food very much as animals do and play critical roles in marine food webs.

VIRUSES

Viruses, remarkably, span the non-living and the living. Unlike living organisms, a virus is a particle not made up of a cell. Viruses consist of only a short chain of genetic material **(nucleic acid)** containing relatively few **genes** and protected by an outer protein coat, or **capsid.** They are parasites that reproduce and develop only when infecting a living cell. Viruses are minute, roughly between 20 and 200 nanometers (nm), 1 nm being equal to one-billionth of a meter, or 1,000 μm (see Appendix A for relative size). They can be seen only with the most powerful microscopes. A recently discovered giant marine virus (Fig. 5.1) is an exception, being 440 nanometers in diameter and thus visible through an ordinary light microscope!

Several types of viruses have been described. **Retroviruses** store their genetic information in the form of single-stranded **RNA,** in contrast to the double-stranded **DNA** of most viruses and all forms of life. Retroviruses are responsible for deadly human diseases, such as AIDS and some types of leukemia. Some viruses reproduce by attaching into a living cell and injecting their nucleic acid into the cell. The viral nucleic acid then commands the cell to produce, or replicate, copies of the virus, which are ultimately released as the infected cell bursts. The new generation of viruses then infects other cells or is released from the organism to infect new hosts. Another type, the **lysogenic** viruses, reproduce by inducing their nucleic acid to become part of the **genome** of the host cell, which then, sometimes long afterwards, directs the production not of host proteins but of new viruses. Many more viruses are then released as the infected cell is destroyed. Of particular importance in the ocean are **bacteriophages,** viruses that specifically target—and destroy—bacteria.

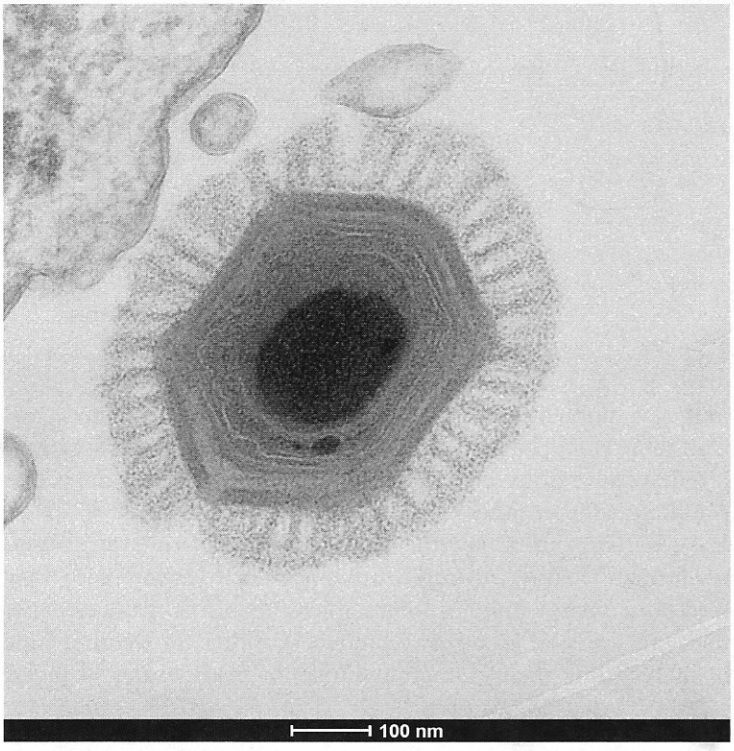

FIGURE 5.1 The largest virus ever recorded, with a diameter of 440 nanometers and bigger than some bacteria, was discovered off the coast of Chile in 2010. It appears to live in marine amebas. The capsid, or outer coat, has hair-like structures. Its DNA has been estimated to have around 1,120 genes, more than some bacteria.

Until recently, marine viruses were practically ignored by marine scientists. They are nearly invisible, so it was not until the development of new techniques (see "Tiny Cells, Big Surprises," p. 92) that viruses were shown to be extremely common in marine environments and to play an important role in the complex cycles of life in the ocean. Though viruses are not referred to as living "organisms" in the strict sense of the word, viruses constitute the most abundant and diverse life-like particles in the ocean. Virus numbers in water samples can be determined by staining them with chemicals and observing them under a microscope, something that can be done on a research vessel. Their numbers in seawater samples can be staggering. Viruses have been found to be extremely abundant in deep-sea sediments (see "Microbes in the Deep Sea," p. 378).

The abundance of viruses in the water is directly related to the abundance of microbial life, particularly bacteria, which they infect and destroy to reproduce. Viruses also infect other marine microbes that form part of the **phytoplankton,** very important primary producers in the ocean (see "Unicellular Algae," p. 93). The bursting of the cells of bacteria and phytoplankton as the result of viral infections also releases into the water large amounts of organic molecules and cell debris, which make up **dissolved organic matter (DOM).** DOM cannot be utilized as such by most organisms. It is, however, readily taken in by bacteria and other microbes. These microbes are eaten by small **zooplankton,** which are then eaten by larger zooplankton, so that the energy contained in DOM, a significant part of primary production by the phytoplankton, is not lost but ultimately is available to all kinds of animals, from small fishes to whales (see "The Microbial Loop," p. 349). The bursting of cells as a result of viral infections also releases some essential nutrients, which can then be made available to primary producers.

Viruses are also responsible for diseases affecting marine life other than microbes. Some viruses affect shellfish of commercial importance, while others cause serious diseases in fishes, sea turtles, and marine mammals. Humans are also vulnerable. Oysters and mussels that filter hepatitis viruses from sewage-contaminated water commonly infect humans eating raw or improperly cooked shellfish.

PROKARYOTES

Prokaryotes are the smallest and structurally simplest true living organisms and the oldest forms of life on Earth. Nonetheless, they carry out nearly all the chemical processes performed by supposedly more complex organisms, as well as many that are unique to prokaryotes (Table 5.1, p. 87). Most of these chemical processes actually evolved first among prokaryotes.

In contrast to viruses, prokaryotes are made up of cells. Prokaryotic cells are enclosed by a protective **cell wall.** The **cell,** or **plasma, membrane,** lies immediately inside the cell wall (see Fig. 4.7). Prokaryotes not only lack a nucleus and most other