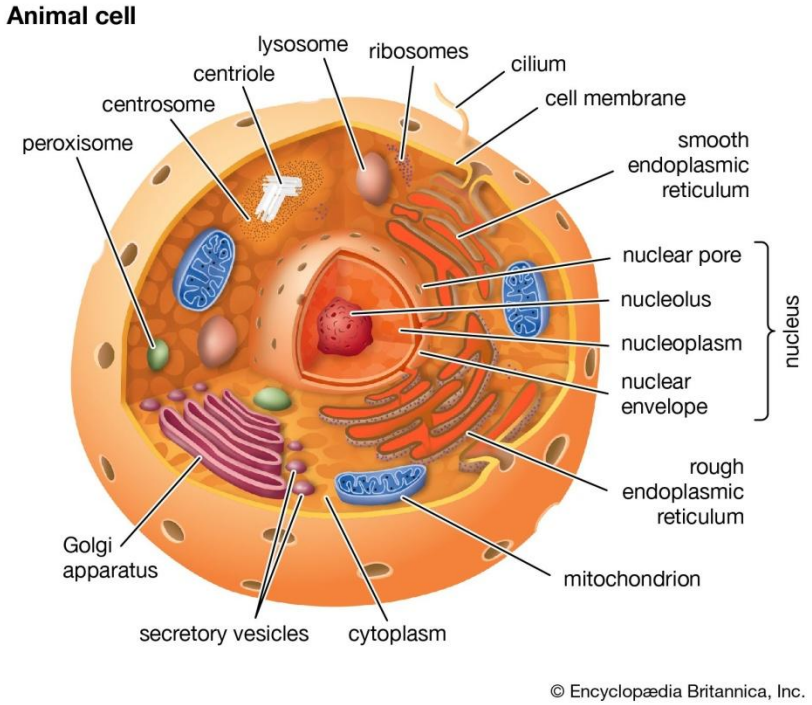
RU RMT 2
Anatomy and Physiology
Lecture 4
Cell Bio Cellular Level

Parts of a Cell

In general, all cells have the following main regions or parts:

* Plasma Membrane
* Cytoplasm
  * Nucleus
  * Organelles



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The Cellular Level of Organization

* Cells are the smallest units of life
  * Human beings contain over 10 trillion cells!
* **Function:** Cells carry out a multitude of functions that help each system contribute to the homeostasis of the entire body
* **Structure:** Cells consist of cytoplasm enclosed by a membrane
* Cells develop from existing cells by the process of cell division, in which one cell divides into two identical cells
* There are many different types of cells in the human body – cells will share some key structures and functions

Plasma Membrane

* **Structure:** The plasma membrane is a flexible, yet sturdy barrier that surrounds and contains the cytoplasm of a cell
  * The plasma membrane contains lipids and proteins
* **Function:** It separates the cells internal environment from the external environment, and creates a selective barrier that controls the movement of substances into and out of the cell
  * It also communicates with surrounding cells and other substances in the external environment

Plasma Membrane

The Lipid Bilayer is composed of the following lipids:

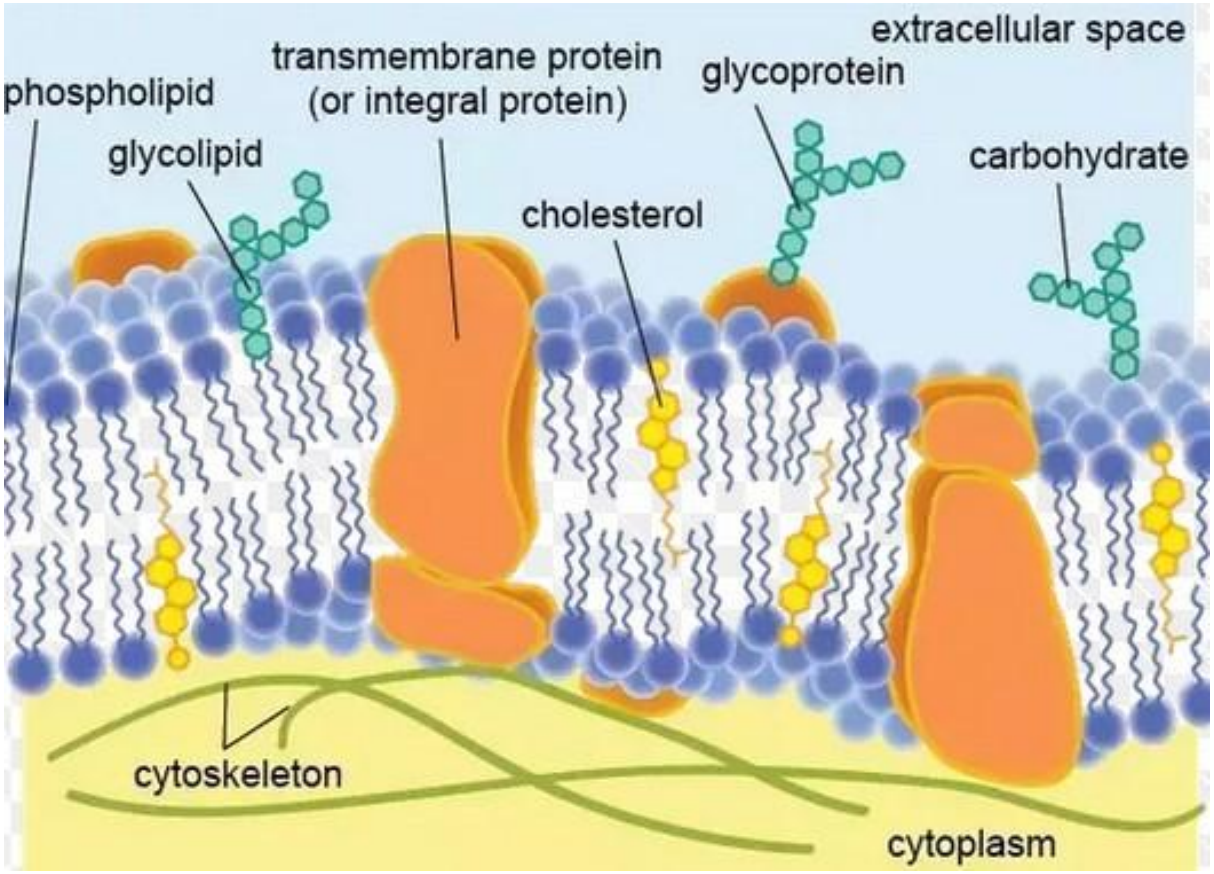
* **Phospholipids** (75%)
  * Amphipathic (polar heads and non--polar tails)
* **Cholesterol** (20%)
  * Interspersed between other lipids in both layers
* **Glycolipids** (5%)
  * Lipids with attached carbohydrate groups
  * Appear only in the layer facing the extracellular fluid

Plasma Membrane

The plasma membrane contains various proteins including:

* **Integral proteins**
  * Extend into or through the lipid bilayer and are firmly embedded in it. Most integral proteins are transmembrane proteins
* **Transmembrane proteins**
  * Span the entire bilayer and extend into the cytosol and extracellular fluid
* **Peripheral proteins**
  * Not as firmly embedded, attached to polar heads of lipid membrane or to integral proteins

Plasma Membrane



Functions of Membrane Proteins

Different cells with have different types of membrane proteins, which will determine the membrane's functions:

* Some integral proteins form **ion channels,** pores or holes that specific ions, such as potassium ions, can flow through to get into or out of the cell
  * These channels are selective: only specific ions can pass through
* Other integral proteins act as **carriers,** selectively moving a polar substance or ion from one side of the membrane to another
  * Carriers are also known as transporters

Functions of Membrane Proteins

* Integral proteins called **receptors** serve as cellular recognition sites. Each type of receptor recognizes and binds a specific molecule
  * Eg. insulin receptors bind the hormone insulin
  * A specific molecule that binds to a receptor is called a **ligand**
* Some integral proteins are **enzymes** that catalyze specific chemical reactions at the inside or outside surface of the cell
* Integral proteins may also serve as **linkers** that anchor proteins in the plasma membranes of neighboring cells to one another, or to protein filaments inside or outside of the cell

Membrane Fluidity

Membranes are fluid structures:

* Most of the membrane lipids and many of the membrane proteins easily move around in their own half of the bilayer
* If a membrane was too rigid, it would lack mobility, but if a membrane was completely fluid, the cell would lack structural organization and mechanical support
* Membrane fluidity depends on both the number of double bonds that make up the lipid bilayer
  * Double bonds create “kinks” that prevent lipid molecules from packing tightly ⍰⍰more fluidity

Membrane Permeability

- **Selective permeability**: plasma membranes permit some substances to pass more readily than others
- The plasma membrane is **highly permeable** to:
  - Non--polar molecules such as oxygen, carbon dioxide and steroids
- The plasma membrane is **moderately permeable** to:
  - Small, uncharged polar molecules such as water and urea
- The plasma membrane is **impermeable** to
  - Large , uncharged polar molecules such as glucose

