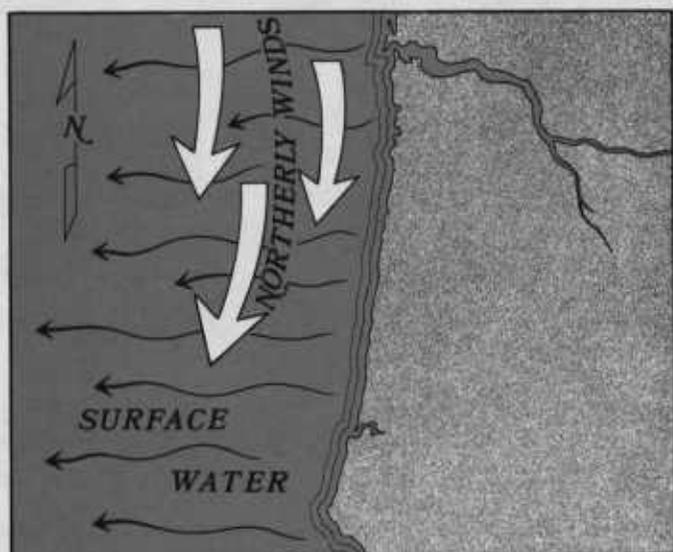
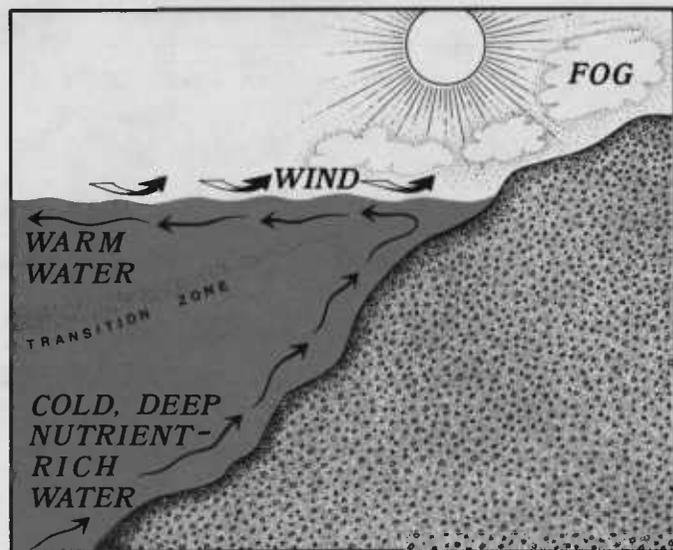


# Phytoplankton: Grass of the Sea

by Herbert Curl, Jr., Professor of Oceanography, Oregon State University



**FIGURE 1:** Ocean winds blow surface water offshore and deep water upwells to replace it.



**FIGURE 2:** Cold, upwelled water cools the air in contact with the water surface causing cool, foggy weather common at the beach during the summer.

Anyone taking a trip at sea or walking on the beach notices that nearshore water along coasts is frequently green or brown and sometimes even red. Often these colors signify the presence of mud or silt carried into the sea by rivers or stirred up from the bottom if the water is sufficiently shallow. However, a murky green or amber appearance is almost always due to the presence of many small, single-celled plants called phytoplankton, or "plant wanderers." These plants contain green pigment, chlorophyll, by which they carry out photosynthesis, using light energy. They also contain other "accessory" pigments which are used either to trap sunlight or to protect the chlorophyll from too much sunlight.

Nearly everything that lives in the sea and much that lives on the land depends for its existence on phytoplankton, the most abundant plants in the world. From carbon dioxide ( $\text{CO}_2$ ) and water, by photosynthesis, they produce more organic matter than any other plants and they release amounts of oxygen proportional to the carbon dioxide they use. Without this production, not only would there not be any food for grazing and filter feeding animals in the ocean but there would be no fish, which feed on the smaller grazers.

In Oregon coastal waters, as well as on most westward-facing coastlines in all parts of the world, massive phytoplankton growths, called *blooms*, occur when cold, nutrient-rich water is brought to the surface from depths of 300 feet or more. This *upwelling* of cold water occurs when persistent ocean winds blow surface water offshore and deep water upwells to replace it (Figure

1). Wind patterns that lead to upwelling are most frequent in the summer. The combination of abundant nutrients and strong sunlight causes the cells to grow and divide until several million cells per liter (about one quart) are present in the upper 150 feet. Of course this high growth rate could use up the nutrients faster than they are brought to the surface. However, the surface waters act as a conveyor belt. As freshly upwelled water along the coast is pushed offshore by wind the cells multiply in numbers and mass and deep water comes to the surface.

