PHYSIOLOGY

FACULTY OF PHARMACEUTICAL SCIENCES

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LECTURE 2, PART (1): CELLULAR LEVEL OF ORGANIZATION

Objectives

1. Discuss **cellular level of organization. (Continue the previous lecture)---Part (1)**

2. Describe **transport processes of solutes and water .---- Part (2)**

(Pages 60-84 of the reference)

THE CYTOPLASM

- **Cytoplasm** consists of all the cellular contents between the plasma membrane and the nucleus.

- It has two components:
- **(1) the cytosol,** is the fluid portion of the cytoplasm that surrounds organelles.
- **(2) organelles**, are tiny structures that perform different functions in the cell.

THE CYTOPLASM

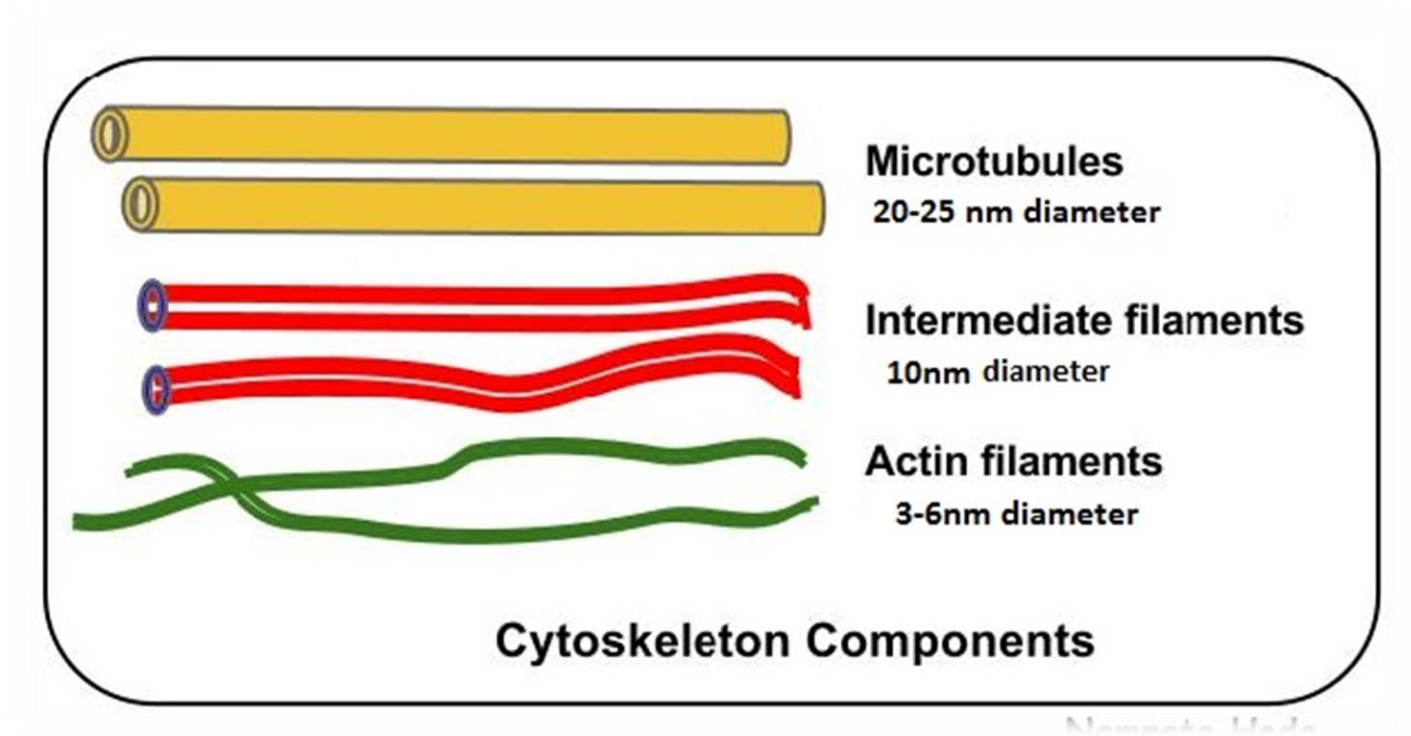
- **Cytosol:**

1. Contains **75–90% water** plus various dissolved and suspended components (i.e. glucose, amino acids, fatty acids, proteins, lipids, ATP, and waste products).

2. It is **the site of many chemical reactions** required for a cell's existence (i.e. glycolysis, maintenance of cell structures and for cell growth).

THE CYTOPLASM

- The **cytoskeleton** is a network of protein filaments that extends throughout the cytosol (**microfilaments, intermediate filaments, and microtubules**).



THE CYTOPLASM

- **Microfilaments:**

1. Are the thinnest elements of the cytoskeleton.
2. They are composed of the proteins actin and myosin.
3. They have two general functions: help generate movement (muscle contraction, cell division, and cell locomotion) and provide mechanical support (basic strength and shapes of cells).

- **Intermediate filaments:**

1. Are thicker than microfilaments but thinner than microtubules.
2. They are found in parts of cells subject to mechanical stress.
3. They help stabilize the position of organelles such as the nucleus and help attach cells to one another.

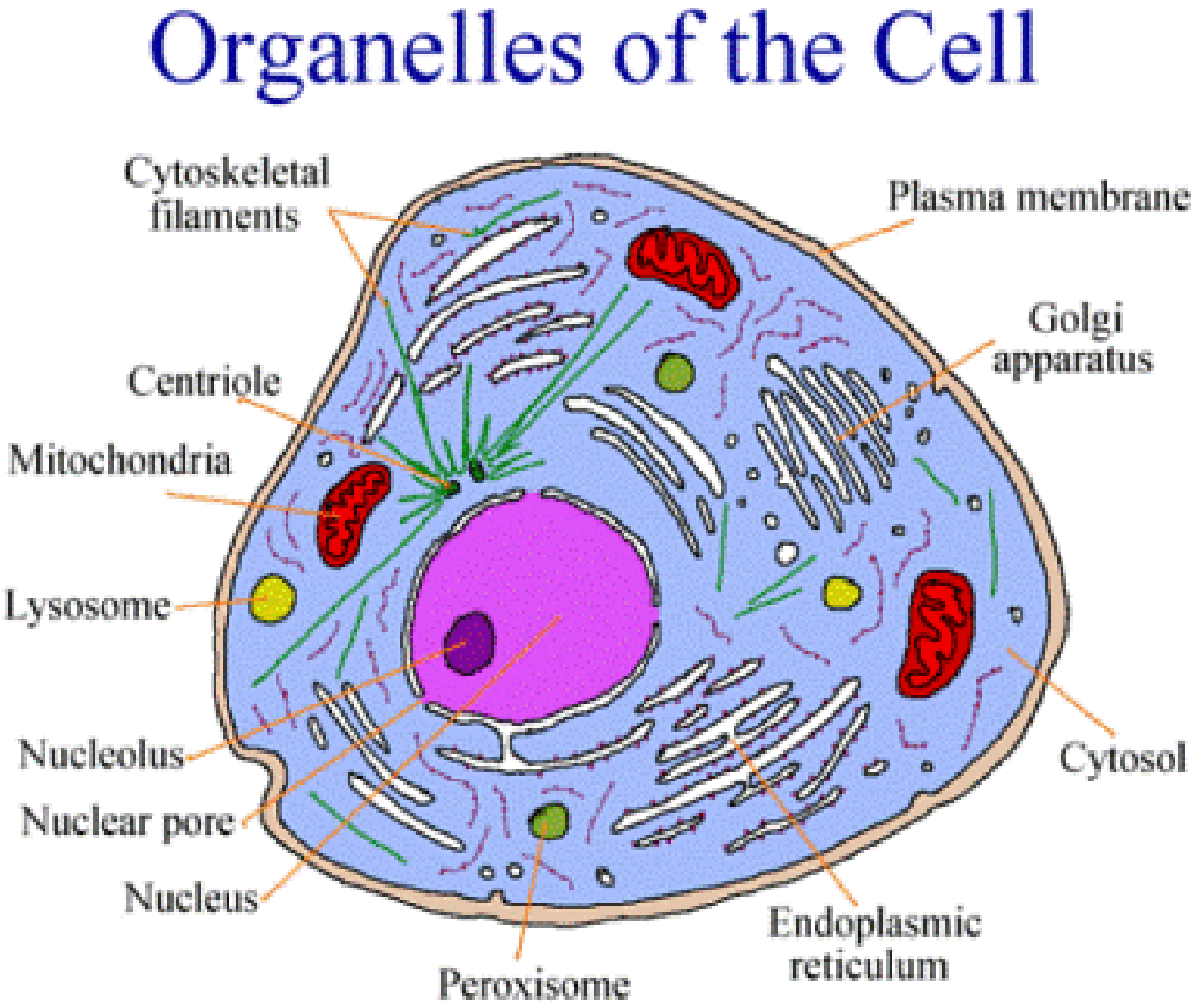
THE CYTOPLASM

- **Microtubules:**

1. Are the largest of the cytoskeletal components.
2. They are composed mainly of the protein tubulin.
3. They help determine cell shape.
4. They also function in the movement of organelles.

THE ORGANELLES

Organelles are **specialized structures** within the cell that have characteristic shapes, and they perform specific functions in cellular growth, maintenance, and reproduction. They often cooperate to maintain homeostasis.

