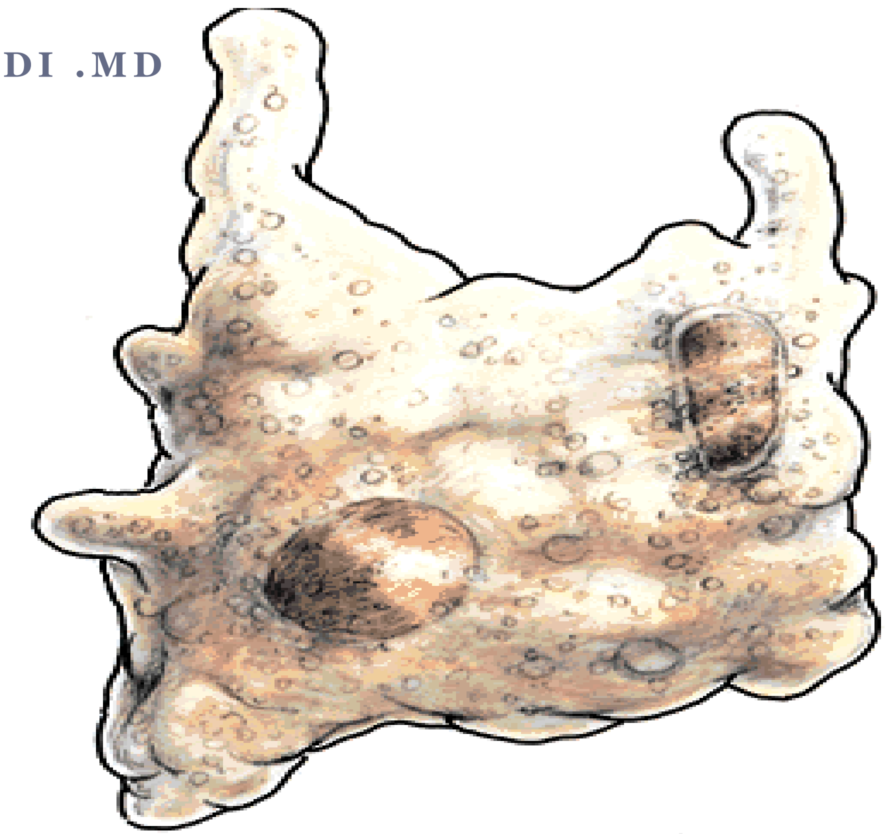
The cells

DANIL HAMMOUDI .MD



Chemical Structure of the Plasma Membrane

14. Describe the plasma membrane according to the fluid mosaic model. Include glycolipids, glycoproteins, phospholipids, cholesterol, integral proteins, and peripheral proteins.

Membrane Transport

15. Define the following terms: intracellular fluid, extracellular fluid, and interstitial fluid.

16. Define diffusion and describe how molecules diffuse across a plasma membrane. Include the following terms in your description: passive process, simple diffusion, facilitated diffusion, carriers, and channels.

17. Define and describe osmosis. Include the following terms in your description: solvent, solute, solution, hypertonic, hypotonic, and isotonic.

18. Explain what happens to a cell placed in a hypertonic, hypotonic, or isotonic solution.

19. List and explain the five factors that affect the rate of transport of substances across cell membranes. These factors are size of the material, temperature, the presence or absence of channels or other facilitating devices, particle charges, and the concentration gradient for the material being transported.

**20. Define and describe active processes by which materials move across cell membranes.
Active processes include active transport and vesicular transport. Include the following terms**

in your description: ATP, pumps, exocytosis, endocytosis, phagocytosis, and receptormediated endocytosis.

Cellular Structures

21. Describe the structures and functions of the following membrane junctions: tight junctions, desmosomes, and gap junctions

Cell Theory

- The cell is the basic structural and functional unit of life
- Organismal activity depends on individual and collective activity of cells
- Biochemical activities of cells are dictated by subcellular structure
- Continuity of life has a cellular basis

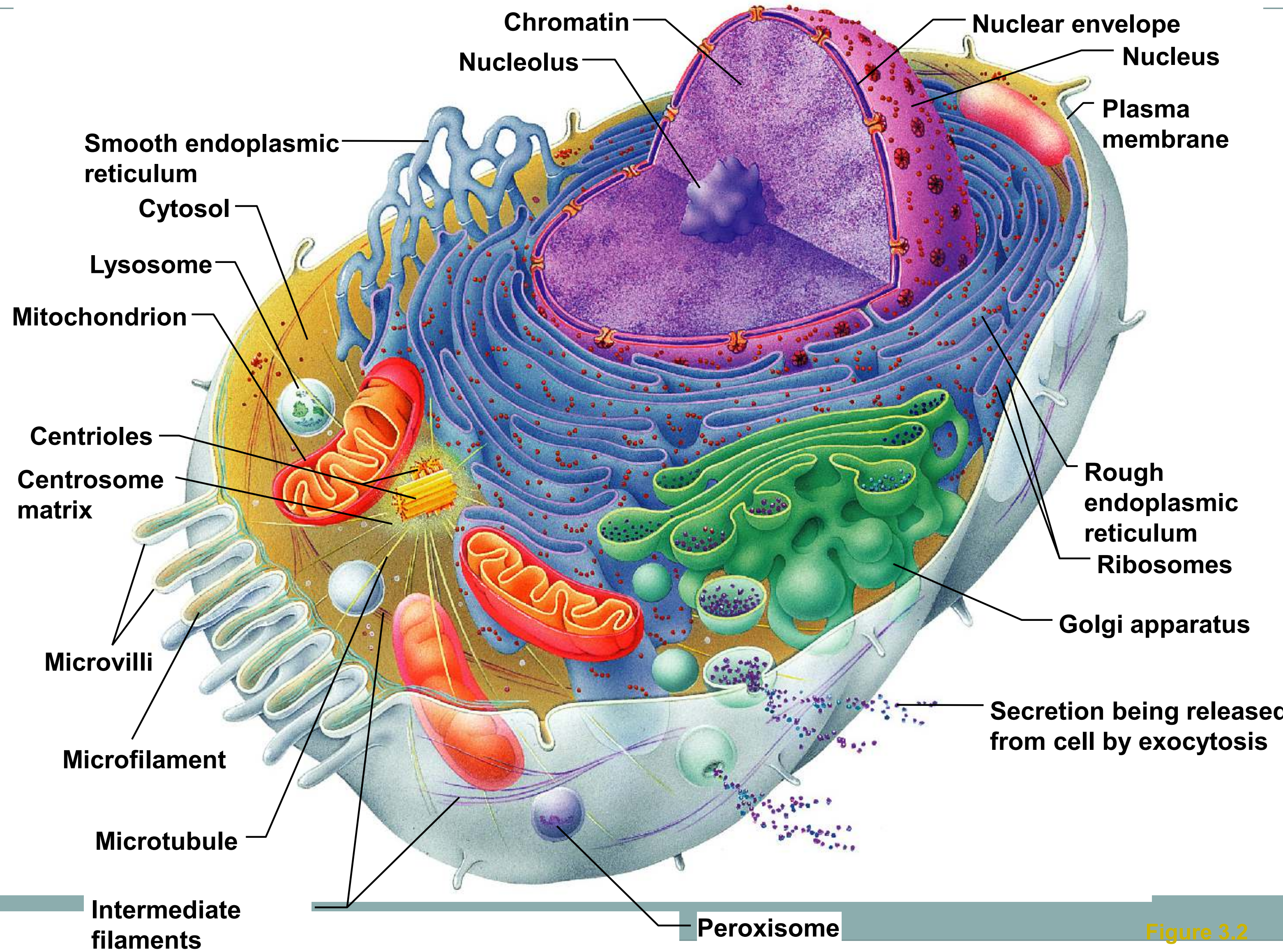
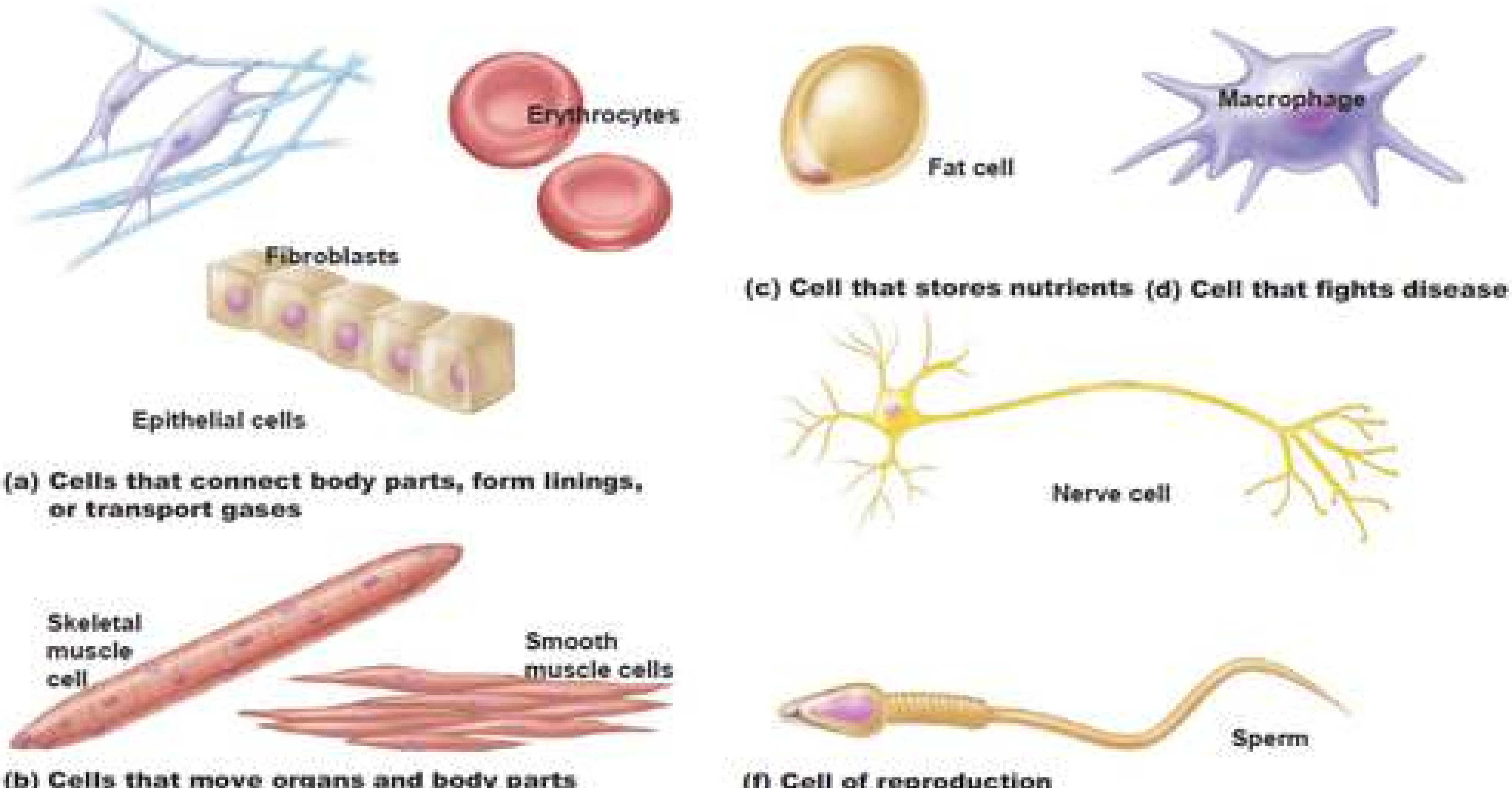
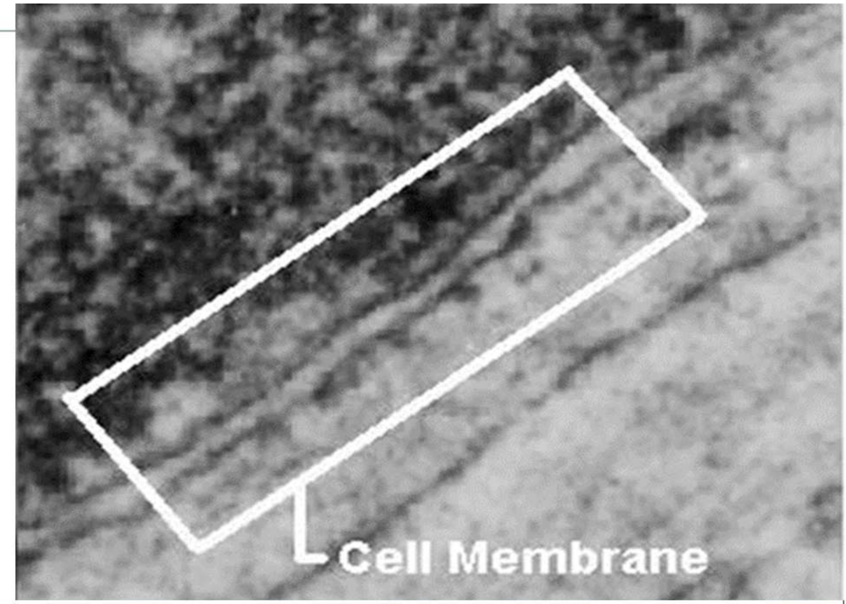

