# Science Background for the Teacher

The following is not intended to be a comprehensive or detailed summary of the science associated with studies of the coast. It does provide basic background for teachers and others who may not have a lot of training in ocean science. Elementary students need not learn all of this information. Teachers who have a good background in science, however, will be better able to take advantage of "teachable moments" at the coast!

Most high school and many college science courses dwell too much on teaching and learning of vocabulary. The most important thing about learning science is to gain understanding of how our world works and an appreciation of its beauty, wonders, and importance. Nevertheless, vocabulary makes communication easier. Also, learning the etymology of terms facilitates the learning of both scientific and non-scientific terms. Therefore, the following includes vocabulary (in **bold** type) that will help clarify the information being reviewed. The vocabulary should be seen as a means for learning and communicating, not an end unto itself. (See pages 147-154 for glossary.)

## Physical (Abiotic) Factors

In general, environmental factors can be divided into living (**biotic**) and non-living (**abiotic** or physical) factors. It is very important to keep in mind (and to teach the children) that all living things depend on the non-living environment. Without energy (primarily from the sun), water, air, minerals, and nutrients, life as we know it on Earth wouldn't exist.

### Geology

Living things depend on their physical environment. The rocks and minerals in that environment provide the substrate upon which organisms live as well as the mineral nutrients that they need. In coastal **ecosystems**, the sea water itself provides dissolved minerals and other nutrients that plants and algae require.

During the Pleistocene Ice Age, about 20,000 years ago, most of North America and Eurasia were covered by a huge sheet of ice. The water in this ice sheet came from the oceans, resulting in a sea level that was more than 400 feet lower than it now is. In some places, the sea shore was more than 60 miles from the current shoreline. **Sediments** from the land formed a "shelf" or **terrace** of sedimentary rock along the coast. Beginning 12,000-10,000 years ago, most of the glaciers melted, and the water from the melted **glaciers** now covers the previously exposed coastal shelf.

The San Andreas **fault** runs along the southern Mendocino County coast, entering the ocean near Point Arena. Movement along this and other faults has resulted in shattering of the rocks offshore. This crushed rock erodes more easily than solid rock, resulting in sand and gravel that may, along with sand brought by rivers and creeks, form beaches, or, under pressure or chemical processes, may reform as new **sedimentary rock.** Movement of the **plates** bordering the San Andreas fault is probably also at least partly responsible for uplifting of the flat rock layers called **"marine terraces"** that edge the coast.

And so, the Mendocino coast is a combination of steep cliffs formed where relatively solid rock resists weathering, and beaches, formed where the waves are gentle enough to allow weathered rock and sand to accumulate. Tide pools generally form on shallow marine terraces near the base of rocky cliffs, as they require rock that is hard enough to resist the weathering forces of the waves, and water that has enough energy to carry away the sand that would otherwise fill the pools.

## Types of Shores

### Estuaries

An **estuary** is formed where a river enters the ocean in such a way that there is significant mixing of the fresh river water and the sea water. Big River and Ten Mile River are examples of estuaries in Mendocino County. San Francisco Bay is essentially a large estuary.

### Sandy and Rocky Beaches

Beaches are formed where waves deposit materials such as sand and gravel. Most of the sand is brought to the coast by rivers and creeks. Beaches are constantly changing, and this movement of the particles has a major impact on **organisms** living or attempting to settle there. Sand may be brought to the beach by currents running along the shoreline. When a rocky headland or a man-made break-water interferes with this long shore current of sand or gravel, the water's energy is dissipated and the sand and rock particles are dropped, forming a beach. On the other hand, a beach may disappear if the source of its sand is interfered with, as sometimes happens when rivers are dammed, or on the "downstream" (down current) side of a breakwater where the sand is trapped on the "upstream" (up current) side. Beaches also change shape due to natural causes such as winter storms.

### Mudflats and Salt Marshes

If a bay is especially shallow, the water may have so little energy that it doesn't even carry away small particles such as mud and clay. In such cases, mud flats and salt marshes may form. These areas are especially important because they provide very rich **environments** for the breeding of many kinds of fish and birds. They are also important because they are often found near river mouths and estuaries, where the aquatic organisms filter out many of the pollutants carried by the rivers. Coastal marshes might be called nature's sewage treatment plants! No large mudflats or salt marshes occur along the Mendocino coast. However, examples occur near the mouths of Big River, Navarro River, and Ten Mile River.

Rocky Intertidal Habitat

This *Guide* focuses on the exploration of the rocky **intertidal** habitat. The term "intertidal" refers to the area between the lowest low tides and the highest high tides. This is where **tide pools** form.

Not all rocky shores are alike. Where the coast is exposed to the direct affects of the oceans, the unprotected outer or open rocky shores, the rocks often form steep shores with a narrow intertidal area. In protected bays, the coast is often more gently sloping with an intertidal zone extending for a considerable distance horizontally.

While classes often come to visit "the tide pools," much of the intertidal life is found outside of the tide pools themselves. Tide pools, however, are an excellent place to observe organisms as they go about their lives in the water.

Tide pools can range in size from inches to yards across, and from inches to several feet deep. They can be described as pools of water that are more or less exposed at low tides, or affected by low tides.

## Zonation

One commonly used classification system for intertidal areas recognizes four tidal "**zones**," which are differentiated by their exposures during different tidal periods and affected by wave action and the contours of the beach/coast. While different scientists may use different systems, most divide the rocky intertidal area into four zones, with zone 4 being the deepest. (Similarly, scientists recognize different zones as one moves up a mountain from foothills to the alpine zone.)

The presence or absence of water, its temperature, wave action, variations in **salinity** (saltiness), exposure to light, and other factors determine what organisms are able to live in each zone. In general, physical factors, especially exposure to drying, limit how far up the shore an organism can live. An organism's lower limit is often determined by predators living in the lower zone or by competition.

Because a tide pool may hold water even during a low tide, a tide pool may provide suitable habitat for organisms that would normally be found in a lower zone. Giant green sea anemones and hermit crabs, for example, are generally found in zones 3 and 4, but may be found in tide pools in zone 2.

Some organisms have a narrow range of tolerance for environmental factors and are found in only one zone, while others have greater tolerance and are found in several zones.

<u>Indicator Organisms</u>

The abiotic (physical) factors of a place, in combination with biotic factors such as competition and predation, determine which organisms are able to live there. Most natural communities include organisms that are found in several communities; i.e., organisms that are "interzonal." Most communities also have a few types of plants and animals that are specific to that zone's particular set of factors, *i.e.*, they are found only in that particular community or even in only a part of the community (**microhabitat**). In this *Guide*, the organisms that identify the community and indicate particular living conditions are referred to as **indicator organisms.**

(Some use the term "indicator species" for species that are particularly susceptible to pollution and are thus indicators of pollution.)

Several microhabitats can be found within the rocky intertidal area. These include tide pools, under rocky ledges, under rocks, in algal masses, on the side of rocks that is exposed to waves, on the less exposed side of rocks, and others.

On page 10 you can find descriptions of the four commonly recognized zones and both indicator organisms and organisms that are found in several zones. Most of the indicator organisms are described and illustrated on pages 43-66 of this *Guide*.

Note

The exposure times and other descriptors of the zones indicated below are approximations and may vary due to the shape of the shore line, latitude, and other factors. Similarly, plants and animals don't always stay in the zones where they are most commonly found.

Note, too, that not all "authorities" agree on the delineation of the various zones or even the number of zones. Keep in mind that these "zones" are simply arrangements of organisms that have been noticed and may be helpful in looking at the intertidal area. Indicator organisms and interzonal organisms also vary according to latitude. Different species occur in Washington than in California, and the species or their relative numbers will vary between Humboldt, Mendocino, San Francisco, and Santa Barbara counties. In a climate with lots of rain and fog, organisms may be found in higher zones, as they tend to dry out less at low tides.

The Intertidal Zonation diagram on page 11 is meant to show some common organisms found in each zone. It includes organisms from both the outer coast (exposed directly to wave action) and the inner coast (sheltered from direct wave action). Also, there are several species of most types of organisms. For example, while periwinkles and limpets are listed in Zone 1, there are also periwinkles and limpets that live in lower zones.

# Zones of the Rocky Intertidal Coast

Zone 1: The Spray or Splash Zone

This area extends from the highest reach of spray and storm waves to the mean height of the high tides. It is usually dry, and relatively few types of organisms can live here. This zone is typically exposed to the air 75-100% of the time.

Indicator organisms for Zone 1 include the rock louse, a type of small acorn barnacle called the buckshot barnacle, and several species of limpet and periwinkle.

Other organisms commonly found in Zone 1 include some larger acorn barnacles, and sometimes green algae, especially if there is a source of fresh water.

Zone 2: The High Intertidal or Rockweed Zone

This zone includes the area from the mean high water to just below mean sea level. This zone is exposed to the air about 35%-75% of the time.

Indicator organisms for Zone 2 include the black turban snail, lined shore crab, and some genera of brown algae called rockweeds, including Fucus, and Pelvetiopsis.

Other organisms commonly found in Zone 2 include limpets and periwinkles, several kinds of crab, acorn barnacles, and green algae such as sea lettuce.

Zone 3: The Middle Intertidal or Midlittoral Zone

This zone extends from just below mean sea level to the upper limit of the average lowest tides, i.e., it is exposed at low tides. In a healthy intertidal area, this zone is rich both in diversity and numbers of organisms. There is generally a dense cover of algae, which provides food and shelter for many animals. This zone is exposed to the air about 7%-35% of the time ... at least once a day for 5-6 hours.

Indicator organisms for Zone 3 include the California mussel, often associated with the stalked barnacle and the ochre star, the brown alga Egregia, purple shore crab, some kinds of chitons, and some kinds of red algae.

Other organisms commonly found in Zone 3 include hermit crabs, the aggregating anemone, the brown turban snail, acorn barnacles, sponges, polychaete worms, the bat star, and sculpins. The sea palm (*Postelsia*) may be found at the lower limits of Zone 3.

Zone 4: The Lower Intertidal or Infralittoral Zone

This zone is exposed to the air only at the lowest tides, less than 9% of the time.

Indicator organisms for Zone 4 include surf grass, the brown alga *Laminaria*, giant green anemones, purple and red urchins, red abalone, kelp crabs, sunflower stars, and brittle stars.

Other organisms commonly found in Zone 4 include red algae, sponges, polychaete worms, rock crabs, hermit crabs, chitons, giant chitons, and the octopus.

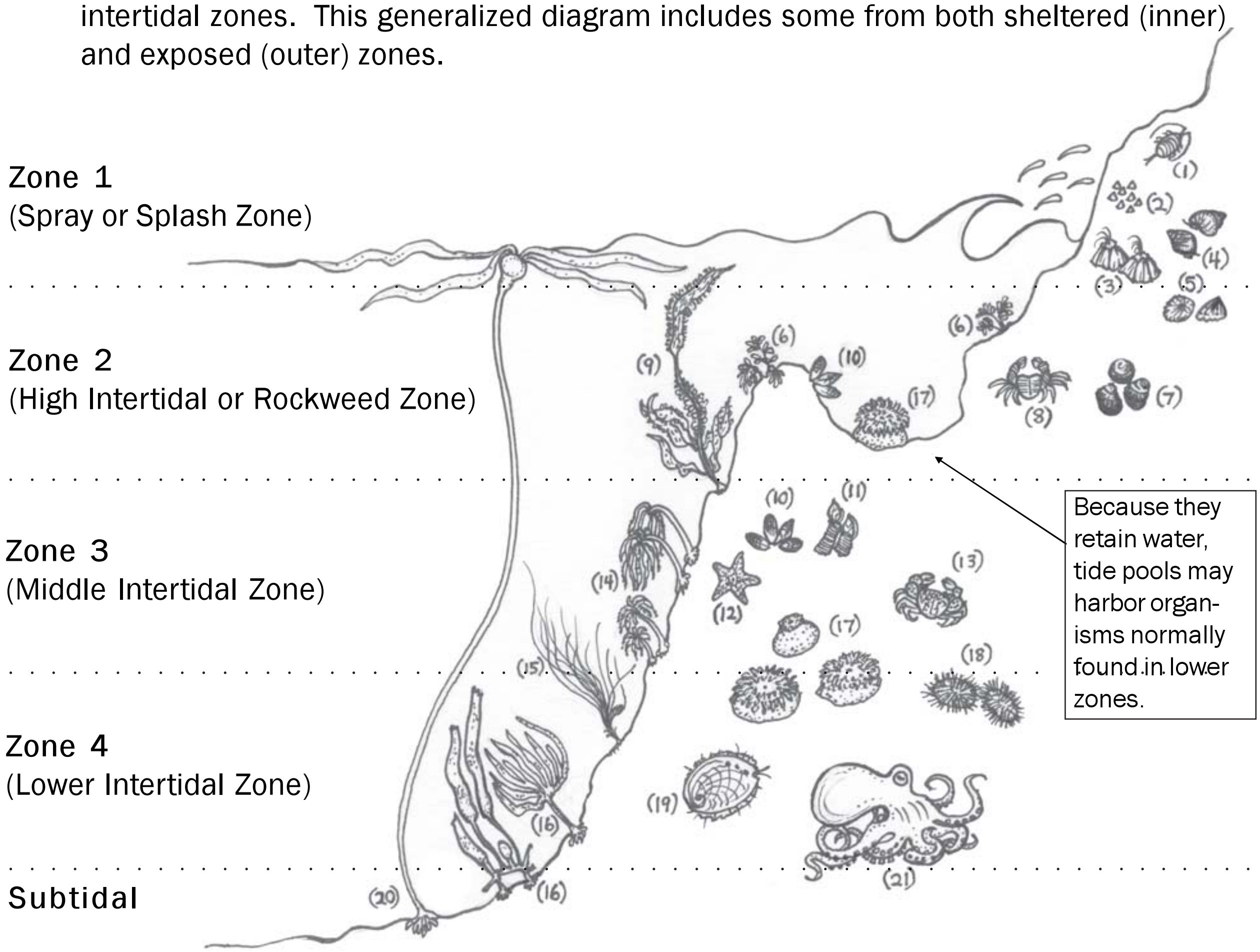
Sub-tidal organisms (from beyond the low tide zone) that you are likely to encounter include bull kelp, many bottom-dwelling invertebrates, and various fish.

