MDI 2
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Carleton UNIVERSITY

uOttawa

Medical Devices

Lecture 2 - The Cell

The Cell

- Cell Biology
- Cell Energy
- Cell Transport
- Bioenergetics

What is the Cell?

http://multimedia.mcb.harvard.edu/media.html

- The cell is the functional unit of the body. Cells are the building blocks of living tissue and of the organism.
- Study of the cell is important because:
  - Most activities required for life happen within the cell.
  - Almost all disease causing processes occur in the cell.
- The animal cell is generally composed of various structures. For the purpose of simplification, the cell is divided into four major components:
  - **Cell membrane:** The covering, outer boundary of the cell separating the internal components from the external environment of the cell. Also called the plasma membrane.
  - **Cytoplasm:** The material (substance) occupying the internal region of the cell membrane (including the organelles).
  - **Organelles:** Internal cell parts with specialized function and specific structure.
  - **Inclusions:** Structures within the cells which function as a warehouse or storage area.

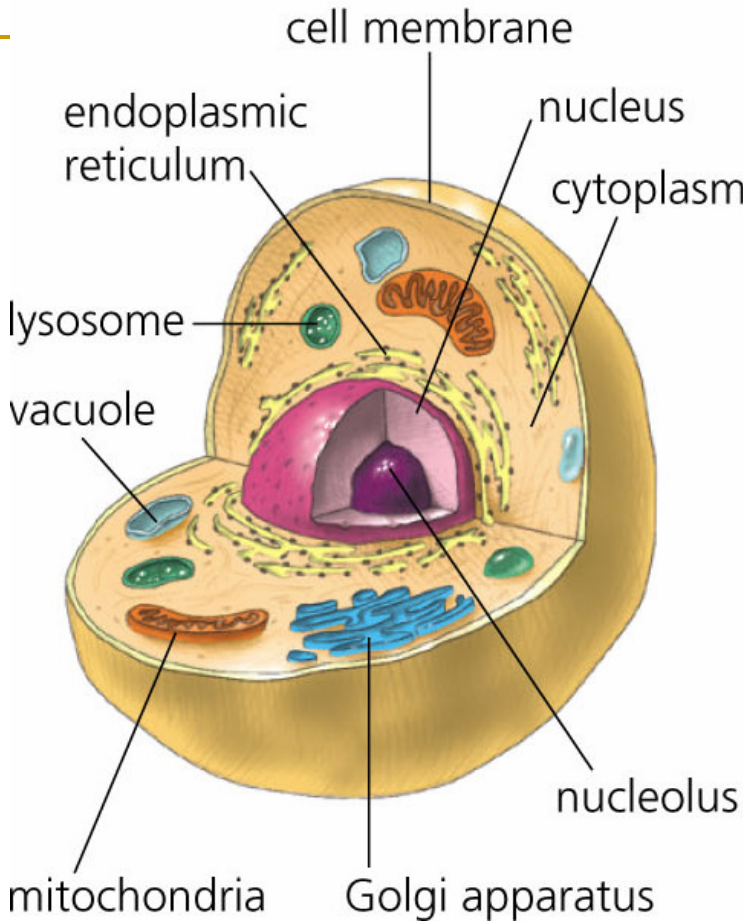
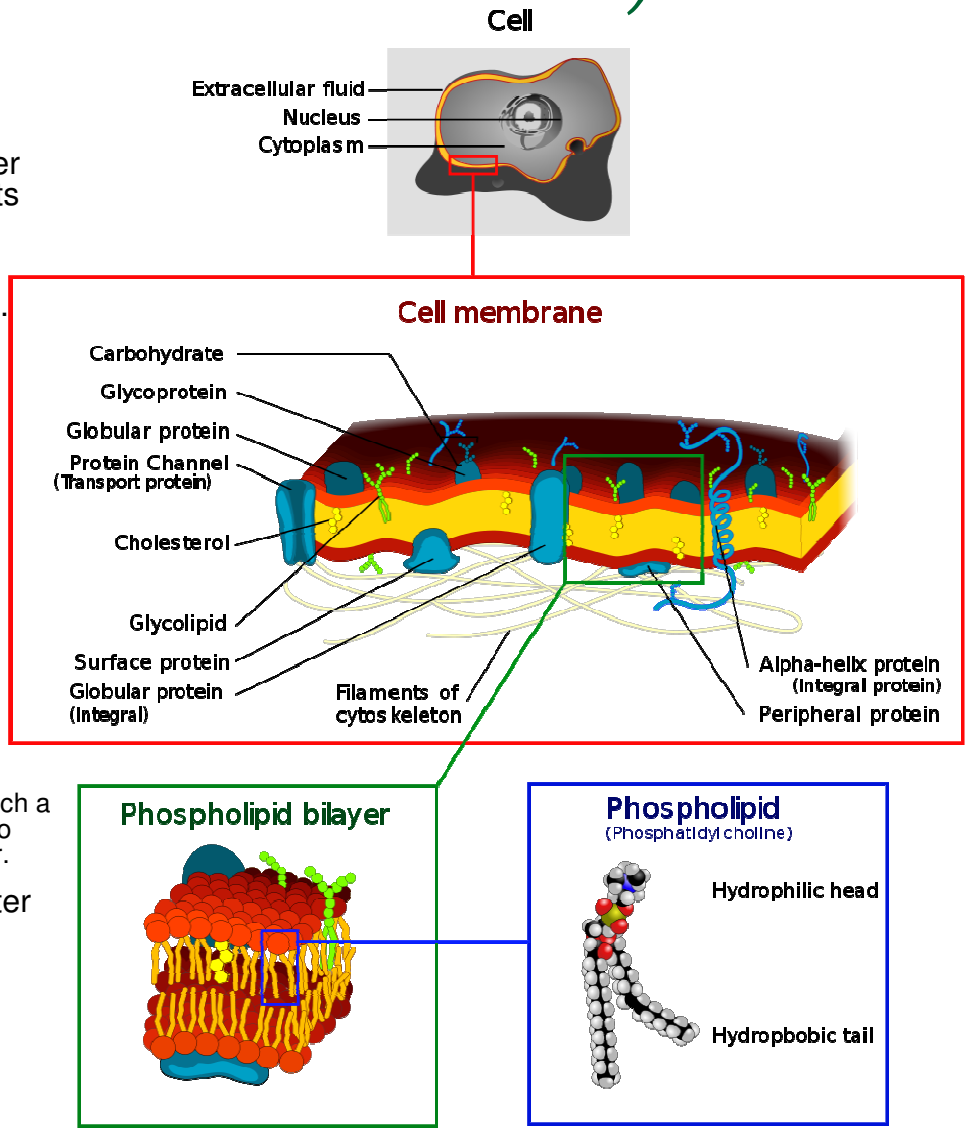


