# University of Baghdad
# College of Medicine
# 2023-2024

**Title: Cell Physiology 1**

**Grade: One**

**Module: HDTD**

**Speaker: Professor Dr. Affan Ezzat Hasan**

**References:**

**1- Guyton and Hall Textbook of Medical Physiology**

**2- Ganong Review of Medical Physiology**

**Objectives:**

**By the end of this lecture the student will be able to:**

- **Describe the basic components of the cell membrane.**
- **Explain the transport process through cell membranes.**
- **Define diffusion and its types.**
- **List the factors that affect the net rate of diffusion.**
- **Define osmosis.**
- **Explain the active transport of substances through membranes.**
- **Give examples on the types of active transport.**

The basic living unit of the body is the cell.

## Membranous Structures of the Cell

Most organelles of the cell are covered by membranes composed primarily of **lipids** and **proteins**.

## The Cell Membrane:

The approximate composition is: proteins 55%; phospholipids 25%; cholesterol 13%; other lipids 4%; and carbohydrates 3%.

Its basic structure is a ***lipid bilayer***

**The Cell Membrane Proteins:**

Two types of proteins occur: ***integral proteins*** that protrude all the way through the membrane and ***peripheral proteins*** that are attached only to one surface of the membrane and do not penetrate all the way through.

***Integral proteins function as:***

(1)structural ***channels*** (or ***pores***)

(2) ***carrier proteins***

(3) ***enzymes*** (catalyze chemical reactions).

(4) ***receptors*** for water-soluble chemicals

**Peripheral protein**

function almost entirely as:

(1) enzymes

(2) controllers of transport of substances through the cell membrane “pores.

## <u>**The Membrane Carbohydrates—The Cell "Glycocalyx."**</u>

Membrane carbohydrates occur in combination with proteins or lipids in the form of ***glycoproteins*** or ***glycolipids***.

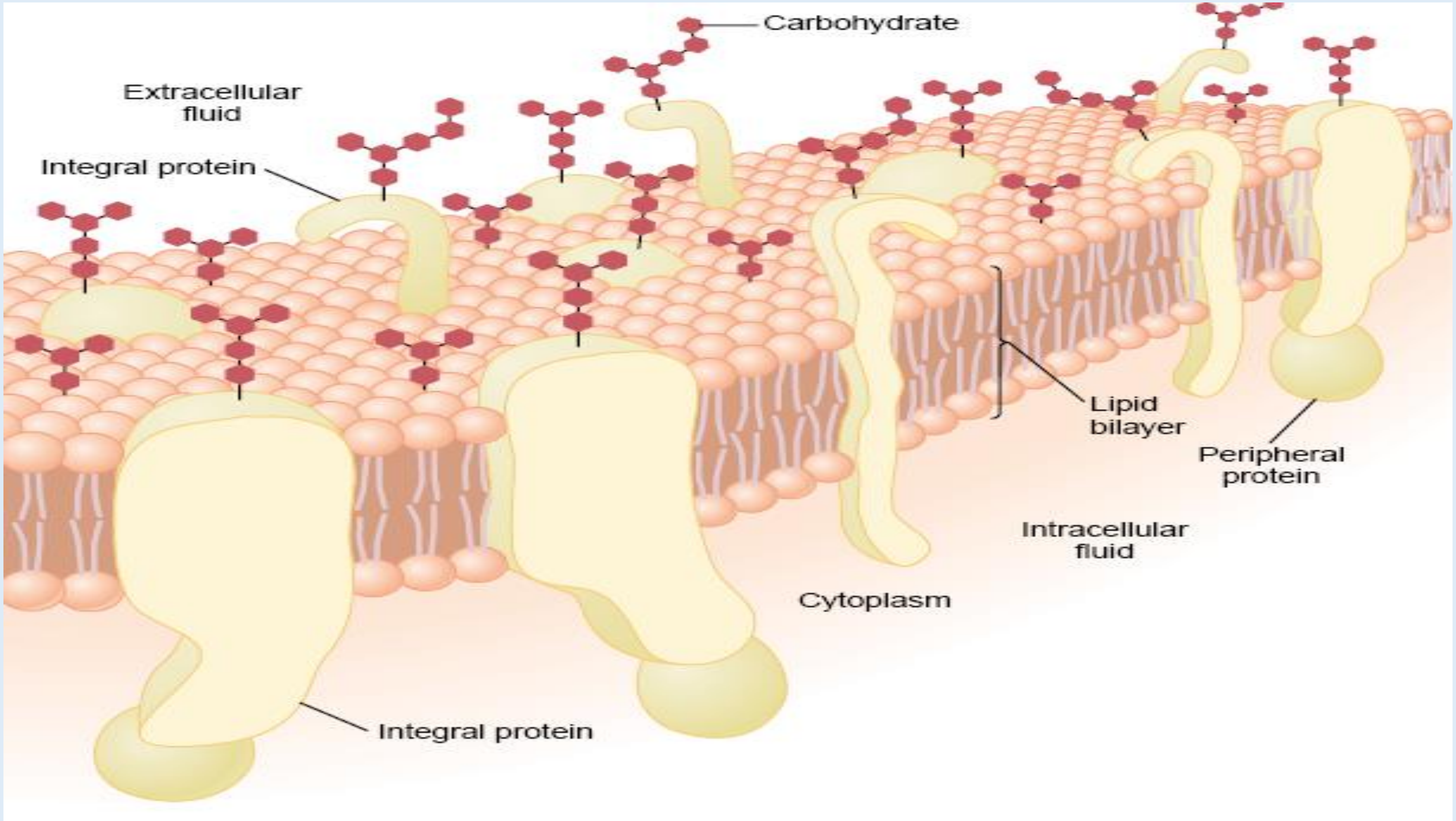
It has several important functions:

