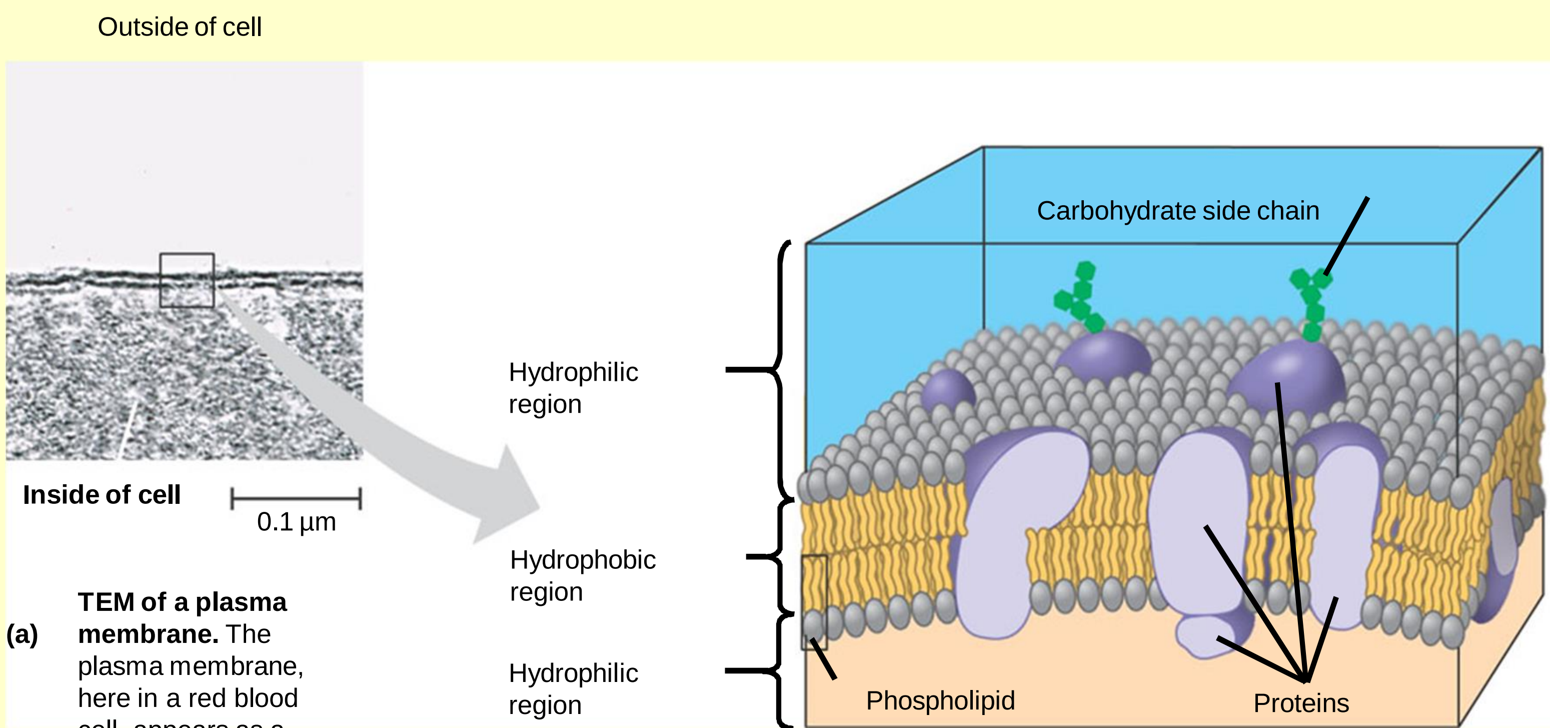
Lecture- 01

Plasma membrane and its physical aspects

The plasma membrane

- Functions as a selective barrier
- Allows sufficient passage of nutrients and waste



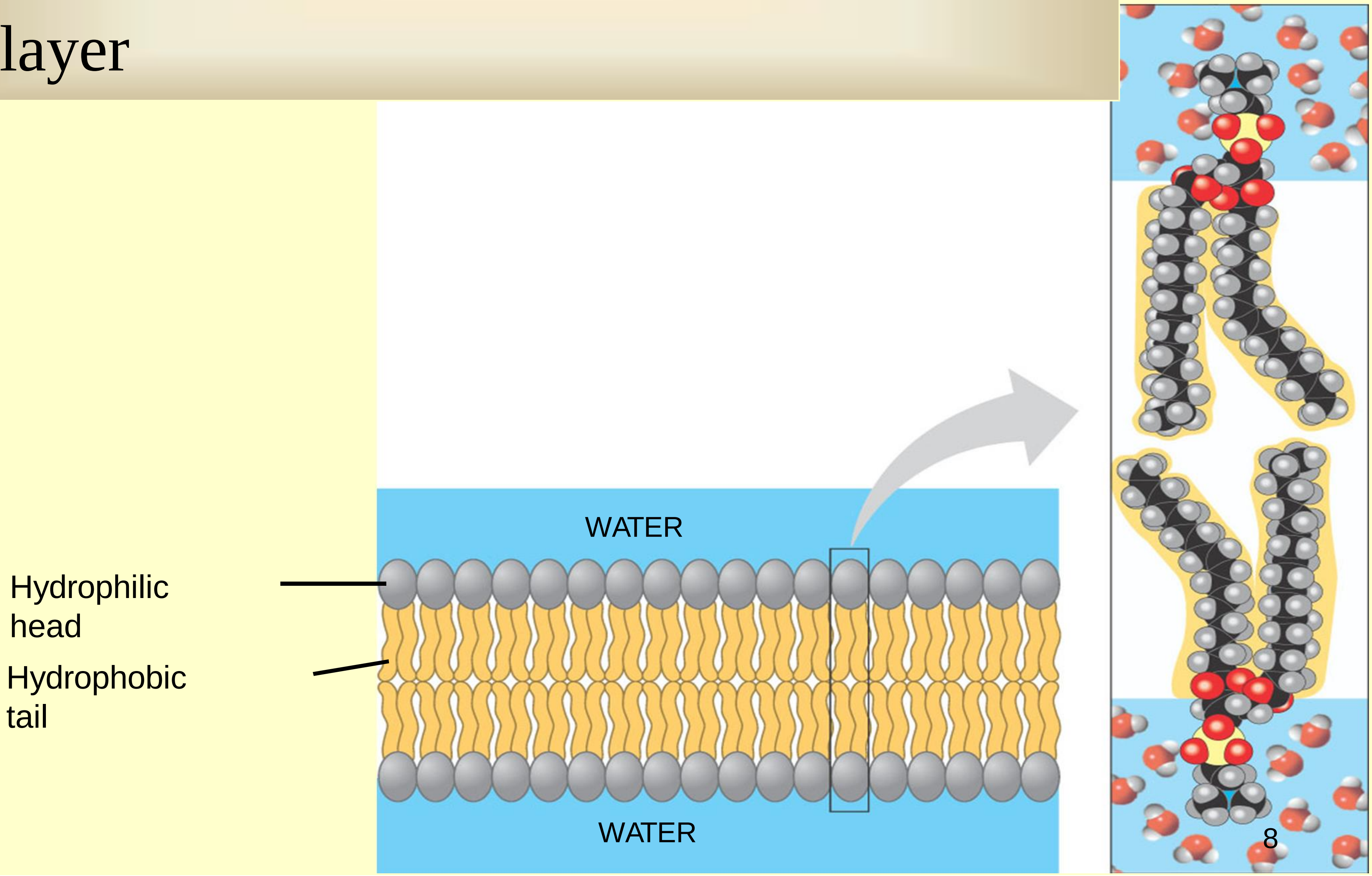
(a) **TEM of a plasma membrane.** The plasma membrane, here in a red blood cell, appears as a pair of dark bands separated by a light band.

