Chhatrapati Shahu Ji Maharaj University, Kanpur

Introduction to Cell Biology

(Cell and Developmental Biology: MBT-1001)

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Learning Outcome

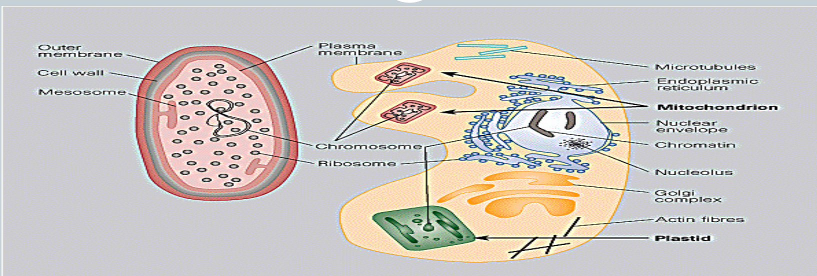
- Learner will be acquainted with cell theory.
- Learner will be able to classify types of cells on basis of structure.
- Learner will be able to understand evolution of cell structure and formation of cell organelles.
- Learner will be able to identify different cell organelles and their functions.

Tenets of Cell Theory

Proposed in 1839. There are three parts to this theory.

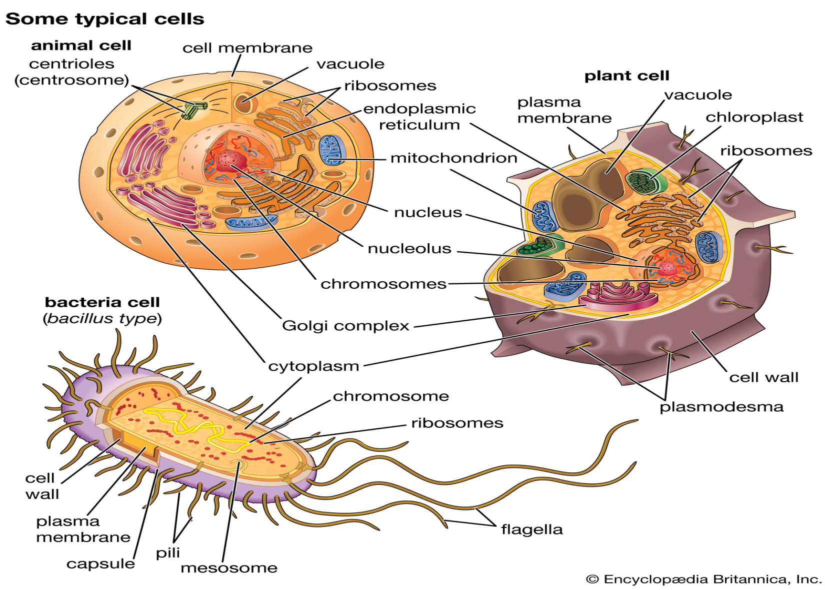
- The all organisms are made of cells.
- Cells are the basic units of life. These postulates were based on a conclusion made by Schwann and Matthias Schleiden in 1838, after comparing their observations of plant and animal cells.
- Cells come from preexisting cells that have multiplied, was described by Rudolf Virchow in 1858, when he stated *omnis cellula e cellula* (all cells come from cells).

Typical Prokaryotic and Eukaryotic Cells



Typical prokaryotic (left) and eukaryotic (right) cells

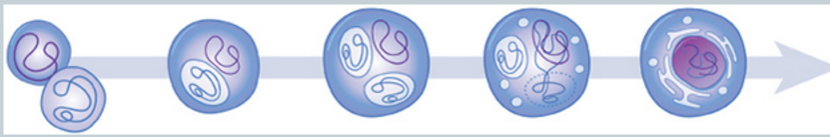
In prokaryotes, the DNA (chromosome) is in contact with the cellular cytoplasm and is not in a housed membrane-bound nucleus. In eukaryotes, however, the DNA takes the form of compact chromosomes separated from the rest of the cell by a nuclear membrane (also called a nuclear envelope). Eukaryotic cells also contain a variety of structures and organelles not present in prokaryotic cells. Throughout the course of evolution, organelles such as mitochondria and chloroplasts (a form of plastid) may have arisen from engulfed prokaryotes.



