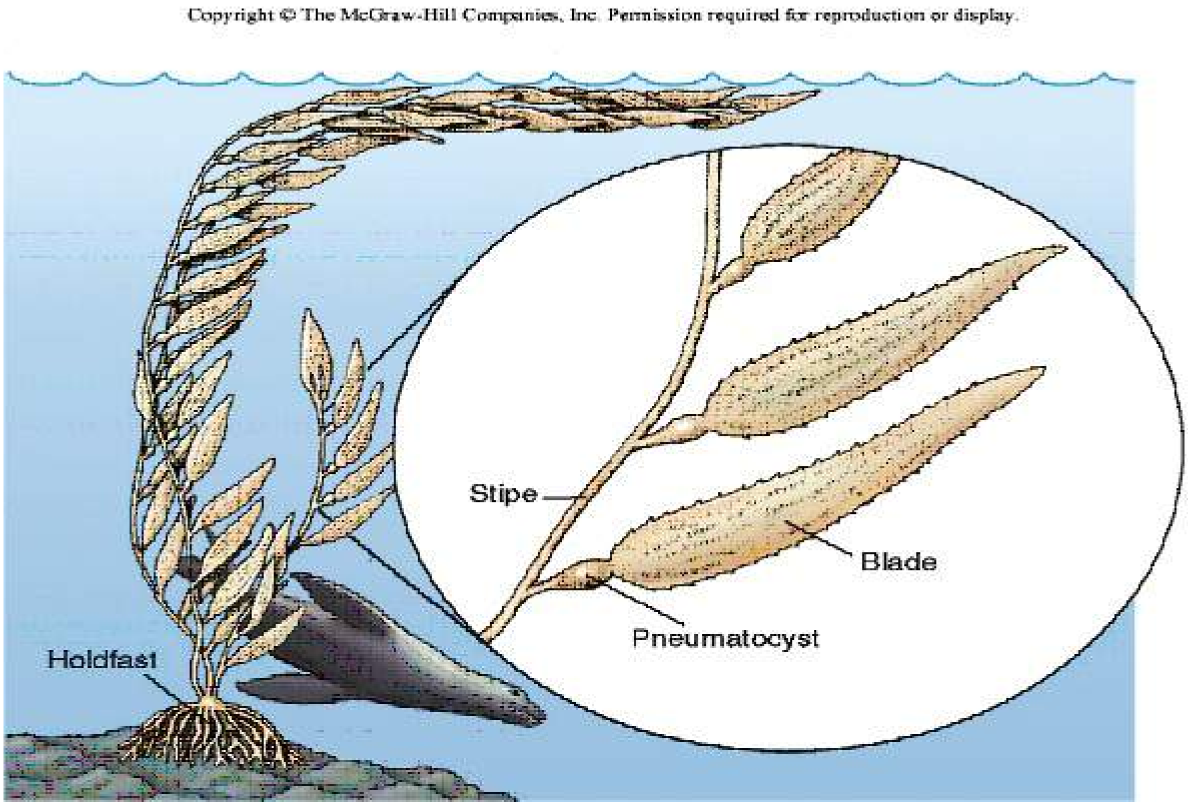
Marine Life: Life on the Benthos



The brown algae, Macrocystis spp., a multicellular primary producer.

Algal species are very different from terrestrial plants. All algae lack *true roots, stems, and leaves*. These plants also lack vascular tissues (like the xylem and the phloem). Instead they have analogous structures. The **holdfast** looks similar to roots, but has specialized cells that produce compounds that hold the plant to the benthos. It does not transport water or nutrients up through the plant, but instead anchors the algae to one spot. Marine algae also lack true stems, but have **stipes**. The stipes are analogous to stems, but lack vascular tissues. Instead they contain parenchamatous tissues (a combination of carbohydrates, lipids and protein) that provides support and increases the surface area of the algae (which is important for reasons mentioned below). Instead of leaves, algae has a structure called the **blade** (or blades). Like the previous structures, blades lack vascular tissues, but provide support in the aquatic environment and increases the surface area of the algae. One other structure we will find on algae/seaweed is the **pneumatocyst**. This gas filled structure (carbon dioxide, nitrogen, or a combination of the two depending on the species) also helps support the plant (and increases surface area). Terrestrial plants lack a structure like this one.

So why is surface area so important in marine plants? Keep in mind they live in water and that light is a limiting resource, especially with depth. Water filters, reflects, refracts, scatters, and absorbs light. So the light is separated into its component wavelengths (see previous lecture session Physical/Chemical Oceanography II), and all of those wavelengths are not available at all depths. The site of photosynthesis for terrestrial plants is the chlorophyl in the leaf, while the site of photosynthesis for marine algae is the entire plant. There are a number of photosynthetic pigments all over the algal plant from holdfast to blades. This is a wonderful adaptation for an environment where light is limiting.

Algal taxonomy is based in large part on the photosynthetic pigments and colors of these plants.

Kelp forest off Catalina Island as seen from below. Note the amount of available for the canopy (surface) versus the understory.

Table 6.1 Chemical Compounds Used in the Characterization of Marine Photosynthetic and Other Light-Capturing Organisms

Group	Photosynthetic and Other Light-Capturing Pigments	Major Food Reserves	Major Cell-Wall Components
Photosynthetic bacteria (except cyanobacteria)	Bacteriochlorophyll *a, b, c, d, e*	Variety of types	Peptidoglycan containing muramic acid
Light-capturing bacteria*	Proteorhodopsin	Variety of types	Peptidoglycan containing muramic acid
Cyanobacteria	Chlorophyll *a* Phycobilins (phycocyanin, phycoerythrin, and others) Carotenoids	Cyanophycean starch, cyanophycin (protein)	Chains of amino sugars and amino acids
Light-capturing archaea*	Bacteriorhodopsin	Variety of types	Variety of types, no muramic acid
Diatoms	Chlorophyll *a, c* Carotenoids	Chrysolaminarin, oil	Silica, pectin
Dinoflagellates	Chlorophyll *a, c* Carotenoids	Starch, oil	Cellulose
Green algae	Chlorophyll *a, b* Carotenoids	Starch	Cellulose, carbonates in calcareous algae
Brown algae	Chlorophyll *a, c* Carotenoids (fucoxanthin and others)	Laminarin, oil	Cellulose, alginates
Red algae	Chlorophyll *a* Phycobilins (phycocyanin, phycoerythrin) Carotenoids	Starch	Agar, carrageenan, cellulose, carbonates in coralline algae
Flowering plants	Chlorophyll *a, b* Carotenoids	Starch	Cellulose

*Prokaryotes that use light energy to manufacture ATP but not organic matter (see Table 5.1, p. 97).

