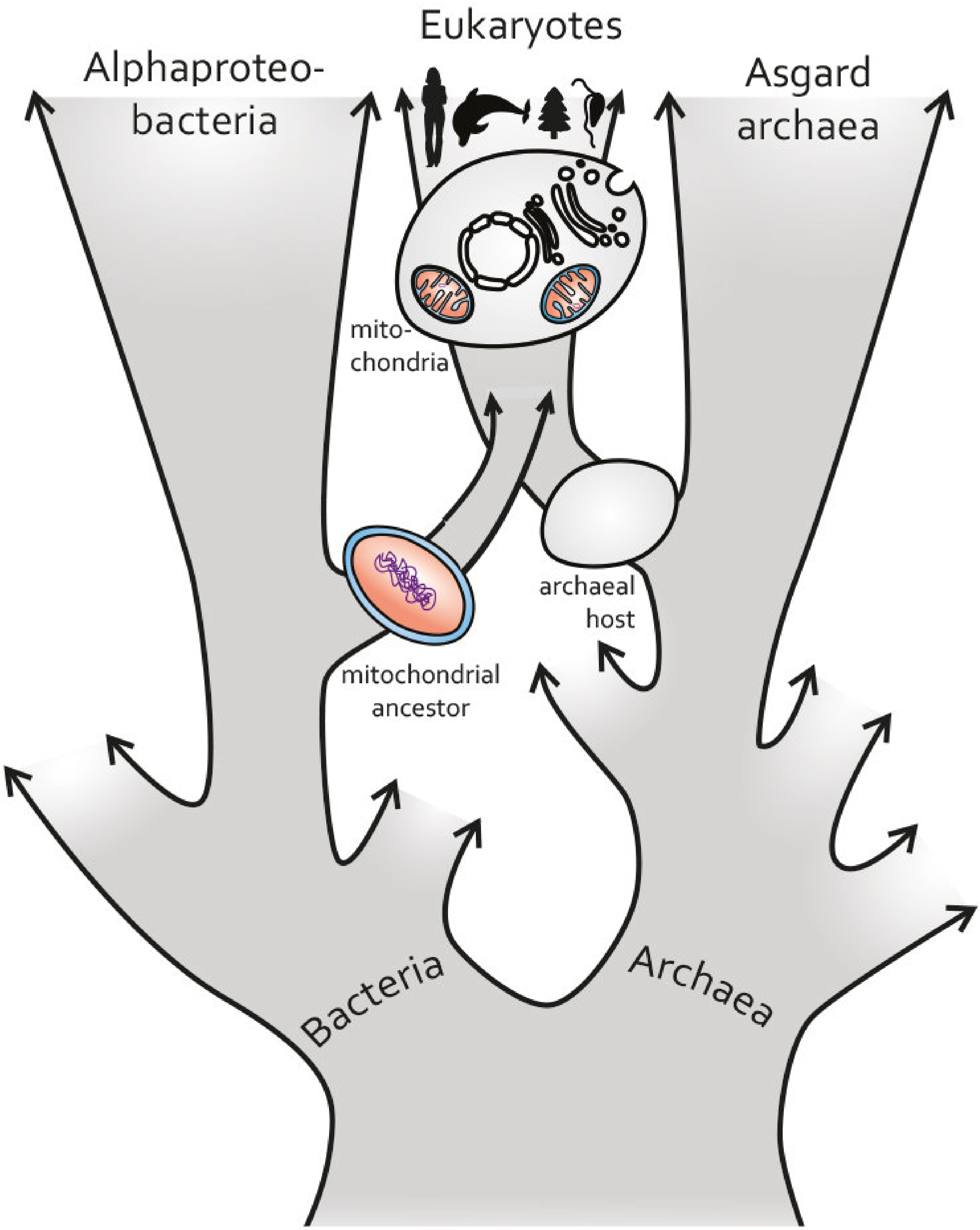
Researchers redefine the origin of the cellular powerhouse

April 25 2018



The bacterial ancestor of mitochondria diverged from the Alphaproteobacteria prior to their diversification and at some point engaged in endosymbiosis with an archaeal host cell related to the Asgard archaea. From their 'union', complex, eukaryotic cells as we know them emerge. Credit: Joran Martijn, Uppsala University.

