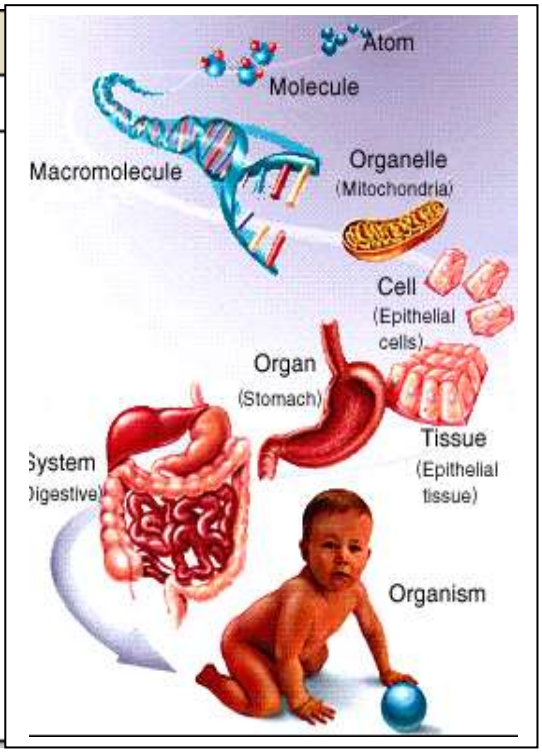
Introduction to the Human Body

Physiology: is the study of the body's functions (while Anatomy deals with the structure of the body).
The two (anatomy & physiology) are closely interrelated.
The body's ability to perform many of its functions changes gradually over years.
In general, the body performs its functions least well at both ends of life – (infancy and old age).

Levels of Organization

Name	Definition	Example
Chemical	Interactions between atoms and their combinations into molecules.	Carbon, oxygen, and nitrogen
Organelles	Components of cells that are built from groups of large molecules.	Mitochondrion, ribosome, and lysosome
Cells	The basic living units of all plants and animals; cells are organized into tissues.	Skin cells, nerve cells, and red blood cells.
Tissues	A group of cells with similar structure and function, together with the extracellular substances located between them.	Epithelial, connective, and muscle tissue
Organs	Composed of two or more tissues types; organs perform one or more common functions or set of functions.	Heart, brain, and stomach
Organ Systems	Groups of organs that work together as a unit because of a common function or set of functions.	Skeletal system, nervous system, and digestive system



Organ Systems

Body Covering

- ❖ Integumentary system, including skin, hair, nails, and various glands,
- ❖ They cover the body, senses changes outside body, & helps regulate body temperature.

Support and Movement

a. Skeletal system is made up of bones & ligaments:
It supports the body, stores inorganic salt,& houses blood forming tissues.
b. Muscular system consists of muscles that provide movement, posture & heat.

Integration and Coordination

a. Nervous system consists of brain, spinal cord, nerves, & sense organs.
It integrates information from receptors & sends impulses to muscles & glands.
b. Endocrine system, include glands that secrete hormones, & integrate metabolism.

Transport

a. Cardiovascular system, made up of heart & blood vessels, distributes O2 & nutrients throughout the body while removing wastes from cells.
b. Lymphatic system, consisting of lymphatic vessels, lymph nodes, thymus, & spleen. It drains excess tissue fluid & includes cells of immunity.

Absorption and Excretion

a. Digestive system: made up of mouth, esophagus, stomach, intestine & accessory organs. It receives, breaks down, & absorbs nutrients.
b. Respiratory system exchanges gases between blood & air.
c. Urinary system, consisting of kidneys, ureters, bladder, & urethra, removes wastes from blood & helps to maintain water & electrolyte balance.

Reproduction

Reproductive system produces new organisms.

a- Male system consists of testes, accessory organs, & vessels that conduct sperm to penis.

b- Female reproductive system consists of ovaries, uterine tubes, uterus, vagina, & external genitalia.

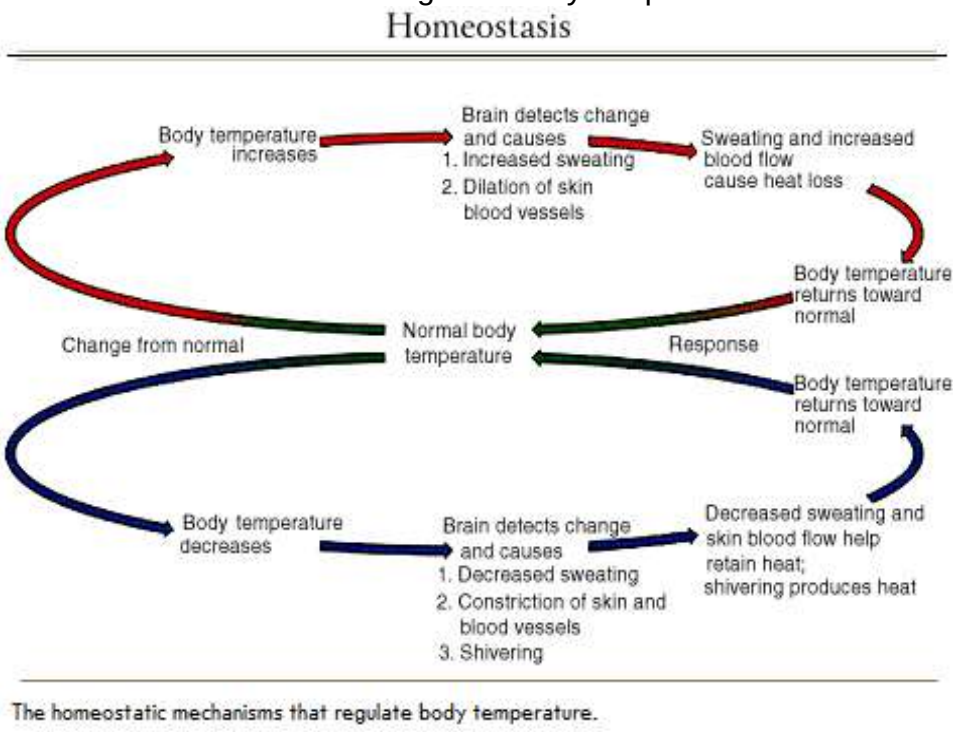
METABOLISM AND HOMEOSTASIS

Metabolism is all of chemical reactions & physical processes that take place within the body. It includes all the characteristics of life.