(1) Have a negative electrical charge,

(2) The glycocalyx of some cells attaches to the glycocalyx of other cells.

(3) Act as receptor substances for binding hormones.

(4) Some carbohydrate types enter into immune reactions.


Carbohydrate
Extracellular fluid
Integral protein
Lipid bilayer
Peripheral protein
Intracellular fluid
Cytoplasm
Integral protein

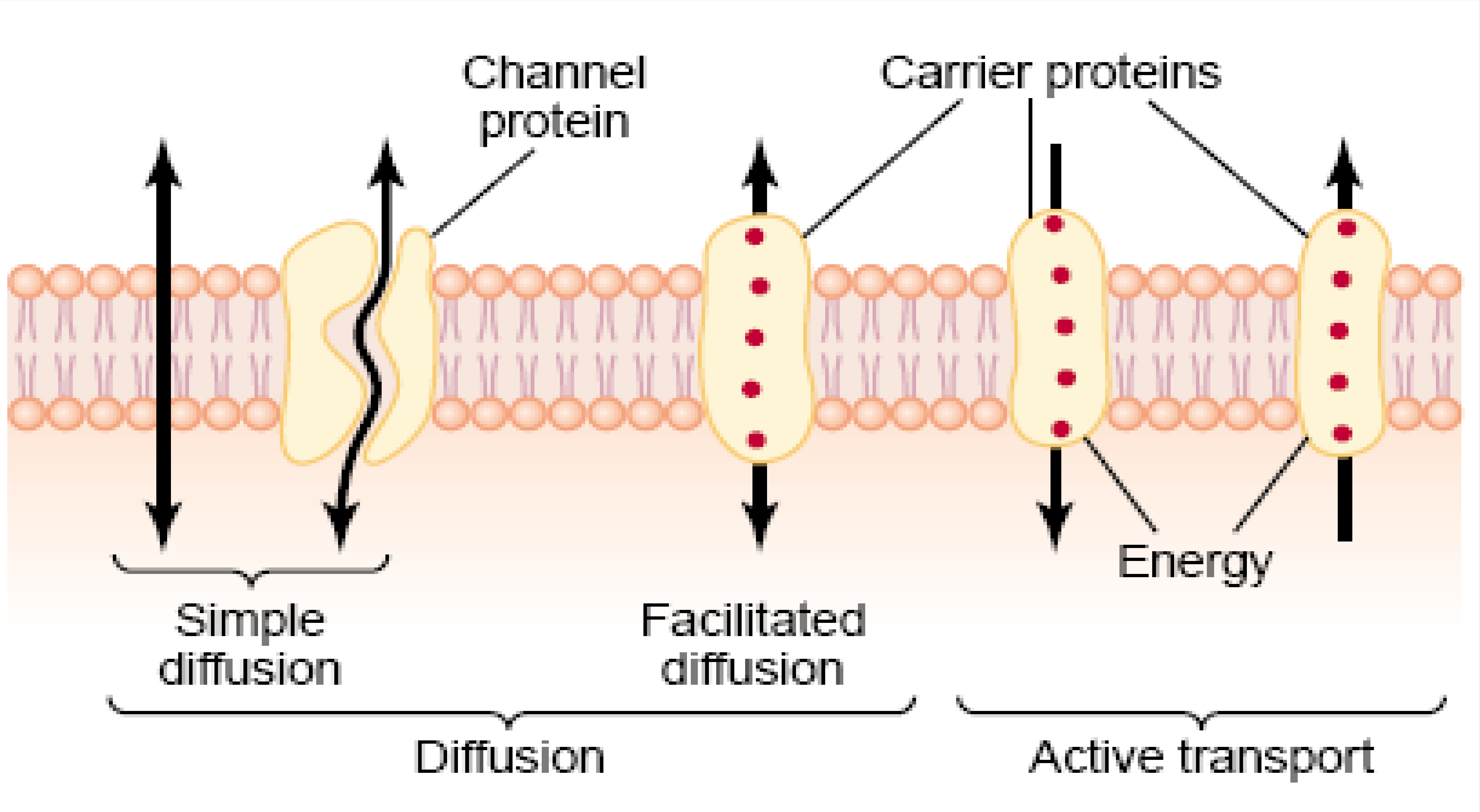
## **Transport through the cell membrane:**

Either directly through the lipid bilayer or through the proteins, occurs by one of two basic processes:

***Diffusion***

means random molecular movement of substances molecule by molecule, either through intermolecular spaces in the membrane or in combination with a carrier protein, the energy that causes diffusion is the energy of the ***normal kinetic motion*** of matter.

***Active transport*** means movement of ions or other substances across the membrane in combination with a carrier protein in such a way that the carrier protein causes the substance to move **against an energy gradient**, such as from a low-concentration state to a high-concentration state, It requires an **additional source of energy** besides kinetic energy.


Channel protein
Carrier proteins
Energy
Simple diffusion
Facilitated diffusion
Diffusion
Active transport

**Diffusion through the Cell Membrane**

Diffusion through the cell membrane is divided into two subtypes called ***simple diffusion*** and ***facilitated diffusion***

Simple diffusion means that kinetic movement of molecules or ions occurs through a membrane opening or through intermolecular spaces without any interaction with carrier proteins in the membrane.

**Diffusion of Lipid-Soluble Substances through the Lipid Bilayer.**

One of the most important factors that determine how rapidly a substance diffuses through the lipid bilayer is the **lipid solubility** of the substance. For example, the lipid solubilities of oxygen, nitrogen, carbon dioxide, and alcohols are high, so that all these can dissolve directly in the lipid bilayer and diffuse through the cell membrane

**Diffusion of Water and Other Lipid-Insoluble Molecules through Protein Channels.**

Water readily passes through channels in protein molecules that penetrate all the way through the membrane. Other lipid-insoluble molecules can pass through the protein pore channels in the same way as water molecules if they are **water soluble and small enough**