Figure 1. **Animal Cells**

Animal Cells Video

Cell Membrane (Plasma Membrane)

- The cell membrane is a very thin, phospholipid bilayer separating the internal environment of the cell from its external surroundings.
- The chemical structure of this very thin plasma membrane varies from 65 to 100 Angstroms in width.
- An Angstrom is $1x10^{-10}$ meter or 0.1 nanometers.
- Cell membrane structure:
  - The plasma membrane consists of 50-70% (by weight) of proteins.
  - Phospholipids.
  - Cholesterol.
  - Water.
  - Carbohydrates.
  - Ions.
- The model of the cell membrane.
- It is composed of a double phospholipid layer.
  - Each layer contains a polar head and a hydrophobic tail.
  - The polar heads and hydrophobic tails are arranged in such a way that the hydrophobic tails of the layers are adjacent to each other and the polar heads are away from each other.
- The polar phosphate containing head mixes with water (hydrophilic).
- The non-polar fatty acid tail of the phospholipid layer does not mix with water (hydrophobic).



Cell Membrane (Plasma Membrane) Video

Plasma Membrane Function

- Provides a flexible boundary enclosing the cell contents.
- The cell membrane (plasma membrane) facilitates contact with the outside environment such as:
  - Other cells
  - Other substances
- The cell membrane has receptors for various chemicals:
  - Antibodies
  - Nutrients
  - Hormones
  - Enzymes
  - Other substances
- The cell membrane facilitates and controls entry and exit of material from the cell:
  - Permits specific substances to enter and/or exit the cell.
  - Restricts the passage of other materials.

