(see "Tiny Cells, Big Surprises," p. 92) but in sediments as well. Some archaea are also known to live symbiotically in sponges, sea cucumbers, and fishes. Thus, the **hypothesis** that archaea are restricted to extreme environments was proven false.

Archaea are prokaryotic microorganisms once thought to be bacteria but more closely related to eukaryotes. They were first known from extreme environments, but they are now known to be common in the marine environment.

Prokaryote Metabolism

Prokaryotes show an amazing variety of chemical reactions that are involved in the transfer of energy and in the manufacture of chemical compounds. Some actually obtain energy in more than one way. **Metabolism** is all the chemical reactions that take place in an organism.

Autotrophs **Autotrophic** bacteria and archaea make their own organic compounds and thus are primary producers. Energy sources vary. Some autotrophic bacteria, such as the cyanobacteria previously mentioned, are photosynthetic or **photoautotrophic.** They contain chlorophyll or other photosynthetic pigments (see Table 5.2, p. 100) to trap light energy to manufacture organic compounds from carbon dioxide (CO_2); cyanobacteria release oxygen in the process (see Table 5.1). Photosynthesis takes place on folded membranes within the bacterial cell (see Fig. 4.7 and photo on p. 73) rather than in chloroplasts, as in algae and plants.

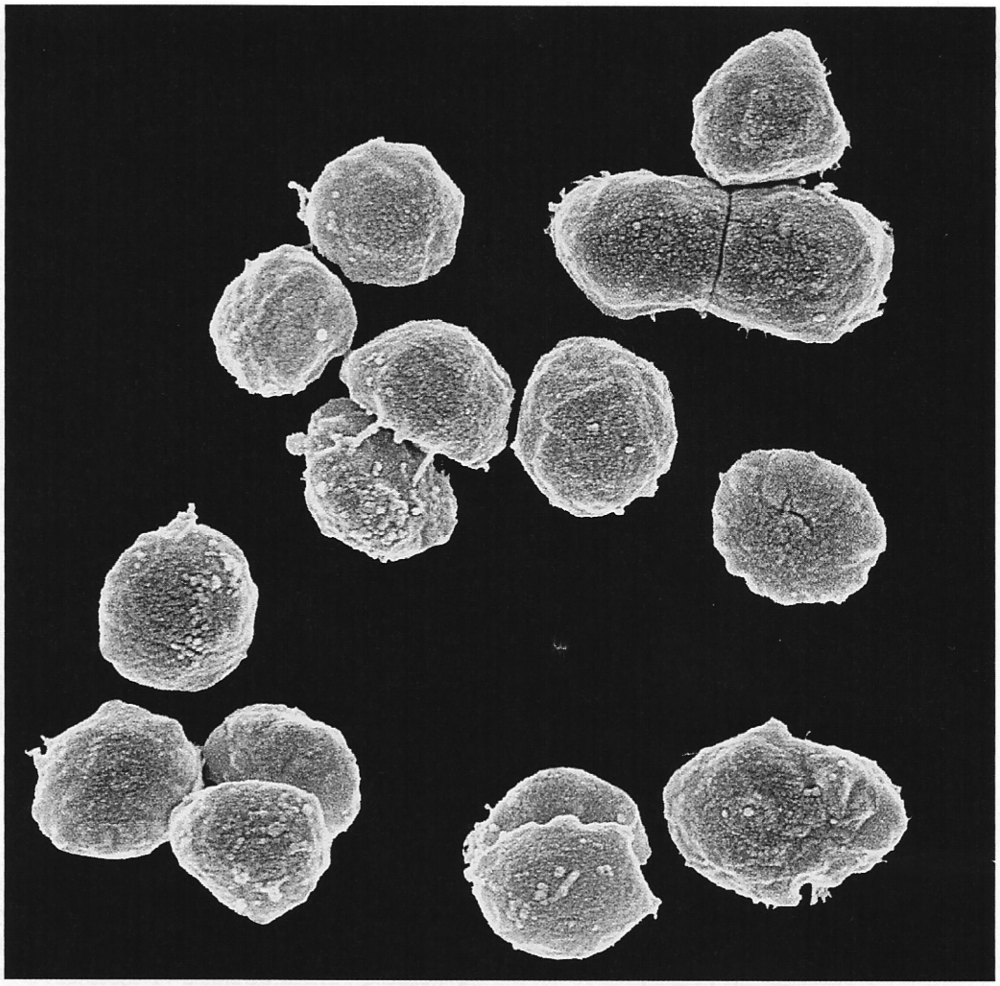

FIGURE 5.5 *Methanocaldococcus jannaschii* is a methane-producing archaeon that lives at high temperatures near deep-sea hydrothermal vents. It was the first archaeon to have its genome sequenced. Some of the cells shown here are dividing.

Photosynthetic bacteria account for much of the primary production in many open-ocean areas. Even bacteria living at depths where no surface light penetrates have been suggested as using the faint glow of hydrothermal vents to perform photosynthesis. Though the end products may be similar, the biochemistry of bacterial photosynthesis is different from that of algae and plants. It also varies considerably among different groups of bacteria. Some photosynthetic bacteria, for example, have a kind of chlorophyll unique to prokaryotes and produce sulfur (S) instead of oxygen (see Table 5.1). It is thought that some bacteria may use a pigment called proteorhodopsin to capture light energy and store it in **ATP.** They do not have chlorophyll or use the energy to manufacture organic compounds from carbon dioxide and thus are not photosynthetic. An archaeum (*Halobacterium*). similarly lacks chlorophyll but contains a pigment, bacteriorhodopsin, that converts light energy directly into ATP. Marine microbes can therefore use light as an energy source in many ways, not just in photosynthesis.

Other bacterial autotrophs, called **chemosynthetic,** or **chemoautotrophic,** derive energy not from light but from chemical compounds, including **hydrogen sulfide (H_2S)** and other sulfur, nitrogen, and iron compounds (see Table 5.1). Chemosynthesis is also involved in altering some of the minerals found in sea-floor rocks (see "Life Below the Sea Floor," p. 28). Some chemosynthetic archaea, the methanogens, produce methane (CH_4). One example is *Methanopyrus,* an archaeum that has been isolated from sediments near hydrothermal vents.

Prokaryotes show a wide variety of metabolic processes. Many bacteria (including cyanobacteria) and some archaea are autotrophs and account for much of the oceanic primary production.

Hydrothermal Vents Undersea hot springs associated with mid-ocean ridges and other geologically active environments.
• Chapter 2, p. 37

Hypothesis A statement about the world that might be true.
• Chapter 1, p. 11

Autotrophs Organisms that can use energy (usually solar energy) to make organic matter.
• Chapter 4, p. 67