Primitive Cell Structure

- Historically, bacteria and archaea were viewed mainly as undifferentiated sacs of jumbled enzymes.
- Technological advances, particularly in imaging, have given rise to a much more complicated and beautiful view of prokaryotic cells.
- These cells are now considered as organized assemblies of macromolecular machines, optimized to travel through and interact with complex and dynamic environments.
- One of the first requirements for the development of a cell is separation from the environment by a selectively porous envelope.
- Cellular membranes must be supported against turgor and environmental pressures.The solution most bacteria use is the peptidoglycan cell wall, which is created by crosslinking long stiff glycan strands into a mesh-like network with short peptide crosslinks.
- Most cells maintain specialized shapes by building an internal scaffold of filaments, or cytoskeleton.
- Prokaryotic cells organize their interior is by clustering functionally related enzymes into specialized compartments, which are functional analogues of eukaryotic organelles.
- Bacterial cells have subcellular organization of their genetic material, packing their chromosomes into the nucleoid (the genome-containing region of the cell)
- Motility is mediated by cellular nanomachines like flagellum.
- Potential orienting mechanism is magnetotaxis eg chemotaxis.
- Both bacteria and archaea store essential nutrients in storage granules during times of sufficiency.
- Cells may coat their envelopes with proteins, creating a layer that provides protection against predation or mediates biofilm attachment.

Origin of a Eukaryotic Cell

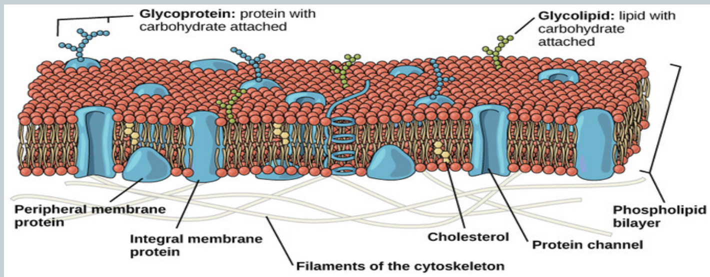


A prokaryotic host cell incorporates another prokaryotic cell. Each prokaryote has its own set of DNA molecules (a genome). The genome of the incorporated cell remains separate (curved blue line) from the host cell genome (curved purple line). The incorporated cell may continue to replicate as it exists within the host cell. Over time, during errors of replication or perhaps when the incorporated cell lyses and loses its membrane separation from the host, genetic material becomes separated from the incorporated cell and merges with the host cell genome. Eventually, the host genome becomes a mixture of both genomes, and it ultimately becomes enclosed in an endomembrane, a membrane within the cell that creates a separate compartment. This compartment eventually evolves into a nucleus.

True Cell Structure

- The eukaryotic cell has a nuclear membrane that surrounds the nucleus, in which the well-defined chromosomes (bodies containing the hereditary material) are located.
- Eukaryotic cells also contain organelles, including mitochondria (cellular energy exchangers), a Golgi apparatus (secretory device), an endoplasmic reticulum (a canal-like system of membranes within the cell), and lysosomes (digestive apparatus within many cell types).
- There are several exceptions to this, however; for example, the absence of mitochondria and a nucleus in red blood cells and the lack of mitochondria in the oxymonad *Monocercomonoides* species.

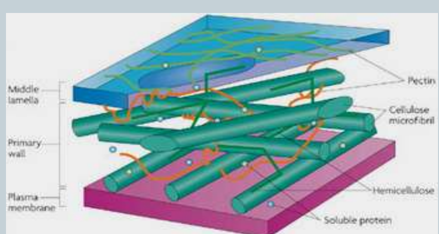
Eukaryotic Plasma Membrane



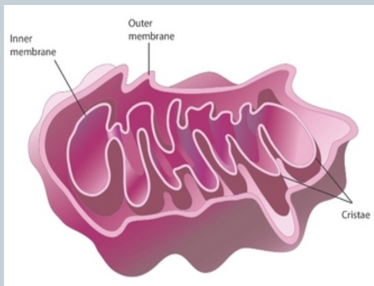
The eukaryotic plasma membrane is a phospholipid bilayer with proteins and cholesterol embedded in it.