Plasma Membrane Function

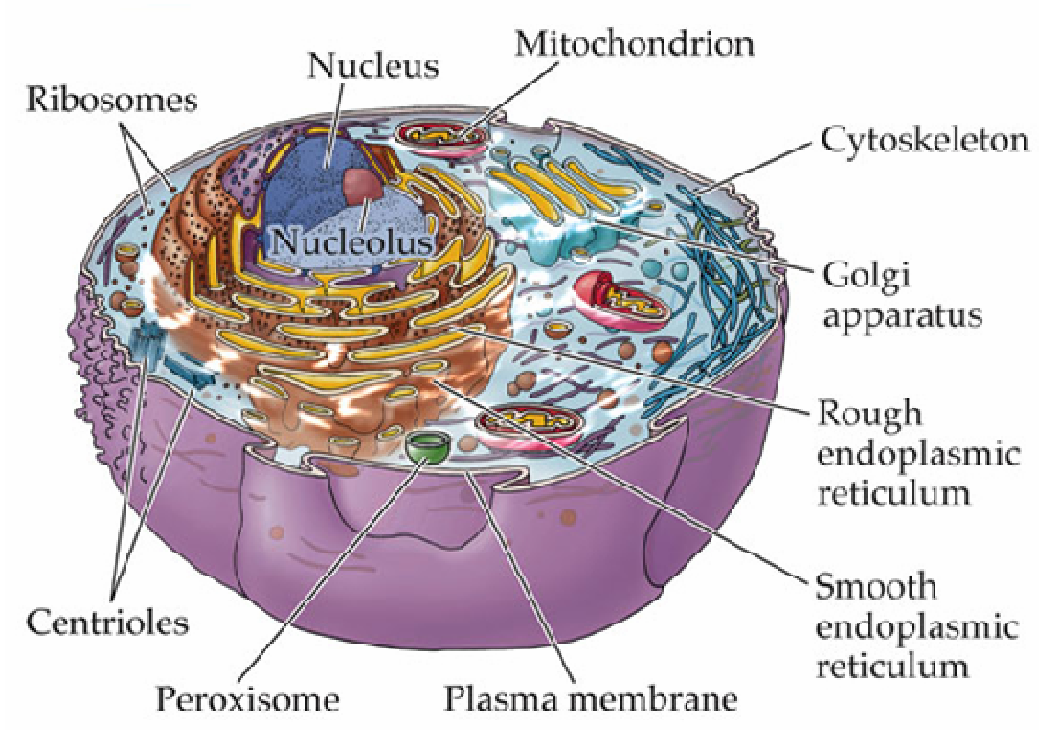
- The cell membrane's ability to allow or resist the passage of substances is called selective permeability:
  - Plasma membrane is not permeable to all substance.
  - However, it does permit some substances to pass more easily than others (i.e., water passes more easily than other substances).
- The selective permeability of the cell membrane is based on:
  - **Molecular size of a substance:** Large molecules cannot pass through the membrane. For example, generally proteins are too large to pass through the membrane whereas amino acids and water are small molecules and they permeate easily.
  - **Lipid solubility:** Substances which dissolve easily in lipids (fats) can pass through the membrane more easily than other substances. Some of the molecules which are lipid soluble are oxygen, carbon dioxide and some hormones (steroids).
  - **Ionic charges:** Ionic charge determines how easily a molecule can pass through the cell membrane. When an ion possesses a charge which is opposite to that of the membrane, it is attracted to the membrane and passes easily. If the charges are the same as the membrane, then the substance is repelled by the membrane and permeability is restricted.
  - **Carrier molecules:** Some substances such as proteins can be carriers, capable of attracting and transporting substances through the membrane regardless of the molecular size, the substance's ability to dissolve in the lipid bilayer, or the membrane charge. This is done by modifying the membrane permeability.

Cytoplasm

- This is the material that is inside of the cell. It is a matrix in which various cellular components are found.
- Its characteristics are:
  - It is very thick, transparent (light white colour), and elastic.
  - It is fluid-like containing suspended particles, tiny tubules and filaments. These filaments, tiny tubes and particles, form the cytoskeleton of the cell.
  - 70-90% of the cytoplasm is water, containing solid components.
  - Solid components of the cytoplasm include: Proteins, Lipids, Carbohydrates and Other materials, such as inorganic substances.
  - The majority of organic components are colloids. Colloid particles carry electrical charges with the same sign. These colloids, having similar charges repel each other creating a force for sustaining suspension.
- Functions of the cytoplasm:
  - Substance in which cellular chemical reactions occur.
  - Receives raw materials from outside the cell.
  - Converts these materials into usable substances (such as energy, proteins, etc.).
  - Facilitates the export and excretion of waste materials.

Organelles

- Inside the cell there are various compartments and these are called organelles. Each has a specific role for:
  - Growth
  - Repair
  - Maintenance
  - Monitoring and control
- The main organelles are:
  - Nucleus
  - Ribosomes
  - Mitochondria
  - Lysosomes
  - Cytoskeleton
  - Centrosome and centrioles
  - Cilia and flagella
  - Cell inclusions



http://heyheyhey12345678.glogster.com/organelles-of-cells/

Nucleus

- Spherical, sometimes oval, organelle (largest organelle).
- Contains hereditary material of the cell (genes).
- Genes control cellular structure and function.
- Some cells do not have a nucleus (e.g. Red Blood Cells). Such cells with no nuclei have:
  - Limited chemical activities
  - Do not have the ability to grow
  - Do not reproduce
- The nucleus is separated from the cytoplasm by a double membrane (nuclear membrane).
- Inside the two layers of the nuclear membrane is a space known as the pre-nuclear cisterna.
- The nuclear membrane has small pores for communication with the cytoplasmic structure known as the endoplasmic reticulum.
- Materials transported to the nucleus go through these small pores.
- Inside the nucleus there are three structures:
  - A gel-like fluid which occupies the nucleus known as the nucleoplasm or sometimes called the karyolymph.
  - Spherical bodies (nucleoli) - one or more.
  - Genetic material (DNA). When the cell is not reproducing the genetic material is in the shape of thread-like chromatin.
  - Before cell reproduction, the chromatin changes shape, shortens and coils into rod-shaped bodies known as chromosomes.
  - Chromosomes basically are DNA. Consisting of elementary subunits of structure called nucleosomes.
  - There are proteins in chromosomes called histones.