Membrane Permeability

* Remember, the lipid bilayer has a non--polar, hydrophobic interior
  * The more hydrophobic or lipid--soluble a substance, the greater the membrane's permeability to the substance

Gradients Across the Plasma Membrane

The selective permeability of a plasma membrane allows a living cell to maintain different concentrations of certain substances on either side of the plasma membrane

* **Concentration gradient:** a difference in concentration of a chemical from the inside of a cell, to the outside of a cell
  * Eg. oxygen and sodium are more concentrated in the extracellular fluid than the cytosol; whereas carbon dioxide and potassium ions are more concentrated in the cytosol
* **Electrical gradient:** a difference in electrical charges between the inside of a cell, to the outside of a cell
  * Eg. the inner surface of the plasma membrane is more negatively charged and the outer surface is more positively charged

Gradients Across the Plasma Membrane

* The concentration and electrical gradients are important because they help move substances across the plasma membrane
  * Substances will move down the concentration gradient: from where it is more concentrated, to where it is less concentrated, to reach equilibrium
  * Similarly, a positively charged substance will move to a negatively charged area, and vice versa

Transport Across The Plasma Membrane

The different types of transport across the plasma membrane depend on the requirement of cellular energy:

* **Active Transport**
  * This process uses cellular energy usually in the form of ATP
  * Substances move ‘uphill’ from regions of low concentration to regions of high concentration and hence move against their concentration gradient

Transport Across The Plasma Membrane

* **Passive Transport**
  * This process does not require energy
  * Substances always move from an area of high concentration to an area of low concentration and so move down their concentration gradient

Transport Across The Plasma Membrane

* **Passive Transport**

  The different types of passive processes include:

  * **Simple diffusion:** movement of substances across the lipid bilayer of the cell membrane
  * **Osmosis:** refers specifically to the diffusion of water through a selectively permeable membrane
  * **Facilitated diffusion:** substances travel through the cell membrane through the assistance of other molecules

Transport Across The Plasma Membrane

The various factors that affect the rate of diffusion and osmosis across a plasma membrane include:

- **Steepness of the concentration gradient**
  - the greater the difference in concentration between the two sides of the plasma membrane, the higher the rate of diffusion
- **Temperature**
  - the higher the body temperature, the faster the rate of diffusion

Transport Across The Plasma Membrane

* **Mass of the diffusing substance (size of the molecule)**
  * the larger the mass of the diffusing molecule, the slower the rate of diffusion rate
* **Surface area**
  * the larger the surface area of the plasma membrane available for diffusion, the faster the rate of diffusion
* **Diffusion distance**
  * the greater the distance over which diffusion must occur, the slower the rate of diffusion

Osmosis

Osmosis

* a process by which molecules of a solvent tend to pass through a semipermeable membrane from a less concentrated solution into a more concentrated one, thus equalizing the concentrations on each side of the membrane

Tonicity

* Tonicity is the measure of the solution's ability to change the volume of cells by altering their water content

* Normally, osmotic pressure in the cytosol is the same as the osmotic pressure of the interstitial fluid outside cells and so the cell volume remains constant

* When a cell is placed in a solution having a different osmotic pressure than cytosol, the shape and the volume of the cell changes since water moves in or out of the cells by osmosis

Tonicity

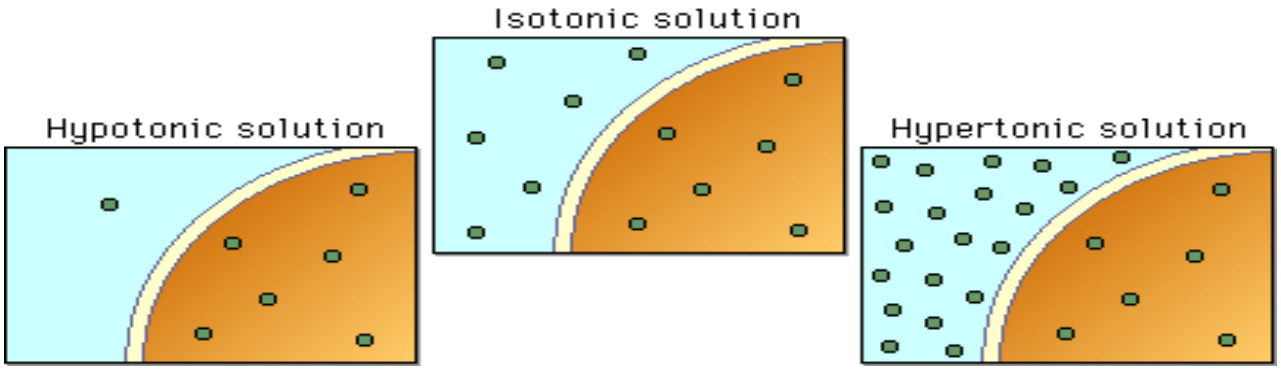
* The different types of solutions based on their tonicity include:
  * **Isotonic solution (iso = same)**
    * An isotonic solution is a solution in which the concentration of the solute is the same as that of the cytoplasm of a cell
    * Since the concentrations of solutes on both sides of the cell membrane are the same, water molecules exit and enter the cell, at the same rate
    * Hence when a cell is immersed in an isotonic solution the cell maintains its normal shape and volume