The upwelled water is quite cold (50°F or 10°C), cooling the air in contact with water and causing cool, foggy weather common at the beach during summer. The fog may be carried inland by the sea breeze to the crest of the Coast Range of mountains (Figure 2).

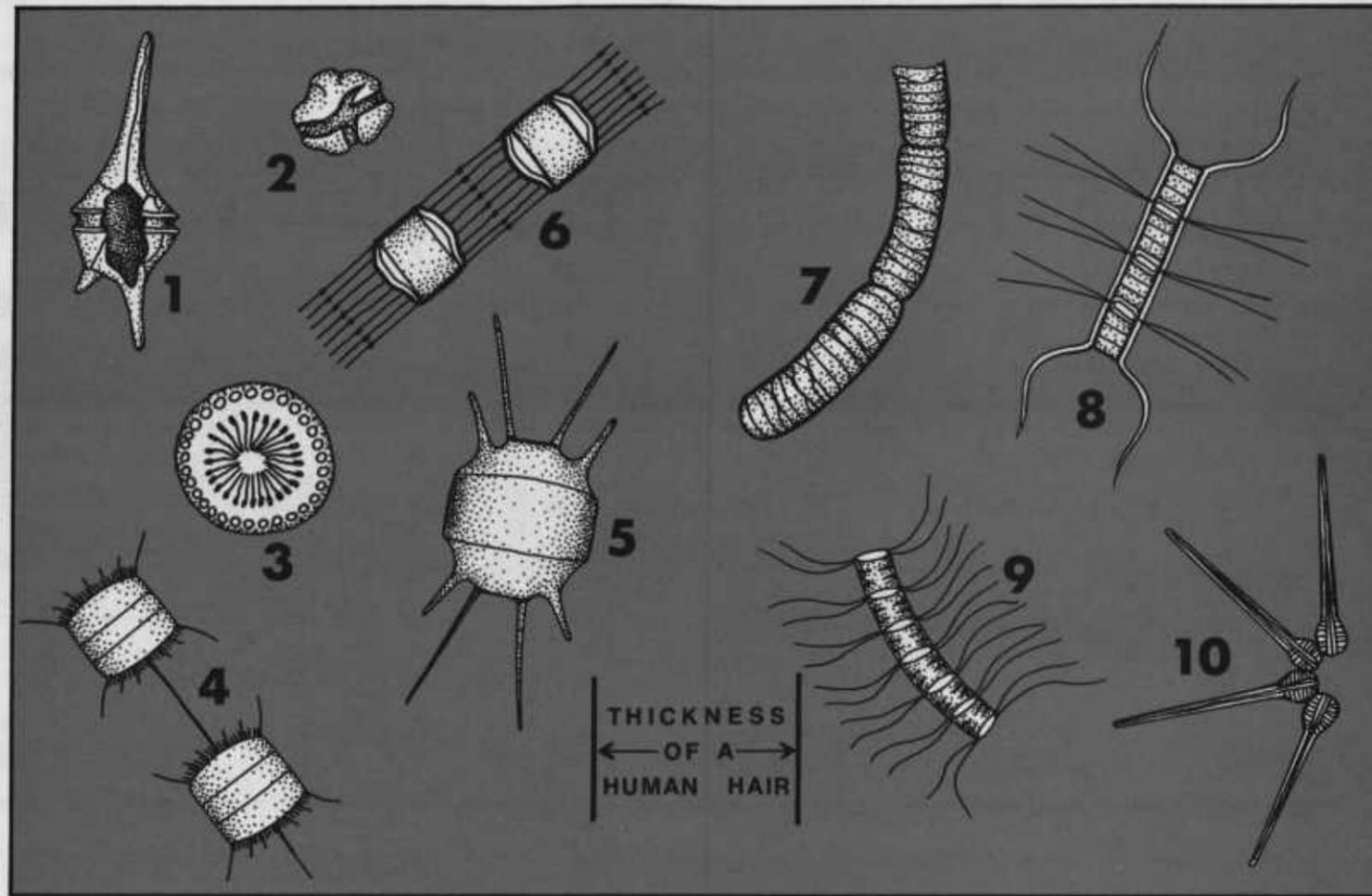
When the wind direction changes and it blows from the south, warm offshore surface water is pushed toward the land, upwelling stops, and the tiny plants are carried onto the beach with each wave; sometimes in such numbers that dark foamy streaks, or windrows, of dead cells are formed. This material provides an abundant harvest for filter feeding and scavenging animals on rocks, in the sand, and in tide pools.

