Animal physiology- /2022-2023/ 1ST semester

Lecture 2

3- **Carrier-mediated transport**

Carriers are used in transportation of ions and molecules. includes facilitated diffusion, primary active transport, and secondary active transport.

a- Facilitated diffusion

Facilitated diffusion is carrier-mediated, occurs down an electrochemical gradient ("downhill"), does not require metabolic energy and therefore is passive, and it is more rapid than simple diffusion. Example, Glucose transport in muscle and adipose cells (fig.2-1). In diabetes mellitus (type 1), glucose uptake by muscle and adipose cells is impaired because the carriers for facilitated diffusion of glucose require insulin.

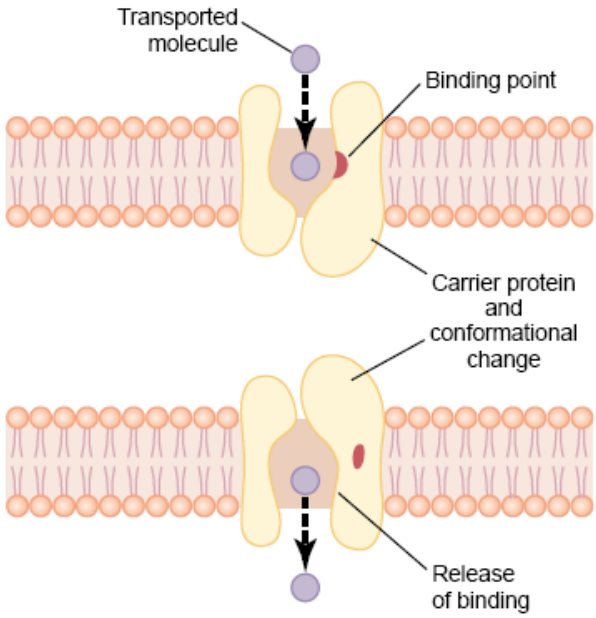

Figure 2- 1: Postulated mechanism for facilitated diffusion

b- **Primary active transport**

occurs against an electrochemical gradient ("uphill"), it is carrier-mediated, and requires direct input of metabolic energy in the form of (ATP) and therefore is active (fig. 2-2)