(b) Structure of the plasma membrane

Membrane Models: *Scientific Inquiry*

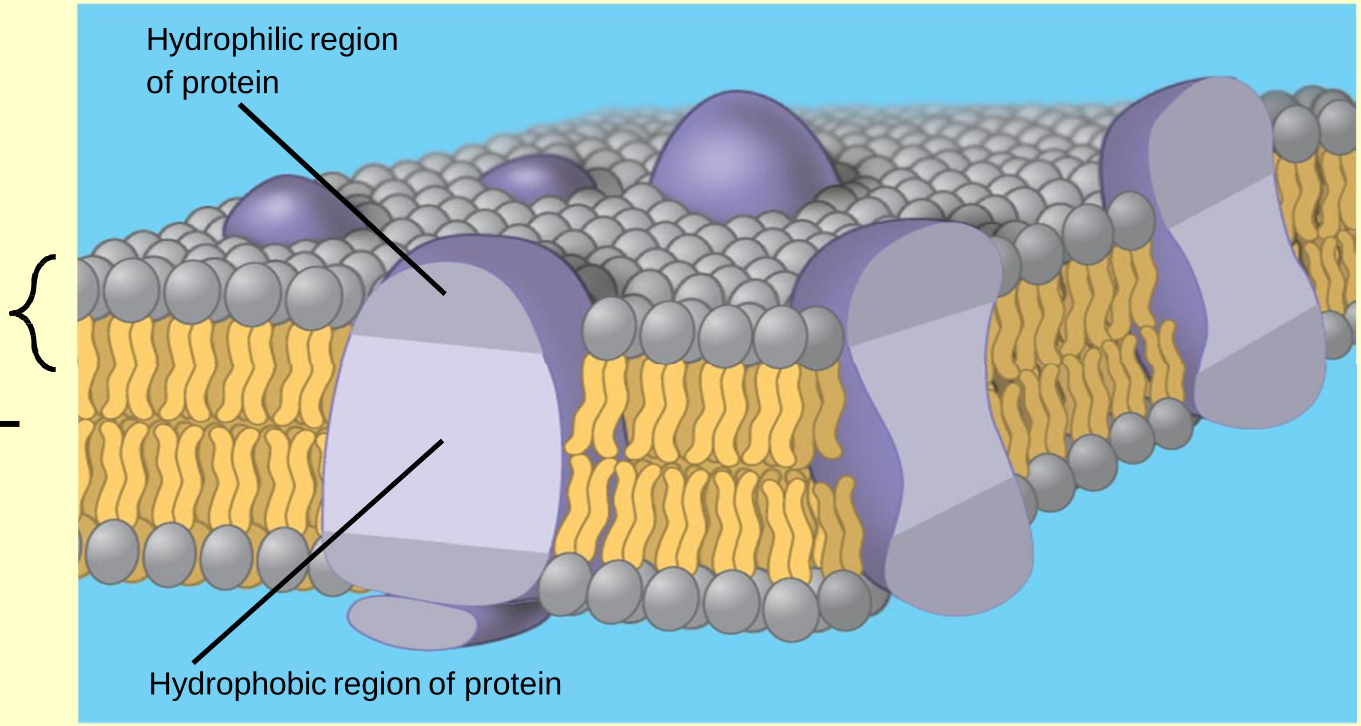
- The fluid mosaic model of membrane structure
  - States that a membrane is a fluid structure with a "mosaic" of various proteins embedded in it
- Membranes have been chemically analyzed
  - And found to be composed of proteins and lipids
- Phospholipids
  - Are the most abundant lipid in the plasma membrane
  - Are amphipathic, containing both hydrophobic and hydrophilic regions

- Scientists studying the plasma membrane Reasoned that it must be a phospholipid bilayer



- The Davson-Danielli sandwich model of membrane structure
  - Stated that the membrane was made up of a phospho-lipid bi-layer sandwiched between two protein layers
  - Was supported by electron microscope pictures of membranes
- In 1972, Singer and Nicolson
  - Proposed that membrane proteins are dispersed and individually inserted into the phospho-lipid bi-layer

Phospholipid
bilayer



Freeze-fracture studies of the plasma membrane

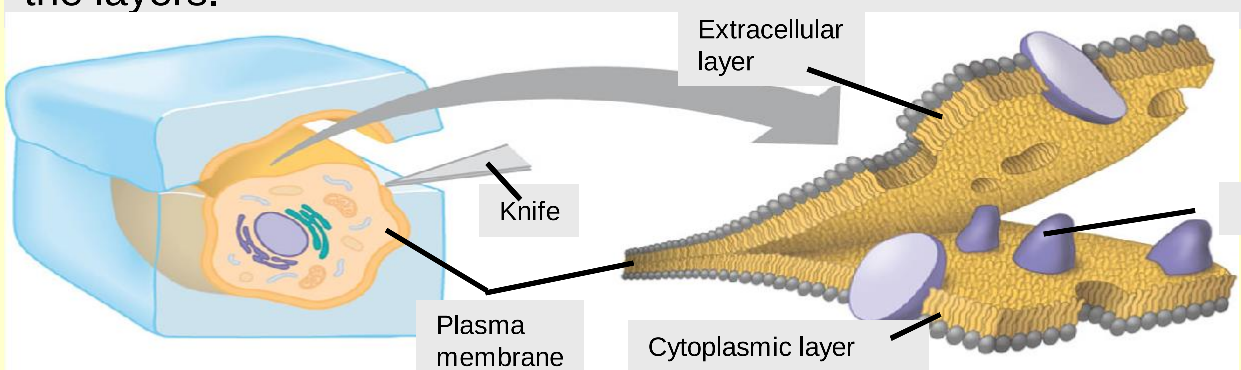
- Supported the fluid mosaic model of membrane structure

APPLICATION

A cell membrane can be split into its two layers, revealing the ultrastructure of the membrane's interior.

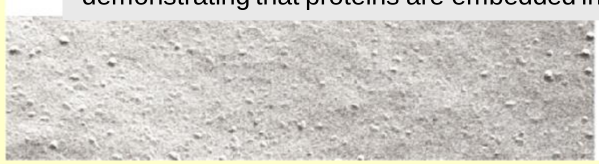
TECHNIQUE

A cell is frozen and fractured with a knife. The fracture plane often follows the hydrophobic interior of a membrane, splitting the phospholipid bilayer into two separated layers. The membrane proteins go wholly with one of the layers.



RESULTS

These SEMs show membrane proteins (the "bumps") in the two layers, demonstrating that proteins are embedded in the phospholipid bilayer.

