Physiology (code)-year 2

LECTURE 2
(HOMEOSTASIS AND TRANSPORT THROUGH CELL MEMBRANE)

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"Homeostasis" means the maintenance of constant internal environment.

The internal environment in the body is the ECF which contains nutrients, ions and all other substances necessary for the survival of the cells and in this environment the cells live.

It includes the blood and interstitial fluid. For the operation of homeostatic mechanism, the body must recognize the deviation of any physiological activity from the normal limits.

Transport through Cell Membrane

Transport mechanism in the body is necessary for the supply of essential substances like nutrients, water, electrolytes, etc. to the tissues and to remove the unwanted substances like waste materials, carbon dioxide, etc. from the tissues.

BASIC MECHANISM OF TRANSPORT

Two basic mechanisms for the transport of substances across the cell membrane are:

1. Passive mechanism
2. Active mechanism

1. **PASSIVE TRANSPORT**

The transport of the substances along the concentration gradient or electrical gradient or both (electrochemical gradient) is called passive transport. Here, the substances move from the region of higher concentration to the region of lower concentration.

It is also known as diffusion or **downhill** movement. It does not need energy. Diffusion or passive transport is of two types:

a) Simple diffusion

b) Facilitated diffusion.

a) SIMPLE DIFFUSION

Simple diffusion is of two types:

1. Simple diffusion through lipid layer
2. Simple diffusion through protein layer

1.Simple Diffusion through Lipid Layer

Lipid soluble substances like oxygen, carbon dioxide and alcohol are transported by simple diffusion through the lipid layer of the cell membrane.

2.Simple Diffusion through Protein Layer

There are specific protein channels that extend from cell membrane through which the simple diffusion takes place. Water soluble substances like electrolytes are transported through these channels. These channels are selectively permeable to only one type of ion.

Accordingly, the channels are named after the ions diffusing through these channels like sodium channels, potassium channels, etc.

Protein Channels

The protein channels are of two types:

1. Ungated channels which are opened continuously.

2. Gated channels which are closed all the time and are opened only when required.

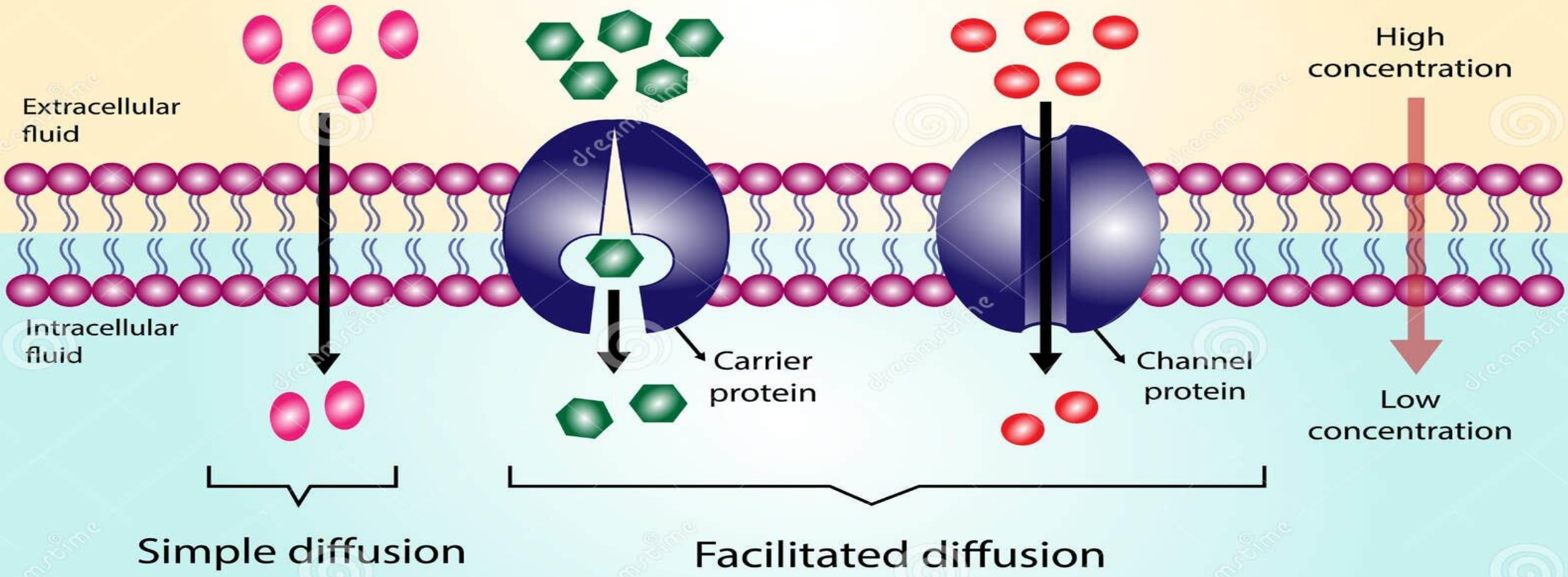
b) FACILITATED OR CARRIER MEDIATED DIFFUSION

In this type of diffusion, some carrier proteins help the transport of substances.