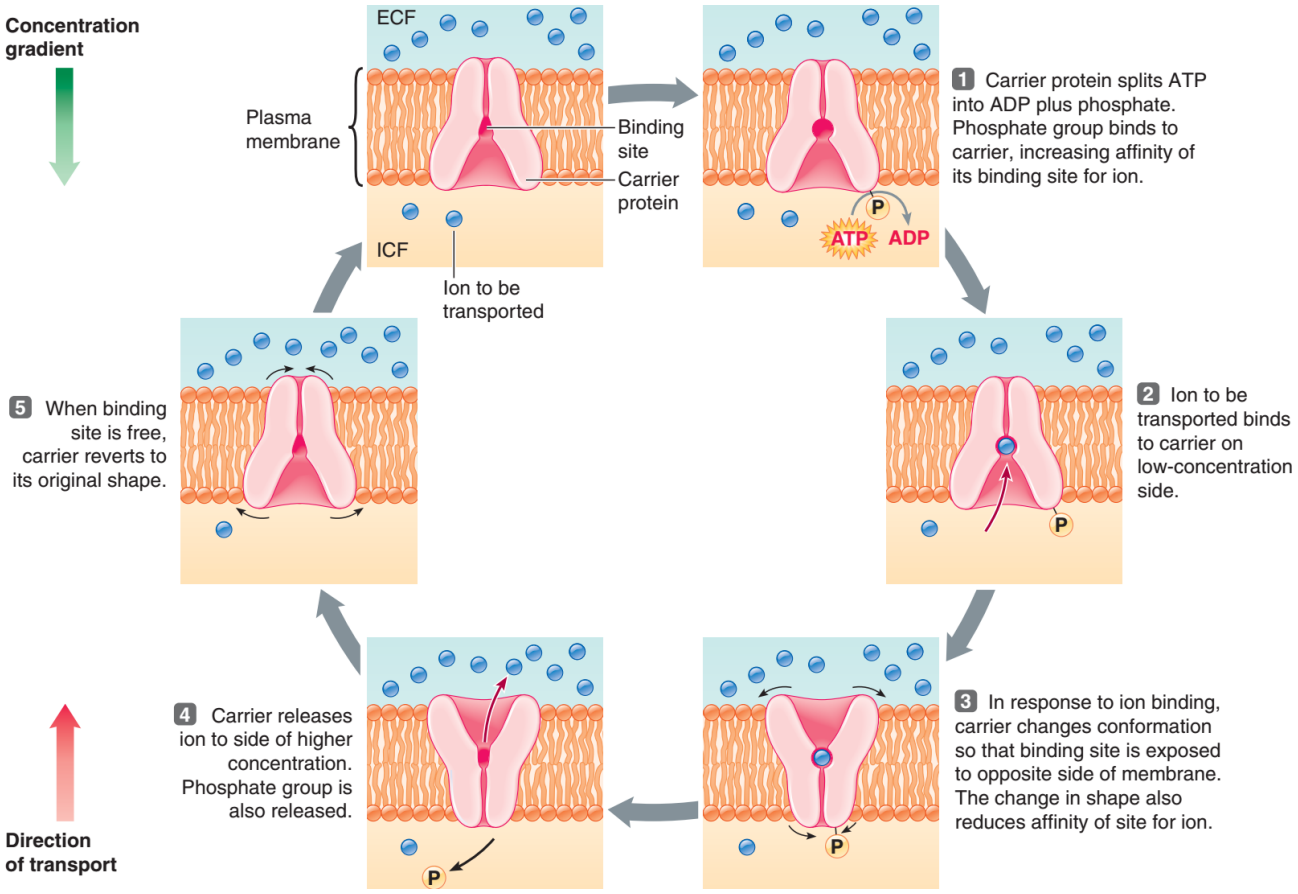

Figure 2-2: Model for active transport. The energy of ATP is required in the phosphorylation – dephosphorylation cycle of the carrier to transport the molecule uphill from a region of low concentration to a region of high concentration

Examples of primary active transport

Na^+, K^+ - ATPase (or Na^+- K^+ pump)
Found in plasma membrane of all types of cells. It transports $3Na^+$ from intracellular to extracellular fluid and $2K^+$ from extracellular to intracellular fluid; it maintains low intracellular Na^+ and high intracellular K^+ (fig.2-3). Specific inhibitors of Na^+,K^+-ATPase are ouabain and digitalis.

Ca^{2+}-ATPase (or Ca^{2+}pump)
in plasma membranes and sarcoplasmic reticulum (sR) transports Ca^{2+} against an electrochemical gradient (fig.2-4).

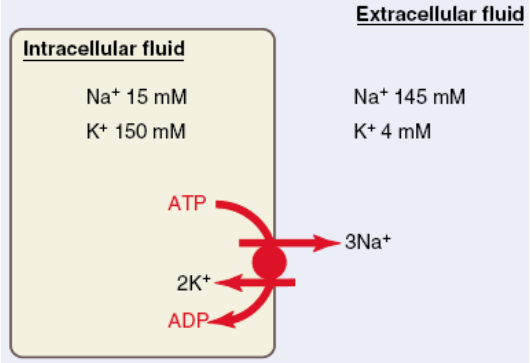

Figure 2-3: Na^+,K^+-ATPase in cell membrane

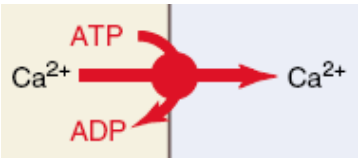

Figure 2- 4: Ca^{2+}- ATPase in cell membrane

H^+, K^+-ATPase

in gastric parietal cells transports H^+ into the lumen of the stomach against its electrochemical gradient, and transports K^+ into the cell. It is inhibited by omeprazole.

