

Natural Selection

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8.1 The Origin of Life

How did life originate? We know from fossils that life has existed on Earth for at least 3.5 billion years. This means that the Earth on which life evolved was very different from the Earth of today. It contained vast, lifeless oceans, violent volcanoes, and a turbulent atmosphere filled with lightning storms and incoming meteors (Figure 8.1). The atmosphere of the early Earth included no oxygen, which came later, as a result of the activity of living things. Although this environment seems a hostile place for life today, it may have been appropriate for producing the first life. Why do we think that the early Earth environment could produce life from nonliving materials? A famous experiment suggests exactly this.

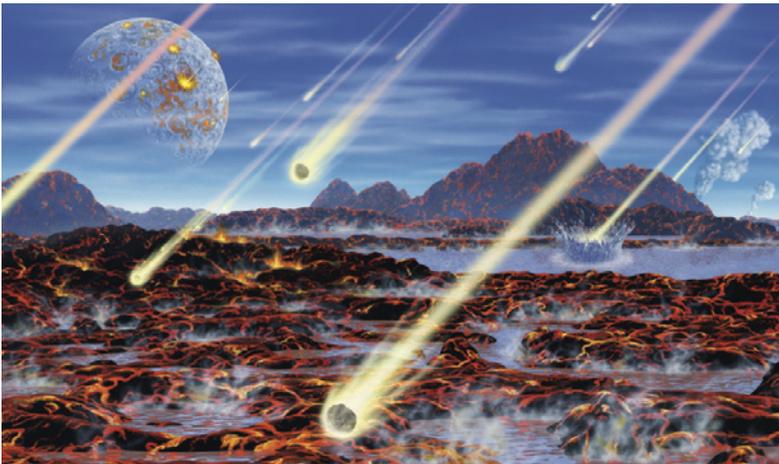
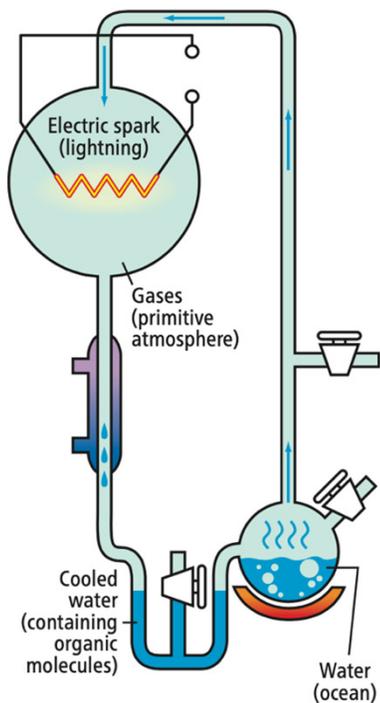


FIGURE 8.1

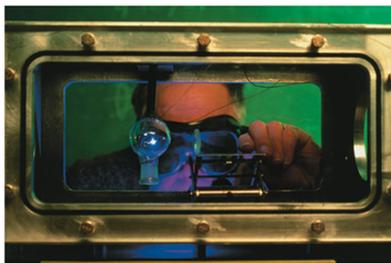
Early Earth was very different from the Earth of today. Volcanoes spewed hot fumes into the atmosphere, and meteors regularly bombarded Earth's surface.

In 1953, Stanley Miller and Harold Urey built a model of the early Earth in a chemistry lab (Figure 8.2). A flask containing a mixture of simple compounds— including water vapor, ammonia, methane, and hydrogen gas—simulated Earth's early atmosphere. Liquid water was added to represent Earth's oceans. Electric sparks sent through the gases simulated lightning. When this model of early Earth was assembled, an amazing thing happened. Many complex organic molecules were formed, including amino acids, the building blocks of proteins. Not only had these molecules formed quickly, but they also formed in huge numbers. Further experiments showed that all the important organic molecules that make up life—not just amino acids but also sugars, lipids, and the nitrogenous bases found in RNA and DNA— can be generated in a similar way.