Other: Many kinds of birds are likely to be seen in or near the intertidal area, including various gulls, black oystercatchers, cormorants, and brown pelicans. Likewise, you may see mammals such as seals, sea lions, whales, and, occasionally, river otters if there is a river nearby.

## Generalized Intertidal Zonation

(With emphasis on indicator organisms*)

NOT DRAWN TO SCALE! Also, the actual shore is generally more horizontally spread out. Note: There are some differences between organisms found in exposed and sheltered intertidal zones. This generalized diagram includes some from both sheltered (inner) and exposed (outer) zones.




**Even "indicator organisms" (marked with *) can sometimes be found in other zones.**

Zone 1: (1) rock lice*; (2) buckshot barnacles (which are small "acorn" barnacles)*; (3) larger acorn barnacles; (4) periwinkles; (5) limpets

Zone 2: (6) rockweed algae*; (7) black turban snails*; (8) lined shore crab*

Zone 3: (9) feather boa algae (*Egregia*)*; (10) mussels*; (11) stalked barnacles*; (12) ochre star; (13) purple shore crab* (mussels, stalked barnacles, and ochre stars often found together); (14) sea palm alga (*Postelsia*)

Zone 4: (14) sea palm alga (*Postelsia*); (15) surf grass (*Phyllospadix*)*; (16) Oar Weed and Split Kelp (*Laminaria* spp.) algae*; (17) giant green anemones*; (18) urchins*; (19) red abalone*

Subtidal: (20) bull kelp (*Nereocystis*)*; (21) octopus

## Tides

The term "tide" refers to the regular periodic rise and fall of the sea along the coasts. "Tide pools" are pools of water that are exposed when the tide is out (low tide) and covered by the sea when the tide is in (high tide). This rise and fall of the water, with the accompanying covering and exposing of the organisms in the tide pools, is, of course, extremely important to coastal ecosystems. These changes or tides are caused by the interaction of the Earth's oceans, the sun, and the moon. Many other factors such as slope, exposure to winds, storms, and the shape of the coast affect the level of the water at a particular place, but the main factor for tides is the **gravitational attraction** between the Earth, moon, and sun, especially the moon.

**Gravity** is the attraction that any two **masses**, such as you and the earth, have for each other. Greater masses have greater gravitational attraction. Gravitational attraction decreases with distance. Even though the sun is about 27 million times as massive as the moon, the moon is so much closer to the Earth that the affect of its gravity on the Earth (and oceans) is far greater than that of the sun.

*Teaching idea: Have the students think of large and small refrigerator magnets. If you hold the magnets near the refrigerator, you will feel the magnetic attraction. If you move the magnets away from the refrigerator, the attraction of the larger one will be felt longer, but eventually you will not be able to feel it.*

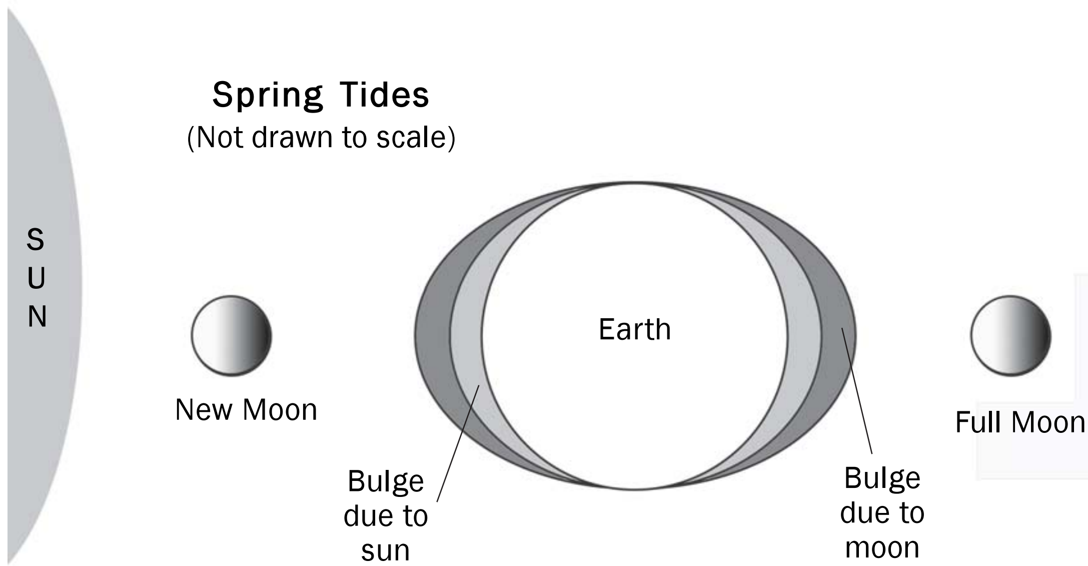
The moon's gravity acts on both the solid Earth and the oceans, of course, but the water in the oceans can move more than the land can. Thus, the oceans "bulge" towards the moon, producing a high tide on that side. The water in the bulge came from somewhere else, and that is where the low tide would be.

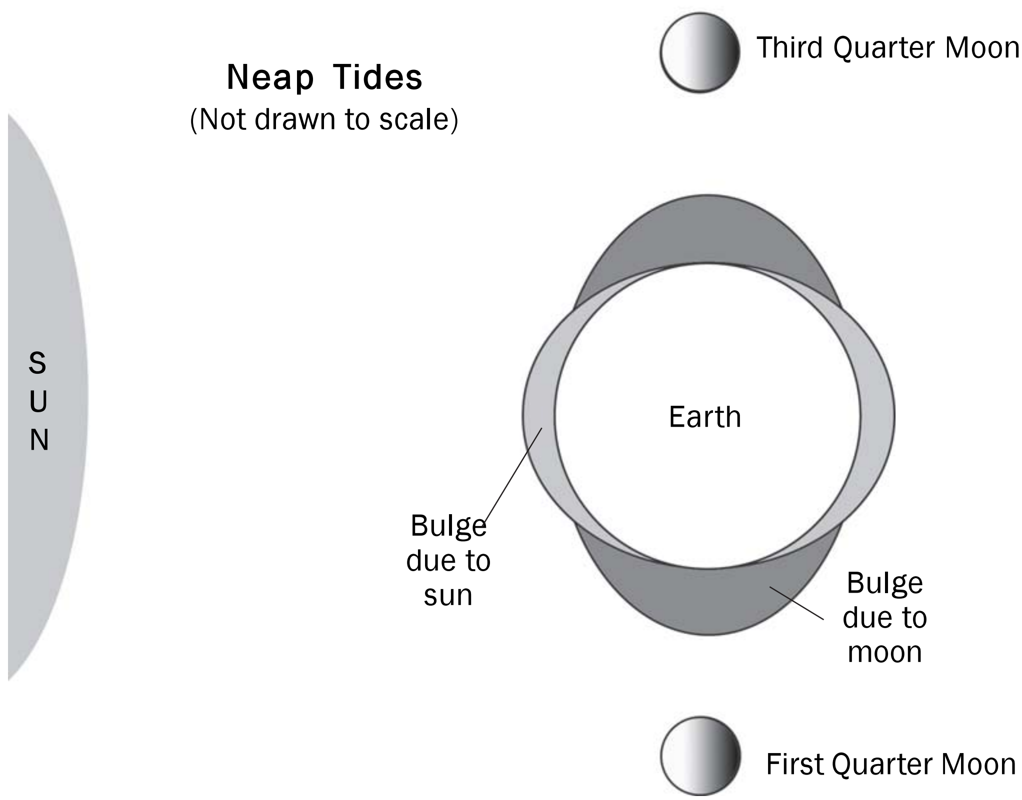
The Earth and the moon form a system in which they revolve around each other as they move around the sun together, with the resulting **"centrifugal force"** causing a bulge in water on the side of the Earth away from the moon. This bulge of water produces a second high tide in each cycle of 24 hours and 50 minutes.

So, as the moon and the Earth revolve, two "bulges" and two "troughs" are produced each day, resulting in two high and two low tides in each rotation, which takes almost 25 hours. After a point on the Earth passes through one of the bulges (high tide), it will pass through a trough about 6 hours later (low tide), then another bulge 6 hours after that (another high tide), and another trough about 6 hours after that (another low tide). This cycle is then repeated.

When the sun, Earth, and moon are all lined up, the gravitational pull on the earth's surface is at its maximum, resulting in the highest high tides and the lowest low tides. The sun, Earth, and moon are lined up during full and new moons, so the highest and lowest tides occur on or shortly after new and full moons. These especially high and low tides are called **"spring tides."** (Spring tides occur each month, not just in the spring.)

When the sun, Earth, and moon aren't lined up, the tides are not so extreme. When the sun, moon, and Earth are at right angles, moderate highs and lows are produced. These moderate tides occur during the first and third quarter moons, and are called **"neap tides."**



Teachers usually want to bring their students to visit tide pools during the lowest tides (i.e., the low spring tides), when the tide is out (low). There are several ways in which one might select dates to visit the tide pools:

As noted above, the highest and lowest tides generally are within a day of full and new moons, which are shown on many calendars.

**Tide tables** are available for finding the dates, times, and heights of the tides. They are available at stores where fishing supplies are sold and at scuba diving shops. They are also available online at several sites. One is the National Ocean Services site: **< co-ops.nos.noaa.gov >** Click on "Predictions" for tide tables.

When reading a tide table booklet, check to see the place for which it was written. There is usually a chart in the front that tells how much to adjust times and heights for other locales.

One thing to note: The levels of the tides on tide tables generally are compared to a "zero" tide which is actually the average of the lower of the low tides, not mean sea level. Thus a tide level of "0" may be about 3 feet below mean sea level, and a tide of minus 0.5 would actually be about 3.5 feet below mean sea level.

Many newspapers, especially in coastal areas, give information on moon phases and tides. Note that the exact times of the lowest tides vary from place to place, so you want to find information for as close as possible to the site of your visit.

If you are planning to visit a state park, a call to the park naturalist will reveal not only dates and times of low tides, but whether tide pool visits are available for your class. Be aware that there is a lot of competition for opportunities to visit park tide pools during the spring months. There is a better chance for an open date if you plan your visit for the fall.

## What is "Sea Level?"

The level of the ocean's water where it meets the land is constantly changing. Tides, storms, and changes in the land beneath the oceans affect where the land meets the sea. What, then, does "sea level" mean?

Different sources define sea level differently. Generally, "mean sea level" is more useful than "sea level," as "mean" refers to an average. The *World Book Encyclopedia* (McArthur, 1993) defines "sea level" as the average level of the sea at a place, based on numerous measurements taken over a long period of time. The *Grolier International Dictionary* (Morris, 1981) defines sea level as "the mean level halfway between high and low tide." But … Which high and low tide? When I examined several oceanography books, I found that most don't even define "sea level!" The clearest definition that I was able to find was in *Oceanography - A View of* *the Earth*, by M. Grant Gross (1972). He defines mean sea level as: "the average height of the surface of the sea for all stages of the tide over a 19-year period, usually determined from hourly readings of tidal height."

For our purposes, we can just define **mean sea level** as the average level where the sea meets the land.

## Waves

The waves that we see at the beach are generated by wind. That wind may be along our coast, or it may be far out to sea, so we may have large waves even when there is little wind at our shore.

As the wind blows across the surface of the water, some of its energy is imparted to the water at the surface. This energy travels through the water as a wave. As the energy wave comes into shallow water, it can cause the water to rise up and move forward with the energy wave. Since the water at the top has less friction than the water at the bottom, where it is influenced by the sand or rock below, the top moves faster, causing the familiar "breaking" of a wave.