The water-soluble substances with larger molecules cannot pass through the protein channels by simple diffusion. Such substances are transported with the help of carrier proteins.

This type of diffusion is faster than the simple diffusion. Glucose and amino acids are transported by this method.

Passive transport



FACTORS AFFECTING RATE OF DIFFUSION

The rate of diffusion of substances through the cell membrane is directly proportional to the following factors:

1. Permeability of the cell membrane.
2. Body temperature.
3. Concentration gradient or electrical gradient of the substance across the cell membrane.

2. ACTIVE TRANSPORT

- Movement of substances against the chemical or electrical or electrochemical gradient is called active transport. It is also called **uphill transport**. Active transport requires energy which is obtained mainly by breakdown of ATP. It also needs a carrier protein.

- **MECHANISM OF ACTIVE TRANSPORT**

- When a substance to be transported across the cell membrane comes near the cell, it combines with the carrier protein of the cell membrane and forms substance – protein complex. This complex moves towards the inner surface of the cell membrane. Now, the substance is released from the carrier proteins. The same carrier protein moves back to the outer surface of the cell membrane to transport another molecule of the substance.

CARRIER PROTEINS

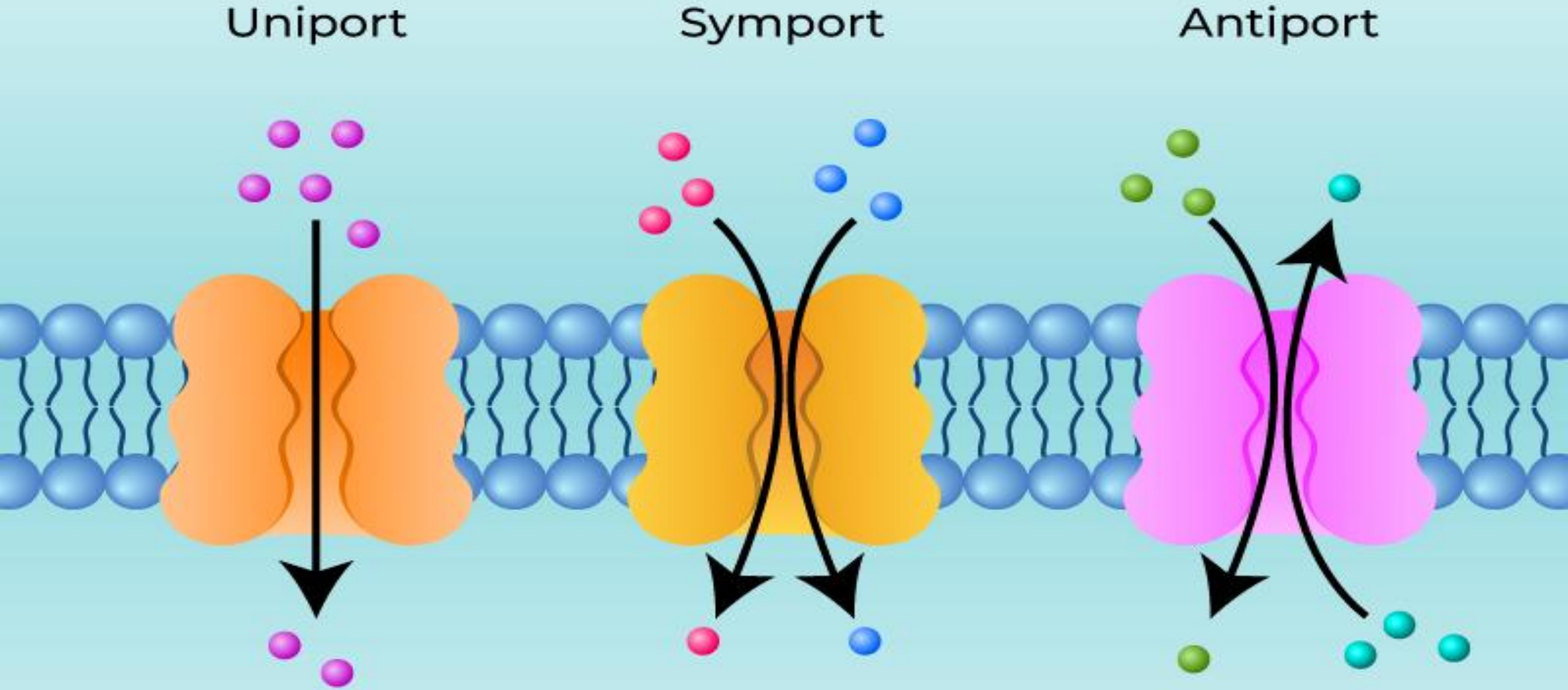
There are three types of carrier proteins:

1. Uniport
2. Symport
3. Antiport

Uniport

The carrier protein that can carry only one substance in a single direction is called uniport. It is also known as **uniport pump**.

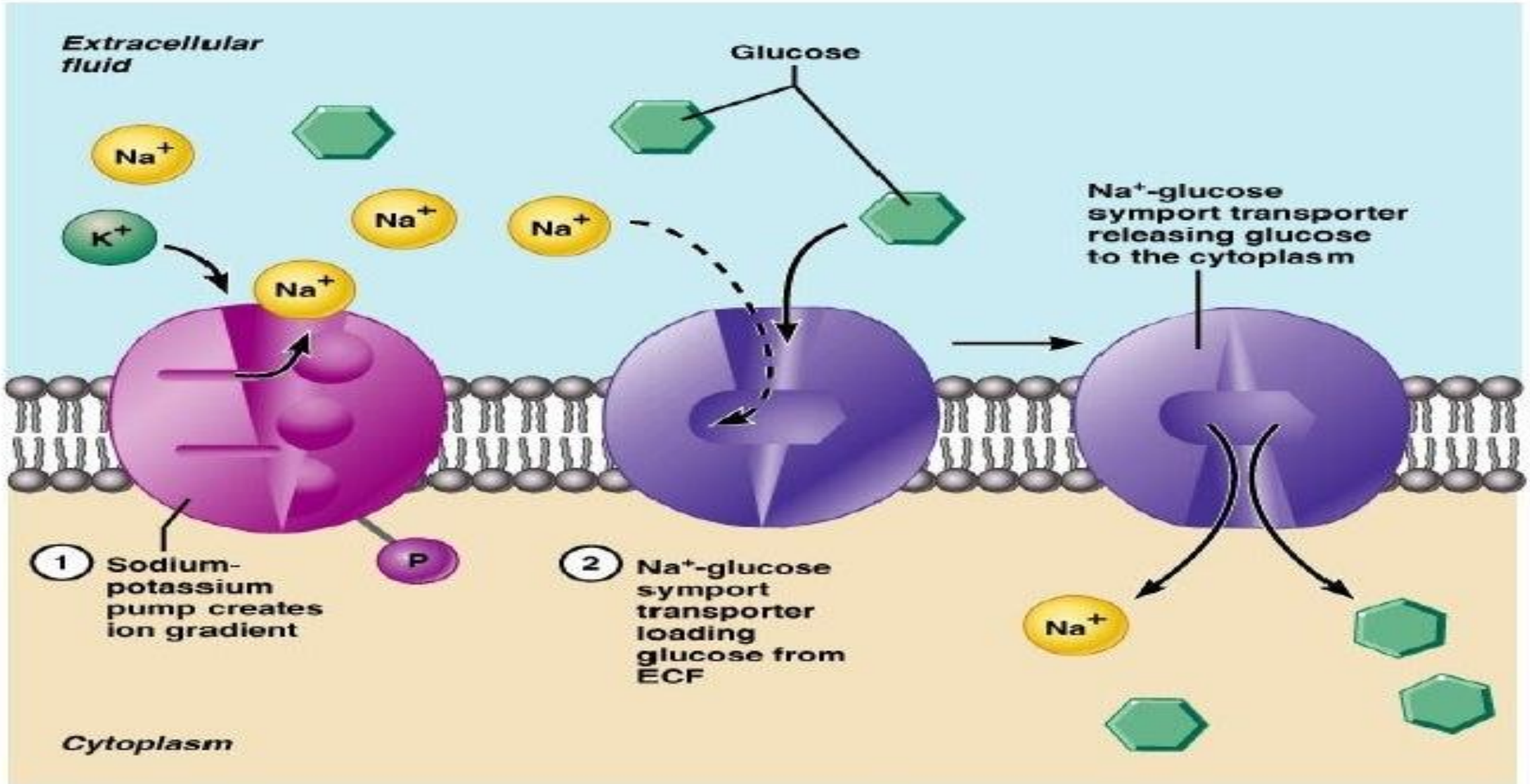
The carrier protein that transports two different substances in the same direction is called **symport.** The carrier protein that transports two different substances in opposite directions is called **antiport.**


