Endosymbiont Theory

Origin of Eukaryotic Cells

The cells can be divided into two groups: prokaryotic cells and eukaryotic cells.

Since the proposal of division of cellular life was proposed, biologists have been fascinated by the question: **What is the origin of the eukaryotic cell?**

It is generally (but not universally) conquered that prokaryotic cells (1) arose before eukaryotic cells and (2) gave rise to eukaryotic cells.

- The first point can be verified directly from the fossil record, which shows that prokaryotic cells were present in rocks approximately 2.7 billion years old, which is roughly one billion years before any evidence is seen of eukaryotes.
- The second point follows from the fact that the two types of cells have to be related to one another because they share many complex traits (e.g., very similar genetic codes, enzymes, metabolic pathways, and plasma membranes) that could not have evolved independently in different organisms.

LYNN MARGULIS AND ENDOSDYMBIOTIC GENESIS THEORY

It was generally believed, till 1970s that eukaryotic cells evolved from prokaryotic cells by a process of gradual evolution in which the organelles of the eukaryotic cell became progressively more complex.

The work of Lynn Margulis, then at Boston University changed all. She resurrected the idea that certain organelles of a eukaryotic cell—most notably the mitochondria and chloroplasts—had evolved from smaller prokaryotic cells that had taken up residence in the cytoplasm of a larger host cell.

This hypothesis is referred to as the **endosymbiont theory because it describes how a single "composite" cell of greater complexity could evolve from two or more separate, simpler cells living in a symbiotic relationship with one another.**

Our earliest prokaryotic ancestors were presumed to have been anaerobic heterotrophic cells: *anaerobic meaning they derived their* energy from food matter without employing molecular oxygen (O_2), and *heterotrophic meaning they were unable to synthesize organic* compounds from inorganic precursors (such as CO_2 and water), but instead had to obtain preformed organic compounds from their environment.

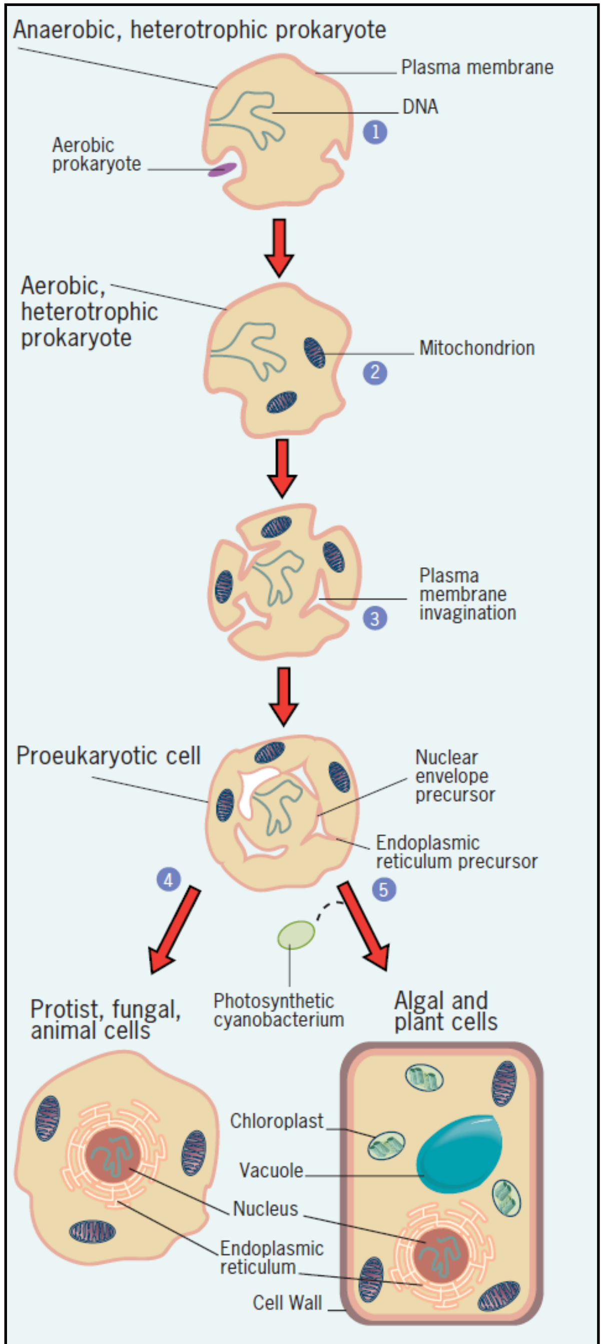

Fig. 1: A model depicting possible steps in the evolution of eukaryotic cells, including the origin of mitochondria and chloroplasts by endosymbiosis.

In step 1, a large anaerobic, heterotrophic prokaryote takes in a small aerobic prokaryote. Evidence strongly indicates that the engulfed prokaryote was an ancestor of modern-day rickettsia, a group of bacteria that causes typhus and other diseases.

In step 2, the aerobic endosymbiont has evolved into a mitochondrion.

In step 3, a portion of the plasma membrane has invaginated and is seen in the process of evolving into a nuclear envelope and associated endoplasmic reticulum. The primitive eukaryote depicted in step 3 gives rise to two major groups of eukaryotes.

In one path (step 4), the primitive eukaryote evolves into nonphotosynthetic protist, fungal, and animal cells.

In the other path (step 5), the primitive eukaryote takes in a photosynthetic prokaryote, which will become an endosymbiont and evolve into a chloroplast.

(*Note: The engulfment of the s ymbiont shown* in step 1 could have occurred after development of some of the internal

membranes, but evidence suggests it was a relatively early step in the evolution of eukaryotes.)

Key Points of Endosymbiotic Theory :

• According to one version of the endosymbiont theory, a large, anaerobic, heterotrophic prokaryote ingested a small, aerobic prokaryote (step 1, Figure 1). Resisting digestion within the cytoplasm, the small aerobic prokaryote took up residence as a permanent endosymbiont. As the host cell reproduced, so did the endosymbiont, so that a colony of these composite cells was soon produced.

• Over many generations, endosymbionts lost many of the traits that were no longer required for survival, and the once-independent oxygen-respiring microbes evolved into precursors of modern-day mitochondria (step 2, Figure 1).

• A cell whose ancestors had formed through the sequence of symbiotic events just described could have given rise to a line of cells that evolved other basic characteristics of eukaryotic cells, including a system of membranes (a nuclear membrane, endoplasmic reticulum, Golgi complex, lysosomes), a complex cytoskeleton, and a mitotic type of cell division. These characteristics are proposed to have arisen by a gradual process of evolution, rather than in a single step as might occur through acquisition of an endosymbiont.

•The endoplasmic reticulum and nuclear membranes, for example, might have been derived from a portion of the cell's outer plasma membrane that became internalized and then modified into a different type of membrane (step 3, Figure 1).

• A cell that possessed these various internal compartments would have been an ancestor of a heterotrophic eukaryotic cell, such as a fungal cell or a protist (step 4, Figure 1). The oldest fossils thought to be the remains of eukaryotes date back about 1.8 billion years.

• It is proposed that the acquisition of another endosymbiont, specifically a cyanobacterium, could have converted an early heterotrophic eukaryote into an ancestor of photosynthetic eukaryotes:
the green algae and plants (step 5, Figure 1). The acquisition of chloroplasts (roughly one billion years ago) must have been one of the last steps in the sequence of endosymbioses because these organelles are only present in plants and algae. In contrast, all known groups of eukaryotes either (1) possess mitochondria or (2) show definitive evidence they have evolved from organisms that possessed these organelles.