Chromatin
Nuclear envelope
Nucleolus
Nucleus
Plasma membrane
Smooth endoplasmic reticulum
Cytosol
Lysosome
Mitochondrion
Centrioles
Centrosome matrix
Microvilli
Microfilament
Microtubule
Intermediate filaments
Peroxisome
Rough endoplasmic reticulum
Ribosomes
Golgi apparatus
Secretion being released from cell by exocytosis

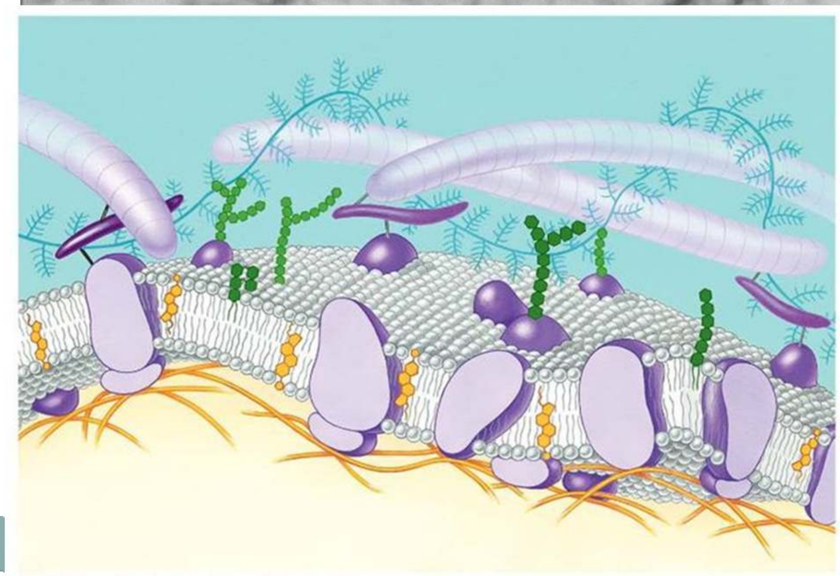
Figure 3.2



Specialised Human Body Cells

- **The plasma membrane, also known as the cell membrane.**
- is a vital structure that **surrounds all cells**.
- A membrane is a Fluid Mosaic of lipids, proteins, carbos
- It serves as a selectively permeable barrier (boundary).
- controlling the passage of substances into and out of the cell.
- The plasma membrane is a **dynamic structure** that plays a crucial role in **maintaining cell integrity and regulating cellular processes, communicate with each other by physical contact**
- **Allows them to interact with the extracellular spaces**.

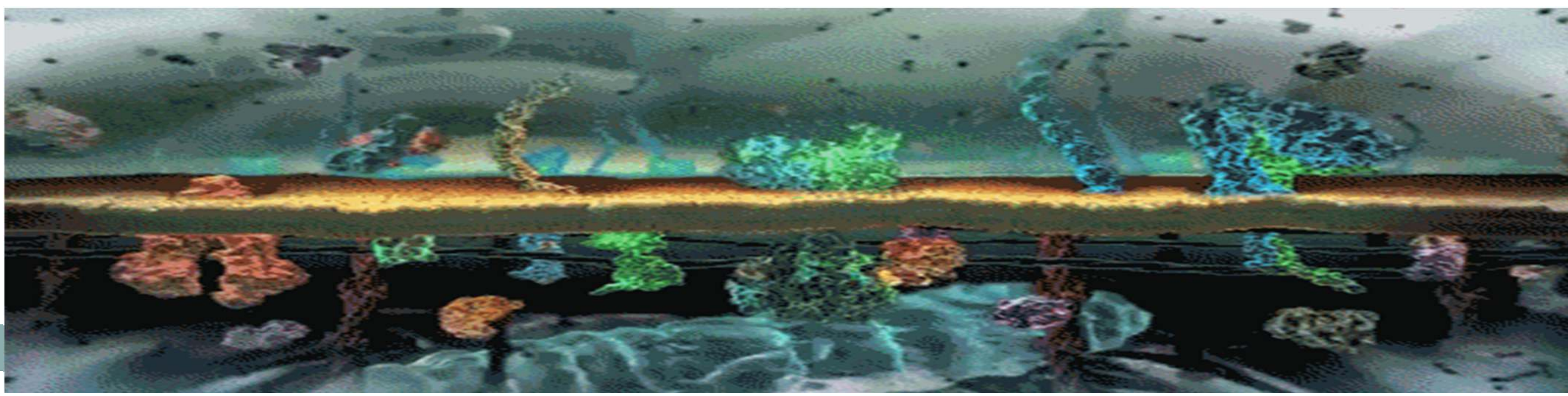




Importance of cell membrane in maintaining homeostasis

- The cell membrane plays a crucial role in maintaining homeostasis
- Homeostasis refers to **the stable internal environment necessary for the proper functioning of living organisms**.
- Homeostasis **ensures that cells can carry out their physiological processes** efficiently and respond to changes in the external environment.
- The importance of the cell membrane in maintaining homeostasis is evident in various ways:

1.Selective Permeability:
2.Ion Balance:
3.Nutrient Uptake:
4.Waste Removal:
5.Water Balance:.
6.Protection from External Factors:
7.Cell Signaling:
8.Temperature Regulation:
9.Cell Adhesion:
10.Organismal Homeostasis:



1. Selective Permeability:

- The cell membrane is selectively permeable, allowing only specific substances to pass through while restricting others.
- This regulation of molecular traffic is vital for maintaining the balance of ions, nutrients, and other molecules inside the cell.

2. Ion Balance:

- The cell membrane helps maintain the balance of ions such as sodium, potassium, calcium, and chloride.
- This balance is crucial for cell signaling, electrical excitability, and overall cellular function.

3. Nutrient Uptake:

- Nutrients necessary for cell metabolism, growth, and energy production must enter the cell.
- The cell membrane facilitates the selective transport of essential nutrients into the cell, contributing to its overall well-being.

4. Waste Removal:

- Metabolic processes within the cell generate waste products that need to be removed.
- The cell membrane controls the exit of waste materials, preventing their accumulation and ensuring cellular health.

5. Water Balance:

- The cell membrane regulates water movement through processes such as osmosis. This is crucial for maintaining proper cell volume and preventing excessive swelling or shrinkage, which could disrupt cellular function.

6. Protection from External Factors:

- The cell membrane acts as a barrier, protecting the cell from harmful substances in the external environment. It prevents the entry of toxins, pathogens, and other potentially damaging agents.

7. Cell Signaling:

- The cell membrane is equipped with receptors and signaling molecules that allow cells to communicate with each other and respond to changes in their environment. This communication is essential for coordinating cellular activities and adapting to external stimuli.

8. Temperature Regulation:

- The lipid bilayer of the cell membrane helps maintain fluidity, allowing cells to function optimally within a specific temperature range. Changes in temperature can affect the permeability and fluidity of the membrane.

9. Cell Adhesion:

- Cell membranes contain proteins involved in cell adhesion, allowing cells to stick together and form tissues. This adhesion is essential for the structural integrity and function of organs and tissues.

10. Organismal Homeostasis:

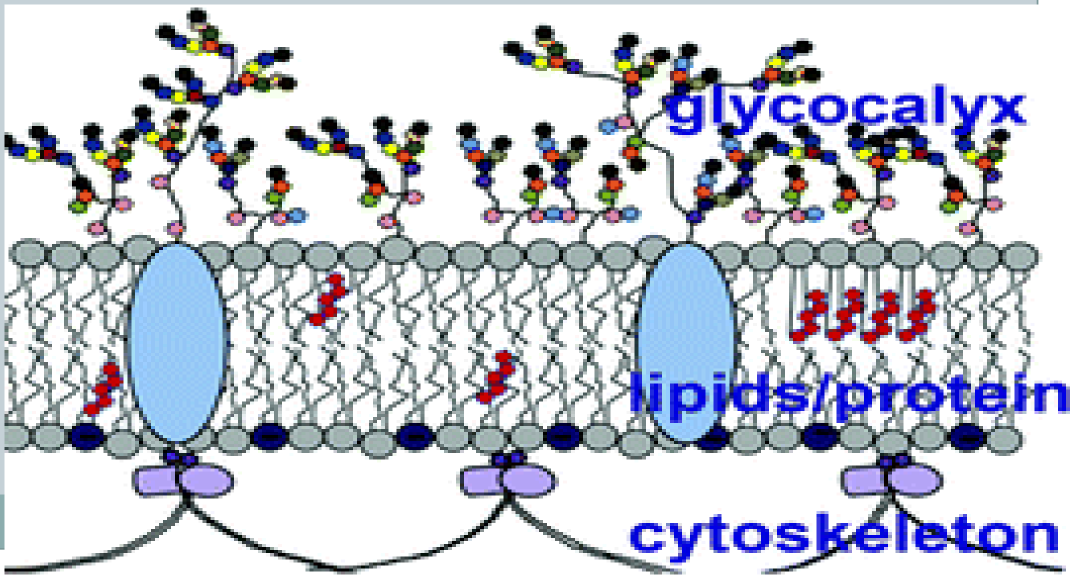
•At the organismal level, the cell membrane's role in maintaining homeostasis contributes to the overall stability of the internal environment, ensuring the well-being of the entire organism.

- Membranes that allow certain materials to pass through based on certain properties
  - size
  - hydrophobicity
  - charge

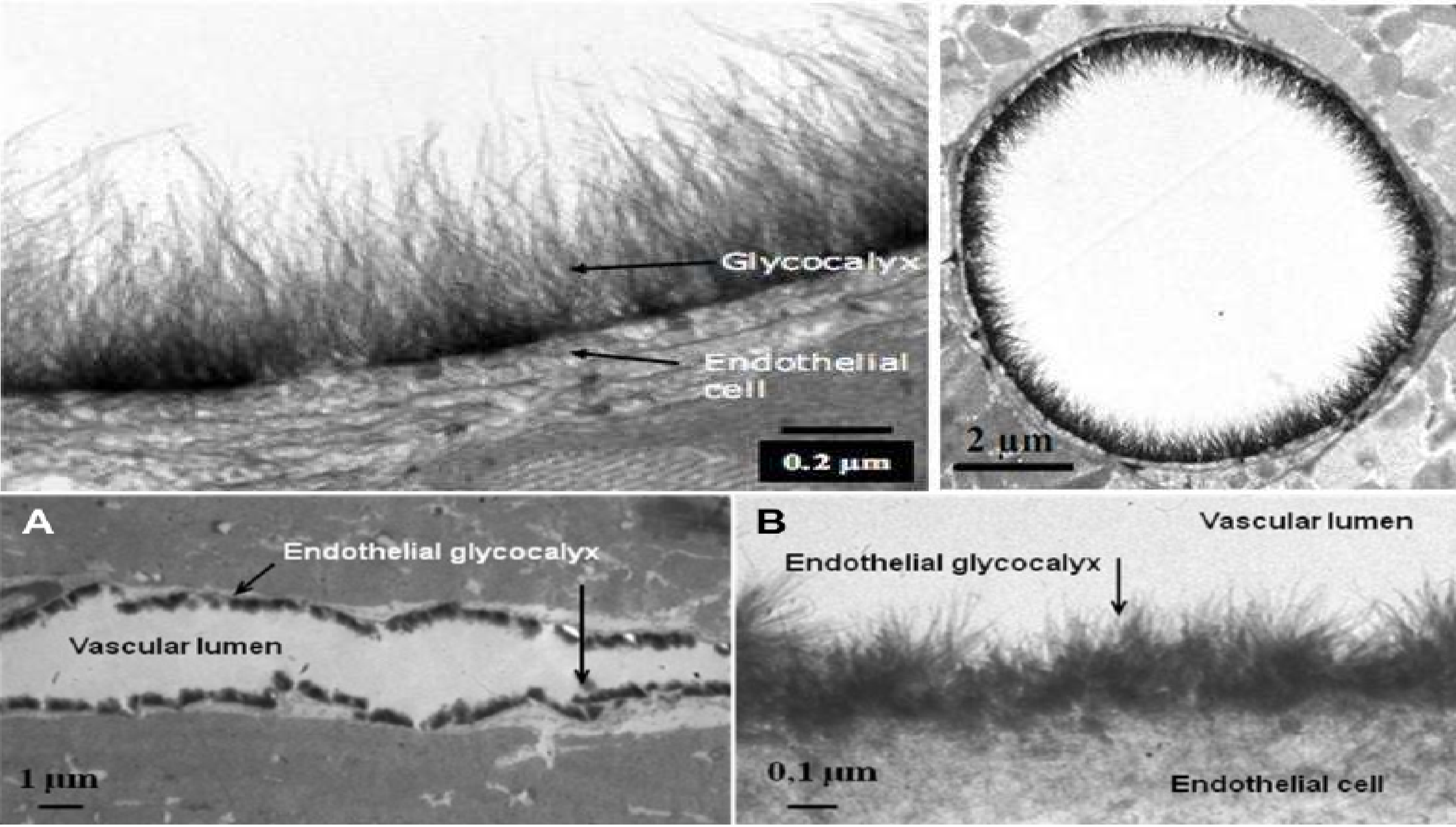
Semipermeable membranes

Plasma Membrane

- Separates intracellular fluids from extracellular fluids
- Plays a dynamic role in cellular activity
- ***Glycocalyx*** is a glycoprotein area abutting the cell that provides highly **specific biological markers** by which ***cells recognize one another, unique to each cells***