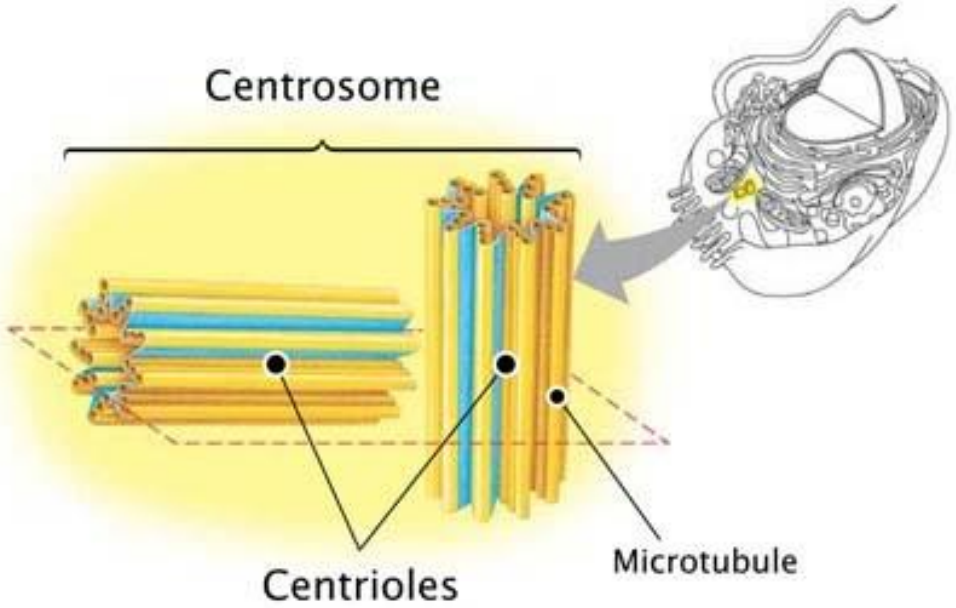


THE ORGANELLES

1. Centrosome.
2. Cilia and Flagella.
3. Ribosomes.
4. Endoplasmic Reticulum.
5. Golgi Complex.
6. Lysosomes.
7. Peroxisomes.
8. Proteasomes.
9. Mitochondria.
10. Nucleus.

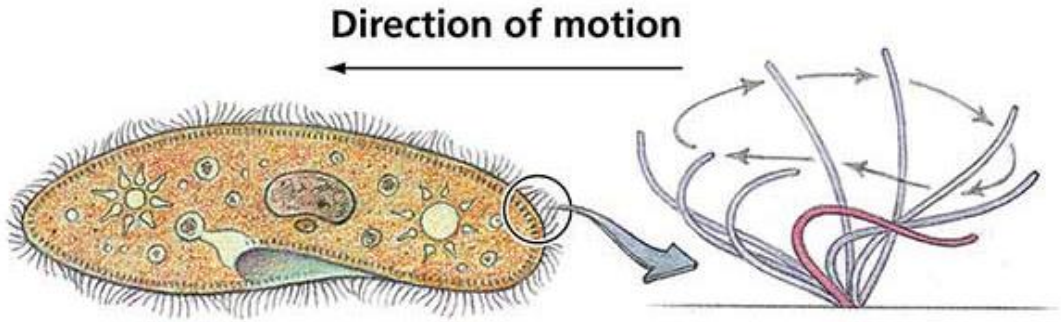
Centrosome

- Is located near the nucleus and it consists of two components: **a pair of centrioles and pericentriolar material**.
- **The centrioles** are cylindrical structures (microtubules). Surrounding the centrioles is pericentriolar material which contains the **tubulin complexes**.
- These complexes organize centers for growth of the mitotic spindle (cell division).



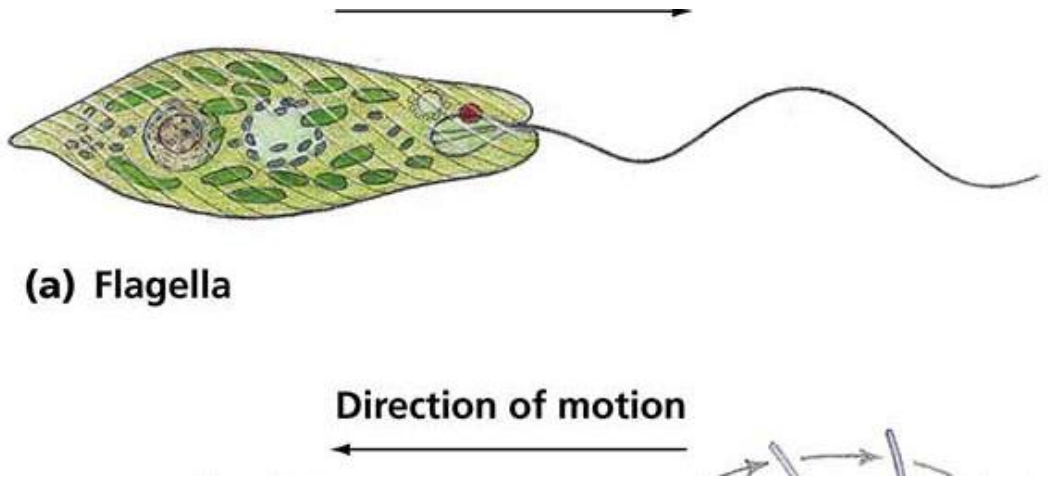
Cilia

- **Microtubules are the dominant components of cilia and flagella**. Both are motile projections. However, cilia is present throughout the surface of a cell, but flagella is present at both the ends or all over the surface.
- Hair-like structure.
- **The main function of motile cilia is to keep the airways clear of mucus and dust.**



(b) Cilia

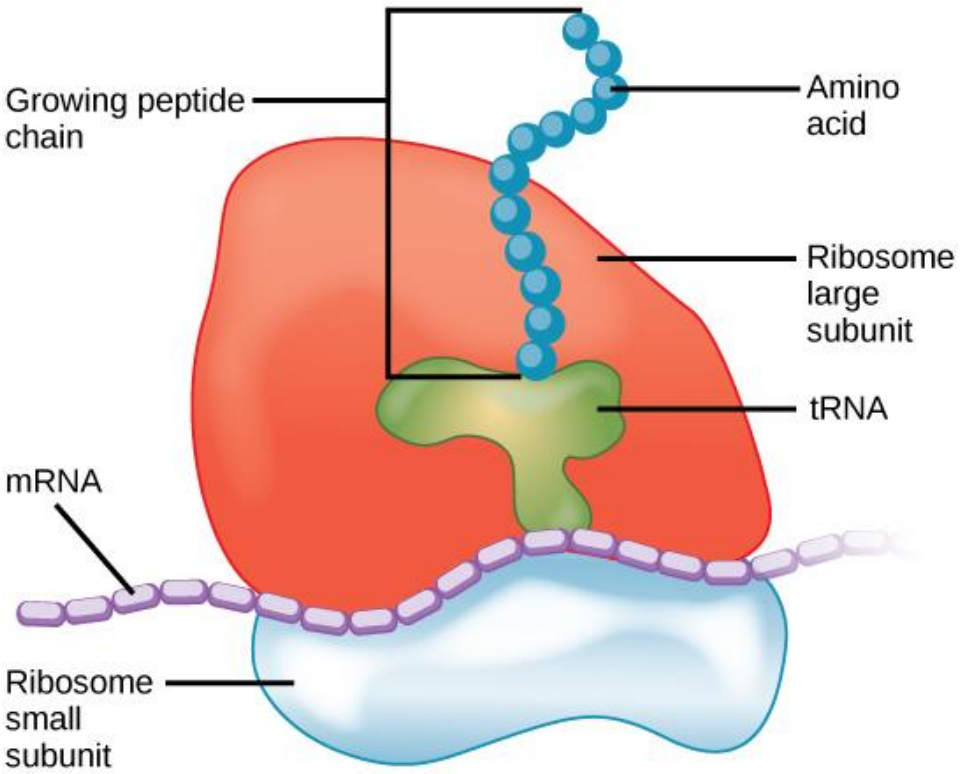
Flagella



- Flagella are similar in structure to cilia but are typically much longer.
- **Flagella usually move an entire cell (i.e. sperm).**
- **The motion of cilia is rotational, very fast moving. The motion of flagella is rotary movement in prokaryotes whereas it is bending movement in eukaryotes. Cilia beat in coordination or one after the other. Flagella beat independent of each other.**

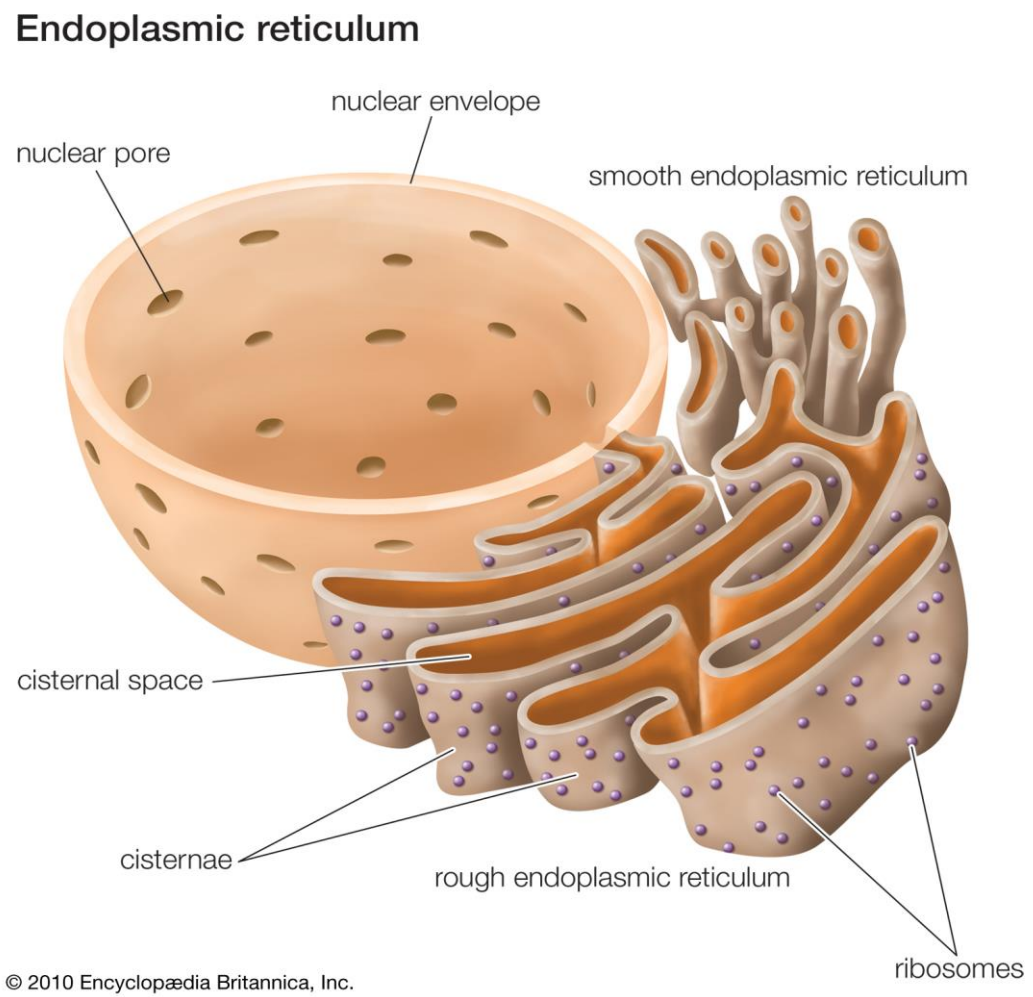
Ribosomes

- **Are the sites of protein synthesis.**
- The name of these tiny structures reflects their high content of one type of ribonucleic acid (ribosomal RNA, or rRNA).
- "Scattered throughout cytoplasm": Some ribosomes are attached to the outer surface of the nuclear membrane and to an endoplasmic reticulum. Ribosomes are also located within mitochondria. Other ribosomes are "free" or unattached to other cytoplasmic structures.