Uniport
Symport
Antiport

- **SUBSTANCES TRANSPORTED BY ACTIVE TRANSPORT**
- The actively transported substances are in ionic form and nonionic form. The substances in ionic form are sodium, potassium, calcium, hydrogen, chloride and iodide. The substances in nonionic form are glucose, amino acids and urea.
- **TYPES OF ACTIVE TRANSPORT**
- The active transport is of two types:
- 1. Primary active transport
- 2. Secondary active transport.

- **PRIMARY ACTIVE TRANSPORT**
- In primary active transport, the energy is liberated directly from the breakdown of ATP. By this method, the substances like sodium, potassium, calcium, hydrogen and chloride are transported across the cell membrane.
- **SECONDARY ACTIVE TRANSPORT**
- The transport of a substance with sodium ions by a common carrier protein is called secondary active transport. It is of two types:
- 1. Co-transport — transport of the substance in the same direction along with sodium
- 2. Counter transport — transport of the substance in the opposite direction to that of sodium

Types of Active Transport



- **Why does active transport require energy?**

VESICULAR TRANSPORT ACROSS MEMBRANES

Vesicular transport is the movement of large substances such as polysaccharides and proteins, from one side of a membrane to another via membrane-bound vesicles.

Vesicular transport also occurs between organelles within a cell. This transport mechanism can be subdivided into two main categories: **endocytosis** and **exocytosis.**