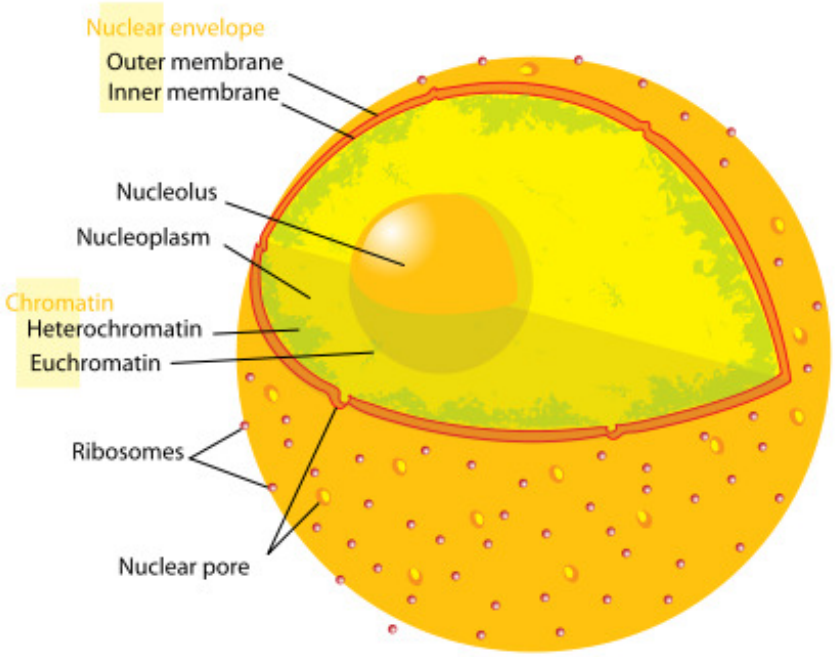


Figure 7. Diagram of a nucleus with two nucleoli

Ribosomes

- Ribosomes are tiny structures.
- Ribosomes are composed of the type of RNA called rRNA and a number of ribosome-specific proteins.
- The rRNA is manufactured by DNA within the nucleus.

