

Amoeba offers key clue to photosynthetic evolution

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Paulinella chromatophora as viewed through a light (top) and electron (bottom) microscope. Cr, chromatophore; G, golgi; M, mitochondrion; N, nucleus; T, theca (cell wall composed of silica scales).

(PhysOrg.com) -- The major difference between plant and animal cells is the photosynthetic process, which converts light energy into chemical energy. When light isn't available, energy is generated by breaking down carbohydrates and sugars, just as it is in animal and some bacterial cells. Two cellular organelles are responsible for these two processes: the chloroplasts for photosynthesis and the mitochondria for sugar breakdown. New research from Carnegie's Eva Nowack and Arthur Grossman has opened a window into the early stages of chloroplast evolution. Their work is published online by the *Proceedings of the National Academy of Sciences* in the week of February 27-March 2.

It is widely accepted that [chloroplasts](#) originated from photosynthetic, single-celled bacteria called [cyanobacteria](#), which were engulfed by a more complex, non-photosynthetic cell more than 1.5 billion years ago. While the relationship between the two organisms was originally symbiotic, over [evolutionary time](#) the cyanobacterium transferred most of its genetic information to the nucleus of the [host organism](#), transforming the original cyanobacterium into a chloroplast that is no longer able to survive without its host.

A similar process resulted in the creation of [mitochondria](#).

To sustain the function of the organelle, proteins encoded by the transferred genes are synthesized in the cytoplasm, or cell's interior, and then imported back into the organelle. In most systems that have been studied, the transport of proteins into the chloroplast occurs through a multi-protein import complex that enables the proteins to pass through the envelope membranes that surround the chloroplast.

Clearly the events that gave rise to chloroplasts and mitochondria changed the world forever. But it is difficult to research the process by which this happened because it took place so long ago. One strategy used to elucidate the way in which this process evolved has relied on identifying organisms for which the events that resulted in the conversion of a bacterium into a host-dependent organelle occurred more recently.

Nowack and Grossman focused their research on a type of amoeba called *Paulinella chromatophora*, which contains two photosynthetic compartments that also originated from an endosymbiotic [cyanobacterium](#), but that represent an earlier stage in the formation of a fully evolved organelle.

These compartments, called chromatophores, transferred more than 30

of the original cyanobacterial genes to the nucleus of the host organism. While gene transfer has been observed for other bacterial endosymbionts, the function of the transferred genes has been unclear, since it does not appear that the endosymbionts (in contrast to organelles) are equipped to recapture those proteins, because they do not have appropriate protein import machineries.

The Carnegie team honed in on three of the *P. chromatophora* transferred genes, which encode proteins involved in photosynthesis, a process localized to the chromatophore. They set out to determine whether these proteins are synthesized in the cytoplasm of the amoeba and whether the mature proteins became localized to the chromatophore.

Using an advanced array of research techniques, they were able to determine that these three proteins are synthesized in the cytoplasm and then transported into chromatophores, where they assemble together with other, internally encoded proteins into working protein complexes that are part of the photosynthetic process.

Interestingly, the process by which these proteins are transported into chromatophores may also be novel and involve transit through an organelle called the Golgi apparatus, prior to becoming localized to the chromatophore. This suggests the occurrence of an initial, rudimentary process for proteins to cross the envelope membrane of the nascent chloroplast. This process ultimately evolved into one that is potentially more sophisticated and that uses specific protein complexes for efficient transport.

"This work demonstrates that *P. chromatophora* is a potentially powerful model for studying evolutionary processes by which organelles developed," Nowack said. "Obtaining a comprehensive list of proteins imported into chromatophores, including their functions and origins, as well as understanding the pathway by which these proteins are imported,

could provide insight into the mechanism that eukaryotic cells use to 'enslave' bacteria and turn them into organelles such as chloroplasts and mitochondria."

Provided by Carnegie Institution

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