Tonicity

* **Hypotonic solution (hypo = less than)**
  * A hypotonic solution is a solution in which the concentration of the solute is less than that of the cytoplasm of a cell
  * Since the concentration of the solute in the solution is less than that of the cytoplasm, water molecules enter the cell faster than they leave the cell
  * This causes the cell to swell and eventually burst and this phenomenon in known as lysis
  * When this happens in red blood cells it is known as hemolysis
  * Pure water is very hypotonic

Tonicity

* **Hypertonic solution (hyper = greater than)**
  * A hypertonic solution is a solution in which the concentration of the solute is more than that of the cytoplasm of a cell
  * Since the concentration of the solute in the solution is more than that of the cytoplasm, water molecules move out of the cell faster than they enter the cell
  * Hence it causes the cell to shrink and when this occurs in red blood cells it is known as crenation



Transport By Vessicles

Transport by Vesicles

* A vesicle is a small, spherical sac that transports a variety of substances into and out of a cell
* This transport using vesicles can occur by either an active or a passive process
* Types of vesicular transport include:
  * **Endocytosis:** the movement of materials into a cell
    * Phagocytosis: movement of solid particles
    * Pinocytosis: movement of liquid substances
  * **Exocytosis:** movement of materials out of a cell
  * **Transcytosis:** combination of movement of a substance into, across, and out of a cell

Cytoplasm

The cytoplasm of a cell consists of two main components:

1. The Cytosol
2. The Organelles

Cytosol

Cytosol

* The cytosol is the fluid portion of cytoplasm that surrounds organelles, and makes up about 55% of cell volume
* It varies in composition and consistency from one part of the cell to another, and consists of 75--90% water, plus dissolved and suspended components
* The cytosol also contains the **cytoskeleton** which is a network of several types of protein filaments that extend throughout the cytoplasm of the cell and provide support to the cell

Cytosol

The cytosol contains three types of protein filaments:

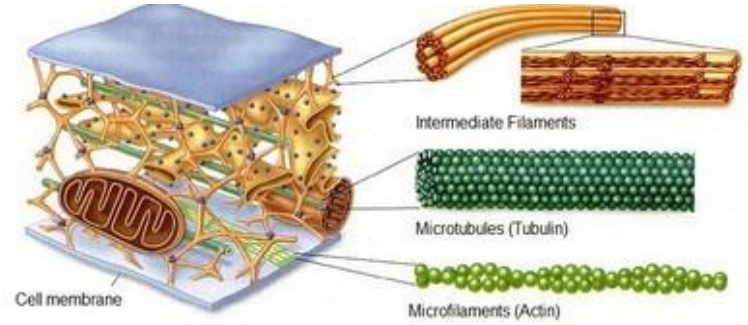
1. Microfilaments
   * They are the thinnest protein filaments in the cytoskeleton
   * They are composed of the protein actin and provide mechanical support to the cell

Cytosol

2. Intermediate filaments
   * They are thicker than microfilaments, but thinner than microtubules and are composed of different proteins and are exceptionally strong
   * They are found in parts of cells subject to mechanical stress and their major function is to help attach cells to one another