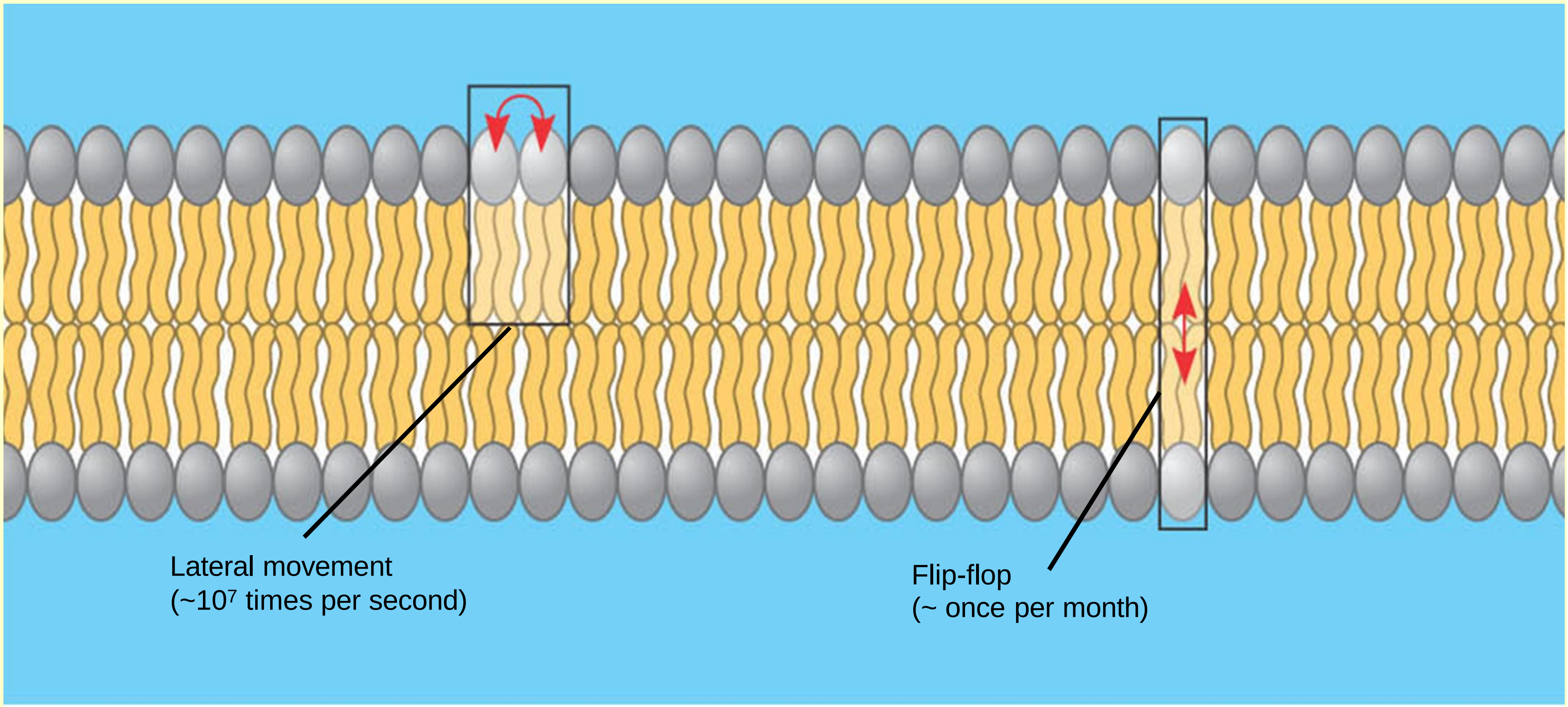


Extracellular layer

Cytoplasmic layer

The Fluidity of Membranes

- Phospholipids in the plasma membrane
  - Can move within the bi-layer



(a) Movement of phospholipids

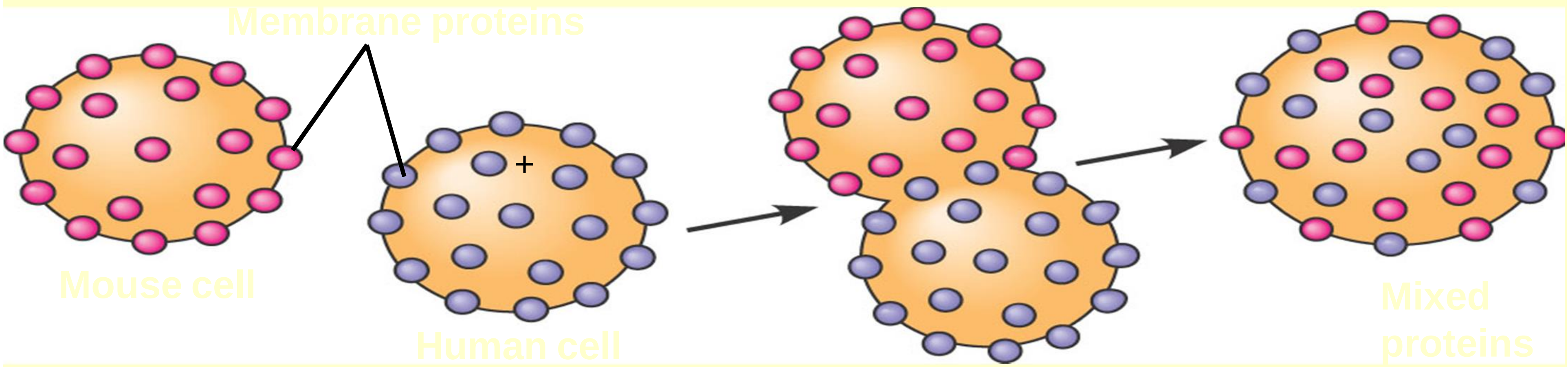
Proteins in the plasma membrane

– Can drift within the bi-layer

EXPERIMENT

Researchers labeled the plasma mambrane proteins of a mouse cell and a human cell with two different markers and fused the cells. Using a microscope, they observed the markers on the hybrid cell.

RESULTS



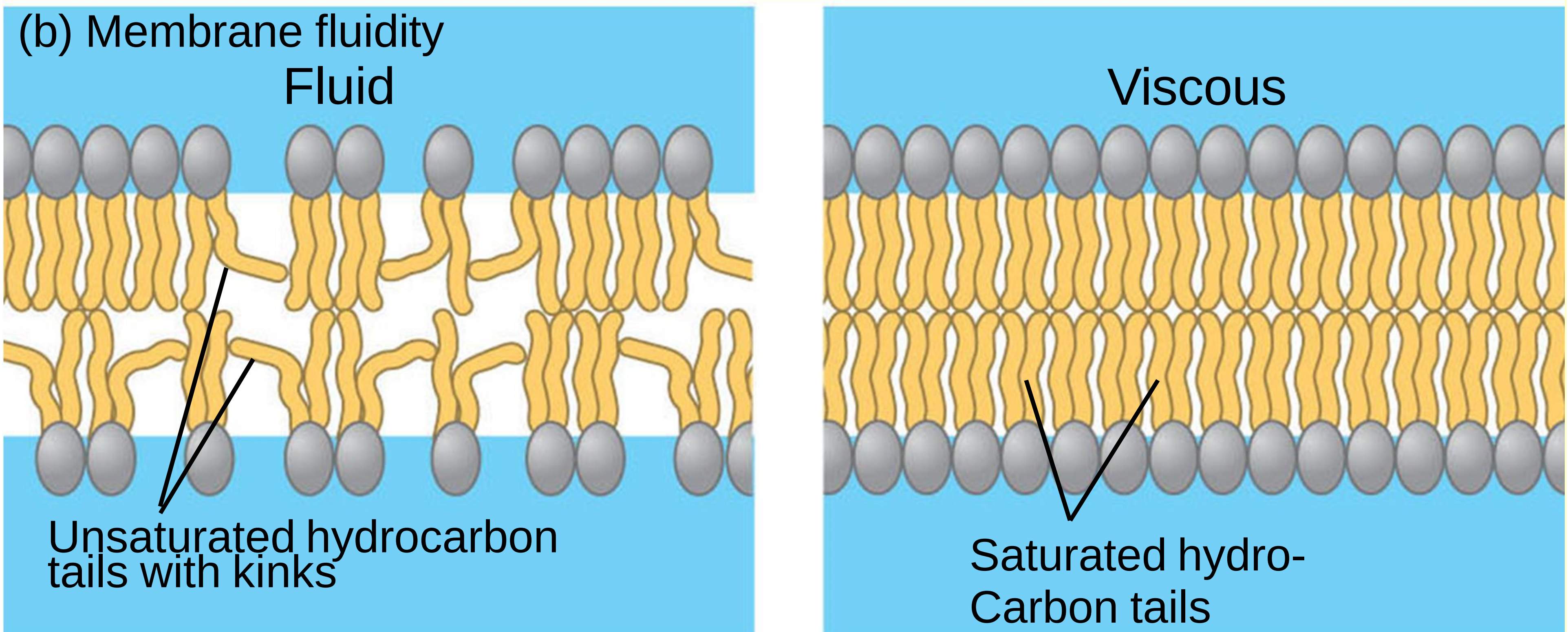
Hybrid cell

after 1 hour

CONCLUSION

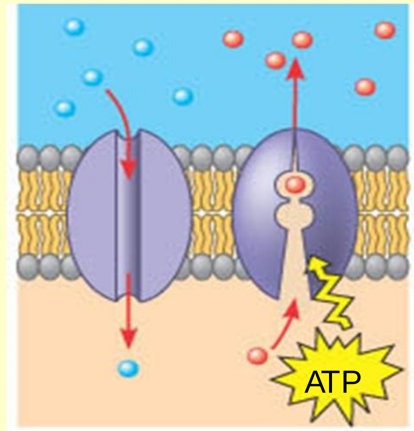
The mixing of the mouse and human membrane proteins indicates that at least some membrain proteins move sideways within the plane of the plasma membrane.