Students sometimes think that waves are large masses of water moving towards shore from somewhere out to sea. This makes sense to them, as they see waves bringing water to crash on the shore. As noted above, though, waves are caused not by an influx of water, but energy moving through the water. If waves were a large movement of water from somewhere else, the water would pile up along the shores and there would be a big hole in the sea!

When strong winds blow in one direction for a long time, though, water may indeed "pile up" along the shore. This is seen when we have major winter storms. The effect of this can be devastating along the coast, especially if it coincides with a high tide.

While waves generally approach the shore in a fairly constant rhythm, visitors to the coast in Mendocino need to be wary of "sleeper waves." These exceptionally large waves approach the shore without warning and have swept unaware beach goers to sea, often with tragic results. Even "normal" waves can catch children unaware when they are intent on looking at tide pool organisms, knocking them down or worse. When exploring tide pools, it is a good idea to have someone on watch for large waves, and children should be warned, and reminded, to be aware of the danger posed by waves.

"Tidal Waves"

True **"tidal waves"** are the rise and fall of the water that we call the high and low tides. What people generally call "tidal waves" are more properly called **tsunamis**. Tsunamis are caused by earthquakes or landslides under the sea or along coastal regions. They are energy waves that move several hundred miles an hour. They may, for example, start near Japan or Alaska and arrive in Hawaii or California in just a few hours. It is easy to see that a large earthquake under the sea can generate a lot of energy. This huge amount of energy may not move the thousands of feet of ocean waters above it very much, but as the energy wave moves into shallow water, it can actually generate water waves over a hundred feet high!

## Temperature

As anyone who has ventured into the ocean in northern California can attest, the ocean off the coast in northern California is cold! There are two main causes for this. First, the current along the coast of northern California flows from the northwestern Pacific Ocean, *i.e.*, the waters off Alaska. This "California Current" brings cold water to our coast year-round. In contrast, the Gulf Stream current brings warmer water northward to the east coast of the U.S.

*Teaching idea: When studying history in 4th or 5th grades, discuss how early explorers in sailing vessels used currents.*

Another cause of our cold water is a process called **upwelling**. Upwelling, as the name implies, is the upward movement of cold water from the depths. It is caused primarily by the prevailing winds, which generally blow from the northwest from mid-February until late July along the Mendocino coast. For complex reasons, these northwesterly winds cause the surface waters to move offshore, to the west. As the surface water moves out to sea, it is replaced by cold water from lower levels. Thus, the Mendocino coastal waters are coldest during the summer months! This upwelling of cold water is very important to the organisms along our coast for several reasons.

When the cold water rises towards the surface, it brings with it nutrients from the depths. These nutrients in the water support algae and plants that form the base of the coastal food chain. Without them, our coast wouldn't be nearly as rich in life.

When moist air from off shore comes in contact with the cool upwelled surface waters, fog is formed. Fog not only cools the coastal environment, it also reduces evaporation, which helps plants and animals exposed at low tide to survive that exposure.

The low temperature of the water also affects organisms as discussed below.

## Water Chemistry

Without water, life as we know it would not exist. Water has many unusual properties, and children can do numerous experiments to learn about this ubiquitous, but unique, substance.

One of water's most important properties is its ability to dissolve many other substances. It is this ability to dissolve chemicals that results in the saltiness of the seas. Most of the salts in the sea came from the land, including the land under the oceans, and were moved to the sea when they dissolved in water. Some come from undersea volcanoes.

When rivers and streams dissolve minute amounts of minerals from the land, they carry those dissolved minerals ("**salts**") to the sea. As water **evaporates** from the sea, the minerals/salts are left behind. Over millions of years, the seas have thus accumulated their saltiness. As the face of the earth has changed, sometimes sea water has become isolated from the world ocean, and as those inland seas evaporated, their salts were left behind, resulting in salt deposits far from the ocean.

What we commonly refer to as table salt is the chemical compound sodium chloride, $NaCl$. To a chemist, though, the term salt applies to many different chemicals that share certain chemical properties. Sea water contains at least tiny (trace) amounts of all of the naturally occurring elements and hundreds of different salts. However, 99 percent of sea salts are made up of only 6 constituents: chlorine, sodium, sulfur/oxygen ions called sulfates, magnesium, calcium, and potassium, with sodium and chlorine alone making up 86 percent. Those constituents are combined with each other and other elements to form a variety of compounds, including potassium iodide, calcium sulfate, and calcium carbonate.

The measure of the amount of salt(s) dissolved in water is called its **salinity**. Sea water typically has a salinity of about 35 parts per thousand, or 3.5 percent. This means that a thousand grams of sea water (about a liter or quart) would have about 35 grams of the various salts (about 6 teaspoons).

*Teaching idea: Bring some sea water to the classroom. Students can do various experiments with it, including experiments to see what factors affect evaporation rate.*

The salinity of surface water may be slightly higher near the equator where evaporation is more extensive, and lower near the coast where rivers bring in fresh water.

Tide pool organisms must be able to survive in a wide range of salinities. In the summer, evaporation during a low tide may increase salinity significantly. In the winter, rain will lower the salinity. These effects are most pronounced in small pools in the higher tide zones.

Dissolved minerals, along with **nutrients** brought to the surface by upwelling and brought to the seas by runoff from land, provide fertilizer for the algae and plants in the sea. These algae and plants, especially the microscopic diatoms, are the basis of the ocean's **food chains**. Since the algae are surrounded by water and nutrients, they don't need specialized roots to absorb water and nutrients, nor do they need special tissues to transport the nutrients to leaves. Algae, therefore, are structurally different from true plants, which are called vascular plants because they have vascular tissues to move fluids up and down.

One of water's characteristics is its **specific heat capacity.** This is an indication of how much energy it takes to change the temperature of a sample of a substance. Water's specific heat capacity is exceptionally high, which means that it takes a lot of energy to raise the temperature of a sample of water. Most other substances have much lower heat capacities. Think, for example, about the temperature of the sand at the beach on a sunny day. The sand is hot, while the water, upon which the sun is also shining, is cold, at least in northern California. At night, the sand may become quite cold, while the sea water is still essentially the same (albeit cold) temperature. Similarly, the metal pot in which you boil water gets hot much more readily than the water itself.

Because of water's high heat capacity, organisms living in the open ocean don't need to deal with wide fluctuations in temperature. Tide pool organisms, however, must be able to deal with much wider variations, from the cold of rain (or even snow) and cold air in the winter to very warm water in the summer, especially in shallow or small pools.

Another important characteristic of sea water is dissolved gas. Oxygen and carbon dioxide are especially important, as algae and plants need carbon dioxide as a raw material for **photosynthesis**, and both plants and animals need oxygen for **respiration**. Cold water can dissolve more gas than warm water, so organisms that need lots of oxygen often do better in cold water. As a result, cold water organisms such as those along the coast of northern California can easily be killed if the water gets too warm. When a low tide leaves a tide pool exposed to warming by the sun, organisms must either leave the pool as the water recedes or must be able to withstand the warming, which can be extensive, especially in shallow pools.

Since tide pools are found at the shore, they are especially vulnerable to human impact in many forms. One of the most insidious is **pollution** from the air, which brings a variety of **toxic** chemicals into the tide pools. The flushing action of the waves and tides helps mitigate this. More harmful can be pollution brought by rivers or simple runoff from the land. **Silt** can accumulate, especially in upper tide pool zones, smothering the organisms within. Dissolved pollutants can become more concentrated as the water evaporates. Another threat to tide pools is posed by visitors who accidentally harm organisms while exploring the intertidal area.

# Coastal Ecology

## What is Ecology?

Ecology is the study of an environment, the organisms that live in the environment, and their interactions. Some people use "ecology" to mean the same thing as conservation or environmental protection. Here, we will use the scientific meaning … the interactions and interconnectedness of organisms and their environment.

*Teaching idea: Much of ecology deals with how organisms meet their needs for food, water, etc. Have students list their own needs and how they are met. Discuss "needs" (which are few) to "wants" (which are usually many), and that there are prices, not just monetary, for meeting those needs and wants.*

## Cycles

There are many **cycles** in nature, and they are important to all organisms, including us. Below are described simplified versions of some of the important cycles in nature. In nature, recycling of matter comes naturally!

Unlike energy, matter (chemical substances) remains in the environment. It is neither created nor destroyed except in unusual (on earth) circumstances. This "Law of Conservation of Matter" is a fundamental law of nature, and warrants discussion with the students. It gives us the basis for the need to recycle, and also explains why pollutants don't just "go away."

*Teaching idea: Ask a student to throw "away" a piece of trash (or how the would throw "away" a piece of trash). The student will no doubt throw it into the trash can. Point out that the trash can isn't really "away." It is just a different place, and the custodian will put it into a dumpster after school. Later, the contents of the dumpster will be deposited in a landfill - still not really gone! Point out, too, that where there now is a landfill, there was once a field, or maybe even a coastal marsh, as in San Francisco Bay. There is no "away!" For better or worse, the matter that we have on Earth will stay with us, and we can't create more!*

<u>The Water Cycle</u>

Energy from the sun causes water from the surface of the Earth to evaporate and enter the air as water vapor. Since the oceans cover about three-fourths of the Earth's surface, the oceans are extremely important in the water cycle.

As water vapor cools, it forms clouds. Further cooling of the water vapor yields precipitation, which may be in the form of rain, snow, or hail.

*Teaching idea: Discuss what happens when students exhale their warm, moist breath on a cold day, either into the air or onto a mirror or window. The condensed water is similar to a cloud.*

Depending on where the precipitation falls, it may re-enter surface water systems such as lakes and oceans, or it may fall onto the ground. Surface water may evaporate, flow downhill as runoff in a stream, or may soak into the ground.

If the water enters the ground, it may be absorbed by plants, join the underground water system (the aquifer), or it may re-emerge as a spring.

Plants move water through their vascular systems, using some in photosynthesis and expelling some through their leaves through a process called transpiration. Animals may take water in and expel the excess through excretion.

Students are often interested in the fact that every bit of water that they drink has been used by thousands of other organisms during its existence on Earth. The same holds true for other substances.

The Oxygen/Carbon Dioxide Cycle, and Photosynthesis

Oxygen enters the air primarily through the process of photosynthesis. In photosynthesis, plants use carbon dioxide and water to produce complex molecules of sugars. In the process, oxygen is released into the environment as a by-product. On land, the oxygen enters the air. In aquatic environments it may be dissolved into the water as it is released by the plants, or it may be released as tiny bubbles.

*Teaching idea: Place a sprig of a leafy plant, or an aquatic plant such as Elodea from an aquarium/fish supply store, in some water. Have students closely observe the small bubbles that form on the leaves. Then place the plant in the sun or under a bright light. Look for more bubbles of oxygen as the plant's photosynthesis increases.*

Plants and other organisms use the sugars produced in photo-synthesis as an energy source through the process of respiration. Respiration is a chemical process in which cells use oxygen and food such as sugars to release energy from the food. (Students often confuse respiration with breathing, which is the physical act of taking air in (inhaling) and exhaling waste from the lungs.)

As the cells use oxygen in respiration, they produce carbon dioxide ($CO_2$). Carbon dioxide is a waste product which must be expelled into the environment. Carbon dioxide is removed from the environment by plants and protists in the process of photosynthesis. In the oceans, carbon dioxide also combines with other chemicals in several chemical reactions. Because of the actions of marine plants combined with chemical reactions, the oceans serve as a major absorber of carbon dioxide.

The Nitrogen Cycle

The element nitrogen makes up about 78 percent of the air. Nitrogen is an important raw material for many chemicals that organisms produce, such as amino acids and nucleic acids. Most organisms, however, are unable to use the nitrogen found in the air.

Some organisms, principally certain bacteria, are able to use the atmospheric nitrogen to form simple compounds such as nitrates. Plants, in turn, use the nitrates to form various more complex chemical compounds that contain nitrogen. Animals, including humans, get nitrogen from the foods, especially plants, that they/we eat.

Nitrogen compounds form an important part of animals' waste products. They provide fertilizer that is used by plants both on land and in the water. Nitrogen is also important because it is a necessary component of proteins, which are an essential group of chemicals for living things, sometimes referred to as the building blocks of life.

When organisms die, the nitrogenous compounds, as well as other chemicals found in the body, are returned to the environment through the process of decomposition. Decomposition is accomplished through the action of various bacteria and fungi on the decomposing body.

*Teaching idea: It is interesting to discuss with students what would happen if we didn't have bacteria and fungi to decompose the dead organisms. They will quickly see that undecomposed bodies would accumulate. More importantly, though, chemicals needed by living organisms would be tied up in the bodies, depriving organisms of the nutrients that they need.*

## Energy

Most energy comes to Earth from the sun. Some of the sun's energy is reflected by the atmosphere before even reaching the Earth's surface. Other solar energy is absorbed by the atmosphere, and re-radiated into space as heat.