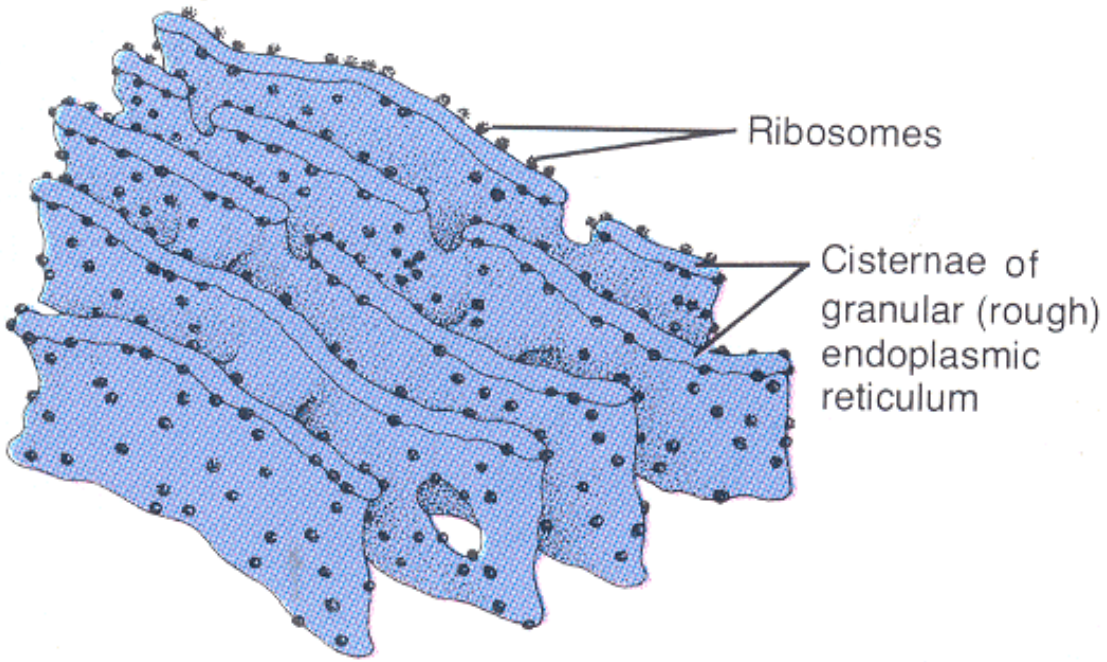


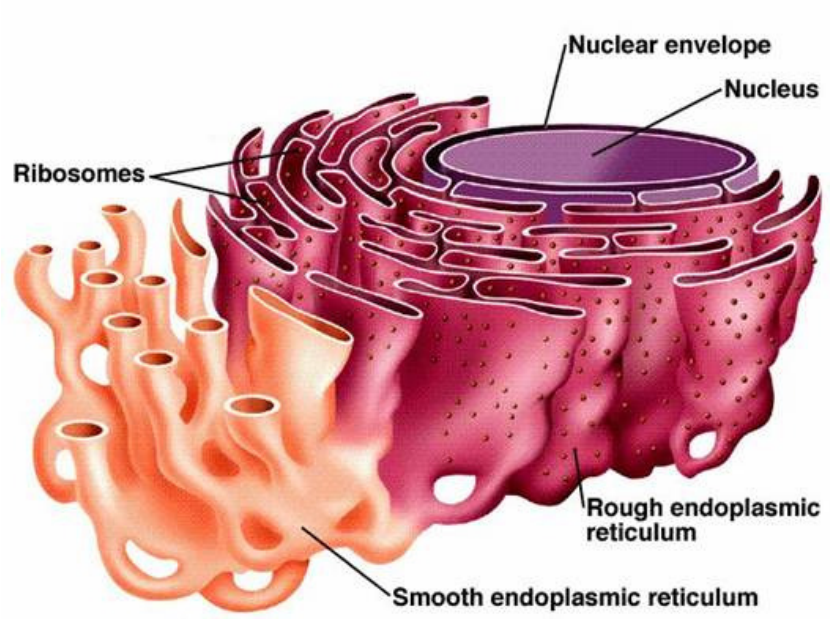
Figure 8. Diagram of granular endoplasmic reticulum (containing ribosomes).

- Ribosomes are where protein is synthesized.
- Ribosomes receive genetic instructions and translate these into proteins.

Endoplasmic Reticulum

- Contains a pair of parallel membranes enclosing narrow cavities of differing shape within the cytoplasm.
- This is called endoplasmic reticulum (ER).
- It is a network of channels or cisternae that run through the cytoplasm and continue to the channels of the nuclear membrane.

- Various functions are related to the ER structures:
  - Homeostasis
  - Mechanical support
  - Distribution of the cytoplasm
  - Conduct intercellular impulses (i.e. muscle cells, which is called sarcoplasmic reticulum)
  - Intercellular exchange of materials with the cytoplasm
  - Provide a large surface area for chemical reactions
  - Provide transportation of substances from one area to another
  - Intercellular circulatory system
  - Provides a storage area for synthesized molecules
  - Assumes the role of synthesis and packaging of molecules.



Golgi Complex

- These are bag-like, flattened channels of 4-8 layers stacked on each other with a bag at the end of each.
- Generally, Golgi Complex is near the nucleus.
- Golgi Complex functions:
  - Packaging of secreted proteins.
  - Golgi Bodies store synthesized proteins, especially in their vesicles (bag-like ends). Once protein accumulates in these ends and they reach a certain size, they are separated from the Golgi Complex and form secretory granules.
  - These secretory granules move toward the surface of the cell and the proteins are secreted into the extracellular space (outside of the cell) and the granule's membrane becomes part of the plasma membrane (a very dynamic process).
  - Another function is associated with the secretion of lipids.
  - The lipids are synthesized by granular endoplasmic reticulum (ER). These lipids pass through the ER into the Golgi Complex. These lipids migrate to the cisterna and become vesicles and are discharged to the cell surface. Some releases may occur inside the cell cytoplasm and these are called lipid droplets.
  - Another function relates to carbohydrate synthesis and this is combined with proteins synthesized by the ribosomes of the granular ER. These molecules can be combined to form glycoproteins.
  - As these carbohydrate-protein complexes accumulate in the Golgi Complex, the vesicles are pinched off and travel to the surface of the cell and discharge their contents through the plasma membrane.
  - Golgi Complexes are well developed in secretory cells such as those found in the salivary glands, pancreas, etc.