C-**Secondary active transport**

The transport of two or more solutes are coupled. One of the solutes (usually Na^+) is transported downhill, and provides energy for the "uphill" transport of the other solute(s). Metabolic energy is not provided directly, but indirectly from the Na^+ gradient that is maintained across cell membranes by Na^+,K^+-ATPase. If the solutes move in the same direction across the cell membrane, it is called **cotransport**, or symport. Examples are Na^+-glucose cotransport in small intestine and proximal tubule epithelial cell (fig.2-5), and Na^+-K^+-$2Cl^-$ - cotransport in the renal thick ascending limb(fig.2-6). If the solutes move in opposite directions across the cell membranes, it is called **counter-transport**, or antiport. Example is Na^+- Ca^{2+} counter-transport occurs through almost all cell membranes (fig.2-7).

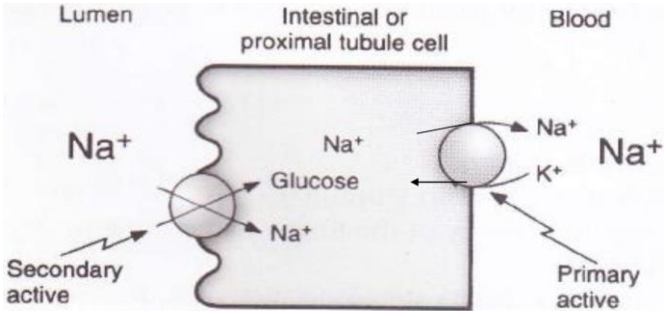

Figure 2-5: Na^+-glucose cotransport
in intestinal or proximal tubule epithelial cell.

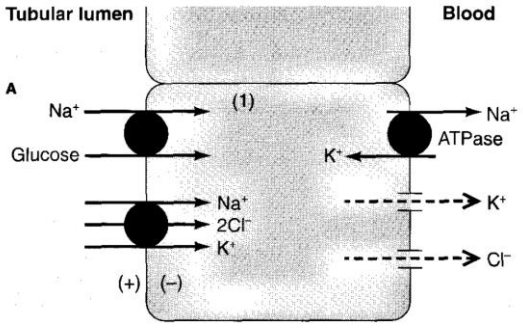

Figure 2-6: Na^+-K^+ -$2Cl^-$ - cotransport in the renal thick ascending limb

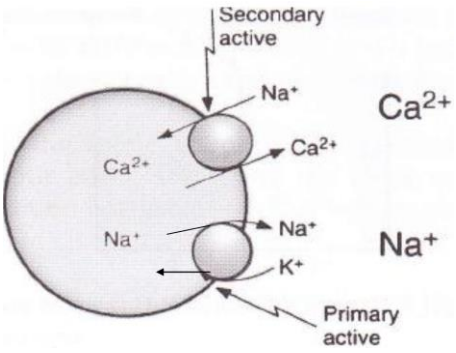

Figure 2-7: Na^+- Ca^{2+} counter-transport (antiport)

4-Vesicular transport

Vesicular transport is the movement of substances in bulk through a membrane in membrane-enclosed vesicles. Vesicular processes that bring matter into a cell are called endocytosis and those that release material from a cell are called exocytosis. There are three basic forms of endocytosis: phagocytosis, pinocytosis, and receptor-mediated endocytosis

Phagocytosis

Phagocytosis or "cell eating," is the process of engulfing particles such as bacteria, dust, and cellular debris by means of pseudopods. Neutrophils, for example, protect the body from infection by phagocytizing and killing bacteria (fig.2-8).