Of the energy reaching the Earth's surface, some is reflected, some is absorbed as heat energy, and some is used for photosynthesis. Most of the energy absorbed is radiated back out to space at night. The energy stored in chemicals through photosynthesis is lost to the environment when the organisms use the products of photosynthesis, releasing the energy stored within.

As a result, the vast majority of organisms depend on the sun for a constant supply of energy. Energy is said to "flow through" ecosystems, as opposed to matter, which is repeatedly recycled.

*Teaching idea: Our society is very dependent on fossil fuels, such as coal, oil, and natural gas. These fuels are essentially solar energy that was stored by plants long ago. We are using them much faster than they are being formed today. The acquisition and transportation of oil is one of the main threats to ocean ecosystems. Use every opportunity to point out to students the importance of reducing our use of fossil fuels, because using less energy means that less oil has to be moved around the world. Point out that the need for fossil fuels is generated by our demands for more energy and more things. If we didn't buy so many things, or use so much gas, etc., "they" wouldn't use the energy to make the things. The decisions of the big companies are dependent on our decisions as individuals.*

## Niches

Just as a human community has people who produce goods and services and those who use or consume those goods and services, so too do natural communities such as the intertidal zone. The cycles described above are part of the natural economy of the coast. In human communities, different people do different jobs. In natural communities, different organisms play different roles. The roles or jobs of organisms are called their **niches**.

In the oceans, the raw materials for producing organic matter surround the organisms. Sea water contains at least small amounts of practically all naturally occurring elements, and thousands of dissolved compounds. Plants and protists such as algae use these chemical raw materials to grow, and animals obtain their raw materials from the foods that they consume. When organisms die, the raw materials from their bodies are recycled by decomposers such as bacteria and fungi, and by plants and protists such as algae.

Some organisms such as green plants and algae can use energy from sunlight, through the process of photosynthesis, to produce the complex chemicals on which life depends. They are called "**producers**," and they form the basis upon which all other organisms depend. At the coast, some producers are large and obvious, such as brown, red, and green algae, and surf grass. Microscopic producers called diatoms and dinoflagellates are extremely important, too, especially where the water is too deep for plants that attach to the bottom.

Organisms that don't photosynthesize, such as animals, must obtain their energy from the food that they eat or consume. They are thus called **consumers**. Consumers are further subdivided into three groups:

- **Herbivores** mostly eat plants.
- **Carnivores** mostly eat other animals.
- **Omnivores** eat both plants and animals.

It is important to remind students that all consumers, including humans, depend on the plants that form the basis of the food chain.

*Teaching idea: Compare the human community in which the students live with natural communities. Compare niches of organisms to jobs of people.*

## Food Chains and Food Webs

A **"food chain"** is a concept that ecologists find useful when studying ecosystems such as the intertidal zone. Basically, a food chain indicates which organisms feed on which other organisms. For example, algae on a rock might be eaten by a snail. The snail might be eaten by a crab. The crab might be eaten by a fish, which is in turn eaten by a harbor seal. Food chains are useful because they provide a simple illustration of predator/ prey relationships. However, they are almost always oversimplifications. The algae might be eaten by several different kinds of snails, limpets, crabs, or even fish. The snail might be eaten by a sea anemone, a fish, or a sea otter. The crab might sometimes eat algae, and it might provide a meal for an otter, or an anemone, or a seagull. And it goes on. Although they are simplified, food chains can be useful in studying ecosystems.

A more realistic, but more complex, concept is that of a **"food web**." The second part of the previous paragraph illustrates part of a food web. A food web shows that most organisms eat and are eaten by several other organisms.

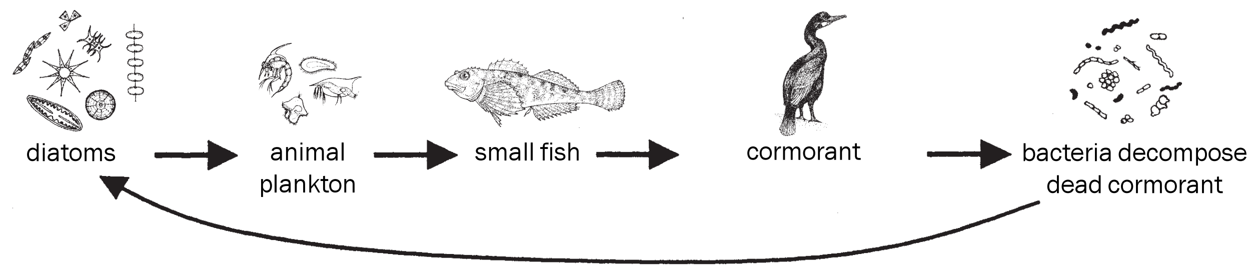
When people discuss (or teach about) food chains and food webs, they often neglect to emphasize the important role of the decomposers. Without decomposers, the raw materials needed by the producers would soon be tied up in the bodies of dead organisms.

While not technically part of food chains and food webs, the physical factors such as sunlight, water, and minerals are also important in food chains and webs.

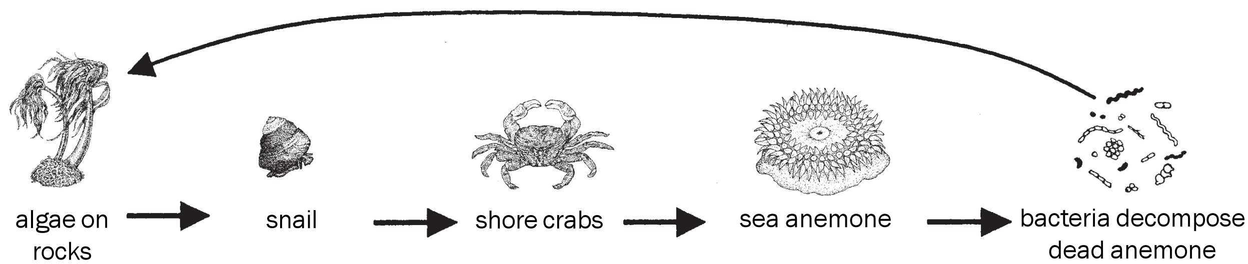
The next page shows examples of food chains and a food web such as might be found in an intertidal community.

## Intertidal Food Chains

An arrow indicates that an organism is eaten by another.
For example, sea urchin ⟶ an otter
(is eaten by)

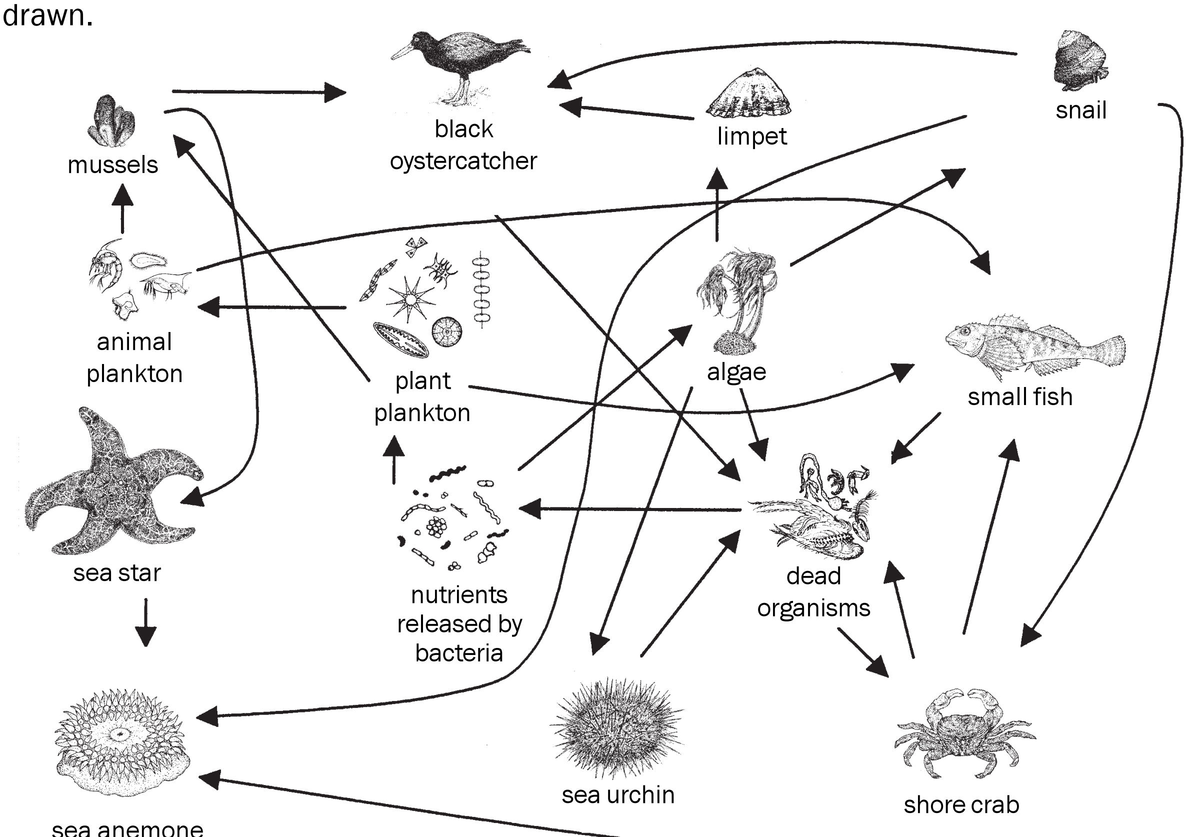



Products of decomposition provide nutrients used by plants and algae




## A Simplified Intertidal Food Web

Remember that the organisms depend on light (energy) from the sun, and minerals and water from the sea. Even in this simplified web, to make it readable, not all connections are drawn.



## Populations

In the study of ecology, a group of a particular species of organism living in a defined area is considered to be a **population**. Thus, when discussing a population, an ecologist will identify both the organism and the place. One might study the population of mussels at a particular beach, the population of crabs in a particular tide pool, or the population of barnacles living on a rock.

The number of individuals is limited by some factor or several factors. Depending on the organism, the factor might be space, food, temperature, predators, or any of a number of other factors. Whatever limits a population is called the **"limiting factor."** Thus, space on a rock might be the limiting factor for barnacles on a rock, while food might be the limiting factor for crabs in a tide pool. The depth to which light penetrates the water may be the limiting factor for algae.

The number of a type of organism in a place is determined by one or more limiting factors. **Carrying capacity** refers to how many of a particular organism can live in a place over a long period of time without damaging the environment. One could place several large fish in a tide pool, but they wouldn't be able to survive for very long. They would soon run out of food, or oxygen, or they would injure themselves on the rocks. The carrying capacity for turban snails in a tide pool is much lower than the carrying capacity for bacteria in the same pool, just as the carrying capacity for deer in a field is much lower than for mice or grasshoppers. If there are too many of an organism for the population to be sustained, they are said to have exceeded the carrying capacity of that place.

Many students will have heard of "**overpopulation**." To an ecologist, "overpopulation" means exceeding the carrying capacity, or exceeding the number of individuals that a place can support without harm to the habitat. With regards to human population, one must consider not just how many people a place (a house, a community, a state, a nation, or the Earth) can support, but also the quality of life for the people (or other organisms). The earth can certainly support many more people living at a subsistence level than it can support at the level of resource use that we have in the United States. Even within the United States, some people use much more of our resource supply than others. It might be useful to discuss quality of life vs. quantity, and whether we should be willing to consume less so that others can have enough to survive.

A discussion of carrying capacity can help the students understand the necessity of trying to minimize their impact on the tide pools or any other environment.

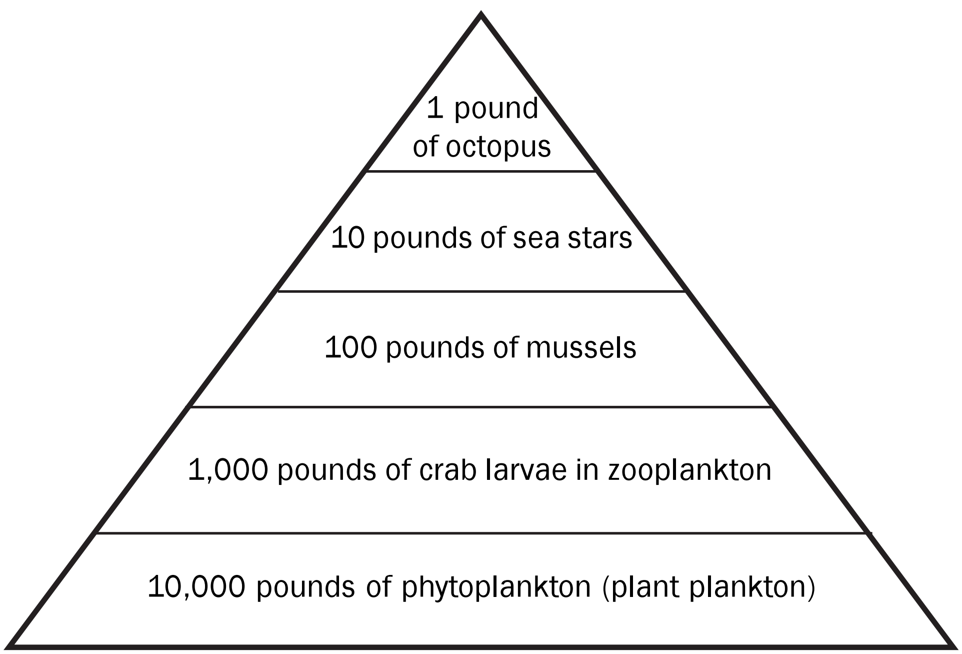
*Teaching idea: Discuss "wants" vs. "needs" with students. Things that many of us consider necessities (telephones, cars, televisions, meat, soda, etc.) would be considered luxuries by much of the world's population. Discuss the idea of "living simply so that others may simply live."*

<u>The Pyramid of Numbers or Pyramid of Biomass</u>

As one goes "up" a food chain, there is a decrease in both numbers and the total mass of the organisms (biomass). This is because organ-isms are not 100% efficient in converting their food into body mass. Some of the food is converted into body mass, but much of it becomes waste. A single grasshopper eats many times its weight in plant material during its life time. A single lizard will eat many insects, and a single coyote will eat many lizards. In a tide pool, a single limpet or turban snail will eat a lot of algae. A single crab may eat many snails, and a single seagull may eat many crabs.

