Major insights into evolution of life reported

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Molecular biologist James A. Lake from the University of California at Los Angeles' Center for Astrobiology.

(PhysOrg.com) -- Humans might not be walking the face of the Earth were it not for the ancient fusing of two prokaryotes -- tiny life forms that do not have a cellular nucleus. UCLA molecular biologist James A. Lake reports important new insights about prokaryotes and the evolution of life in the Aug. 20 advance online edition of the journal *Nature*.

Endosymbiosis refers to a cell living within another cell. If the cells live together long enough, they will exchange genes; they merge but often keep their own cell membranes and sometimes their own genomes.

Lake has discovered the first exclusively prokaryote endosymbiosis. All other known endosymbioses have involved a eukaryote — a cell that contains a nucleus. Eukaryotes are found in all multicellular forms of life, including humans, animals and plants.

"This relationship resulted in a totally different type of life on Earth," said Lake, a UCLA distinguished professor of molecular, cell and developmental biology and of human genetics. "We thought eukaryotes always needed to be present to do it, but we were wrong."

In the *Nature* paper, Lake reports that two groups of prokaryotes — actinobacteria and clostridia — came together and produced "double-membrane" prokaryotes.

"Higher life would not have happened without this event," Lake said. "These are very important organisms. At the time these two early prokaryotes were evolving, there was no oxygen in the Earth's atmosphere. Humans could not live. No oxygen-breathing organisms could live."

The oxygen on the Earth is the result of a subgroup of these double-membrane prokaryotes, Lake said. This subgroup, the cyanobacteria, used the sun's energy to produce oxygen through photosynthesis. They have been tremendously productive, pumping oxygen into the atmosphere; we could not breathe without them. In addition, the double-membrane prokaryotic fusion supplied the mitochondria that are present in every human cell, he said.

"This work is a major advance in our understanding of how a group of organisms came to be that learned to harness the sun and then effected the greatest environmental change the Earth has ever seen, in this case with beneficial results," said Carl Pilcher, director of the NASA Astrobiology Institute, headquartered at the NASA Ames Research Center in Moffett Field, Calif., which co-funded the study with the National Science Foundation.

"Along came these organisms — the double-membrane prokaryotes — that could use sunlight," Lake said. "They captured this vast energy resource. They were so successful that they have more genetic diversity in them than all other prokaryotes.

"We have a flow of genes from two different organisms, clostridia and actinobacteria, together," he said. "Because the group into which they are flowing has two membranes, we hypothesize that that was an endosymbiosis that resulted in a double membrane. It looks as if a single-membrane organism has engulfed another. The genomes are telling us that the double-membrane prokaryotes combine sets of genes from the two different organisms."

For this study, Lake has looked back more than 2.5 billion years. He conducted an analysis of the genomics of the five groups of prokaryotes.

Lake is interested in learning how every organism is related.

"We all are interested in our ancestors," he said. "A friend at UC Berkeley, Alan Wilson, was the first person to collect DNA from large numbers of people around the world. He showed that we are all related to a woman who lived in Africa 200,000 years ago. Some in the media called her Eve. He called her the Lucky Mother, the mother of us all.

"In our field, we have enormous amounts of data but cannot make sense of it all. Endosymbiosis allows us to start to understanding things; it tells us that many genes are exchanged.

"We have been overlooking how important cooperation is," Lake said. "If two prokaryotes get together, they can change the world. They restructured the atmosphere of the Earth. It's a message that evolution is giving us: Cooperation is a way to get ahead."

Actinobacteria have an unusual DNA composition, with a very high amount of "G" and "C" nucleotides — chemicals whose patterns carry the data required for constructing proteins. Nucleotides are designated by the letters G (guanine), C (cytosine), A (adenine) and T (thymine); the sequence of nucleotides serves as a chemical code.

Some actinobacteria are pathogens, including ones that cause tuberculosis and leprosy. Some clostridia can photosynthesize, which no other single-membrane prokaryote does. Photosynthesis may have been developed in clostridia.

Double-membrane prokaryotes include the pathogens that cause ulcers, as well as the organisms that led to the creation of the chloroplasts that are in all green plants and which make plant growth possible.

Source: University of California - Los Angeles