- The type of hydrocarbon tails in phospholipids
  - Affects the fluidity of the plasma membrane

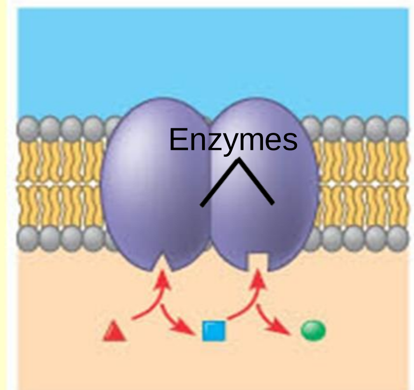


An overview of six major functions of membrane proteins

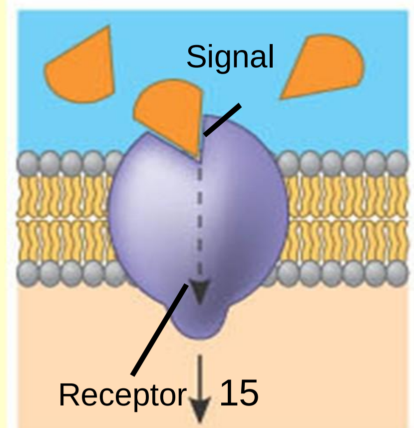
(a) **Transport**. (left) A protein that spans the membrane may provide a hydrophilic channel across the membrane that is selective for a particular solute. (right) Other transport proteins shuttle a substance from one side to the other by changing shape. Some of these proteins hydrolyze ATP as an energy source to actively pump substances across the membrane.



(b) **Enzymatic activity**. A protein built into the membrane may be an enzyme with its active site exposed to substances in the adjacent solution. In some cases, several enzymes in a membrane are organized as a team that carries out sequential steps of a metabolic pathway.



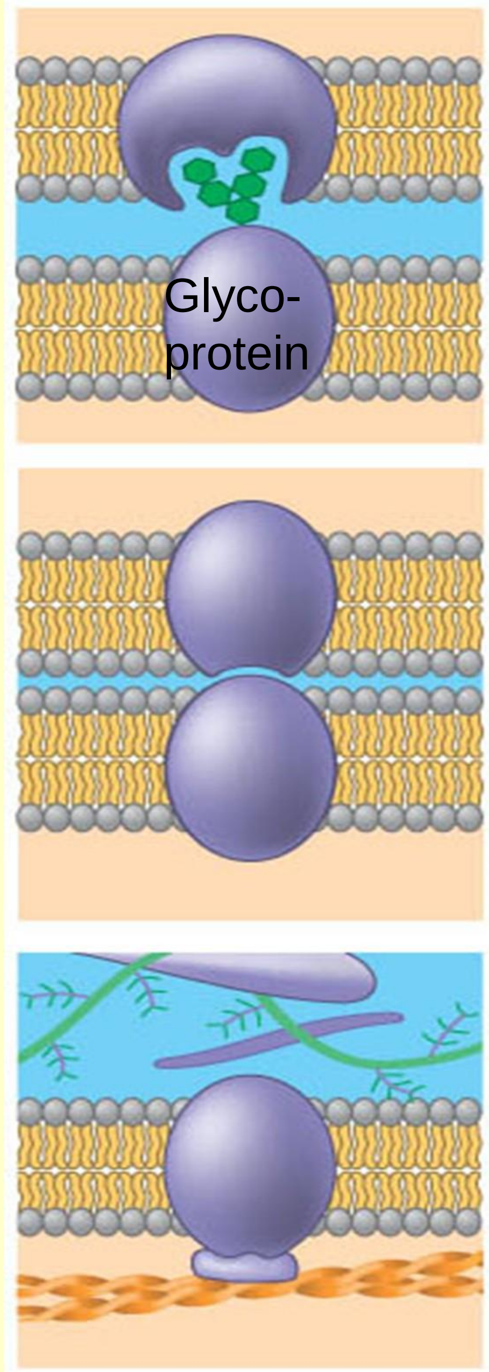
(c) **Signal transduction**. A membrane protein may have a binding site with a specific shape that fits the shape of a chemical messenger, such as a hormone. The external messenger (signal) may cause a conformational change in the protein (receptor) that relays the message to the inside of the cell.



(d) Cell-cell recognition. Some glyco-proteins serve as identification tags that are specifically recognized by other cells.

(e) Intercellular joining. Membrane proteins of adjacent cells may hook together in various kinds of junctions, such as gap junctions or tight junctions

(f) Attachment to the cytoskeleton and extracellular matrix (ECM). Microfilaments or other elements of the cytoskeleton may be bonded to membrane proteins, a function that helps maintain cell shape and stabilizes the location of certain membrane proteins. Proteins that adhere to the ECM can coordinate extracellular and intracellular changes



The Permeability of the Lipid Bilayer

Membrane structure results in selective permeability

- Hydrophobic molecules
  - Are lipid soluble and can pass through the membrane rapidly
- Polar molecules
  - Do not cross the membrane rapidly

Cell Membrane Transport

Factors affecting transport

- Cell membrane
- Chemical gradient
- Electrical gradient
- Rate of transport

Types

Passive transport

- Diffusion
- Osmosis
- Facilitated diffusion

Active transport

- Pumps
- phagocytosis
- Endocytosis/exocytosis

- The membrane is permeable to:

- H_2O
- Gases (O_2, CO_2, N_2)
- Lipids
- Small, neutral molecules (such as urea)

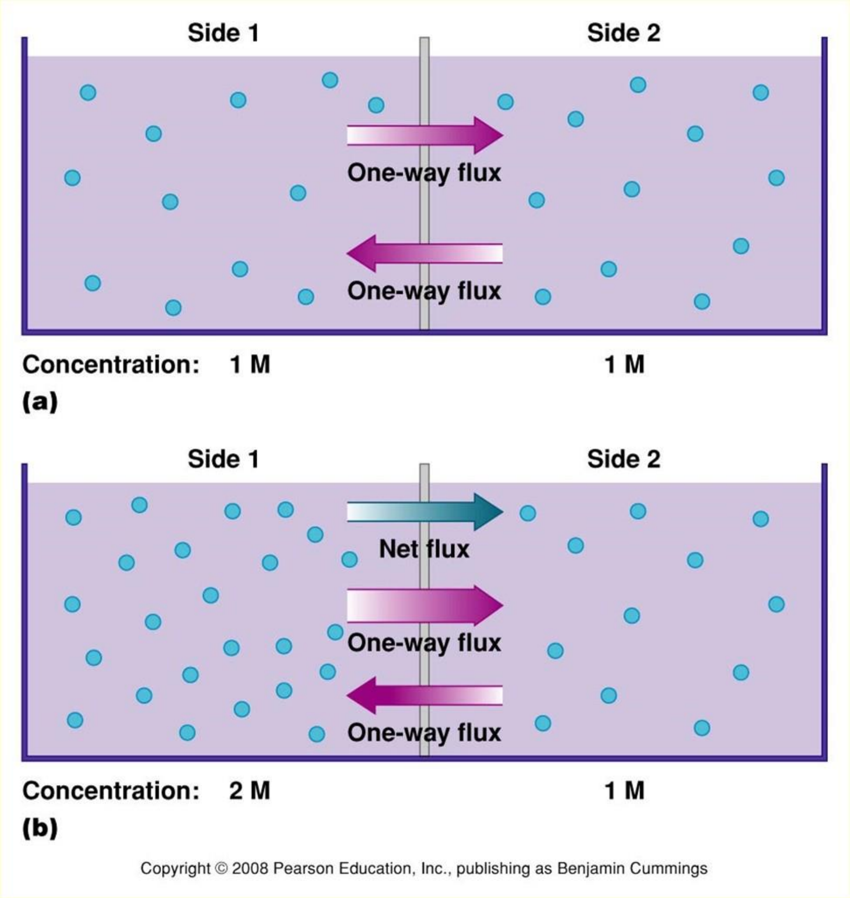
- The membrane is impermeable to:

- Small, charged molecules
- "large molecules" such as amino acids, glucose and larger

→ these compounds must go through channels present in the membrane in order to enter or exit the cell