*Teaching tip: Have the students discuss what would happen if this inefficiency were not true. Ask a student to estimate how much she or he eats in a day. If they were 100% efficient, that amount of weight would be gained each day! Have the students calculate how much weight they would gain in a week if their body added all of their food to itself. Point out that eventually all potential food matter would be "tied up" in living bodies!*

In reality, of course, most of the food that we eat is not added to our bodies, even though it may seem like it during the holidays! Most of the food that we take in is expelled from our bodies either as solid waste (feces), liquid waste (urine and perspiration), or gaseous waste ($CO_2$ and water vapor in our breath). While the efficiency of conversion varies among organisms, ten percent is an often used approximation. Using that estimate, we can create a hypothetical food pyramid of numbers or biomass like the one below.




An important consequence of this inefficiency is that more steps in a food chain result in fewer top consumers (such as man). A given amount of land can support more people if they eat plants such as corn, wheat, or rice than if the land is used to raise cattle for people to eat. Basically, the Earth can support more vegetarians than carnivores. A field can support more grasshoppers or mice than lizards or foxes, and a tide pool can support more limpets or snails than crabs or octopi.

## Habitat, Community, and Ecosystem

Basically, a **habitat** is a place where an organism lives. A tide pool is a habitat, as is a sandy beach, a pine forest, or a desert. Each type of habitat is defined by a particular set of abiotic and biotic factors.

All of the organisms in a habitat are called a **community**. Just as our human communities have people that do different jobs, so too do natural communities include organisms that make their living in different ways and depend on each other. The tide pool community includes algae, plants, animals, bacteria, and fungi. Each member of the community fulfills its particular role, or niche, whether it is a producer, herbivore, carnivore, omnivore, scavenger, or decomposer.

When we combine the community of organisms with the habitat in which they live, we have an **ecosystem**. Within the ecosystem, the organisms interact with each other and with the physical environment.

## The Role of People

Throughout our history, the coast has been important to people, and people have been important to the coast.

The first people to live along northern California's coast were the California Indians. Most historians agree that people arrived in North America by crossing a land bridge that was exposed during an ice age over 10,000 years ago. Recent evidence suggests that additional people came from Asia by following the coastline in boats. Either way, the plants and animals that they found along the coast provided food, clothing, tools, and many other resources.

By using the resources, the California Indians had an impact on the natural coastal communities. In the Mendocino area, the Pomo Indian people used many animals from the tide pools. For example, they ate abalone, several kinds of algae, crabs, and octopus. Shells of various types were prized for their beauty. Coastal resources were valuable for trade with inland groups.

The first "white men" to arrive in the Mendocino area were Russians hunting mammals such as seals, sea otters, and whales. They were so successful that they wiped out the sea otters north of Monterey, and later Yankee whalers nearly wiped out gray whales along the west coast.

Spanish and American soldiers and settlers came to the northern California coast in the 1830s and 1840s. During the gold rush, people came to the Mendocino area to cut and ship the giant redwood trees that were used to build San Francisco. Naturally, fishing to support the lumber workers was an important part of the economy, and harvesting tide pool animals such as abalone contributed to the fisheries.

As trees were cut inland, streams suffered serious damage from silt and from the use of stream beds to haul logs to the coast. The salmon fisheries were decimated by the destruction of spawning grounds. Conservation efforts since the 1970s have helped restore some salmon populations, but they are still far below their previous numbers. Agricultural run-off and other forms of pollution further damaged waterways and coastal ecosystems.

Shallow coastal areas such as estuaries and mud flats are important as breeding grounds for many marine fish, and since they are shallow, they are especially susceptible to damage from pollution.

Today the intertidal zone provides recreational and educational value. Tourism is a major economic force in coastal towns such as Mendocino and Fort Bragg, and many tourists come to scuba dive, to explore the intertidal areas, or to fish for abalone.

Since the 1940s and 1950s, students have been visiting the intertidal zone to learn about the fascinating plants and animals that live there. In those early days, many teachers didn't worry about preserving intertidal life. Life at the coast seemed unlimited. Some even required students to collect dozens of specimens. Today, many of the best intertidal areas are protected in parks, and most people realize that they need to protect the fragile intertidal ecosystem.

Even though we understand the need to protect intertidal organisms, it is difficult for students to resist the temptation to take "just one" shell or other specimen. It is critical that teachers remind students that the empty shell or dead animal that they find at the coast is a necessary part of the ecosystem. It should also be emphasized that thousands of other students want to visit the intertidal zone every year, and that they, too, will want to see the shells, rocks, plants, and animals.

*Teaching idea: A trip to the intertidal zone provides an opportunity to discuss the beautiful shells that can be found for sale in gift shops. The empty shells that the students find at the coast will seldom be perfect. They will generally be broken, or have barnacles on them, or be damaged in some way. To obtain the perfect shells that are offered for sale, thousands of living organisms are collected and killed just for their shells. Imperfect shells are often discarded. While recognizing the beauty of the shells that are for sale, students should be discouraged from purchasing them. Sometimes abalone divers donate the shells from their catch to visitor centers at parks.*

See the section on Field Trips (page 67) for suggestions on how to minimize damage when visiting the intertidal zone.

Students may wish to find out how to help protect and improve our coastal ecosystems. For that reason, several organizations are listed in the Resources section at the end of this *Guide*.

## Environmental Concerns

One value of field trips to natural areas such as the intertidal zone is the increased level of environmental awareness and concern that students can develop through exposure to interesting ecosystems. While it is important not to overwhelm students with bad news about the environment, it is also important that they become aware of environmental concerns. When teaching students about environmental problems, it is essential to also teach them about ways that the problems can be addressed.

Students need to visit natural ecosystems to truly appreciate their beauty and importance. Merely learning about the plants and animals is not enough, though. Students should come away with not only an appreciation, but a desire and willingness to try to protect and improve their environment. The teacher's example, not only on a field trip, but also in day-to-day classroom life, can be very powerful.

Discussions of "needs" vs. "wants" are important. It is also important to help students realize the impact of population on the environment.

| Environmental Issue | What's the problem? | What can I do about it? |
|---|---|---|
| Tide pool overuse | Overuse of the intertidal zone takes several forms. Some people harvest mussels, sea urchins, abalone, fish, algae, or other organisms from the tide pools. Over fishing can be a problem.<br>Even people just exploring the tide pools can do damage either intentionally or accidentally. Taking shells or even living organisms used to be common practice, and some people just can't seem to resist. Pulling organisms off of rocks to examine them, or moving something like a crab to a different area presents the risk of damage to the organism. Merely walking among the tide pools makes it likely that some organisms will be stepped on or otherwise damaged. | Intertidal organisms, because they live in such a demanding environment, tend to be pretty resilient creatures. There is a limit to the impact that they can endure, though, and students need to learn to minimize the damage that they do.<br>Teachers need to realize that taking a class of students to the tide pools will probably result in some damage, and be sure that there is a net positive effect to the visit. Environmental protection must be taught whenever possible, and teachers must set a good example. |

| Environmental Issue | What's the problem? | What can I do about it? |
|---|---|---|
| Pesticides | Pesticides are poisons. Sometimes they wash from the land into streams that run to the sea. Even if the concentration in the runoff water is low, some pesticides tend to become more concentrated in marine animals as they move through the food web (biological magnification) and may reach harmful levels. | Learn ways to grow plants without using pesticides.<br>Support stores that sell organic produce.<br>If using pesticides, use only the minimum amount needed. |
| Fertilizers | Fertilizers, including both artificial fertilizers and animal waste, become a problem when they wash into aquatic ecosystems from the land, primarily farmland. Aquatic protists and plants use the fertilizers and may grow so profusely that they cause problems. One of the main problems develops when the plants die. Bacteria decomposing the dead plants may use up so much oxygen that fish and other animals die, which makes the problem even worse. This is called eutrophication. | Learn ways to grow plants without using artificial fertilizers.<br>If using fertilizers, use only the minimum amount needed. |
| Litter, solid waste, debris | Litter at the coast is, of course, an eyesore. Nobody wants to see a beautiful environment messed up by litter. Some kinds of litter can also be dangerous to people and organisms. Feet can be cut by broken glass and sharp can lids. Fish hooks and syringes present obvious dangers. Fish lines and nets entangle and kill thousands of birds and mammals every year. Sea turtles swallow plastic bags, which look like jellyfish, and die as a result. Six-pack rings strangle birds and mammals. | Learning about problems associated with litter will encourage students to properly dispose of or recycle their waste.<br>Every year there is a "coastal cleanup day" all along the California coast. Student groups can have fun while cleaning up the beaches.<br>The California Coastal Commission has published *Save Our Seas, a Curriculum for Kindergarten Through the Twelfth Grade*. It is an "interdisciplinary marine debris curriculum anthology." See the Resources section of this *Guide*. |

| Environmental Issue | What's the problem? | What can I do about it? |
|---|---|---|
| Municipal runoff from storm drains | Municipal runoff brings whatever goes into the gutters to streams and, eventually, to the ocean. It not only contains oil from oil changes and leaky oil pans on cars, but soap from washing cars, spills from gas station fill-ups, pesticides and fertilizers from over application, and hundreds of other potentially dangerous chemicals. | When students learn about problems associated with municipal runoff, they can inform their parents. Some students have stenciled signs near storm drains telling people not to dump waste into the gutters. |
| Sewage | Most municipal sewage is treated to varying degrees. Untreated or under-treated sewage has the potential of bringing dangerous bacteria and viruses to the ecosystem. It can also bring nutrients and act as a fertilizer.<br>Sometimes people will relieve themselves in a natural environment rather than seeking out a restroom. | Students need to learn why sewage treatment plants are necessary. This may lead to support for improved sewage treatment.<br>Students need to learn why they should make the effort to find and use restrooms. |
| Changes in the coastline | When people build breakwaters, piers, jetties, or other structures at the coast, they change not only the immediate environment, but the adjacent environment for a consider-able distance. One way that the environment is changed is by alteration of the flow of sand along the shore. Sand may be caused to accumulate and bury rocky areas or, in other places, may be washed away, allowing for erosion of land formerly protected by sandy beaches. Dams on rivers may also interfere with the natural addition of sand to the coast. | Learning about problems associated with changes in the coastline may encourage students to support coastal protection when they are adults. The California Coastal Commission helps regulate coastal development, but they need the support of citizens! |

| Environmental Issue | What's the problem? | What can I do about it? |
|---|---|---|
| Warm water | A major source of warm water is power plants. Power plants use coal, oil, natural gas, or nuclear power to produce steam to turn turbines, which turn generators to make electricity. The steam needs to be cooled for reuse, and that process warms up water, which is then released to the environment. That need for cold water is one reason why nuclear power plants are built along the coast, lakes, or rivers.<br>Organisms naturally occurring in northern California's coastal waters are adapted to the cold water found there. If warm water is added, some that can not move may die, and some that can move away do so, which, of course affects the ecosystem. Also, warm water organisms may invade, displacing or feeding on the native species. When the power plant is off, of course, the flow of warm water ceases and cold water replaces it, causing still more problems! | Anything that saves energy will reduce the amount of warm water that is released into the environment.<br>Supporting lawmakers who will regulate the power industry and support alternative energy sources, as well as conservation, is important. |
| Silt | Silt causes problems for marine organisms if it accumulates so fast that neither the natural flushing action of the waves nor the efforts of the organism can keep it from covering the organism. Many organisms rely on gills for obtaining oxygen and/or filter feeding mechanisms for obtaining food. Silt can clog both gills and feeding systems, and it covers eggs. Silt can also make the water so "muddy" that light can't penetrate, harming plants and protists. | Silt is often generated by poor farming practices, clearing of land, or poor logging practices. While students may not be able to do much about these practices unless they are in the relevant industries, they can become adults who support lawmakers that pass laws that encourage environmentally sound farming, logging, and other land use practices. |

| Environmental Issue | What's the problem? | What can I do about it? |
|---|---|---|
| Over fishing | Many of the world's important ocean fisheries are in serious decline. This decline has several causes, including pollution, environmental changes, and over fishing. There are occasional "good" years, but most species show a definite decline. This is true also of coastal fisheries for animals such as mussels, oysters, clams, abalone, rock fish, salmon, and crabs. Not only are the coastal areas important for the species that live there, but many fish that live in the open ocean spawn in the shallow waters along the coast. | Students need to understand that coastal waters are important for a wide variety of species, including many that are commercially important food sources. Some of the most important fish breeding grounds are in marshlands, which are sometimes seen as useless and buried under "landfills." Students who learn about the importance of coastal resources are probably more likely to support their protection as adults. |

## Vocabulary

While the teaching and learning of vocabulary should not be the main emphasis in a science curriculum, an understanding of vocabulary makes it easier to communicate. Also, learning about the differences between different terms may encourage students to study science in more detail.