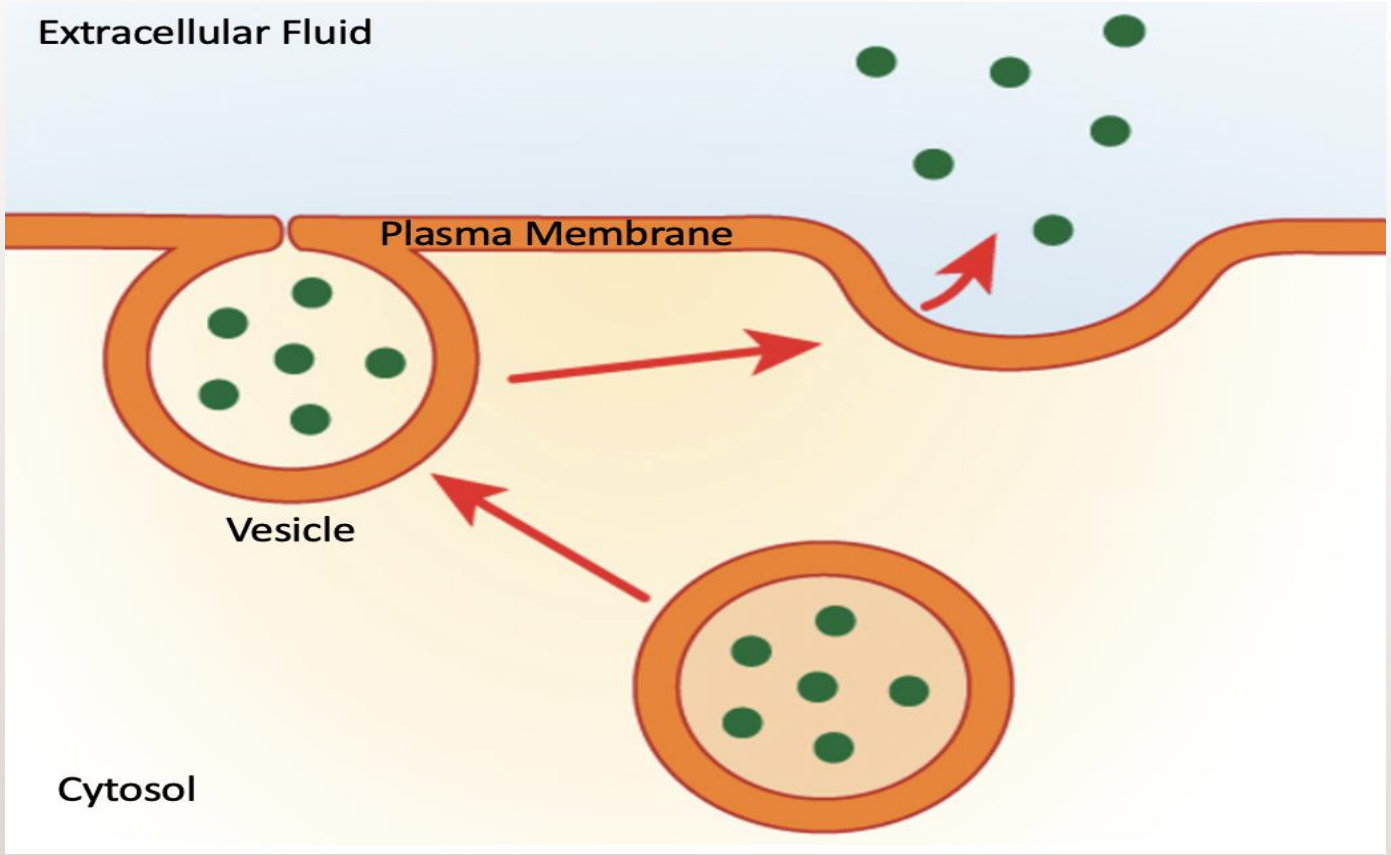
Exocytosis

Exocytosis (“exo” = outside) is the cellular process that involves transporting materials from the inside of a cell into the extracellular fluid via the fusion of a vesicle with the membrane.

Material within the cell’s endomembrane system become enveloped in a vesicle, and that vesicle then fuses with the plasma membrane’s interior.

This fusion opens the membranous envelope on the cell’s exterior, and the material is expelled into the extracellular space .

The vesicle membrane then becomes integrated into the plasma membrane, with the vesicle’s luminal (inside) surface becoming the plasma membrane’s extracellular surface.

