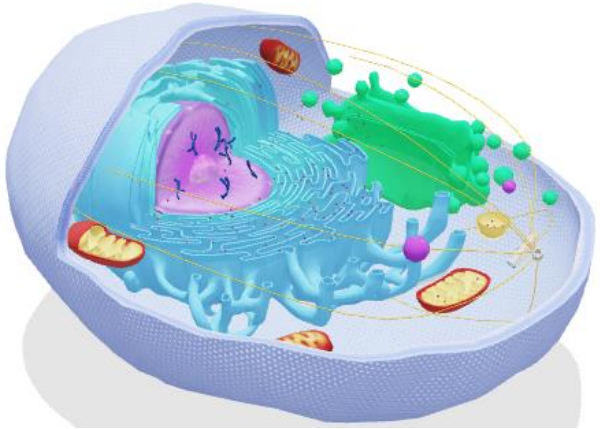
Ashur University
College of Medicine

Grade 2
Neuroscience

Cell Physiology

lecture 3



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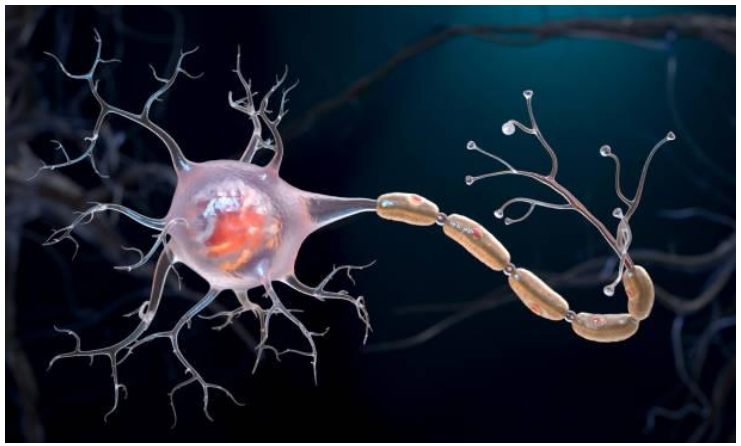
28/09/2024



- **Objectives:**

- Explain The importance of Na+ -K+ Pump in Controlling Cell Volume.
- Describe Primary Active Transport of Hydrogen Ions.
- Explain the Sodium Counter-Transport of Calcium and Hydrogen Ions.
- Describe the Sodium-hydrogen counter-transport.
- Define The Ca 2 + Pump.
- Explain the Bulk Transport.
- Define Phagocytosis.

The importance of Na+ -K+ Pump in Controlling Cell Volume

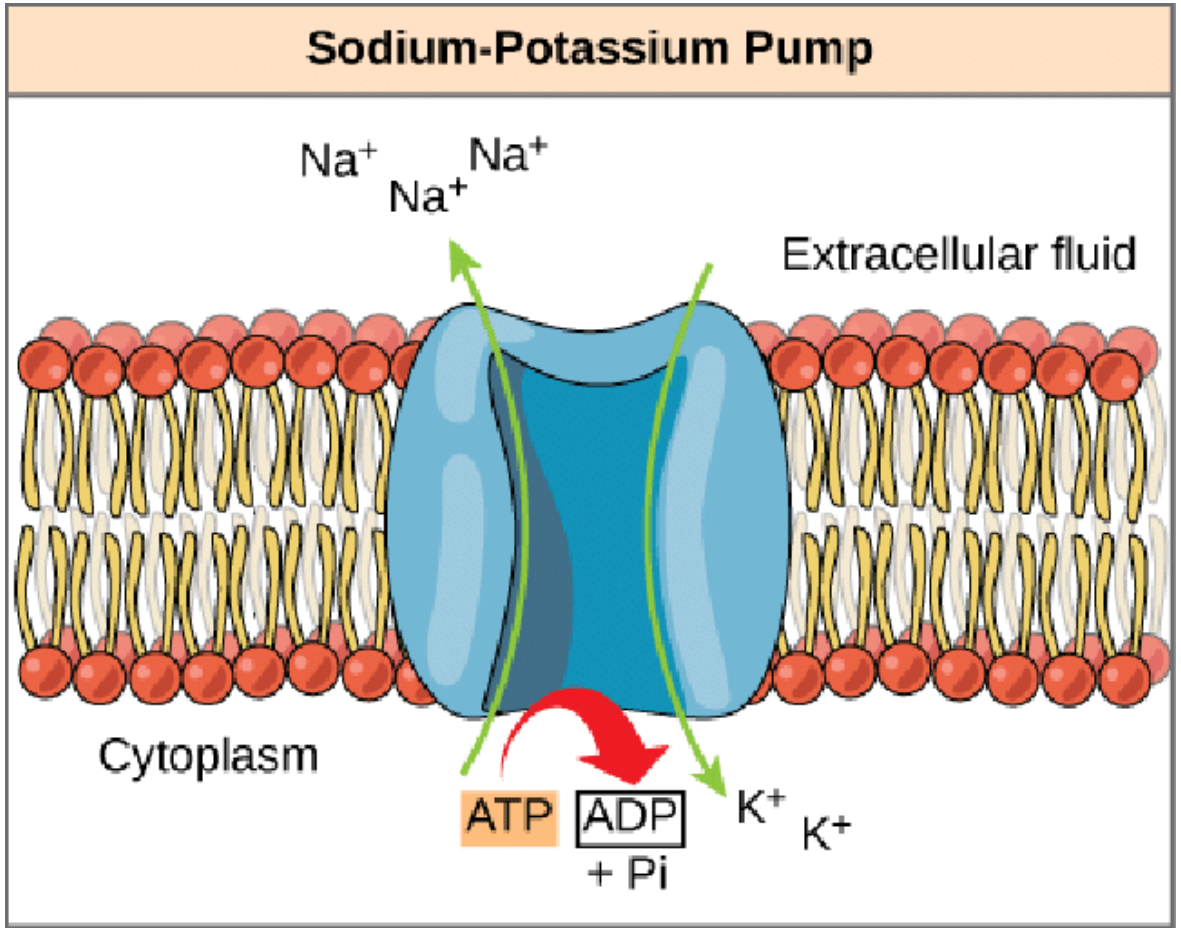
- The sodium and potassium move against the concentration gradients.

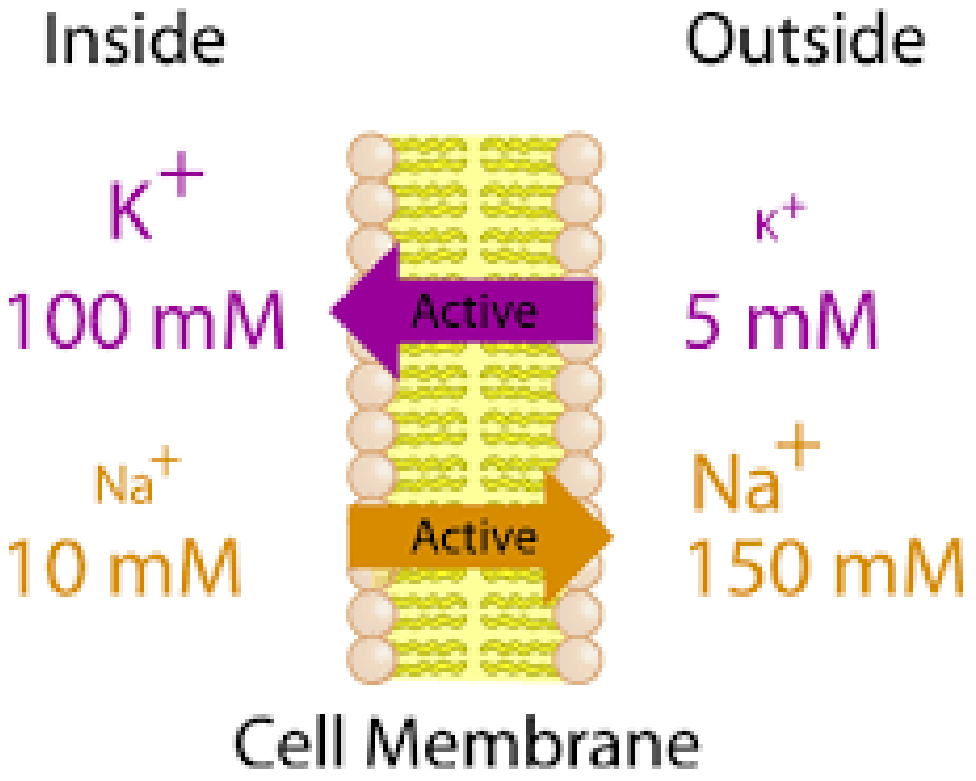
  The **Na+ K+ pump** **maintains** the gradient of a **higher concentration of sodium extracellularly** and a **higher level of potassium intracellularly**.