Homeostasis

It is Maintenance of a stable internal environment inside the body**,** which is regulated through the control systems which have receptors, a set point & effectors.

- Many of the body's homeostatic controls are negative feedback mechanisms.
- **Example:** Homeostatic mechanisms that regulate body temperature.



The homeostatic mechanisms that regulate body temperature.

Characteristics of life (life processes):

1. *Movement*: it has types within the body (on cellular level & on muscular level).
2. *Responsiveness:* detect changes in internal or external environment & react to that change.
3. *Growth:* increase in size either increase in number of cells or increase in size of each cell
4. *Reproduction*: (new organisms or new cells)
5. *Respiration*: (use of oxygen; removal of CO2)
6. *Digestion*: (breakdown of food into simpler forms)
7. *Assimilation:* (changing nutrients into chemically different forms)
8. *Absorption* :(movement of substances through membranes and into fluids)
9. *Excretion*: (removal of metabolic wastes)
10. *Differentiation**:*** developmental process by which unspecialized cells change into specialized.

Maintenance of Life:

Life depends on the availability of the following from the environment:

Water, (Nutrients) Food, Oxygen, Heat, Pressure

- Each individual uses homeostatic mechanisms to keep body levels within a normal range.

Inorganic Compounds of Importance

1. ***Water***—makes up 60 - 75% of the body. It is:
• Solvent—for transport of nutrients in blood & excretion of wastes in urine.
• Lubricant—mucus in the digestive tract.
• Prevents sudden changes in body temperature; absorbs body heat in evaporation of sweat.
➢ *Water compartments*—the locations of water within the body.
❖ *Intracellular*—within cells ; 65% of total body water.
❖ *Extracellular*—35% of total body water
— **Plasma**—in blood vessels.
— **Lymph**—in lymphatic vessels.
— **Tissue fluid**—in tissue spaces between cells.
---Specialized fluids—synovial fluid, cerebrospinal fluid, aqueous humor in the eye, & others.

2. ***Oxygen***—21% of the atmosphere.
• Essential for cell respiration: breakdown of food molecules to release energy. Cell respiration—the energy-producing processes of cells).

3. ***Carbon dioxide***
• Produced as a waste product of cell respiration.
Glucose + O2 → CO2 + H2O + ATP +heat

4. ***Acids, bases, and pH***
• pH scale ranges 0 - 14;
7 = neutral; < 7 = acidic; >7 = alkaline.
• Buffer systems maintain normal pH by reacting with strong acids or strong bases to change them to substances that do not greatly change pH.

5. ***Trace elements***—minerals needed by the body in small amounts.

TRACE ELEMENTS

Element	Function
Calcium	• Provides strength in bones and teeth • Necessary for blood clotting • Necessary for muscle contraction
Phosphorus	• Provides strength in bones and teeth • Part of DNA, RNA, and ATP • Part of cell membranes
Iron	• Part of hemoglobin in red blood cells; transports oxygen • Part of myoglobin in muscles; stores oxygen • Necessary for cell respiration
Copper	• Necessary for cell respiration • Necessary for hemoglobin synthesis
Sodium and potassium	• Necessary for muscle contraction • Necessary for nerve impulse transmission
Sulfur	• Part of some proteins such as insulin and keratin
Cobalt	• Part of vitamin B12
Iodine	• Part of thyroid hormones—thyroxine

ORGANIC COMPOUNDS OF IMPORTANCE

All contain covalently bonded carbon & hydrogen atoms and perhaps other elements. They include: 1. Carbohydrates (CHO) 2. Lipids. 3. Proteins

Name	Function
Monosaccharides—"Single Sugars Glucos ,Fructose, Galactose	• Most important energy source for cells • Converted to glucose by the liver, then used for energy production
Disaccharides—"Double" Sucrose, lactose& maltose	Present in food; digested to monosaccharides, which are then used for energy production
Oligosaccharides—"Few'' Sugars	• Form "self" antigens on cell membranes; important to permit the immune system to distinguish "self" from foreign antigens (pathogens)
Polysaccharides—"Many" Starches Glycogen Cellulose	• Found in plant foods; digested to monosaccharide & used for energy production. • Storage form for excess glucose in the liver and skeletal muscles • Part of plant cell wall; provide fiber to promote peristalsis in colon

Table 2–5 FUNCTIONS OF PROTEINS

Type of Protein	Function
Structural proteins	• Form pores and receptor sites in cell membranes • Keratin—part of skin and hair • Collagen—part of tendons and ligaments
Hormones	• Insulin—enables cells to take in glucose; lowers blood glucose level • Growth hormone—increases protein synthesis and cell division
Hemoglobin	• Enables red blood cells to carry oxygen
Myoglobin	• Stores oxygen in muscle cells
Antibodies	• Produced by lymphocytes (white blood cells); label pathogens for destruction
Myosin and actin	• Muscle structure and contraction
Enzymes	• Catalyze reactions

