Eukaryotic cells: evolutionary advancements in cellular complexity.

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Introduction

Eukaryotic cells are one of the two main types of cells found in living organisms, the other being prokaryotic cells. Unlike prokaryotic cells, eukaryotic cells are more complex and evolved to have various cellular structures that allow them to carry out a wider range of functions. The evolution of eukaryotic cells is an essential part of understanding the complexity of living organisms.

The Evolution of Eukaryotic Cells

The origin of eukaryotic cells remains a mystery, and there are several theories about how they evolved. One popular theory is the endosymbiotic theory, which proposes that eukaryotic cells arose from a symbiotic relationship between two different types of prokaryotic cells. Specifically, it is thought that a smaller prokaryotic cell was engulfed by a larger one, leading to a mutually beneficial relationship in which the smaller cell provided energy while the larger cell provided protection [1,2].

Over time, the smaller cell evolved into an organelle within the larger cell, eventually leading to the development of the complex eukaryotic cell. Evidence supporting the endosymbiotic theory includes the similarities between certain organelles in eukaryotic cells (such as mitochondria and chloroplasts) and free-living prokaryotes. For example, both mitochondria and bacteria have circular DNA, and both have similar enzymes involved in DNA replication.

Structures and Functions of Eukaryotic Cells

Eukaryotic cells are much larger than prokaryotic cells and have various cellular structures that allow them to carry out a wider range of functions. One of the most significant differences between eukaryotic and prokaryotic cells is the presence of a nucleus in eukaryotic cells. The nucleus contains the cell's genetic material and is surrounded by a double membrane called the nuclear envelope. The nuclear envelope has pores that allow the movement of molecules in and out of the nucleus.

Another important organelle in eukaryotic cells is the mitochondrion, which is responsible for generating the cell's energy in the form of ATP [3]. Mitochondria have their own DNA and ribosomes and are believed to have evolved from free-living bacteria that were engulfed by eukaryotic cells through endosymbiosis.

Chloroplasts are another organelle found in eukaryotic cells and are responsible for photosynthesis in plant cells. Like mitochondria, chloroplasts have their own DNA and ribosomes and are thought to have evolved from free-living bacteria that were engulfed by eukaryotic cells through endosymbiosis.

Other structures found in eukaryotic cells include the endoplasmic reticulum, Golgi apparatus, lysosomes, and peroxisomes. The endoplasmic reticulum is a network of membranes that is responsible for protein and lipid synthesis. The Golgi apparatus is responsible for modifying, sorting, and packaging proteins for transport to different parts of the cell or secretion from the cell. Lysosomes are organelles that contain enzymes that break down waste and cellular debris. Peroxisomes are organelles that are involved in the breakdown of fatty acids and the detoxification of harmful substances in the cell.

Advantages of Eukaryotic Cells

Eukaryotic cells have several advantages over prokaryotic cells, including increased size, complexity, and flexibility. The larger size of eukaryotic cells allows for the development of complex structures and the ability to carry out a wider range of functions. The presence of a nucleus and other organelles in eukaryotic cells allows for compartmentalization of different cellular functions, making the cell more efficient.

Compartmentalization: Eukaryotic cells are compartmentalized, meaning that different cellular processes occur within distinct membrane-bound organelles. This allows for more efficient and specialized functions, and reduces the risk of unwanted reactions between different cellular components.

Increased size: Eukaryotic cells are typically larger than prokaryotic cells, which allows for a larger genome and greater complexity [4,5]. This allows eukaryotic cells to carry out more specialized functions and to adapt to a wider range of environmental conditions.

More complex cytoskeleton: Eukaryotic cells have a complex cytoskeleton made up of microtubules, microfilaments, and intermediate filaments, which provide structural support, facilitate cell movement, and enable the transport of materials within the cell.

Greater genetic diversity: Eukaryotes have the ability to undergo sexual reproduction, which generates genetic diversity by allowing for the shuffling and recombination of genetic material.

Enhanced communication: Eukaryotic cells have specialized communication pathways, such as gap junctions and

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***Received**: 22-Feb-2023, Manuscript No. AAACSM-23-92181; **Editor assigned**: 23-Feb-2023, PreQC No. AAACSM-23-92181(PQ); **Reviewed**: 08-Mar-2023, QC No. AAACSM-23-92181; **Revised**: 13-Mar-2023, Manuscript No. AAACSM-23-92181(R); **Published**: 18-Mar-2023, DOI:10.35841/AAACSM-7.2.137*

***Citation:** Nunes Y. Department of Pediatrics, Harbor-UCLA Medical Center, Torrance, CA 90502-2006, United States. J Cell Sci Mut. 2023;7(2):137*

plasmodesmata, which allow for direct cell-to-cell communication and coordination of cellular processes . This is not possible in prokaryotic cells, which lack these specialized structures.

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Citation: *Nunes Y. Department of Pediatrics, Harbor-UCLA Medical Center, Torrance, CA 90502-2006, United States. J Cell Sci Mut. 2023;7(2):137*