

## THE ORIGIN OF EUKARYOTIC CELLS

The first cells were most likely very simple prokaryotic forms. Radiometric dating indicates that the earth is 4 to 5 billion years old and that prokaryotes may have arisen more than 3.5 billion years ago. Eukaryotes are thought to have first appeared about 1.5 billion years ago.

The eukaryotic cell might have evolved when a large anaerobic (living without oxygen) amoeboid prokaryote ingested small aerobic (living with oxygen) bacteria and stabilized them instead of digesting them. This idea is known as the **endosymbiont hypothesis** (figure 1a) and was first proposed by Lynn Margulis, a biologist at Boston University. (**Symbiosis** is an intimate association between two organisms of different species.) According to this hypothesis, the aerobic bacteria developed into mitochondria, which are the sites of aerobic respiration and most energy conversion in eukaryotic cells. The possession of these mitochondria-like endosymbionts conferred the advantage of aerobic respiration on the host.

Flagella (whiplike structures) may have arisen through the ingestion of prokaryotes similar to spiral-shaped bacteria called

spirochetes. Ingestion of prokaryotes that resembled present-day cyanobacteria could have led to the endosymbiotic development of chloroplasts in plants.

Another hypothesis for the evolution of eukaryotic cells proposes that the prokaryotic cell membrane invaginated (folded inward) to enclose copies of its genetic material (figure 1b). This invagination resulted in the formation of several double-membrane-bound entities (organelles) in a single cell. These entities could then have evolved into the eukaryotic mitochondrion, nucleus, and chloroplasts.

Although the exact mechanism for the evolution of the eukaryotic cell will never be known with certainty, the emergence of the eukaryotic cell led to a dramatic increase in the complexity and diversity of life-forms on the earth. At first, these newly formed eukaryotic cells existed only by themselves. Later, however, some probably evolved into multicellular organisms in which various cells became specialized into tissues, which, in turn, led to the potential for many different functions. These multicellular forms then adapted to life in a great variety of environments.

**FIGURE 1**  
Two Hypotheses on the Evolution of the Eukaryotic Cell. (a) Endosymbiont hypothesis. (b) Membrane invagination hypothesis. A prokaryotic cell (1) duplicates its genetic material (genome) (2) The plasma membrane then invaginates to form double-membrane-bound organelles, and the individual genomes separate from each other (3) The nuclear genome eventually enlarges, while the other organelle genomes lose many of their genes, resulting in a eukaryotic cell (4) Redrawn from T. Uzzell and C. Spolsky, "Origin of the Eukaryotic Cell," American Scientist 62:334-343, copyright 1974 Sigma Xi, The Scientific Research Society. Used by permission.

