The Evolution of the Eukaryotic Cell

- The fossil record indicates that eukaryotes evolved from prokaryotes more than 2 billion years ago… ***so how did this happen?????***
- The widely accepted theory involves a combination of two processes:
  - Membrane Infolding
  - Serial Endosymbiosis
- Under one evolutionary scenario, the endomembrane system of eukaryotes (nuclear envelope, endoplasmic reticulum, Golgi apparatus, and related structures) may have evolved from ***infoldings of prokaryotic plasma membrane***.
- Another process, called ***serial endosymbiosis***, probably led to mitochondria, plastids*, and perhaps other eukaryotic features.

**Plastids are a family of closely related plant organelles that include chloroplasts.*

Mitochondria and plastids evolved from endosymbiotic bacteria

- Scientific evidence now strongly suggests that the eukaryotic cell originated from evolving symbiotic relationships of multiple prokaryotic ancestors.
- A mechanism for this was originated by a Russian biologist and developed extensively by Lynn Margulis of the University of Massachusetts.
- The theory of **serial endosymbiosis** suggests that mitochondria and chloroplasts were formerly small prokaryotes living within larger cells.
  - Cells that live within other cells are called *endosymbionts*.
- The proposed ancestors of mitochondria were ***aerobic heterotrophic prokaryotes (bacteria)***.
- The proposed ancestors of chloroplasts were ***photosynthetic prokaryotes (cyanobacteria)***.
- These ancestors probably originally entered the host cells as undigested prey or internal parasites.
- Eventually, this evolved into a mutually beneficial symbiosis.
  - A heterotrophic host could get nourishment from photosynthetic endosymbionts.
  - In an increasingly aerobic world, an anaerobic host cell would benefit from aerobic endosymbionts that could use oxygen.
- As host and endosymbiont evolved, both would become more interdependent, evolving into a single organism, its parts inseparable.
  - All eukaryotes have mitochondria or genetic remnants of mitochondria.
  - However, not all eukaryotes have chloroplasts.
- The serial endosymbiosis theory suggests that mitochondria evolved ***before chloroplasts***.
- Many examples of symbiotic relationships among modern organisms are analogous to proposed early stages of the serial endosymbiotic theory.

- Several lines of evidence support a close similarity between bacteria and the chloroplasts and mitochondria of eukaryotes.
  - These organelles and bacteria are similar is size.
  - Enzymes and transport systems in the inner membranes of chloroplasts and mitochondria resemble those in the plasma membrane of modern prokaryotes.
  - Replication by mitochondria and chloroplasts resembles binary fission in bacteria.
  - The single circular DNA in chloroplasts and mitochondria lack histones and other proteins, as in most prokaryotes.
  - Both organelles have tRNAs, ribosomes, and other molecules for transcription of their DNA and translation of mRNA into proteins.
  - The ribosomes of both chloroplasts and mitochondria are more similar to those of prokaryotes than to those in the eukaryotic cytoplasm that translate nuclear genes.

The eukaryotic cell is a chimera of prokaryotic ancestors

- The chimera of Greek mythology was part goat, part lion, and part serpent.
- Similarly, the eukaryotic cell is a chimera of prokaryotic parts:
  - » mitochondria from one bacteria
  - » plastids from another
  - » nuclear genome from the host cell
- The search for the closest living prokaryotic relatives to the eukaryotic cell has been based on molecular comparisons because no morphological homologies connect species so diverse.
  - Sequence comparisons of the small ribosomal subunit RNA (SSU-rRNA) among prokaryotes and mitochondria have identified the closest relatives of the mitochondria as the ***alpha proteobacteria group***.
  - Sequence comparisons of SSU-rRNA from plastids of eukaryotes and prokaryotes have indicated a close relationship with ***cyanobacteria***.
- While mitochondria and plastids contain DNA and can build proteins, they are not genetically self-sufficient.
  - Some of their proteins are encoded by the organelles' DNA.
  - The genes for other proteins are located in the cell's nucleus.
  - Other proteins in the organelles are molecular chimeras of polypeptides:
    - some synthesized in the organelles themselves
    - some imported from the cytoplasm (and ultimately from nuclear genes).
- A reasonable hypothesis for the collaboration between the genomes of the organelles and the nucleus is that the endosymbionts transferred some of their DNA to the host genome during the evolutionary transition from symbiosis to integrated eukaryotic organism.
  - Transfer of DNA between modern prokaryotic species is common (for example, by transformation).