppliers)
- wax pencils or markers and masking tape for labeling containers

Procedure:

1. Provide each group of students with four containers. Have students label the containers as follows:
    i. **+** Sun, **+** Nutrients, Group Name or Number
    ii. **+** Sun, **-** Nutrients, Group Name or Number
    iii. **-** Sun, **+** Nutrients, Group Name or Number
    iv. **-** Sun, **-** Nutrients, Group Name or Number

2. Add 15 mL of water to each test tube or container.
3. Add 5 drops of algal culture to each container.
4. Add 5 drops of liquid fish fertilizer to each container labeled "**+** Nutrients".
5. Completely cover each container labeled "**-** Sun" with aluminum foil, so that no light can penetrate the container.
6. Seal each container securely to avoid evaporation.
7. Place all containers in a sunny window or under an artificial light source where they can receive equal amounts of light and they can be exposed to the same temperature (i.e., don't place some on a heater and others near an open window).

Activity: Pressing Seaweed and Artwork

Duration: 1-2 hours

Description:

Discover seaweeds natural beauty by pressing seaweed and creating artwork and seaweed keys.

Materials:

- Basins
- A4 sheets of paper
- Paint brush
- Pencil
- Colored cardboard
- String/ribbon
- Hole punch
- Seaweed
- Newspapers
- Nappy liners (if available) / absorbent sheets
- Paint /items for decorating the cover

Background:

As the tide goes out on the rocky shore there is an array of color. Look closely and notice how each tidal zone has its own color, depending on the type of seaweed that lives there.

Seaweeds are classified into three groups. These relate to their pigmentation color:

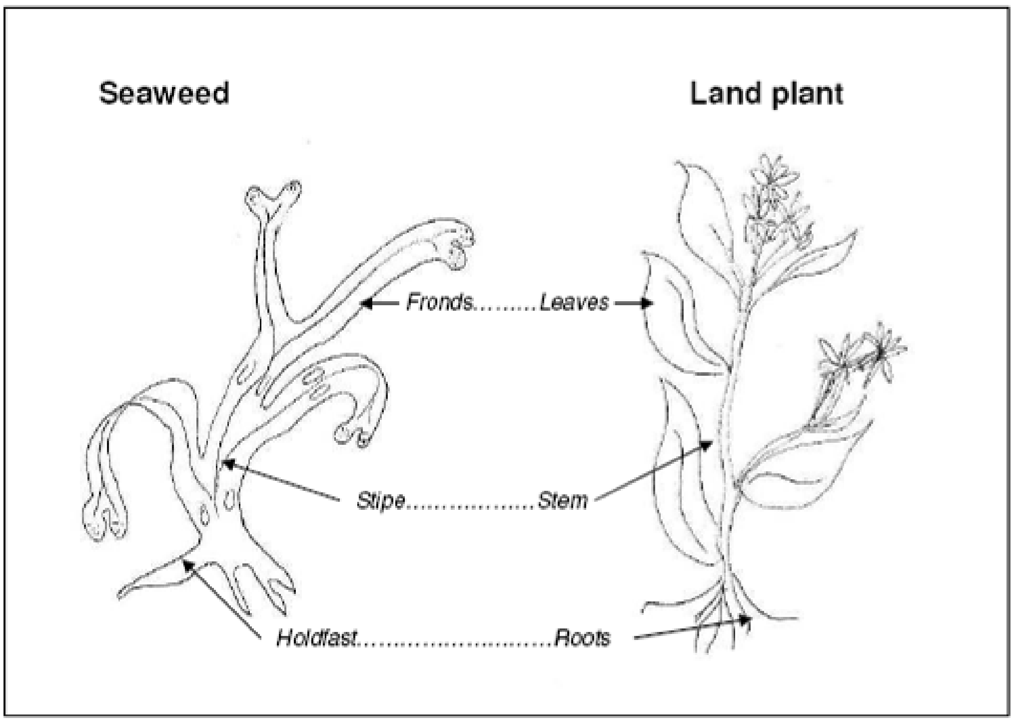
- red seaweed
- brown seaweed
- green seaweed.

