The Evolution and Structure of Cells of Higher Organisms

Because the evolution of cells occurred over many millennia and researchers rely on observations of existing organisms to infer how cellular evolution progressed, concepts are based on speculation not all of which is likely to be correct. Nevertheless, it is possible to draw several conclusions:

a. First there was at least one free living organism in which DNA evolved as its coding sequence.

b. Next, at least three types of independent single celled organisms evolved that each had their own DNA – the first we might think of as a primitive nucleus; the second we might think of as a primitive mitochondrion and the third as a primitive chloroplast.

c. These primitive cells evolved into the sophisticated 'eukaryote' cells we see now, probably by a mechanism akin to symbiosis – where each organism benefits from the shared association.

d. Probably before the 'symbiosis', the membrane that enclosed the primitive nucleus acquired the ability to produce membrane extrusions that could bleb off smaller membrane bound organelles that could then perform different functions, as needed.

   The outer nuclear membrane still preserves this ability and the organelles that originate from the outer nuclear membrane are now called '*golgi apparatus*', '*endoplasmic reticulum*', *'lysosomes'*, '*peroxisomes*' and '*endosomes*' and each of these has a specific function.

   I am going to call this the 'precursor cell'.

   The next stage of cellular evolution probably involved engulfment or symbiotic joining of precursor cells with primitive mitochondria and/or chloroplasts. Further evolution separated organisms into plant cells with both mitochondria, chloroplasts and cell walls and animal cells without chloroplasts.

   There are, however, a few gastropods (snail family) that have chloroplasts.

'Endomembrane' Organelles

The 'Endomembrane' Organelles as we now know them are the organelles formed from the outer nuclear membrane. The following is a summary of their functions:

***Golgi Bodies** (apparatus) – Cellular 'factory' and 'sorting' system*

Golgi bodies have many critical roles:

(1) Processing of proteins by glycosylation, phosphorylation, sulfation, and selective proteolysis
(2) Packaging of secretory materials for discharge

(3) Synthesis of some polysaccharides and glycolipids
(4) Sorting of proteins that will be sent to various locations.
(5) Production of new membranous elements for the plasma membrane
(6) Reprocessing of membrane components

Endoplasmic reticulum *(smooth and rough)*

In humans, the endoplasmic reticulum (ER) is absent from red blood cells and from sperm but in all other cell types, there are two different types of ER.

The **rough ER** is composed of *flattened* membrane-enclosed sacs called cisternae. Rough gets its name because it is studded with ribosomes that play a key role in protein synthesis. A ribosome binds to the ER when a specific protein-nucleic acid complex forms in the cytosol. Once attached to the ribosome, the messenger RNA is translated into a protein.

Rough ER is connected to the nuclear membrane but NOT to the Golgi. However, proteins are commonly shuttled between the Golgi and rough ER by **membrane-bound transport vesicles.** Transport from the ER to other organelles appears to occur by close association.

The **smooth ER** is found in the cytoplasm and has tubular membranes. It has some functions that overlap with the rough ER, including the synthesis of lipids and cholesterol, but it does not metabolize steroids nor have any role in detoxification.

The smooth ER also gives rise to a few different types of spherical organelles that are each bound by a single membrane. These organelles vary in number both in cells of different types and under different physiological conditions. The organelles have quite specialized functions. They include:

Lysosomes

Lysosomes replicate by membrane growth. They are between 0.5 and 1 micron in diameter and their enzymes function under low oxygen and lower pH than the remainder of the cell. Lysosomal proteins are synthesized by the rough ER and there are more than 50 known human genetic disorders known as *Lysosomal storage diseases*. These genes are involved in several neurodegenerative diseases, cancer, cardiovascular and other ageing related diseases. Each disease fails to break down a specific substance.

Dysfunctional lysosome activity is heavily implicated in the biology of ageing including Alzheimer's, Parkinson's, Cardiovascular Diseases and SLE (*Serum Lupus Erythematosus*).

Lysosomes are capable of fusing with other organelles and digesting large structures or debris.

Peroxisomes *(also found in plants and yeast)*

These membrane-bound organelles are found in most eukaryotic cells. They are derived both from the smooth ER and by replication and growth of existing peroxisomes.

The role of peroxisomes is to generate hydrogen peroxide (H_2O_2) and undertake scavenging activities. Unlike other organelles, proteins do not need to be unfolded to move into peroxisomes.

These organelles play key roles in lipid metabolism and in converting ROS (reactive oxygen species) and provide up to 10% of the activity of G6PD and 6GPGD in the pentose phosphate pathway.

Peroxisomes are especially prevalent in liver cells and like Lysosomal storage diseases, several serious genetic diseases are associated with defective peroxisome function. These usually involve the nervous system.

Endosomes

Endosomes are described as 'sorting organelles'. They have three levels of 'maturity' each with somewhat altered roles, but their major role is to provide a place where material can be sorted before it is transferred to lysosomes for degradation.

Endosomes regulate the movement of proteins and lipids among other subcellular compartments of the secretory and endocytic pathway, specifically the plasma membrane, the Golgi, a network between Golgi bodies called the trans-Golgi network (TGN), and vacuoles and lysosomes.

The Nucleus and Mitochondria

Mitochondria are (somewhat) independent organelles that have their own DNA. At fertilization, the egg cytoplasm contributes all the mitochondria to the fertilized egg and thus, mitochondria are maternally inherited. The membrane-bound protein complexes create biological energy in the form of ATP (Adenosine triphosphate).

Although mitochondria evolved from an independent organism, they have lost their independence in the course of evolution. The 'modern' mitochondria only retains a few components of its ancestral DNA, can produce only rRNA and tRNA and hence almost none of the proteins it would require for independence. Nevertheless, eukaryote cells are equally dependent on mitochondria for their energy production.

Unlike the other Endomembrane Organelles, mitochondria have a double outer membrane that has pores.

The **nucleus** is central to cellular function. Not only does it contain all the genetic information essential to organismic growth and function, it undergoes an extremely refined process of division that is a subject of its own.

Because telomeres and telomere length are an organism's time clock, these will be discussed as a separate subject in Lesson 2.