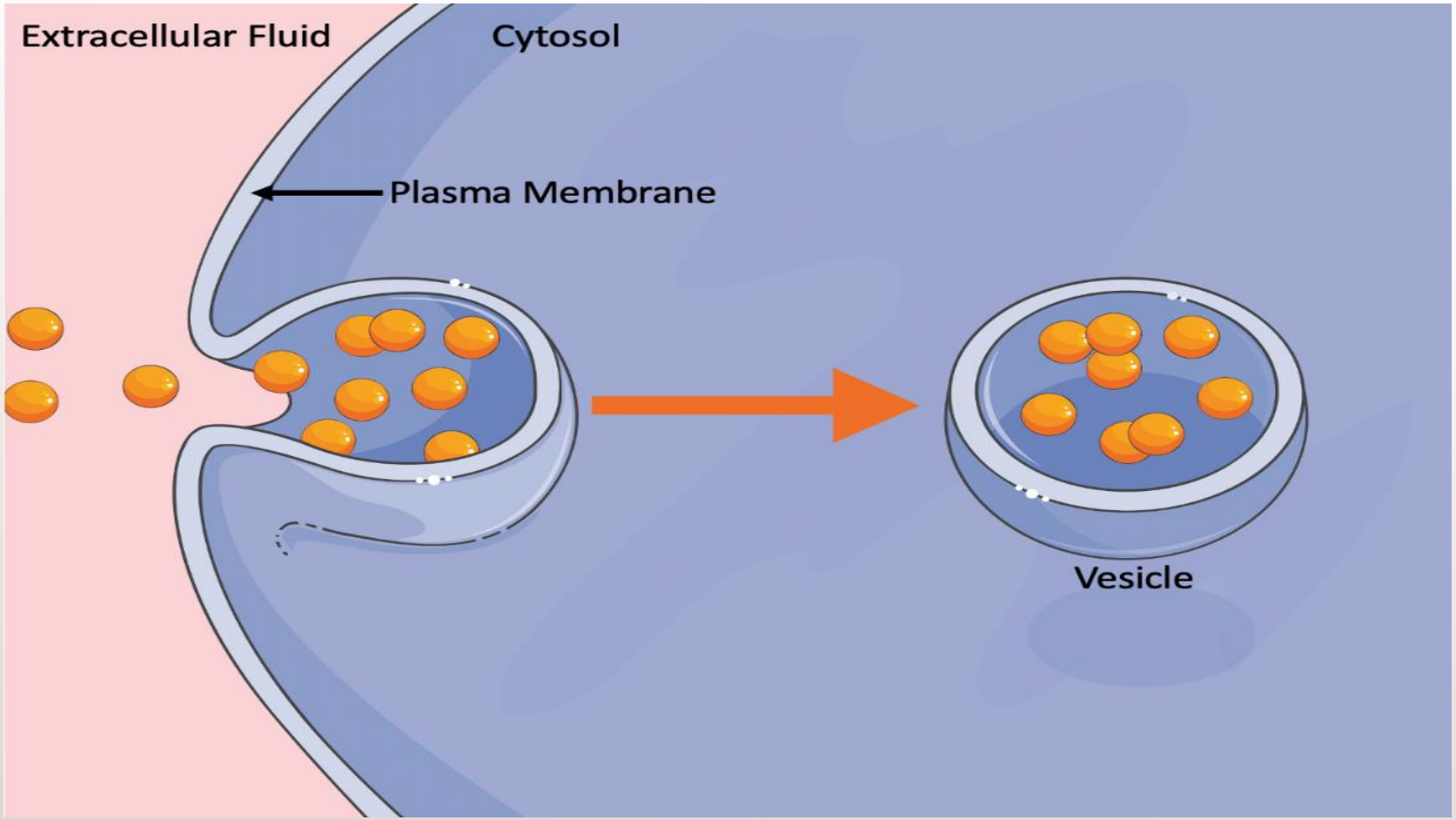


During exocytosis, vesicles containing substances (green circles) from the cytoplasm of a cell fuse with the plasma membrane and expel contents into the extracellular space .

- An example of animal cells releasing molecules via exocytosis include extracellular matrix protein secretion, neurotransmitter secretion (by neurons), peptide hormone secretion (by endocrine cells), the release of digestive enzymes into the gut, and the elimination of waste products.
- Exocytosis is regulated by a complex interplay of factors, including changes in the **cytosolic calcium concentration**, **enzyme activity** and **interactions with proteins in the membrane.**
- These regulations are critical for ensuring that the proper amount of material is secreted at the appropriate time and place, to maintain cellular homeostasis.