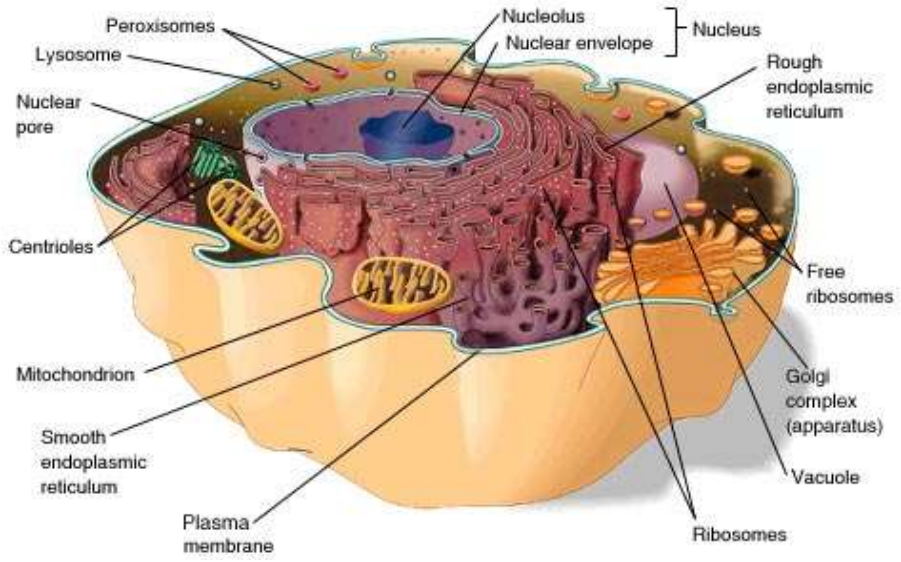
Table 2–4 LIPIDS

Name	Function
True fats	• Storage form for excess food molecules in subcutaneous tissue • Cushion organs such as the eyes and kidneys
Phospholipids	• Part of cell membranes (lecithin) • Form the myelin sheath to provide electrical insulation for neurons
Steroids (cholesterol)	• Part of cell membranes • Converted to vitamin D in the skin on exposure to UV rays of the sun • Converted by the liver to bile salts, which emulsify fats during digestion • Precursor for the steroid hormones such as estrogen in women (ovaries) or testosterone in men (testes)

CELL PHYSIOLOGY

Cell is the Smallest living base structural & functional unit of life. All cells have:

- Plasma membrane - Cytoplasm (Cytosol) , & organelles within the cytoplasm.



Plasma (cell) Membrane Structure

It is the boundary between extracellular fluid (ECF) & intracellular fluid (ICF), composed of:

I. Phospholipids are arranged in two layers with their hydrophobic fatty acid tails to interior of membrane & their hydrophilic polar heads on inner & outer surfaces.

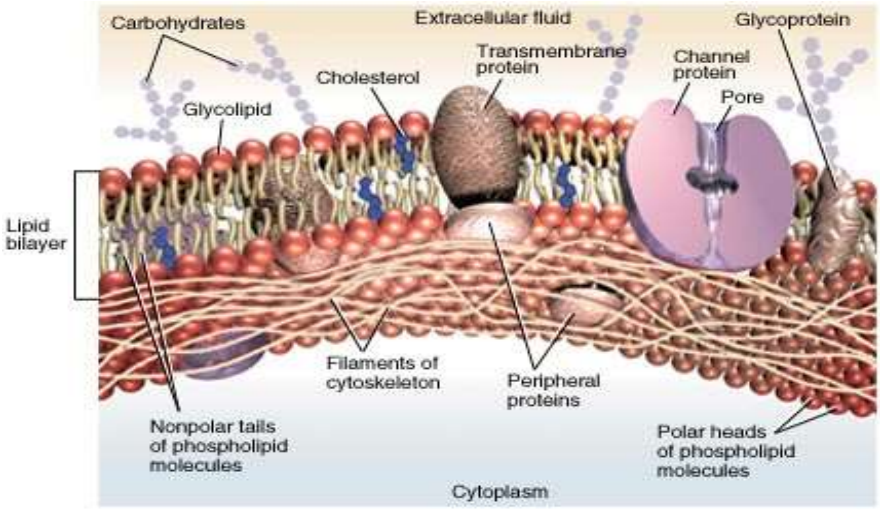
II. Proteins are another important component. There are two types of proteins:
- integral (transmembrane) proteins that pass through the entire membrane
- peripheral proteins that do not protrude into phospholipid layer but adhere to intracellular face of membrane.

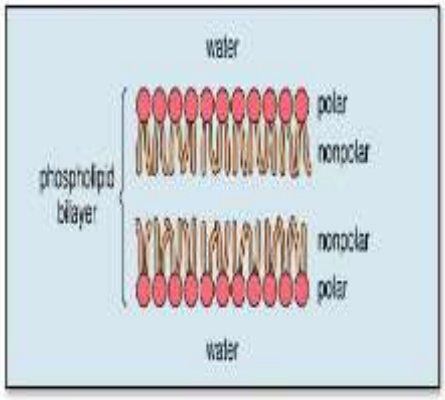
❖ Some of phospholipids & integral proteins have CHO chains attached to them forming glycolipids & glycoproteins.

III. Cholesterol is also found within cell membrane.

Components of membrane slowly drift past one another, so making membrane fluid.