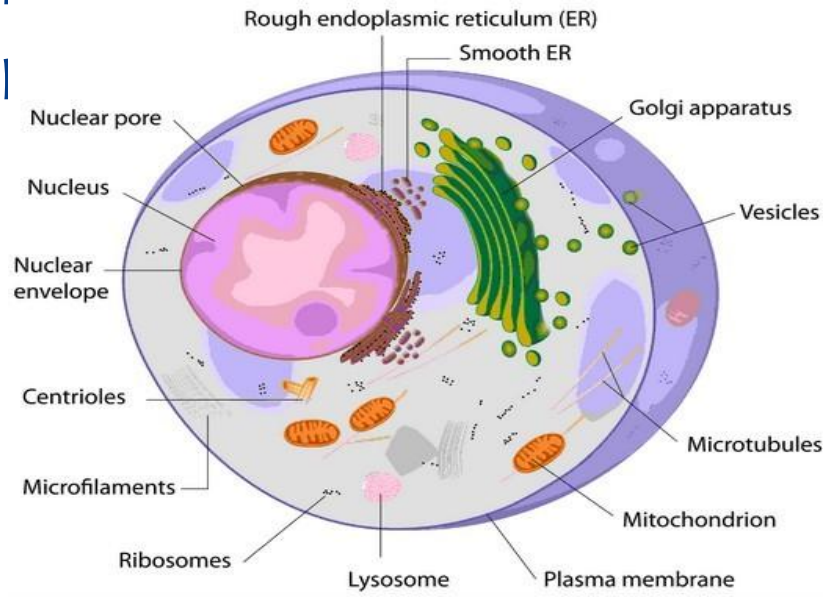
Cytosol

3. Microtubules
   * These are the thickest of the cytoskeleton components and they are actually long, unbranched hollow tube
   * They are responsible for the intracellular movement of organelles, migration of chromosome during cell division, movement of specialized cell projections such as cilia and flagella



Organelles

* **Organelles** are specialized tiny structures that perform specific functions in the cell and work together to maintain homeostasis
* Organelles have characteristic shapes and their numbers and types vary in different cells, depending on the cell's function
* The different organelles that are p
  * **Mitochondria**
  * **Ribosomes**
  * **Endoplasmic Reticulum**
  * **Golgi Complex**
  * **Lysosomes**
  * **Cilia/Flagella**
  * **Nucleus**



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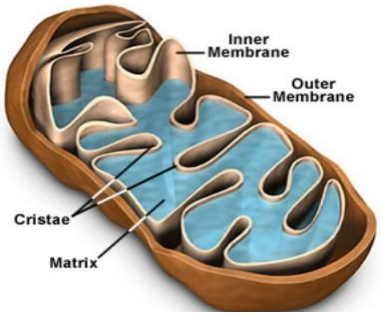
Mitochondria

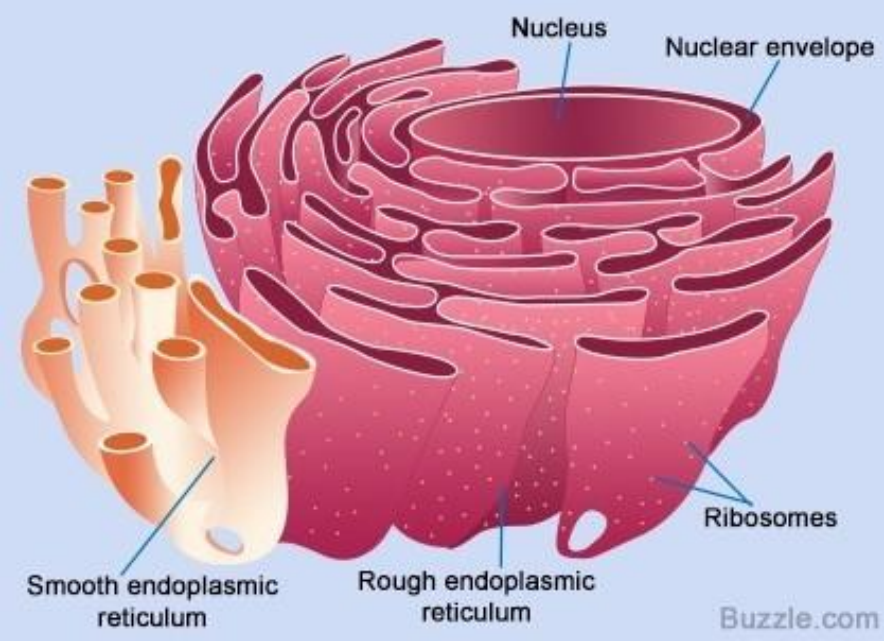


* Function:
  * mitochondria generate ATP through aerobic respiration
* Structure:
  * A mitochondrion is bound by a double membrane, separated by a small fluid--filled space
  * The outer mitochondrial membrane is smooth, while the inner mitochondrial membrane consist of a series of folds called cristae
  * The central fluid--filled cavity enclosed by the inner membrane is called the matrix
  * Depending on the activity of the cell, it may have a few hundred to several thousand mitochondria