- **Controlling cell volume:**

  When this is higher than the osmolarity outside of the cell, water flows into the cell through **osmosis**. This can cause the cell to swell up and lyse. The Na +- K + pump helps to maintain the right concentrations of ions.

- The brain requires Na +- K + pump . Neurons need the Na +- K + pump to reverse postsynaptic sodium flux to re-establish the potassium and sodium gradients which are necessary to fire action potentials.





Primary Active Transport of Hydrogen Ions

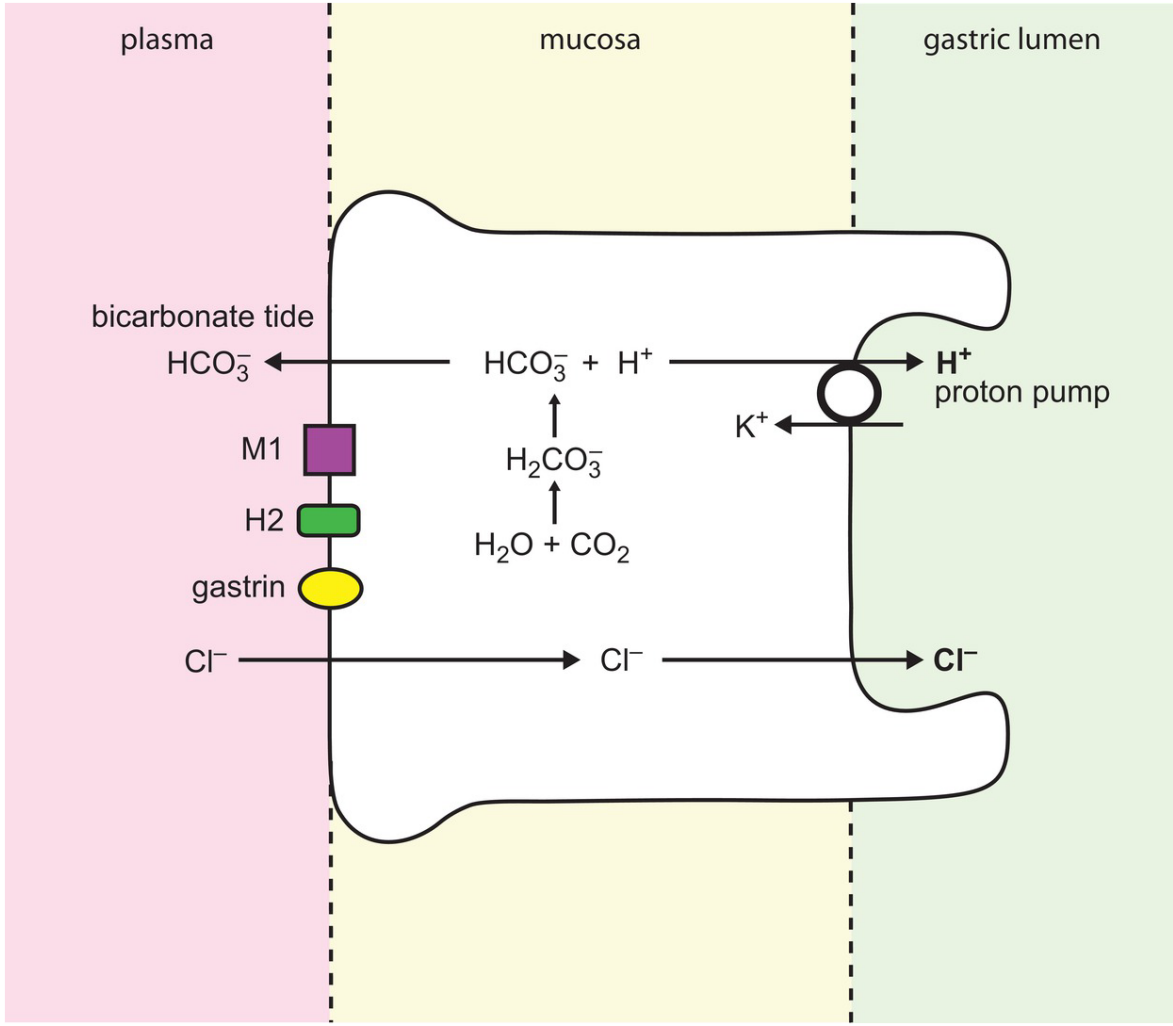
- Primary active transport of hydrogen ions is especially important at two places in the body:

(1) In the gastric glands of the stomach.

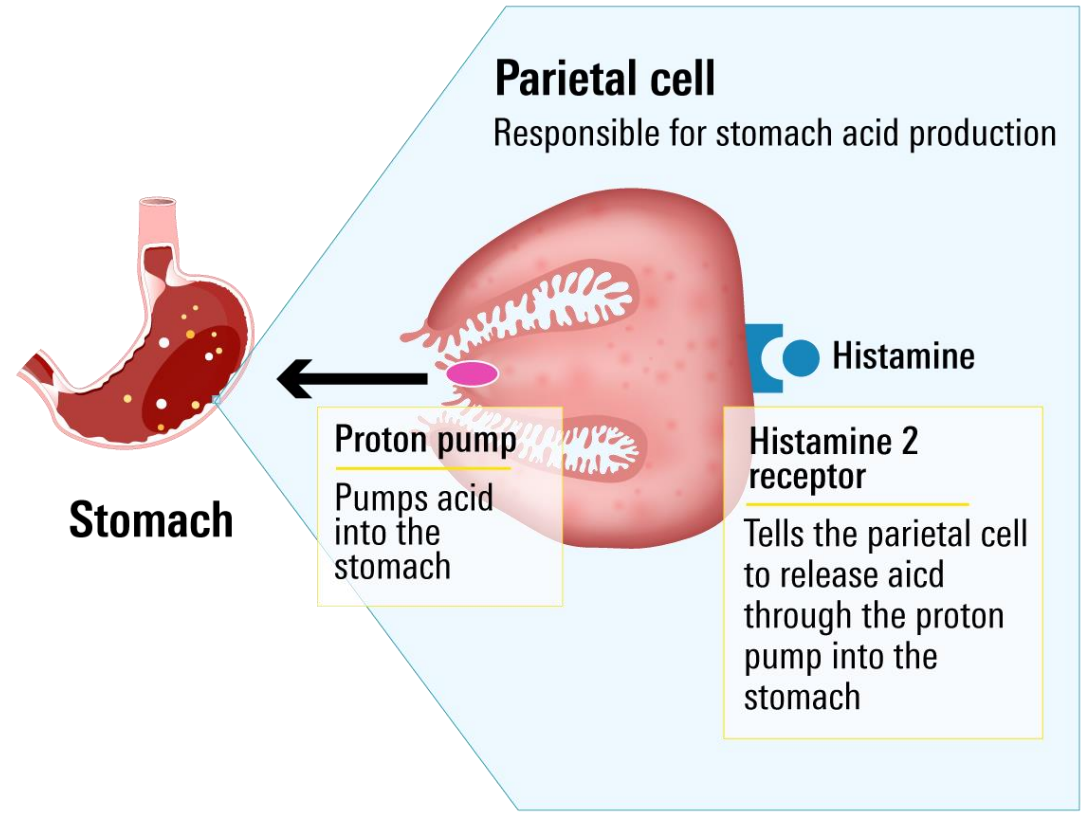
(2) In the distal tubules and cortical collecting ducts of the kidneys.

In the **gastric glands**, the deep-lying **parietal cells** have the most potent primary active mechanism for transporting hydrogen ions of any part of the body. This mechanism is the basis for secreting **hydrochloric acid** in stomach digestive secretions.

N.B. Proton pump inhibitors (PPI) suppresses stomach acid secretion by specific inhibition of the H^+/K^+-ATPase system found at the secretory surface of gastric parietal cells.