❖ This theory of structure of plasma membrane called *fluid-mosaic model.*





The functions of membrane proteins are:

1) Provide receptor sites for chemical messengers such as hormones (Hs)& neurotransmitters (NT).

2) Enzymes catalyze reactions near the membrane.

3) Channel proteins are constantly open to allow passage of various solutes all the time. There are ion channels specific for K+, Na+, Ca2+,& Cl−, as well as channels that are nonselective for cations or anions.

4) Gated channels :They have tightly regulated pores that can be **gated** opened or closed in response to local changes :

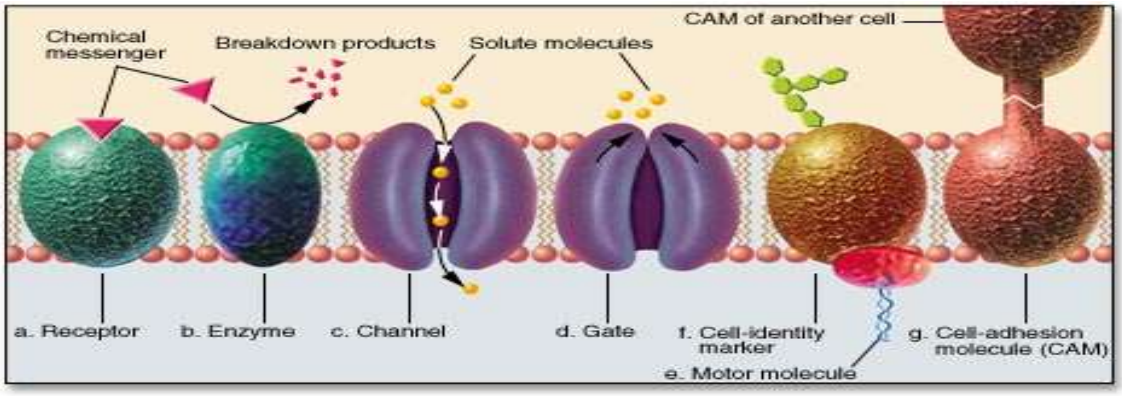
a. **Voltage-gated channels,** gated by alterations in membrane potential.
b. **Ligand-gated channels ,** opened or closed in response to external ligand, (eg, N or H) or internal ligand; intracellular Ca2+, cAMP, or G proteins.
c. **Mechanosensitive channels** opened by mechanical stretch that play an important role in cell movement.

5) Motor molecules are proteins that pull membrane proteins & cause cellular movement.

6) Glycoproteins function in cellular identification.

7) Cell adhesion molecules (CAMs) bind one cell to another.

8) Carrier proteins: integral proteins that bind to specific molecules ,change their configuration & transport them to the other side of the membrane (not shown in the diagram). Many carrier molecules are ATPases enzymes that catalyze hydrolysis of ATP, e.g sodium–potassium adenosine triphosphatase (Na, K ATPase= Na, K pump) , H- K ATPases & Ca2+ ATPase.

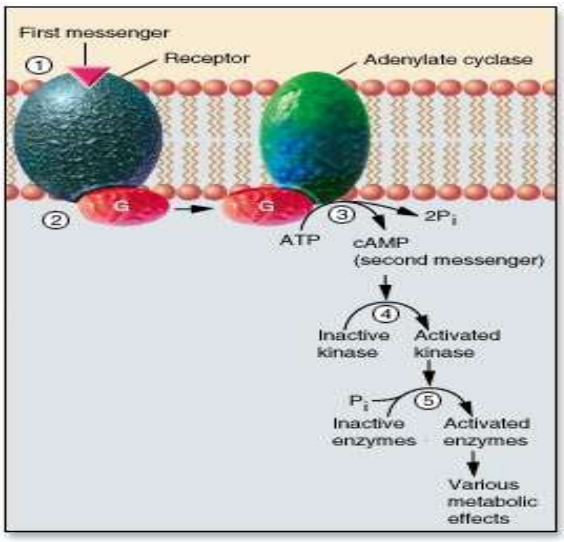


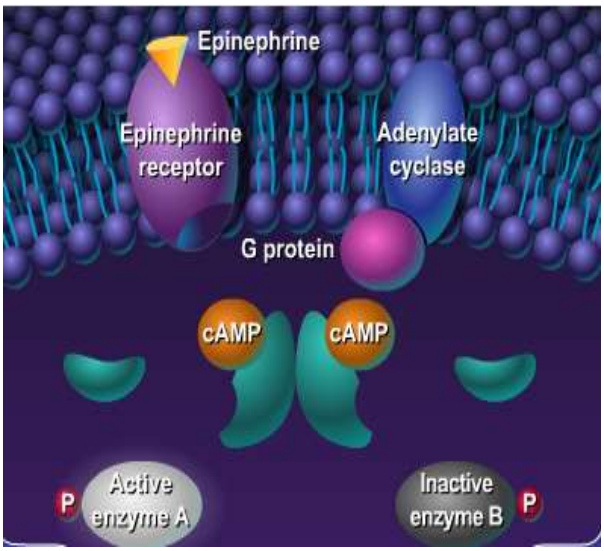
Notes:

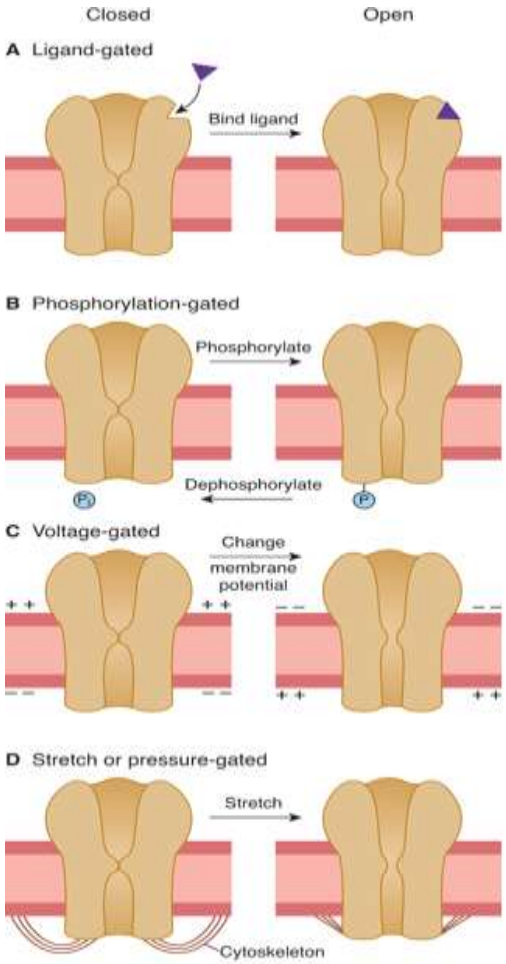
- **Chemical gradient:** movement of substances from high to low concentration,
- **Electrical gradient**): cations move to negatively charged areas while anions move to positively charged areas.
- **Uniports :** protein transporter proteins that transport only one substance.
- **Symports** protein transport that requires binding of more than one substance for the transportation.
- **Antiports:** protein transporter that exchange one substance for another.

Regarding action of Membrane proteins in activating second messenger systems:

- First messenger such as H or NT binds to its receptor site.
- Receptor release G protein, which bind to a membrane-bound enzyme e.g adenylatecyclase.
- Adenylatecyclase converts ATP to cyclic AMP (cAMP is one of the second messenger).
- cAMP activates kinase, (which is an enzyme that adds phosphate groups to other cytosolic enzymes, thus activating some & deactivating others), leading to alteration in metabolic activities.







Source: Barrett KE, Barman SM, Boitano S, Brooks H: *Ganong's Review of Medical Physiology, 23rd Edition*: http://www.accessmedicine.com

Cytoplasm

- it is a watery solution of minerals, gases, organic molecules, & cell organelles.
- **Cytosol** is the water portion of cytoplasm, & chemical reactions take place within it.
- ***Cytoplasmic organelles*** are intracellular structures, bounded by their own membranes, & have specific functions in cellular metabolism. They includes :
  Nucleus , mitochondria, ribosome, endoplasmic reticulum, Golgi apparatus, lysosome & others.

NUCLEUS

- All human cells have a nucleus (except for RBC).
- It lies within cytoplasm & is bounded by nuclear membrane with many pores.
- It contains one or more nucleoli & chromosomes.
  - Nucleoli form ribosomal RNA (rRNA), which becomes part of ribosomes.
  - It is control center of cell because it contains chromosomes. Chromosome made of DNA & protein.
  - DNA is the genetic code for the characteristics & activities of the cell.
  - A **gene** is the genetic code for one protein.

Endoplasmic reticulum (ER)

- It is a network of membranous tubules that extend from nuclear membrane to cell membrane.
- *Rough ER* has numerous ribosomes on its surface, whereas *smooth ER* has no ribosomes.
- *Function:*
  • Passageway for transport of materials within the cell
  • Synthesis of lipids by smooth ER.

Ribosomes

- Small structures made of protein & rRNA.
- Some are found on rough ER, while others float freely within cytoplasm.
- *Function:*
  • Site of protein synthesis.

Proteasome

- It is an organelle that is made of enzymes (protease enzymes).
- *Function:*
  • Site of destruction of old or damaged proteins into peptides or amino acids, which may be used again for protein synthesis on ribosomes.
- Proteasomes are particularly important during cell division (embryo).

Golgi apparatus,

- a series of membranous sacs.
- *Function:*
  • Synthesis of carbohydrates (CHO)
  • Packaging of materials for secretion from the cell. small sacs of Golgi membrane break off & fuse with cell membrane, releasing substance to the exterior of cell (**exocytosis)**.

Mitochondria

- Oval organelles bounded by a double membrane.
- They contain their own genes in a single DNA molecule(mitochondrial DNA - mDNA), which is of maternal origin,(from the ovum).
- *Function:*
  • Site of aerobic cell respiration—ATP production

Lysosomes

- Single-membrane structures that contain digestive enzymes.
- *Function :*
  • Contain enzymes to digest ingested material or damaged tissue.

Centrioles

- Structures located just outside the nucleus.
- *Function:*

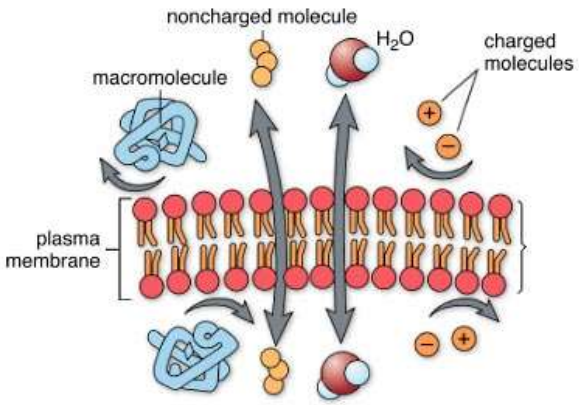
• Organize the spindle fibers during cell division.(spindle fibers are contracting proteins) .