Depending on the season, the amount of sunlight and the age of the seaweed -these colors can vary. For example, brown seaweed can look green and red seaweed can looks maroon or dark purple.

Seaweed is a form of marine algae and has a vigorous life on the shore where it has to survive in salty water, crashing waves, tides and exposure to the heat and sun.

Seaweed provides an important source of food and protection for a wide variety of marine animals as well as generating life and providing oxygen in the water.
Unlike land plants, seaweeds lack roots, leaves, and stems but have other specialized structures. For example:

- Instead of roots that reach down into the ground seaweeds have holdfasts which anchor them firmly to the rocks on which they live.
- Instead of leaves seaweeds have a blade or series of branching fronds growing from the holdfast. Like leaves from seed-producing plants, the blades and fronds are the photosynthesizing or food-producing parts of the plant.
- Instead of stems seaweeds have stipes which absorb the shock of the crashing waves and tides. Some seaweed has air-filled bladders that help their blades rise up towards the surface of the water, where they have a better chance of absorbing the sun's energy.
- Seaweeds also produce a gelatinous substance that minimizes water loss – particularly when the tide is out.



Activity:

1. Discuss the role seaweed plays in the rocky shore ecosystem. Introduce the vocabulary of seaweed - holdfast, stipe, blade / frond compare seaweed with land plants. Investigate the role seaweed plays in the rocky shore ecosystem.
2. Collect a range of seaweeds from the seashore. Try and find seaweeds that show different colours, texture and shapes which are located at the various zones of the seashore. If you look closely at seaweed you'll not only find an array

of color and some interesting adaptations for coping with waves and tides, but also some beautiful patterns. Enjoy discovering the patterns of marine algae by doing a seaweed print.

3. Divide up the seaweed amongst the students. The class will need to wait up until the seaweed has dried to create seaweed artwork. The students will be able to use the dried seaweed to make a variety of artwork such as:
    - seaweed keys (booklet)
    - a seaweed display board (i.e. showing the zones of where the different seaweeds are found on the seashore)
    - seaweed cards
    - seaweed collages and more.

Procedure:

1. Select a piece of seaweed and wash it in (fresh?) water.
2. Put the seaweed into a basin filled with (fresh?) water. It is a good idea to float the seaweed in the water until it opens up fully.
3. Slip the A4 sheet of paper in the water underneath the seaweed.
4. While still submerged, arrange the seaweed with the paint brush so as all the parts are visible.
5. When you are satisfied with the presentation of the seaweed pull the sheet from the top out of the water, the seaweed should secure itself to the sheet. Seaweed has a natural gelatinous coating that acts like glue.
6. Tip the paper to drain off the water. Once you lift the paper, make sure you don't disturb the seaweed.
7. Place the wet paper and seaweed on newsprint.
8. Place a sheet of the nappy liners / absorbent paper over the seaweed.
9. Press the plant between newsprint and weigh it down with a heavy object e.g. books. To help the seaweed dry out quickly and prevent it going mouldy, replace the dry newspaper sheets every one to three days.
10. Leave pressing for at least 10 days until the seaweed is dry.
11. When the seaweed is dry, label the page that the seaweed is stuck on with the following information:
    - the date it was collected
    - the location where it was found
    - type of seaweed it is
    - Label the holdfast, blade, and stipe on your seaweed.
12. Compare the differences/similarities with a common land plant.
13. When you have pressed a number of different types of seaweeds, combine the pages to make a book. Place a colored sheet of paper at the front and the back of the collection. Punch a hole through pile of sheets and tie together with a piece of string/ribbon. The cover can be decorated using a seaweed theme and should include a title, the student’s name, class and date the book was produced.

Activity: Edible Algae

Duration: 2 hours

Overview

What is seaweed? Why is it in ice cream? Students find out by exploring the characteristics of seaweed and making seaweed extract. They then make ice cream with and without the extract to find out why seaweed is added to so many foods and personal products.