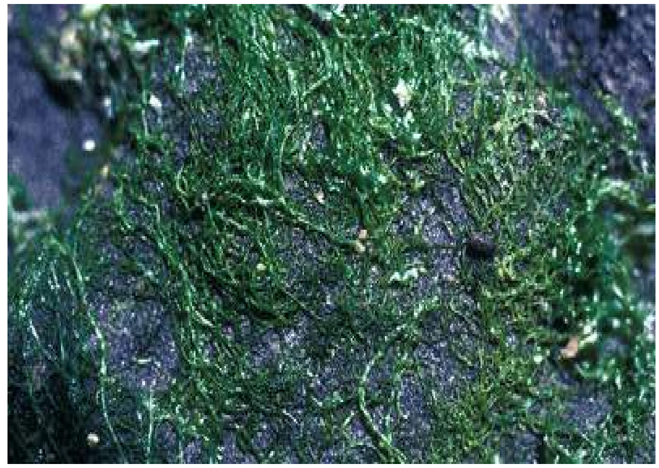
Major photsynthetic pigments and energy storage structures for aquatic primary producers.

The taxonomy of marine algae and plants is based on color and the photosynthetic pigments these plants have. Another important characteristic is the life cycle, which for some groups can be amazingly complex and includes the "alternation of generations" for those plants and algae that sexual reproduce. A good working definition of the alternation of generations are organisms that have both a diploid and haploid stage sometime during the life cycle. Sexual reproduction involves the production of gametes by the process of meiosis (reduction division that occurs in the nucleus of sexually reproducing organisms to produce gametes). This reduces the chromosome number by half so that fusion (which happens at fertilization) results in a cell with its full complement of chromosomes (this special cell is called the zygote).

Major Marine Algal and Plant Groups:

Phylum Bacillariophyta - diatoms, previously covered
Phylum Chysotphyta - golden algae, primarily benthic diatoms, previously covered
Phylum Dinoflagellata or Pyrophyta - dinoflagellates, previously covered
Phylum Chlorophyta - green algae
Phylum Phaeophyta - brown algae
Phylum Rhodophyta - red algae
Phylum Anthophyta - flower producing plants (most are terrestrial, but there are a few marine

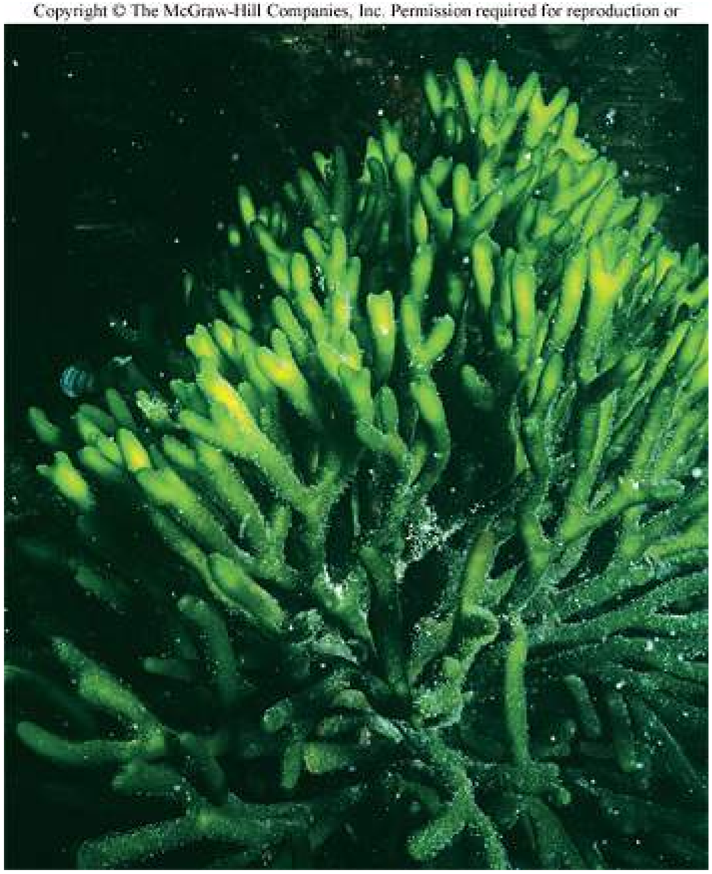
types).

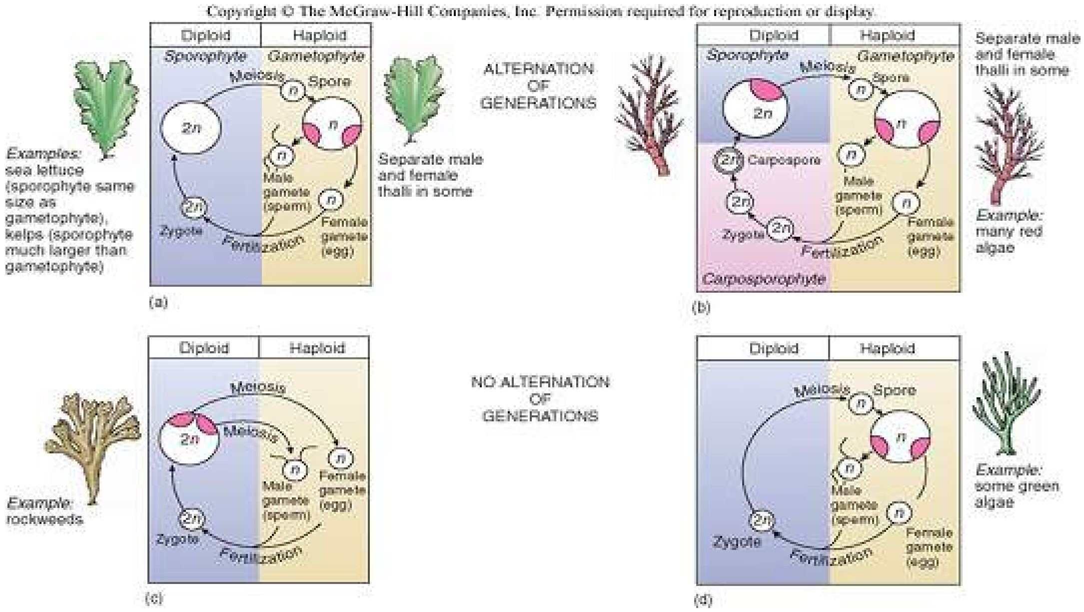
Two representatives of the Phylum Chlorophyta. Sea lettuce (*Ulva spp*., left) and maiden hair, also known as sea lettuce (*Entromopha spp*., right). Images courtesy Genny Anderson.

The golden sheen on the surface of the mud are thousands of benthic diatoms, Phylum Chrysophyta. Image courtesy Genny Anderson.

The green and golden brown algae have the shallowest distribution of marine plants. While representatives of the other phyla may be found in the same habitats, green and golden brown algae are the dominant plant forms in the intertidal and subtidal habitats. Brown algae have an intermediate distribution, while the red algae are generally the deepest occurring of these major groups. We have to remember that the zone with the most available light is the euphotic zone, depending on water clarity.