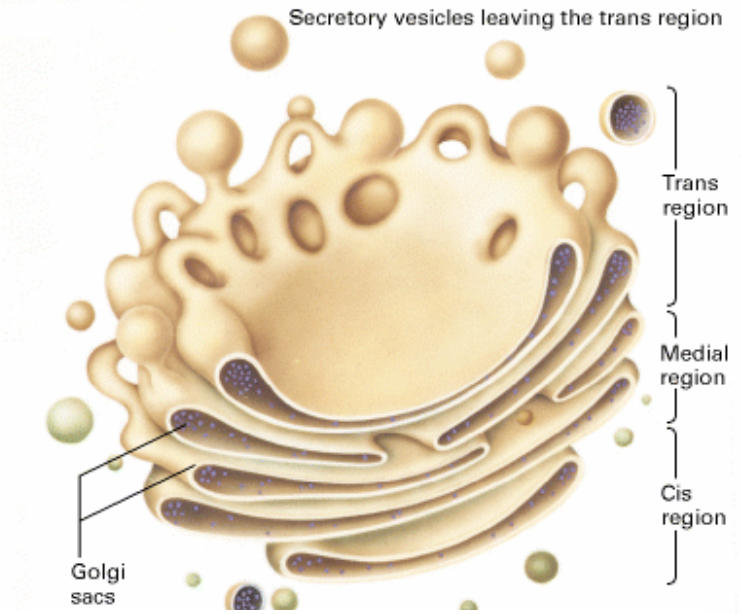


Figure 10. Diagram of the Golgi Complex

Mitochondria

- Small rod-shaped organelle in the cytoplasm.
- It consists of two membranes. The outer membrane is smooth, while the inner membrane is arranged in a series of folds (cristae). The central part of the mitochondria is called the matrix.
- Mitochondria provide a large surface area for chemical activities.
- Contains enzymes for the production of ATP such as:
  - Citric acid (Krebs Cycle)
  - Respiratory pathway

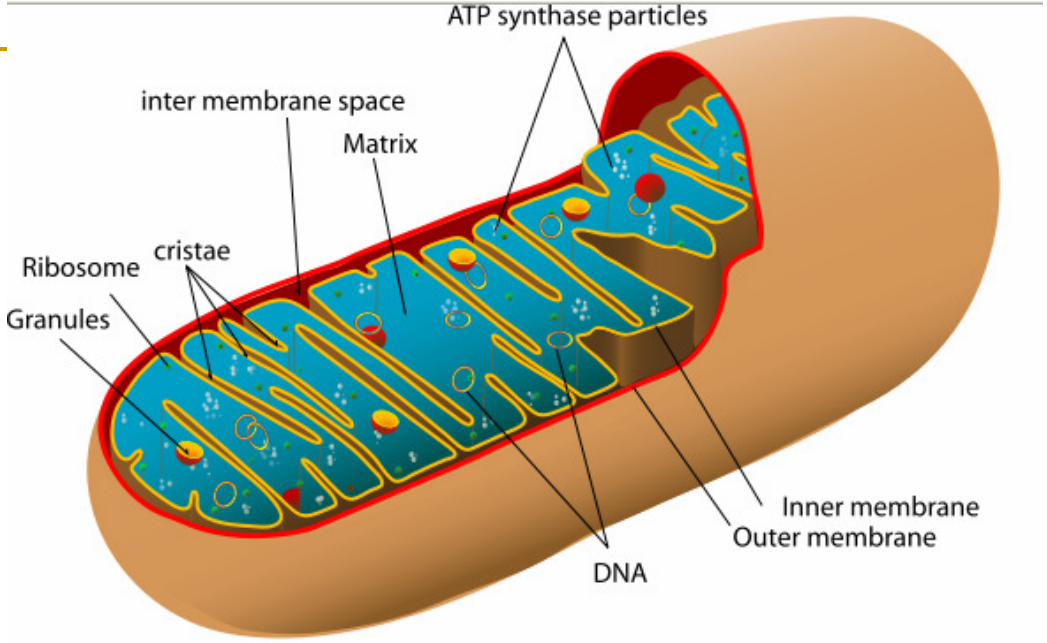


Figure 11. Diagram of a mitochondria showing internal structure.

- Mitochondria are the site for oxidative chemical reactions to produce energy (ATP).
- The produced energy is in the form of adenosine triphosphate (ATP).
- ATP is broken down by various enzymes such as phosphatases and ATPases resulting in energy for cellular activity.
- Mitochondria also contain ribosomes (where proteins are synthesized).
- The inner membrane of mitochondria is highly permeable (unlike the outer membrane). This permeability allows substances such as malate, pyruvate, citrate, calcium ions, phosphate, and Mg^{2+} to pass through.