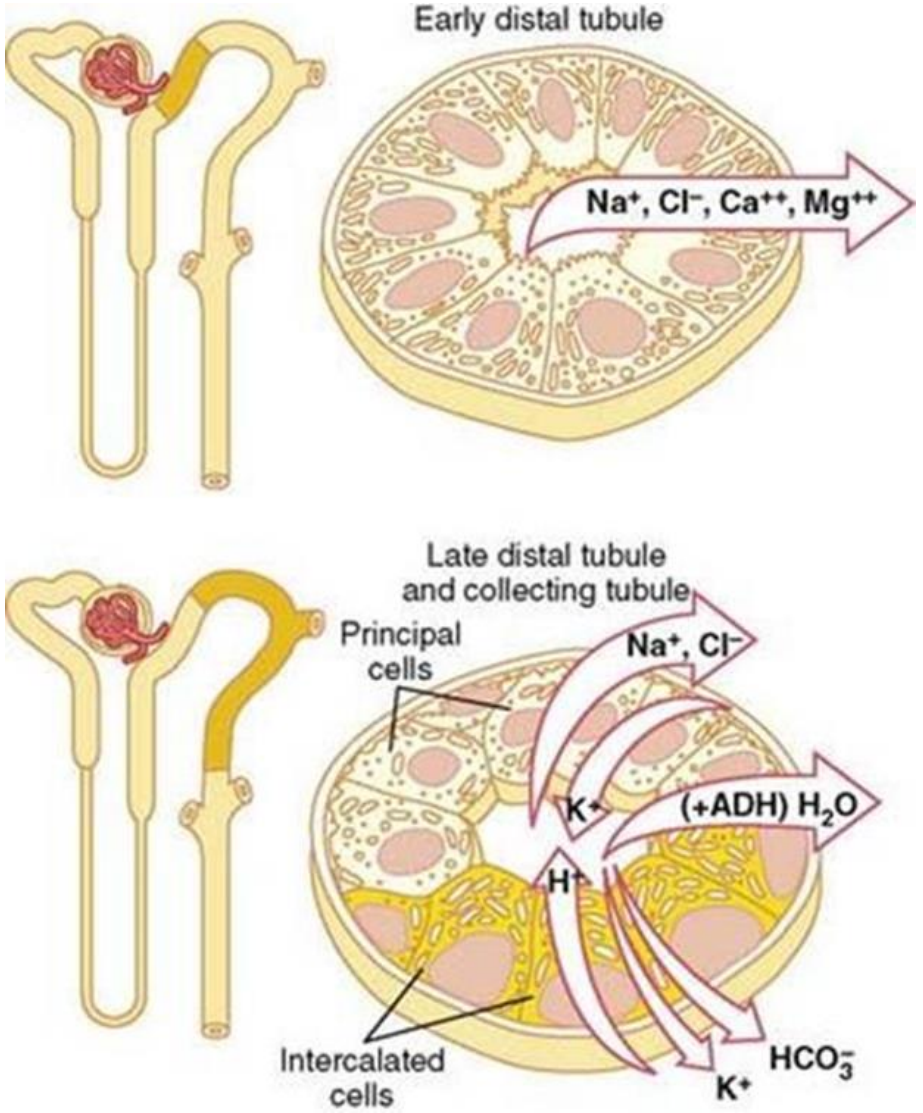
Gastric Acid Production



- In the renal tubules, special **intercalated cells** found in the late distal tubules and cortical collecting ducts also transport hydrogen ions by primary active transport. In this case, large amounts of hydrogen ions are secreted **from the blood into the renal tubular fluid** for the purpose of **eliminating excess hydrogen ions from the body fluids**.
- The tubular secretion of H+ and NH4+ from the blood into the tubular fluid is involved in blood pH regulation. The movement of these ions also helps to conserve sodium bicarbonate (NaHCO3).

The typical pH of urine is about 6.0,

while pH is ideally 7.35 to 7.45 for blood.



Sodium Counter-Transport of Calcium and Hydrogen Ions

- **Two** especially important counter-transporters

(i.e., transport in a direction opposite to the primary ion) are:

(1) Sodium-calcium counter-transport and

(2) Sodium-hydrogen counter-transport.

- **Sodium-calcium counter-transport :**

  occurs through all or almost all cell membranes, with sodium ions moving to the interior and calcium ions to the exterior.

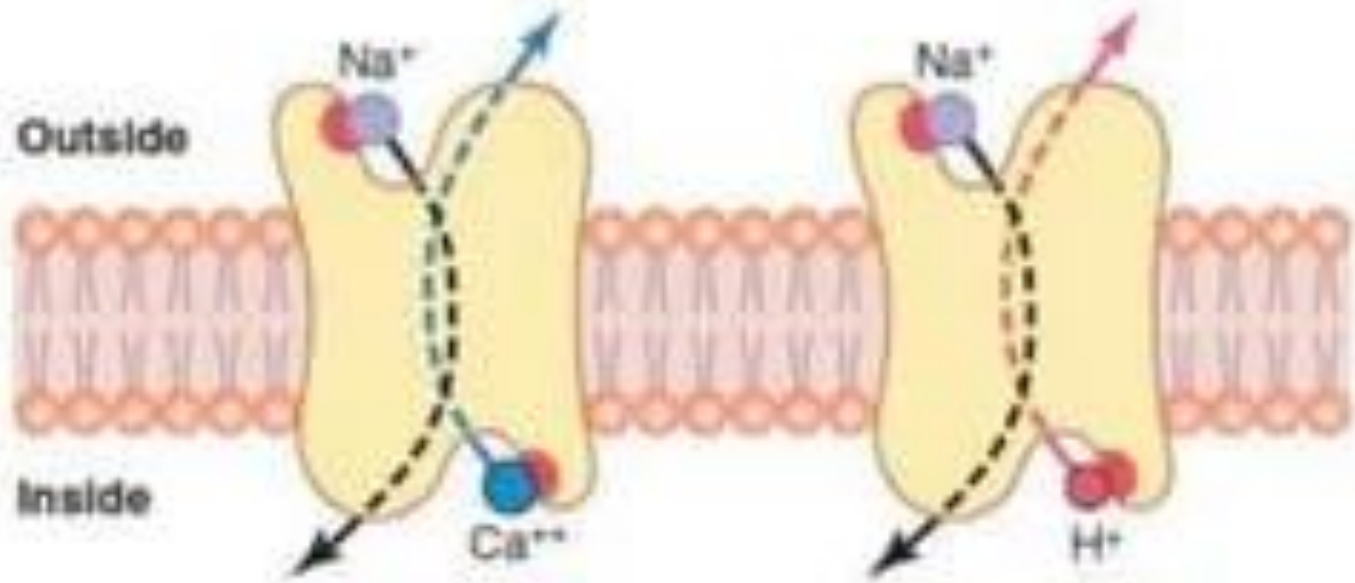
- **Sodium-hydrogen counter-transport :**

  occurs in several tissues , especially in the proximal tubules of the kidneys.

transports Na into the cell, and H out of the cell.



Sodium Counter-Transport of Calcium and Hydrogen Ions:



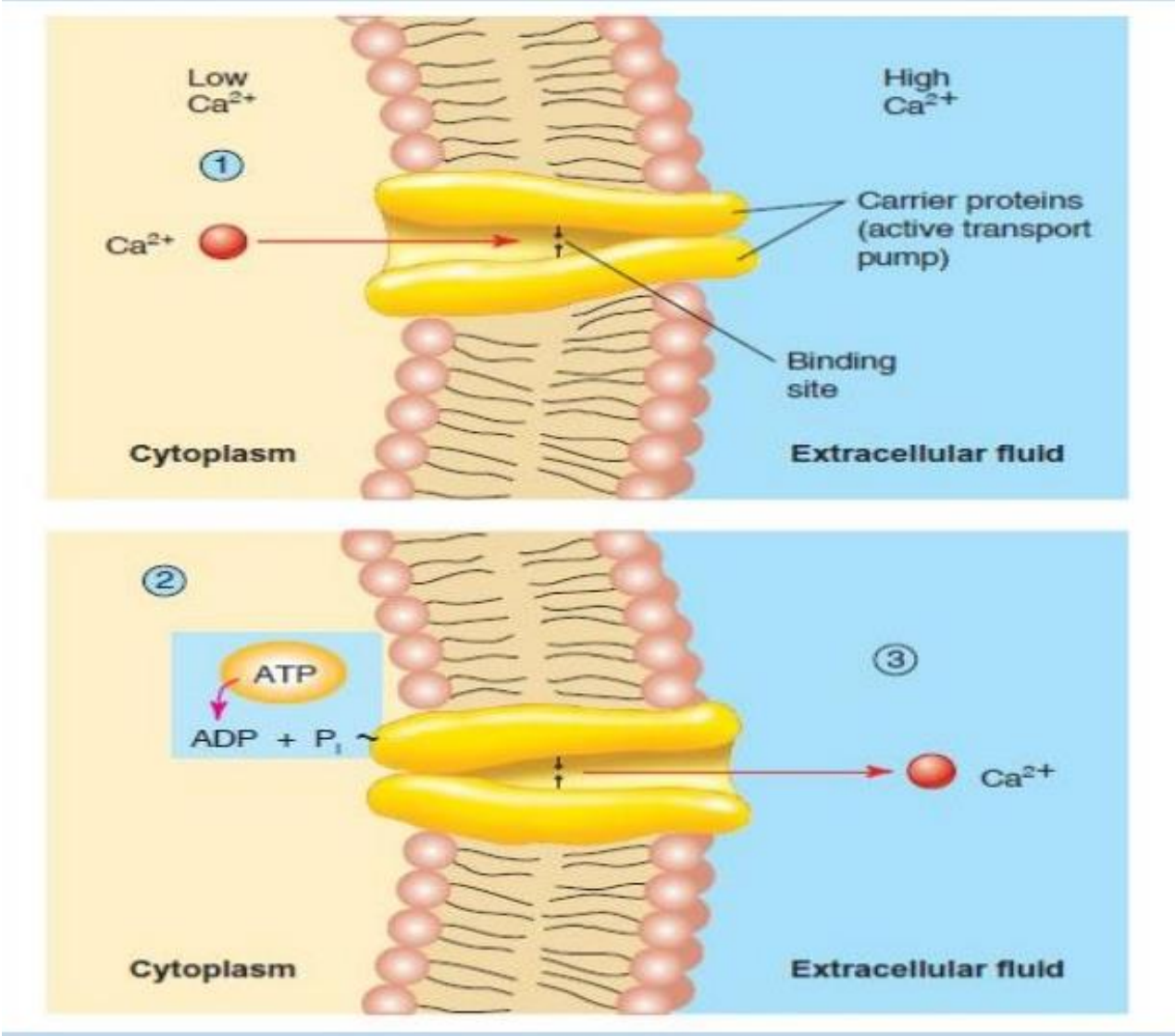
The Ca 2 + Pump

- **Ca 2 + pumps** are located in the plasma membrane of all cells, and in the membrane of the endoplasmic reticulum of striated muscle cells and others.
- **Calcium ions** are involved in regulating almost all biological functions of the body, such as the **heart** and **muscle** contractions, **neuro-**information transmission, **learning** and **memory**.
- The plasma membrane **Ca2+-ATPase (PMCA) pumps** play a critical role in the maintenance of Ca2+ homeostasis, crucial for optimal neuronal function and cell survival.
- **Loss of Ca2+ homeostasis** is a key precursor in neuronal dysfunction associated with **brain aging** and in the pathogenesis of **neurodegenerative disorders**.

- The figure presents a simplified model of the **Ca 2 + pump**.
- Notice that there is a binding site that is accessible to Ca 2 + from the cytoplasm, and that the pump is activated by **phosphorylation**, using the

P i derived from ATP.

- **Pi** : **inorganic phosphate**
- **ATP** : **Adenosine triphosphate**
- **ADP** : **Adenosine diphosphate**



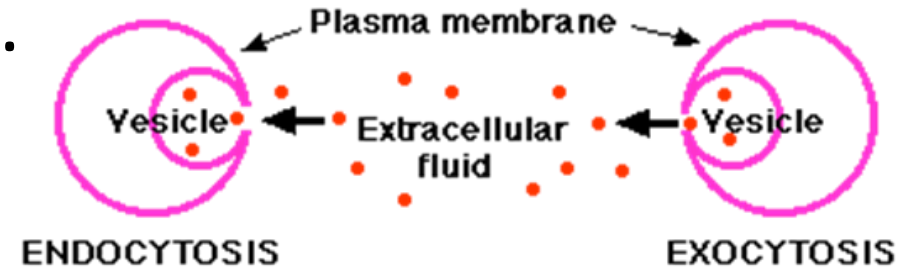
Bulk Transport

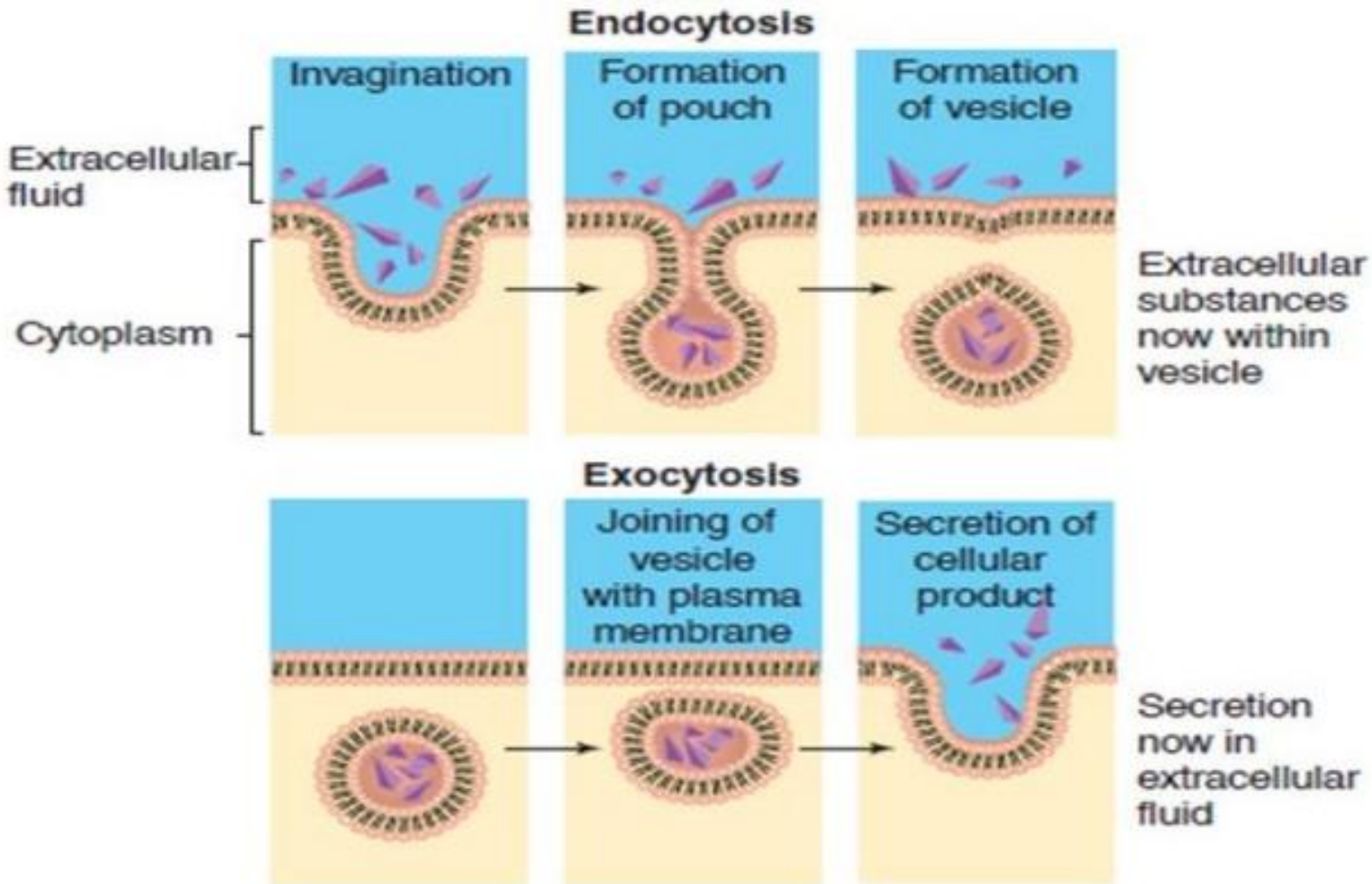
(The term bulk is used because many molecules are moved at the same time)

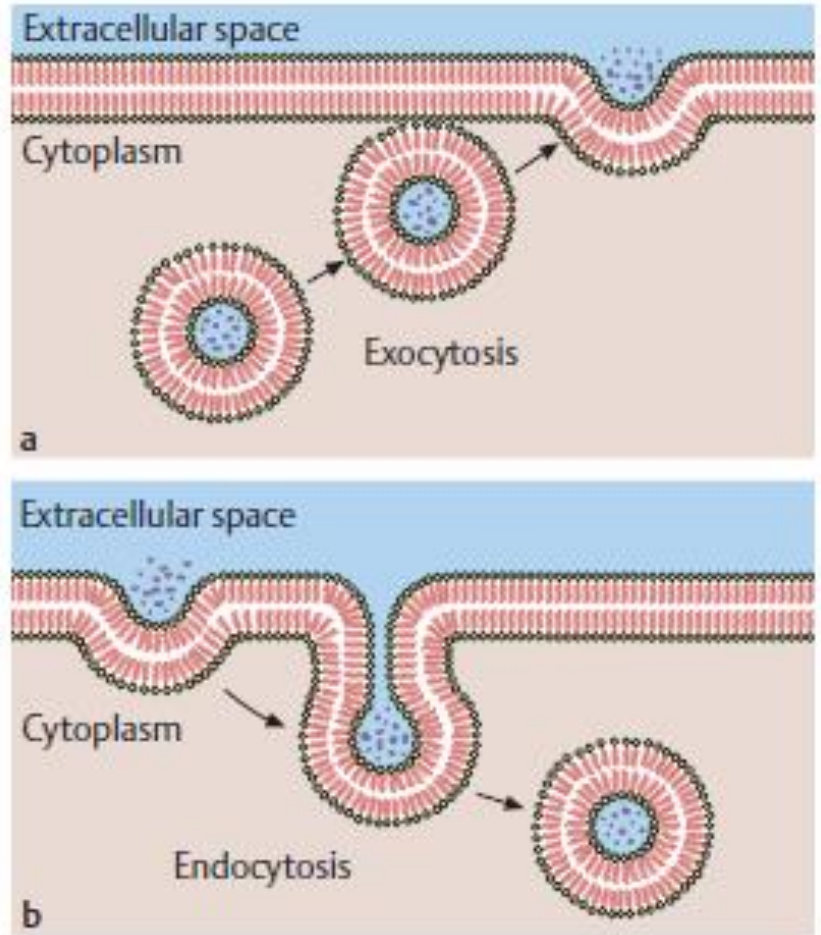
Exocytosis and **endocytosis** together provide bulk transport out of and into the cell, respectively. Polypeptides and proteins, as well as many other molecules, are too large to be transported through a membrane by the carriers.