Endoplasmic Reticulum

- **The endoplasmic reticulum (ER)** is a network of membranes in the form of flattened sacs or tubules.
- The ER extends from the nuclear envelope (membrane around the nucleus), to which it is connected and projects throughout the cytoplasm.
- Cells contain two distinct forms of ER (**rough ER and smooth ER**), which differ in structure and function.



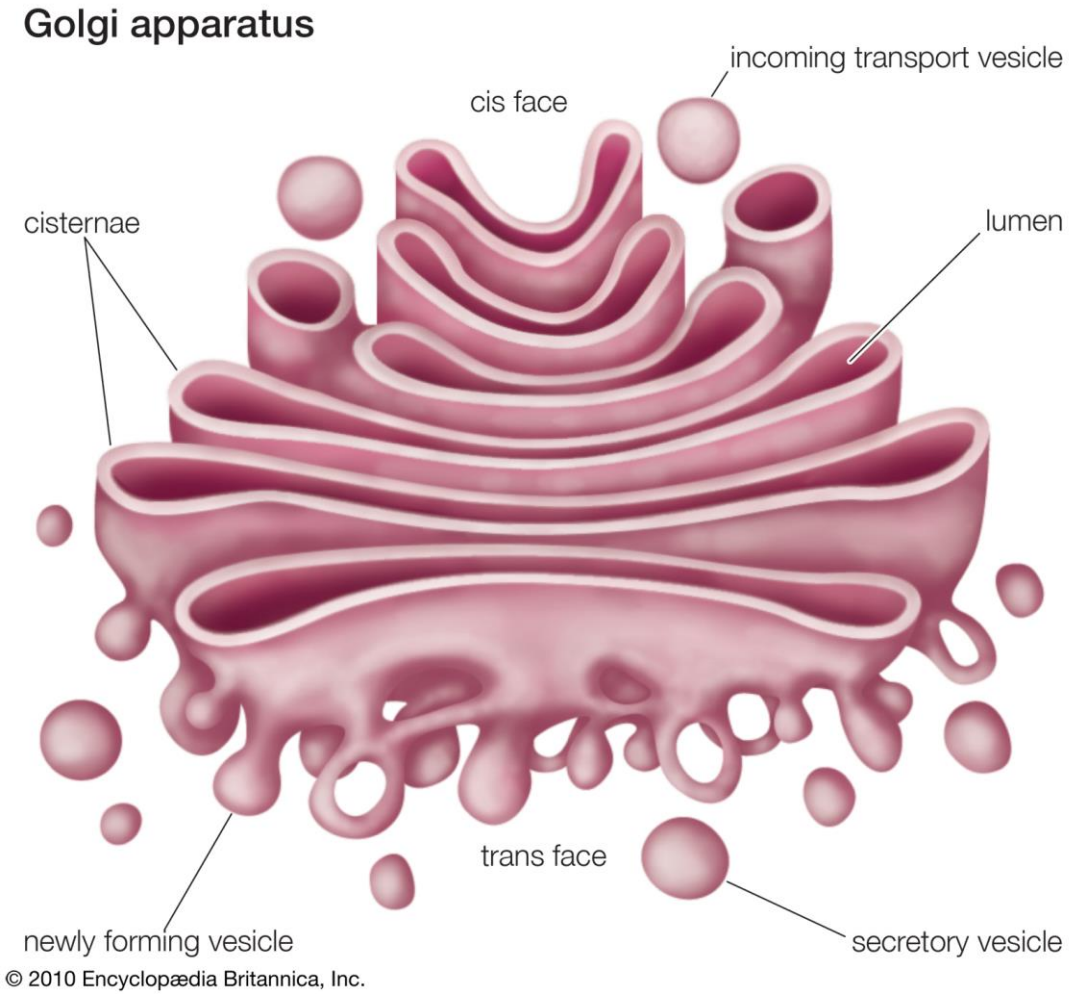
Endoplasmic Reticulum

- The outer surface of **rough ER** is studded with ribosomes (membrane-bound ribosomes). Proteins synthesized by ribosomes enter spaces within the ER for processing and sorting. Thus, rough ER produces secretory proteins, membrane proteins, and many organellar proteins.

- Unlike rough ER, **smooth ER** does not have ribosomes on its membrane. However, smooth ER contributes to lipids and carbohydrates synthesis, making phospholipids bilayer for cell membranes as well as it stores and releases calcium ions that trigger contraction in muscle cells.

Golgi Complex

- Most of the proteins synthesized by ribosomes attached to rough ER are ultimately transported to other regions of the cell (i.e. **Golgi complex**).



Golgi Complex

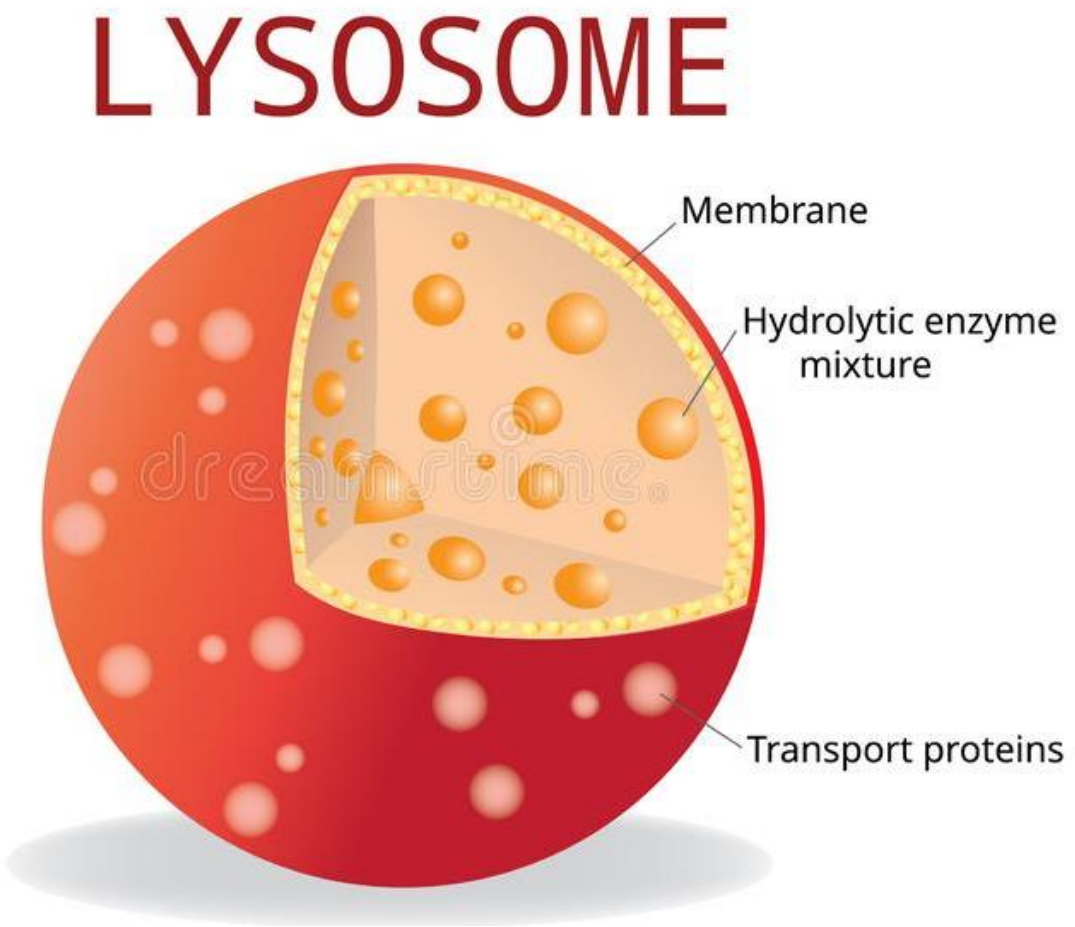
- **Functions of Golgi Complex:**

1. Modifies, sorts, packages, and transports proteins received from the rough ER (through face or cis entry). Enzymes in the middle site of the Golgi complex modify the proteins to form glycoproteins, glycolipids, and lipoproteins.

2. Forms secretory vesicles that discharge processed proteins via exocytosis (through exist or trans face) into extracellular fluid and forms transport vesicles that carry molecules to other organelles, such as lysosomes.

Lysosomes

- **Lysosomes** are membrane-enclosed vesicles that form from the Golgi complex.
- They can contain as many as 60 kinds of **powerful digestive and hydrolytic enzymes** that can break down a wide variety of molecules.