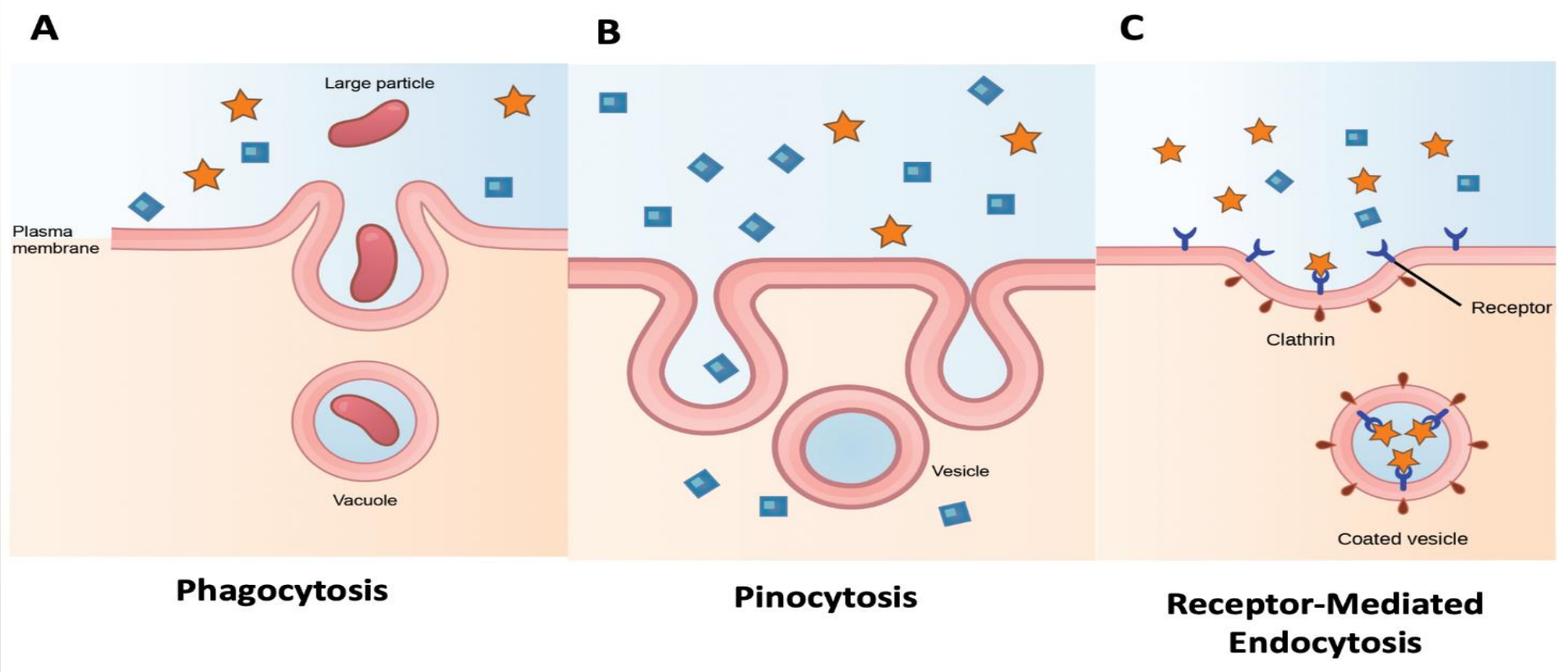
Endocytosis

- **Endocytosis** (“endo” = inside/within) is a type of transport in which a cell takes in materials from its surrounding environment by forming a vesicle or vacuole around those materials. The cell’s membrane invaginates, forming a pocket around the target substance(s). The pocket pinches off, resulting in a newly created intracellular vesicle (sometimes also called a vacuole) formed from the membrane .
- There are several subcategories of endocytosis, including phagocytosis, pinocytosis, and receptor-mediated endocytosis.



During endocytosis the plasma membrane invaginates to form a pocket around one or more extracellular substances (orange circles), the pocket pinches off to create an intracellular vesicle.

- **Phagocytosis**
- **Phagocytosis** (“phago” = eat) involves the internalization of relatively large substances, such as bacteria or debris, by a cell .
- During phagocytosis, the cell extends pseudopodia (finger-like extensions of the membrane) around a substance, which is driven by actin microfilaments of the cytoskeleton .The pseudopodia fuse with each other to form a **phagosome**, a vesicle that encloses the substance. This vesicle is then released from the membrane.
- To digest the engulfed substances, the vesicle must then fuse with a lysosome that contains hydrolytic enzymes that catalyze the degradation of the engulfed substances into smaller components, which can be used by or eliminated from the cell.



*Three subcategories of endocytosis: Phagocytosis, pinocytosis and receptor-mediated endocytosis (**A**) In phagocytosis, the cell membrane surrounds a particle and engulfs it into the cell. (**B**) In pinocytosis, the cell membrane invaginates, surrounds a small volume of fluid, and pinches off. (**C**) In receptor-mediated endocytosis, the cell's uptake of substances targets a single type of substance that binds to the receptor on the cell membrane's external surface.*

- The process of phagocytosis is essential for the immune system of many animals, as it helps to remove pathogens and other foreign particles from living systems. For example, when microorganisms invade the human body, a type of white blood cell, neutrophil, will remove the invaders through this process; surrounding and engulfing the microorganism, which the neutrophil then destroys.
- In addition to its role in the immune system, phagocytosis also plays a role in other cellular processes, such as the internalization of hormones, the removal of dead cells, and the uptake of nutrients. Defects in phagocytosis can result in numerous disorders, including immunodeficiencies and chronic inflammatory diseases.

