

The Endosymbiotic Theory

A Theory on the Origins of Eukaryotic Cells: Mitochondria and Chloroplasts

There are a great many differences between **Eukaryotic cells** and **Prokaryotic cells** in size, complexity, and internal compartments. However, there is a curious similarity between prokaryotic cells and some **organelles** of eukaryotic cells. Some of these similarities were first noted in the 1880s, but were largely ignored for almost a century.

| | Prokaryotes | Eukaryotes | Mitochondria | Chloroplasts |
|---------------------------------|--|--|---|---------------------------------|
| DNA | single, circular chromosome | Multiple, linear chromosomes in a nucleus | single, circular chromosome | single, circular chromosome |
| Replication | Binary Fission | Mitosis | Binary Fission | Binary Fission |
| Ribosomes | "70 S" configuration | "80 S" configuration | "70 S" configuration | "70 S" configuration |
| Electron Transport Chain | Found in the plasma membrane around cell | Found only in the cell's mitochondria and chloroplasts | Found in the inner mitochondrial membrane | Found in the thylakoid membrane |
| Size (approximate) | ~1-10 microns | ~10 - 500 microns | ~1-10 microns | ~1-10 microns |
| Appearance on Earth | ~3.8 - 2.5 BYA | ~1.5 billion years ago | ~1.5 billion years ago | ~1.5 billion years ago |

The Endosymbiotic Theory ... first postulated by Lynn Margulis in 1967.

The Endosymbiotic Theory was first proposed by former Boston University Biologist Lynn Margulis in the 1960's and officially in her 1981 book *Symbiosis in Cell Evolution*. Although now accepted as a well-supported theory, both she and the theory were ridiculed by mainstream biologists for a number of years. Thanks to her persistence, and the large volumes of data that support this hypothesis gathered by her and many other scientists over the last 50 years, biology can now offer a plausible explanation for the evolution of eukaryotes.

Dr. Margulis was doing research on the origin of eukaryotic cells. She looked at all the data about prokaryotes, eukaryotes, and organelles. She proposed that the similarities between prokaryotes and organelles, together with their appearance in the fossil record, could **best** be explained by "endo-symbiosis".

[Endo = "within"]

[**Endocytosis** = (cyto = cell) a process of 'cell eating' - cells are engulfed, but then usually digested as food....]

[**Endosymbiosis** = cells are engulfed, but not digested...cells live together in a mutually benefiting relationship]

Her **hypothesis** originally proposed that:

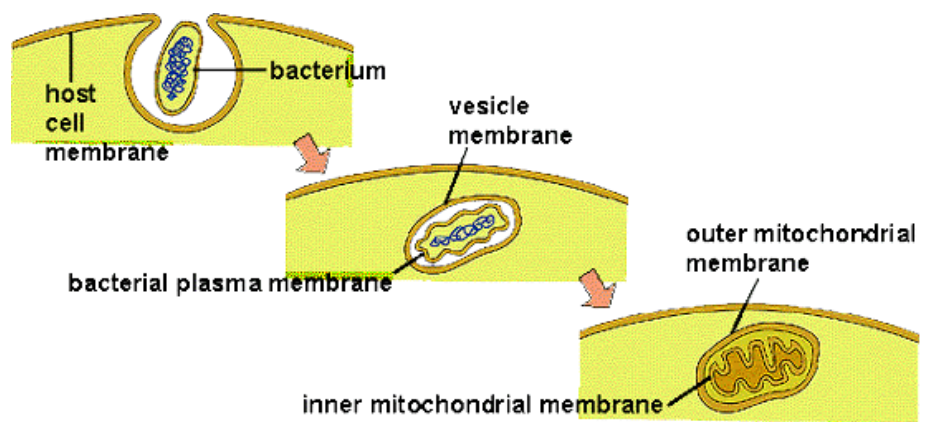
- mitochondria are the result of **endocytosis of aerobic bacteria** by larger anaerobic cells.
- chloroplasts are the result of **endocytosis of photosynthetic bacteria** by larger anaerobic cells.
- this arrangement became a mutually beneficial relationship (**symbiosis**) for both cells.

Evidence That Supports This Theory

A timeline of life on Earth:

- Scientists have fossil evidence of bacterial life on Earth ~3.8 billion years ago. At this time, the atmosphere of the Earth did not contain oxygen, and all life (bacterial cells) was **anaerobic**.
- About ~3.2 billion years ago, fossil evidence of **photosynthetic bacteria**, or **cyanobacteria**, appears. These bacteria use the sun's energy to make sugar. **Oxygen**, released as a byproduct, began to accumulate in the atmosphere. However, oxygen is actually pretty toxic to cells, even our cells! As a result, **anaerobic** cells were now a disadvantage in an oxygen-containing atmosphere, and started to die out as oxygen levels increased.
- Aerobic cells appear in the fossil record shortly after that (~2.5 Billion years ago). Their cells were able to use that 'toxic' oxygen and use it to convert carbohydrates into energy (ATP) and water. Organisms that could thrive in an oxygen-containing atmosphere were now 'best suited to the environment'.

The aerobic bacteria (now mitochondria) would have handled the toxic oxygen for the anaerobic host, while the host would have ingested food and protected the aerobic endosymbiont. The result is a cell with a double-membrane bound organelle. The inner lipid bilayer would have been the bacterial cell's plasma membrane, and the outer lipid bilayer came from the cell that engulfed it.



Organelles have their own DNA, and divide independently of the cell they live in

When Margulis initially proposed the Endosymbiotic Theory, she predicted that, if the organelles were really bacterial (prokaryotic) symbionts, they would have their own DNA. If her theory could best explain the origin of eukaryotic cells, she reasoned, organelles would have DNA that resembled bacterial DNA and be different from the cell's DNA (located in the nucleus membrane). Amazingly, in the 1980's this was proven to be the case for two classes of organelles, the mitochondria and chloroplasts.

Address the following questions on a separate sheet of paper

1. What is the difference between aerobic and anaerobic cells?
2. Do anaerobic organisms still exist? If no, why not? If yes, give two examples.
3. In what ways are mitochondria and chloroplasts similar to some prokaryotic cells?
4. What do cells gain from having mitochondria? What about chloroplasts?
5. Why do you think Dr. Margulis met so much resistance with her introduction of endosymbiosis?