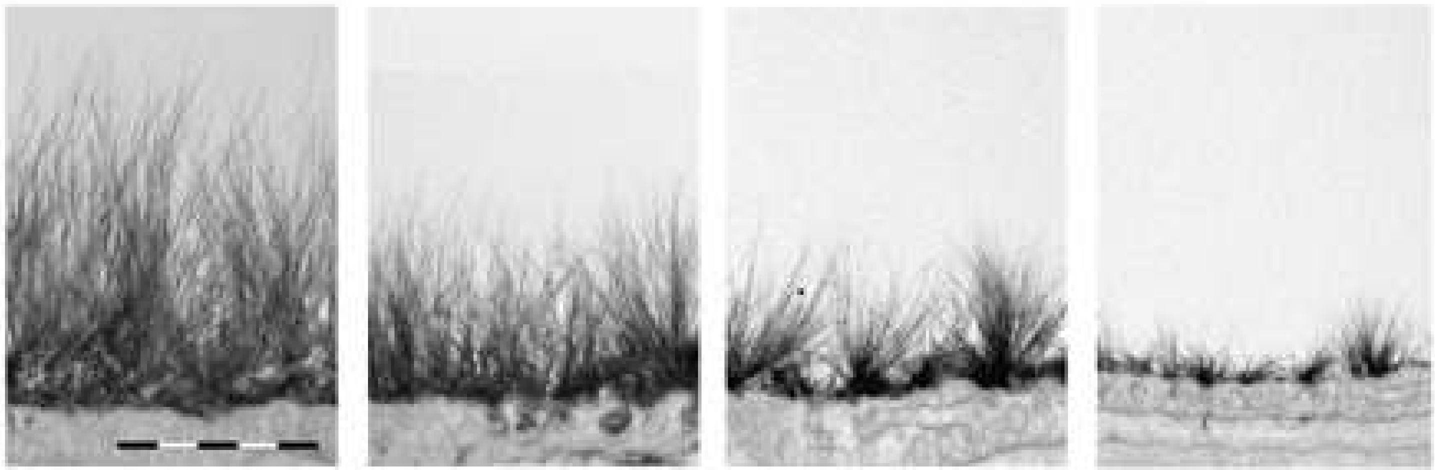


- **Act as an ID tag**
- **Block cancer signal**
- **Embryo growth**
- **Cell protection**
- **Immunity to infection**
- **Cell adhesion**
- **Fertilization**


Glycocalyx
Endothelial cell
0.2 µm
2 µm
A
Endothelial glycocalyx
Vascular lumen
1 µm
B
Vascular lumen
Endothelial glycocalyx
0.1 µm
Endothelial cell

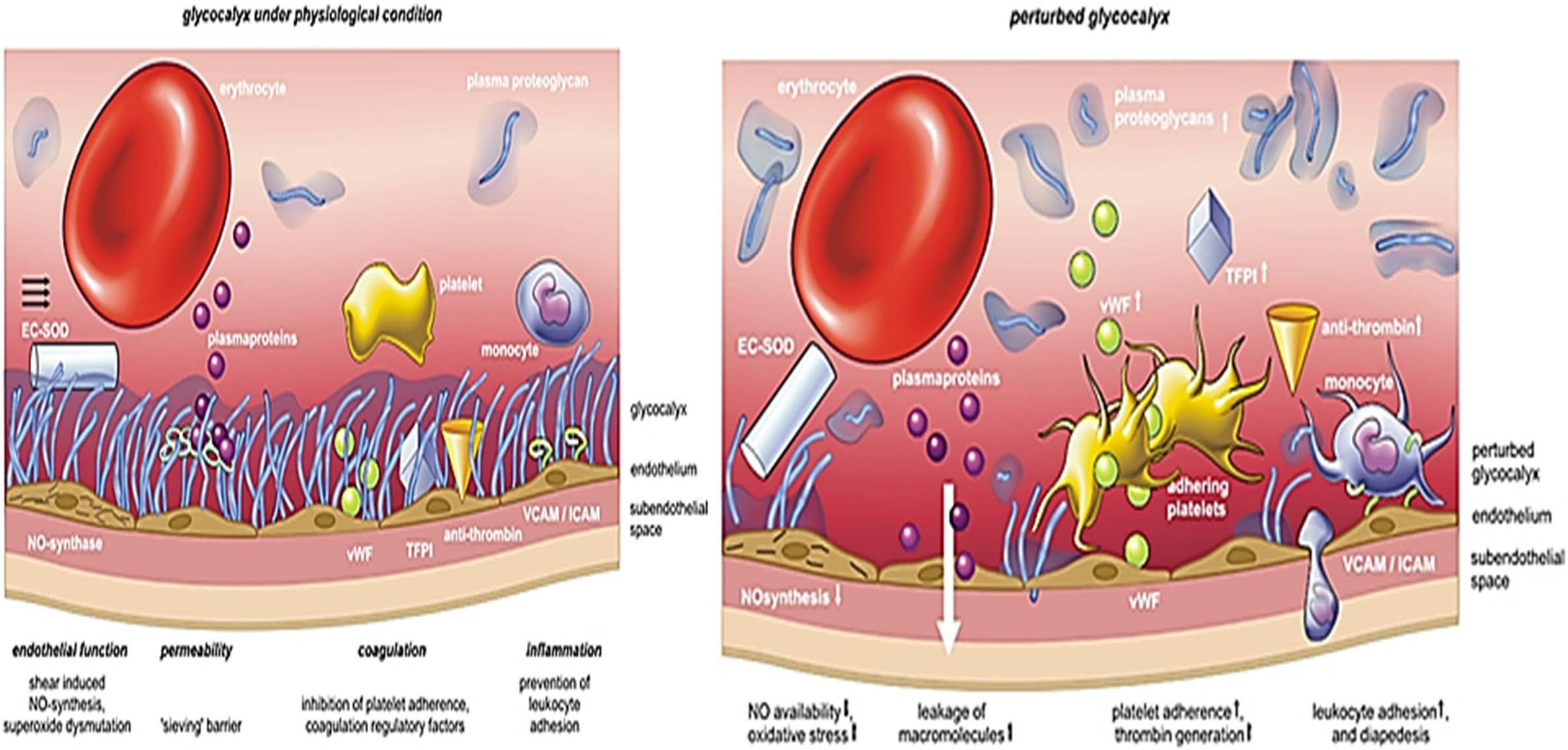
GLYCOCALYX AFFECTED BY:

Aging
Diet
Disease
Exercise
Genetics
Smoking
Stress



HEALTHY GLYCOCALYX — **UNHEALTHY** GLYCOCALYX

MICROCALYX



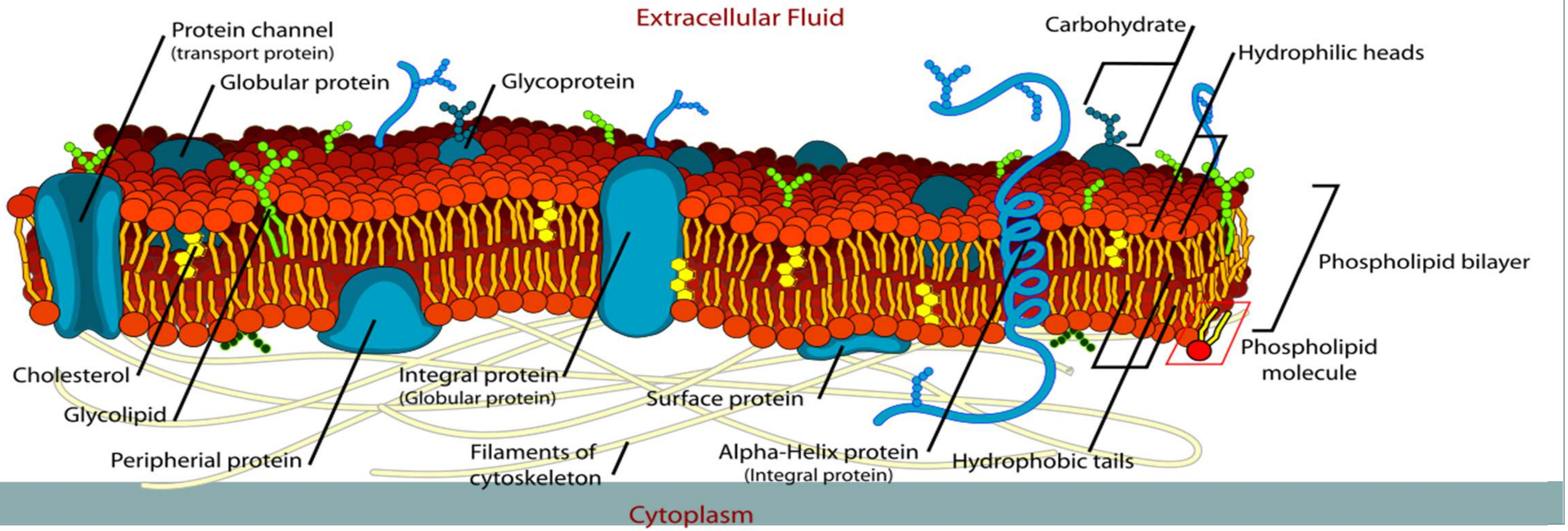
glycocalyx perturbation occurs when the circulation gets exposed to atherogenic stimuli such as oxidized lipoproteins, hyperlipidemia, and hyperglycemia.

Fluid Mosaic Model:

•The fluid mosaic model describes the dynamic nature of the plasma membrane, with lipids and proteins in constant motion.

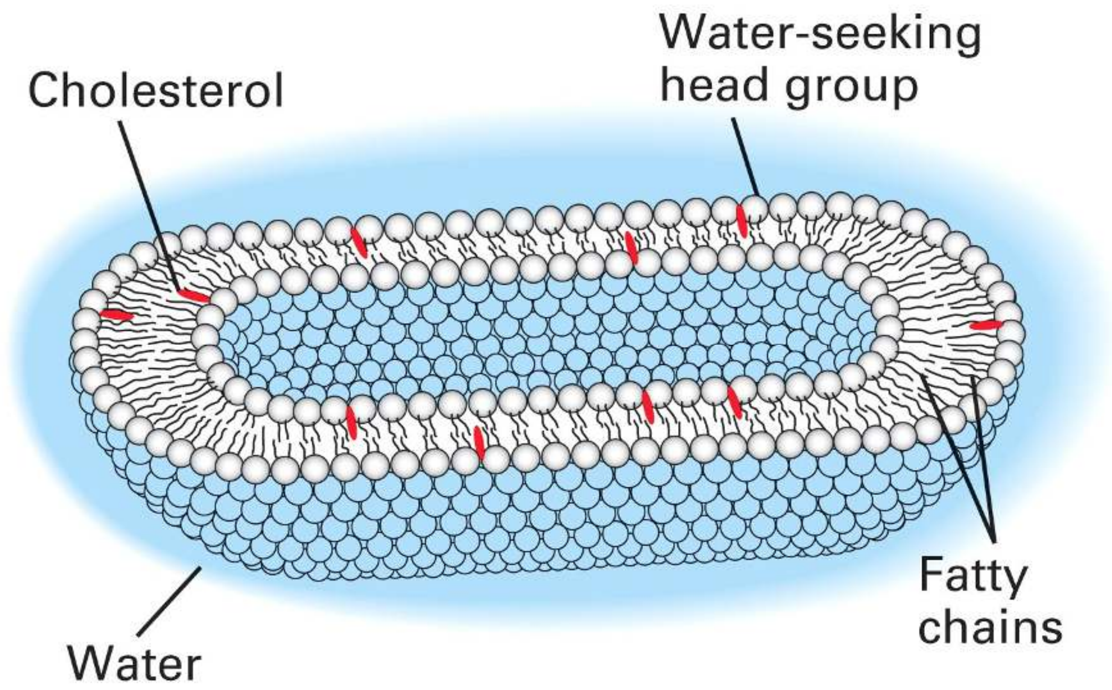
•The membrane is not rigid but rather has a flexible and fluid structure.