Plants comprising phytoplankton are of many different species, all microscopic in size (Figure 3). Usually the most abundant are diatoms: beautiful, symmetrical cells, living singly or in colonies with thin, glassy walls similar to opal. The second most abundant organisms are dinoflagellates, that have whip-like flagella by which they can propel themselves slowly. Many species of dinoflagellates are bioluminescent; that is, they are capable of producing light. Some dinoflagellates produce toxins directly into the water thereby killing fish ("red tides") or tainting the flesh of ocean clams and mussels that feed on them.

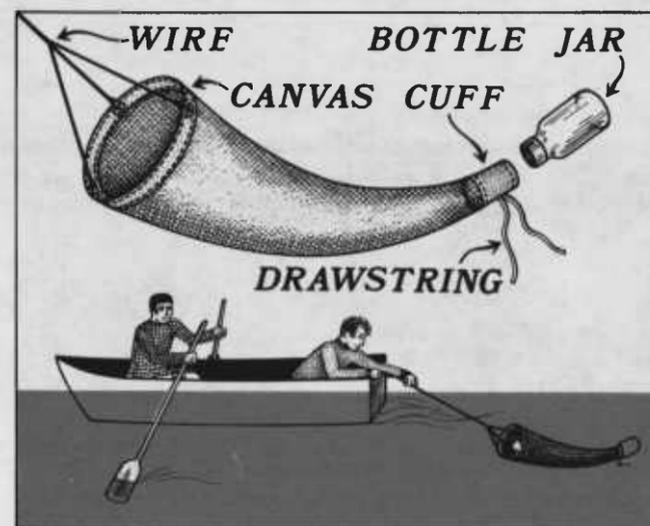
Other phytoplankton organisms include coccolithophores, which also can propel themselves and have an external shield of little plates made of calcium carbonate; silicoflagellates, which have internal skeletons of silica; and blue-green algae, which are found only in warm water.

Since the largest phytoplankton cells are barely visible to the unaided eye, a microscope or powerful hand lens is necessary for viewing them. To capture the cells a plankton net made of fine nylon cloth is used (Figure 4). A simple, homemade sampling net may be made easily from a good grade of muslin or cheesecloth with wire from a coat hanger for support of the mouth. Pulling this net behind a boat, by hand while swimming, or casting it with a fishing rod will yield material which will include both phytoplankton and zooplankton, or animal plankton.

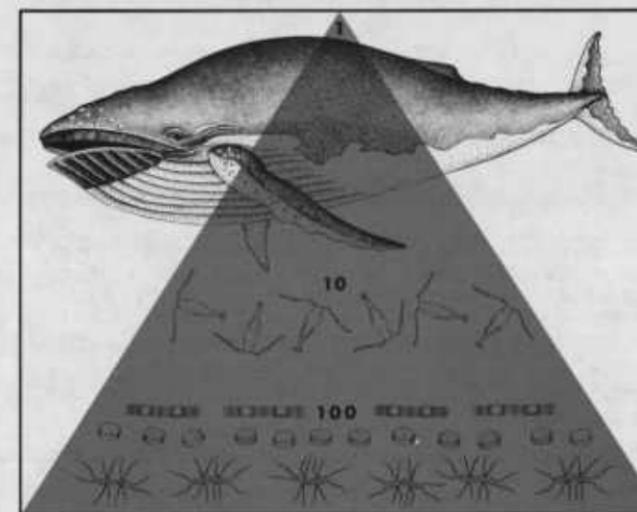
The amount of phytoplankton in the water is usually estimated by measuring the concentration of chlorophyll and other pigments after they have been extracted with solvents. However, a simple volumetric comparison



**FIGURE 3: Some single-celled plants of the phytoplankton: 1. *Ceratium furca*; 2. *Gymnodinium breve*, (both 1 and 2 are dinoflagellates; the latter causes "red tides" in the Gulf of Mexico); 3. *Melosira sulcata*; 4. *Thalassiosira decipiens*; 5. *Bidulphia mobiliensis*; 6. *Skeletonema costatum*; 7. *Rhizosolenia stolterfothii*, 8. *Chaetoceros affinum*; 9. *Chaetoceros curvisetum*; 10. *Asterionella japonica*. Organisms 3 through 10 are diatoms. *Skeletonema* is one of the most abundant near-shore plants in the ocean. The diameter of a human hair is shown for comparison.**



**FIGURE 4: A simple method for capturing phytoplankton cells is shown above. Materials for the net are easily obtained.**



**FIGURE 5: A typical ocean food chain. Approximately 100 tons of phytoplankton are required to produce a one ton whale.**

may be made by towing the net over the same distance at different times and allowing the contents to settle in a test tube.