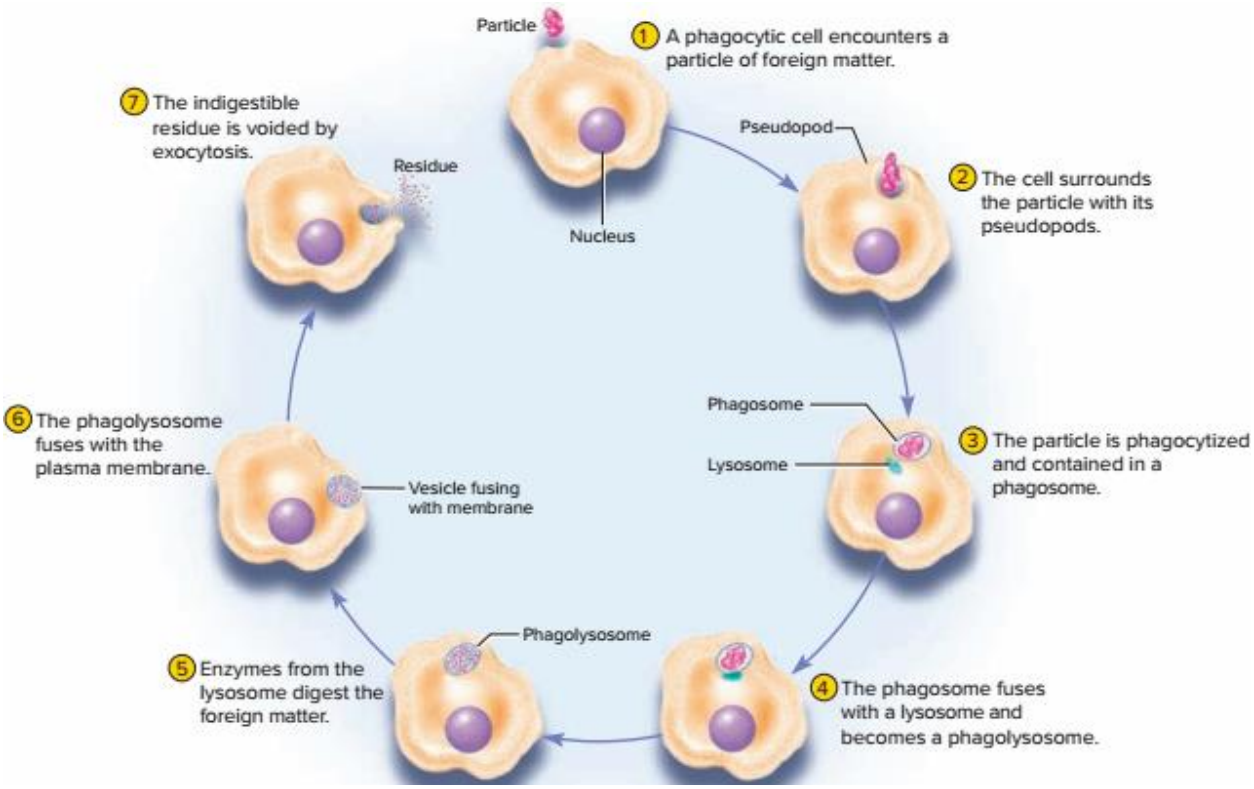

Figure 2-8: Phagocytosis, intracellular Digestion, and exocytosis.

Pinocytosis

Pinocytosis or "cell drinking," is the process of taking in droplets of ECF containing molecules. pinocytosis occurs in all human cells. The process begins as the plasma membrane becomes dimpled at points.These pits soon separate from the surface membrane and form small pinocytotic vesicles in the cytoplasm (fig. 2-9).