Ribosomes

Ribosomes

* Function:
  site of protein synthesis
  * They connect amino acids to build long chains (proteins)
* Some ribosomes are attached to the endoplasmic reticulum while others float freely in the cytoplasm

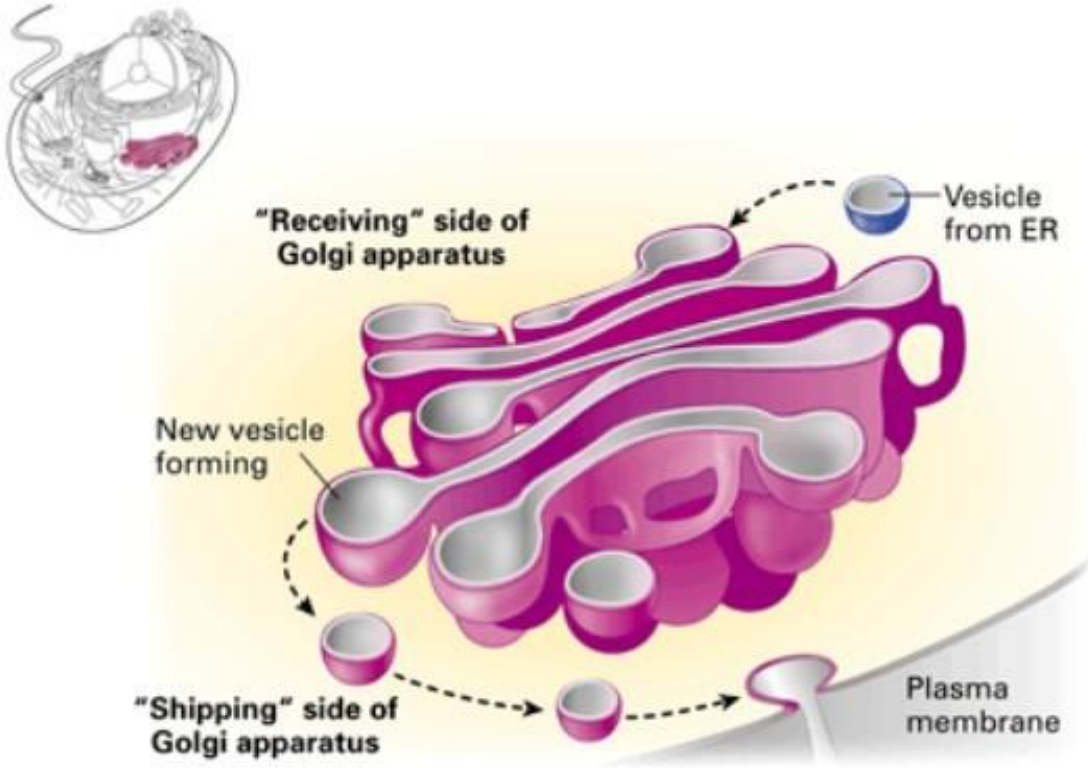


Endoplasmic Reticulum

* Function: responsible for synthesis of different molecules
* Structure: The ER consists of a network of membrane--enclosed sacs or tubules that extend throughout the cytoplasm
* There are two types of endoplasmic reticulum:
  * **Rough endoplasmic reticulum:**
    * The outer surface is studded with ribosomes
    * It is responsible for synthesis of proteins
  * **Smooth endoplasmic reticulum**
    * It does not have ribosomes on its surface
    * Synthesizes fatty acids and steroids (estrogens, testosterone) but does not synthesize proteins

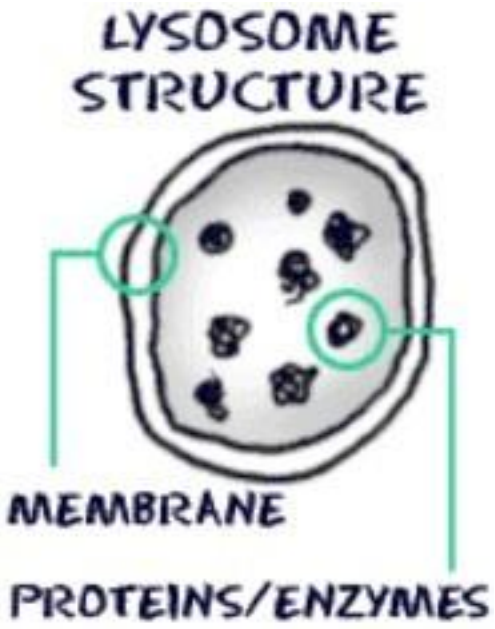
Golgi Complex

* Function: modifies, sorts, and packages lipids and proteins received from the endoplasmic reticulum
* Structure: small, flattened membranous sacs with bulging edges



