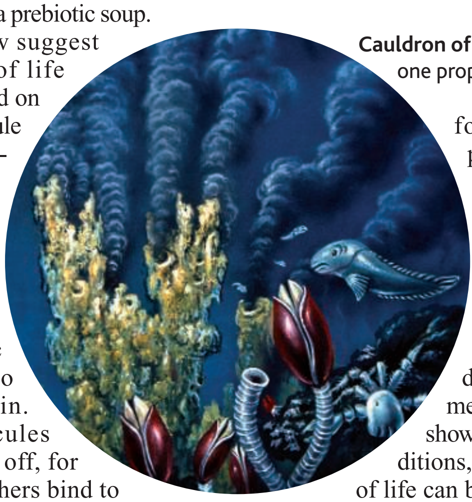
Special Section

# How and Where Did Life on Earth Arise

For the past 50 years, scientists have attacked the question of how life began in a pincer movement. Some approach it from the present, moving backward in time from life today to its simpler ancestors. Others march forward from the formation of Earth 4.55 billion years ago, exploring how lifeless chemicals might have become organized into living matter.

Working backward, paleontologists have found fossils of microbes dating back at least 3.4 billion years. Chemical analysis of even older rocks suggests that photosynthetic organisms were already well established on Earth by 3.7 billion years ago. Researchers suspect that the organisms that left these traces shared the same basic traits found in all life today. All free-living organisms encode genetic information in DNA and catalyze chemical reactions using proteins. Because DNA and proteins depend so intimately on each other for their survival, it's hard to imagine one of them having evolved first. But it's just as implausible for them to have emerged simultaneously out of a prebiotic soup.

Experiments now suggest that earlier forms of life could have been based on a third kind of molecule found in today's organisms: RNA. Once considered nothing more than a cellular courier, RNA turns out to be astonishingly versatile, not only encoding genetic information but also acting like a protein. Some RNA molecules switch genes on and off, for example, whereas others bind to proteins and other molecules. Laboratory experiments suggest that RNA could have replicated itself and carried out the other functions required to keep a primitive cell alive.



Cauldron of life? Deep-sea vents are one proposed site for life's start.

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Only after life passed through this "RNA world," many scientists now agree, did it take on a more familiar cast. Proteins are thousands of times more efficient as a catalyst than RNA is, and so once they emerged they would have been favored by natural selection. Likewise, genetic information can be replicated from DNA with far fewer errors than it can from RNA.

Other scientists have focused their efforts on figuring out how the lifeless chemistry of a prebiotic Earth could have given rise to an RNA world. In 1953, working at the University of Chicago, Stanley Miller and Harold Urey demonstrated that experiments could shed light on this question. They ran an electric current through a mix of ammonia, methane, and other gases believed at the time to have been present on early Earth. They found that they could produce amino acids and other important building blocks of life.

Today, many scientists argue that the early atmosphere was dominated by other gases, such as carbon dioxide. But experiments in recent years have shown that under these conditions, many building blocks of life can be formed. In addition, comets and meteorites may have delivered organic compounds from space.

Just where on Earth these building blocks came together as primitive life forms is a subject of debate. Starting in the 1980s, many scientists argued that life got its start in the scalding, mineral-rich waters streaming out of deep-sea hydrothermal vents. Evidence for a hot start included studies on the tree of life, which suggested that the most primitive species of microbes alive today thrive in hot water. But the hot-start hypothesis has cooled off a bit. Recent studies suggest that heat-loving microbes are not living fossils. Instead, they may have descended from less hardy species and evolved new defenses against heat. Some skeptics also wonder how delicate RNA molecules could have survived in boiling water. No single strong hypothesis has taken the hot start's place, however, although suggestions include tidal pools or oceans covered by glaciers.

Research projects now under way may shed more light on how life began. Scientists are running experiments in which RNA-based cells may be able to reproduce and evolve. NASA and the European Space Agency have launched probes that will visit comets, narrowing down the possible ingredients that might have been showered on early Earth.

Most exciting of all is the possibility of finding signs of life on Mars. Recent missions to Mars have provided strong evidence that shallow seas of liquid water once existed on the Red Planet—suggesting that Mars might once have been hospitable to life. Future Mars missions will look for signs of life hiding in underground refuges, or fossils of extinct creatures. If life does turn up, the discovery could mean that life arose independently on both planets—suggesting that it is common in the universe—or that it arose on one planet and spread to the other. Perhaps martian microbes were carried to Earth on a meteorite 4 billion years ago, infecting our sterile planet.

–CARL ZIMMER

Carl Zimmer is the author of *Soul Made Flesh: The Discovery of the Brain—and How it Changed the World.*

**How do organs and whole organisms know when to stop growing?**
A person's right and left legs almost always end up the same length, and the hearts of mice and elephants each fit the proper rib cage. How genes set limits on cell size and number continues to mystify.

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**How is asymmetry determined in the embryo?**
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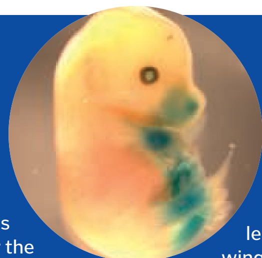

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