Lysosomes

- **Functions of lysosomes:**

1. **Digest substances (within the cell)** that enter a cell via endocytosis and transport final products of digestion into cytosol.
2. Carry out **autophagy**, the digestion of worn-out organelles.
3. Implement **autolysis**, the digestion of an entire cell.
4. Accomplish **extracellular digestion**.

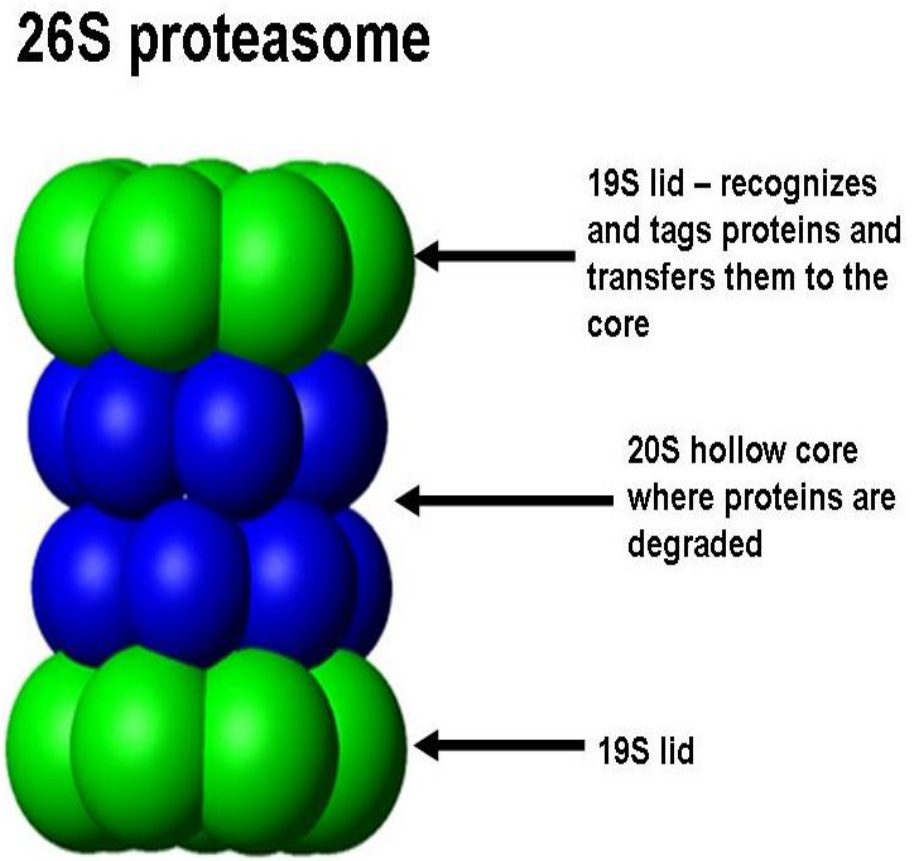
Peroxisomes

- **Peroxisomes** contain several **oxidases**, enzymes that can oxidize (remove hydrogen atoms from) various organic substances.
- They protect the cells from oxidative damage.
- They protect other parts of the cell from the toxic effects of potentially toxic compounds.
- Peroxisomes are very abundant in the liver, where **detoxification of alcohol** and other damaging substances occurs.
- Peroxisomes also contain the enzyme **catalase**, which decomposes by-product of the oxidation reactions which is hydrogen peroxide (H_2O_2); thus, it decomposes hydrogen peroxide to water and oxygen.

Proteasomes

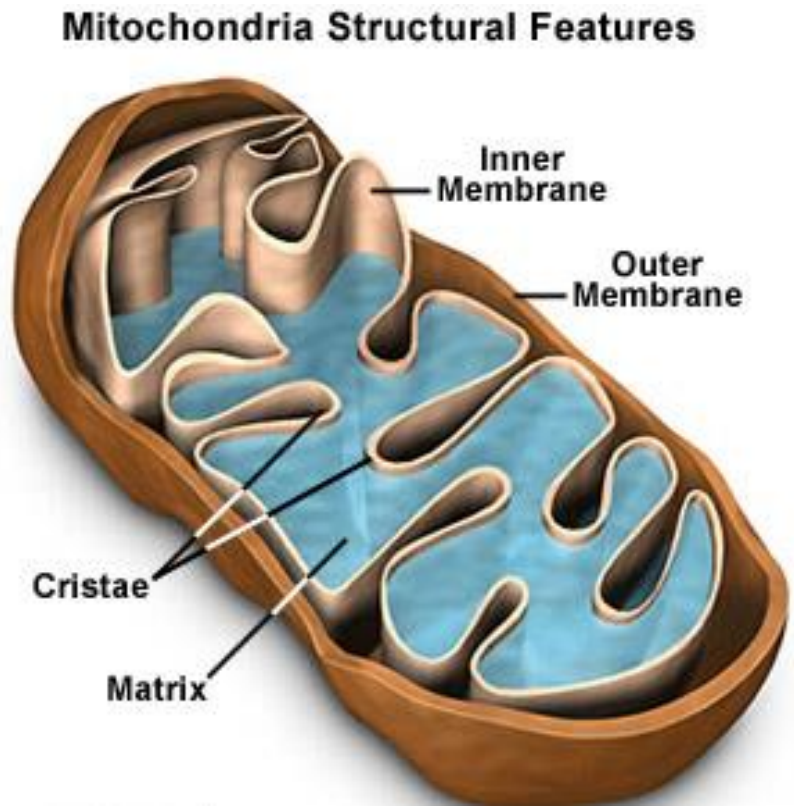
- Cytosolic proteins require disposal at certain times in the life of a cell. **Continuous destruction of unneeded, damaged, or faulty proteins** is the function of tiny barrel-shaped structures consisting of four stacked rings of proteins around a central core called **proteasomes.**

- Proteasomes were so named because they contain **proteases, enzymes that cut proteins into small peptides**. Once the enzymes of a proteasome have chopped up a protein into smaller chunks, **other enzymes then break down the peptides into amino acids, which can be recycled into new proteins.**



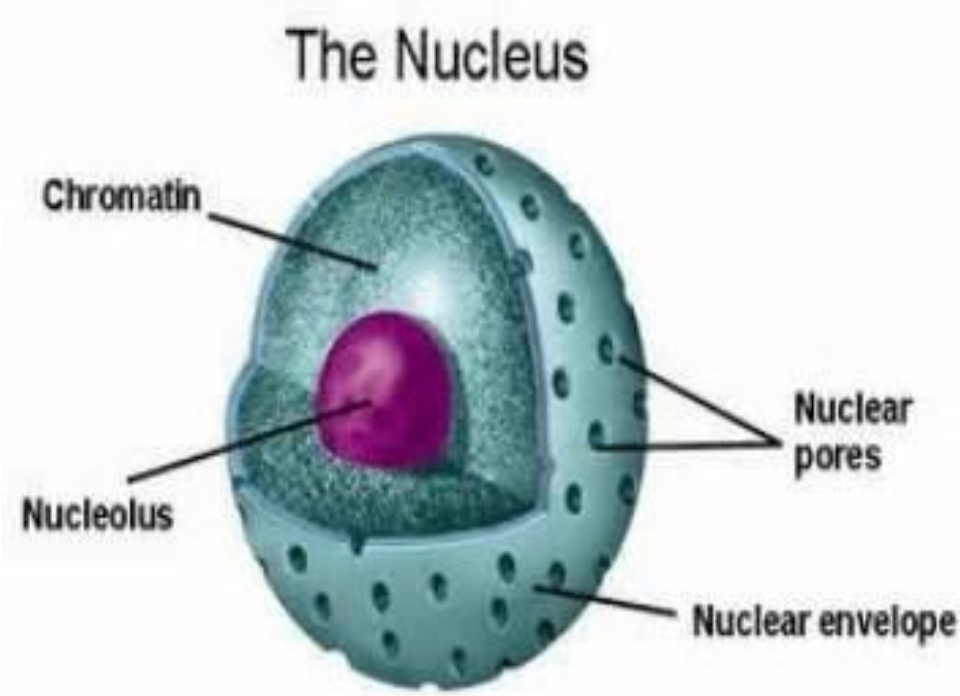
Mitochondria

- **Mitochondria** generate most of the ATP through aerobic (oxygen requiring) respiration, ("**powerhouses**" of the cell). The enzymes that catalyze the chemical reactions which are part of the aerobic phase of cellular respiration are located in the mitochondria.
- Active cells that use ATP at a high rate—such as those found in the muscles, liver, and kidneys—have a large number of mitochondria.
- A mitochondrion consists of an **outer mitochondrial membrane** and an **inner mitochondrial membrane** with a small fluid-filled space between them (**mitochondrial matrix**.).



Nucleus

- **The nucleus** is a spherical or oval-shaped structure that usually is the most prominent feature of a cell.
- Most cells have a single nucleus, although some, such as mature red blood cells, have none. Other types of cells have multiple nuclei.
- A double membrane called the **nuclear envelope** separates the nucleus from the cytoplasm. Many openings called **nuclear pores** extend through the nuclear envelope.
- The complex of DNA, proteins, and some RNA is called **chromatin**. The total genetic information carried in a cell, or an organism is its **genome**.



Nucleus

- **Functions of nucleus:**

1. Controls **cellular structure**.
2. Directs **cellular activities**.
3. **Produces ribosomes** in nucleoli.
4. Nuclear pores control the **movement of substances** between the nucleus and cytoplasm.

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LECTURE 2, PART (2): TRANSPORT PROCESSES OF SOLUTES AND WATER

Membrane permeability:

- The permeability of the plasma membrane to different substances varies.
- **The hydrophobic interior of the plasma membrane allows nonpolar molecules** to rapidly pass through, but prevents passage of ions and large, uncharged polar molecules.
- Because **water and urea** are small polar molecules that have no overall charge, they can **move from one gap** (small gaps appear in the hydrophobic environment of the membrane's interior) to another until they have crossed the membrane without any assistance.
- **Transmembrane proteins that act as channels and carriers** (very selective) increase the plasma membrane's permeability to a variety of **ions and uncharged polar molecules** (need assistance).