Cilia & flagella

- Mobile thread-like projections through cell membrane.
- *Function:*
  - Cilia sweep materials across the cell surface. e.g Cells lining the fallopian tubes.
  - Flagellum provides motility (ability of the cell to move). The only human cell with a flagellum is the sperm cell.

Movement Through Cell Membranes

- Water & small, noncharged molecules (like O2) crossing lipid portion of membrane easily.
- Ions , charged molecules & large molecules cannot cross easily.
- Some mechanisms by which substances enter or leave cells require energy (active transport); others do not (passive transport). Some mechanisms require carrier proteins; others do not.
- Active Transport : Carrier – mediated Process that requires ATP & can move substances against a concentration gradient.
- Passive transport: membrane transport processes that do not require cellular energy (ATP)



Diffusion

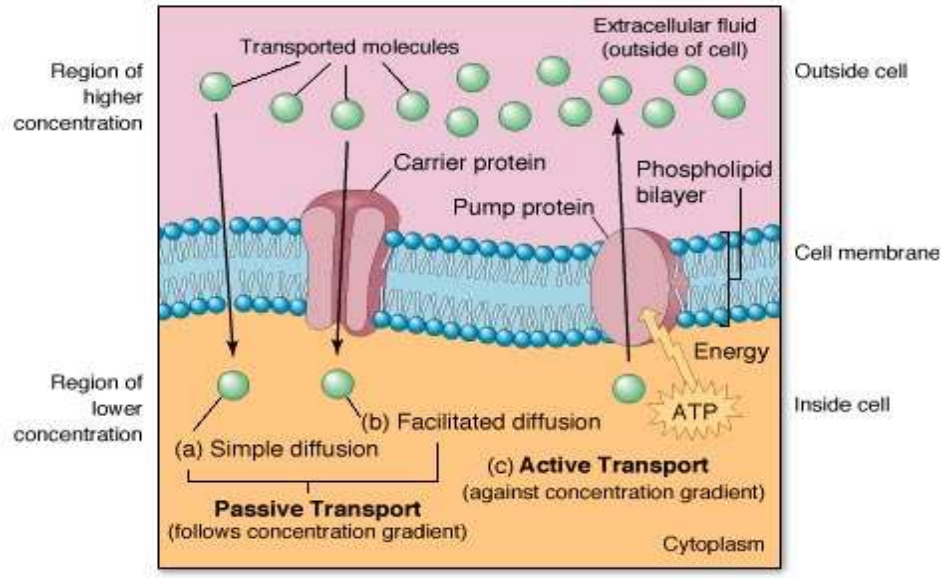
- Molecules that readily cross plasma membrane enter or leave cells by diffusion.
- A substance will tend to move from an area of high to low concentration (i.e., toward equal distribution). It diffuses down its concentration gradient.
- Example: Gas exchange in lungs. CO2 concentration is low in alveolar air high in blood, & thus CO_2 will diffuse (from high to low concentration) from blood into air in alveolus.

Osmosis

- It is the diffusion of water across a membrane. Water will move from high to low area of concentration.
- The more solute in a solution, the lower the concentration of water in that solution.
- A solution with higher solute concentration is hypertonic. A solution with lower solute concentration is hypotonic. If two solutions have the same concentration, → isotonic.
- Water will move from a hypotonic to a hypertonic solution.

Facilitated Diffusion

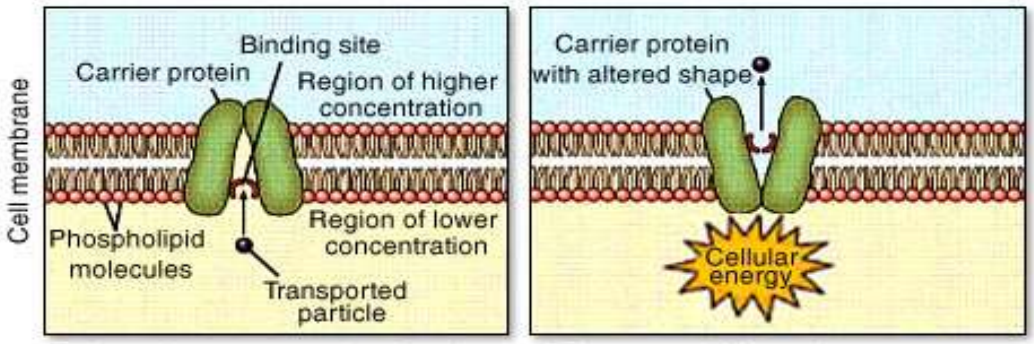
- Both simple & facilitated diffusion involve a substance following its concentration gradient.
- If the substance is lipid-soluble, it readily passes through membrane.
- If it is not lipid-soluble, it crosses membrane only with a specific carrier protein (through facilitated diffusion).
- Neither simple diffusion nor facilitated diffusion requires the cell to expend energy because the substance moves down its concentration gradient.



Active Transport

- Primary active transport is movement of molecules against a concentration gradient via use of membrane carrier molecules called pumps.
- It requires the use of cellular energy ATP, so called "active" process.

- After **ligand** binds to a carrier→ carrier hydrolyzes ATP, & is phosphorylated. Phosphorylation causes the carrier to undergo a conformational change, releasing ligand on the other side of the membrane.