The sponge-like deadman's fingers (*Codium fragile*). This green algae gets its common name because of the way the blades move in the wave surge.



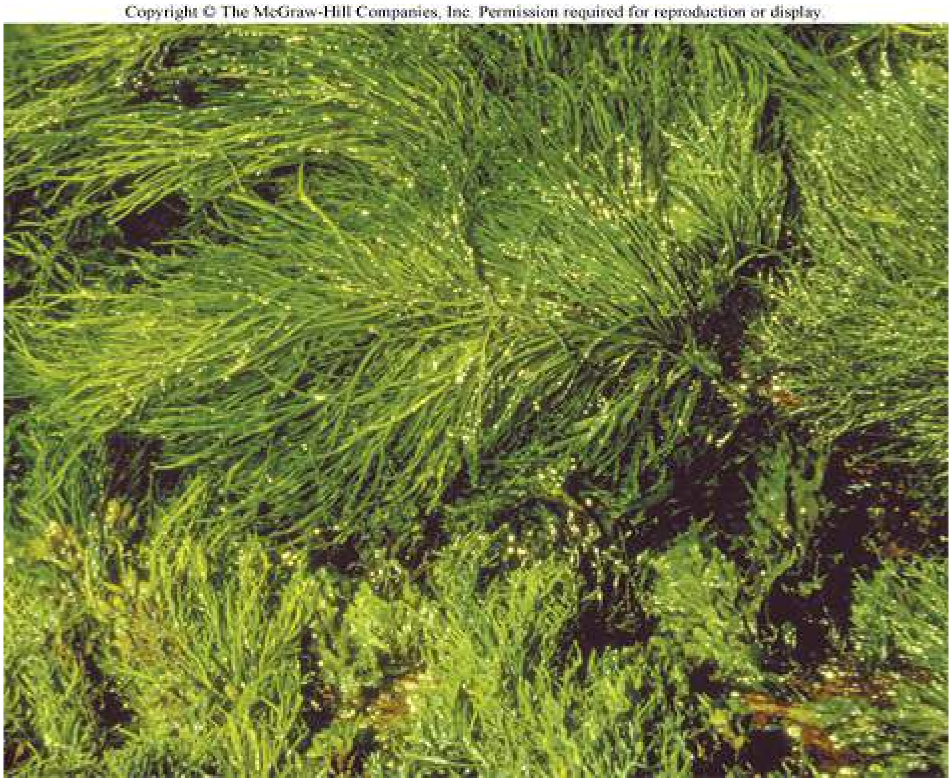
Life cycles of representative marine plants. Occasionally, alternation of generations includes a changes in morphology (form) along with changes in chromosome number.

***Padina spp*., a brown algae from the intertidal zone/ The shape of the blade is adaptive for the surge/wave conditions.**

The color of algae varies because of the type and concentration of photosynthetic pigments and environmental conditions, water quality (e.g. mineral content, pH, suspended particulates, etc.). So while the most common color for the algae in the Phylum Chlorophyta is green, some will appear golden, brown, and shades of red. The characteristic color for the phaeophytes is brown, but these may also appear green, shades of red, black, yellow, or orange. The situation becomes more interesting with the Phylum Rhodophyta. Red algae has phycocyanin (blue pigment) and phycoerythrin (red pigment, see above) that contributes to their colors. But the red algaes will also appear green, brown, golden, yellow, and others. The color can also vary with the life history stages during the alternation of generations. As you can see, color alone is not the best characteristic for identification of these plants.

***Porphyra spp*. may look like a brown algae, but it is a red and is commercially harvested.**

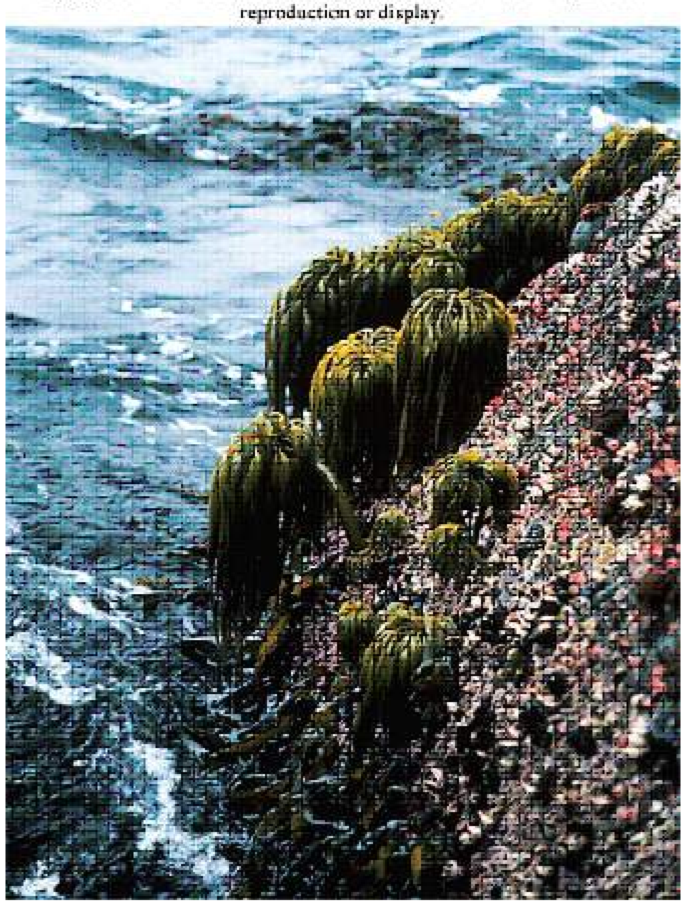
Fucus spiralis **is a common intertidal brown algae lacking pneumatocysts.**



Which phyla is represented here? ***Ascophyllum nodosum*** **is a brown algae.**

Marine plants increase the diversity of nearshore habitats. Many vertebrates and invertebrates use the areas for refuge, nursery sites for their early life history stages, as well as for food. While there are many invertebrate herbivores, there are only a few fishes that are obligate herbivores (algae makes up a significant portion of their diet).

Zebra perch (*Hermosilla azurea*, left) and the feather boa (*Egregia spp*., right) with the kelp limpet (*Discurria insessa*). Note the impressions left from previous feeding sessions. Zebra perch photo courtesy www.fishbase.org and feather boa image courtesy Genny Anderson.



The sea palm, *Postelsia palmaeofomis*, is a brown algae that commonly occurs on rocky shores exposed to high wave energy. This plant also has an unusual life history strategy as a result. Offspring are produced and live next to parental plants.