Gradients across the Plasma Membrane:

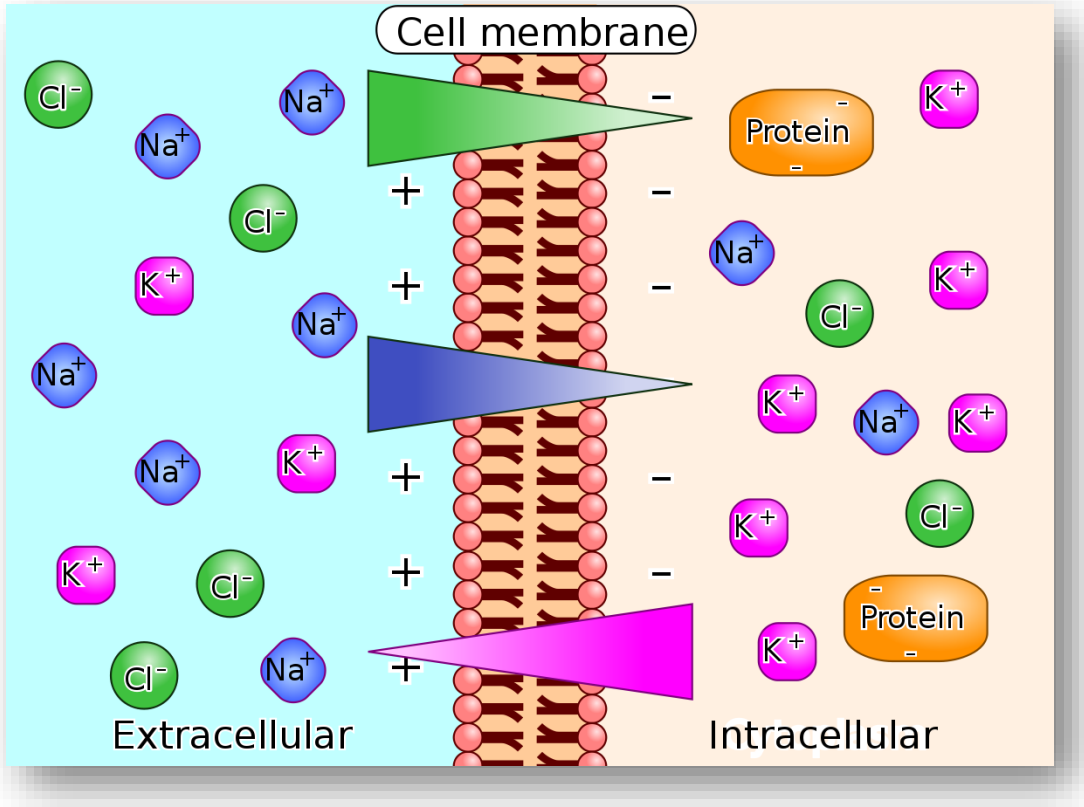
- A ***concentration gradient*** is a difference in the concentration of a chemical from one place to another, such as from the inside to the outside of the plasma membrane. A substance will move "downhill," from where it is more concentrated to where it is less concentrated, to reach equilibrium.

- The plasma membrane also creates a difference in the distribution of positively and negatively charged ions between the two sides of the plasma membrane.

Gradients across the Plasma Membrane:

- The difference in electrical charges between two regions constitutes an ***electrical gradient***. This termed **the membrane potential.** A positively charged substance will tend to move toward a negatively charged area, and a negatively charged substance will tend to move toward a positively charged area.

- The combined influence of the concentration gradient and the electrical gradient on movement of a particular ion is referred to as its ***electrochemical gradient***.



TRANSPORT ACROSS THE PLASMA MEMBRANE

- Substances generally move across cellular membranes via **transport processes** that can be classified as passive or active, depending on whether they require cellular energy.

- In **passive processes**, a substance moves down its concentration or electrical gradient to cross the membrane using only its own kinetic energy (energy of motion).

- In **active processes**, cellular energy (in the form of adenosine triphosphate (ATP)) is used to drive the substance "uphill" against its concentration or electrical gradient.

TRANSPORT ACROSS THE PLASMA MEMBRANE

Another way that some substances may enter and leave cells is an **active process** in which tiny, spherical membrane sacs referred to as **vesicles** are used. Examples include **endocytosis**, in which vesicles detach from the plasma membrane while bringing materials into a cell, and **exocytosis**, the merging of vesicles with the plasma membrane to release materials from the cell.

PASSIVE PROCESSES

- **Diffusion** is a passive process in which the random mixing of particles (solutes, the dissolved substances, and the solvent) in a solution occurs because of the particles' kinetic energy.

- If a particular solute is present in high concentration in one area of a solution and in low concentration in another area, solute molecules will diffuse toward the area of lower concentration—they move down their concentration gradient (the solution after diffusion is said to be at equilibrium).

PASSIVE PROCESSES

- Substances may also diffuse through a membrane, if the membrane is permeable to them. **Several factors influence the diffusion rate of substances across plasma membranes:**

1. **Steepness of the concentration gradient** (the greater the difference in concentration between the two sides of the membrane, the higher is the rate of diffusion).
2. **Temperature** (the higher the temperature, the faster the rate of diffusion).
3. **Mass of the diffusing substance** (the larger the mass of the diffusing particle, the slower its diffusion rate).
4. **Surface area** (the larger the membrane surface area available for diffusion, the faster is the diffusion rate).
5. **Diffusion distance** (The greater the distance over which diffusion must occur, the longer it takes).

DIFFUSION

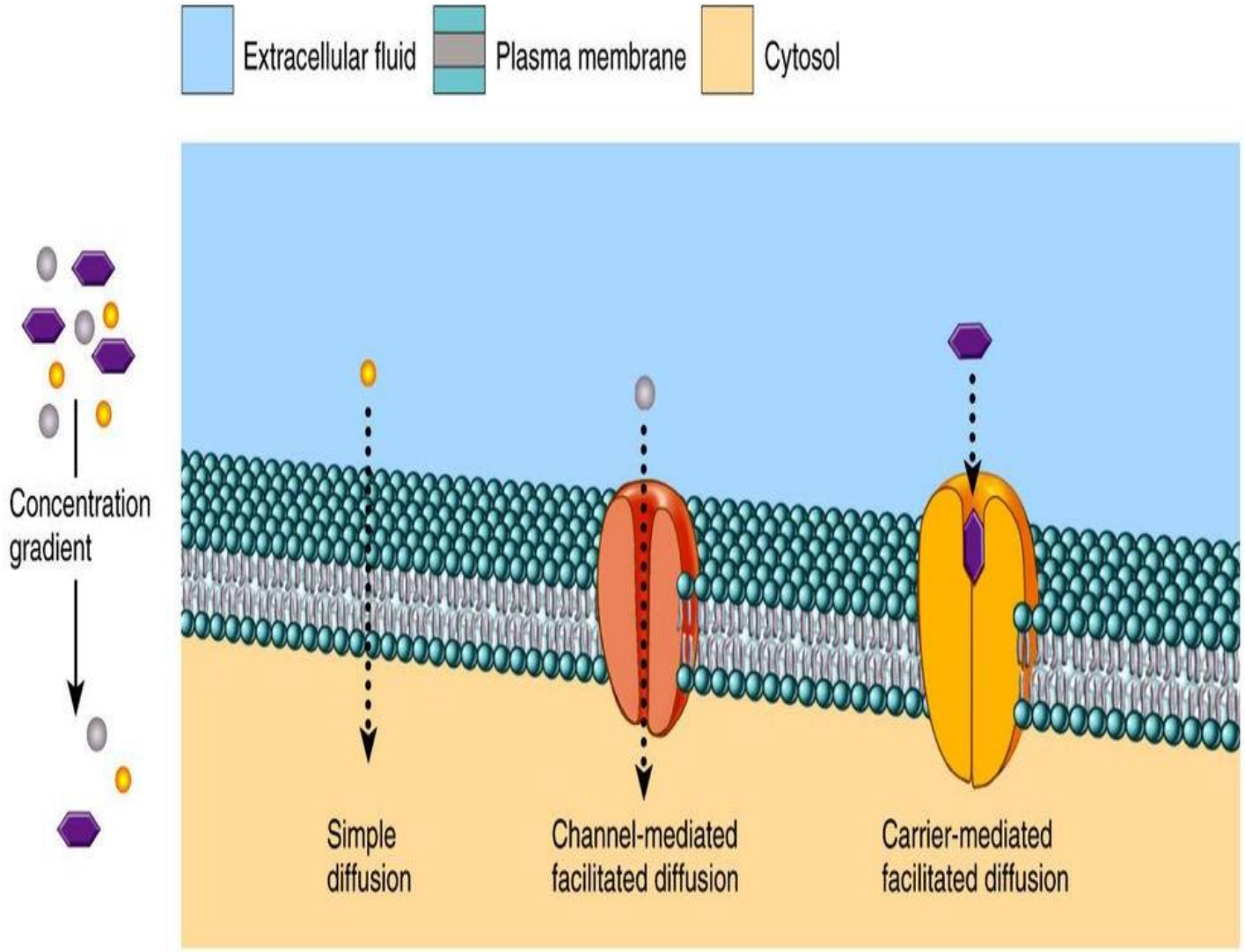
1- Simple diffusion

a substance moves across the lipid bilayer of the plasma membrane without the help of membrane transport proteins

2- Facilitated diffusion

channel-mediated facilitated diffusion, and carrier-mediated facilitated diffusion

A substance moves across the lipid bilayer aided by a channel protein or a carrier protein



DIFFUSION

Examples of simple diffusion

Nonpolar, hydrophobic molecules include oxygen, carbon dioxide, and nitrogen gases; fatty acids; steroids; and fat-soluble vitamins (A, D, E, and K) as well as small, uncharged polar molecules such as water, urea, and small alcohols.

Examples of facilitated diffusion

Too polar or highly charged solutes.

FACILITATED DIFFUSION

1. Channel- mediated facilitated diffusion

- Most membrane channels are ion channels integral transmembrane proteins that allow passage of small, inorganic ions that are too hydrophilic to penetrate the nonpolar interior of the lipid bilayer.