Exocytosis: This involves the fusion of a membrane-bound vesicle that contains these cellular products with the plasma membrane, so that the membranes become continuous.

Endocytosis resembles exocytosis in reverse.

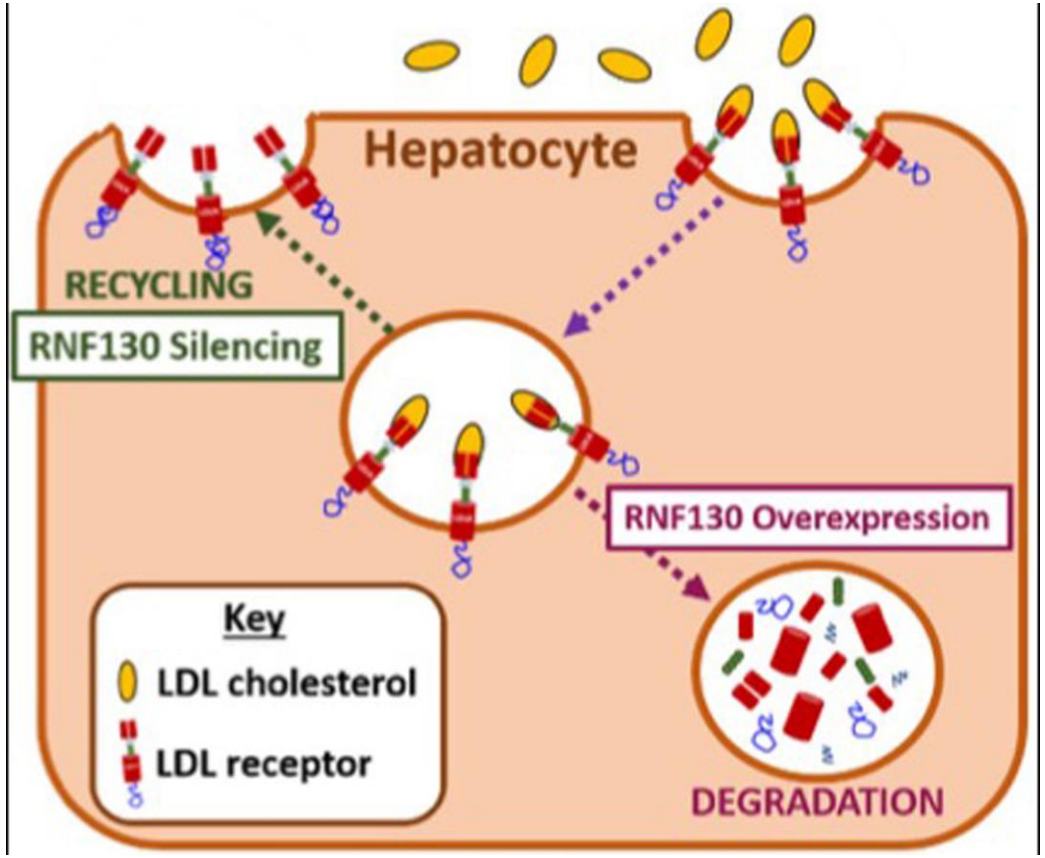



Endocytosis
Invagination
Formation of pouch
Formation of vesicle
Extracellular fluid
Cytoplasm
Extracellular substances now within vesicle
Exocytosis
Joining of vesicle with plasma membrane
Secretion of cellular product
Secretion now in extracellular fluid


Extracellular space
Cytoplasm
Exocytosis
a
Extracellular space
Cytoplasm
Endocytosis
b

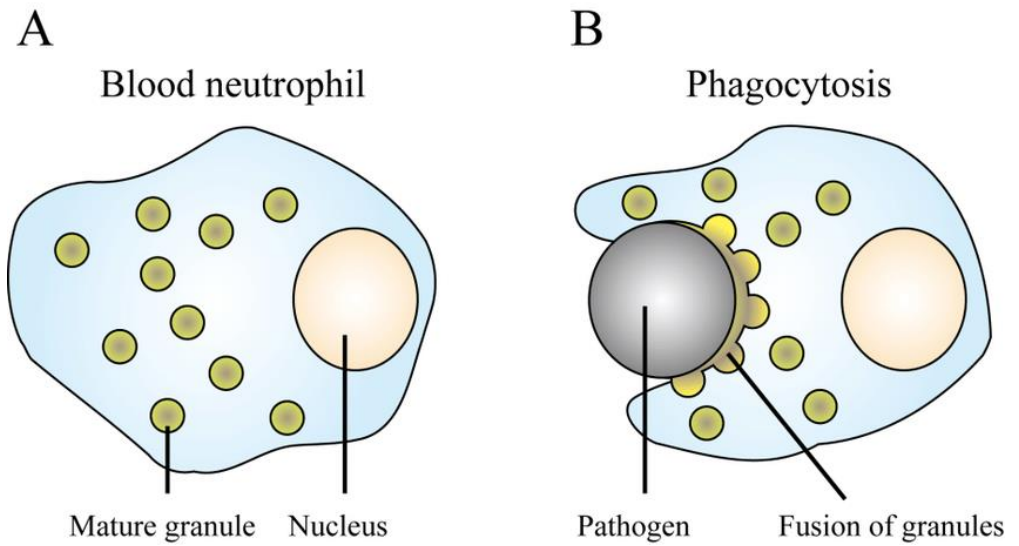
- In **Receptor-Mediated Endocytosis**: specific molecules, such as **protein bound cholesterol**, can be taken into the cell because of the interaction between the cholesterol transport protein and a protein receptor on the plasma membrane.

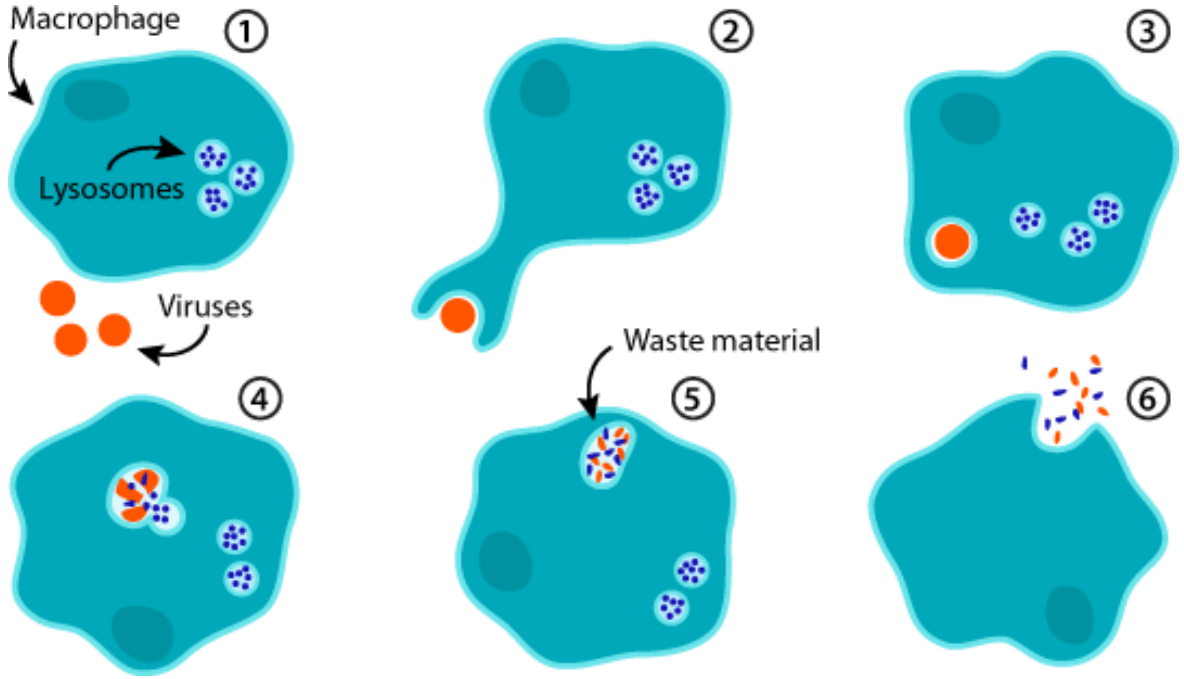
Cholesterol is removed from the blood by the liver and by the walls of blood vessels through this mechanism.