Listed on the next page are some vocabulary terms that are useful in studying the tide pools. Most are indicated by **bold** type in this *Guide*. The terms are divided into two groups.

The "Basic" terms are those with which most students should have some familiarity, even if they can't recite their definitions. These are terms that students will almost certainly hear the ranger or interpretive specialist use.

The "Additional" vocabulary will be useful for communicating more in depth understanding. Definitions and examples can be found in the Glossary at the end of this guide (pages 147-154).

## Basic Vocabulary (Students should be familiar with these terms.)

adaptation
alga/algae
camouflage
carnivore
current
cycle
decomposer
ecology
economy
endangered species
environment
erosion
evaporation
extinct
fertilizer
food chain
food pyramid
food web
habitat
herbivore
high tide
intertidal
kelp
larva/larvae
limiting factor
low tide
marine
mean
native
niche
nutrient
omnivore
organism
overpopulation
pesticide
photosynthesis
plankton
pollution
population
predator/predatory
prey
respiration
runoff
salinity
salt
sea level
sediment
sedimentation
species
tide
tide pool
threatened species
vertebrate
zone

## More Advanced Vocabulary

abdomen
abiotic
appendage
barbule
bioluminescence
biomass
biotic
blade
carrying capacity
centrifugal force
cephalothorax
classification
classify
cnidocyte
common name
community
consumer
crest (of wave)
detritus
diatom
dinoflagellate
ecosystem
estuary
eutrophication
exoskeleton
float
genus
gravitational
gravity
holdfast
Indicator organism
invasive
invertebrate
littoral
mantle
mass
mean sea level
microhabitat
neap tide
nekton
nematocyst
notochord
phloem
phytoplankton
plate
plate tectonics
producer
protist/Protista
radula
red tide
scavenger
scientific name
sedimentary (rock)
silt
siphon
specific heat capacity
spring tide
stinging cell
stipe
substrate
subtidal
taxonomy
terrace
test
thermal pollution
thorax
tidal wave
tide table
toxic
trough (of wave)
tsunami
upwelling
vascular
wave
weather/weathering
xylem
zonation
zooplankton

# Organisms

## What's in a Name? (An angry crab by any other name is still crabby!)

When a child sees a new type of animal, the first thing he or she usually wants to know is its name. This is true of adults, too, and indicates a basic desire to establish a connection with an organism by naming it.

For most organisms, there are two names – the **"common name"** and the **"scientific name."** Our common name, for example, is "human," while our scientific name is *Homo sapiens*. There are advantages and disadvantages to both common and scientific names.

Common names are usually easier for us to understand - they're in our common language. They are often descriptive. A starfish (or, preferably, sea star) does, indeed, have something of a star-like shape, and it is found in the sea, as are many fish. Sea lettuce does look a bit like lettuce and lives in the sea. However, a starfish isn't actually a fish, and sea lettuce isn't lettuce, so common names can also be misleading. They can also be confusing. We all know that Flipper was a dolphin – a mammal related to the whale. However, there is also a true fish called a dolphin. A "lady bug" isn't truly a bug (it's a beetle), and, of course, the males aren't "ladies." "Ladybird beetle" is a better name, but still doesn't identify a particular species, as there are many species of orange-backed beetles that we call ladybugs or ladybird beetles. And they certainly aren't birds!

Another disadvantage of common names is that they differ in different places. Our Douglas Fir tree, for example, is called an "Oregon Pine" in Oregon - and it's neither a true fir nor a pine! Most of us are familiar with the pocket gopher that digs up our lawns - but in the southeastern states, there lives a tortoise called a gopher tortoise! Consider, too, that different languages have different names for the same organism. To the Pomo Indians of the Mendocino coast, the <u>mussel</u> is <u>kah-lah</u>, while a Russian trading with them for otter pelts would have called the same animal <u>midiya</u>. A Spaniard coming to the Mendocino coast from the Petaluma adobe would call the mussel <u>mejillon</u>, while a Chinese worker coming from San Francisco might have called the same animal <u>cheng hau</u>. A German logger might call the mussel <u>Miesmuschel</u>. Scientists from around the world, though, would know the mussel common in California's intertidal zone as *Mytilus californianus*.

Scientific names, on the other hand, may be hard to pronounce or remember, as they are typically derived from Latin or Greek words, or "Latinized" forms of other words. They are, however, generally descriptive of the organism. The biggest advantage of scientific names is that every kind of organism has its own scientific name. Biologists around the world know that *Eschrichtius robustus* is the name of the gray whale, and all other kinds of whales have different scientific names.

Another advantage of a scientific name is that it has two parts, the genus name and the species. The genus of an organism indicates a group of animals that are very similar (closely related evolutionarily) to each other. The species indicates the particular (specific) kind of organism. The genus is written first and is a capitalized proper noun, followed by the species name, which is usually an adjective and not capitalized. Both genus and species are italicized or underlined. For example, a common crab in local tide pools is the purple shore crab, *Hemigrapsus nudus*. It is similar to a close relative called *Hemigrapsus oregonensis*. It is less closely related to the market or Dungeness crab named *Cancer magister*, which is in the genus *Cancer*.

## What's a "Species?"

By "species," scientists typically mean organisms that are able to mate and produce fertile offspring. All kinds of domestic cats are able to mate and produce fertile offspring, and do so naturally, so all domestic cats are of the same species – *Felis domesticus*. An alley cat is the same species as a Siamese cat, as is a Persian cat. They can all successfully mate. The mountain lion (a.k.a. cougar, a.k.a. catamount, a.k.a. puma, a.k.a. panther) is classified in the same genus as the domestic cat because they have many structural similarities. It is, of course, a different species – *Felis concolor*. Both *F. domesticus* and *F. concolor* have 30 teeth. Bob-cats, while they look much like domestic cats, can't successfully mate with them and are different in other ways, such as the ratio of tail length to foot length and number of teeth (28), so they are classified as a different genus and species – *Lynx rufus*. The Canadian lynx is closely related to the bobcat (They, too, have 28 teeth.), so it is classified in the same genus, but as a different species – *Lynx canadensis*. Bottom line: scientific names show how organisms are related to each other and each kind of organism has its own unique scientific name that is the same anywhere in the world.

Plants and animals were originally grouped or classified by observation of their physical structures. Some kinds of organisms from very different groups have developed similar looking structures. For example, porpoises have an external appearance much like some fish, and bats have wings like birds. Sometimes these superficial appearances led to mistakes in classification. Over time, though, scientists have developed a variety of methods, including closer examination of physical traits (body structures), fossil evidence, analysis of DNA, genetic studies, blood chemistry, and other means to develop more accurate information about how different organisms are related. This study of how organisms are related is called **taxonomy**, and taxonomists continue to clarify organisms' relationships to each other.

In this *Guide*, both common and scientific names of organisms will be given. If the student or teacher wishes to find out more about a particular organism, I recommend using the scientific name, as it will yield more precise information. Sometimes a common name applies to more than one species. In such cases, I've indicated the genus name (capitalized and italicized), followed by "spp," to indicate more than one species. For example, there are many species of "polychaete (bristle) worms," so they are listed as *Nereis* spp.

When I took high school biology in the early 1960s, we were taught that living things could be divided into two "kingdoms": Plantae (plants) and Animalia (animals). Some things that didn't quite fit either category were called protists. Currently, most taxonomists use 5 or 6 kingdoms:

- Archaebacteria: some ancient types of bacteria, without a nucleus
- Eubacteria: most bacteria; without a true nucleus or nuclear membrane; chemically different from Archaebacteria
- Protista: organisms with a nucleus and membrane-bound organelles; includes algae
- Plantae: green plants…mosses, ferns, grasses, trees, flowers
- Fungi: molds, mushrooms, yeasts
- Animalia: animals

Each kingdom is divided hierarchically into smaller groups of organisms. Within each subgroup, the organisms are more closely related to each other than they are to organisms in other groups. A kingdom has several phyla (singular: phylum). Each phylum has several classes, which typically have several orders, which have several families, which have several genera (plural of genus). Most genera have several species.

It should be noted that the study of organisms and how they are related and classified (taxonomy) is a constantly evolving science. Not only does it change as we find out more about organisms, but names of groups change and not all taxonomists agree on every classification.

## Classification

Here is a simplified classification for the California mussel, *Mytilus californianus,* which is classified in the groups indicated in **BOLD CAPITAL LETTERS** below.

**Kingdom** - All living things are usually classified into the 6 kingdoms listed on page 37:

| | | | | | |
|---|---|---|---|---|---|
| Archaebacteria | Eubacteria | Protista | Fungi | Plantae | **ANIMALIA** |

**Phylum** - Animalia is divided into different phyla (singular: phylum), including (among others):

| | | | | | |
|---|---|---|---|---|---|
| Porifera | Cnidaria | Platyhelminthes | **MOLLUSCA** | Chordata | Arthropoda |
| (sponges) | (corals, anemones) | (flat worms) | (snails, clams) | (fish, birds, mammals) | (spiders, insects) |

**Class**: Phylum Mollusca is divided into different classes, including:

| | | | | |
|---|---|---|---|---|
| Polyplacophora | Gastropoda | **BIVALVIA** | Cephalopoda | Scaphopoda |
| (chitons) | (snails, slugs) | (clams, oysters, mussels) | (squid, octopus) | (tooth shells) |

**Order**: Class Bivalvia is divided into different orders, including:

| | | |
|---|---|---|
| Protobranchia | **MYTILOIDA** | Eulamellibranchia |
| (primitive molluscs) | (mussels, oysters, scallops) | (various clams) |

**Family**: Order Mytiloida is divided into different families, including:

| | | | | |
|---|---|---|---|---|
| Osteridae | Pectinidae | **MYTILIDAE** | Cardiidae | Veneridae |
| (oysters) | (scallops) | (mussels) | (cockles) | (Pismo clam) |

**Genus**: The genus Mytilus is divided into different species, including:

| | |
|---|---|
| ***Mytilus californianus*** | *Mytilus trossulus* |
| California mussel | blue mussel, a.k.a. bay mussel |

**Species**: There is one kind of animal, the California mussel, named ***Mytilus californianus.*** Sometimes a species is divided further into subspecies, races, or varieties.

<u>Note</u>: The names of species generally are a combination of the genus (capitalized and italicized) and the species, which is italicized, but not capitalized.

Another way to look at the classification of the California mussel would be:

- **Kingdom**: Animalia
  - **Phylum**: Mollusca
    - **Class**: Bivalvia
      - **Order**: Mytiloida
        - **Family**: Mytilidae
          - **Genus**: *Mytilus*
            - **Species, epithet or trivial name**: *californianus*
              - **Scientific/species name**: *Mytilus californianus*

Knowing some word roots can help make the learning or at least understanding of scientific names less intimidating to teacher and student alike. Learning word roots is useful for everyday reading, too. Consider the names of the groups in the classification of the California mussel above:

- Animalia: Obviously, the word root is “animal,” which the mussel is.
- Mollusca: from the Latin word *mollis*, meaning soft … which they are, except for their shells. To mollify is to calm, pacify, or soften.
- Bivalvia: “bi” for two, as in bicycle, “valve” refers to the shell
- Mytiloida, Mytilidae, and *Mytilus*: from *mytilos*, which is the Greek term for the animal that we call the mussel. (“Mussel” comes from the Latin musculus, “little mouse,” which the sea animal somewhat resembles in size and shape.)
- *californianus*: refers to California, where it is common

Some students enjoy learning about the etymology (origins) of words and word roots. Knowledge of word roots can be valuable in later schooling and elsewhere. A good source for science word roots is:

< **www.biology.ualberta.ca/courses.hp/zool250/Roots/RootsMain.htm** >

A good resource for word roots is the *Dictionary of Word Roots and Combining Forms,* by D.J. Borror.