- Some gated channels randomly alternate between the open and closed positions; others are regulated by chemical or electrical changes inside and outside the cell. When the gates of a channel are open, ions diffuse into or out of cells, down their electrochemical gradients.

FACILITATED DIFFUSION

2. Carrier- mediated facilitated diffusion

- The solute binds more often to the carrier on the side of the membrane with a higher concentration of solute and is released on the other side after the carrier undergoes a change in shape.

- Once the concentration is the same on both sides of the membrane, solute molecules bind to the carrier on the cytosolic side and move out to the extracellular fluid.

- Substances that move across the plasma membrane by carrier mediated facilitated diffusion include glucose, fructose, galactose, and some vitamins.

OSMOSIS

- **Osmosis** is a type of diffusion that occurs only when a membrane is permeable to water but is not permeable to certain solutes.

- In living systems, the solvent is water, which moves by osmosis across plasma membranes from an area of **higher water concentration to an area of lower water concentration**. In other words, water moves through a selectively permeable membrane **from an area of lower solute concentration to an area of higher solute concentration**.

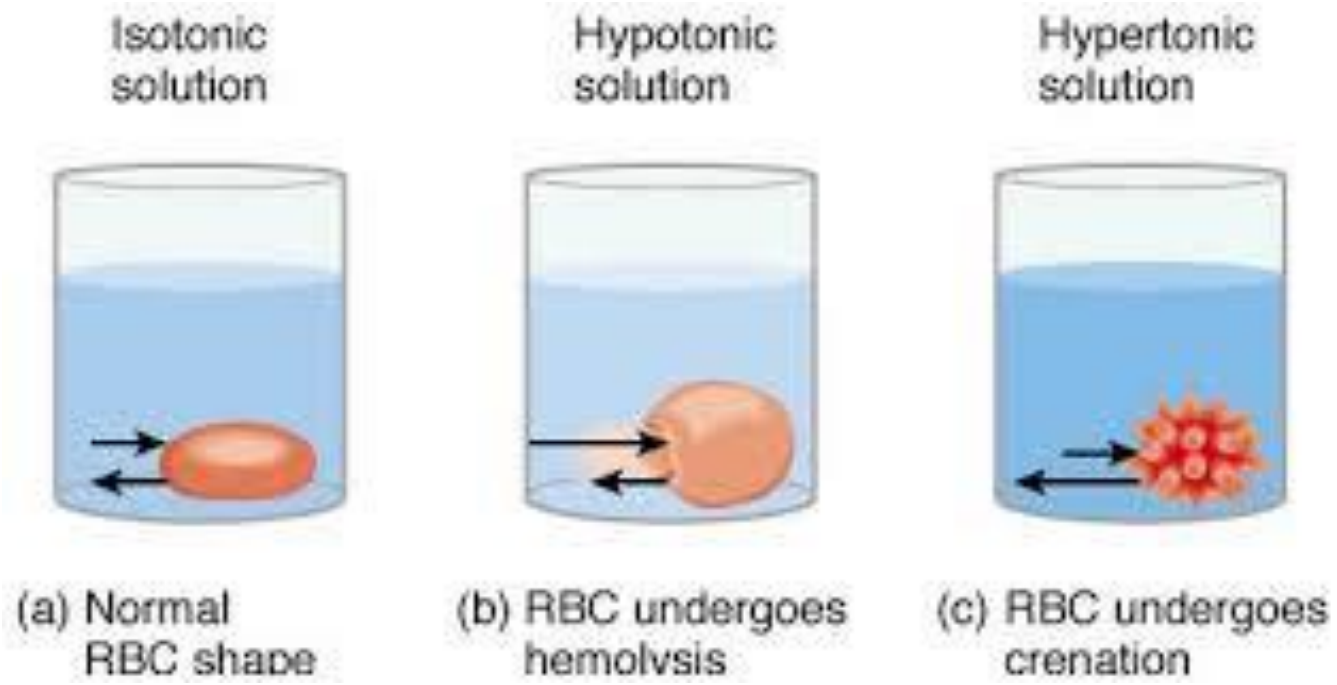
OSMOSIS

- Any solution in which a cell maintains its normal shape and volume is an **isotonic solution**. The concentrations of solutes that cannot cross the plasma membrane are the same on both sides of the membrane in this solution.

- A different situation results if the cells are placed in **a hypotonic solution**, a solution that has lower concentration of solutes than the cytosol inside the cells. In this case, water molecules enter the cells faster than they leave, causing the cells to swell and eventually to burst (lysis).

OSMOSIS

- A **hypertonic solution** has a higher concentration of solutes than does the cytosol inside cells. In such a solution, water molecules move out of the cells faster than they enter, causing the cells to shrink. Such shrinkage of cells is called crenation.



ACTIVE PROCESSES

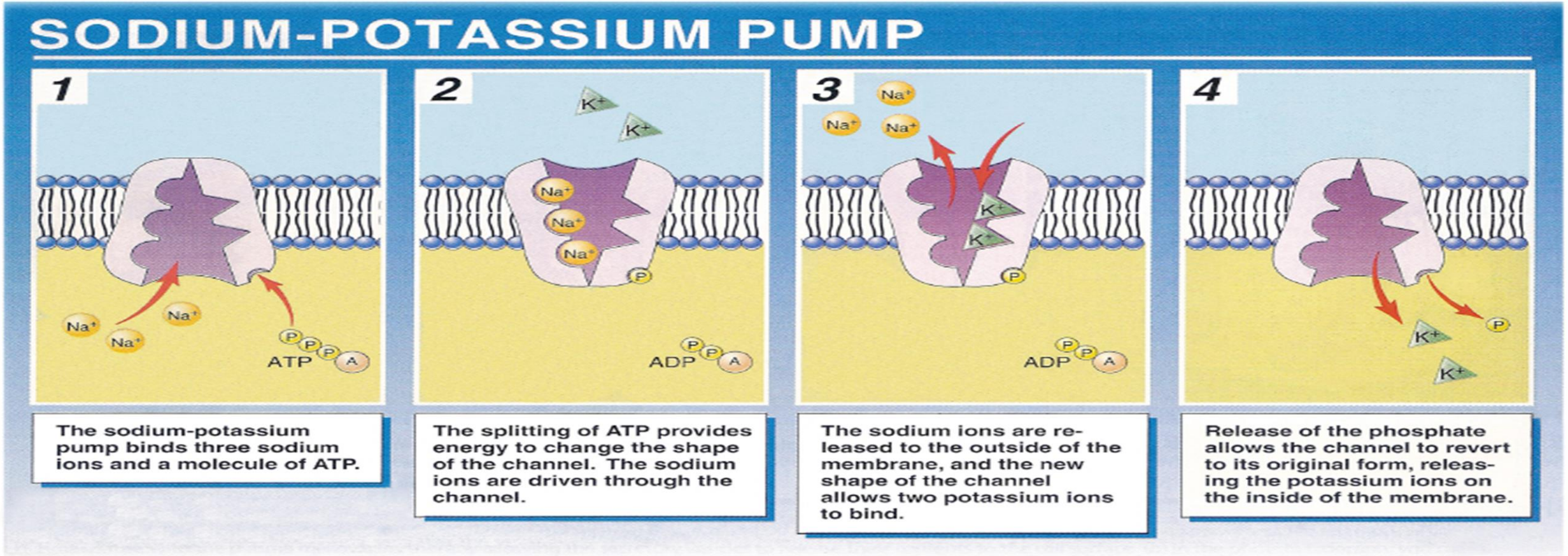
- **Two sources of cellular energy can be used to drive active transport:**

1. Energy obtained from hydrolysis of adenosine triphosphate (ATP) is the source in **primary active transport**.
2. Energy stored in an ionic concentration gradient is the source in **secondary active transport**.

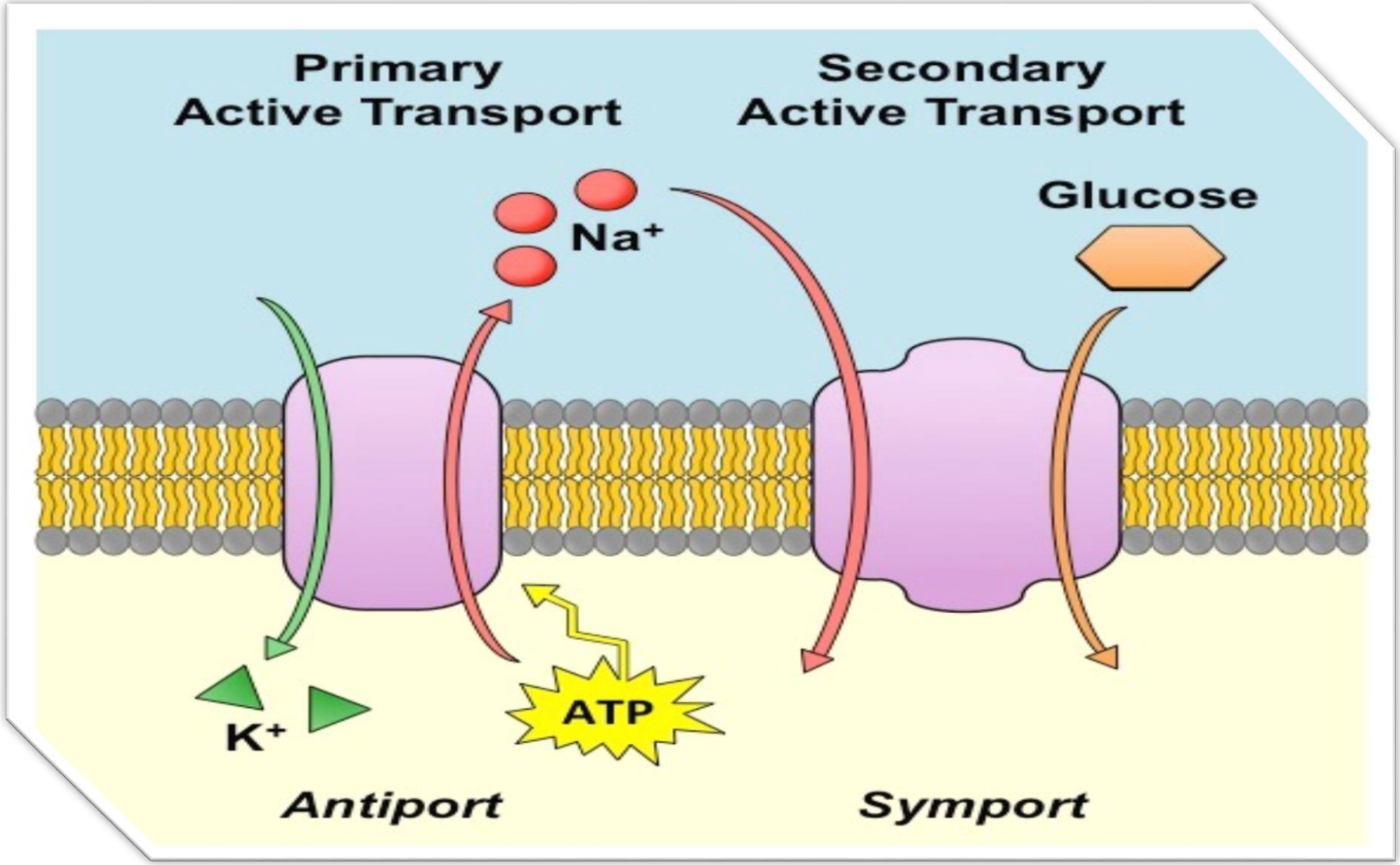
- Carrier proteins that mediate primary active transport are often called **pumps.**