Phagocytosis

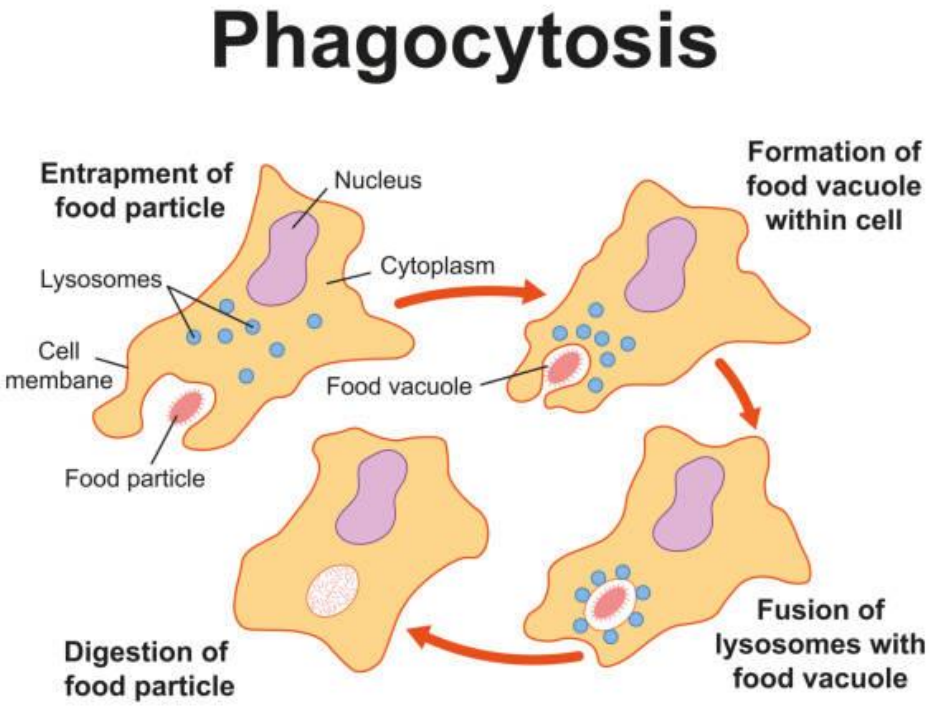
- Most of the movement of molecules and ions between the intracellular and extracellular compartments involves passage through the plasma membrane. Bulk transport includes the processes of **phagocytosis** and **endocytosis**. White blood cells known as **neutrophils**, and **connective tissue** cells called **macrophages** (literally, **"big eaters"**), are able to perform amoeboid movement (move like an amoeba, a single-celled animal).