Objectives

Students will be able to:

- Compare and sort various seaweeds.
- Understand that properties of substances can change when they are mixed, cooled or heated.
- Describe the importance of seaweed and why it is used in food and household products.

Background

Kelp and other seaweeds not only provide habitat for ocean animals but are also used in many foods and household products. Some toothpastes, sauces, medicines and cosmetics contain seaweed extracts. Seaweeds are types of large multicellular algae that occur in the ocean. Algae are simple chlorophyll-containing organisms. Sometimes algae are called plants; sometimes they are called protists or protoctists. Algae range from microscopic one-celled diatoms to the large, multicellular seaweeds. Unlike plants, algae do not have true roots, stems and leaves. However, like plants, algae are producers that use the sun's energy and the pigment chlorophyll to convert water and carbon dioxide into sugars and oxygen through the process of photosynthesis. Seaweeds play a very important role in an ecosystem. As primary producers, they create oxygen and are the first link in almost all aquatic food webs. Seaweeds also provide important habitat for many plant and animal species. For example, kelp forest seaweeds provide a three-dimensional living space where species may find food and protection from rough open water waves and predators. Even seaweeds pulled loose during storms may end up on the beach or in the deep sea providing important habitat and food sources for beach-dwelling and deep sea animals.

Seaweeds are an important part of the human food web, too. Some are eaten in soups or used for sushi wraps. Alginates, agar, carageenan and beta carotene are extracted from different seaweeds and used in a variety of products. In a mixture, these extracts often act as thickeners and help hold ingredients together. For example, without seaweed extract or another emulsifier, ice cream would be coarse and icy.

Seaweeds are found in three phyla described by predominant color:

• Red Algae (Rhodophyta)

There are 6000 known species of red algae. Red algae are red or pink, but can also appear purple, yellow, green or brown. Porphyra is a seaweed used in sushi. Botryocladia (red sea grape) and Gigartina (Turkish towel) are often seen in tide pools.

Human uses: Gels such as agar and carrageenan are extracted from red algae. Agar is used in foods and in microbiology. Carrageenan is used as an emulsifier in ice cream and other dairy products, cosmetics, toothpaste and medicines.

• Brown Algae (Phaeophyta)
There are 1800 species of brown algae. Most all are marine. Brown algae include the intertidal rockweeds and the kelps. Fucus and Pelvetia are rockweeds. Macrocystis is giant kelp. Nereocystis is bull kelp and Egregia is the feather boa kelp.

Human uses: Alginates are extracted from brown algae for use as highly efficient thickening, stabilizing, suspending and gelling agents. Alginates are used to bind oily and watery fluids together and to suspend particles in mixtures. These gels are used in desserts, dairy products, canned and frozen foods, salad dressings, toothpaste, paint, livestock and poultry feed, cosmetics, building materials, fertilizers and beer foam. Dried seaweeds are also used to add delicious flavor to soups!

• Green Algae (Chlorophyta)
There are 8000 known species of green algae which are found both in water and on land. Many green algae are bright green. Ulva (green sea lettuce), Codium (deadman's fingers) and Cladophora (which looks like fine green hair) can be found in tide pools.

Human uses: Green algae like Ulva (green sea lettuce) is often eaten whole in salads and soups.

Materials

Teacher Preparation
1. Make copies of the three Edible Algae data sheets for each student group or ensure students have science notebooks to use instead. Gather a few seaweed images (see Resources for possibilities) or from ocean-themed magazines and calendars.

2. Place a two-inch square piece of red seaweed, such as nori (Porphyra), into a small, zippered plastic bag for each student group.

3. Use the enclosed recipe to make a trial batch of ice cream so as to better troubleshoot or prevent problems when students try it.

4. Gather the materials to create three seaweed stations. You may choose to have students visit each station or provide station materials for each student group.

- Seaweed Exploration Station: Provide hand lenses and a variety of seaweeds for students to touch, smell and illustrate. You may provide seaweeds for them to eat, too. Look in the Asian foods section of the grocery store to find different seaweeds used in cooking.