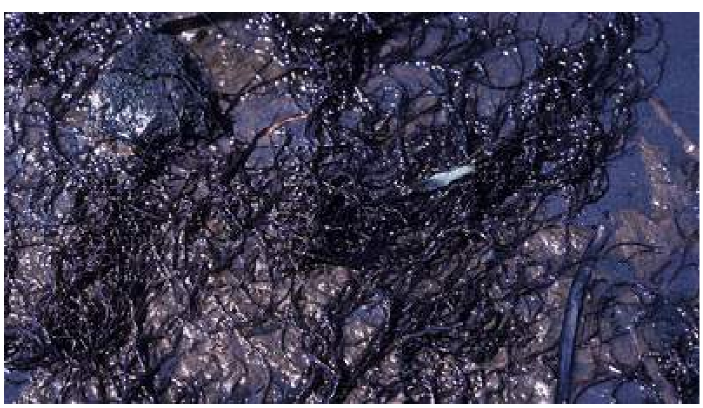
 

Bull kelp (*Nereocystis luetkeana*) and Elk kelp (*Pelagophycus porra*) are brown algae found in deeper cool waters of southern California or in the subtidal habitats in northern California, Oregon and Washington. The length of the blades can be very long (15-20m), and both species have very large pneumatocysts.

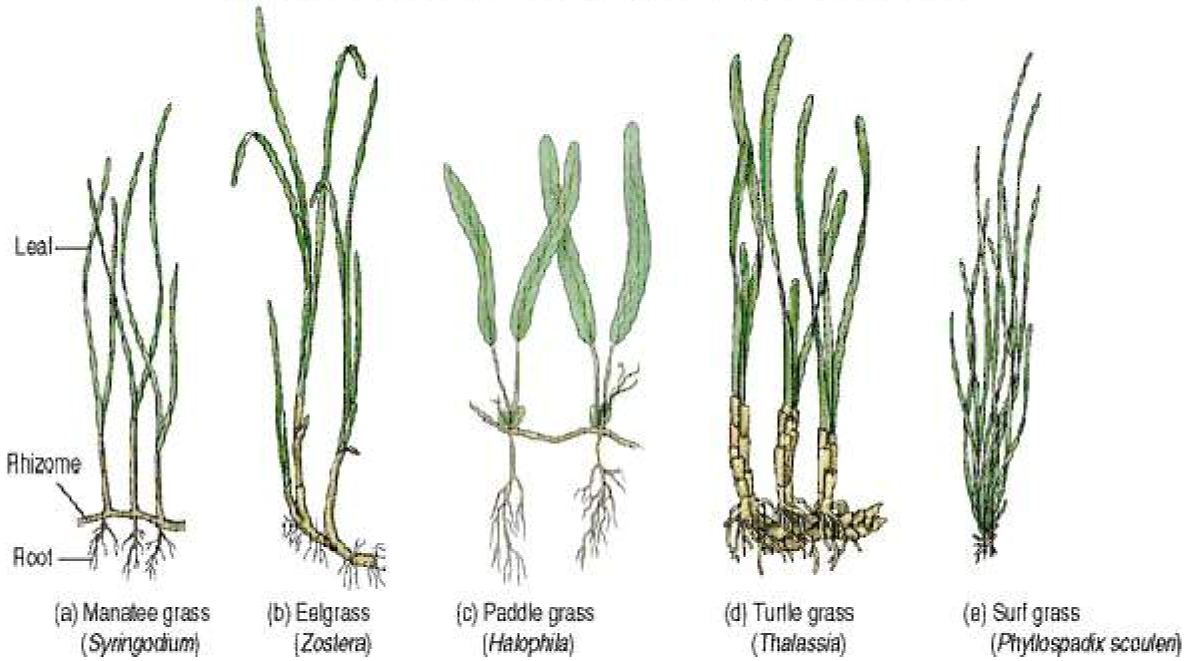
This is the growing end of the giant kelp *Macrocystis pyrifera*. This part of the plant is analogous to the apical meristem of terrestrial plants. Some algae can grow up to a meter a day.

Corallina spp**. is one of the red coralline algae representatives (yes, this one is red).**

Algae in the Phylum Rhodophyta are very diverse. Their life cycles are extremely complex and the plants may occur in a number of forms depending on the life history stage. The plants may be leafy (board), foliose (thin blades), filamentous, crustose (encrusting), coralline, or in combinations depending on the species, conditions and life history stages. Coralline algae have calcium deposits within their cell walls. Some warm-water species are critical in the formation of coral reefs.



Sea spaghetti, *Gracilariopsis sjoestedtii*, is a filamentous red algae common in bays and estuaries.



Some common seagrasses.

About 1.5% of the flower producing plants (Phylum Anthophyta) live in the ocean. The high saline environment presents special challenges for these organisms. Most have specialized cells or glands that facilitate salt removal and aids in osmotic balance. Like their terrestrial cousins, marine angiosperms have true roots, stems, and leaves. They also have vascular tissues (xylem and phloem) for the movement of water and nutrients through out the plant. Like terrestrial plants, marine anthophytes have a dominant sporophyte generation, and reproductive structures called flowers. The seagrasses (above) are the only truly marine group, but there are a few species found o the margins of the marine environment.

Looking seaward at a good minus tide with surf grass, *Phyllospadix torreyi* exposed.

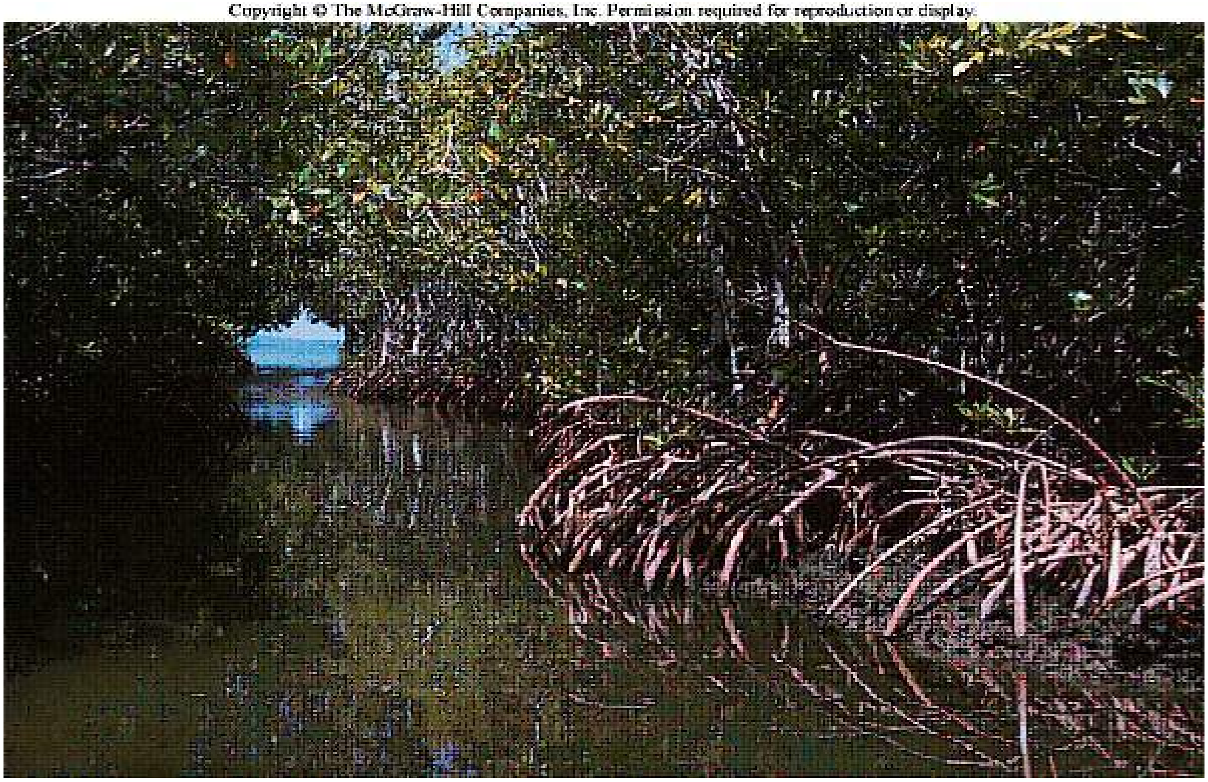
A related species of surf grass, *Phyllospadix scouleri*. This one occurs in areas of mixed sand and rock.

