**The Origin of Mitochondria in Eukaryotic Cells** Author: Alix Paulsen
Major: Microbiology
Department of Microbiology and Molecular Genetics, Oklahoma State University, Stillwater, OK 74078, USA

**Key Words:**

Mitochondria, Eukaryotic cells, Eukaryogenesis

 **For a long time, it has been understood that mitochondria in eukaryotic cells did not originate in the cells but are the product of an ancestor engulfing and incorporating early mitochondria into the cell. However, no one has truly determined when the mitochondria was engulfed, or whether the mitochondria was acquired before or after the cell became complex. To get a proper timeline of eukaryogenesis and how the processes in the cell came to function the way that they do, mitochondria becoming an endosymbiont of the cell is essential. If the cell was already complex before the mitochondria arrived in the cell, then the mitochondria might not have had a large impact on how eukaryotic cells work now, but if it arrived early, then mitochondria might contribute greatly to cellular processes. In a recent study, more evidence was discovered that seems to point towards the cell incorporating the mitochondria after it had already become a complex cell in its own right. The data the study resulted in suggests that mitochondria might not have impacted eukaryotic cell development to the extent it might have, if it was introduced sooner.**

**Introduction**

Mitochondria are organelles within cells where cellular respiration and ATP synthesis occurs. They contain their own genome independently of the cell and replicate within the cell on their own. This has led scientists to wonder where exactly mitochondria came from, if they did not originate in the cell. Mitochondria play a huge role in the cell, making it possible for the cell to function. Understanding when mitochondria was integrated into the cell allows more insight into how the cell functions, and exactly what role the mitochondria played in making the cell what it is today. There have also been studies that support the idea that the mitochondria, as it has its own genome, can cause disease in people and may have something to do with some genetic disorder. Just like any other set of DNA, it is possible for a disruption in the mitochondrial DNA to change many things in the cell and how it functions [1]. The diagnosis of these disorders can be very difficult, and for that reason, it could be advantageous to learn more about how the mitochondria works within the cell and how much it affects the cell.

**Recent Progress**

More recently, there has been an in depth study into just when the eukaryotic cell acquired mitochondria. Trying to determine when the mitochondria appeared, researchers tried grouping eukaryotic cells in different manners and then checking to see just how close evolutionarily the groups were to the last eukaryotic common ancestor, or LECA for short. If one group was closer to the last eukaryotic common ancestor than another group, then the first group would be closer to LECA on a timeline [2]. A solid timeline would greatly aid with pinning down exactly when mitochondria appeared in the cells. The results of their first test showed that cells with bacterial origins were more closely related to the last eukaryotic common ancestor, and archaeal and actinobacterial origins of cells were less related. Mitochondrial proteins and families involved in metabolic processes were shown to also be more closely related to LECA [2]. LECA families seemed to be more associated with endomembrane related compartments, and alphaproteobacterial-derived genes were associated with mitochondria. Alphaproteobacterial-derived families, however, were not considered closely related to LECA. This means that LECA cannot be bacterial because of an alphaproteobacterial endosymbiont. If this were the case, the two would be much more closely related than they are. The implications of this are that LECA acquired bacterial traits before it encountered the alphaproteobacterial endosymbiont, and because the alphaproteobacterial endosymbiont is closely related to mitochondria, LECA must have already had bacterial traits before it got mitochondria. This means that LECA was much more complex before the incorporation of mitochondria into the cell and places the absorption of the mitochondria later in the process of eukaryogenesis. This new research seems to support more of a later mitochondria incorporation, even saying that mitochondria likely became an endosymbiont of cells towards the end of the process that eventually led to current eukaryotic cells. In these eukaryotic cells, there have also been several disorders that have been attributed to mutations in the mitochondrial DNA. They are hard to diagnose, but once it has been correctly attributed to mitochondrial DNA, it helps only slightly. There isn’t any exact way to treat a mutation in the genome of the mitochondria, but complications can be treated. Some attempts have been made to find a way to correct mutated mitochondrial DNA, such as adding synthetic wild-type mitochondrial DNA into cells or removing the mutated mitochondrial DNA altogether. Adding DNA has not been successful, and removing the mutated DNA is proving much more difficult than expected. It is possible, eventually, to correct these mutations and disorders, but it might not be very practical [2]. To do it, the process would have to happen in early development, before anything too permanent can occur. For something to be done this early would be difficult and not something that can happen as of now.

**Discussion**

The idea that mitochondria was introduced into the cell late into the process of eukayogenesis seems to be supported by the data that the new research has uncovered, but it hardly seems like anything very solid. It is very possible that the researchers are correct and that mitochondria did arrive late in the process, but with mitochondria playing such an important role in cell functions, including cellular respiration and the synthesis of most of the energy in the cell, it seems somewhat unlikely that eukaryogenesis was almost completed by the time mitochondria became an endosymbiont of the cell. If mitochondria did arrive later in the timeline, then the incorporation of it into the cell’s processes would have to have changed a good deal of what was already in place. If the mitochondria became so integrated into cellular processes in the eukaryotic cell, it would make more sense for it to have been present for more than just the very end of eukaryogenesis. However, because the research seems to point very strongly in the direction of mitochondria arriving towards the very end of eukaryogenesis, then it should be considered, researched, and looked into more. If more research data can point in the direction that this new data does convincingly, then it is very possible that mitochondria was incorporated into cells that were already almost eukaryotic. As for the research on mutations of the mitochondrial DNA, learning more about the mitochondria seems important before any new and definitive research can be made into correcting the mutations. Nothing seemed to answer the question of how to solve the problem, but there were theories proposed to solve the problems one day, when more research into the mitochondria has been completed. These results seem inconclusive, but they have promise. If more could be understood about when mitochondria came into the cell and how exactly it impacts cellular processes within the cell, then it might become more possible to correct anything wrong with the mitochondrial DNA. It seems that mitochondria needs to be understood better from the base of how it originated. If this were done, more could be done for individuals with disorders with mitochondria. With this new research, it seems that more information is coming to light about just how and when the mitochondria came to be working inside the eukaryotic cell.

**References**

Chinnery, P. F., Schon, E. A. 2003. Mitochondria. Journal of Neurology, Neurosurgery & Psychiatry. Volume 74.

Gabaldón, Toni, Pittis, Alexandros A. 2016. Late acquisition of mitochondria by a host with chimaeric prokaryotic ancestry. Nature.