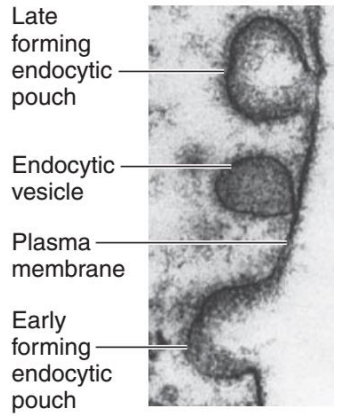

Figure 2-9: Diagram and electron micrograph of pinocytosis

Receptor-mediated endocytosis

The cell take in specific molecules from the ECF with a minimum of unnecessary fluid. Particles in the ECF bind to specific receptors on the plasma membrane.The receptors then cluster together and the membrane sinks in at this point, creating a pit coated with a peripheral membrane protein called *clathrin*.The pit soon pinches off to form a *clathrin-coated vesicle* in the cytoplasm. One example is the uptake of *low-density lipoproteins (LDLs)*-protein-coated droplets of cholesterol and other lipids in the blood. The thin endothelial cells that line blood vessels have LDL receptors on their surfaces and absorb LDLs in clathrin-coated vesicles. Inside the cell, the LDL is freed from the vesicle and metabolized, and the membrane with its receptors is recycled to the cell surface.

Receptor mediated endocytosis is not always to our benefit; hepatitis, polio, and AIDS viruses "trick" our cells into engulfing them by receptor-mediated endocytosis (fig.2-10).

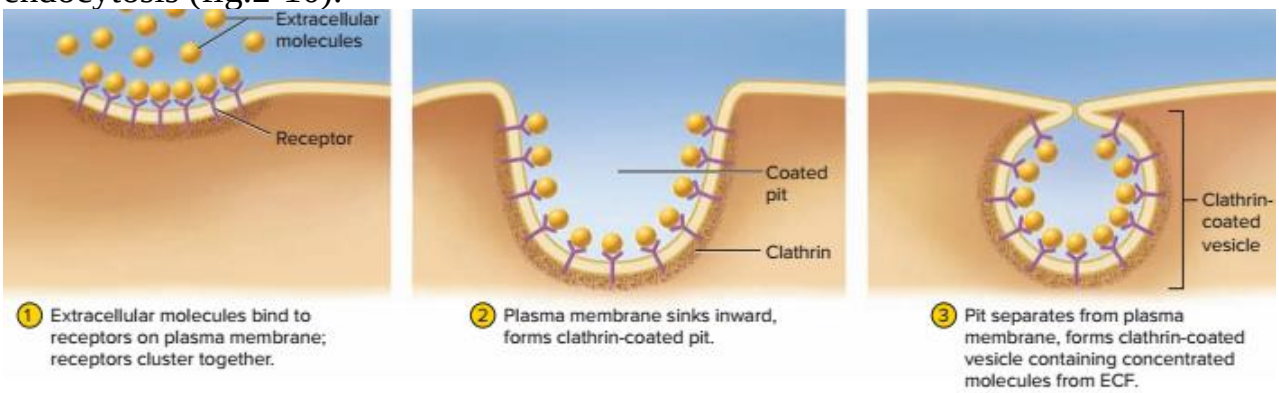

Figure 2-10: Receptor-mediated endocytosis.

Exocytosis

Exocytosis (fig.2-11) is the process of discharging material from a cell. A secretory vesicle in the cell migrates to the surface and "docks" on peripheral proteins of the plasma membrane. These proteins pull the membrane inward then the membrane unite with vesicle to form a fusion pore through which the vesicle contents are released. for example, when breast cells secrete milk, gland cells release hormones, and sperm cells release enzymes for penetrating an egg.