## **Diffusion Through Protein Channels, and “Gating” of These Channels**

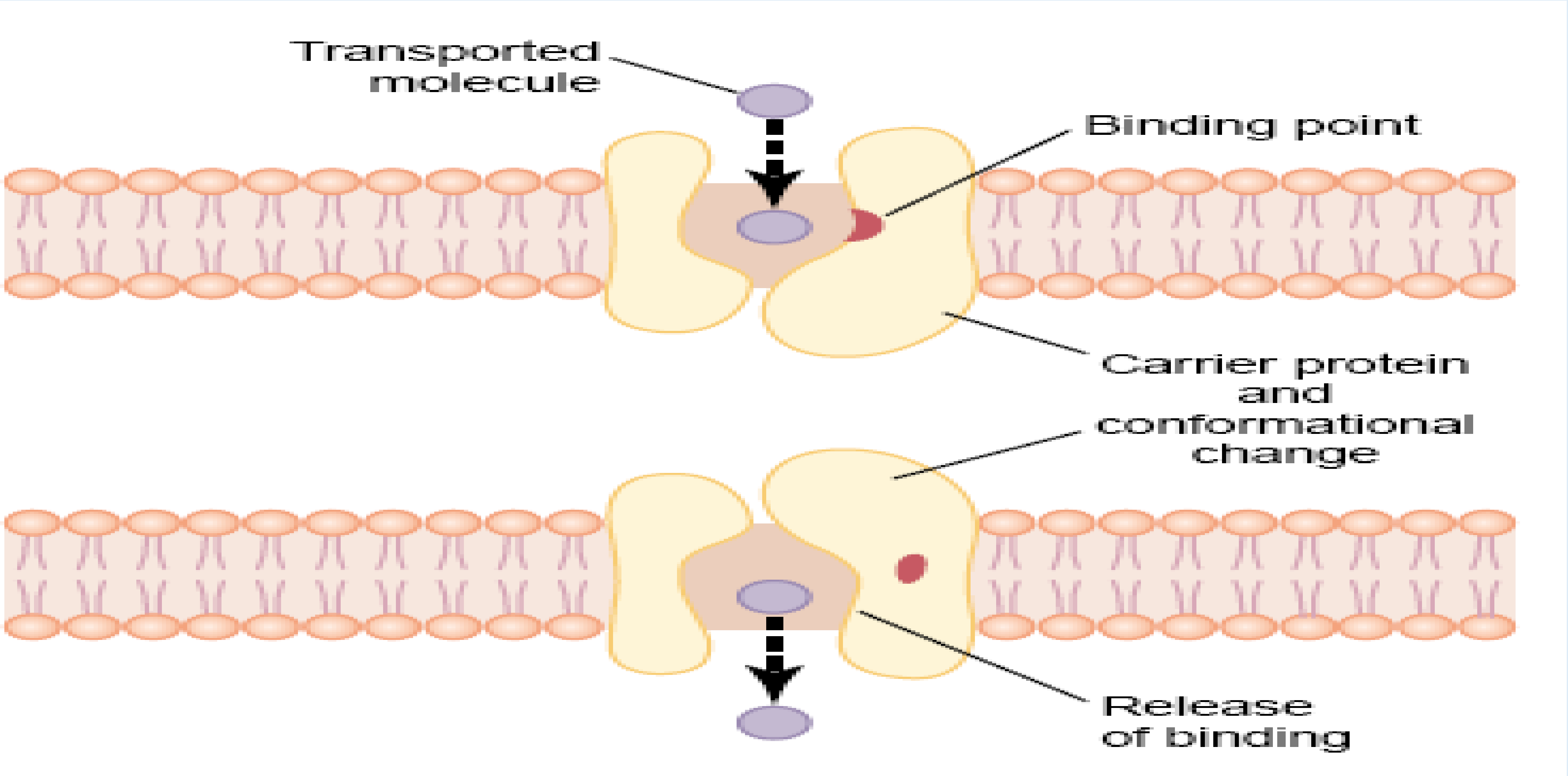
The protein channels are distinguished by two important characteristics:

(1) they are often ***selectively permeable*** to certain substances, and

(2) many of the channels can be ***opened or closed by gates***.