•The protein can be anchored or freely moving



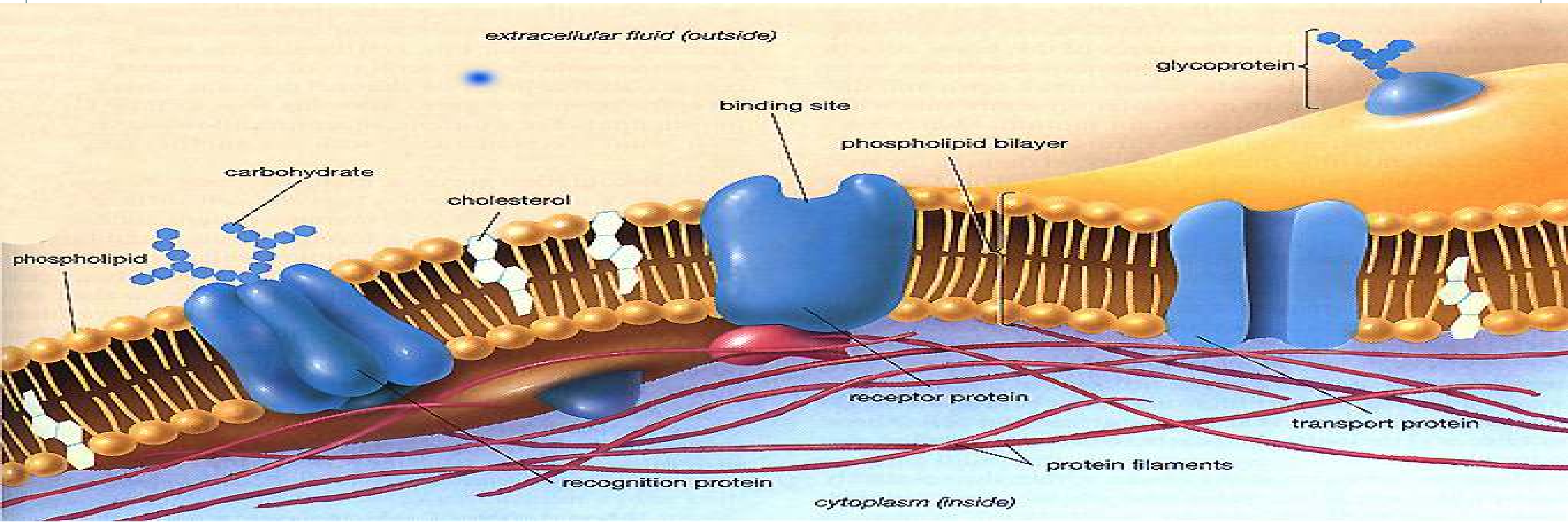
Membranes define cellular and organelle boundaries

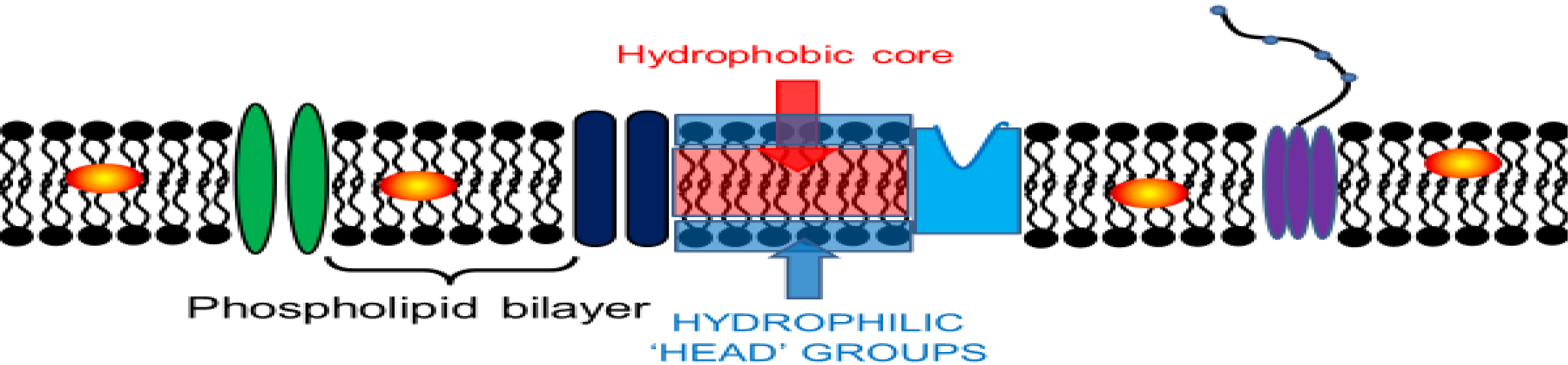
- How does chemistry dictate function?
- Why are there different lipid types?
- How does material get across membranes?



Fluid Mosaic Model

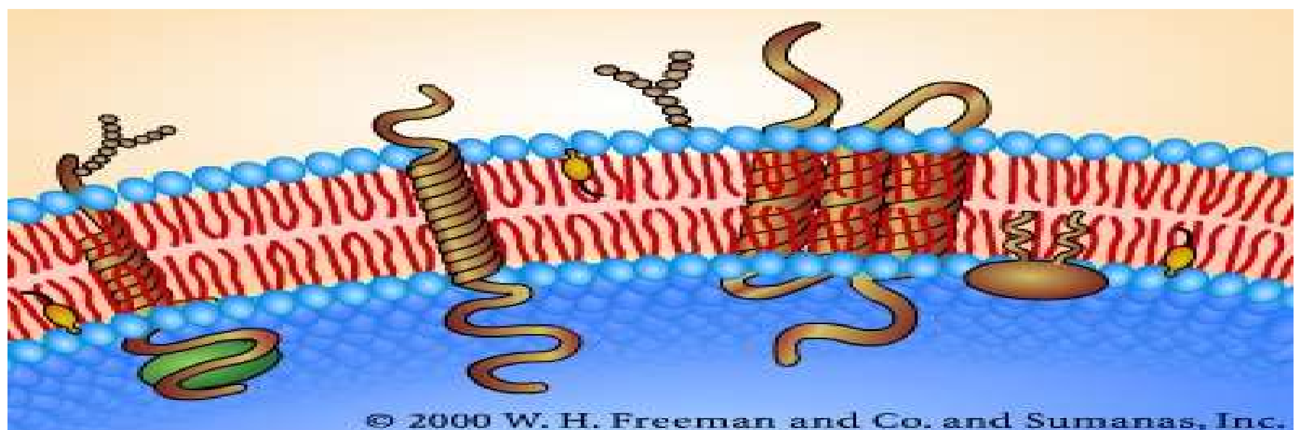
- **Double bilayer of lipids** with imbedded, dispersed **proteins**
- Bilayer consists of ***phospholipids, cholesterol, and glycolipids***
  - Glycolipids are lipids with bound carbohydrate
  - **Phospholipids have hydrophobic and hydrophilic bipoles**





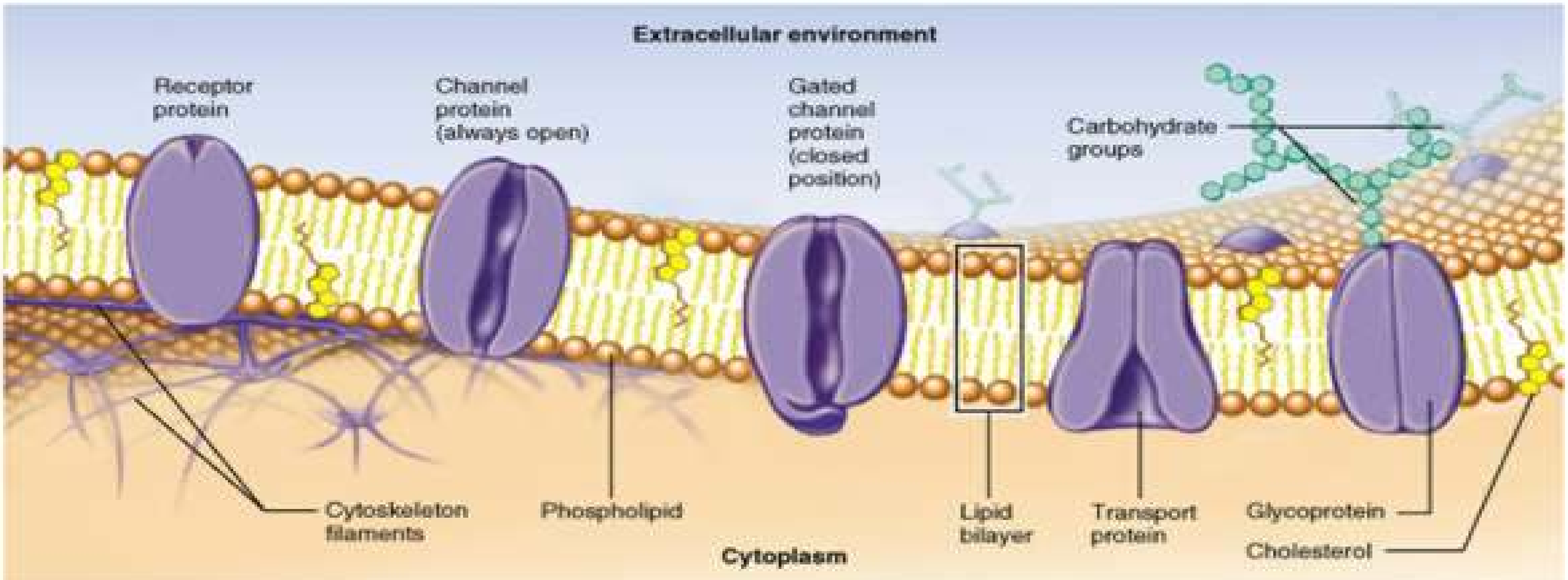
In addition to phospholipids, the membrane has proteins and cholesterol embedded in it.

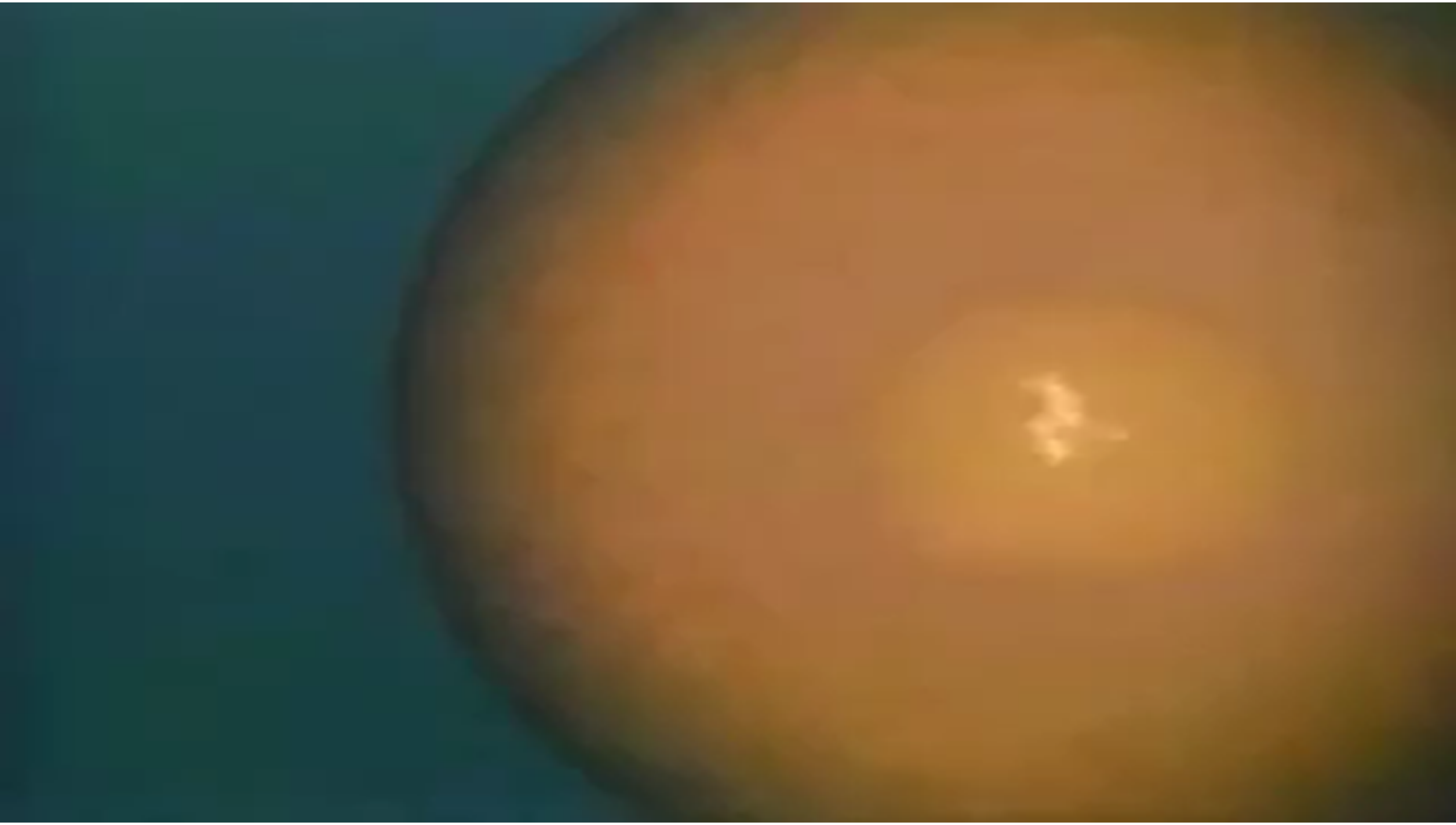
<u>Model</u>: The membrane is made up of <u>many smaller parts</u> and the structure <u>moves like a fluid</u>