The Cell Wall

The cell wall is a rigid covering that protects the cell, provides structural support, and gives shape to the cell. Fungal and protistan cells also have cell walls. While the chief component of prokaryotic cell walls is peptidoglycan, the major organic molecule in the plant cell wall is cellulose, a polysaccharide comprised of glucose units. A plant cell wall is arranged in layers and contains cellulose microfibrils, hemicellulose, pectin, lignin, and soluble protein. These components are organized into three major layers: the primary cell wall, the middle lamella, and the secondary cell wall (not pictured). The cell wall surrounds the plasma membrane and provides the cell tensile strength and protection.

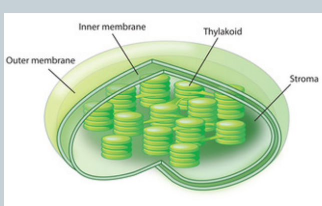


Mitochondrial Structure



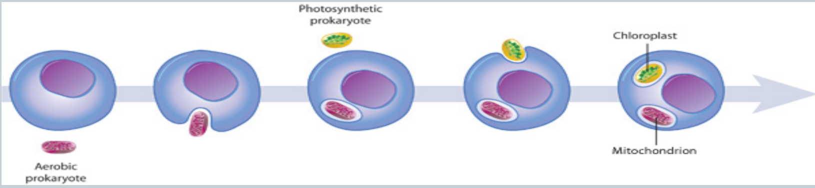
- This electron micrograph shows a mitochondrion as viewed with a transmission electron microscope.
- This organelle has an outer membrane and an inner membrane.
- The inner membrane contains folds, called cristae, which increase its surface area.
- The space between the two membranes is called the intermembrane space, and the space inside the inner membrane is called the mitochondrial matrix.
- ATP synthesis takes place on the inner membrane.

Plastids



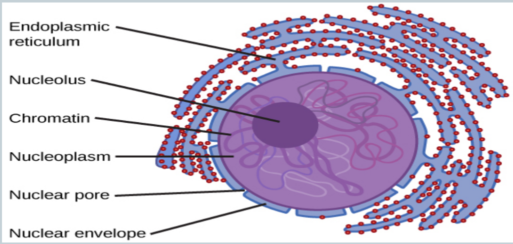
- Like mitochondria, chloroplasts are surrounded by two membranes.
- The outer membrane is permeable to small organic molecules, whereas the inner membrane is less permeable and studded with transport proteins.
- The innermost matrix of chloroplasts, called the stroma, contains metabolic enzymes and multiple copies of the chloroplast genome.
- Chloroplasts also have a third internal membrane called the thylakoid membrane, which is extensively folded and appears as stacks of flattened disks in electron micrographs.
- The thylakoids contain the **light-harvesting complex**, including pigments such as chlorophyll, as well as the electron transport chains used in photosynthesis

The origin of mitochondria and chloroplasts



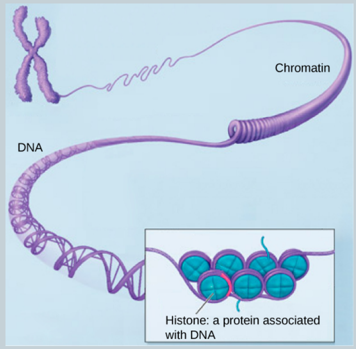
Mitochondria and chloroplasts likely evolved from engulfed bacteria that once lived as independent organisms. At some point, a eukaryotic cell engulfed an aerobic bacterium, which then formed an endosymbiotic relationship with the host eukaryote, gradually developing into a mitochondrion. Eukaryotic cells containing mitochondria then engulfed photosynthetic bacteria, which evolved to become specialized chloroplast organelles.