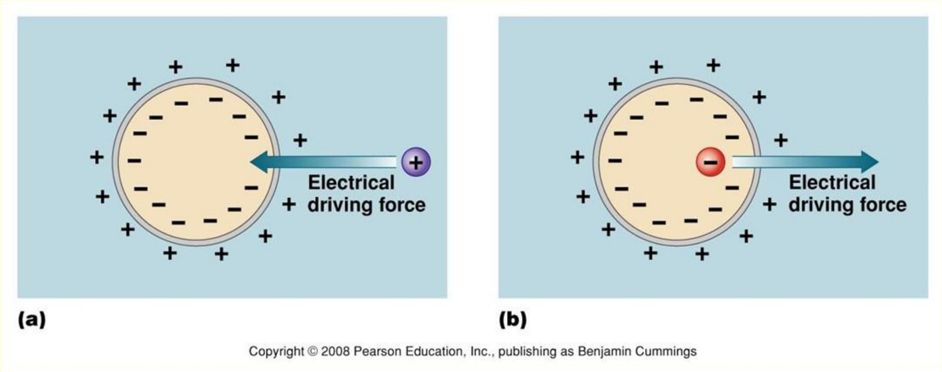
Factors affecting transport: Chemical gradient

- Compound moves from an area of high concentration to low concentration (or concentration gradient)
- All compounds permeable to the phospholipid bilayer will move this way



Factors affecting transport: Electrical force

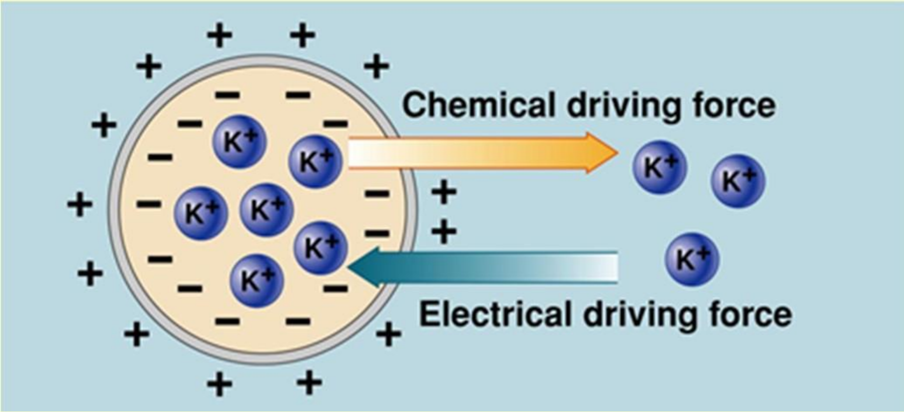
- Positive ions are attracted to negative ions and vice versa



- Ions are repelled by ions of the same charge (+ against + and – against -)

Movement across the cell membrane

- Both chemical and electrical forces (electrochemical force) drive the movement of compounds across the cell membrane



Factors affecting the rate of transport

- The rate of transport will depend on:
  - the concentration gradient
  - the compound permeability to the membrane
  - the type and number of charges present on the compound

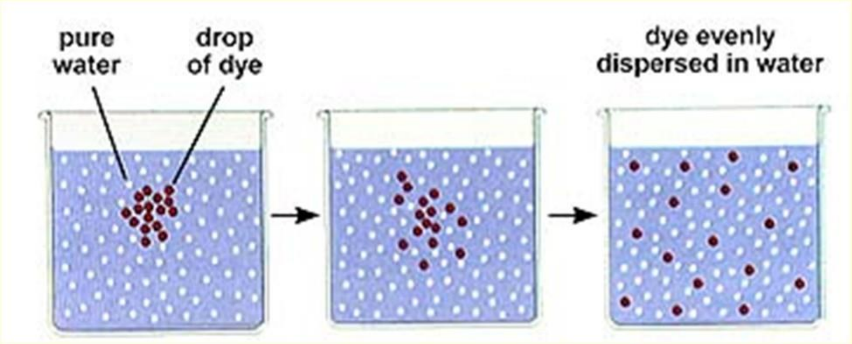
Passive transport

- Compounds will move from area of high concentration toward area of lower concentration
- No ATP is needed for this type of transport

Diffusion

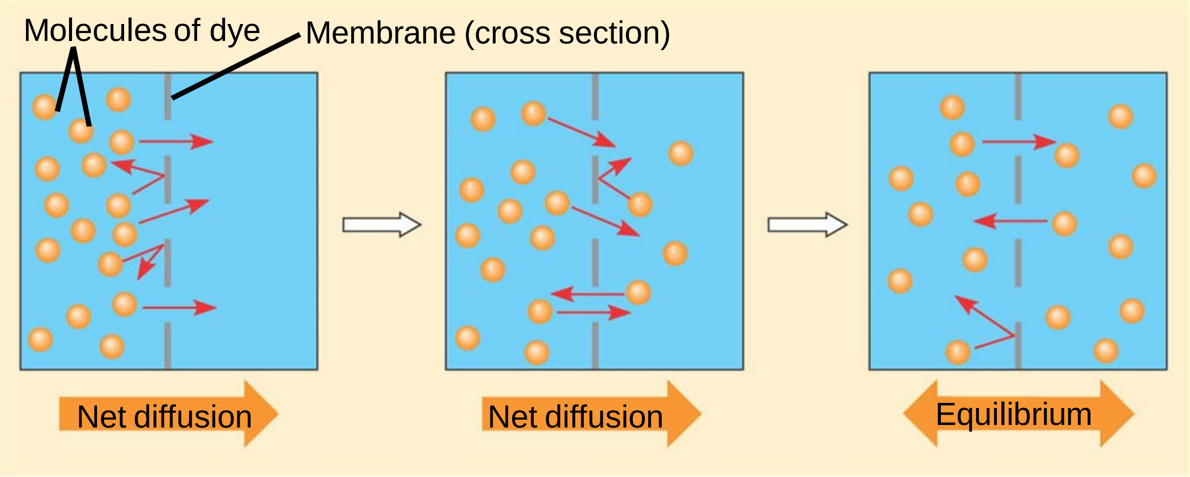
Is the tendency for molecules of any substance to spread out evenly into the available space

- Compounds move toward the area of lower concentration
- Compounds permeable to the cell membrane will move through diffusion. (Compounds unable to pass through the membrane will only pass if membrane channels open)

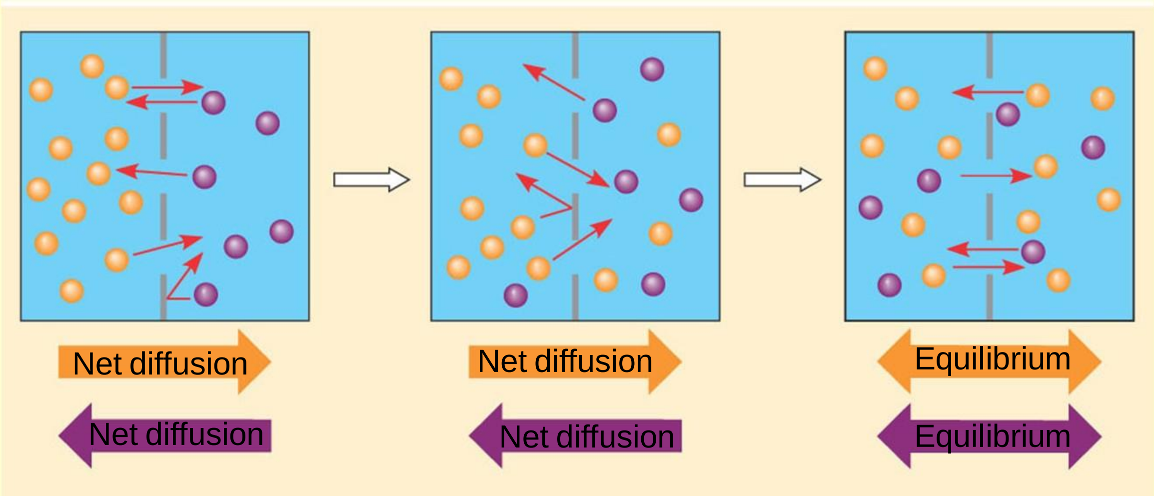


Diffusion

A) Diffusion of one solute. The membrane has pores large enough for molecules of dye to pass through. Random movement of dye molecules will cause some to pass through the pores; this will happen more often on the side with more molecules. The dye diffuses from where it is more concentrated to where it is less concentrated (called diffusing down a concentration gradient). This leads to a dynamic equilibrium: The solute molecules continue to cross the membrane, but at equal rates in both directions.