ACTIVE PROCESSES

- The most prevalent primary active transport mechanism expels sodium ions from cells and brings potassium ions in (**sodium–potassium pump**). **All cells have thousands of sodium–potassium pumps in their plasma membranes.**



ACTIVE PROCESSES



TRANSPORT IN VESICLES

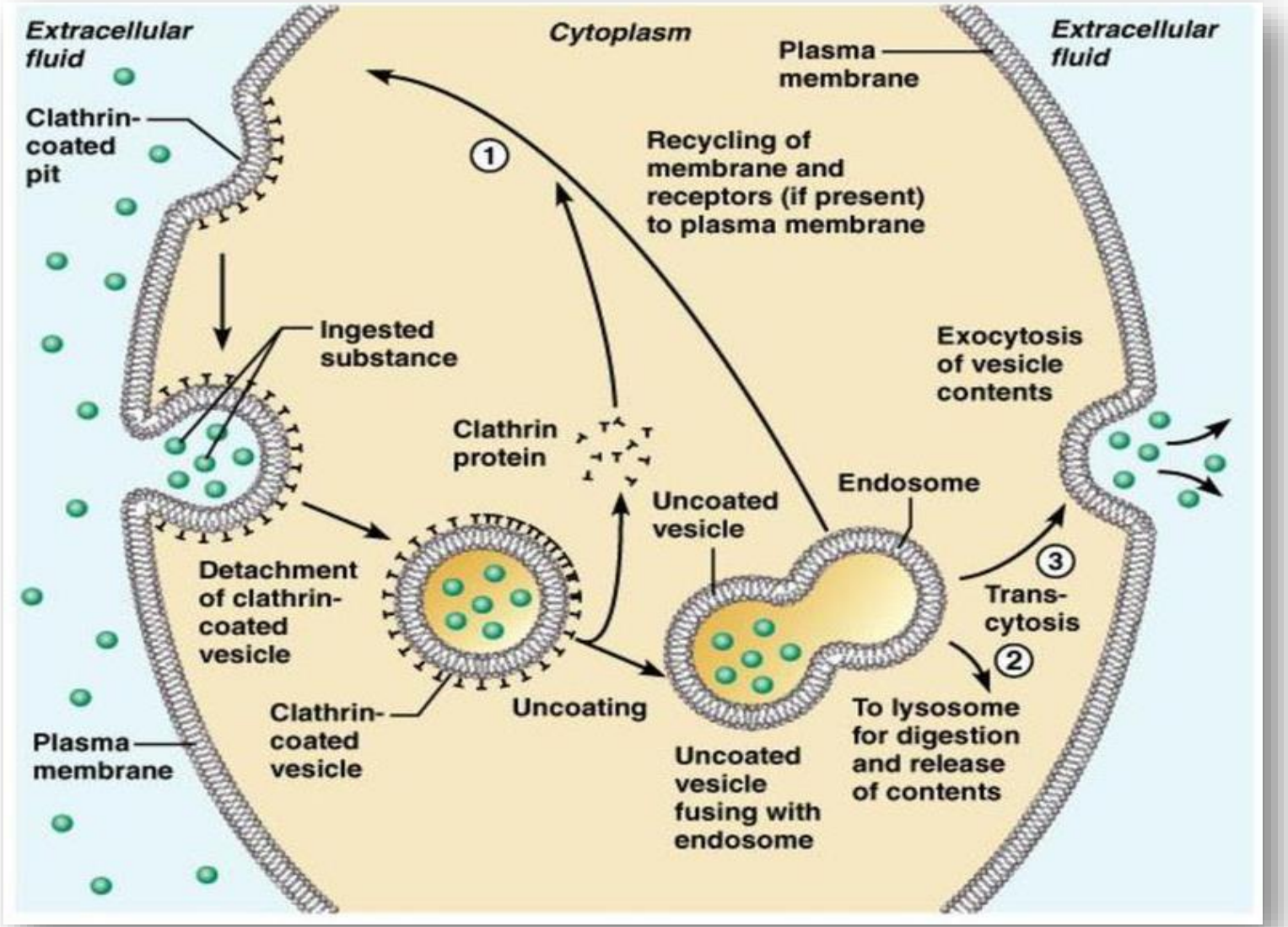
- During **endocytosis**, materials move into a cell in a vesicle formed from the plasma membrane.
- In **exocytosis**, materials move out of a cell by the fusion with the plasma membrane of vesicles formed inside the cell.
- Both endocytosis and exocytosis require energy supplied by ATP. Thus, **transport in vesicles is an active process.**

- **The three types of endocytosis:**

1. Receptor-mediated endocytosis.
2. Phagocytosis.
3. Bulk-phase endocytosis.

RECEPTOR-MEDIATED ENDOCYTOSIS

- Cells take up cholesterol-containing low-density lipoproteins (LDLs), transferrin (an iron-transporting protein in the blood), some vitamins, antibodies, and certain hormones by receptor-mediated endocytosis.



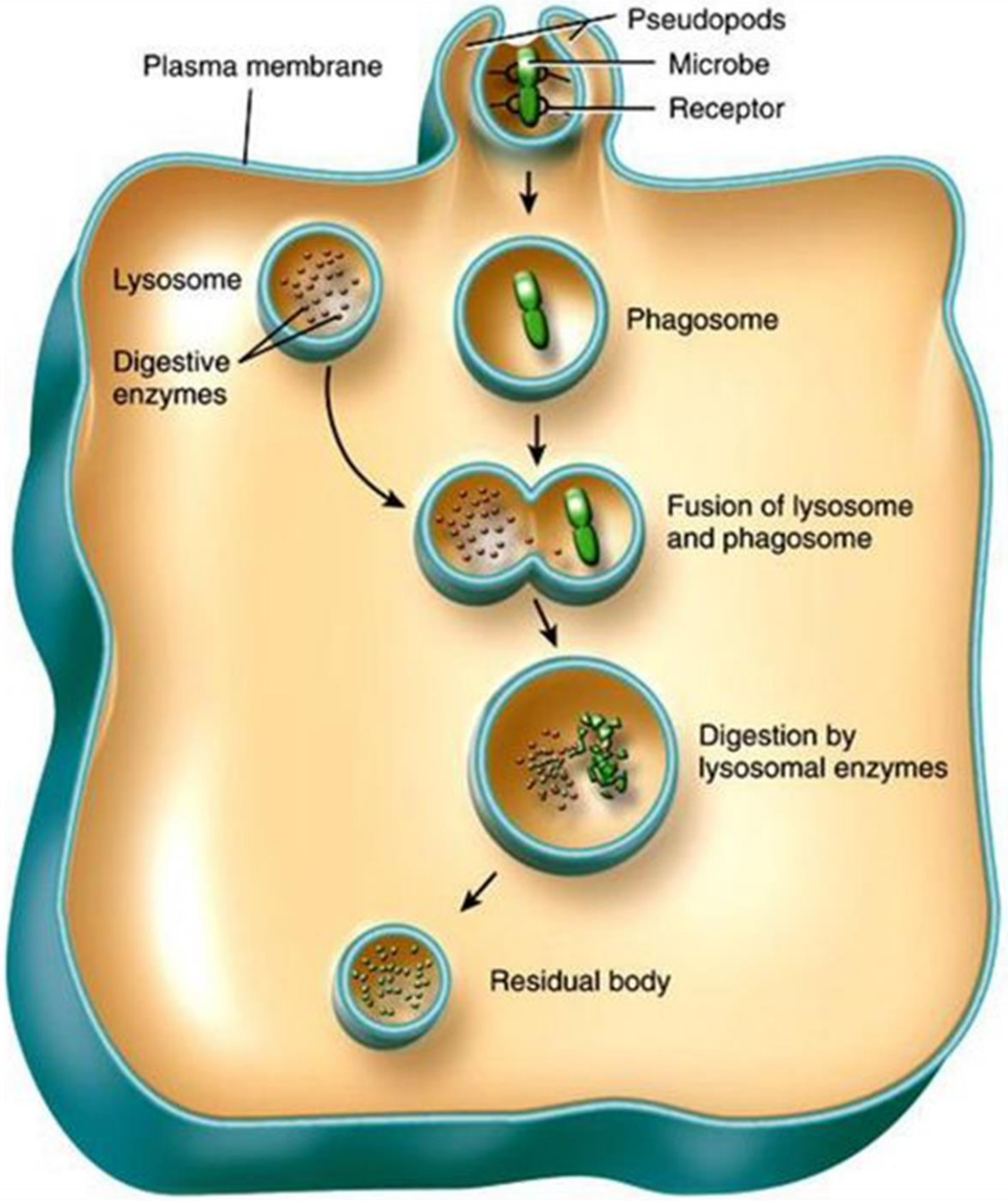
PHAGOCYTOSIS

- **Phagocytosis** is a form of endocytosis in which the cell engulfs large solid particles, such as worn-out cells, whole bacteria, or viruses.