Nucleus



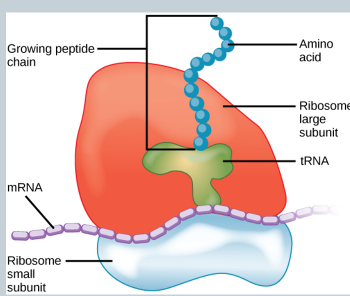
- The nucleus stores chromatin (DNA plus proteins) in a gel-like substance called the nucleoplasm.
- The nucleolus is a condensed region of chromatin where ribosome synthesis occurs.
- The boundary of the nucleus is called the nuclear envelope.
- It consists of two phospholipid bilayers: an outer membrane and an inner membrane.
- The nuclear membrane is continuous with the endoplasmic reticulum.
- Nuclear pores allow substances to enter and exit the nucleus.

Chromatin Organisation



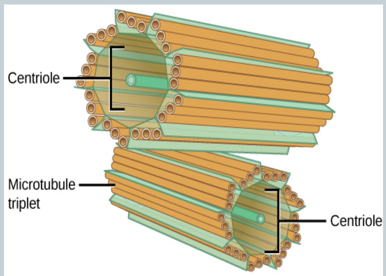
DNA is highly organized: This image shows various levels of the organization of chromatin (DNA and protein). Along the chromatin threads, unwound protein-chromosome complexes, we find DNA wrapped around a set of histone proteins.

Ribosomes



Ribosomes are responsible for protein synthesis: Ribosomes are made up of a large subunit (top) and a small subunit (bottom). During protein synthesis, ribosomes assemble amino acids into proteins.

The Centrosome Structure



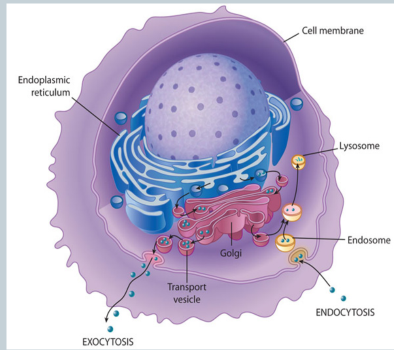
- The centrosome consists of two centrioles that lie at right angles to each other. Each centriole is a cylinder made up of nine triplets of microtubules. Nontubulin proteins (indicated by the green lines) hold the microtubule triplets together.

Vacuoles

- Plant cells additionally possess large, fluid-filled vesicles called **vacuoles** within their cytoplasm.
- Vacuoles typically compose about 30 percent of a cell's volume, but they can fill as much as 90 percent of the intracellular space.
- Plant cells use vacuoles to adjust their size and turgor pressure.
- Vacuoles usually account for changes in cell size when the cytoplasmic volume stays constant.
- Some vacuoles have specialized functions, and plant cells can have more than one type of vacuole.
- Vacuoles are related to lysosomes and share some functions with these structures; for instance, both contain degradative enzymes for breaking down macromolecules.
- Vacuoles can also serve as storage compartments for nutrients and metabolites. For instance, proteins are stored in the vacuoles of seeds, and rubber and opium are metabolites that are stored in plant vacuoles.

Endomembrane System

- The endomembrane system includes the **endoplasmic reticulum** (ER), **Golgi apparatus**, and **lysosomes**.
- Membranes and their constituent proteins are assembled in the ER. This organelle contains the enzymes involved in lipid synthesis, and as lipids are manufactured in the ER, they are inserted into the organelle's own membranes.
- The Golgi apparatus functions as a molecular assembly line in which membrane proteins undergo extensive post-translational modification.
- The Golgi apparatus consists of set of flattened sacs. Vesicles that bud off from the ER fuse with the closest Golgi membranes, called the **cis-Golgi** and reach the end of the assembly line at the farthest sacs from the ER — called the **trans-Golgi**.
- Lysosomes break down macromolecules into their constituent parts, which are then recycled. These membrane-bound organelles contain a variety of enzymes called **hydrolases**.
- The lumen of a lysosome is more acidic than the cytoplasm. This environment activates the hydrolases and confines their destructive work to the lysosome



References and Further Readings

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