- “Kelp in your Cupboard” Station: Find products at home containing seaweed extracts (carrageenan, agar or alginates) to bring into class. You may want to buy a few additional products to add variety. Shampoos, ice creams, toothpastes, cake mixes, fruit snacks, cosmetics and medicines may all contain seaweed.
- Seaweed Extract and Cooking Station: Bring in a hot plate or electric kettle to provide hot and boiling water. Each group will need a plastic bag with the seaweed sample, two tablespoons of hot water to make seaweed extract, a strainer and a pot or bowl of hot water large enough to hold two baggies. The groups will also need to eventually simmer two quart-sized plastic bags of ice cream mixture in a large pot.
- Ice Cream Making Station: Supply measuring cups and spoons and ingredients for making ice cream. Each group will need two quart-sized plastic bags, 2 clear plastic cups, 1 cup of whole milk, 4 tablespoons of sugar, 1/2 teaspoon cocoa powder (for baking) and 1/4 teaspoon of vanilla.

For the class:

- various products containing carrageenan, agar and alginates
- samples of seaweeds from Asian foods section of a grocery store
- hot/boiling water in a pan/bowl
- newspaper to cover stations
- measuring cups and spoons
- plastic spoons for tasting
- permanent markers for labeling
- rulers
- a strainer
- freezer or ice chest
- images of seaweed in natural habitat (optional)

For each lab group:

- notebooks or copies of Edible Algae data sheets
- hand lenses
- 1 finger-sized piece of red seaweed such as nori (Porphyra) in a small zipper plastic bag
- 1 cup whole milk
- 4 tablespoons of sugar
- 1/2 teaspoon cocoa powder (not mix)
- 1/4 teaspoon vanilla (optional)
- 2 clear plastic cups
- 2 quart-sized plastic bags with zippers
- small wire whisk or plastic spoon
- measuring cup and 3 spoons

Procedure

1. SET THE STAGE FOR A SEAWEED INVESTIGATION.
Generate interest in seaweed. What is seaweed? (plant-like organisms called algae) Where does seaweed grow? (mostly in water, although some other algae grow on land) Share images of a kelp forest or seaweed in its natural habitat. Why is it important? (animal habitat, human use in various products) You may give them hints by asking who likes ice cream or brushed their teeth that morning. Tell students they are going to investigate why seaweed is in toothpaste and various other products.

2. EXPLORE THE PROPERTIES OF SEAWEEDS IN SMALL GROUPS.
Divide students into small groups. Pass out the three Edible Algae data sheets. Have students use the Seaweed Exploration Station to investigate various kinds of seaweed. Encourage them to use as many senses as possible and make accurate illustrations on their data sheet.

3. STUDENTS MAKE SEAWEED EXTRACT AND RECORD THEIR OBSERVATIONS.
Pass out the small plastic bags with 2-inch red seaweed samples to each group. (The seaweed may not look red when it is dried out because it also has the green pigment chlorophyll.) Have students go to the Seaweed Extract and Cooking Station and assume the role of a “measurer,” data recorder and timer and finish the Edible Algae #1 data sheet. Students will need two tablespoons of very hot water to add to their bags of seaweed. Then they will need to place the bag in hot water for 20 minutes. Students should go to the Kelp in Your Cupboard Station while they wait.

4. STUDENTS IDENTIFY SEAWEED EXTRACTS IN A VARIETY OF FOODS AND PRODUCTS.
Have students explore various products that contain seaweed extracts at the Kelp in Your Cupboard Station and record observations on the Edible Algae #2 data sheet. When the 20 minutes are up, help groups finish making the seaweed extract at the Seaweed Extract and Cooking Station by using a strainer to remove the seaweed and capture the solution.

5. STUDENTS MAKE ICE CREAM MIXTURES.
Have students follow the instructions on Edible Algae #2. They will make and compare two ice cream mixtures; a control sample (without extract) and an experimental sample (with extract). You will need to then simmer the students’ mixtures for about eight minutes and then place them in the freezer or ice chest until frozen.