**Facilitated Diffusion**.

Also called ***carrier-mediated diffusion,*** requires interaction of a carrier protein. The carrier protein aids passage of the molecules or ions through the membrane by binding chemically with them and shuttling them through the membrane.



## Factors That Affect the Net Rate of Diffusion

What is usually important is the ***net*** rate of diffusion of a substance in the desired direction. This net rate is determined by several factors.

(1)**Effect of Concentration Difference on Net Diffusion through a Membrane.**

The rate at which the substance diffuses *inward* is proportional to the concentration of molecules on the *outside*, because this concentration determines how many molecules strike the outside of the membrane each second .

Net diffusion μ (Co - Ci)

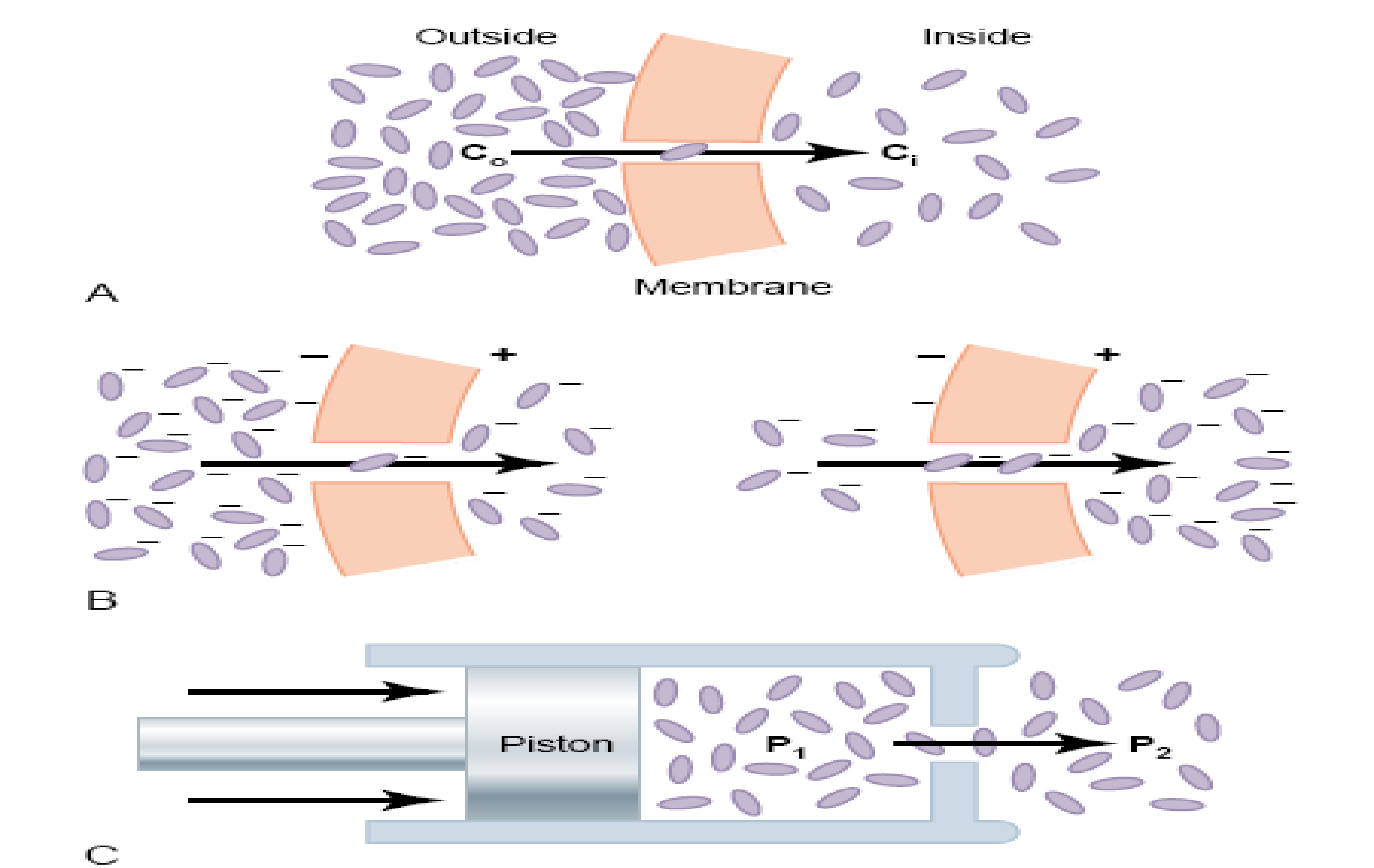
in which Co is concentration outside and Ci is concentration inside.