B) Diffusion of two solutes. Solutions of two different dyes are separated by a membrane that is permeable to both. Each dye diffuses down its own concentration gradient. There will be a net diffusion of the purple dye toward the left, even though the *total* solute concentration was initially greater on the left side.

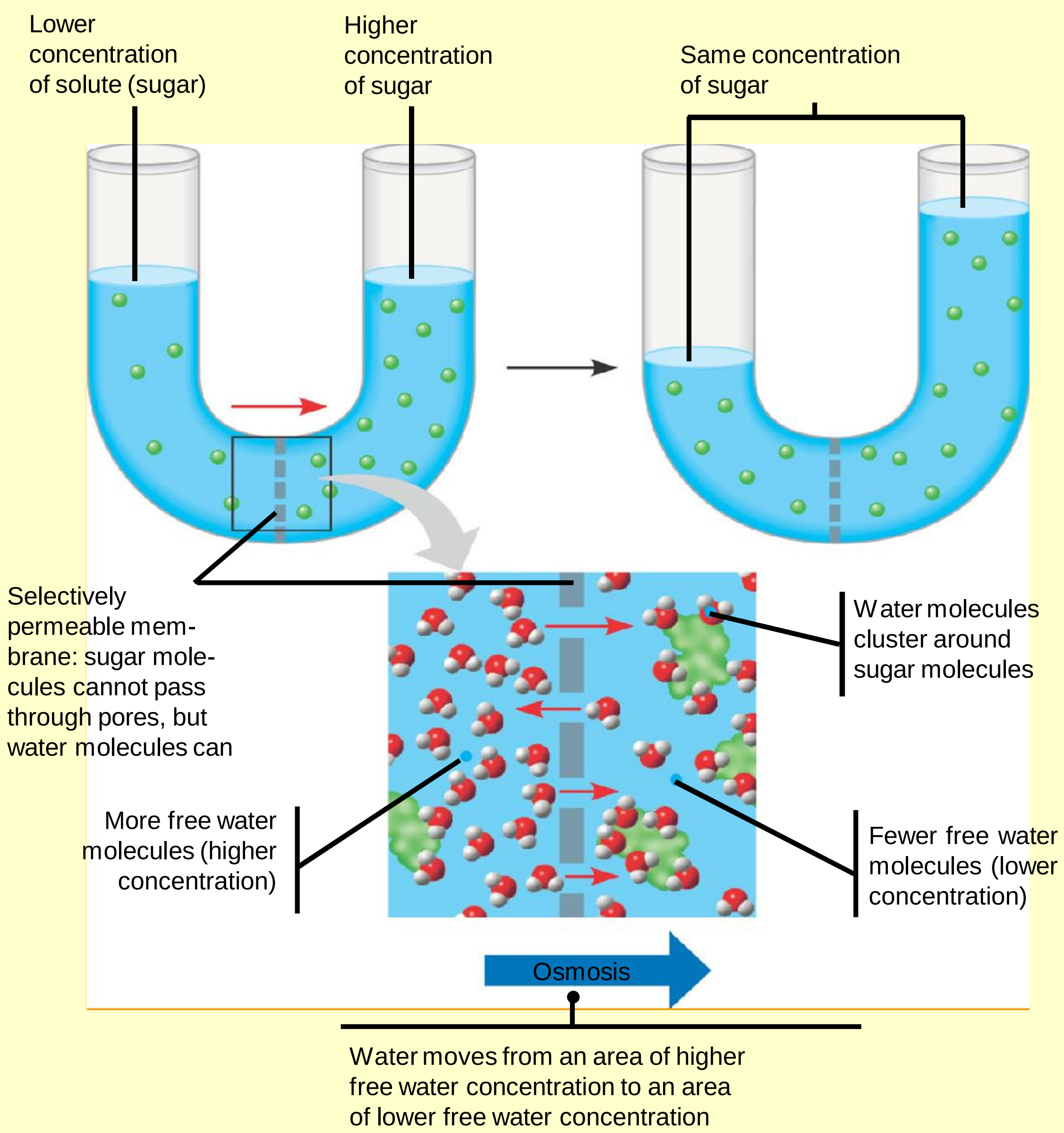


Osmosis

Osmosis is the movement of water across a semipermeable membrane

- Each compound obeys the law of diffusion
- However, some compounds are unable to cross the cell membrane (glucose, electrolytes…)
- Water can cross → will enter or exit the cell depending its concentration gradient
- Note: the cell membrane is a semipermeable membrane

– Is affected by the concentration gradient of dissolved substances

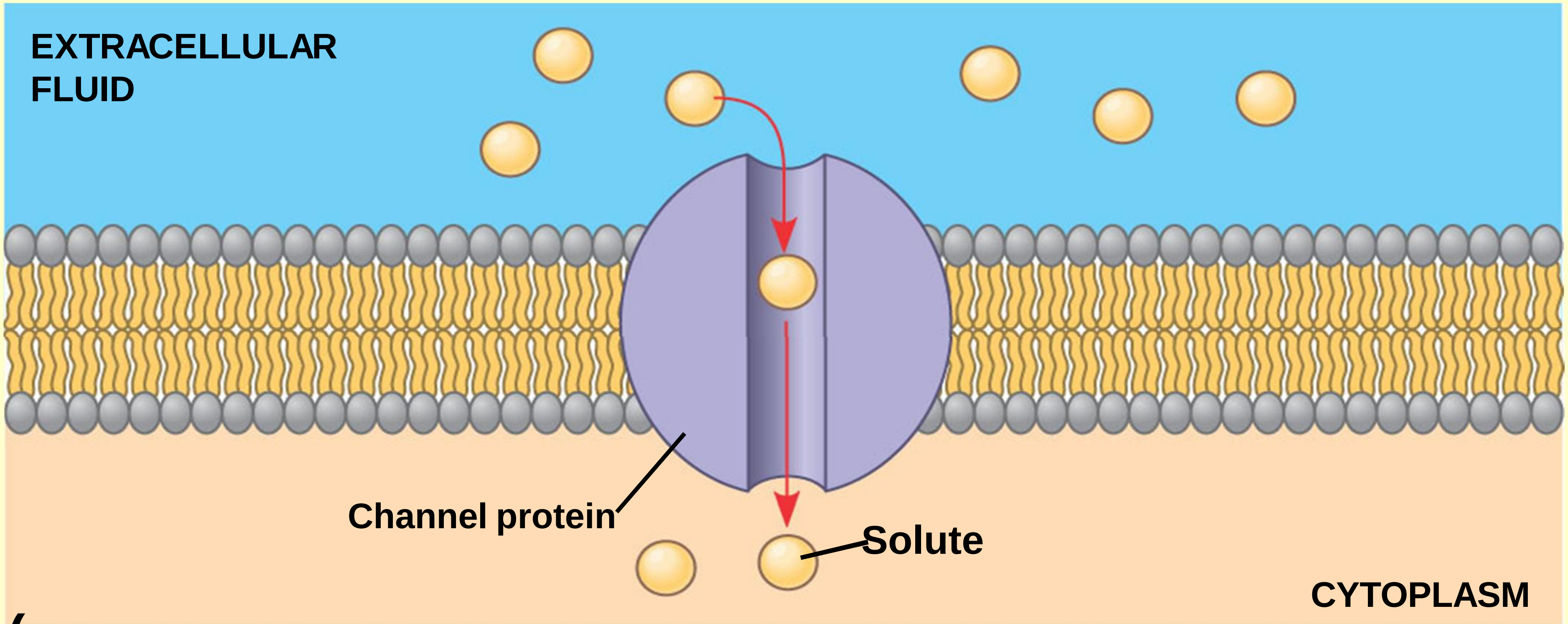


Facilitated Diffusion: Passive Transport Aided by Proteins

- Some compounds are unable to diffuse through the membrane.
- They will be allowed to cross if the membrane has proteins that can bind these compounds and enable to cross toward the area of lower concentration. These type of proteins are **Transport proteins.**
- In facilitated diffusion
  - **Transport proteins** speed the movement of molecules across the plasma membrane

