

Microreviews in Cell and Molecular Biology

Endosymbiosis, a Proven Theory or Evolution Myth?

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The Endosymbiotic theory is a theory that explains the evolution of the mitochondria and chloroplast, which are organelles of eukaryotic cells. This theory originated at the end of the 1800s by Andreas Schimper, and later published by Lynn Margulis in the 1960's in her book "Symbiosis in Cell Evolution." According to this theory, these organelles originated as separate prokaryotic organisms, which were taken inside the cell as endosymbionts. Theory states that Mitochondria developed from proteobacteria (in particular, Rickettsiales or close relatives) and chloroplasts from cyanobacteria. There has been much debate about this theory and many questions have emerged because of it.. Is it truly possible for simple prokaryotes to evolve and also succeed as a complex eukaryote?

Introduction

Konstantin Mereschkowsky first suggested that plastids were originally endosymbionts in 1905- the same idea for mitochondria was suggested by Ivan Wallin in the 1920s. These theories were initially dismissed on the assumption that they did not contain DNA. This was proven false in the 1960s, leading Hans Ris to resurrect the idea.

Endosymbiosis is a debate that has been widely accepted in the molecular biology world. The theory of endosymbiosis is a concept that mitochondria and chloroplasts are the result of numerous decades of evolution. This evolution was initiated by endocytosis of bacteria and blue green algae. This is possible because of the idea that instead of the bacteria becoming digested, the two bacteria became symbiotic (1). As early as 1890, German cell biologist Richard Altmann proposed that the mitochondrion was an autonomous form of life, which coincides with the understanding of bacteria (4).

Some proteins encoded in the nucleus are transported to the organelle, and both mitochondria and plastids have small genomes compared to bacteria. This is consistent with an increased dependence on the eukaryotic host after forming an endosymbiosis. Most genes on the organelle genomes have been lost or moved to the nucleus. Most genes needed for mitochondrial and plastid functions are

located in the nucleus. Many originate from the bacterial endosymbiont.

Recent Progress

Interest in this theory of mitochondria evolution was retouched once scientists discovered that mitochondria have their own genomes. Finding that they do not follow the Mendelian rules, and are able to synthesize their own proteins. Similarities have also been found between mitochondrion proteins and the proteins that were found through phylogenetic processes. These findings suggest that the endosymbionts that lead way for the mitochondria must have been related to an organism similar to that of alpha-proteobacteria (2). Both mitochondria and plastids contain DNA that is fairly different from that of the cell nucleus and that is similar to that of bacteria (in being circular and in size). Two or more membranes surround the mitochondria and chloroplasts organelles, and the innermost of these membranes displays differences in composition, compared to the other membranes in the cell. The composition is like that of a prokaryotic cell membrane.

These renewals of interest lead to the "seminal reformation" of the endosymbiosis theory by Lynn Margulis. This second idea of the theory suggests that a bacterial endosymbiont had established one's self into a prokaryotic cell and became the powerhouse of the cell,

or in other terms the mitochondrion. Schwartz and Dayhoff (1978) used the process of phylogenetic analysis to find the cytochromes that were mitochondrial-encoded were of the same nature as alpha-proteobacteria. Alpha- and Beta- Proteobacteria clearly indicated that the alpha-proteobacteria nature of mitochondrion RNA compared relatively well with the eukaryotic cell's mitochondria 16S ribosomal RNA (2). This theory also indicates that the eukaryotic itself evolved from numerous prokaryotic precursors (4).

In addition to the factors that attempt to prove this theory correct, there are also some elements that lie against the Endosymbiotic theory. For example, the mitochondria and chloroplast both as separate organelles only code for a few proteins. In addition, most of the proteins that are found within these organelles are coded for by the nuclear DNA (1). This statement helps understand why both a chloroplast and mitochondria are able to live independently outside the barrier and when completely isolated from a eukaryotic cell. Mitochondria are believed to have originated much earlier than plastid proteins (chloroplasts). The first form of plastids did not arrive until the cell had already maintained an efficient, successful system for targeting cytosolic ally synthesized proteins to mitochondria (5).

Both mitochondria and chloroplasts contain numerous of thousands of proteins that they each import into respective organelles from their own nucleus (5). The backing behind the endosymbiosis theory explains why both of these organelles have their own DNA, are able to encode such proteins as previously stated. DNA sequence analysis and phylogenetic estimates suggests that nuclear DNA contains genes that probably came from the plastid.

In addition to external view, much of the internal structure and biochemistry of plastids (the presence of thylakoids and particular chlorophylls) is very similar to that of cyanobacteria. Phylogenetic estimates constructed with bacteria, plastids, and eukaryotic genomes also suggest that plastids are most closely related to cyanobacteria (3). Plastids are present in very different groups of protists, some of which are closely related to forms lacking plastids. This suggests that if chloroplasts were not taken from outside, they evolved multiple times, in which case their close similarity to each other is difficult to explain. Many of these protists contain "secondary" plastids that have been acquired from other plastid-containing eukaryotes, not from cyanobacteria directly. These organelle's ribosomes are like those found in bacteria (70s).

Furthermore, it is also being suggested that there was a chloroplast division system. For example, some of the structures and functions that have been identified in protein division also resemble several instances that are present in both chloroplast and mitochondria division.

The main principles and underlining processes of the chloroplast division system demonstrates that this form of division is conserved across many lineage systems, including those with secondary chloroplasts. New mitochondria and plastids are formed only through a process similar to binary fission. In some algae, such as Euglena, the plastids can be destroyed by certain chemicals or prolonged absence of light, without otherwise affecting the cell. In such a case, the plastids will not regenerate. It is also been shown that this may in fact reflect primeval features in mitochondria division, once again possibly showing proof that these two organelles did derive from a bacteria source.

Discussion

Even though that it is widely accepted that these are the definite origins of the mitochondrial organelle, can one claim that mitochondria are in fact a form of bacteria? It is also believed that his scenario lies in similar hand as the ideas that domains Archea and Eukarya are on a higher taxonomic level than Archea is to Bacteria, which happens to be a more recent common ancestor (4). In addition to the lines of taxonomy, if mitochondria truly did generate from a form of bacteria, and represents itself as a monophyletic group, which originated from a singular ancestor; how many different types of mitochondria are in existence taxonomically speaking? However, studies that have been performed by Cambridge college has proven that all mitochondria have within a 8% identity to each other when numerous samples were taken from including but not limited to Neanderthal mitochondria, chimpanzee mitochondria, and human mitochondria.

New findings have led many to take this theory as fact. If the theory is true, then one must ask what the original cell was like without the use and roles played by both the mitochondria and the chloroplasts. How would a cell survive? Is Glycolysis a possibility? And more importantly if this theory is in fact a truth; why is it still up for debate; and essentially why have not any forms of primitive eukaryotic cells ever been found that are without these organelles? If one day this theory does prove itself as true, it is strongly suggested that the reason no findings have been found has to do with the processes of natural selection and evolution, that over time these more advanced eukaryotic cells took the place of the primitive ones if this is the case (3).

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