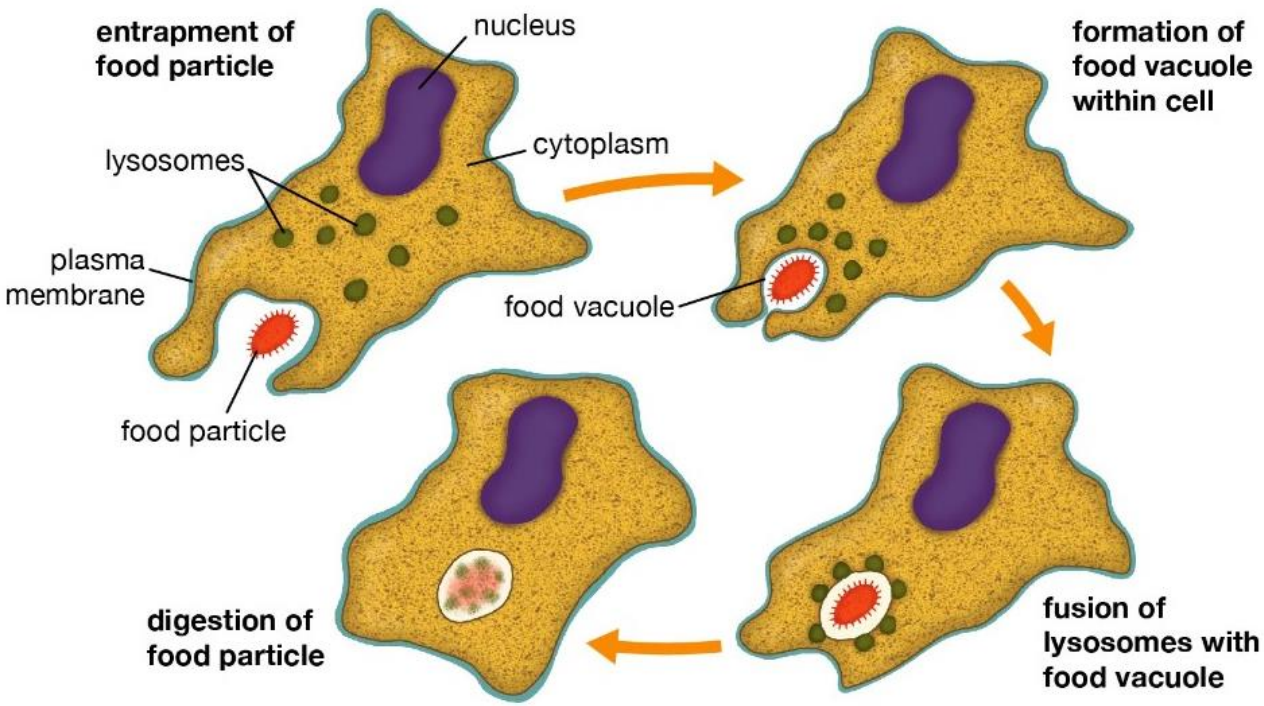


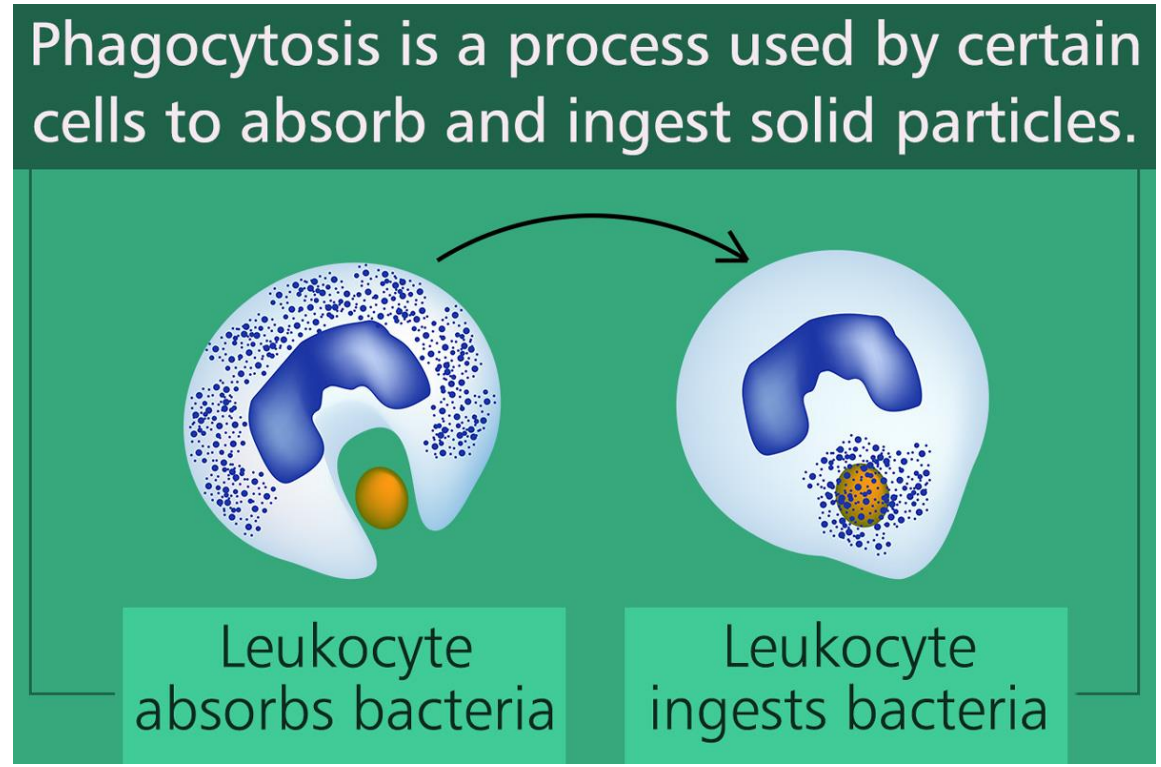


Phagocytosis

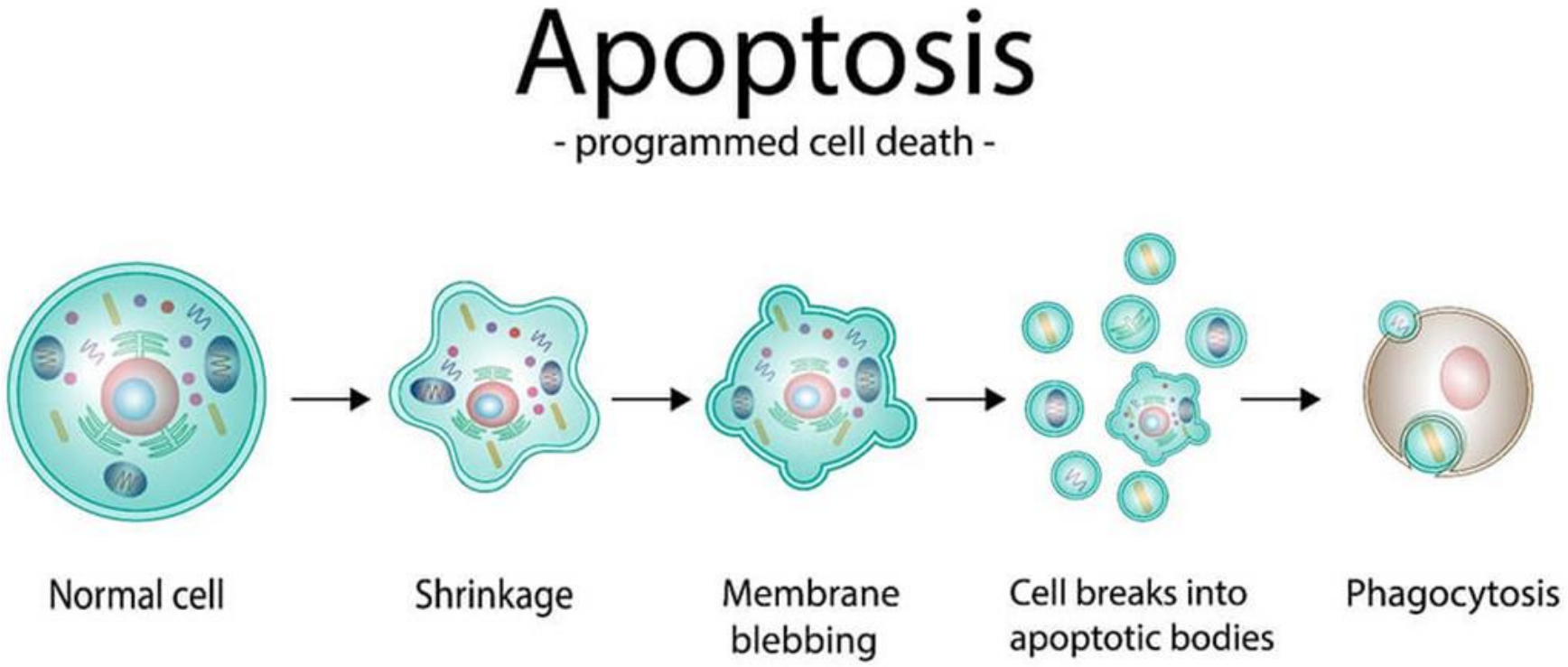
- This involves extending parts of their cytoplasm to form **pseudopods (false feet)**, which pull the cell through the extracellular matrix —generally, an extracellular gel of proteins and carbohydrates.
- Use pseudopods to surround and engulf particles of organic matter (such as bacteria). This process is a type of cellular "eating" called **phagocytosis**. The ingested particle is now contained in an organelle called a **food vacuole** within the cell. The food vacuole will subsequently fuse with an organelle called a **lysosome** , and the particle will be digested by lysosomal enzymes.



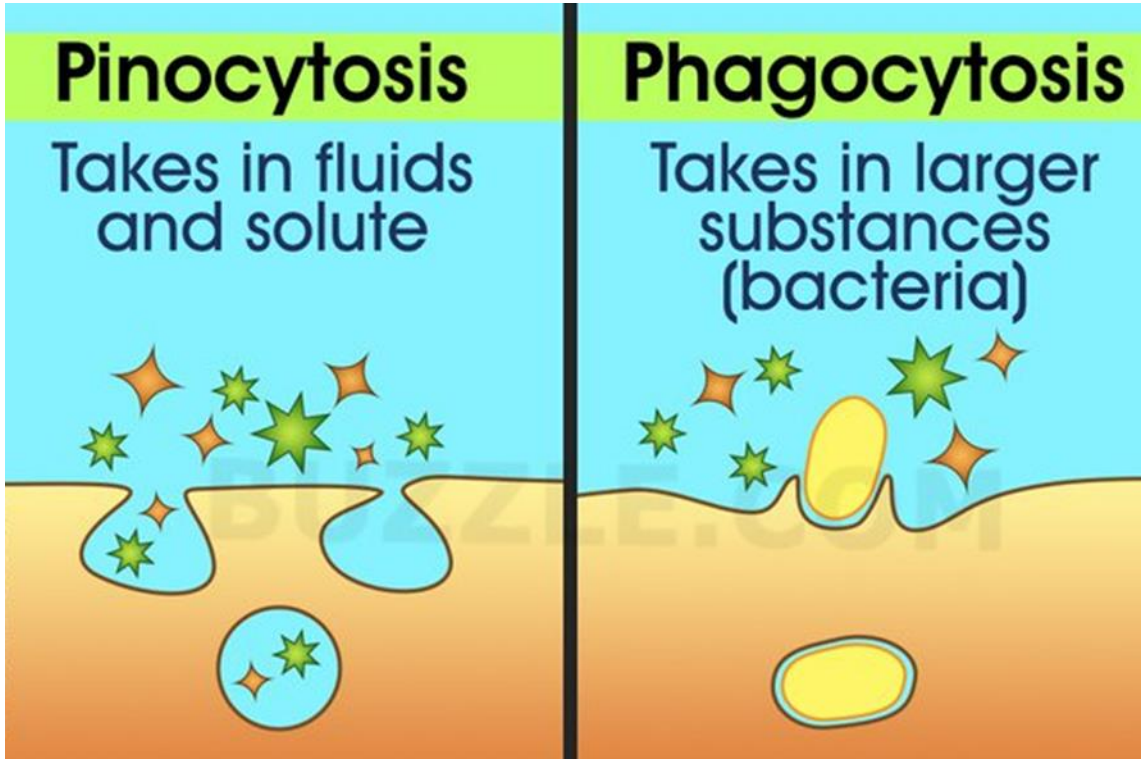

entrapment of food particle
nucleus
lysosomes
cytoplasm
plasma membrane
food particle
formation of food vacuole within cell
food vacuole
fusion of lysosomes with food vacuole
digestion of food particle


Phagocytosis is a process used by certain cells to absorb and ingest solid particles.
Leukocyte absorbs bacteria
Leukocyte ingests bacteria

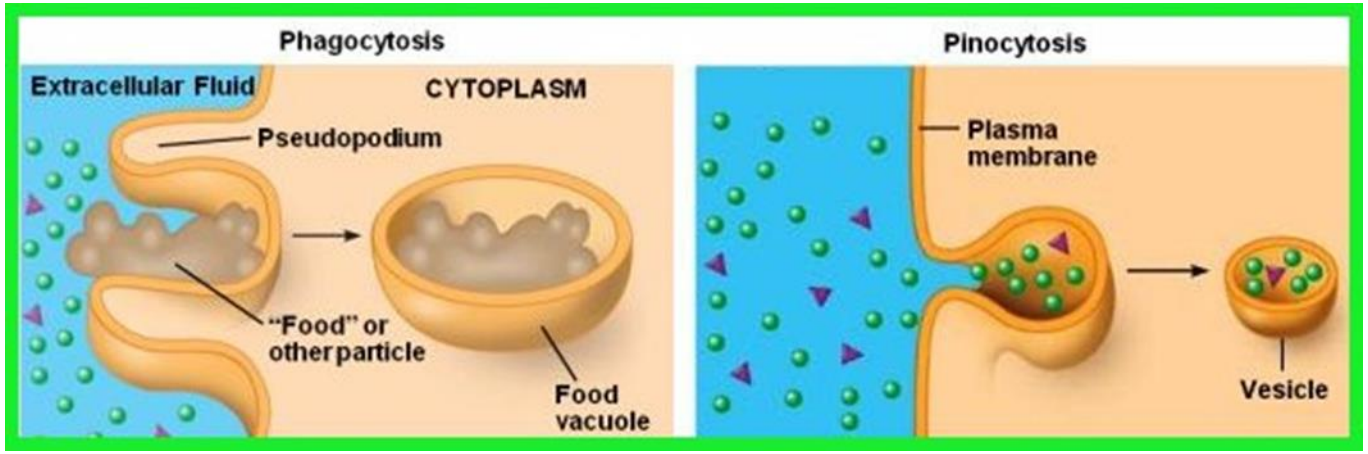
- **Phagocytosis**, largely by **neutrophils** and **macrophages**, is an important immune process that defends the body and promotes inflammation.
- **Phagocytosis by macrophages** is also needed for the removal of senescent (aged) cells and those that die by **apoptosis** (cell suicide). Apoptosis is a normal, ongoing activity in the body and is not accompanied by inflammation.



