

SCIENCE

# Meet Luca, the Ancestor of All Living Things

By NICHOLAS WADE JULY 25, 2016

A surprisingly specific genetic portrait of the ancestor of all living things has been generated by scientists who say that the likeness sheds considerable light on the mystery of how life first emerged on Earth.

This venerable ancestor was a single-cell, bacterium-like organism. But it has a grand name, or at least an acronym. It is known as Luca, the Last Universal Common Ancestor, and is estimated to have lived some four billion years ago, when Earth was a mere 560 million years old.

The new finding sharpens the debate between those who believe life began in some extreme environment, such as in deep sea vents or the flanks of volcanoes, and others who favor more normal settings, such as the “warm little pond” proposed by Darwin.

The nature of the earliest ancestor of all living things has long been uncertain because the three great domains of life seemed to have no common point of origin. The domains are those of the bacteria, the archaea and the eukaryotes. Archaea are bacteria-like organisms but with a different metabolism, and the eukaryotes include all plants and animals.

Specialists have recently come to believe that the bacteria and archaea were the two earliest domains, with the eukaryotes emerging later. That opened the way for a group of evolutionary biologists, led by William F. Martin of Heinrich Heine University in Düsseldorf, Germany, to try to discern the nature of the organism from which the bacterial and archaeal domains emerged.

Their starting point was the known protein-coding genes of bacteria and archaea. Some six million such genes have accumulated over the last 20 years in DNA databanks as scientists with the new decoding machines have deposited gene sequences from thousands of microbes.

Genes that do the same thing in a human and a mouse are generally related by common descent from an ancestral gene in the first mammal. So by comparing their sequence of DNA letters, genes can be arranged in evolutionary family trees, a property that enabled Dr. Martin and his colleagues to assign the six million genes to a much smaller number of gene families. Of these, only 355 met their criteria for having probably originated in Luca, the joint ancestor of bacteria and archaea.

Genes are adapted to an organism’s environment. So Dr. Martin hoped that by pinpointing the genes likely to have been present in Luca, he would also get a glimpse of where and how Luca lived. “I was flabbergasted at the result, I couldn’t believe it,” he said.

The 355 genes pointed quite precisely to an organism that lived in the conditions found in deep sea vents, the gassy, metal-laden, intensely hot plumes caused by seawater interacting with magma erupting through the ocean floor.

Deep sea vents are surrounded by exotic life-forms and, with their extreme chemistry, have long seemed places where life might have originated. The 355 genes ascribable to Luca include some that metabolize hydrogen as a source of energy as well as a gene for an enzyme called reverse gyrase, found only in microbes that live at extremely high temperatures, **Dr. Martin and colleagues reported Monday in Nature Microbiology.**

The finding has “significantly advanced our understanding of what Luca did for a living,” James O. McInerney of the University of Manchester wrote in a commentary, and provides “a very intriguing insight into life four billion years ago.”

Dr. Martin’s portrait of Luca seems likely to be widely admired. But he has taken a further step that has provoked considerable controversy. He argues that Luca is very close to the origin of life itself. The organism is missing so many genes necessary for life that it must still have been relying on chemical components from its environment. Hence it was only “half alive,” he writes.

The fact that Luca depended on hydrogen and metals favors a deep sea vent environment for the origin of life, Dr. Martin concludes, rather than the land environment posited in a leading rival theory proposed by the chemist John Sutherland of the University of Cambridge in England.

Others believe that the Luca that Dr. Martin describes was already a highly sophisticated organism that had evolved far beyond the origin of life, meaning the formation of living systems from the chemicals present on the early Earth.

Luca and the origin of life are “events separated by a vast distance of evolutionary innovation,” said Jack Szostak of Massachusetts General Hospital, who has studied how the first cell membranes might have evolved.

From Dr. Martin’s data, it is clear that Luca could manage the complicated task of synthesizing proteins. So it seems unlikely that it could not also synthesize simpler components, even though the genes for doing so have not yet been detected, said Steven A. Benner of the Foundation for Applied Molecular Evolution. “It’s like saying you can build a 747 but can’t refine iron.”

Dr. Sutherland too gave little credence to the argument that Luca might lie in some gray transition zone between nonlife and life just because it depended on its environment for some essential components. “It’s like saying I’m half alive because I depend on my local supermarket.”

Dr. Sutherland and others have no quarrel with Luca’s being traced back to deep sea vents. But that does not mean life originated there, they say. Life could have originated anywhere and later been confined to a deep sea environment because of some catastrophic event like the Late Heavy Bombardment, which occurred 4 billion to 3.8 billion years ago. This was a rain of meteorites that crashed into Earth with such force that the oceans were boiled off into an incandescent mist.

Life is so complex it seems to need many millions of years to evolve. Yet evidence for the earliest life dates to 3.8 billion years ago, as if it emerged almost the minute the bombardment ceased. A refuge in the deep ocean during the bombardment would allow a longer period in which life could have evolved. But chemists like Dr. Sutherland say they are uneasy about getting prebiotic chemistry to work in an ocean, which powerfully dilutes chemical components before they can assemble into the complex molecules of life.

Dr. Sutherland, working from basic principles of chemistry, has found that ultraviolet light from the sun is an essential energy source to get the right reactions underway, and therefore that land-based pools, not the ocean, are the most likely environment in which life began.

“We didn’t set out with a preferred scenario; we deduced the scenario from the chemistry,” he said, chiding Dr. Martin for not having done any chemical simulations to support the deep sea vent scenario.

Dr. Martin’s portrait of Luca “is all very interesting, but it has nothing to do with the actual origin of life,” Dr. Sutherland said.

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