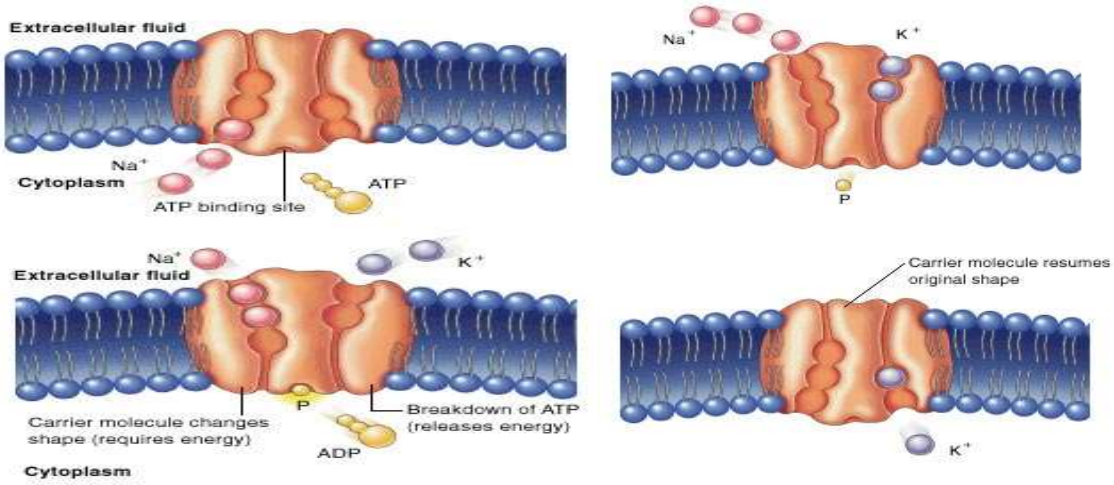
During active tranport, a molecule or ion combines with a carrier protein, whose shape is altered as a result.

This process, which requires energy, transports the particle through the cell membrane.

Sodium-Potassium Exchange Pump

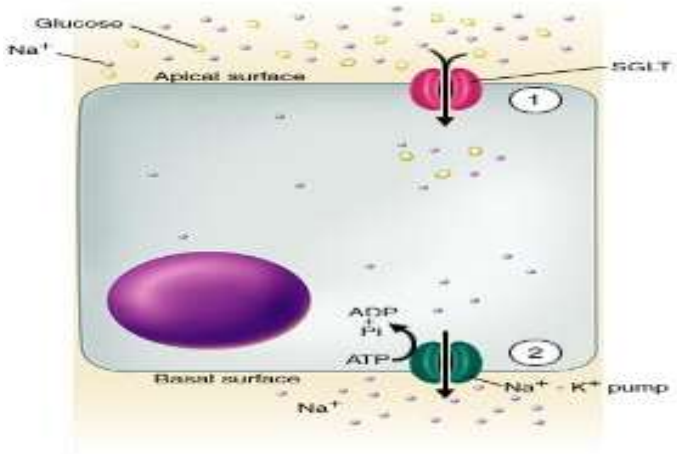
it is an important example of a primary active process. It pumps $3Na^+$ ions out of the cell, then pumps $2\ K^+$ ions into cell against its concentration gradient (from low to high concentration).

- A large protein in plasma membrane provides the doorway through which Na & K ions can move. ATP is the energy source.
- 3 Na ions inside the cell bind to the protein.
- The addition of a phosphate group from ATP changes the shape of protein & Na is expelled.
- Phosphate is released &, as protein returns to its shape, 2 K ions are moved across the membrane.
- Na can once again bind to protein, & the process repeats as long as there is a supply of ATP.



In secondary active transport, transport of one molecule is dependent upon transportation of another molecule. The first molecule will not be transported unless a second molecule binds to carrier as well. An example of this is **reabsorption of glucose by kidneys**.

- Glucose binds to a carrier & is transported across membrane only after Na binds to the carrier as well; thus, the carrier is called a sodium-dependent glucose transporter (SGLT).
- Na is being transported by facilitated diffusion. When Na is transported, glucose is transported as well (up the concentration gradient). ATP is not necessary to phosphorylate SGLT.
- To maintain low concentration of Na inside cell, sodium-potassium pump continuously pumps Na back out of the cell.
- Secondary active transport at cell's apical surface is dependent upon a primary active transport system on cell's basal surface.



Transport Maximum

Carrier-mediated transport systems (facilitated diffusion & active transport) have a transport maximum (maximum rate at which a carrier can transport a solute). This because carriers exhibit:

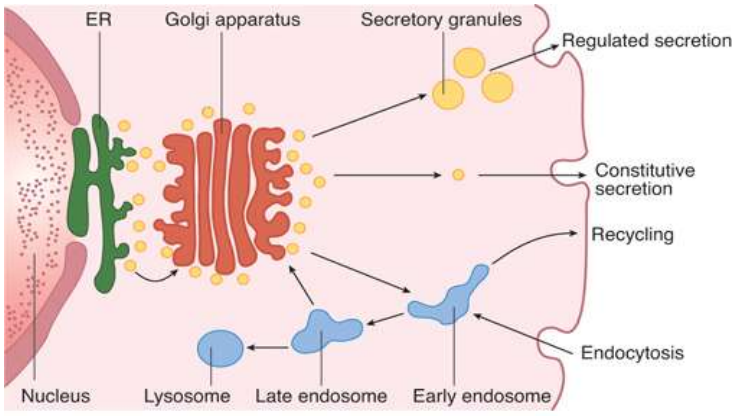
Specificity which is ability to bind with only one ligand. A carrier will only be able to transport a specific solute. As solute concentration increases, the rate of transport increases as well, until saturation, & no more carriers available to increase transport speed. This is transport maximum.

Exocytosis & Endocytosis

A cell that secretes large protein molecules are unable to pass through lipid bilayer. They leave cell instead by a process called exocytosis.