**(2)Effect of Membrane Electrical Potential on Diffusion of Ions—The "Nernst Potential."** If an electrical potential is applied across the membrane, the electrical charges of the ions cause them to move through the membrane even though no concentration difference exists to cause movement. At normal body temperature (37°C), the electrical difference that will balance a given concentration difference of *univalent* ions—such as sodium (Na+) ions—can be determined from the following formula, called the *Nernst equation:*

$$\text{EMF (in millivolts)} = \pm 61 \log \frac{C_1}{C_2}$$

**(3)Effect of a Pressure Difference across the Membrane**

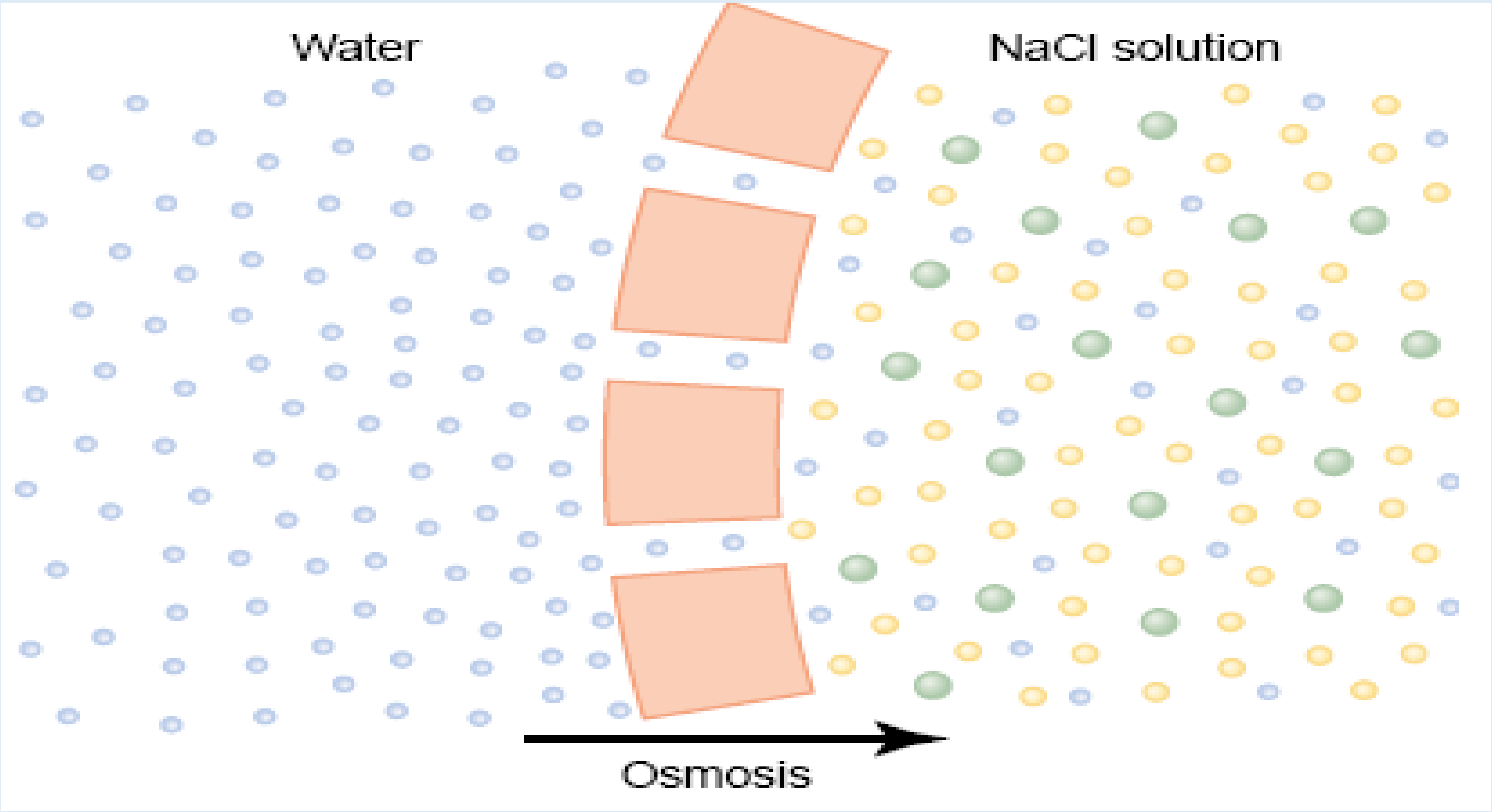
Pressure means the sum of all the forces of the different molecules striking a unit surface area at a given instant. Therefore, when the pressure is higher on one side of a membrane than on the other, this means that the sum of all the forces of the molecules striking the channels on that side of the membrane is greater than on the other side. The result is that increased amounts of energy are available to cause ***net movement of molecules from the high-pressure side toward the low-pressure side.***