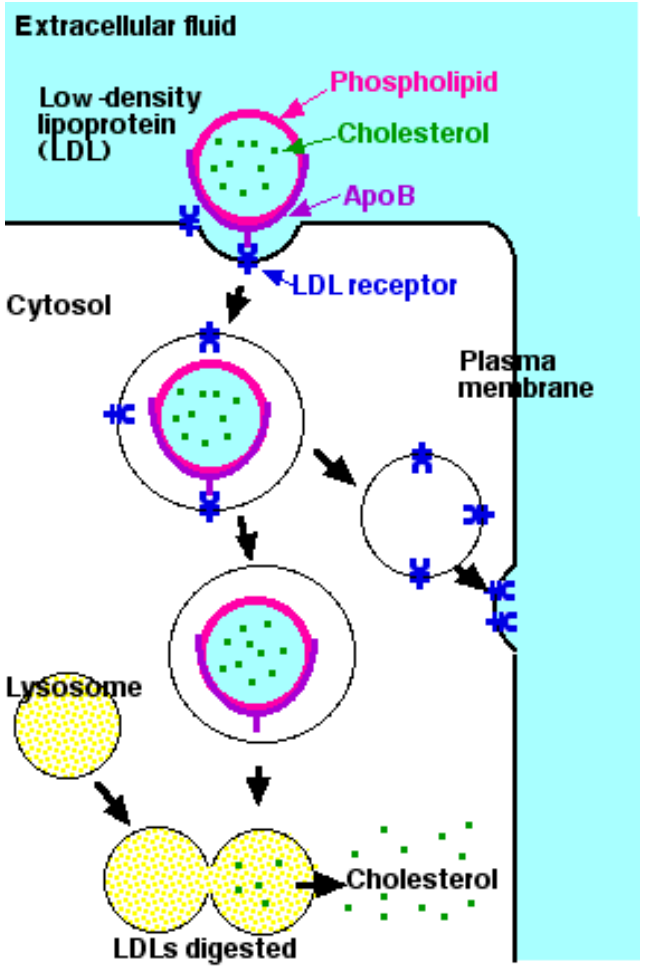
- **Endocytosis** is a process in which the plasma membrane furrows inward, instead of extending outward with pseudopods. One form of endocytosis, **pinocytosis**, is a nonspecific process performed by many cells.
- **Pinocytosis** is an active , process where extracellular fluid and solutes are taken up into a cell via small vesicles. It is a type of endocytosis, which refers to the uptake of substances by a cell.

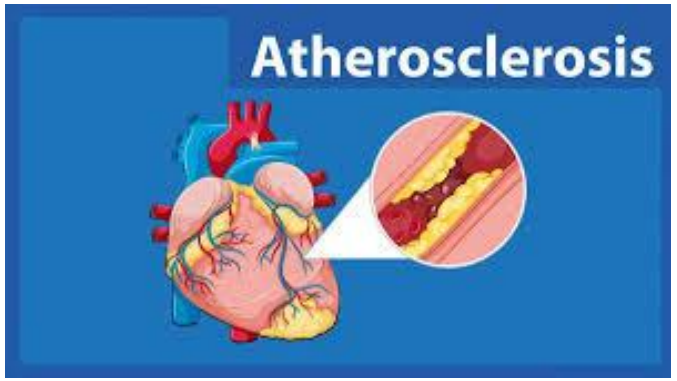


Because the extracellular molecules must bind to very specific receptor proteins in the plasma membrane, this process is known as **receptor mediated endocytosis.**



- **Cholesterol** attached to specific proteins, for example, is taken up into artery cells by **receptor-mediated endocytosis**. This is in part responsible for **atherosclerosis**.
- **Oxidative modification converts LDL into atherogenic particles that initiate inflammatory responses**. Uptake and accumulation of oxidatively modified LDL (oxLDL) by macrophages initiates a wide range of bioactivities that may drive development of atherosclerotic lesions.
- People who inherit defective (mutant) genes for the LDL receptor have receptors that function poorly or not at all. This creates excessively high levels of LDL in their blood and predisposes them to **atherosclerosis** and heart attacks. The ailment is called **familial hypercholesterolemia** (because it is inherited).



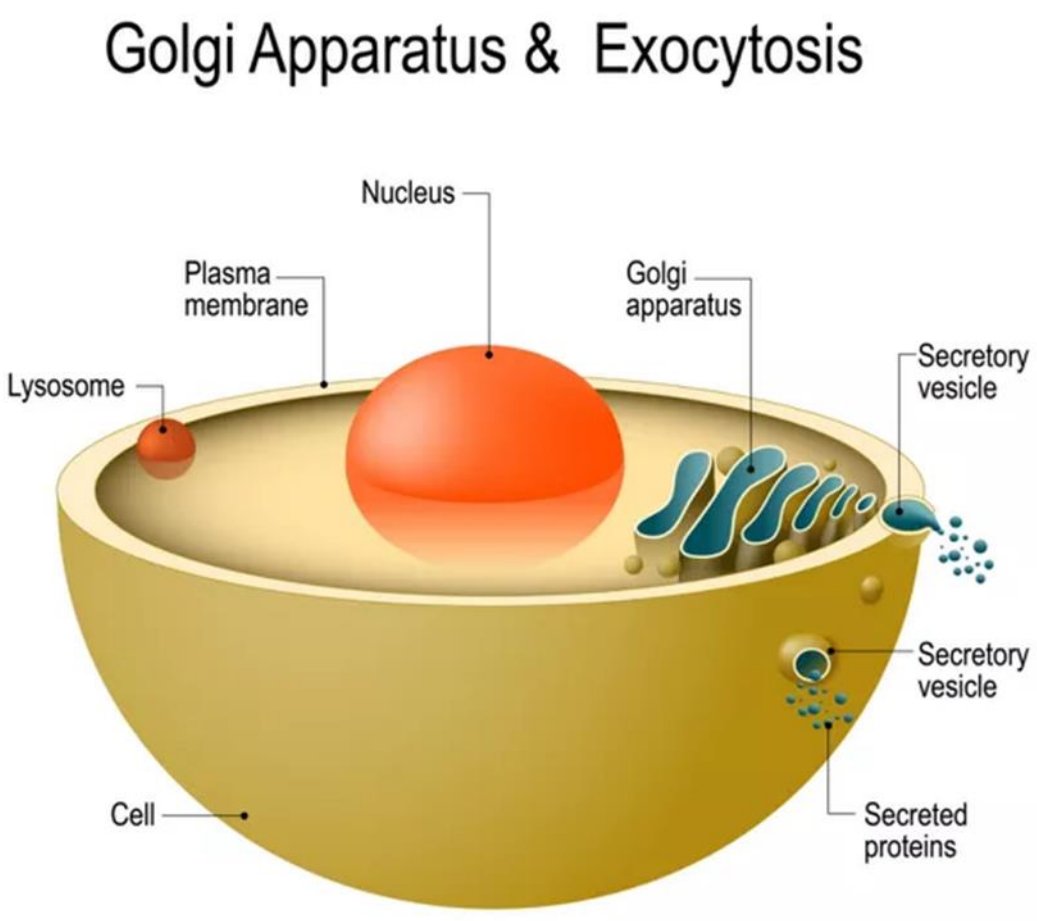


- **Exocytosis** is a process by which cellular products are secreted into the extracellular environment.

  Proteins and other molecules produced within the cell that are destined for export (secretion) are packaged within vesicles by an organelle known as the **Golgi complex (Golgi apparatus)**

- In the process of exocytosis, secretory vesicles fuse with the plasma membrane and release their contents into the extracellular environment .

  Nerve endings, for example, release their chemical neurotransmitters in this manner.




THANK YOU!
Any questions?