Nearly all of the phytoplankton species are used as food by small invertebrate animals that feed by filtering the water. Zooplankton, such as copepods and euphausiids, and attached organisms, such as clams, feed this way. These animals are fed upon, in turn, by larger invertebrates and fish. Approximately 100 tons of phytoplankton are required to produce 10 tons of large crustacea which, when eaten, produce one ton of whale or large fish. The loss of 90 percent of the energy at each step occurs in respiration and natural mortality (Figure 5).

The production of phytoplankton can be measured in units of grams of carbon converted to organic matter per unit area of sea surface per year (grams of carbon per square meter per year, or g C/m<sup>2</sup>/yr). Very productive areas of the world include Lake Maracaibo, Venezuela (500 g C/m<sup>2</sup>/yr.), Long Island Sound (up to 500 g C/m<sup>2</sup>/yr.), water off Southern California, in the Antarctic Ocean, and in the Benguella current (200-400 g C/m<sup>2</sup>/yr.). The Oregon coast is also very productive, averaging .300 g C/m<sup>2</sup>/yr. out to a distance of 25 miles from shore. The centers of the oceans, except along the equator, are the least productive (50 g C/m<sup>2</sup>/yr.) due to the absence of current systems.\*

Many people regard the ocean as an unlimited source of food which we have not yet begun to tap. The total amount of marine food produced depends on the annual rate of production of phytoplankton, the type of organisms we can economically harvest and find edible, and on the number of steps in between. The maximum sustainable yield (production which can be sustained year after year without the yield decreasing) of ocean fish of the kinds we presently eat, can be doubled from the present harvest of 60 million tons per year, according to some marine biologists. To exceed this yield would require that we harvest directly the organisms that fish feed upon, such as euphausiids, shrimp, and squid. These organisms are more abundant but also more expensive to catch and this approach does not seem feasible or economical. Even the present yield is imperiled by overfishing, and by pollution from pesticides, herbicides, and oil. For example, DDT has a negative effect on photosynthesis of algae at a concentration of just one part in a billion parts of water, and an oil layer reduces the light available for photosynthesis (among other effects).

In summary, phytoplankton are of importance to the economy of the ocean and the world far out of proportion to their visibility or our awareness of them. The health of these organisms has a direct impact on human welfare.

\* The highly productive parts of the world's oceans occupies only a very small fraction of the total area. Thus the average rate of production for all the oceans is also 50 g C/m<sup>2</sup>/yr.

**Want to know more about phytoplankton?**

For the student or teacher who wishes to learn more about phytoplankton, the books listed below offer detailed information about phytoplankton and their relationship to the oceans and to humanity.

Cupp, E. E., *Marine Plankton Diatoms of the West Coast of North America* (University of California Press, 1943—out of print; reprinted Ann Arbor: University Microfilms, University of Michigan).

Newell, G. E., and R. C. Newell, *Marine Plankton* (London: Hutchinson, 1963; paperback).

Round, F. E., *The Biology of the Algae* (London: Edward Arnold, 1965).

Wimpenny, R. S., *The Plankton of the Sea* (New York: American Elsevier, 1966).



**Want other marine information?**

Oregon State University's Extension Marine Advisory Program issues educational materials periodically that should be of value to students and teachers who want to learn more about marine science. If you would like to receive a list of these materials, please write to:

Extension Marine Education  
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Scientists who study the characteristics of life in the ocean (including phytoplankton) and in estuaries work in various laboratories at the center.

In the top photo, a marine education specialist shows youngsters how to use the center's handling pool.

In the lower photo, the 177-foot (54-meter) R/V *Wecoma* is the newest of the research vessels that



the OSU School of Oceanography berths at the center. The 78-foot (24-meter) R/V *Cayuse* is also an

ocean-going vessel; the 32-foot (10-meter) *Paute* is used within the bay and on the nearshore ocean.

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