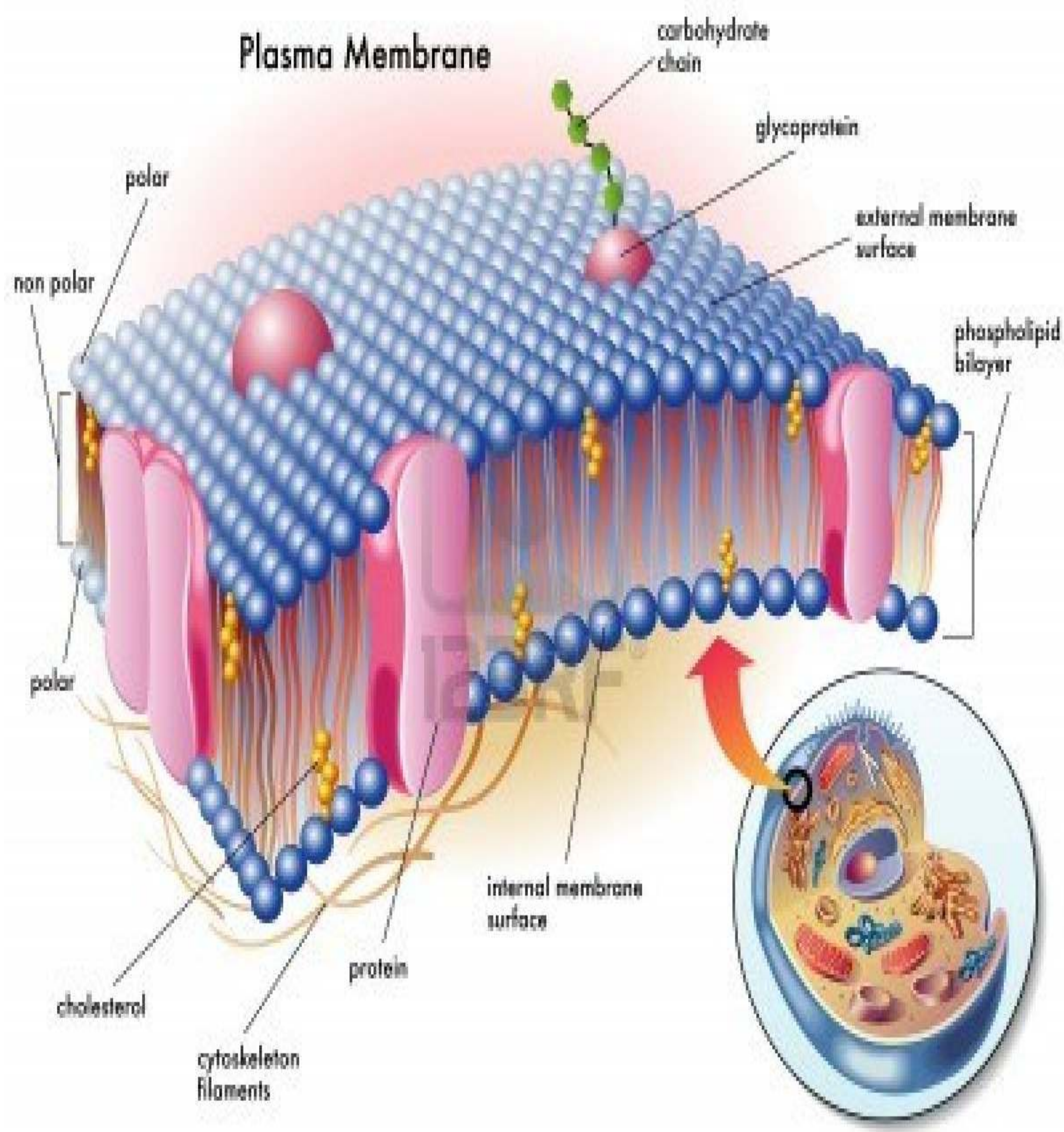


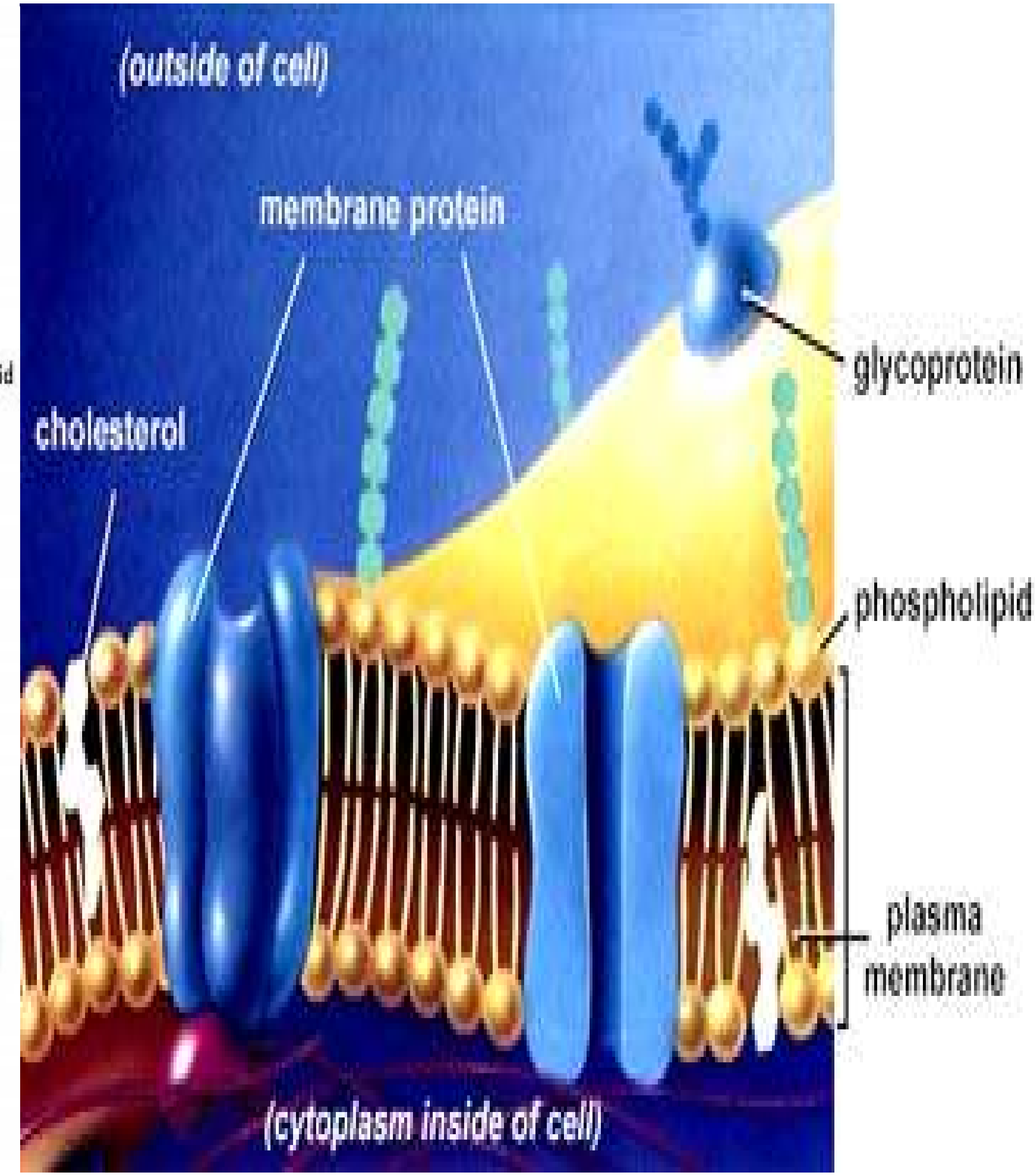
- http://www.susanahalpine.com/anim/Life/memb.htm

<u>Phospholipids</u> and <u>proteins</u> make up most of the membrane. <u>Cholesterol</u> helps with flexibility, and <u>carbohydrate chains</u> help communicate with other cells



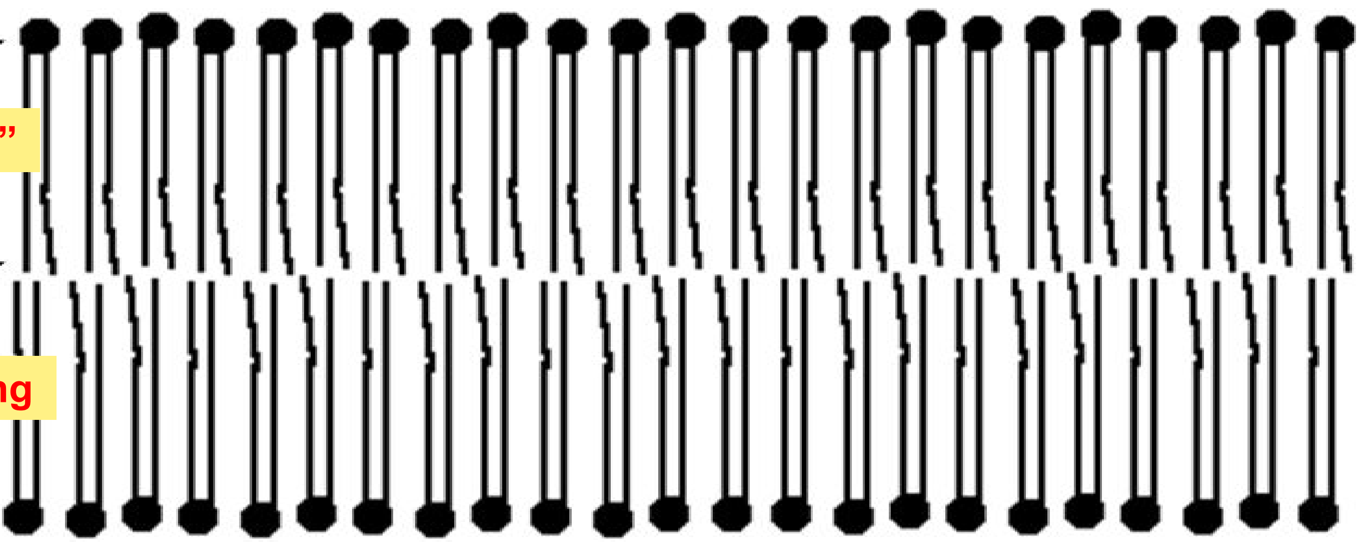



Plasma Membrane
carbohydrate chain
glycoprotein
polar
external membrane surface
non polar
phospholipid bilayer
polar
internal membrane surface
protein
cholesterol
cytoskeleton filaments


(outside of cell)
membrane protein
glycoprotein
cholesterol
phospholipid
plasma membrane
(cytoplasm inside of cell)

Cell Membrane Structure

Lipid Bilayer (composed of phospholipids)



Hydrophilic

hydrophilic means “water loving”

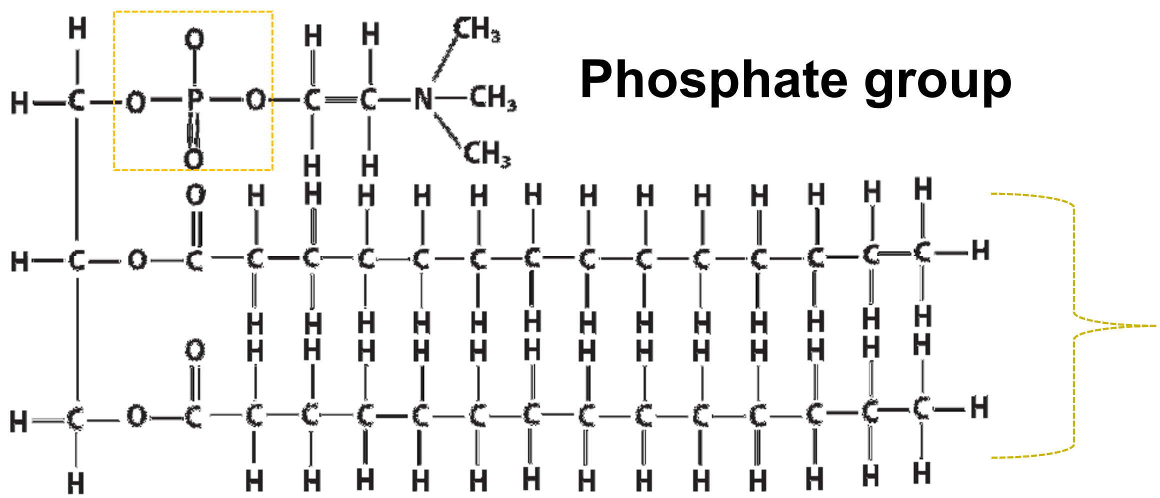
Hydrophobic

hydrophobic means “water repelling

Hydrophilic

Plasma Membrane: Phospholipids

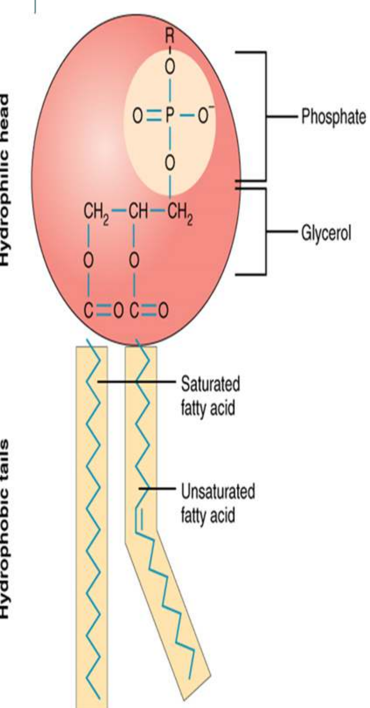
- Lipids with a **phosphate** group!