Lysosomes

- **Lysosomes** are vesicles (bags) containing enzymes coming from the ER and Golgi apparatus.
  - Lysosomes are involved in protein transport and breakdown of substances taken in by phagocytosis and pinocytosis.
  - They are involved in the breakdown of the cell's organelles, such as cytolysomes.
  - Lysosomes contain powerful enzymes which are capable of breaking down many molecules such as bacteria. Generally, the enzymes do not destroy the cells themselves. This is thought to be because the lysosomal membrane, in healthy cells, is impermeable to the enzyme. If the enzymes breakthrough the membrane, they cause autolysis or self-destruction.
  - Indigestible materials are transported to the periphery of the cells and are excreted by exocytosis.
  - Lysosomes are also involved in the removal of cell parts for reshaping.

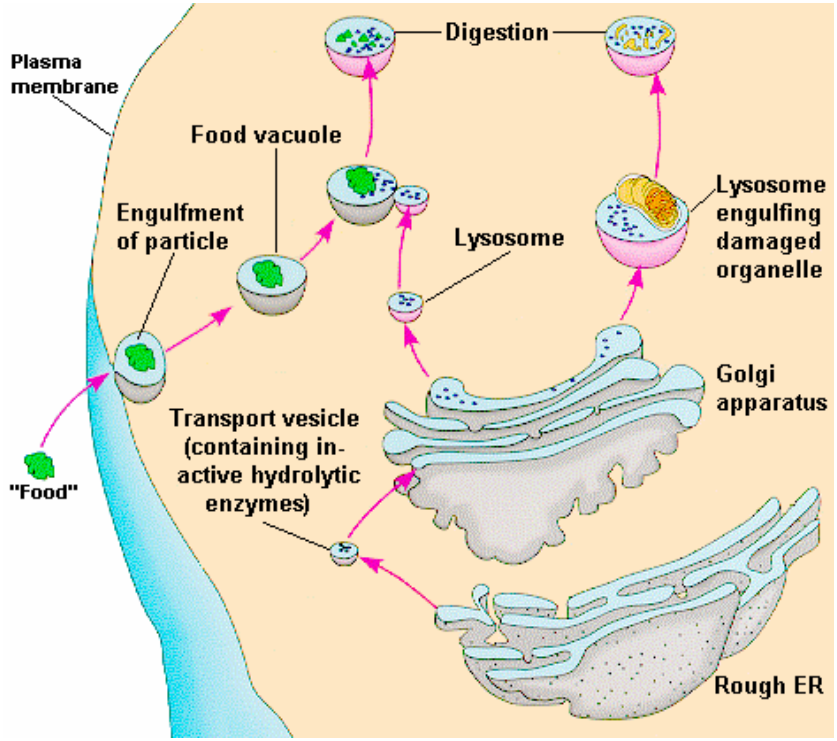


Image from: http://sun.menloschool.org/~cweaver/cells/e/lysosomes/

Peroxisomes

- **Peroxisomes** are small organelles, similar to lysomes (but much smaller).
  - Numerous in liver cells.
  - Many contain enzymes related to metabolism of hydrogen peroxide (H_2O_2). This substance is very toxic to body cells. The enzyme, called catalyase, breaks down hydrogen peroxide into water and oxygen to eliminate the toxicity.

Cytoskeleton

- The cytoskeleton is a collection of various structural or skeletal components in the cell. It consists mainly of microfilaments and microtubules.
- Microfilaments are rod-like structures (30-120 Angstroms, where an Angstrom is 1 x 10^{-10} metres).
  - They can be randomly scattered throughout the cytoplasm or be organized.
  - Examples of microfilaments are actin and myosin. Both are proteins especially common in muscle tissues.
- Microtubules are straight, slender and cylindrical and about 180-300 Angstroms in length.
  - Microtubules are made from a protein called tubulin.
  - They provide support and shape for the cell.
  - Form flagella, cilia and centrioles.
  - They may be involved in the mitotic spindle used in cell division.

Centrosomes and Centrioles

- Dense, spherical materials near the nucleus are known as centrosomes.
- Within each centrosome is a pair of cylindrical structures called the centrioles.
- Each centriole is composed of a ring of nine evenly spaced bundles. Each bundle contains three microtubules.
- They are involved in cell division.
- Centrioles contain DNA that controls their self-replication.