Not able to withstand much desiccation, this plant grows much like garden grass, sending out lateral runners along the surface and establishing new plants, creating masses of vibrant green at sea level.

During minus tides the surfgrass is left dry for a short time, but is a wonderful visual cue to where sea level is located. As a photosynthetic plant it creates oxygen as a waste product of photosynthesis. Normally this is washed away by the ocean currents, but at a minus tide, surfgrass in still tidepools on sunny days is covered with bubbles of pure oxygen.

Oxygen bubbles produced via photosynthesis by surf grass at low tide on a sunny day.

The surfgrasses and algal species provide oxygen (which is usually cared away at high tide), food for herbivores, shelter from the bright sun, and hiding places for a variety of invertebrates and vertebrates.



The red mangrove (*Rhizophora mangle*) is an important species in the areas where it occurs. Many birds, fish, and invertebrates use these areas as feeding and nursery grounds.

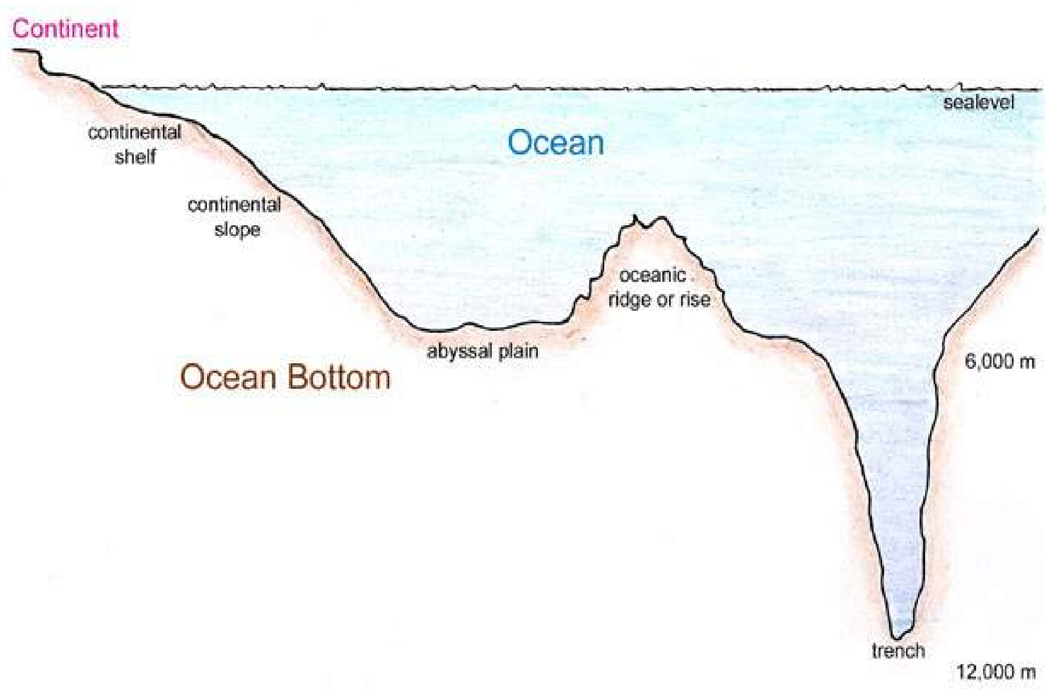
Mangroves are trees and shrubs that are adapted to live in marine environments. They function to hold soft sediments (sand and mud), and can be important in the formation of land masses in the sea. Like the chaparral communities in the rolling hills in southern California (that burn from time to time), mangrove communities include at least 80 species of mostly unrelated salt tolerant plants. The leaves and trunk of mangrove trees like *Rhizophora* very thick as an adaptation to water loss from their tissues. Chapter 6 in your text (Castro and Huber) has detailed information on these primary producing benthic organisms.

(a) (b)

A seedling of the red mangrove (*Rhizophora mangle*, a) as it appears in the parent tree before its released, and one that has taken root (b) in the soft sediment.

We will frequently encounter mixed surf grass and algal assemblages on rocky shores. The image on the left is surf grass with sea lettuce (*Ulva spp*.), and the image on the right is surf grass with feather boa (*Egregia spp*.). Both images courtesy Genny Anderson.

Life on the benthos also includes a multitude of animal life. Some of these animals are *sessile*, which means they live permanently attached to the substrate. Others are *benthic* or associated with the substrate, but can move freely. Many benthic animals have a planktonic larval stage. It allows these organisms to exploit more than one habitat during their lives. The benthos extends from the intertidal zone, to the continental shelf, past the continental rise, along the abyssal plain, into the hadal zone (deep sea trenches). This habitat is not homogenous and thus contributes to great diversity.

