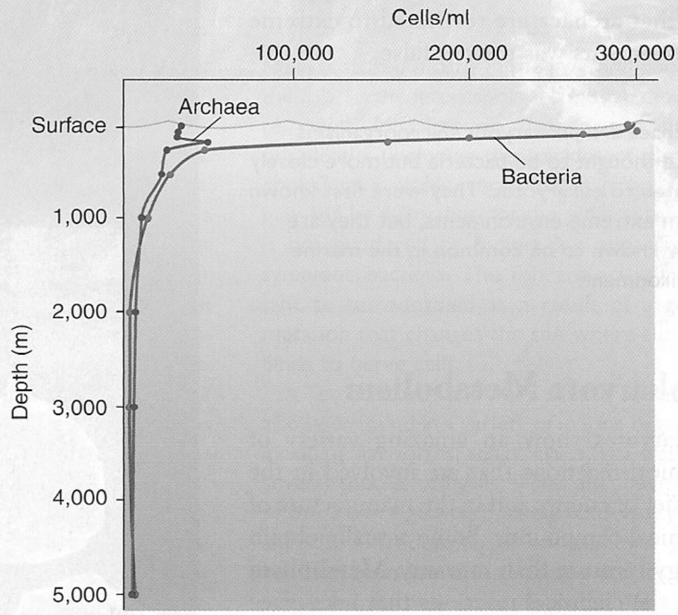
Tiny Cells, Big Surprises

It is surprising how little biologists know about the lives of marine microbes. We know they are everywhere but we are not sure how many types there are, how common they are, and what exactly they are up to. The situation is rapidly changing as we apply new techniques and approaches to studying the private lives of marine microorganisms that call the ocean home.

Information about marine microbes (what nutrients the microbes need to grow, the type of compounds they produce, and such) has traditionally been gathered mostly from organisms collected in water samples and then grown under artificial conditions. Many organisms, unfortunately, do not grow in the lab, and their presence in samples goes undetected. At least some of this information has been used by marine ecologists to deduce the role of microbes in the big ocean world—the role of decay bacteria in releasing nutrients, for example, and of bacteria that convert free nitrogen into nitrates or make dissolved organic matter (DOM) available to larger forms of life. Still, bacteria and other marine microbes are poorly understood. Some groups of microbes remained undiscovered for a long time. Most archaea, for instance, have been known only since the 1970s.

Viruses and the minute prokaryotic cells of bacteria and archaea and the smallest eukaryotic cells of some algae and other organisms seem to be everywhere but are very difficult to collect and characterize by the microscopic examination of cells. Instead of culturing or filtering out these cells, fragments of nucleic acid (see "Nucleic Acids," p. 65) are collected from the water and **sequenced.** The presence of organisms can be detected by identifying characteristic DNA or RNA sequences, a research approach called **metagenomics** (see "A Fourth Domain of the Tree of Life?," p. 93). Furthermore, the partial sequences can yield information about the unique characteristics of these microbes, even if whole cells or whole nucleic acid molecules are not collected.

The presence of RNA sequences characteristic of archaea in seawater and sediment samples has shown archaea to be abundant. In 2001 two groups of archaea were found to be extremely abundant in water samples collected from depths below the photic zone—that is, where light does not penetrate (see Chapter 16). The samples, collected from the Pacific Ocean south of Hawai'i, showed that archaea were rare at the surface but sharply increased in abundance below depths of 250 m (720 ft). Below 1,000 m (3,280 ft) archaea were as common as bacteria. Judging from their numbers and the huge volume of the ocean in question, these archaea are among the ocean's most abundant forms of life. DNA sequences in samples from the Sargasso Sea have demonstrated the presence of at least 1,800, and possibly as many as 50,000, new species of microbes.



Depth distribution of bacteria and archaea in the subtropical North Pacific.

Similar techniques based on the detection of characteristic nucleic acid sequences have been used to identify previously unknown eukaryotic microorganisms. These eukaryotes are larger than prokaryotes but still minute (smaller than 2 to 3 μm), making them difficult to collect and study. This sharply contrasts with other unicellular but larger eukaryotes in the plankton, which are relatively easy to collect using plankton nets (see "The Plankton: A New Understanding," p. 333). In 2001 two new groups related to dinoflagellates were discovered at depths of 250 to 3,000 m (720 to 9,840 ft) near Antarctica. Similar but unique groups of eukaryotic microorganisms (including yet another new group related to dinoflagellates) were reported at the same time by another team working at depths of 75 m (246 ft) in the tropical Pacific. The fact that some of these microorganisms, collected in relatively shallow water where light still penetrates, are photosynthetic, adds a new dimension to the discovery. They represent a previously unknown source of primary production in typically unproductive tropical waters. Other groups of minute algae have been discovered in recent years, including three groups that are related to dinoflagellates. Other groups certainly remain to be discovered.

Heterotrophs Most marine bacteria, like animals, are **heterotrophs** that obtain energy from organic matter by **respiration** (see Table 5.1). Many heterotrophic bacteria and archaea are decomposers. Respiration in **aerobic** bacteria and archaea uses oxygen, as in most other groups of organisms, whereas in **anaerobic** species respiration does not require oxygen. Anaerobic bacteria do not grow when oxygen is present and thrive when it is absent, as in sediments that are devoid of oxygen, or **anoxic.** This is the case in bacteria that use sulfate (SO_4^{-2}) instead of oxygen to perform respiration, producing in the process the hydrogen sulfide (H_2S) that is to blame for the rotten-egg smell of some sediments (see Fig. 11.29).

Heterotrophic prokaryotes obtain energy from organic matter. Many are decomposers.

Nitrogen Fixation Many planktonic cyanobacteria (such as *Trichodesmium*) carry out **nitrogen fixation,** converting gaseous nitrogen (N_2) into ammonium (NH_4^{+1}), which, like nitrate