Evolution of Eukaryotes

Characteristics of Eukaryotes

Data from these fossil records reveals that living eukaryotes are all descendants of a single common ancestor. The oldest eukaryotic fossil is approximately 1.5 billion years old (Proterozoic period). The following characteristics must have been present in the members of Eukaryotes-

1. Cells with nuclei surrounded by a nuclear envelope with nuclear pores. This is the single characteristic that is both necessary and sufficient to define an organism as a eukaryote. All extant eukaryotes have cells with nuclei.
2. Mitochondria. Some extant eukaryotes have very reduced remnants of mitochondria in their cells, whereas other members of their lineages have "typical" mitochondria.
3. A cytoskeleton containing the structural and motility components called actin microfilaments and microtubules. All extant eukaryotes have these cytoskeletal elements.
4. Flagella and cilia, organelles associated with cell motility. Some extant eukaryotes lack flagella and/or cilia, but they are descended from ancestors that possessed them.
5. Chromosomes, each consisting of a linear DNA molecule coiled around basic (alkaline) proteins called histones. The few eukaryotes with chromosomes lacking histones clearly evolved from ancestors that had them.
6. Mitosis, a process of nuclear division wherein replicated chromosomes are divided and separated using elements of the cytoskeleton. Mitosis is universally present in eukaryotes.
7. Sex, a process of genetic recombination unique to eukaryotes in which diploid nuclei at one stage of the life cycle undergo meiosis to yield haploid nuclei and subsequent karyogamy, a stage where two haploid nuclei fuse together to create a diploid zygote nucleus.
8. Members of all major lineages have cell walls, and it might be reasonable to conclude that the last common ancestor could make cell walls during some stage of its life cycle. However, not enough is known about eukaryotes' cell walls and their development to know how much homology exists among them. If the last common ancestor could make cell walls, it is clear that this ability must have been lost in many groups.

Biologists are almost certain that eukaryotes evolved from prokaryotes because:

1. Both use RNA and DNA are the genetic material
2. Both use the same 20 amino acids
3. Both have ribosomes and DNA and RNA
4. Both have a lipid bilayer cell membrane.
5. Both use L amino acids and D sugars

Biologists are also almost certain that eukaryotes evolved only once (i.e., are monophyletic- descendants of a single common ancestor) because they all share:

1. microtubules (composed of the protein tubulin) and actin molecules-
    - cytoskeleton for support or intracellular transport.-
    - flagella (or cilia)
2. DNA in chromosomes (intertwined with histone protein)
3. Membrane-bound organelles.

Actin makes a process called **cytosis** possible, while microtubules make mitosis and cell locomotion possible.

Cytosis is the ability of membranes to grow and fuse and it allows cells to both secrete substances efficiently (**exocytosis**) and to bring them into the cell more efficiently (**phagocytosis**).

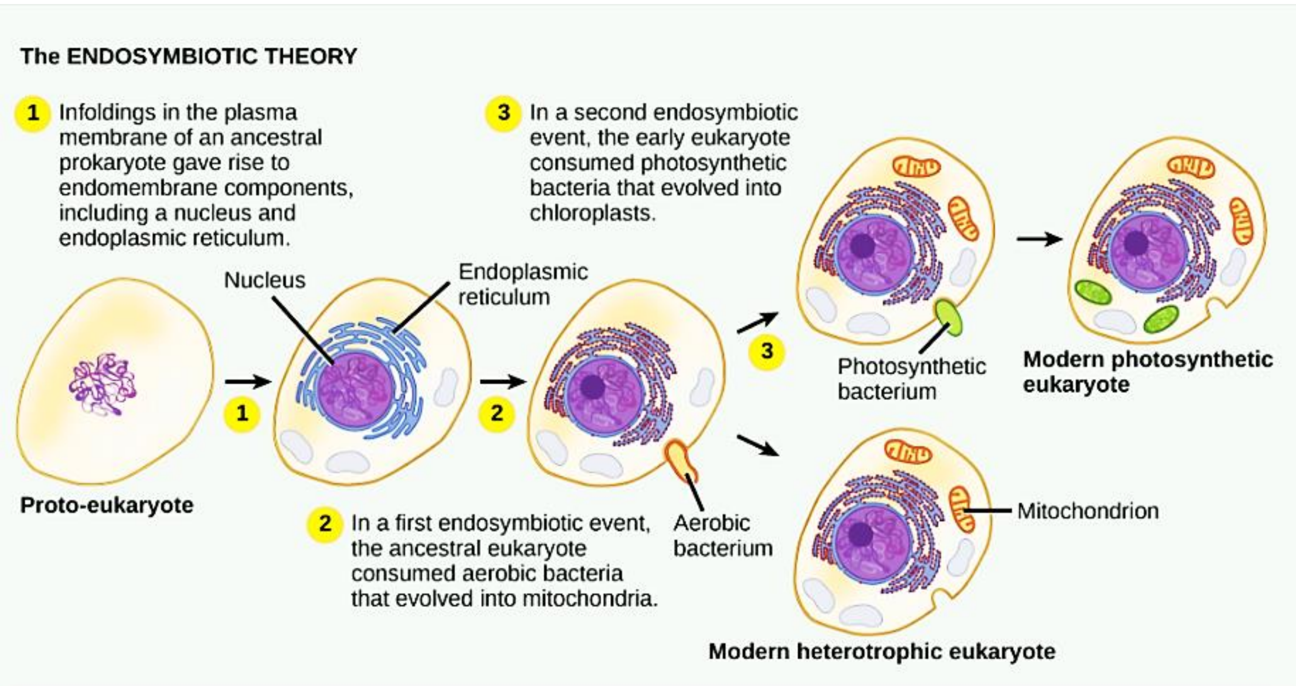
There are two different stories to tell about the origin of eukaryotes, one for the origin of organelles such as mitochondria and chloroplasts, and another for the origin of the other parts of the cell.