## Adaptations for Survival

Students (and others) might wonder why there is such a diversity of life in the intertidal area or in any other ecosystem. Consider the variety of appearances, abilities, and personalities among the students in a class. What causes that diversity? A scientist would answer that our complex DNA results in a seemingly infinite variety of genetic combinations. This genetic variability results in great diversity among humans and, indeed, among all types of organisms. As a result of this variation and diversity, each individual organism is slightly different from the others. Most of those differences are insignificant, while others may give an individual organism an advantage or disadvantage in the struggle to survive and reproduce. If a characteristic helps an organism to survive, it is called an **adaptation**.

Some adaptations are physical (wings, fins, scales, etc.), while others could be called lifestyle adaptations. When thinking about adaptations, it should be kept in mind that <u>organisms **don’t** develop adaptations to survive.</u> Those that <u>**already**</u> have certain adaptations may survive and reproduce, while those that don’t have them might not survive and reproduce. Thus, offspring inherit “good” adaptations from successful parents.

The intertidal zone is a very stressful place for organisms to inhabit. Surviving the varying conditions requires tide pool organisms to have many special adaptations. Consider the range of conditions that they must endure: The temperature and salinity in a shallow tide pool on a hot summer day are very different from the temperature and salinity during a freezing rain storm at night, or when the tide pool is covered by the sea at high tide. Many students enjoy learning about the varied adaptations that enable intertidal organisms to survive. Some of the environmental factors and ways that intertidal organisms are adapted to them are:

### Exposure to the Force of Waves

Imagine the force that an intertidal organism must endure when a wave crashes over it! If the wave doesn't smash it, the organism may be broken, or washed away. Some seek shelter in crevices in the rock, or hide among clusters of mussels, or in the holdfasts of algae. Some, like the sea palm and the stalked barnacle, develop strong but flexible stalks. Acorn barnacles attach themselves firmly to the rock and develop strong shells. Others, such as limpets and chitons, develop streamlined shapes that minimize the force of the waves on their bodies.

### Exposure to Drying Out (Desiccation)

When the tide goes out, many organisms such as some fish simply move with the water. Others hide in nooks and crannies in the rocks or beneath clumps of algae. Some, like barnacles and mussels, close up as tightly as possible, thereby not only reducing exposure to the drying air, but also trapping moisture in their shells or plates. Limpets hunker down on the rock, even producing a mucus "gasket" that effectively seals their shell. Some even orient their head end downward, thus providing a little more time in the water for the gills. Mussels and aggregating anemones cluster in large masses, which also reduces moisture loss. Aggregating anemones even attach bits of shell and sand to their bodies, further reducing exposure to the air and drying.

### Variations in Salinity

Organisms in a tide pool exposed to the sun not only have to deal with water loss, but also with increased salinity as the water evaporates and leaves salts behind. Conversely, the salinity in a tide pool is lowered when it is exposed to the rain. Animals survive these salinity changes in the same ways that they deal with exposure, mostly by seeking shelter or sealing themselves off from the environment. Intertidal organisms also have a higher tolerance of variations in salinity than do most other organisms.

### Variations in Temperature

As with salinity, temperatures in the intertidal zone have a wide range, and organisms must have a tolerance for a wide range of temperatures. The water temperature of the open ocean changes little, partly due to the sheer volume and constant mixing, and partly due to water's high specific heat and heat capacity. A small exposed tide pool, however, may be significantly warmer than the nearby ocean in the summer and significantly colder in the winter. There isn't much an organism can do to change the temperature, so those that can't survive the variation simply die, leaving those that are adapted to the temperature range to live and reproduce.

Obtaining Food

A quick review of the great variety of intertidal organisms shows a great diversity of food-getting adaptations. Limpets, chitons, and some snails use a rasping tongue called a radula to scrape algae from the rocks. Crabs use their "pinchers" to grab food and hard, sharp mouth parts to bite off pieces. The common whelk is an effective predator on barnacles. Barnacles use their "legs" to filter microscopic pieces of food from the water, while sponges filter food from the water as they pass it through their bodies. Sea anemones use tentacles armed with special cells called cnidocytes, containing harpoon-like nematocysts that paralyze their prey, which is then pulled into the body cavity for digestion. Sea stars actually extrude or evert their stomach between mussel shells to digest the mussel in its own shell! Fish patrol the tide pools looking for food, while algae get their nutrients from the water that surrounds them. Variations for obtaining food are as diverse as the organisms themselves.

Competition

One adaptation that many intertidal organisms have is that their young have a different lifestyle than the parent. This is an advantage for the survival of the species, as the offspring aren't competing with the adults. For example, algae, which may be attached to the rock, will produce free floating offspring which will be carried by the water to another location. Similarly, crabs, barnacles, and many other bottom-dwelling intertidal animals produce offspring that float, are suspended, or swim in the water. Floating organisms are called **plankton**; plant plankton are called **phytoplankton,** while floating animals are **zooplankton**.

Not only do free-floating offspring avoid competing with their parents for space, but they also generally feed on different types of food. This also helps the species survive.

Protection from Predators

Many adaptations serve more than one purpose. Shells and tough skins not only protect from drying out, but also from predators. The sea urchin's spine not only offers protection, but some species use their spines to scrape holes in rocks, which provides further protection. Tide pool fish not only swim quickly, but they are well camouflaged. Similarly, crabs are hard to spot and will scurry away at the first hint of danger. The octopus can even change its color and markings to match its background, which helps both with protection from predators and with its own hunting. Some snails have a trap door-like "operculum" with which they seal off the opening to their shell. Some algae produce sulfur containing chemicals that apparently deter other organisms from eating them. Many organisms seek safety in numbers, especially with regards to reproduction. Rather than producing one or two young, many species will produce thousands of eggs. If only a few of the resulting offspring survive, the species will survive, and that, after all, is the purpose of reproduction.

Reproduction

The production of numerous offspring is one important adaptation for intertidal organisms. Some organisms form clusters, which helps assure that eggs that are released into the water will be fertilized by their sperm, which are also released into the water. Forming clusters also allows those organisms with internal fertilization to mate with their neighbors. Some, like nudibranchs and most common barn-acles, are hermaphroditic, containing both male and female organs, which is an advantage for a stationary or slow-moving organism.

A Few Words About Evolution

Some teachers are hesitant to teach about evolution, and this is understandable, as some parents reject the idea and don't want their children to be exposed to anything with which they disagree. The state of California, on the other hand, supports the teaching of the theory of evolution as a valid part of science education. It even uses evolution as a theme progressing through the grades, provides examples of court cases supporting education about evolution, and provides examples of evolution education in the *1990 Science Framework for California Public Schools*.

One approach is to, first of all, teach evolution as a theory (albeit a well accepted and supported theory), and not require students to say that they accept or agree with the theory. When parents have asked that their children not be taught about evolution, the child can be excused, but only after discussing it with the parent. The teacher can point out that the child will need to understand evolution if they are to be able to counter the arguments for it that they will doubtless encounter later in life.

Examination and discussion of the great diversity of life in the intertidal zone provides an excellent opportunity to discuss the diversity and competition that form the basis of the theory of natural selection. In fact, much of Darwin's work during his famous voyage on the *Beagle* was done with intertidal organisms.

# Common Intertidal Organisms

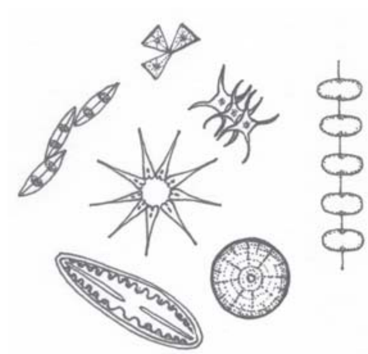
The following are brief descriptions of a few of the hundreds of plants and animals that students might find in the tide pools. This is not a complete list, but it includes many of the most common or conspicuous organisms. Please see the references at the end of this *Guide* for several books that might be worthwhile additions to classroom libraries.

## Bacteria

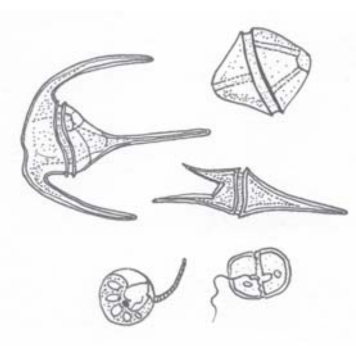
While students won't see individual bacteria, or even populations of bacteria, it is important to keep in mind that they play very important roles in the life of the sea, as well as all other ecosystems. They provide food for many small organisms. Just as importantly, they serve as recyclers of dead organisms, returning nutrients to the ecosystem through the process of decomposition.

## Protista (Including Algae)

Like bacteria and other small organisms, small **protists** are important because they are a source of food for many other organisms. Two groups of tiny protists warrant special mention:



**Diatoms** are small photosynthetic protists, sometimes called yellow or golden algae. They are photosynthetic and provide 80 percent of the world's oxygen as well as food for many other organisms. They are sometimes called the "grass of the sea." Diatoms form beautiful glass-like cell walls, which accumulate on the sea floor after the organisms die and form "diatomaceous earth," which has many uses.



**Dinoflagellates** are very interesting organisms, partly because they photosynthesize like plants, but use whip-like flagella to swim, like animals. Some kinds of dinoflagellates produce "**bioluminescence**" and glow in the dark. Some also produce toxins which are very poisonous and are the cause of **"red tides"** that can be dangerous if people eat organisms such as mussels that have themselves eaten dinoflagellates.

**Algae** constitute the majority of the protists that are visible without a microscope. Algae are generally grouped into three groups – the green, brown, and red algae. Of these, the brown algae are the most conspicuous types of "seaweeds."

Unlike plants, algae lack specialized systems for moving water and minerals up from the roots and food down from the leaves. Marine algae don't need to; they are surrounded by water and minerals and the whole organism is able to photosynthesize! Many algae attach to rocks with a structure called a **holdfast**, which resembles a mass of spaghetti-like roots. Holdfasts provide shelter and food to whole communities of organisms. Most algae have broad flat surfaces called "**blades**," which resemble the leaves of vascular plants. These blades increase the surface area available for photosynthesis, much like the leaves of a tree. Some algae have a float or air bladder that supports the blades at the surface of the water, much like a tree's branches. Connecting the blades to the holdfast may be a stem-like **stipe**. (See the diagram of the bullwhip kelp *Nereocystis* on the next page.)

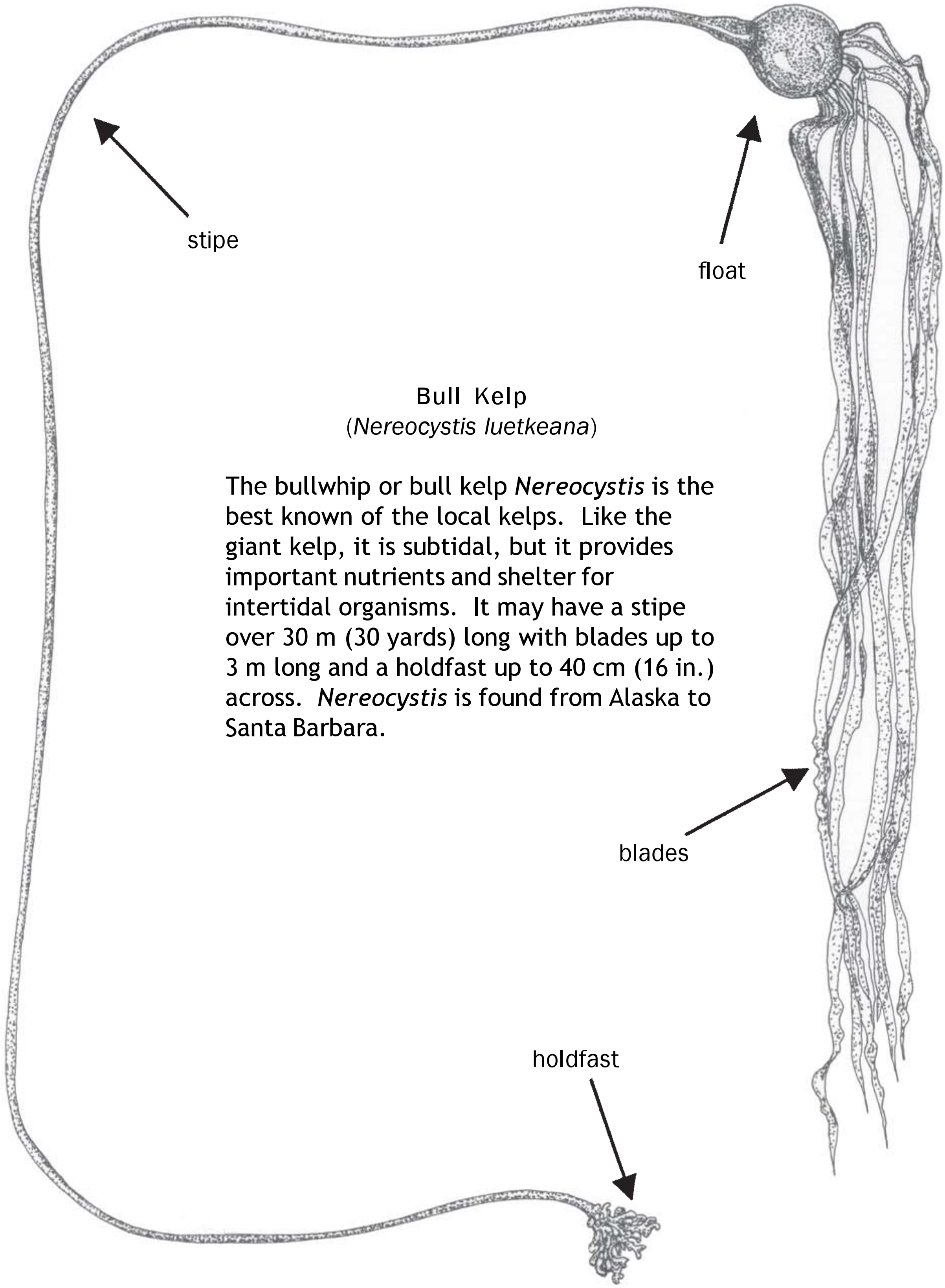
Along with diatoms and dinoflagellates, algae form the basis of the marine food chain. Algae provide many materials that we use. Some red algae, called nori, are used in sushi and other foods. Red algae also provide agar, the material used to grow bacteria. Large brown kelp provide a source of potassium in fertilizers. Brown algae also provide algin, a substance used as a thickening agent in cosmetics, ice cream, and many other materials.

