EYE ON SCIENCE

A Fourth Domain of the Tree of Life?

Most biologists classify all organisms into three domains (see Fig. 4.24), a system that relies heavily on the chemistry of cells. Such differences led to the recognition that archaea are different from bacteria and that each of these two groups belongs in a separate domain, even though both look similar under the microscope. A three-domain system of classification thus far works fine. Recent studies that use increasingly sophisticated techniques have nevertheless hinted that the three-domain system is too simple and that a fourth domain might exist hidden somewhere in the ocean.

It all started when microbiologist J. Craig Venter took seawater samples from around the world during a 2003–2007 cruise on his yacht. The water samples were analyzed by a team from Venter's institute and the University of California Davis using **metagenomics,** a technique where the genomes of unknown organisms are recovered directly from the environment, not from laboratory cultures as is traditionally done (see "Tiny Cells, Big Surprises," p. 92). The genomes in Venter's samples were cut into pieces, the nucleic acid chains sequenced, and the sequenced pieces put back together and matched with the help of computers.

The analysis of the water samples showed sequences that were different from any studied before. These included sequences related to two "superfamilies" of "housekeeping genes," those genes involved in the maintenance of the basic cell functions. Housekeeping genes are nearly universal among living organisms, and are even carried by some viruses, which do not consist of cells and are not strictly living. The first superfamily, called *recA,* includes genes that are involved in controlling the repair of DNA chains and in the exchange of pieces of genetic information between DNA chains in the chromosomes, which carry the DNA. The second superfamily, *rpoB,* is involved in passing the information contained in DNA into RNA, the first step in the manufacture of proteins (see "Nucleic Acids," p. 65).

Any potential evolutionary relationships between the sequences found in the seawater samples and known sequences of the same "superfamilies" found in the other domains were used by computers to draw "trees" similar to those shown on page 85 and in Figure 4.23. Some branches of these trees did not fit with the data on the known sequences, thus suggesting that they did not belong in any of the three known domains but instead belong in an unknown group of microorganisms. These branches might therefore represent an unknown branch, probably a new domain, in the tree of life.

It is possible, however, that the sequences belong to an unknown group of marine viruses, which are not included in any of the recognized domains because they are not classified as living organisms. The discovery of these sequences has triggered all sorts of questions, the aim of current and future research. Do the unusual gene sequences belong to a microorganism having a yet unknown cellular organization and function or do they instead belong to a bizarre virus? The questions are fascinating and challenging. Archaea were once regarded as insignificant and irrelevant, but are now found practically everywhere and are involved in many important processes, one of which is the production of methane, a greenhouse gas. Do they live in the water column or associated with more "complex" organisms? The unusual gene sequences contain complete genes. Can we predict from the known sequences the biology and role of the unknown organisms (or viruses)? What did they evolve from or evolve into? Future confirmation of an unexpected fourth domain of the tree of life could lead to significant new discoveries and hypotheses as did the discovery of Archaea. It could prove to be another example of the open, ever-expanding, and self-correcting nature of science.

For more information, explore the links provided on the Marine Biology *Online Learning Center.*

(NO_3^{-1}) and other nitrogen compounds into which most of the ammonium is transformed (see Table 5.1), can be used as a nitrogen source by primary producers (see "Cycles of Essential Nutrients," p. 226). Other bacteria and some archaea are also known to be nitrogen fixers. Nitrogen fixation requires energy, which is provided by ATP generated from photosynthesis or other reactions.

Some prokaryotes, particularly cyanobacteria, are nitrogen fixers. They convert gaseous nitrogen into ammonium, which is used by primary producers.

UNICELLULAR ALGAE

Algae (singular, **alga**) are a very diverse group of simple, mostly aquatic (that is, marine and freshwater), mostly photosynthetic organisms. Being eukaryotic, their cells contain a nucleus and other organelles enclosed by membranes. Photosynthesis takes place in **chloroplasts**—green, brown, or red organelles with layers of internal membranes that contain photosynthetic pigments (see Fig. 4.8*b*). The color of algae is a result of the pigments and their concentration. In contrast to the land plants with which we are familiar, algae lack flowers and have relatively simple reproductive structures. Their nonreproductive cells are also mostly simple and unspecialized. Algae lack true leaves, stems, and roots.

Biologists used to refer to algae as plants. Many of the unicellular algae, however, show animal-like characteristics. Some swim by moving their flagella, and distinguishing these free-swimming algae from some of the structurally simpler animals can be difficult at first glance. Some species carry out photosynthesis as plants do, and very similar species move and eat food particles as animals do. Some species do both and are claimed by both botanists

ATP The molecule used to store and transfer energy in metabolic reactions.
• Chapter 4, p. 66

Heterotrophs Organisms that cannot make their own food and must use the organic matter produced by autotrophs.
• Chapter 4, p. 67