In a new study published by *Nature*, an international team of researchers led by Uppsala University in Sweden proposes a new evolutionary origin for mitochondria—also known as the "powerhouse of the cell." Mitochondria are energy-converting organelles that have played key roles in the emergence of complex cellular life on Earth.

Mitochondria are essential organelles that are best known for the energy conversion reactions that fuel cells. Mitochondria represent important hallmarks of eukaryotic cells—these comprise all complex cell types, including animals, plants, fungi, and so on—essentially all multicellular organisms. The fact that all eukaryotic cells have (or once had) mitochondria indicates that the origin of these organelles likely played a profound role in the evolutionary emergence of complex eukaryotic cells. Evidence from the past few decades strongly supports that mitochondria evolved via endosymbiosis, a process in which a free-living bacterium is taken up by a host cell. Yet, the identity of the mitochondrial ancestor, as well as the nature of the endosymbiosis, are subjects of fierce debates.

"Previous work has provided strong evidence that mitochondria are related to a bacterial group known as the Alphaproteobacteria," says Joran Martijn, postdoctoral researcher at Uppsala University and first author of the study. "From which alphaproteobacterial lineage mitochondria evolved is still unclear—different studies have pointed to radically different alphaproteobacterial groups. For understanding the origin of mitochondria, but also that of eukaryotes, knowing the identity of the mitochondrial ancestor is crucial."

Some scientists have proposed that mitochondria evolved from the Rickettsiales, a parasitic group of bacteria that, like mitochondria, live inside eukaryotic cells and are generally completely dependent on their host cell for survival. Its most renowned member, Rickettsia prowazekii, is a notorious human pathogen that causes typhus.

"We believe that there are two main reasons for the lack of consensus on the identity of the mitochondrial ancestor," says Thijs Ettema, researcher at the Department of Cell and Molecular Biology at Uppsala University, who led the team conducting the study. "First, it is possible that present-day relatives simply have not been found yet—if they even still exist. Second, the reconstruction of the evolutionary history of the mitochondria is extremely challenging, and can easily lead to very different and hence conflicting results."

The Uppsala team tried to tackle this impasse by employing a bold approach. By analysing large amounts of environmental sequencing data from the Pacific and the Atlantic Ocean, they managed to identify several previously unidentified alphaproteobacterial groups. Using newly developed methods, the team then managed to reconstruct the genomes of over 40 alphaproteobacteria, belonging to 12 different groups.

"The expanded set genomes of these newly identified alphaproteobacteria substantially helped our efforts to pinpoint the position of mitochondria," says Martijn. "We hoped that by using a more balanced set of alphaproteobacteria in our analyses, we could overcome some of the problems that previous studies were struggling with."

Unexpectedly, their analyses supported a new position of mitochondria, which were now placed outside of the Alphaproteobacteria.

These results indicate that mitochondria are not the closest relatives to any of the currently recognized alphaproteobacterial groups, including the Rickettsiales. Rather, the mitochondria evolved from an ancestor which later gave rise to all currently recognized Alphaproteobacteria.

"We suspect that the popular Rickettsiales-related ancestry of mitochondria is the result of a methodological artefact." explains Martijn. "Mitochondria and Rickettsiales have evolved under very similar conditions, which could have resulted in very similar but independent modes of evolution and sequence patterns. This in turn may have complicated previous efforts to determine the evolutionary origin of mitochondria."

The study failed to identify any present-day relatives of the mitochondrial ancestor.

"This was somewhat disappointing of course," says Ettema. "But perhaps we have been looking in the wrong place. In this study, we focused on oceanic waters as these were known to contain a multitude of uncharacterised alphaproteobacteria."

Ettema and his team will continue their quest for mitochondrial relatives. "Unravelling the origin of mitochondria is key to understanding the origin of complex life. If modern mitochondrial relatives still exist, I am convinced we will find them at some point."

More information: Joran Martijn et al, Deep mitochondrial origin outside the sampled alphaproteobacteria, *Nature* (2018). DOI: 10.1038/s41586-018-0059-5

Provided by Uppsala University

27 April 2024 from https://phys.org/news/2018-04-redefine-cellular-powerhouse.html