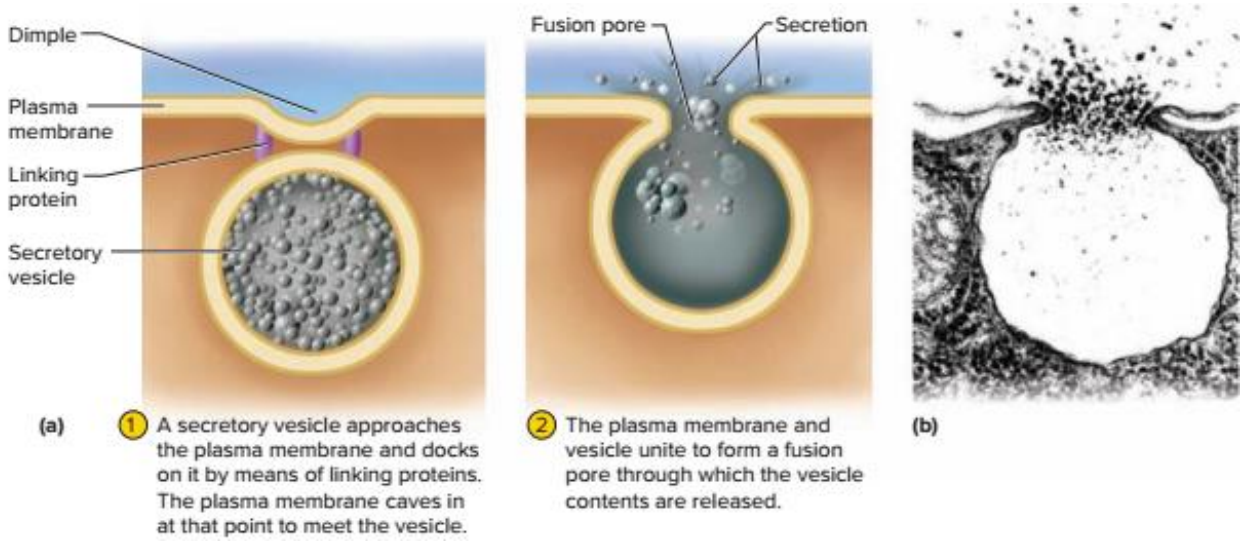

Figure 2-11: Exocytosis. (a) Stages of exocytosis. (b) Electron micrograph of exocytosis.

Functional classification of intercellular chemical signals

Intercellular chemical signals allow one cell to communicate with other cells. Cells communicate by releasing **signaling molecules** (chemical messengers) that bind to **receptor** proteins located in the plasma membrane, cytoplasm, or nucleus. Cause physiological response in target cells.

These signals coordinate and regulate the activities of most cells (fig. 2-12).

1-**Autocrine**

are released by cells and have a local effect on the same cell type from which the chemical signals are released. Examples include prostaglandin like chemicals released from smooth muscle cells and platelets in response to inflammation. These chemicals cause the relaxation of blood vessel smooth muscle cells and the aggregation of platelets. As a result, the blood vessels dilate and blood clots.

2-**Paracrine**

are released by cells and affect other cell types locally without being transported in the blood. For example, a peptide called somatostatin is released by cells in the pancreas and functions locally to inhibit the secretion of insulin from other cells of the pancreas.

3-**Endocrine**

Hormones are chemical signals Secreted into the blood by endocrine glands; travels some distance to target tissues; influences specific activities. Example: Thyroxine, insulin.

4-**Neurotransmitters**

Neurotransmitter are chemical signals Produced by neurons and secreted into extracellular spaces by presynaptic nerve terminals; travels short distances; influences postsynaptic cells. Example: Acetylcholine, epinephrine.

5-**Pheromones**

are chemical signals secreted into the environment that modify the behavior and the physiology of other individuals. For example, pheromones released in the urine of cats and dogs at certain times are olfactory signals that indicate fertility.