6. STUDENTS COMPARE ICE CREAM SAMPLES TO OBSERVE HOW EXTRACT AFFECTS ICE CREAM.
Pass out the frozen ice cream samples and spoons to students. Have them complete the Edible Algae #3 data sheet.

7. AS A CLASS, DISCUSS STUDENTS’ FINDINGS.
Have students share their observations with the class. Discussions questions may include; What is extract? Why is seaweed extract added to ice cream?

What can you infer about other mixtures seaweed extract is added to? How can you change the properties of a mixture? Why is seaweed important?

Name:

Edible Algae #1

Seaweed Exploration Station

Record your observations about samples of seaweed below.

Name of Seaweed	Illustration	Observations

Seaweed Extract and Cooking Station: Make a Seaweed Extract

Describe your seaweed sample in the data chart below.

Stage I: Observe the seaweed as it appears in the plastic bag. Record your observations.

Stage II: Add two tablespoons of hot water, wait 2 minutes and record new observations.

Stage III: Place the bag with water and seaweed in a hot water bath for 20 minutes. Visit other stations while you wait. Once all the seaweed is dissolved, strain extract into a small container.

Stage	Time	Drawing	Observations
I			
II			
III			

Name:

Edible Algae #2

Kelp in your Cupboard Station

Use the table below to record your observations of various products. Look at each list of ingredients to find these seaweed extracts:

- **Agar (red algae):** Used instead of gelatin to hold substances like sour cream and marshmallows together. Also used in laboratory Petri dishes to culture bacteria.
- **Carrageenan (red algae):** Helps change liquids into gels and are used to "keep the shape" of many products.
- **Algin/Alginates (brown algae):** Helps sauces and syrups pour smoothly and keep their texture. Also used in dry mixes, like pancake mix, to help product absorb liquid and keep ingredients from separating once mixed.

Product Name	Seaweed Extract	Appearance and Texture

Ice Cream Making Station

1. Get two plastic cups. Add 1/2 cup milk, 2 tablespoons of sugar and 1 teaspoon cocoa to each cup. A drop of vanilla extract is optional. Mix the liquid until the sugar dissolves.
2. Label one cup "with" and one cup "without." Add your seaweed extract to the cup labeled "with" and mix gently.
3. Compare the two mixtures and record your observations in the table below.
   - •How does each mixture drip from the spoon?
   - •What does each mixture look like?
   - •Pick up the cups to observe the mixture settled on the bottom. What do you notice?

State	Without Extract	With Extract

4. Write your names on two quart-size plastic bags. Label one "with" and one "without." Transfer your mixtures into the bag. Give it to your teacher to simmer for eight minutes and then freeze.
5. Predict what you think will happen to the liquids. How will the mixtures be the same? How will they be different?

Name:

Edible Algae #3

Compare Ice Cream Samples

Obtain the frozen "ice cream" and record your observations below.

- What is the appearance of each mixture?
- What is the taste?
- What is the texture?

State	Without Extract	With Extract

Discussion Questions

1. Give examples of the different states of matter (solid, liquid and gas) you observed in this experiment.

2. How did changes of temperature affect the ice cream mixture?

3. How did seaweed extract affect the ice cream mixture?

4. Describe the importance of seaweed.

Resources

http://en.wikipedia.org/wiki/Algae
http://botany.si.edu/projects/algae/index.htm
http://www.hcs.ohio-state.edu/hcs300/algae.htm
http://tuberose.com/Algae.html
http://www.agrra.org/background/algaeback.html
http://oceanservice.noaa.gov/education/kits/corals/coral02_zooxanthellae.html
http://www.earthlife.net/lichens/lichen.html
http://teachingboxes.org/upwelling/lessons/lesson1_activity1.jsp
http://www.absoluteastronomy.com/topics/Red_algae
http://www.hcs.ohio-state.edu/hcs300/algae.htm
Images: Google images