Last universal common ancestor more complex than previously thought

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Scientists call it LUCA, the Last Universal Common Ancestor, but they don't know much about this great-grandparent of all living things. Many believe LUCA was little more than a crude assemblage of molecular parts, a chemical soup out of which evolution gradually constructed more complex forms. Some scientists still debate whether it was even a cell.

New evidence suggests that LUCA was a sophisticated organism after all, with a complex structure recognizable as a cell, researchers report. Their study appears in the journal *Biology Direct.*

The study builds on several years of research into a once-overlooked feature of microbial cells, a region with a high concentration of polyphosphate, a type of energy currency in cells. Researchers report that this polyphosphate storage site actually represents the first known universal organelle, a structure once thought to be absent from bacteria and their distantly related microbial cousins, the archaea. This organelle, the evidence indicates, is present in the three domains of life: bacteria, archaea and eukaryotes (plants, animals, fungi, algae and everything else).

The existence of an organelle in bacteria goes against the traditional definition of these organisms, said University of Illinois crop sciences professor Manfredo Seufferheld, who led the study.

"It was a dogma of microbiology that organelles weren't present in

bacteria," he said. But in 2003 in a paper in the *Journal of Biological Chemistry*, Seufferheld and colleagues showed that the polyphosphate storage structure in bacteria (they analyzed an agrobacterium) was physically, chemically and functionally the same as an organelle called an acidocalcisome (uh-SID-oh-KAL-sih-zohm) found in many single-celled eukaryotes.

Their findings, the authors wrote, "suggest that acidocalcisomes arose before the prokaryotic (bacterial) and eukaryotic lineages diverged." The new study suggests that the origins of the organelle are even more ancient.

The study tracks the evolutionary history of a protein enzyme (called a vacuolar proton pyrophosphatase, or V-H+PPase) that is common in the acidocalcisomes of eukaryotic and bacterial cells. (Archaea also contain the enzyme and a structure with the same physical and chemical properties as an acidocalcisome, the researchers report.)

By comparing the sequences of the V-H+PPase genes from hundreds of organisms representing the three domains of life, the team constructed a "family tree" that showed how different versions of the enzyme in different organisms were related. That tree was similar in broad detail to the universal tree of life created from an analysis of hundreds of genes. This indicates, the researchers said, that the V-H+PPase enzyme and the acidocalcisome it serves are very ancient, dating back to the LUCA, before the three main branches of the tree of life appeared.

"There are many possible scenarios that could explain this, but the best, the most parsimonious, the most likely would be that you had already the enzyme even before diversification started on Earth," said study co-author Gustavo Caetano-Anollés, a professor of crop sciences and an affiliate of the Institute for Genomic Biology at Illinois. "The protein was there to begin with and was then inherited into all emerging

lineages."

"This is the only organelle to our knowledge now that is common to eukaryotes, that is common to bacteria and that is most likely common to archaea," Seufferheld said. "It is the only one that is universal."

The study lends support to a hypothesis that LUCA may have been more complex even than the simplest organisms alive today, said James Whitfield, a professor of entomology at Illinois and a co-author on the study.

"You can't assume that the whole story of life is just building and assembling things," Whitfield said. "Some have argued that the reason that bacteria are so simple is because they have to live in extreme environments and they have to reproduce extremely quickly. So they may actually be reduced versions of what was there originally. According to this view, they've become streamlined genetically and structurally from what they originally were like. We may have underestimated how complex this common ancestor actually was."

More information: "Evolution of Vacuolar Proton Pyrophosphatase Domains and Volutin Granules: Clues Into the Early Evolutionary Origin of the Acidocalcisomes," *Biology Direct.*

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