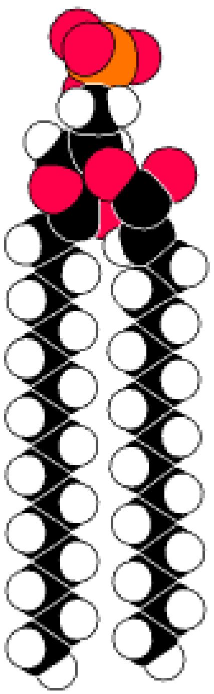


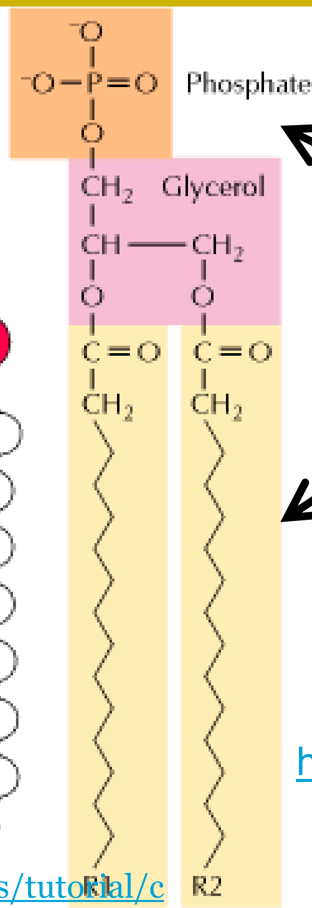
- Main component of **plasma membrane** and organelle membranes (eukaryotes).

A phospholipid is a type of lipid that has 2 fatty acid tails and a phosphate head.

Amphipathic = has **both** hydrophilic and hydrophobic components

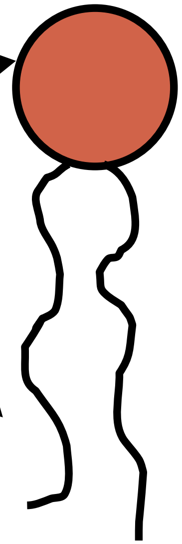






The phosphate head is hydrophilic because it is attracted to water

The fatty acid tails are hydrophobic
Because they are repelled by water
Can be saturated or unsaturated

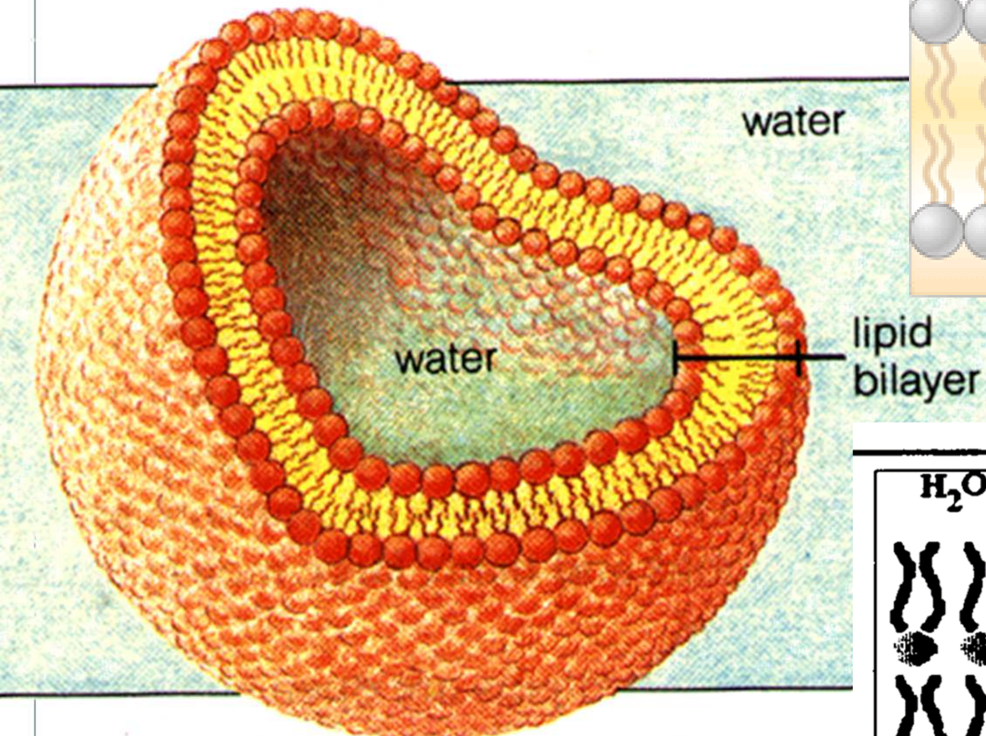


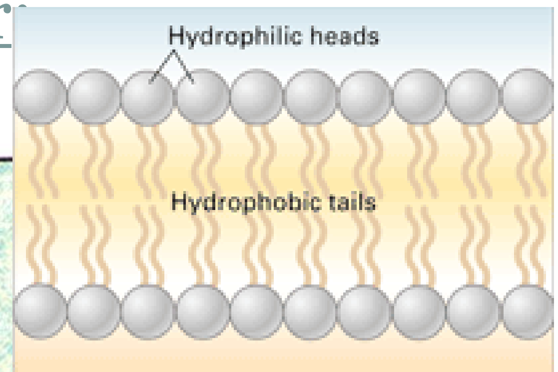
https://www.youtube.com/watch?v=pzpZdijjqX8

Use E-Life animation 6.3

- http://telstar.ote.cmu.edu/Hughes/tutorial/cellmembranes/

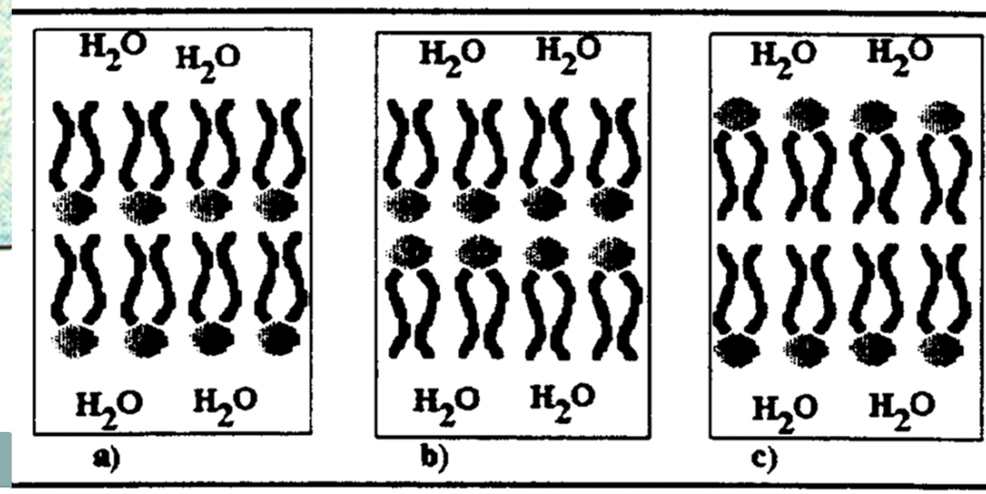
The phospholipid bilayer forms because the inside and outside of the cell are mostly water.





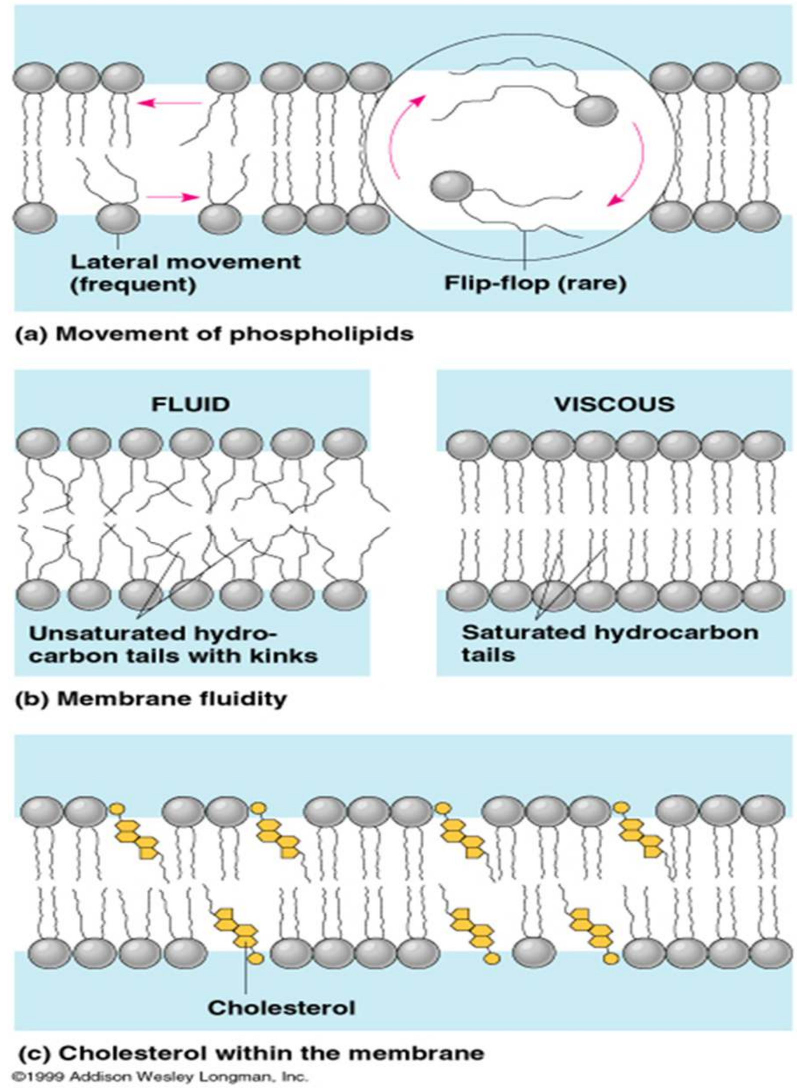
The plasma membrane is like a lipid sandwich.

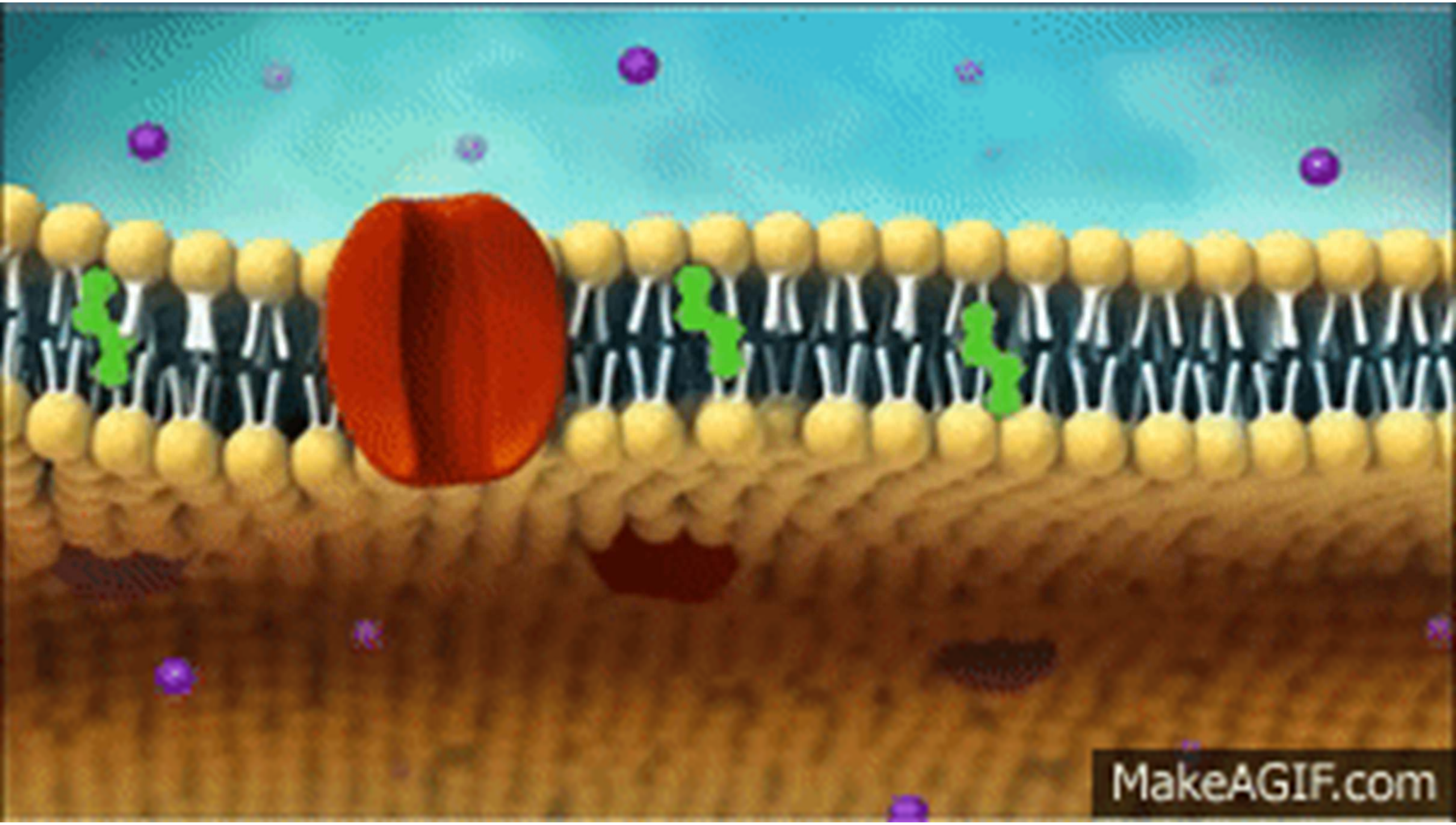
Two layers of phospholipids interact to form a bi-layer. Make an educated guess to which picture represents an accurate membrane drawing!