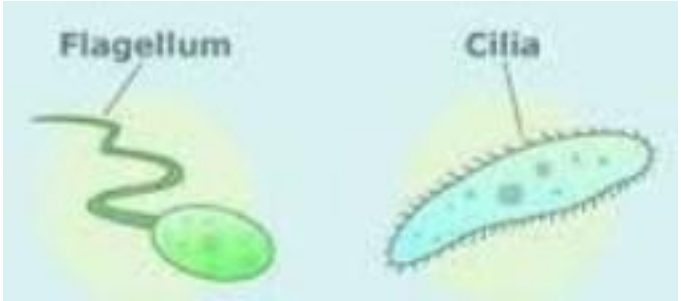
Lysosomes

* These are membrane--enclosed vesicles that contain digestive and hydrolytic enzymes
* “waste disposal”
* Tay--Sachs disease:
  * Tay--Sach’s disease is a lysosomal disorder caused by faulty or absent lysosomal enzymes which causes the increased accumulation of gangliosides in neurons due to a reduced breakdown of the gangliosides
  * As excess gangliosides accumulate in the neurons they function less efficiently leading to seizures and muscle rigidity



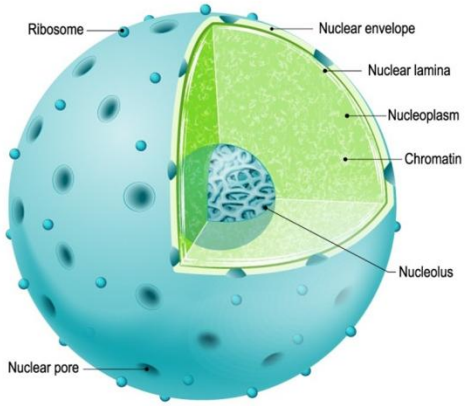
Cell Wall Projections

* **Cilia:**
  * short, hair--like projections extending from the surface of a cell
  * They are found throughout the body (eg. the respiratory tract and fallopian tubes)
  * Chronic smoking can inhibit the movement of cilia and destroy the cilia in the lining of the respiratory system
* **Flagella:**
  * They are similar to cilia but are much longer
  * They move an entire cell by generating forward motion by rapidly wiggling in a wave--like pattern
  * The only example of a flagellum in the human body is the sperm cell