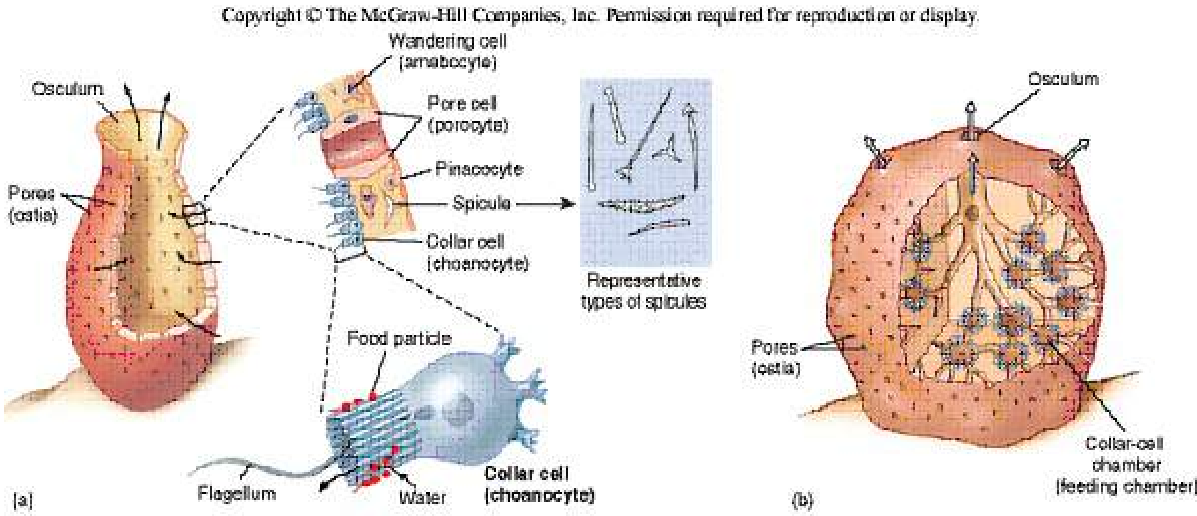


Schematic of the benthic provinces in the marine environment. Abiotic variables may be very important to life found on the benthos in various zones.

We have briefly introduced some organisms, but let's get into more detail about the benthic critters in the Kingdom Animalia. Unlike the primary producers (which are mostly autotrophic), all animals are heterotrophic, eukaryotic organisms. Benthic animals are very diverse with most major groups/phyla represented. The first major group we will cover are the *invertebrates*, those animals without backbones. At least 97% of all species of animals are invertebrates, with many species only found in marine environments.

Phylum Porifera - Sponges (pore bearing animals)

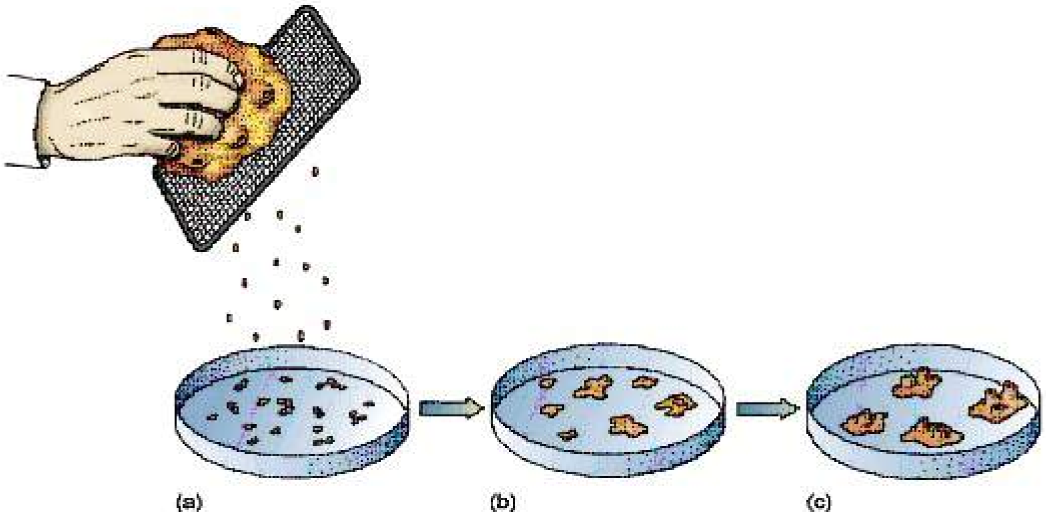
Sponges are the simplest multicellular animal. While all sponges have eukaryotic cells, they all lack organized tissues, organs, and organ systems. While sponges lack specialized tissues, they do have complex aggregations of cells with unique functions.



Sponges have specialized cells that do not occur in other animal groups. Collar cells, or choanocytes trap nutrients in simple (a) and complex (b) sponges.

Here is a listing of these specialized cells and their functions:
Choanocytes/collar cells - flagellated cells that trap nutrients and generate water flow through the sponge.
Pinocytes - flat cells that comprise the outer surface of the sponge.
Porocytes - tube-like cells which allow water to pass through the sponge. The osculum may be large or small and is the ex-current pore. The ostia serve as the in-current pores.
Spongin - Protein complex produced by amebocytes that give sponges their "spongy" characteristics.
Amebocytes - Analogous to the universal cell of the sponge. These cells have a number of important functions: 1) they distribute nutrients through the body of the sponge; 2) they produce spongin; 3) they produce spicules, which are either calcareous or siliceous and provide support to larger sponge, and the shapes are species specific; lastly 4) these cells may go through meiosis so that sexual reproduction can occur.

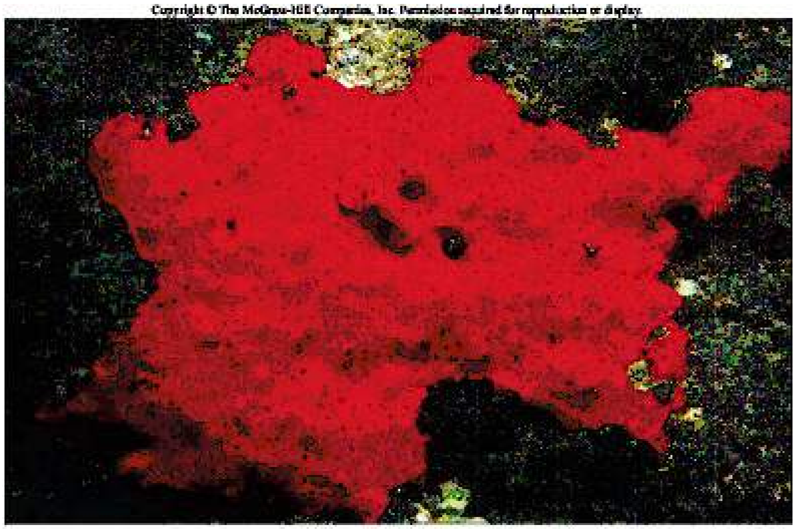
Sponges may reproduce asexually or sexually, most do not have specific shapes 9they are said to be amorphic, and almost all are suspension feeders (they filter the water column for nutrients).



Some sponges reproduce asexually by a process called fragmentation (demonstrated above). As long as there are enough specialized cells in each part, the fragments will grow into genetically identical sponges. This is a cool adaptation in regions subject to major storms.

Sponge taxonomy is based largely on the amount of spongin, and the type and concentration of spicules sponges have. Of the 6,000 or so species of sponge that have been described most are found in marine environments, and all of them are sessile.

<u>Class Calcarea - rock sponges</u>
This group includes some of the brightly colored encrusting sponges, sclerosponges (or coralline sponges). A few species of boring sponge (somewhat like this lecture section...) Bore through the calcium carbonate shells of clams and corals as their settlement sites.



(b)

(B)This is an encrusting sponge from Hawaii

(c)

C) Ceratoporella nicholsoni, a sclerosponge or coralline sponge photographed at 52 m in the waters of Puerto Rico.