1. **Origin of Mitochondria and Chloroplasts: theory of Endosymbiosis**

   One of the most intriguing speculations is that Mitochondria and Chloroplasts arose not by a gradual evolutionary process but abruptly in an unusually striking manner, i.e., **Symbiosis**.
   As cell biology developed in the twentieth century, it became clear that mitochondria were the organelles responsible for producing ATP using aerobic respiration. In the 1960s, American biologist **Lynn Margulis** developed **Endosymbiotic theory**, which states that eukaryotes may have been a product of one cell engulfing another, one living within another, and evolving over time until the separate cells were no longer recognizable as such.

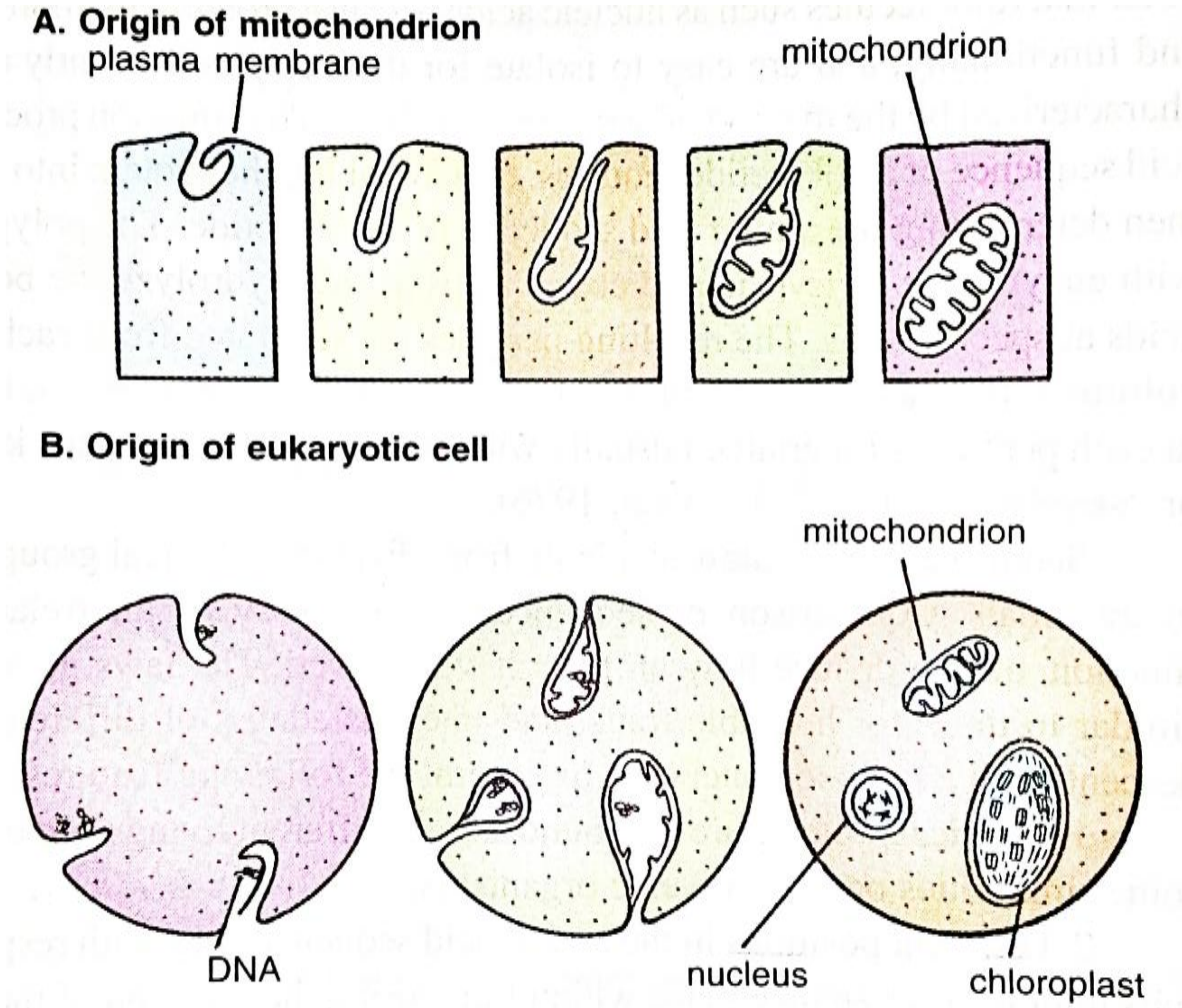
   Endosymbiosis hypothesis originally proposed that-
   - mitochondria are the result of **endocytosis** of aerobic bacteria
   - chloroplasts are the result of **endocytosis** of photosynthetic bacteria
   - in both cases by large anaerobic bacteria who would not otherwise be able to exist in an aerobic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