General Membrane Characteristi

- Held together by hydrophobic interactions
- Most lipids/proteins can drift laterally
- Molecules rarely flip transversely
- Phospholipids move faster than proteins
- Some proteins are connected to the cytoskeleton, can't move far
- Unsaturated Hydrocarbon tails on lipids increase fluidity
- Cholesterol decreases fluidity at warmer temps, more fluid at colder temps. (plant survival adaptation)




MakeAGIF.com

Fluid Mosaic Model

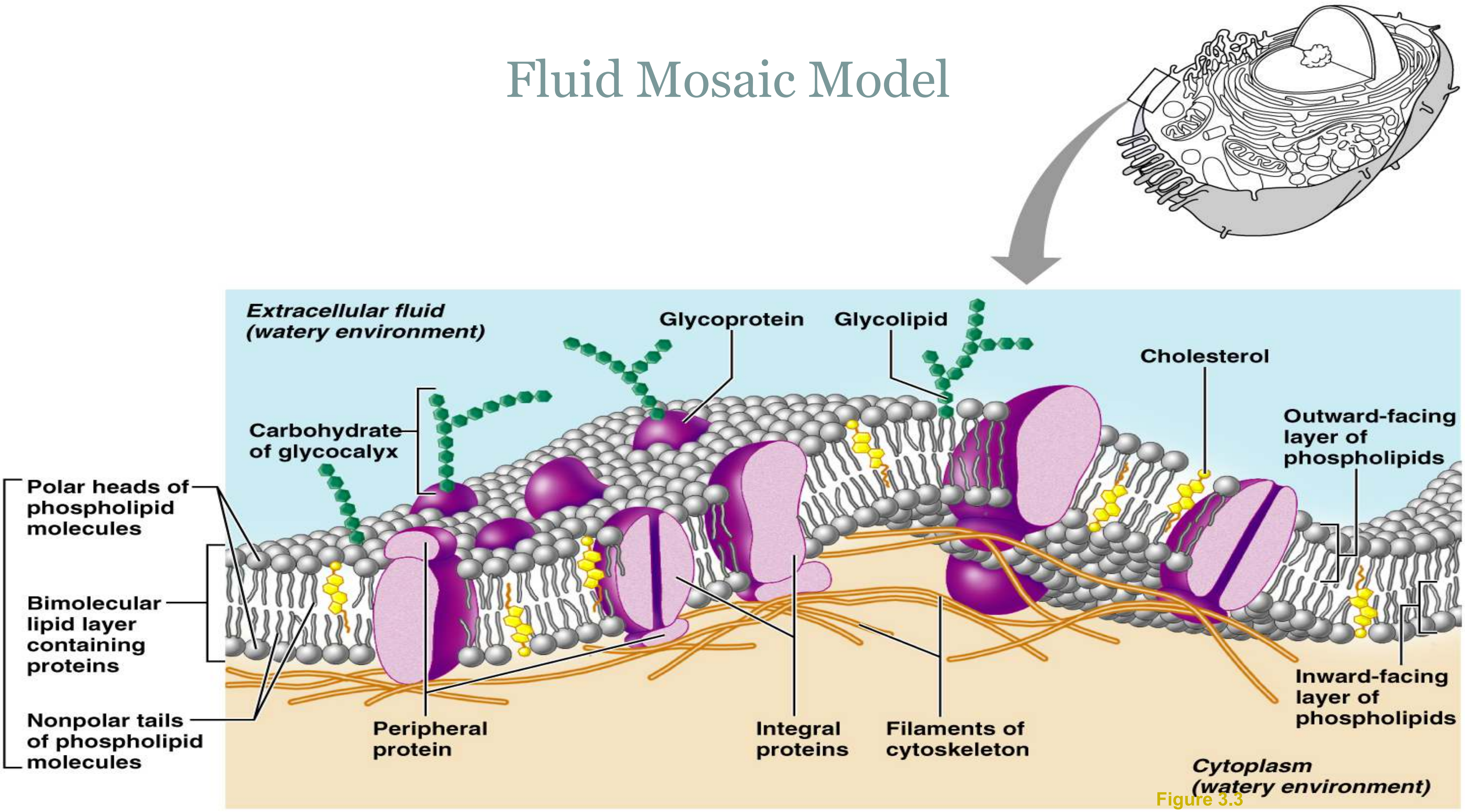
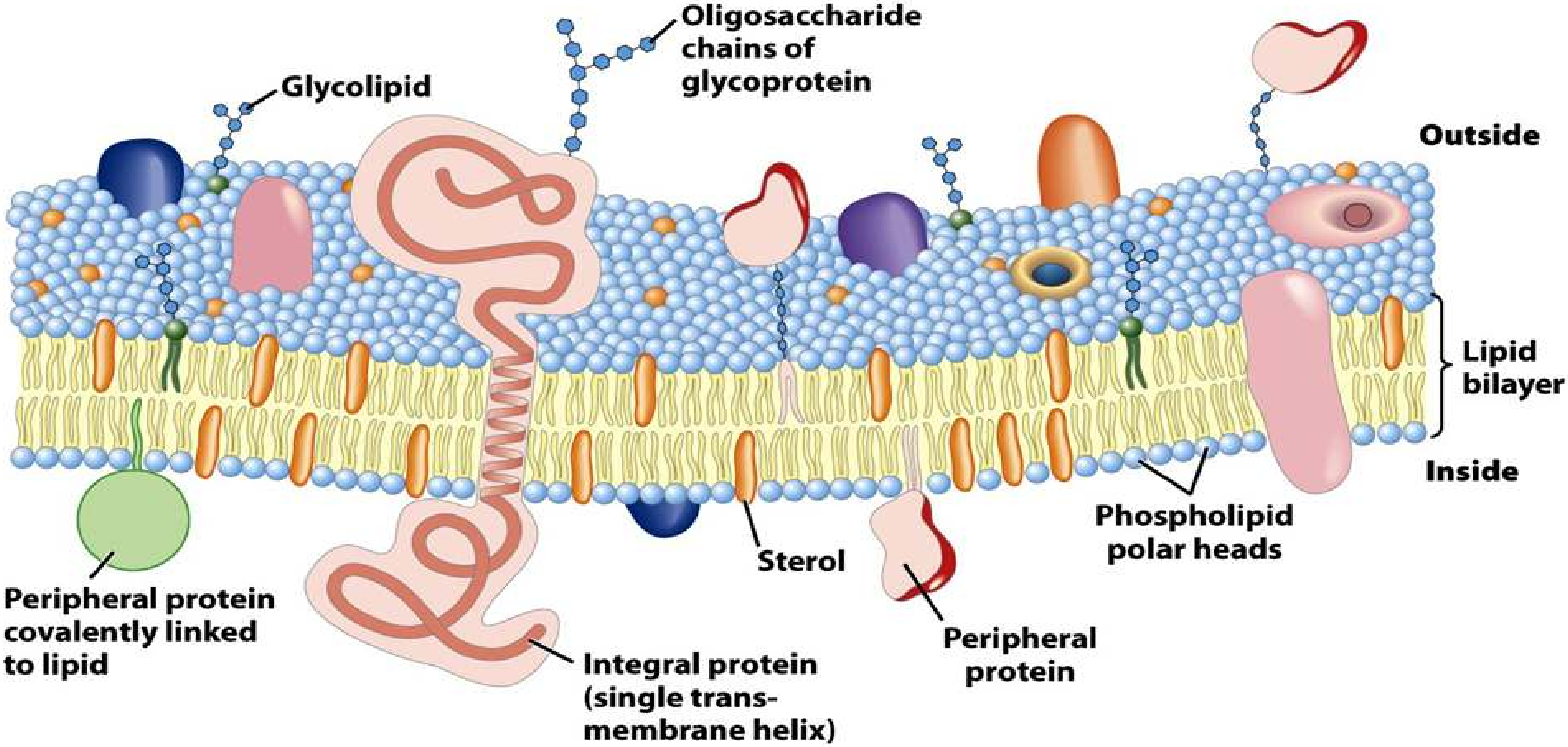


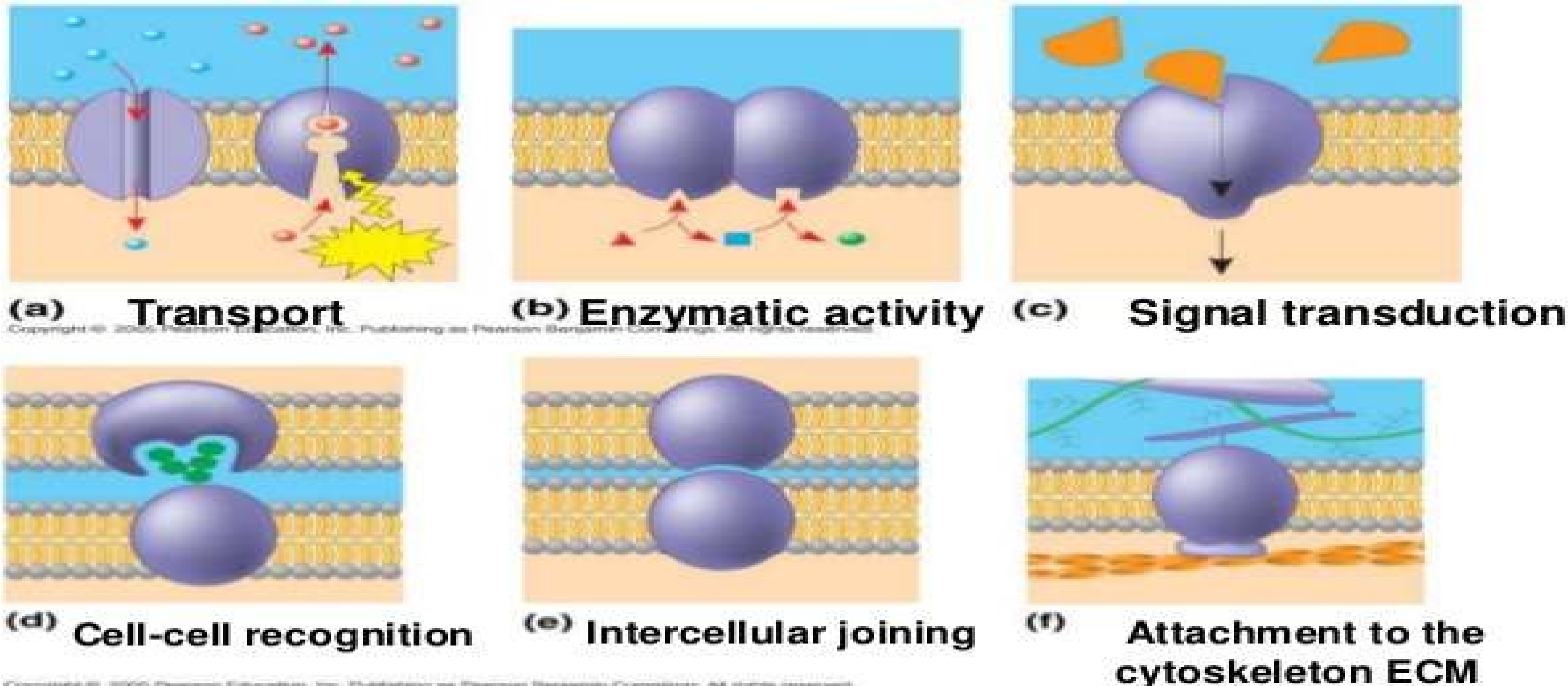
Figure 3.3


Oligosaccharide chains of glycoprotein
Glycolipid
Outside
Lipid bilayer
Inside
Phospholipid polar heads
Sterol
Peripheral protein covalently linked to lipid
Integral protein (single trans-membrane helix)
Peripheral protein

