Origin of Eukaryotic Cells

Several important events in the history of life have been revealed through molecular studies of cells and their organelles. One of these events is the origin of eukaryotic cells, which are cells that have nuclei. About 2 billion years ago, prokaryotic cells—cells without nuclei—began evolving internal cell membranes. The result was the ancestor of all eukaryotic cells.

The Endosymbiotic Theory Then, something radical seems to have happened. Other prokaryotic organisms entered this ancestral eukaryote. These organisms did not infect their host, as parasites would have done, and the host did not digest them, as it would have digested prey. Instead, the smaller prokaryotes began living inside the larger cell, as shown in **Figure 17–12.** Over time, a symbiotic, or interdependent, relationship evolved. According to the **endosymbiotic theory,** eukaryotic cells formed from a symbiosis among several different prokaryotic organisms. One group of prokaryotes had the ability to use oxygen to generate energy-rich molecules of ATP. These evolved into the mitochondria that are now in the cells of all multicellular organisms. Other prokaryotes that carried out photosynthesis evolved into the chloroplasts of plants and algae. **The endosymbiotic theory proposes that eukaryotic cells arose from living communities formed by prokaryotic organisms.**

This hypothesis was proposed more than a century ago, when microscopists saw that the membranes of mitochondria and chloroplasts resembled the plasma membranes of free-living prokaryotes. Yet, the endosymbiotic theory did not receive much support until the 1960s, when it was championed by Lynn Margulis of Boston University.

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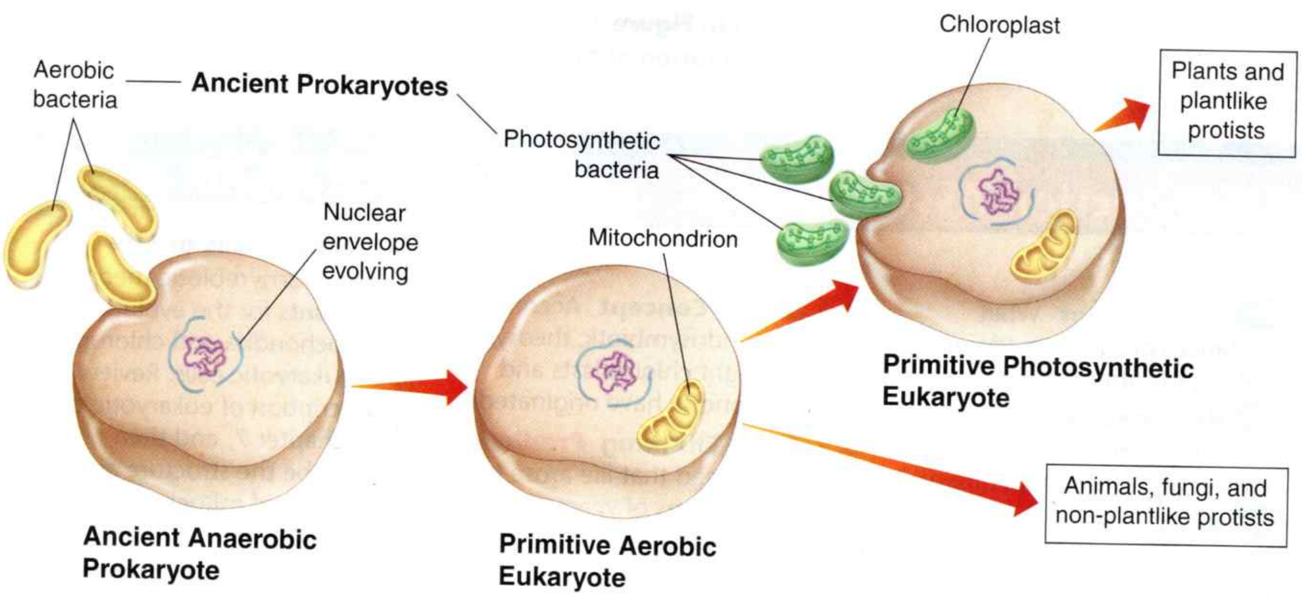
▼ **Figure 17–12 The endosymbiotic theory proposes that eukaryotic cells arose from living communities formed by prokaryotic organisms.** Ancient prokaryotes may have entered primitive eukaryotic cells and remained there as organelles.



▲ **Figure 17–13** This ancient jellyfish, an early multicellular animal from Precambrian Time, did not have bones or other hard parts, but it left behind a fossil that allowed biologists to infer its overall shape. **Observing** *What evidence shows that this organism had body parts arranged around a central point?*

The Evidence Lynn Margulis and her supporters built their argument on several pieces of evidence: First, mitochondria and chloroplasts contain DNA similar to bacterial DNA. Second, mitochondria and chloroplasts have ribosomes whose size and structure closely resemble those of bacteria. Third, like bacteria, mitochondria and chloroplasts reproduce by binary fission when the cells containing them divide by mitosis. Thus, mitochondria and chloroplasts have many of the features of free-living bacteria. These similarities provide strong evidence of a common ancestry between free-living bacteria and the organelles of living eukaryotic cells.

Sexual Reproduction and Multicellularity

Some time after eukaryotic cells arose, those cells began to reproduce sexually. This development enabled evolution to take place at far greater speeds than ever before. How did sexual reproduction speed up the evolutionary process?

Most prokaryotes reproduce asexually. Often, they simply duplicate their genetic material and divide into two new cells. Although this process is efficient, it yields daughter cells that are exact duplicates of the parent cell. This type of reproduction restricts genetic variation to mutations in DNA. Sexual reproduction, on the other hand, shuffles and reshuffles genes in each generation, much like a person shuffling a deck of cards. The offspring of sexually reproducing organisms, therefore, never resemble their parents exactly. By increasing the number of gene combinations, sexual reproduction increases the probability that favorable combinations will be produced. Favorable gene combinations greatly increase the chances of evolutionary change in a species due to natural selection.

A few hundred million years after the evolution of sexual reproduction, evolving life forms crossed another great threshold: the development of multicellular organisms from unicellular organisms. These first multicellular organisms, such as the one shown in **Figure 17–13**, experienced a great increase in diversity. The evolution of life was well on its way.

17–2 Section Assessment

1. **Key Concept** What substances probably made up Earth's early atmosphere?
2. **Key Concept** What molecules were the end products in Miller and Urey's experiments?
3. **Key Concept** How did the addition of oxygen to Earth's atmosphere affect life of that time?
4. **Key Concept** According to the endosymbiotic theory, how might chloroplasts and mitochondria have originated?
5. **Critical Thinking** **Predicting** You just read that life arose from nonlife billions of years ago. Could life arise from nonlife today? Explain.

Focus on the BIG Idea

Cellular Basis of Life
The endosymbiotic theory accounts for the evolution of mitochondria and chloroplasts in eukaryotic cells. Review the description of eukaryotic cells in Chapter 7, and then describe the structure and function of mitochondria and chloroplasts.