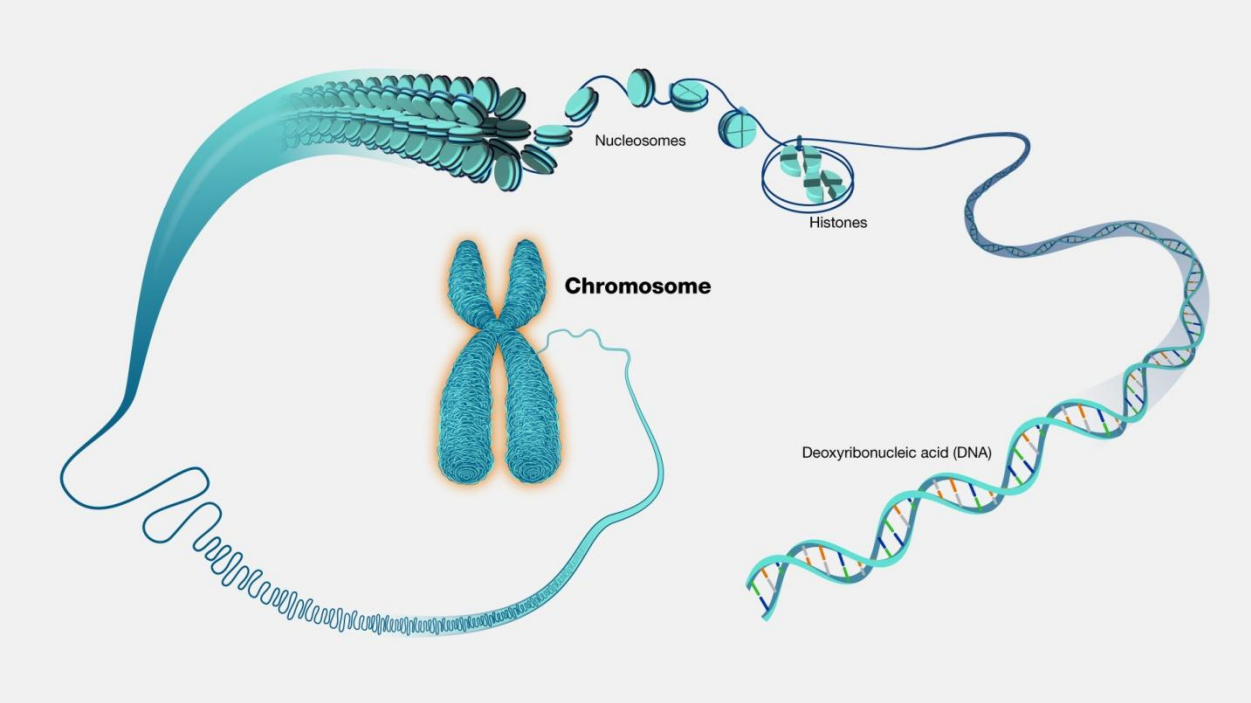
Nucleus

* Function: “the brain” of the cell, housing all of the genetic material (chromosomes)
* Structure: spherical or oval shaped;
  most prominent feature/largest organelle of a cell
* Contains **nucleoli**, small, spherical bodies inside of the nucleus (production site for ribosomal RNA)
* Most body cells have a single nucleus (uninucleated), while some, such as mature red blood cells. have no nucleus (anucleated), while others, such as skeleta e several nuclei (multinucleated)



Chromosomes

* Each chromosome is a long linear strand of DNA
* Each individual segment of a chromosome that regulates one particular activity is known as a gene
* Human somatic cells have 46 chromosomes of which 23 are derived from each parent
* Sperms and ova have 23 chromosomes



Cellular Diversity

* Cells vary considerably in size, shape and function and may be round, oval, flat, cube--shaped, column--shaped, elongated, star-- shaped, cylindrical or disc--shaped
* A cell's structure is related to its function:
  * a sperm has a long whip like tail (flagellum) that it uses for locomotion
  * the disc shape of a red blood cell gives it a larger surface area that enhances its ability to supply oxygen to other cells
  * the long spindle shape of a relaxed smooth muscle shortens as it contracts. This change in shape allows groups of smooth muscle cells to narrow or widen the lumen of blood vessels

Genomics

Genomics refers to the study of the relationships between the genome (the genetic makeup of an organism) and the biological functions of that organism

* Recombinant DNA:

* Scientists have developed techniques for inserting genes from other organisms into a variety of host cells

  Manipulating the cells in this way can cause the host organism to produce proteins it normally does not synthesize

* These altered organisms are called recombinants and their DNA, which is a combination of DNA from different sources, is called recombinant DNA

* This technique of producing recombinant DNA is referred to as genetic engineering.

Protein Synthesis

* The most basic function of cells is to produce both structural and functional proteins which in turn determine the physical and chemical characteristics of the cell
* **Gene Expression:** a process in which a gene's DNA is used as a template for synthesis of a specific protein

Protein Synthesis

- Protein Synthesis involves the following two steps:

* **Transcription**
  * Transcription occurs inside the nucleus
  * The information in a specific region of DNA is copied to produce a specific molecule of RNA
* **Translation**
  * Translation occurs outside the nucleus in the cytoplasm
  * The RNA molecule that is synthesized from a DNA molecule attaches to a ribosome and this information is used to produce a sequence of amino acids that form a protein

Cell Types

The two basic cell types in humans include:

* **Somatic cell:**
  * They include all the cells in the body except the germ cells
  * Somatic cells contain 46 chromosomes and are written as "2n" since they contain sets each of two similar chromosomes, each derived from a parent
* **Germ cell:**
  * A germ cell is also known as a gamete and includes the sperms and ova
  * Germ cells contain 23 chromosomes

Chromosome Types

Chromosomes are of two types namely:

* **Homologous chromosomes:**
  * the two chromosomes that make up each pair in a set and contain similar genes arranged in the same order
* **Sex chromosomes:**
  * They are the X and Y chromosomes
  * Females have two X chromosomes, while males have one X chromosome and a much smaller Y chromosome