Outside
Inside
$C_o$
$C_i$
Membrane
A
B
C
Piston
$P_1$
$P_2$

# Osmosis Across Selectively Permeable Membranes— “Net Diffusion” of Water

***net movement of water caused by a concentration difference of water***



# “Active Transport” of Substances Through Membranes

Active transport is divided into two types according to the source of the energy used to cause the transport:
***primary active transport*** and ***secondary active transport***

In ***primary active transport***, the energy is derived directly from breakdown of adenosine triphosphate (ATP) or of some other high-energy phosphate compound.
In ***secondary active transport,*** the energy is derived secondarily from energy that has been stored in the form of ionic concentration differences of secondary molecular or ionic substances between the two sides of a cell membrane, created originally by primary active transport.

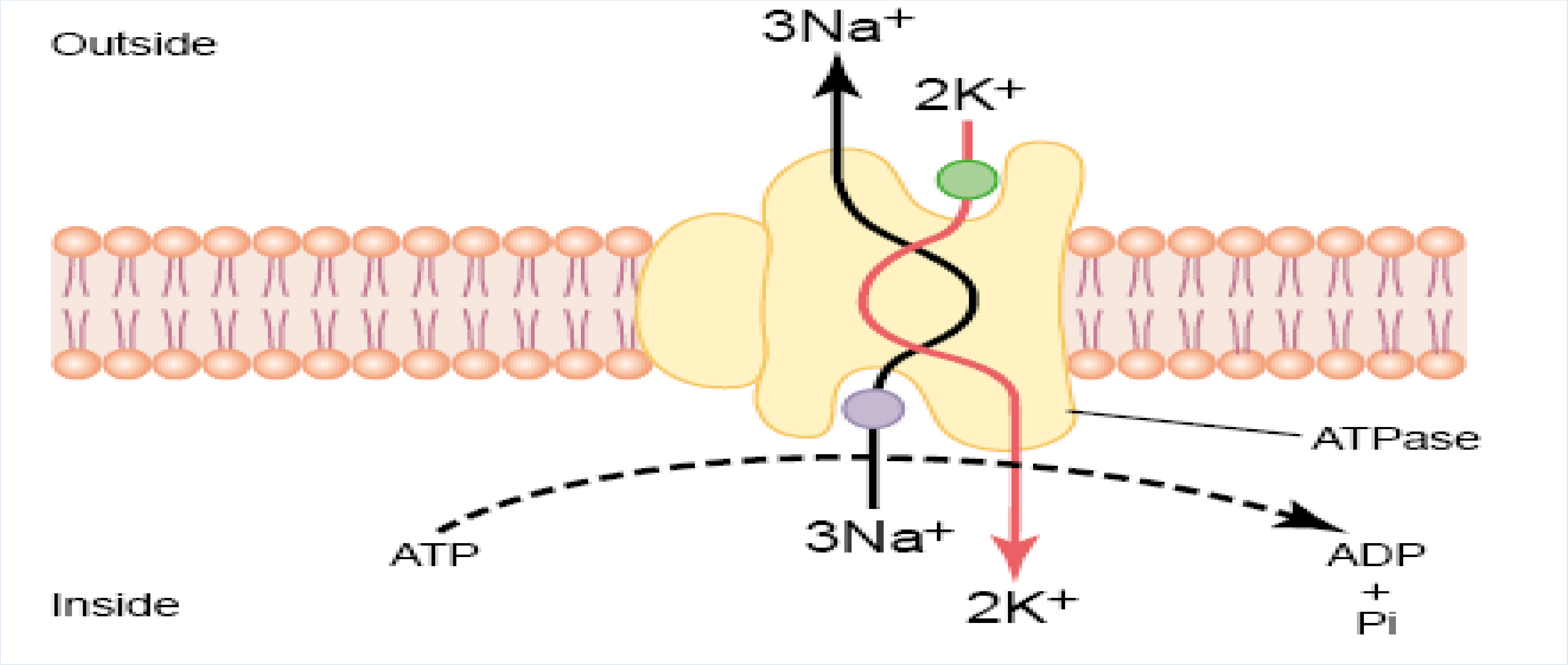
***The carrier protein in active transport is capable of imparting energy to the transported substance to move it against the electrochemical gradient***.

**Sodium-Potassium Pump as an example of Primary Active Transport:**

**1.** It has three ***receptor sites for binding sodium ions*** on the portion of the protein that protrudes to the inside of the cell.

**2.** It has two ***receptor sites for potassium ions*** on the outside.

**3.** The inside portion of this protein near the sodium binding sites has ***ATPase activity***.




**Electrogenic Nature of the Na+-K+ Pump**

It creates an electrical potential across the cell membrane. This electrical potential is a basic requirement in nerve and muscle fibers for transmitting nerve and muscle signals.

## Secondary Active Transport:

## Co-Transport and Counter-Transport

When sodium ions are transported out of cells by primary active transport, a large concentration gradient of sodium ions across the cell membrane usually develops—high concentration outside the cell and very low concentration inside. This gradient represents a storehouse of energy because the excess sodium outside the cell membrane is always attempting to diffuse to the interior.

Under appropriate conditions, this diffusion energy of sodium can pull other substances along with the sodium through the cell membrane. This phenomenon is called ***co-transport****;* it is one form of ***secondary active transport.***

In ***counter-transport,***

the sodium ion binds to the carrier protein where it projects to the exterior surface of the membrane, while the substance to be counter-transported binds to the interior projection of the carrier protein. Once both have bound, a conformational change occurs, and energy released by the sodium ion moving to the interior causes the other substance to move to the exterior.

**Co-Transport of Glucose and Amino Acids Along with Sodium Ions**

Sodium co-transport of glucose and amino acids occurs especially through the epithelial cells of the intestinal tract and the renal tubules of the kidneys to promote absorption of these substances into the blood.