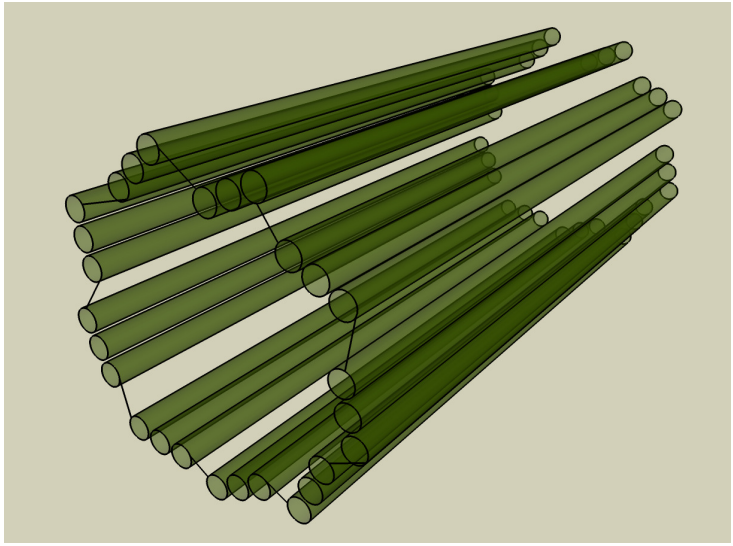


Figure 13. Centriole in longitudinal section.

Flagella and Cilia

- These are projections from the cell body used for moving the cell or substances along the surface of the cell.
- When the projections are few and long, they are called flagella (e.g. sperm cell's tail).
- When the projections are numerous and short, they are called cilia (e.g. digestive tract ciliated cells which move mucus).

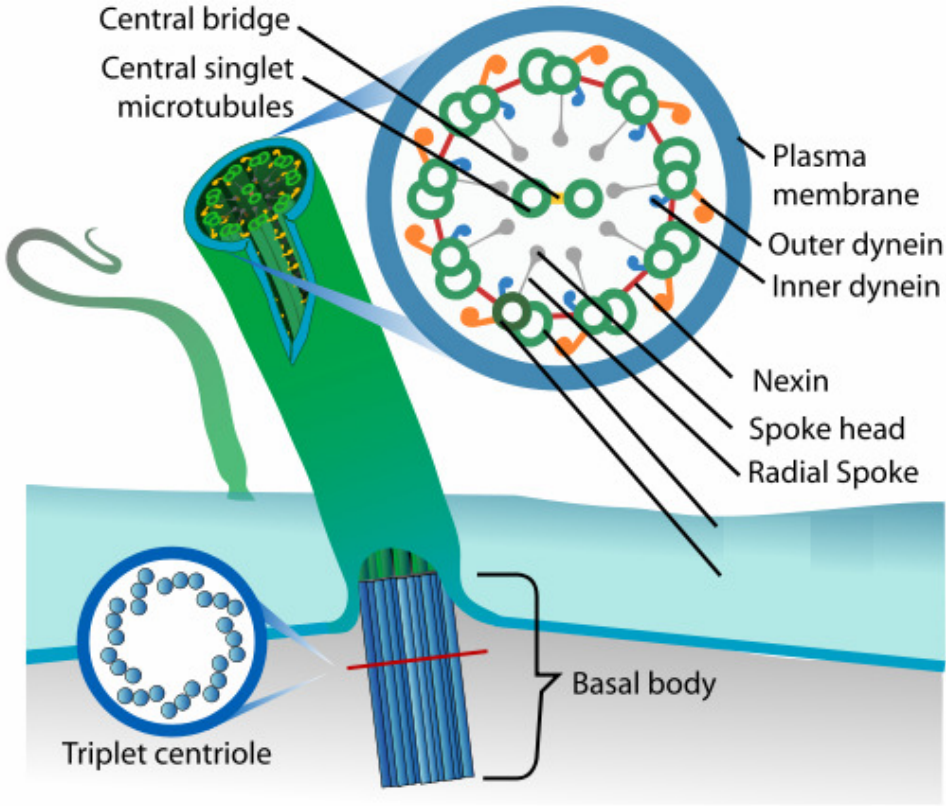


Figure 14. Structure of a flagellum or cilium.

Cell Inclusions

- A large and diverse group of substances.
- They can appear and disappear during the cell's life.
- Examples of cell inclusions are:
  - **Melanin:** A pigment stored in certain cells of the skin, hair or eyes, which protects the body by screening out harmful ultra-violet rays.
  - **Glycogen:** A storage of polysaccharide, principally in the liver and skeletal muscle cells. Used for the production of quick energy. Broken down into glucose.
  - **Lipids:** Stored fats which can be decomposed for energy production.
  - **Mucus:** Produced by cells lining the organs. It provides lubrication and protection.

Summary

- All living organisms have cells.
- Cells are the smallest structural and functional units of living organisms.
- Cells are surrounded by a membrane.
- Inside the membrane is a material called cytoplasm, which contains the organelles.
- Organelles each have specific functions essential to the cell's operation.
- The health and abnormality of the organism is the sum of the activity processes of the cells of an organism.
- Cells can divide and produce new cells.
- The chemical composition of all cells is very similar.