   So, the 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.



Evolution of Eukaryotic cell thorough symbiosis

2. **Membrane Infolding / Invagination of surface membrane**
The invasions of the host prokaryote cell probably were successful because the host cell membrane infolded to surround both invading prokaryote cells and thereby help transport them into the cell. The membrane did not dissolve but remained intact, and thereby created a second membrane around the protomitochondria and protochloroplast. It is also known that in modern-day eukaryotes the inner membrane of both the mitochondria and chloroplast contain structures more similar to prokaryotes than eukaryotes, whereas the outer membrane retains eukaryote characteristics! It is also suggested that continued membrane infolding created the endomembrane system. It can be said that possibly the first eukaryotic cell type was miraculously born from prokaryotic, symbiotic, multicell interactions.



Hypothetical scheme of the origin of eukaryotic organelles from the surface membrane. A—Development of the mitochondrion from the surface membrane; B—Origin of a eukaryotic cell by the invagination of the surface membrane in several places (after Volpe, 1985).

The alternative theories for the evolution of eukaryotes

1. **Autogenous**
According to the autogenous model, the eukaryotes arose directly from a single prokaryote ancestor by compartmentalization of functions brought about by infoldings of the prokaryote plasma membrane. This model is usually accepted for the endoplasmic reticulum, golgi, and the nuclear membrane, and of organelles enclosed by a single membrane (such as lysosomes). According to the autogenous hypothesis, mitochondria and chloroplasts have evolved within the protoeukaryote cell by compartmentalizing plasmids (vesicles of DNA) within a pinched off invagination of the cell membrane.
Similarities between mitochondria or chloroplasts and eubacteria can be accounted for by **mosaic evolution** in which the components in the compartment evolve more slowly than other parts of the cell, and thus retain many eubacterial features. Mitochondria or chloroplasts may have acquired their double-membrane status by secondary invagination or more elaborate folding of membranes.

2. **Synapomorphies (**characteristics present in an ancestral species and shared exclusively by its evolutionary descendants**)–**
The alternative theories make quite different predictions about the similarities that one might expect to find among eubacterial, nuclear, and organellar genomes. The autogenous origin hypothesis predicts that plastid and mitochondrial genomes should share more synapomorphies to nuclear genomes than to prokaryotic (eubacterial and archebacterial) genomes in basic features of structure, organization and expression. This is because organellar and nuclear genomes would have shared a common ancestor more recently than organellar and prokaryote genomes. The xenogenous origin hypothesis predicts just the opposite and specifically predicts that organellar genomes should share more synapomorphies with eubacterial than with either nuclear or archebacterial genomes.