- **Pinocytosis**

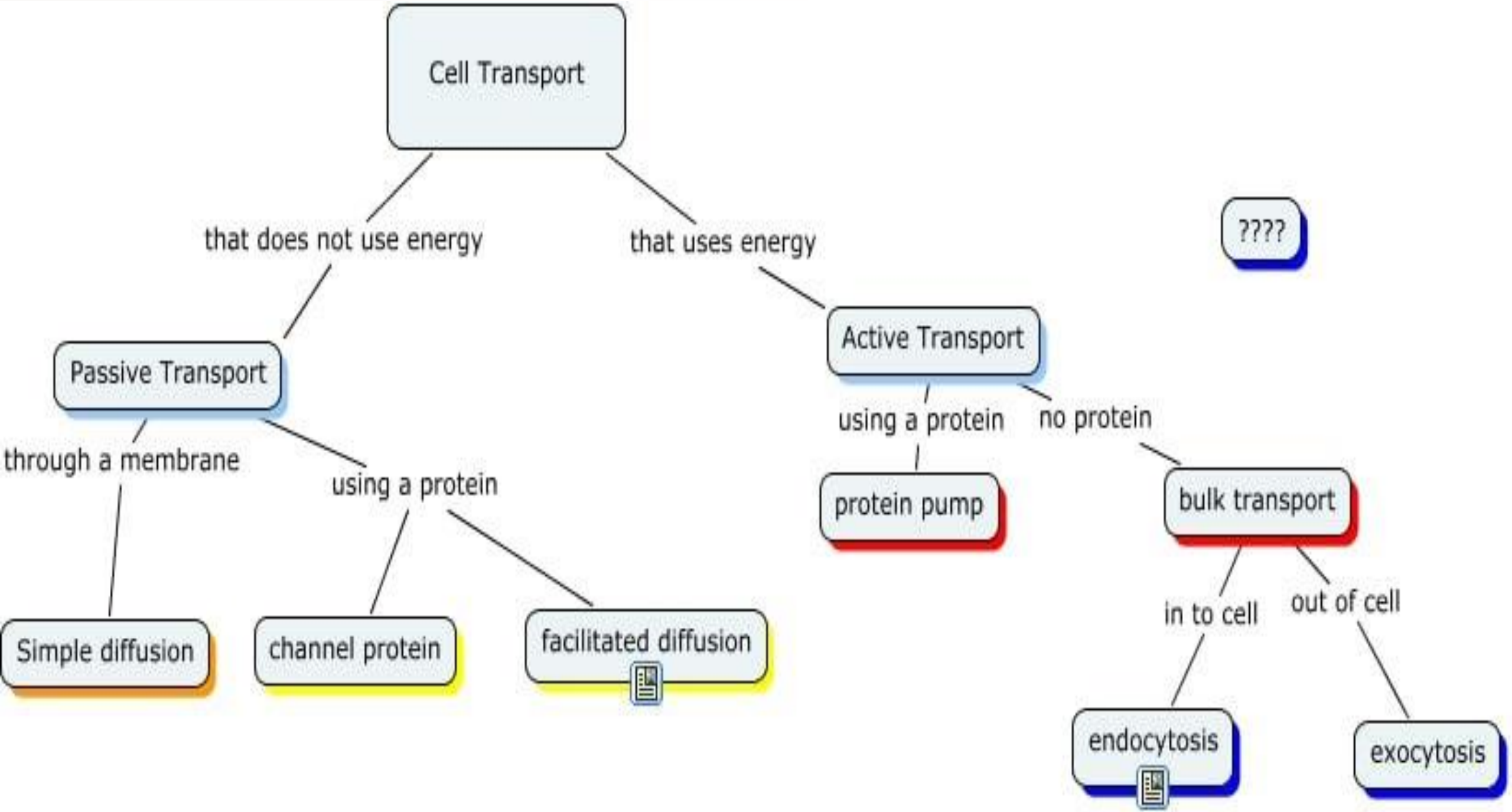
- **Pinocytosis** (“pino” = drink) involves an intake of fluids and whatever solutes are in that fluid, such as components of the extracellular matrix. Pinocytosis results in a much smaller vesicle than phagocytosis, and the vesicle does not need to merge with a lysosome.

- The process of pinocytosis begins with the formation of small invaginations or the membrane. The invaginations pinch off to form small vesicles, called **pinosomes,** which then move into the cytosol and fuse with other intracellular vesicles.

- This mechanism can also be used by some pathogens, like viruses, to enter host cells and establish infections. As a result, the regulation of pinocytosis is critical for maintaining cellular and organismal homeostasis.

- **Receptor-mediated Endocytosis**
- **Receptor-mediated endocytosis** is characterized by the internalization of specific molecules into a cell through the action of receptor proteins in the membrane that have specific binding affinities .In receptor-mediated endocytosis, proteins called clathrin first attach to the membrane's cytoplasmic side.
- The process begins with the binding of a specific ligands, such as a hormone or growth factor, to a specific receptor on the cell surface. The receptor-ligand complex then clusters together with other receptors to form a clathrin-coated invagination which pinches off from the cellular membrane to form a vesicle.

- The vesicle moves into the cytoplasm and fuses with endosomes to form endocytic vesicles, which sort and direct the internalized molecules to their destination within the cell, such as the lysosome for degradation or the nucleus for regulation of gene expression.
- Receptor-mediated endocytosis is also crucial in physiological roles such as hormone regulation, signaling and nutrient uptake.


Cell Transport
that does not use energy
that uses energy
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Passive Transport
Active Transport
through a membrane
using a protein
using a protein
no protein
protein pump
bulk transport
Simple diffusion
channel protein
facilitated diffusion
in to cell
out of cell
endocytosis
exocytosis


Thank you