(a)



(b)

FIGURE 8.2

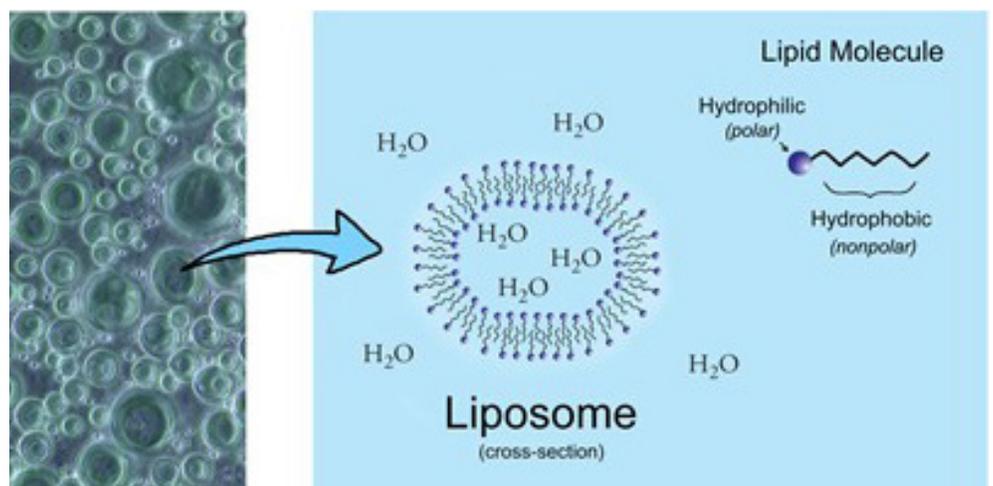
Stanley Miller and Harold Urey built a model of the early Earth and showed that complex organic molecules could be formed during lightning storms. (a) Miller and Urey built a model of Earth's early atmosphere and oceans. (b) A scientist repeats Miller and Urey's experiment.

However, some scientists today question the importance of the Miller–Urey experiment. They think that Earth's early atmosphere was actually quite different from the model atmosphere Miller and Urey used and that organic molecules may not have been so easy to generate. These scientists have proposed two other hypotheses for how Earth got its first organic building blocks. One hypothesis is that organic molecules were brought to Earth by meteorites. Earth was steadily bombarded by meteorites during its early history, and some of the meteorites recovered here do in fact contain a wide variety of complex organic molecules, presumably formed in outer space. For example, a meteorite found in Australia in 1969 contained nearly one hundred different amino acids. A second hypothesis is that large numbers of organic molecules were formed in deep-sea environments on Earth, similar to the hydrothermal vent habitats of today.

The next question is how these many separate organic molecules advance to become living cells. Scientists do not know the entire story, but they have discovered some clues. For example, when certain lipids are added to water, for reasons easily explained by chemistry, they spontaneously form tiny hollow spheres called liposomes. Liposomes have double membranes similar to cell membranes. Although they are not alive, liposomes sometimes behave like living cells—they grow, shrink, and divide (Figure 8.3). Liposomes also run chemical reactions inside their membranes and control what molecules move into and out of them, two key features of living cells.

FIGURE 8.3

A liposome is a spherical organization of lipid molecules. Hydrophobic regions of each lipid molecule are sandwiched between the hydrophilic regions forming a bilayer membrane that encapsulates an interior of water. Liposomes show some cell-like behaviors. Some of these liposomes (shown left) are growing and dividing.



Some liposomes may have eventually captured nucleic acids—that is, primitive genes. These early genes were probably made of RNA, not DNA. This is because, even in the absence of cells and enzymes, short strands of RNA can spontaneously assemble from individual nucleotides and even reproduce themselves. With a few more changes, RNA-containing liposomes may have become the very first cells—the first organisms on Earth. However it occurred, the transition to living cells was complete by 3.5 billion years ago, the time of the earliest known fossil organisms. Figure 8.4 shows some bacteria fossils from early in the history of life.



FIGURE 8.4

Ancient fossils of bacteria show that life has existed on Earth for a long time. This fossil stromatolite, left by mats of photosynthetic bacteria, is 2.72 billion years old.

READING CHECK

1. **Miller and Urey found that organic molecules are easily formed in large quantities from nonorganic materials. But why do some scientists question the importance of their experiment?**

CHECK YOUR ANSWER

1. Some scientists think that the conditions on early Earth were different from what Miller and Urey modeled. Specifically, they think the composition of gases in Earth's atmosphere was different from what Miller and Urey assumed.

For more on meteorites, the Miller-Urey experiment, and more, see:

<https://www.pbs.org/exploringspace/meteorites/murchison/index.html>