(a)

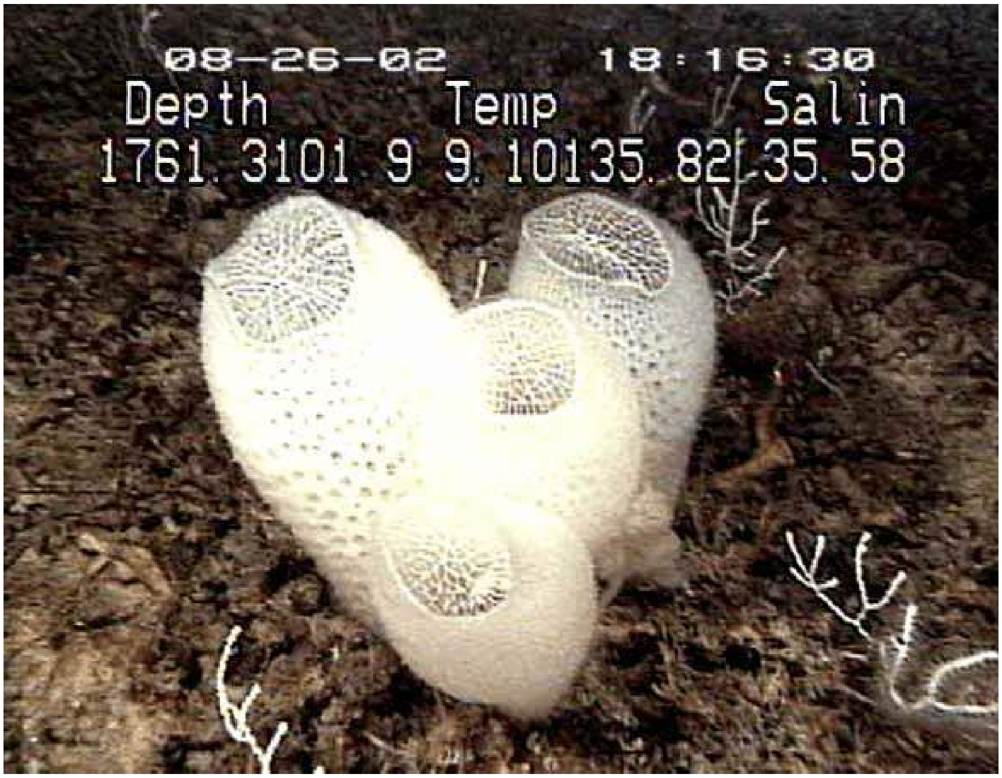
(A) *Verongia archeri*, one of the exquisite glass sponges from the deep waters of the Caribbean. These sponges have fused siliceous spicules, and little in the way of spongin.

Class Demospongiae - the bath sponges. These sponges are characterized by having few spicules but abundant spongin. Like all sponges, bath sponges occur in a variety of shapes, sizes and colors. These sponges are still harvested for bathing and some are sold in art supply outlets. Also, many invertebrates and a few fish use sponges for shelter and food.

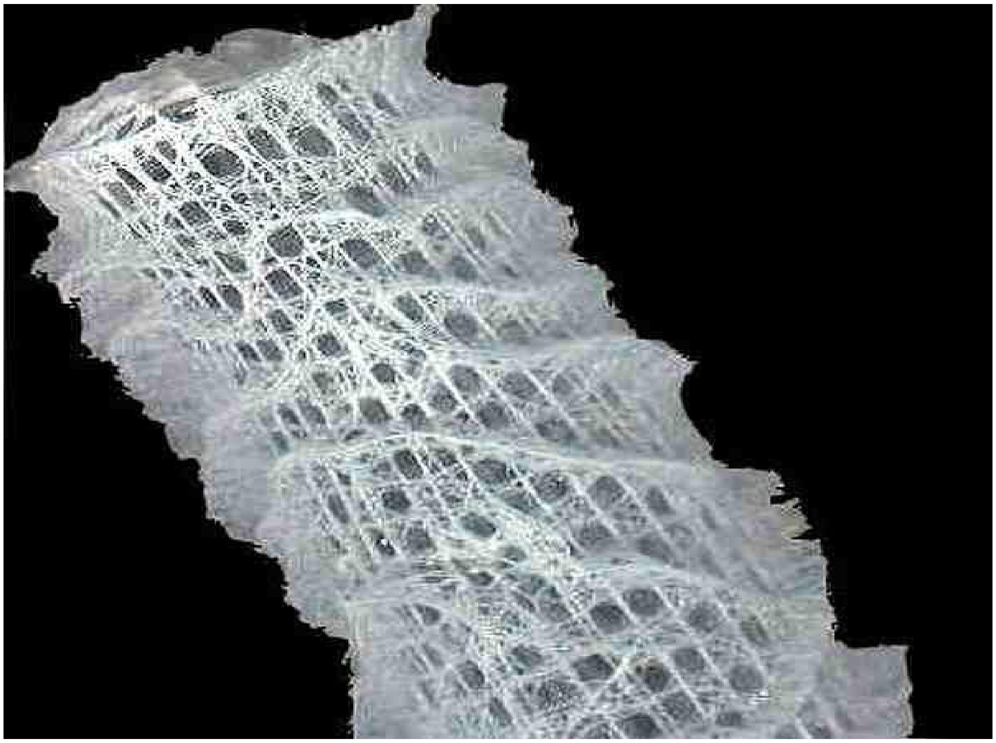
Two examples of bath sponges illustrating the groups diversity. *Ianthella basta* from Papua New Guinea is one the left, and *Phkellia* spp. from south Atlantic is represented on right. Both images courtesy http://tolweb.org/Ceractinomorpha/20442.

This is what we usually think about when we see "bath sponge". Image courtesy http://www.esu.edu.

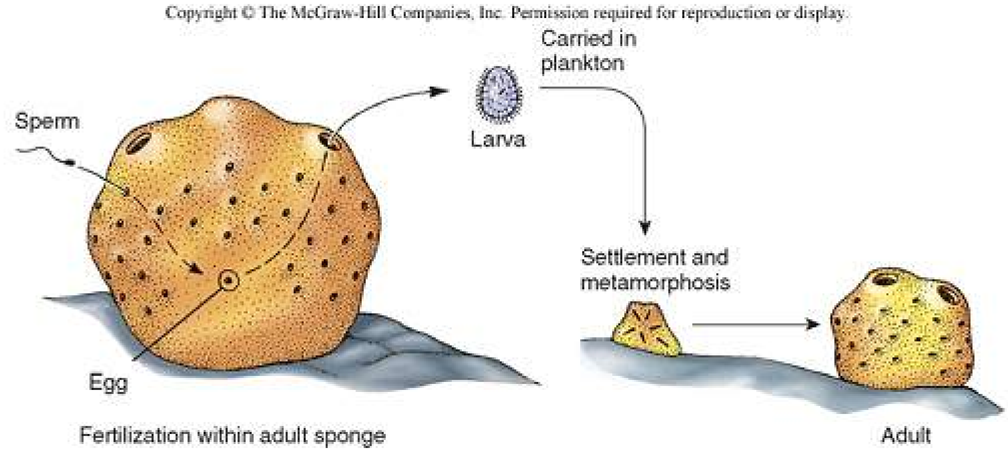
Class Hexactinellinida - the glass sponges
These sponges are different from the others because of the fused siliceous spicules. These sponges also generally occur deeper than the others because of their delicate structures.