- Protein molecules are produced in ER,then packaged in a vesicle. The vesicle moves to Golgi apparatus where they are processed into their final functional form. Their membranes merge & vesicle releases its contents for modification. As molecules leave Golgi apparatus they are again packaged in a vesicle that moves to plasma membrane. As membranes merge again, the contents leave the cell without actually crossing plasma membrane. This process can also occur in reverse, allowing large molecules to enter a cell, which is termed endocytosis.

There are various types of endocytosis named for the size of particles being ingested as well as the regulatory requirements for the particular process. These include phagocytosis (cell eating), pinocytosis ("cell drinking"),clathrinmediated endocytosis, caveolae-dependent uptake,& nonclathrin/noncaveolae endocytosis.



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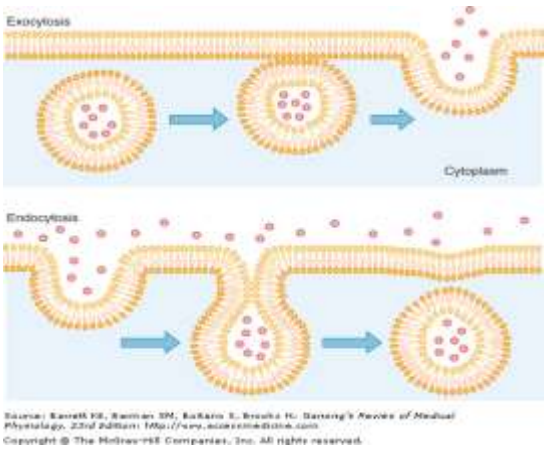


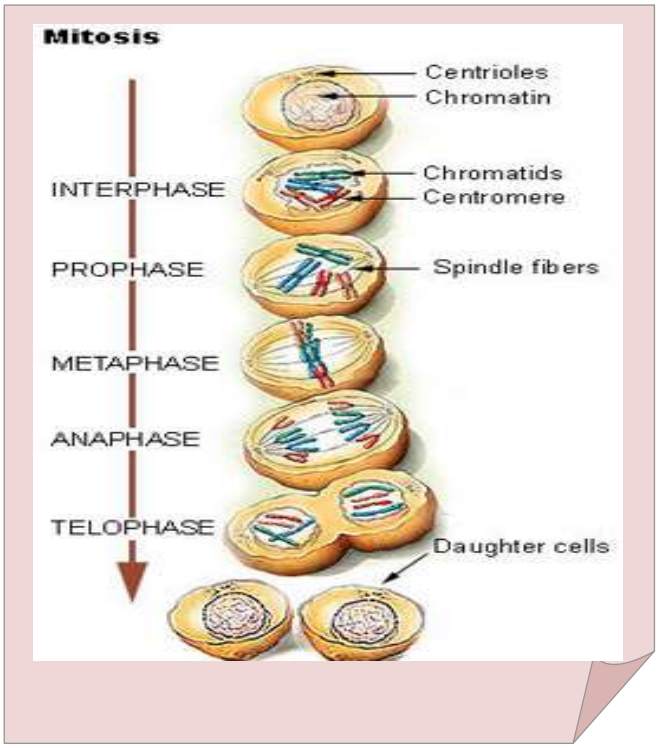
Cell division

- The process by which new cells are formed for growth, repair, & replacement in the body.
- It includes

- division of nuclear material
- division of cytoplasm (called *cytokinesis)*.

- All cells in the body (somatic cells), except those that give rise to eggs & sperm (gametes), reproduce by *mitosis*.
- Stages of mitosis are Interphase, prophase, metaphase, anaphase, division of the cytoplasm, occurs during telophase.

- Egg & sperm cells are produced by *meiosis* in which the number of chromosomes is halved (23 chromosome). So, when fertilization occurs, the resulting cell will again have 46 chromosomes**.**

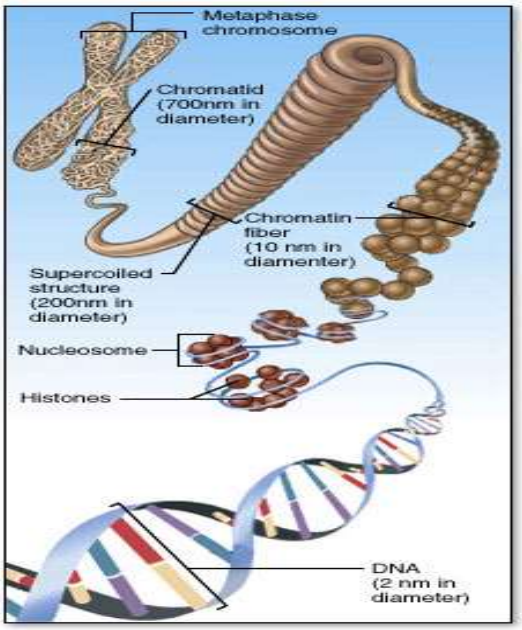


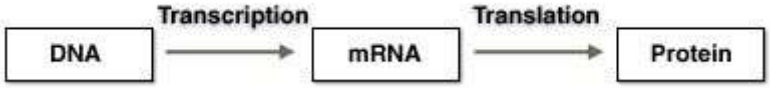
protein synthesis

- DNA in the nucleus directs protein synthesis in the cytoplasm.
- A gene: is portion of DNA molecule that controls synthesis of one specific protein molecule.
- Messenger RNA carries genetic information from DNA in nucleus to protein synthesis sites in cytoplasm.

DNA Structure

DNA molecules are located within nucleus of the cell in complex structures called chromosomes.
DNA strands wrap around histones proteins, which help to organize the DNA.





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