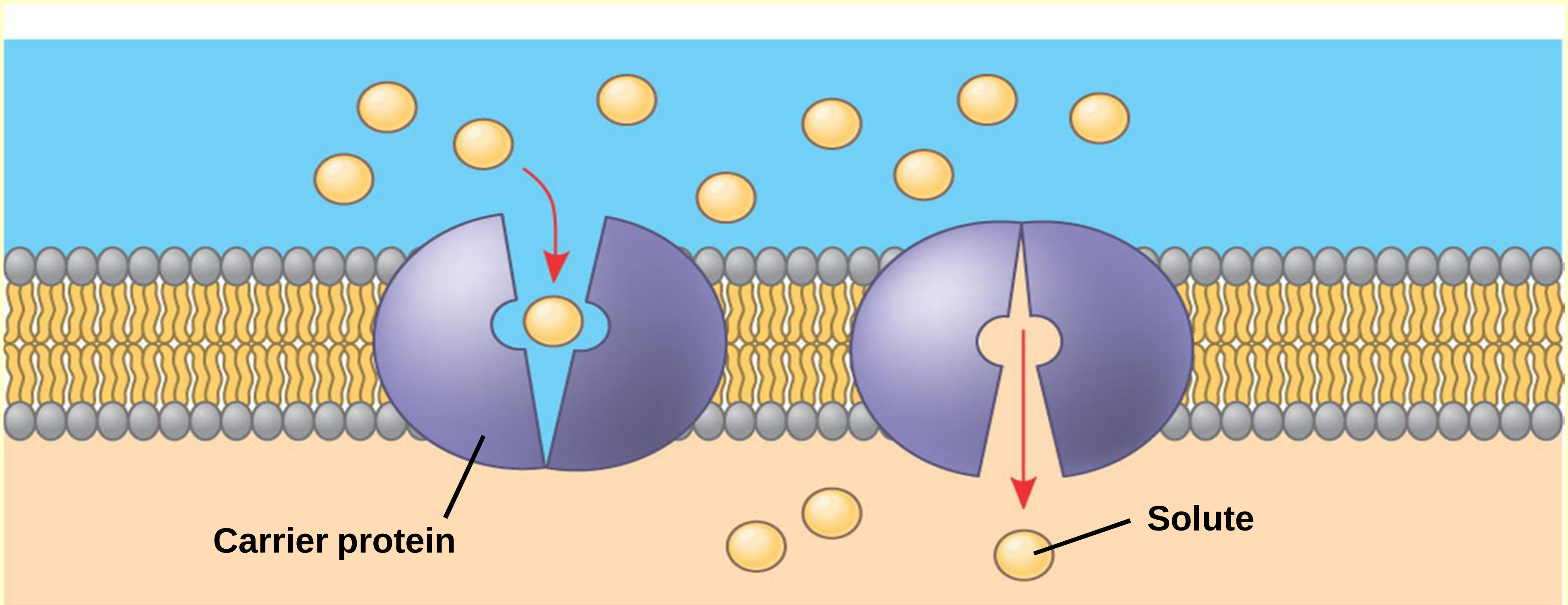
Channel proteins

- Provide corridors that allow a specific molecule or ion to cross the membrane



(a) A channel protein (purple) has a channel through which water molecules or a specific solute can pass.

- Carrier proteins
  - Undergo a subtle (little) change in shape that translocates the solute-binding site across the membrane



(b)

A carrier protein alternates between two conformations, moving a solute across the membrane as the shape of the protein changes. The protein can transport the solute in either direction, with the net movement being down the concentration gradient of the solute.

Active transport

- Compounds move from area of low concentration toward area of higher concentration
- Requires energy, usually in the form of ATP → pump

i.e. Active transport uses energy to move solutes against their gradients

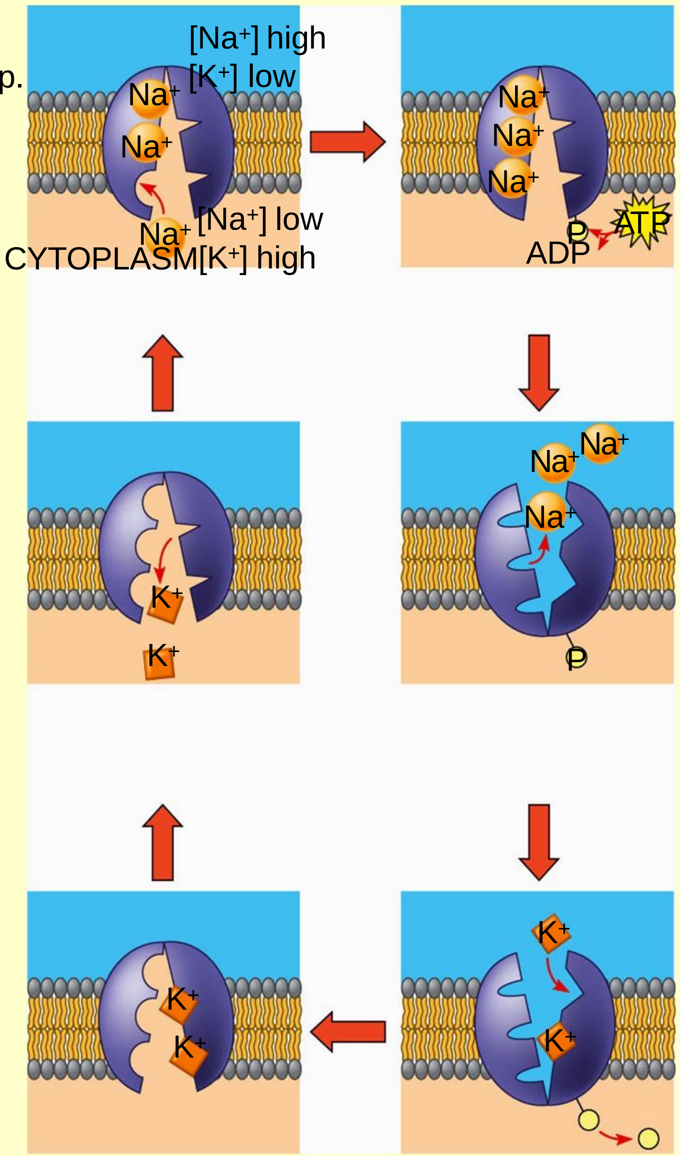
The most common: Na/K pumps → reestablish membrane potential. Present in all cells.