Venus' flower basket, *Euplectella aspergilium*, as fused spicules and occurs in deeper ocean waters. Image courtesy http://www.freewebs.com/anaturalworld/theearliestanimals.htm.



A higher magnification image of the glass sponge Venus' flower basket.



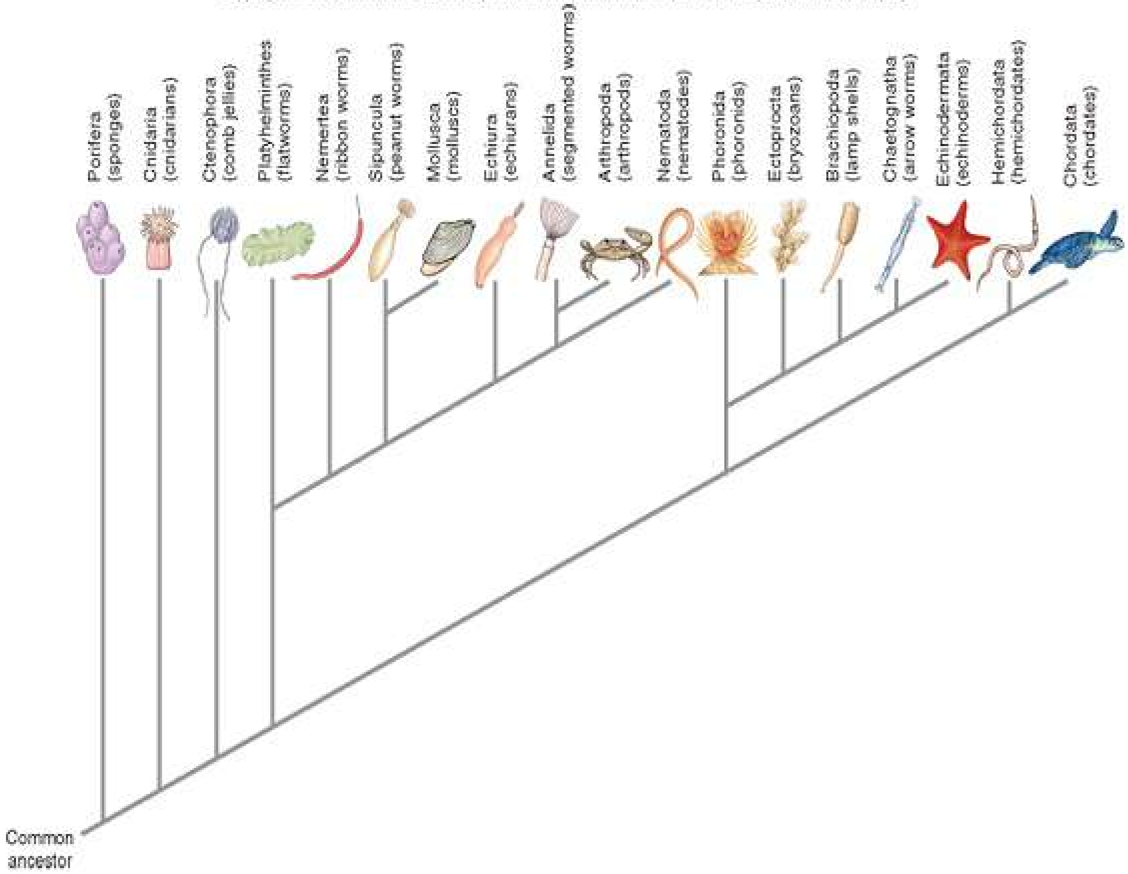
Sexual reproduction in many marine sponges involves gamete formation (via meiosis), fertilization, larval development, metamorphosis, and settlement. Some sponges release both eggs and sperm into the water column.

Table 7.1 Some of the Most Important Characteristics of the Major Animal Phyla

Phylum	Representative Groups	Distinguishing Features	General Habitat
Porifera (sponges)	Sponges	Collar cells (choanocytes)	Benthic
Cnidaria (cnidarians)	Jellyfishes, sea anemones, corals	Nematocysts	Benthic, pelagic
Ctenophora (comb jellies)	Comb jellies	Ciliary combs, colloblasts	Mostly pelagic
Platyhelminthes (flatworms)	Turbellarians, flukes, tapeworms	Flattened body	Mostly benthic, many parasitic
Nemertea (ribbon worms)	Ribbon worms	Long proboscis	Mostly benthic
Nematoda (nematodes)	Nematodes, roundworms	Body round in cross section	Mostly benthic, many parasitic
Annelida (segmented worms)	Polychaetes, oligochaetes, leeches	Segmentation	Mostly benthic
Sipuncula (peanut worms)	Peanut worms	Long, retractable anterior end	Benthic
Echiura (echiurans)	Echiurans	Non-retractable proboscis	Benthic
Mollusca (molluscs)	Snails, clams, oysters, octopuses, chitons	Foot, mantle, radula (absent in some groups)	Benthic, pelagic
Arthropoda (arthropods)	Crustaceans (crabs, shrimps), insects	Exoskeleton, jointed legs	Benthic, pelagic, some parasitic
Ectoprocta (bryozoans)	Bryozoans	Lophophore, colonial	Benthic
Phoronida (phoronids)	Phoronids	Lophophore, worm-like body	Benthic
Brachiopoda (lamp shells)	Lamp shells	Lophophore, clam-like shells	Benthic
Chaetognatha (arrow worms)	Arrow worms	Transparent body with fins	Mostly pelagic
Echinodermata (echinoderms)	Sea stars, brittle stars, sea urchins, sea cucumbers	Tube feet, five-way radial symmetry, water vascular system	Mostly benthic
Hemichordata (hemichordates)	Acorn worms	Dorsal, hollow nerve cord, gill slits	Mostly benthic
Chordata (chordates)	Tunicates, vertebrates (fishes, reptiles, birds, mammals)	Dorsal, hollow nerve cord, gill slits, notochord	Benthic, pelagic

Major marine phyla and identifying characteristics.

There are many other species that are benthic. We will cover organisms in the phyla Cnidaria, Ctenophora, Platyhelminthes, Nemertea, Nematoda, Mollusca, Annelida, Arthropoda, and Echinodermata in the next lecture series. We will cover the identifying characteristics for each phylum, the major classes, and representative critters.



Evolutionary cladogram of the major marine taxa. The organisms are more complex and/or derived as you move from sponges to chordates.