Plankton:
Background for the teacher

By Dr. William Hamner, Ph.D

Phytoplankton must live near the surface of the sea because, like all plants, they require light for photosynthesis, the transformation of water and carbon dioxide into short chain sugars. Unlike terrestrial plants that must counteract gravity to reach toward the sun with strong trunks, branching stems and large leaves, plants in the pelagic zone are exceptionally small, microscopic, and single-celled, buoyantly supported by the density of the surrounding water. Plants, of course, do not have muscle tissues, so they cannot swim like oceanic animals. Without special adaptations of some type, these tiny plants would eventually sink to the bottom and die. Plants can remain near the surface only if they are almost neutrally buoyant. Small objects weigh less than large ones and small objects have a large surface area in relation to their volume. Since phytoplankton are very small indeed, often only 1/1000th of a millimeter in diameter, they don't weigh very much and they have a very large surface area/volume ratio. Interestingly, some of the very smallest plants, the dinoflagellates, have tiny motile, tail-like appendages, called flagella, that propel the single-celled plant slowly through the water. Because the cells sink very slowly, equally slow swimming speeds can maintain these plants near the surface. Other types of cells change their buoyancy by manufacturing light-weight oils when they sink too deep. Since oil floats, the positively buoyant cell now floats slowly back toward the surface.

Phytoplankton also remain near the surface because the surface waters of the open sea and large lakes are regularly mixed each day by the wind. The sun brings light for photosynthesis to the water surface but it also brings heat, and the warm surface water floats above the denser and colder deeper water mass. The transition between these two bodies of water, where the temperature changes abruptly, is called the *thermocline*. When the wind blows, it mixes the surface waters but only down to the thermocline. There the density difference is sufficiently strong to resist further mixing, so heat accumulates mostly near the surface. The waters above the thermocline mix completely each day, from the surface to depths of 10 to 100 meters. Single celled plants sink at rates of only a few meters each day, so even though some kinds of phytoplankton, such as diatoms, sink inexorably toward the bottom, they are mixed over greater distances and more rapidly throughout the upper water column by the wind each day, far faster than they can ever sink.

Miniature, almost invisible planktonic animals, the *zooplankton,* eat these tiny plant cells. We can not see most zooplankton without a microscope. At sea or in a large lake at the surface during the day, when we look down into the water from shore or from a small boat, we generally do not see anything at all in the clear, blue surface waters. Yet when we drag a fine plankton net through the water behind the boat and carefully examine the catch in a clear glass jar we see thousands of tiny animals darting about within the jar. Most of these animals are less than about a millimeter long, less than 1/16th of an inch, and most are quite transparent. They are called "net zooplankton" because we can only investigate them by the use of plankton nets. Individually these animals are difficult to see in the sea or in the lake because our eyes cannot easily resolve individual spots less than about one millimeter in size, yet when crowded together in the collecting jar of the plankton net these animals are collectively visible as a cloudy, milling mix of tiny creatures. Small size is an important survival strategy in the open sea because many pelagic predators are visual predators with eyes much like our own. If we can not see these tiny animals, then predatory fish probably can not see them either!

We examine our catch of net plankton carefully under the lens of a microscope or magnifying glass, and we see now that not only are there thousands of tiny animals but also there are many different types of animals, with strange shapes and appendages. Some of the most common are tiny crustaceans, darting copepods with long antennae but with shrimp-like legs. Other recognizable animals are tiny jellyfish, rapidly beating their transparent bells. Tiny clams lie quietly on the bottom of the dish but then they suddenly open their valves and dart off into the water. Other animals are unlike anything that we have ever seen before, strange creatures that live only in the plankton, like arrow worms and radiolarians, and we are amazed and yet perplexed by the diversity of so many different types of such tiny animals all living in such clear water, apparently devoid of living things.

Other kinds of zooplankton also occur at the surface of the sea during the day…the gelatinous zooplankton. This is an assemblage of much larger animals than we captured in our nets, consisting of large jellyfish, planktonic, transparent snails, comb jellies, large arrow worms, and pelagic tunicates, like salps and appendicularians. All of these animals are transparent, soft bodied, and delicate, with the consistency of Jell-O. Many scientists refer to this group of animals as "jello-plankton". Gelatinous zooplankton are fairly large animals, from centimeters to meters in diameter for the largest jellyfish. They do not swim rapidly but remain buoyant despite large size because the mixture of salts in their gelatinous tissue is lighter than the weight of the salt in the seawater within which they swim. Gelatinous zooplankton almost never occur in fresh water habitats because in the absence of salts in fresh water they cannot regulate their buoyancy to remain in the pelagic realm. At sea gelatinous zooplankton are both important predators (jellyfish and comb jellies) and filter-feeding herbivores (pelagic tunicates), and they can have an enormous impact on the food webs of the sea. Historically these animals were difficult to study because their delicate tissues were invariably damaged by nets. During the past 20 years, however, gelatinous zooplankton have been investigated extensively by scuba divers who hand-collect animal at sea, capturing perfect, undamaged specimens one at a time into individual jars that are then transported back to the laboratory aquarium for study. Gelatinous zooplankton are also difficult to study because they are hard to see within the sunlit waters of the open sea, yet their transparency provides important protection from visual predators in the open sea.

At night the larger herbivores and carnivores migrate up to the surface to feed. In the dark they cannot be seen by visual predators, so they can feed in relative safety near the surface. Ultimately all of the food in the sea comes from the surface waters where the phytoplanktonic plants live, and it makes sense to come to the surface because that is where the food is located. But at dawn, light once again penetrates the surface, the migratory animals become visible, they must migrate swiftly down into the permanent dark of the deep for protection. This periodic vertical swimming behavior therefore occurs twice a day. The behavior pattern is called *vertical diurnal migration*, and it one of the most pervasive behavior patterns on earth. In the exceptionally clear waters of the open sea, sunlight can penetrate to almost a thousand feet during the day, and so vertical migrators often have to swim several thousands of feet twice a day. This can be accomplished only by relatively large animals with good swimming ability, and consequently most of the vertical migrators are between 1 and 10 centimeters long (1/2 to 4 inches), much larger than net zooplankton. Shrimp-like krill, small squids and many species of small fishes make up the vertical diurnal assemblage. At night, therefore, when one fishes the surface waters with a plankton net, the catch is much different than it was during the day because at night the net captures tiny net zooplankton, larger vertical diurnal migrators, and, of course, gelatinous animals, which are usually damaged and squished by the net.

There are interesting and predicable seasonal changes in plankton communities. There is little phytoplankton growth during the winter, but winter storms mix the open waters of the sea to great depths, bringing nutrients to the surface. In spring, the days begin to lengthen once again, the surface of the sea begins to warm, and a shallow, seasonal thermocline is formed anew. Now is the optimal time for phytoplankton growth, and these rapidly growing tiny plants experience population explosions, “blooms”, and “red tides”, utilizing the nutrients upwelled in winter. Later in the spring, zooplankton populations begin to rapidly expand, grazing upon the phytoplankton. Then top carnivores, like pelagic fish, spawn and produce vast shoals of larval fish that feed in turn on zooplankton. In summer, marine mammals calve and produce pups, just as the larval fish have turned into bite sized juveniles. Then summer passes, predators migrate toward the tropics, the winds of fall and winter winds begin to blow, and the annual cycle repeats.