The sodium-potassium pump

– Is one type of active transport system

1 Cytoplasmic Na^+ binds to the sodium-potassium pump.

2 Na+ binding stimulates phosphorylation by ATP.



3 Phosphorylation causes the protein to change its conformation, expelling Na^+ to the outside.

4 Extracellular K^+ binds to the protein, triggering release of the Phosphate group.

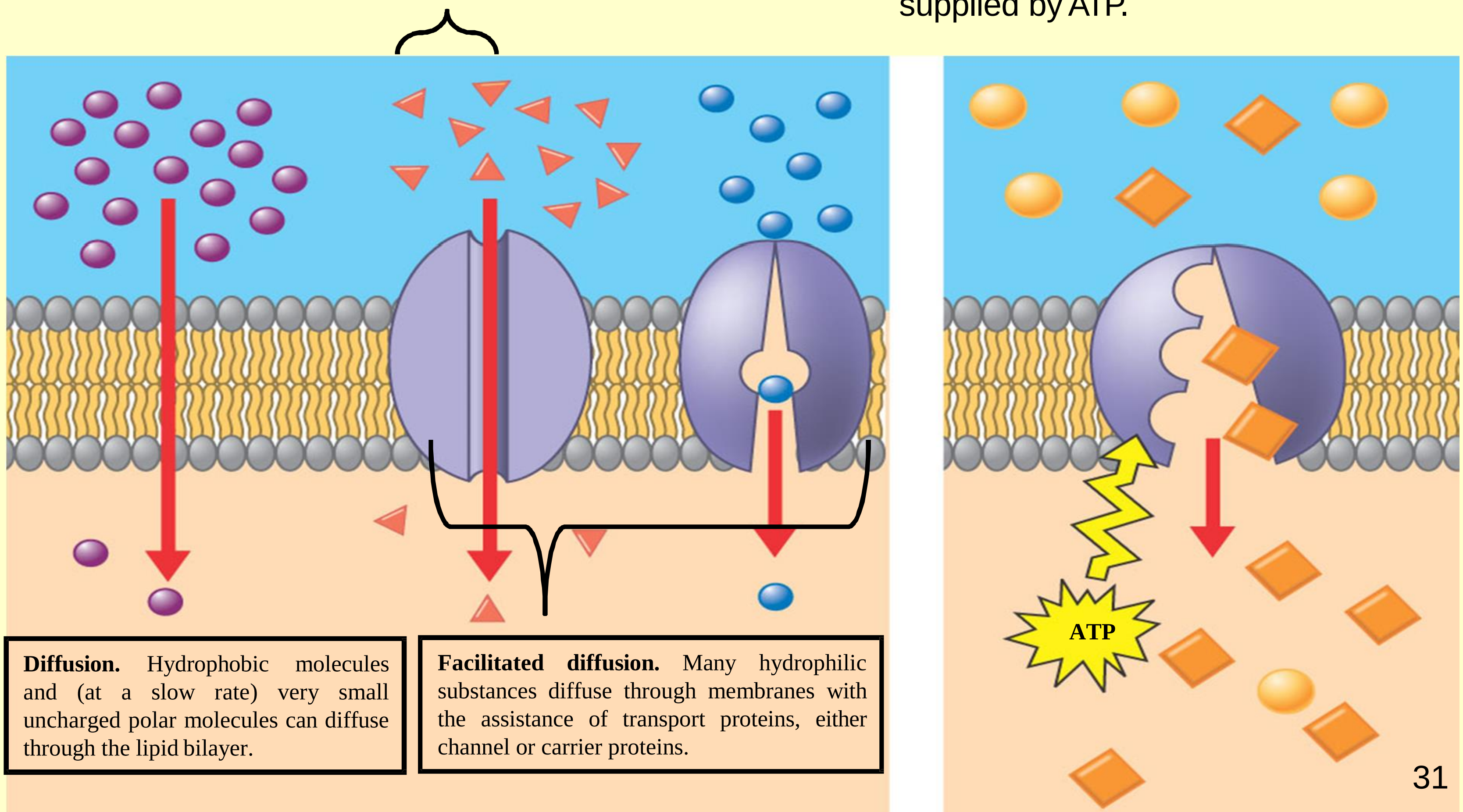
5 Loss of the phosphate restores the protein's original conformation.

6 K^+ is released and Na^+ sites are receptive again; the cycle repeats.

Review: Passive and active transport compared

Passive transport. Substances diffuse spontaneously down their concentration gradients, crossing a membrane with no use of energy by the cell. The rate of diffusion can be greatly increased by transport proteins in the membrane.

Active transport. Some transport proteins act as pumps, moving substances across a membrane against their concentration gradients. Energy for this work is usually supplied by ATP.



Diffusion. Hydrophobic molecules and (at a slow rate) very small uncharged polar molecules can diffuse through the lipid bilayer.

Facilitated diffusion. Many hydrophilic substances diffuse through membranes with the assistance of transport proteins, either channel or carrier proteins.

Phagocytosis Endocytosis/exocytosis Pinocytosis

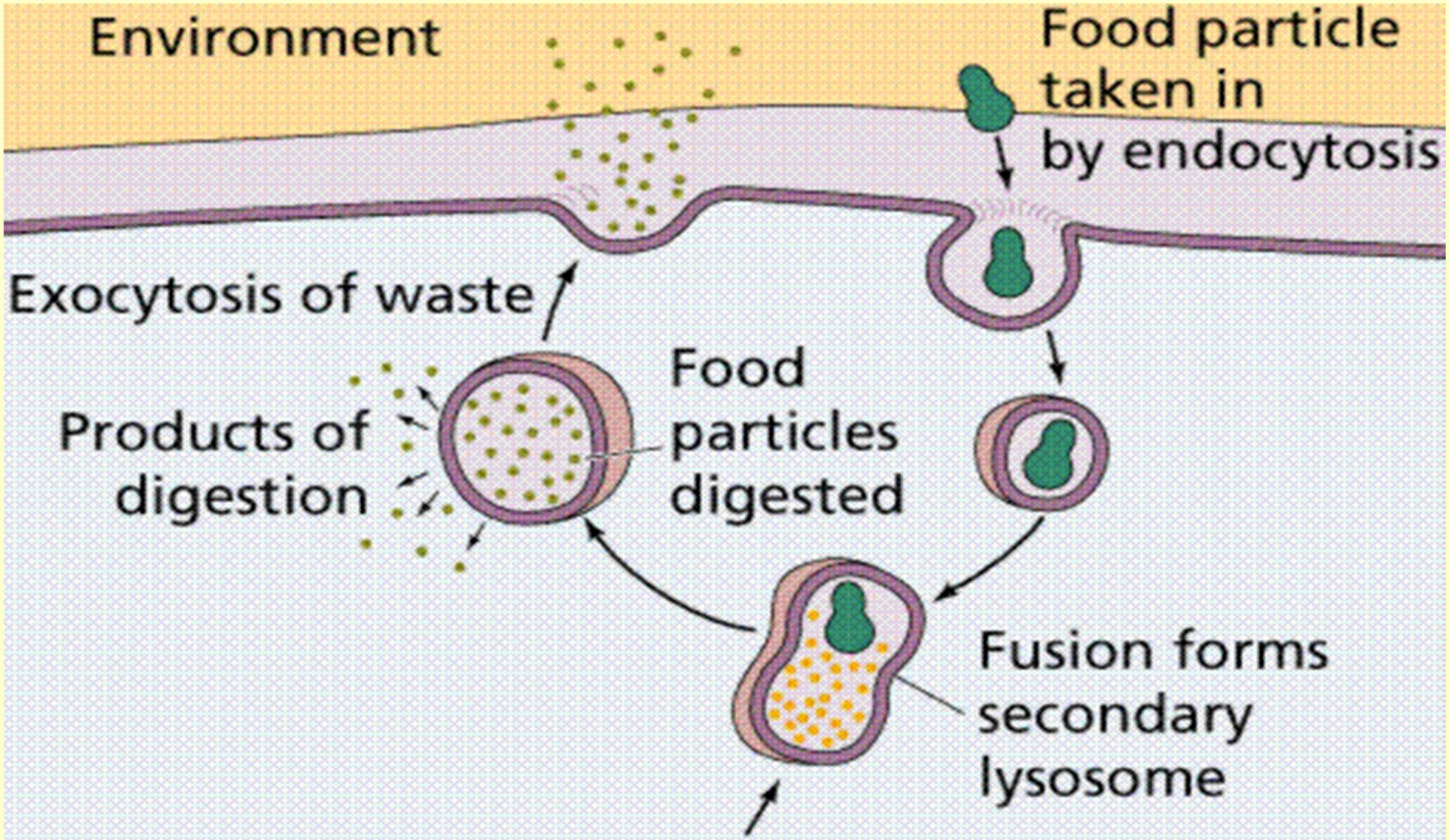
Endocytosis is the case when a molecule causes the cell membrane to bulge inward, forming a vesicle. “Endocytosis” is defined as the process of engulfing molecules.

Exocytosis is the term applied when transport is out of the cell

Phagocytosis is the type of endocytosis process of engulfing nutrients with a particular size only which is 0.75 nanometers in diameter. Examples of these are: dust particles, cell debris, and apoptotic cells

Pinocytosis is when the external fluid is engulfed.

Receptor-mediated endocytosis occurs when the material to be transported binds to certain specific molecules in the membrane. Examples include the transport of insulin and cholesterol into animal cells.



Environment
Food particle
taken in
by endocytosis
Exocytosis of waste
Food
particles
digested
Products of
digestion
Fusion forms
secondary
lysosome

Phagocytosis