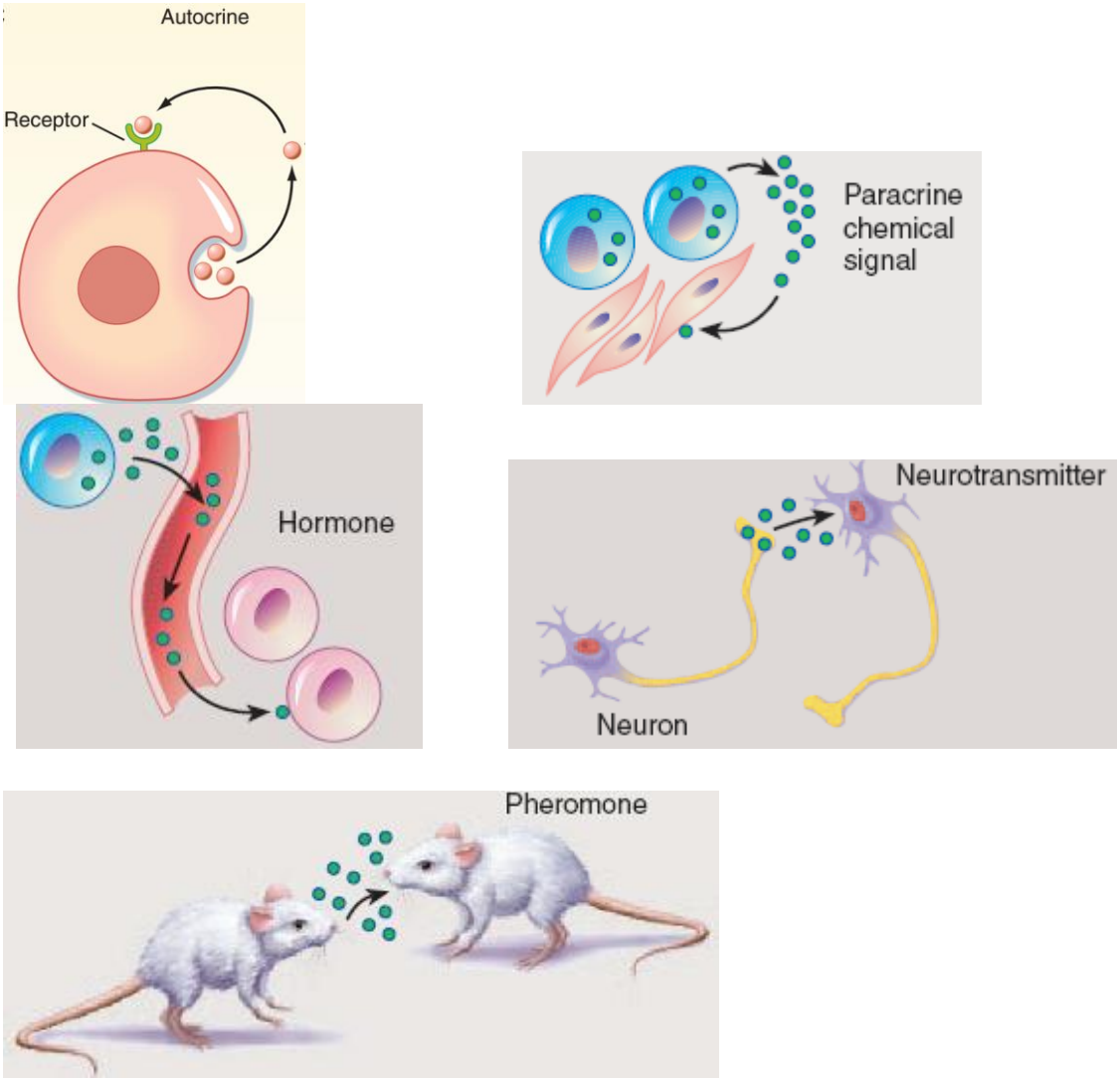

Figure 2-12: Functional classification of intercellular chemical signals

Questions

1- In secondary active transport**,** if the solutes move in the same direction across the cell membrane, it is called -------

2-Name and describe intercellular chemical signals.

3- Choose the correct answer: LDLs enters the endothelial cells by

a-simple diffusion b-pinocytosis c-receptor mediated endocytosis d-phagocytosis

4- If endocytosis continually takes away bits of plasma membrane to form intracellular vesicles, why doesn't the membrane grow smaller and smaller?

Dr. Karim R. Hamad