Green Algae

*Ulva* or "Sea lettuce" is a green alga that can be found from about mean sea level up to about the middle of the intertidal zone, in zones 2-3. It forms thin green sheets from a few centimeters to 60 cm or so in length (a few inches to 2'). Ulva may grow attached to rocks, other algae, or even on crabs!

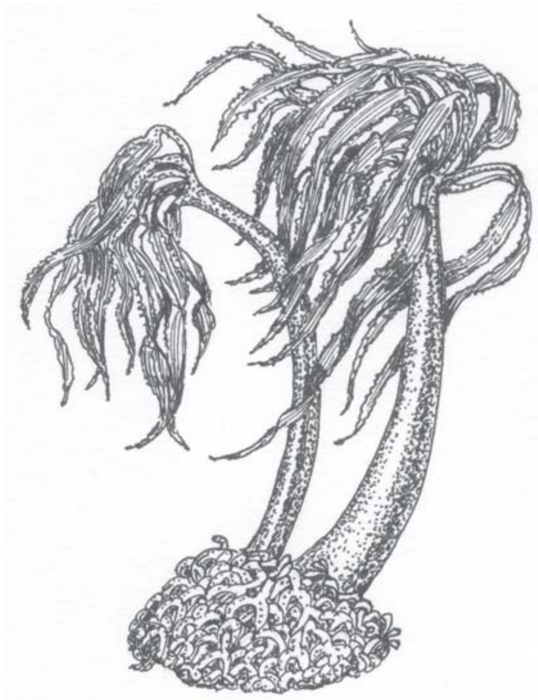
Brown Algae

The most familiar "seaweeds" that we see are the large brown algae called kelps. The giant kelp *Macrocystis* grows beyond the low tide zone and is one of the fastest growing plants in the world, sometimes growing up to 45 cm (18") in a day under ideal conditions! It grows mostly from Monterey south, forming large kelp beds or "kelp forests."




### Bull Kelp
(*Nereocystis luetkeana*)

The bullwhip or bull kelp *Nereocystis* is the best known of the local kelps. Like the giant kelp, it is subtidal, but it provides important nutrients and shelter for intertidal organisms. It may have a stipe over 30 m (30 yards) long with blades up to 3 m long and a holdfast up to 40 cm (16 in.) across. *Nereocystis* is found from Alaska to Santa Barbara.

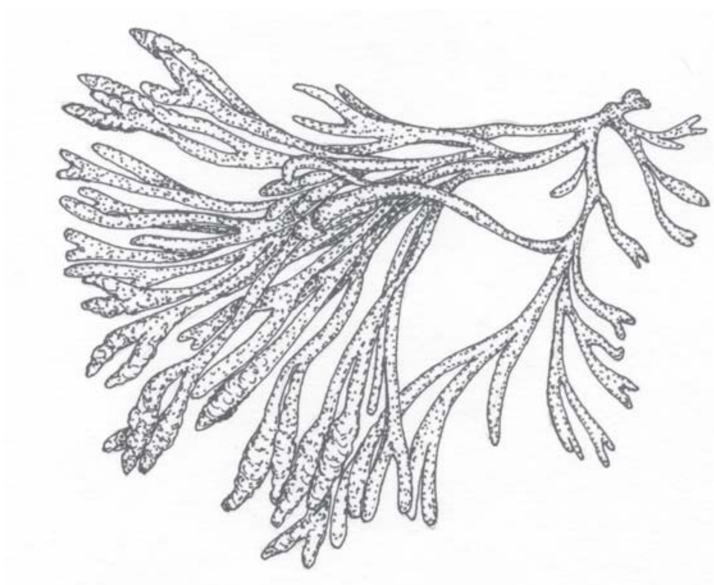


Sea Palm
(*Postelsia palmaeformis*)
to 60 cm (24") tall
zone 4 to subtidal

The sea palm (*Postelsia*) grows from the low tide zone to the subtidal zone and may be up to 60 cm (24") tall. It survives the crashing surf by being flexible and bending when the waves strike it. If you are among *Postelsia*, you are at the bottom of the intertidal region.

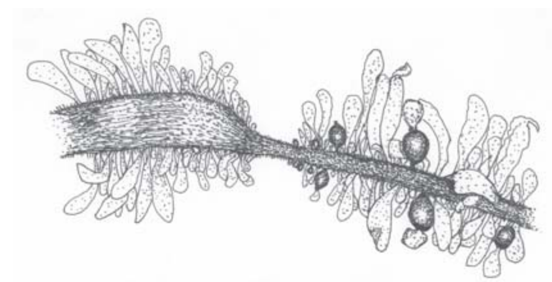
Several brown algae are called "rockweed." Among the most common are the dark brown *Pelvetiopsis*, which grows in the highest zones and is up to 8 cm (3") tall, the olive-green and broader *Fucus*, which is 20-50 cm (8-20") tall, and, farther south, *Pelvetia*, which grows lower and is 15-40 cm (6-16") tall.

"Rockweed" may cover large areas of rock in the mid to high tide zones. The swollen bumps are reproductive structures.



Rockweed
(*Pelvetiopsis limitata*)
usually to 8 cm (3") tall, may be to18 cm (7") tall
zone 2

The "feather boa" (*Egregia*) is another common brown alga and is commonly found in zone 3.

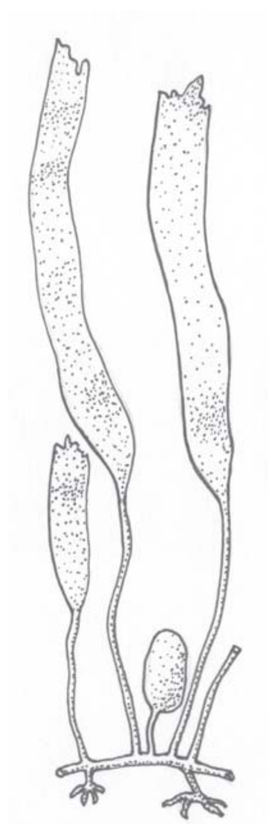


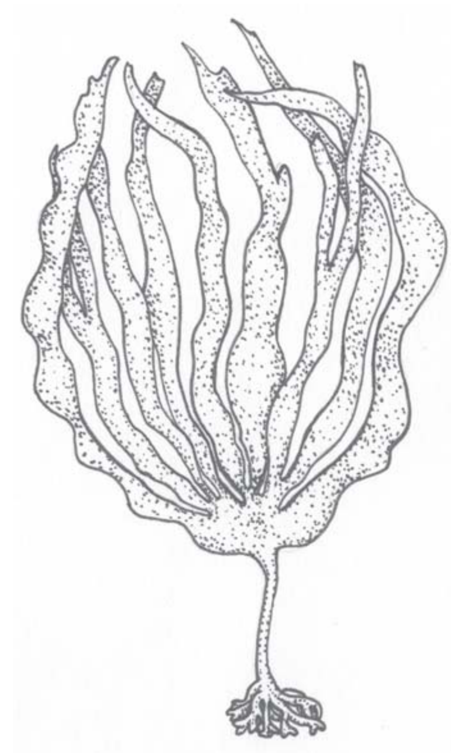
detail

**Feather Boa**
(*Egregia spp.*)
to 7.5 m (8 yd) long
(usually to 5 m long)
zone 3

The genus *Laminaria* is common in the lower zones and includes the "oar weed" and "split kelp." In the past, *Laminaria* were burned to make soda ash, which was used for making soap and glass.

*Laminaria* vary in size and in the number and shape of the blades.





**Oar Weed** and **Split Kelp**
(*Laminaria spp.*)

Oar Weed: to 39" (1 m) long and 1.25" (3 cm) wide, zone 4

Split Kelp: to 32" (80 cm) long and 10" (20 cm) wide, zone 4

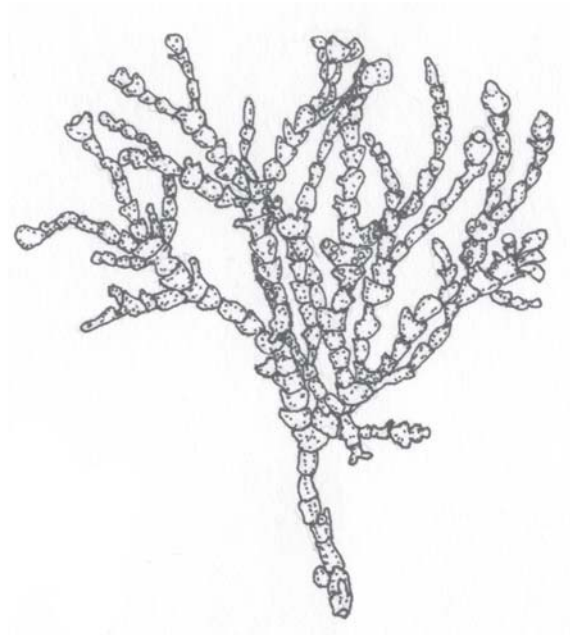
<u>Red algae</u>

Red algae are often found in the deeper parts of the intertidal zones.

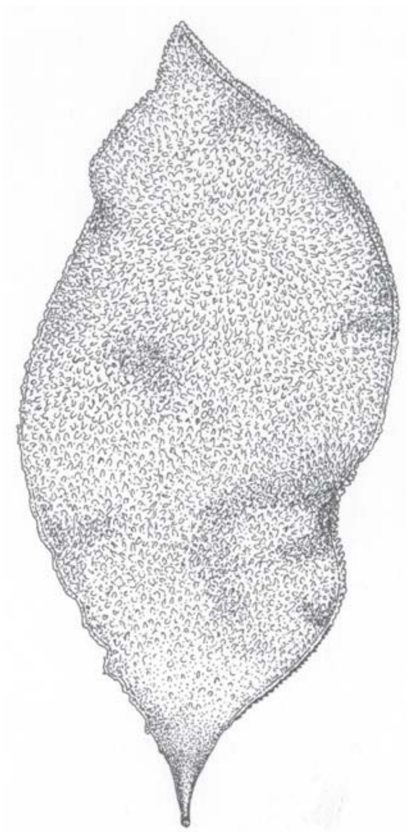
Coralline red algae such as *Lithophyllum* form pinkish encrusting layers on rocks in mid to low tide zone pools.

Some coralline red algae, such as *Calliarthron,* form pink-lavender branching structures. The organism grows to between 12 and 30 cm tall (4-12"), depending on the species.

Dead *Calliarthron* are commonly found on the beach and look like bleached white corals. The hard calcareous "skeleton-like" layer provides protection against animals that may try to eat it.



Coralline Algae (*Calliarthron* spp.)
12-30 cm (4-12") depending on the species
some zone 3, mostly zone 4-subtidal



Sea Tongue
(*Chondracanthus* spp.)
depending on species, to 90 cm (35") tall
zone 3

Other red algae form broad sheets up to a meter (a yard) long. One of these is *Chondracanthus* (formerly *Gigartina*), which is found in mid to low tide zones. Because of the many bumps on its surface, it is sometimes called "sea tongue," "cow's tongue," "Neptune's washcloth," or "Turkish towel." At one stage in its life cycle, *Chondracanthus* forms a thin coating on the rocks, looking much like a coating of tar. At one time, this "Petrocelis" stage was thought to be a different species.

Depending on the species, the organism may be up to 90 cm (35") tall.

The red alga *Mazzaella* (formerly *Iridaea*) has broad purplish red blades that are iridescent when wet and may be up to a meter (1 yard) in length.