- Two main types of phagocytes are macrophages, located in many body tissues, and neutrophils, a type of white blood cell.

PHAGOCYTOSIS

- Any undigested materials in the phagosome remain indefinitely in a vesicle called **a residual body**. The residual bodies are then either secreted by the cell via exocytosis or they remain stored in the cell.

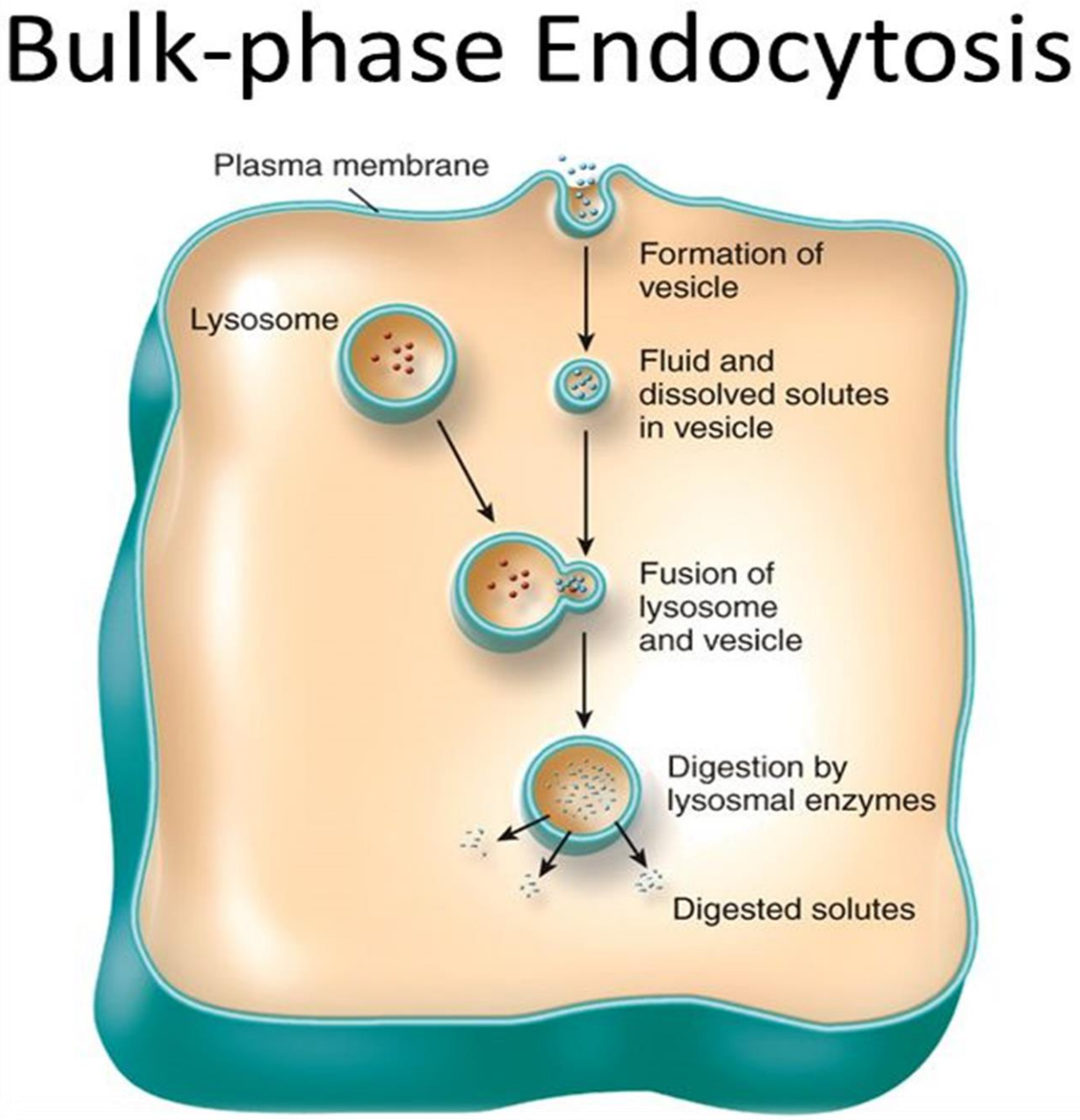


BULK-PHASE ENDOCYTOSIS (PINOCYTOSIS)

- Bulk-phase endocytosis is a form of endocytosis in which tiny droplets of extracellular fluid are taken up (all solutes dissolved in the extracellular fluid are brought into the cell.).

- **No receptor proteins are involved**.

- Bulk-phase endocytosis occurs in most cells, especially absorptive cells in the intestines and kidneys.
- The resulting smaller molecules leave the lysosome to be used elsewhere in the cell.



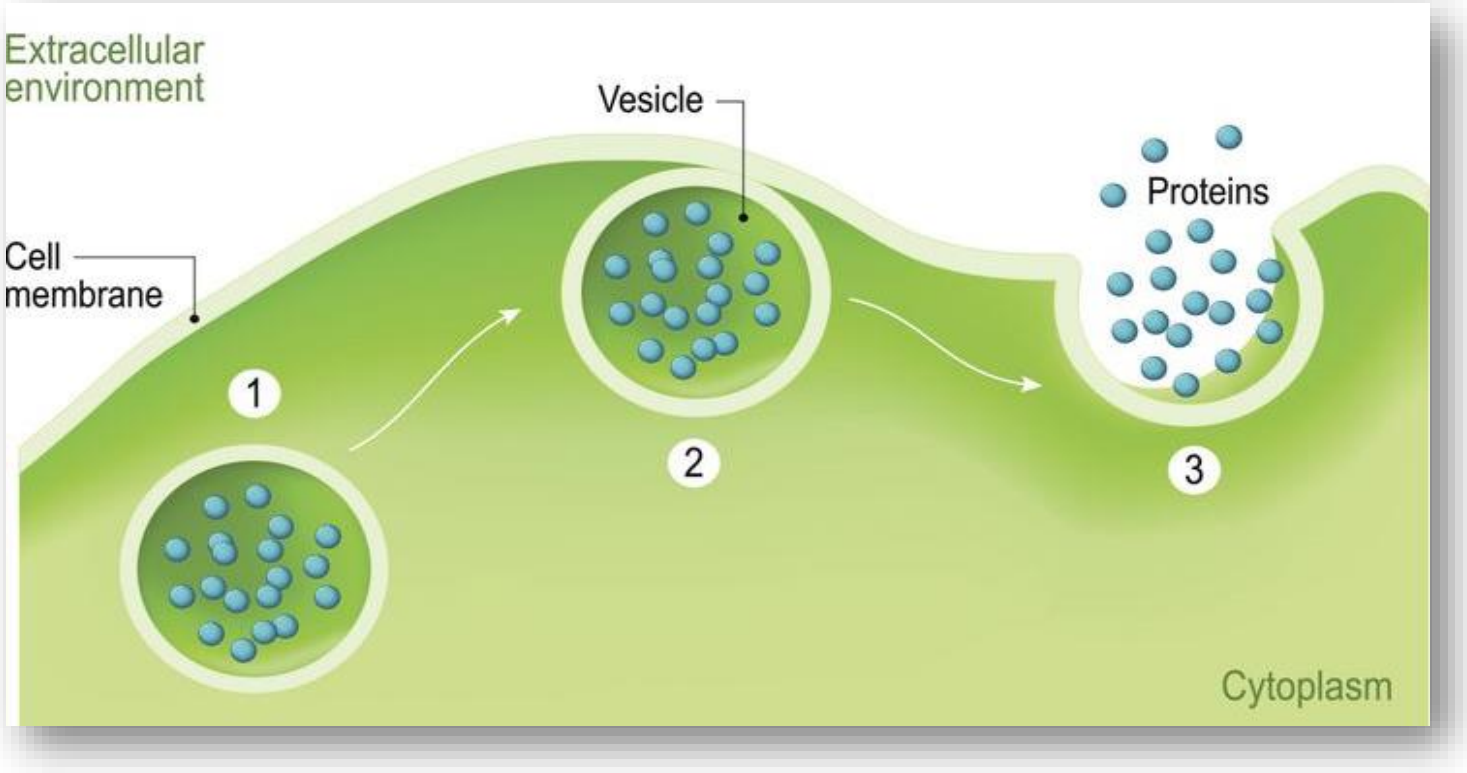
EXOCYTOSIS

- In contrast with endocytosis, which brings materials into a cell, exocytosis releases materials from a cell.

- All cells carry out exocytosis, but it is especially important in two types of cells: **(1) secretory cells that liberate digestive enzymes, hormones, mucus, or other secretions and (2) nerve cells that release substances called neurotransmitters.**

EXOCYTOSIS

- In some cases, wastes are also released by exocytosis. During exocytosis, membrane-enclosed vesicles called **secretory vesicles** form inside the cell, fuse with the plasma membrane, and release their contents into the extracellular fluid.



Segments of the plasma membrane lost through endocytosis are recovered or recycled by exocytosis. The balance between endocytosis and exocytosis keeps the surface area of a cell's plasma membrane relatively constant.

TRANSCYTOSIS

- Vesicles **undergo endocytosis on one side of a cell, move across the cell, and then undergo exocytosis on the opposite side**.

- **Transcytosis occurs most often across the endothelial cells that line blood vessels** and is a means for materials to move between blood plasma and interstitial fluid.

- For instance, when a woman is pregnant, some of her antibodies cross the placenta into the fetal circulation via transcytosis.

THANK YOU

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