CC4: Cell Biology
Unit 3: Cytoplasmic organelles II
Endosymbiotic hypothesis

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I. 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, internal compartments. However, there is a curious similarity between prokaryotic cells and the organelles of eukaryotic cells.

	Prokaryotes	Eukaryotes	Mitochondria of Eukaryotic cells	Chloroplasts of Photosynthetic eukaryotes
DNA	1 single, circular chromosome	Multiple linear chromosomes compartmentalized in a nucleus	1 single, circular chromosome	1 single, circular chromosome
Replication	Binary Fission (1 cell splits into 2)	Mitosis	Binary Fission (1 cell splits into 2)	Binary Fission (1 cell splits into 2)
Ribosomes	"70 S"	"80 S"	"70 S"	"70 S"
Electron Transport Chain	Found in the plasma membrane around cell	Not found in the plasma membrane around cell (found only in the cell's mitochondria and chloroplasts)	Found in the plasma membrane around mitochondrion	Found in the plasma membrane around chloroplast
Size (approximate)	~1-10 microns	~50 - 500 microns	~1-10 microns	~1-10 microns
Appearance on Earth	Anaerobic bacteria: ~3.8 Billion years ago Photosynthetic bacteria: ~3.2 Billion years ago Aerobic bacteria: ~2.5 Billion years ago	~1.5 billion years ago	~1.5 billion years ago	~1.5 billion years ago

II. The Endosymbiotic Theory (Postulated by Lynn Margulis in the 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 persistance, and the large volumes of data that support this hypothesis gathered by her and many other scientists over the last 30 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"]

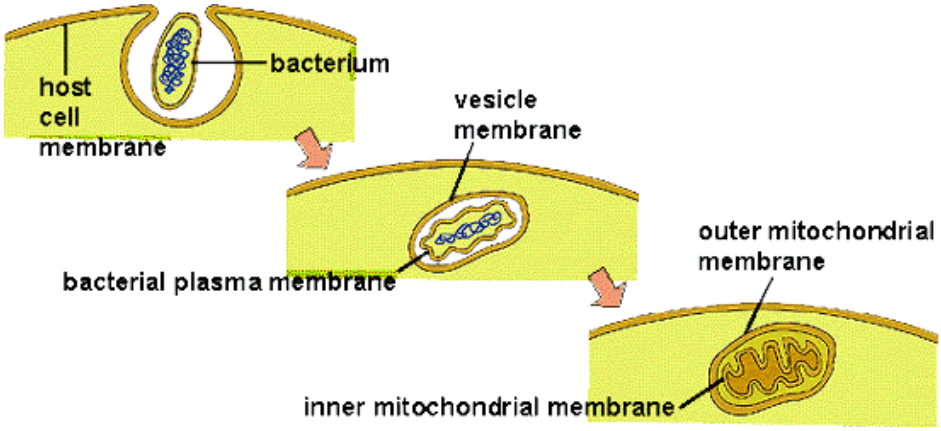
[Endocytosis = (cyto = cell) a process of 'cell eating' - cells are engulfed, but then usually digested as food....**]**

[Endosymbiosis = cells are engulfed, but not digested...cells live together is a mutually benefitting relationship, or symbiosis**]**

Lynn Margulis' hypothesis originally proposed that:

- mitochondria are the result of **endocytosis of aerobic bacteria**
- chloroplasts are the result of **endocytosis of photosynthetic bacteria**
- in both cases by large **anaerobic bacteria** who would not otherwise be able to exist in an aerobic environment.
- this arrangement became a mutually beneficial relationship for both cells **(symbiotic)**.

Margulis' original hypothesis proposed that **aerobic bacteria** (that require oxygen) were ingested by **anaerobic bacteria** (poisoned by oxygen), and may each have had a **survival advantage** as long as they continued their partnership.



Each would have performed mutually benefiting functions from their symbiotic relationship. The aerobic bacteria would have handled the toxic oxygen for the anaerobic bacteria, and the anaerobic bacteria would ingested food and protected the aerobic "symbiote"..
The result = a cell with a double-membrane bound organelle. The inner lipid bilayer would have been the bacterial cell's plasma membrane, and the ouler lipid bilayer came from the cell that engulfed it.

Other evidence that supports this hypothesis:

1. **The timeline of life on Earth:**

a. **Anaerobic bacteria:** 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**.

years ago	Important Dates
4.5 Billion	Origin Of The Earth
3.5 Billion	**Prokaryote** Bacteria Dominate
2.5 Billion	**Oxygen** Accumulates In Atmosphere
1.5 Billion	**Eukaryotes**—First Nucleated Cell
0.5 Billion	Cambrian Explosion Of Multicellular Eukaryote Organisms

Figure 1-1

b. **Photosynthetic bacteria**: 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.

c. **Aerobic** cells appear in the fossil record shortly after that (~2.5 Billion years ago). There cells were able to use that 'toxic' oxygen and convert it into energy (ATP) and water. Organisms that could thrive in an oxygen-containing atmosphere were now 'best suited to the environment.

2. **Organelles have their own DNA, and divide independently of the cell they live in:** When Margulis initially proposed the Symbiotic Theory, she predicted that, if the organelles were really bacterial (prokaryotic) symbionts, they would have their own DNA. If her theory DID 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. Further, in the late 1980's a team of Rockefeller University investigators announced their similar discovery regarding centrioles, structures that provide the eukaryotic cell with the ability of locomotion and cell division

The Endosymbiotic Theory provides the most plausible explanation for the development of organelles within the eukaryotic cell.