MOSAICISM

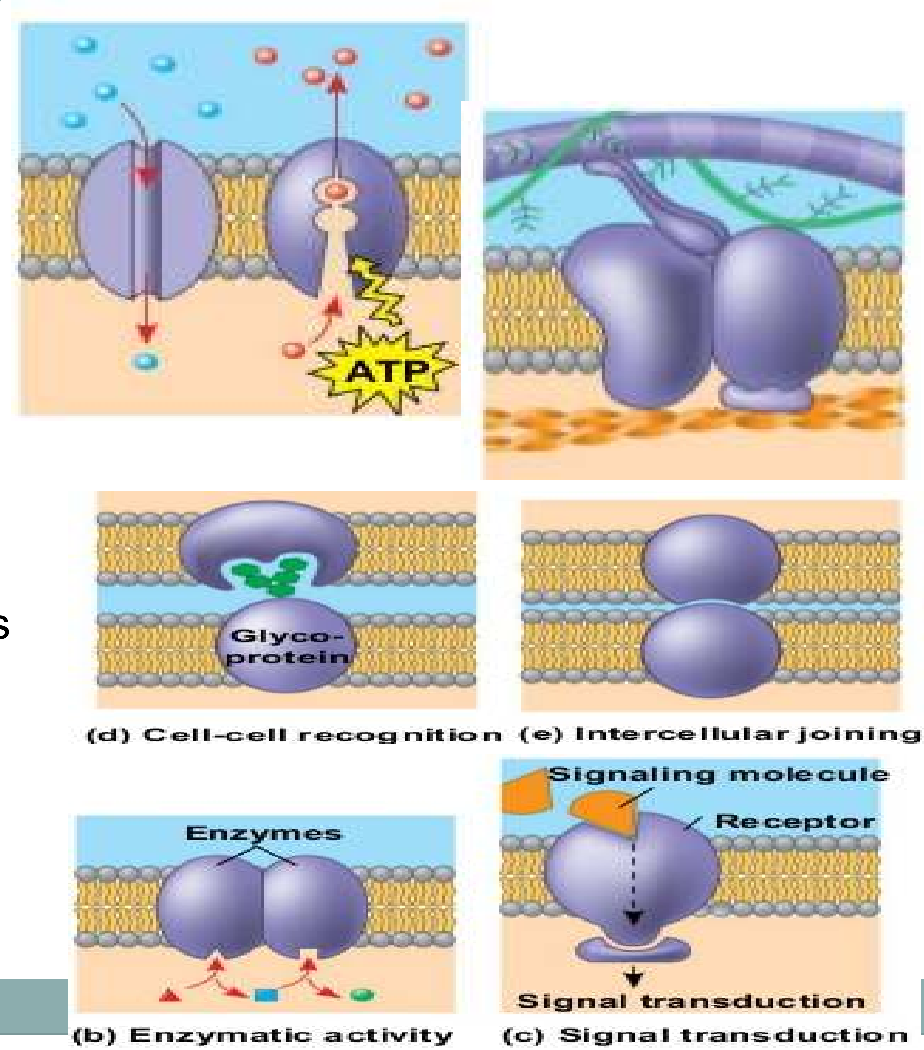
- **Membranes are mosaics of floating proteins in a lipid bilayer. 2 ways:**
  - **Integral Proteins:** **transmembrane, have both hydropohilic and hydrophobic parts**
  - **Peripheral Proteins:** **Attached to membrane's surface by:**
    - **Attachment to integral proteins or ECM fibers (outside)**
    - **Attachment to filaments of cytoskeleton (inside)**

Six major functions of membrane proteins



Functions of Proteins in the Membrane

- **Transport**
  - Regulate movement of some molecules across the membrane.
- **Structural**
  - Anchor cell to the extracellular matrix
  - Anchors proteins near the cell membrane
- **Recognition**
  - Glycoproteins: sugars attached to proteins allow cells to “recognize” each other
- **Communication**
  - Receptors and enzymes
  - Activation initiates cellular processes



Functions of Membrane Proteins

- **Transport**

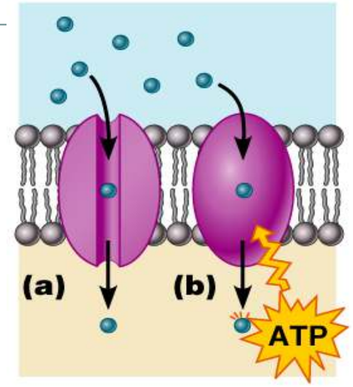
Transport Protein

- **Enzymatic activity**

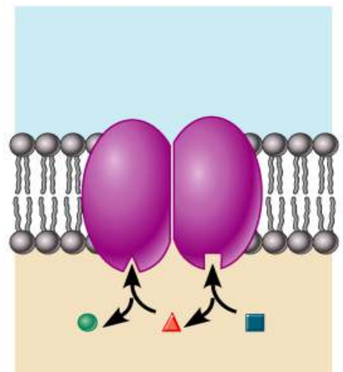
Enzymes

- **Receptors for signal transduction**

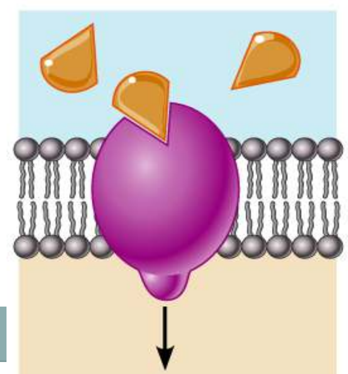
Receptor Proteins



Transport
(a) A protein that spans the membrane may provide a hydrophilic channel across the membrane that is selective for a particular solute. **(b)** Some transport proteins hydrolyze ATP as an energy source to actively pump substances across the membrane.



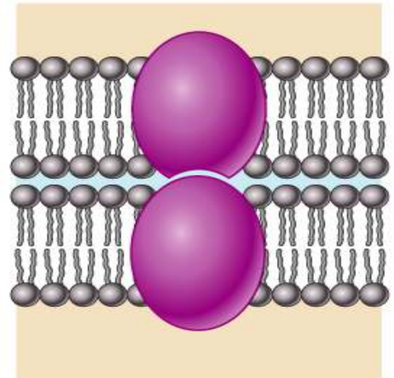
Enzymatic activity
A protein built into the membrane may be an enzyme with its active site exposed to substances in the adjacent solution. In some cases, several enzymes in a membrane act as a team that catalyzes sequential steps of a metabolic pathway as indicated (right to left) here.



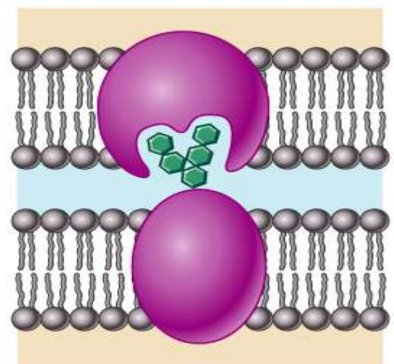
Receptors for signal transduction
A membrane protein exposed to the outside of the cell may have a binding site with a specific shape that fits the shape of a chemical messenger, such as a hormone. The external signal may cause a conformational change in the protein that initiates a chain of chemical reactions in the cell.

Functions of Membrane Proteins

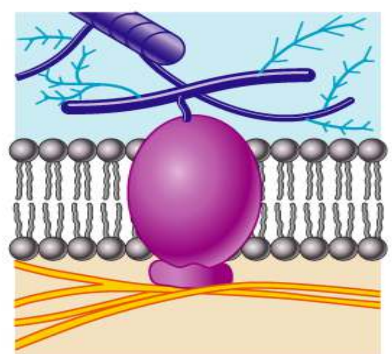
- **Intercellular adhesion**
- **Cell-cell recognition**
- **Attachment to cytoskeleton and extracellular matrix**



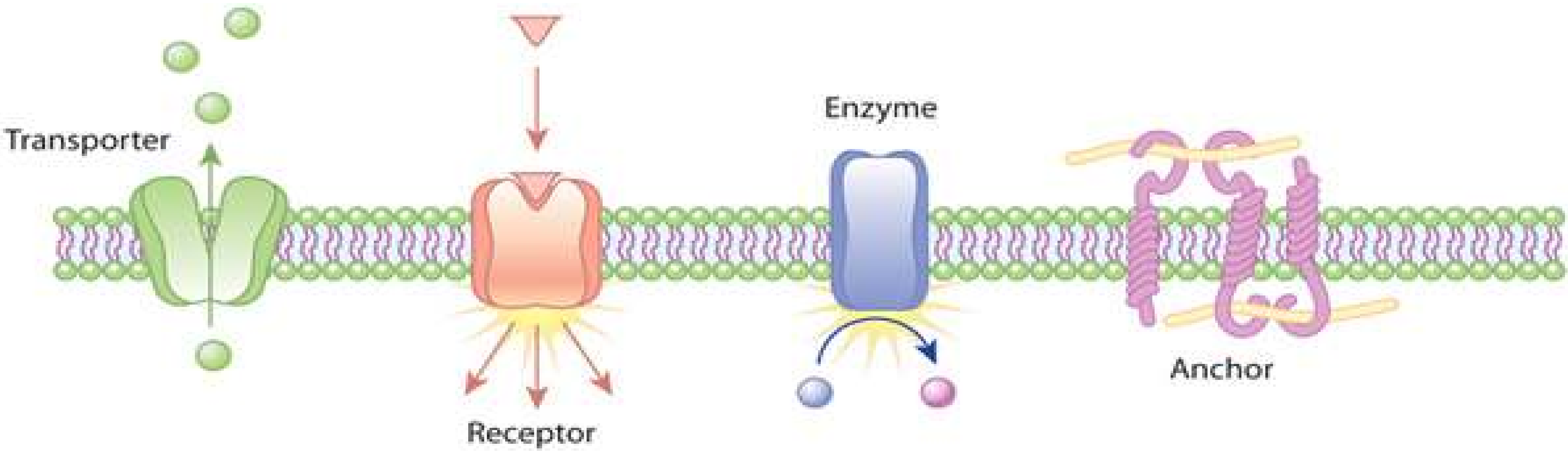
Intercellular joining
Membrane proteins of adjacent cells may be hooked together in various kinds of intercellular junctions. Some membrane proteins (CAMs) of this group provide temporary binding sites that guide cell migration and other cell-to-cell interactions.

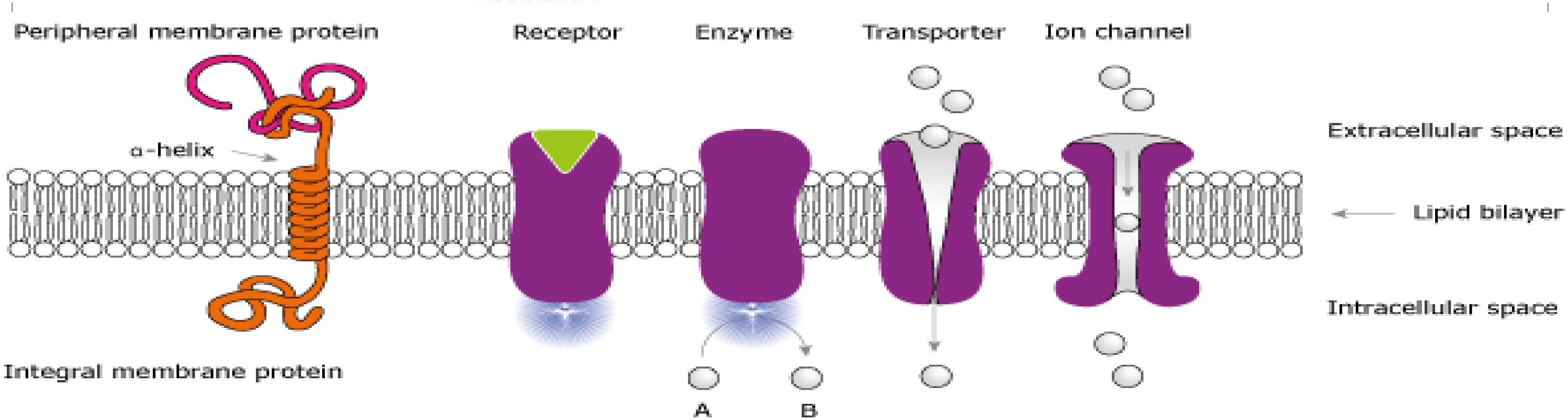


Cell-cell recognition
Some glycoproteins (proteins bonded to short chains of sugars) serve as identification tags that are specifically recognized by other cells.



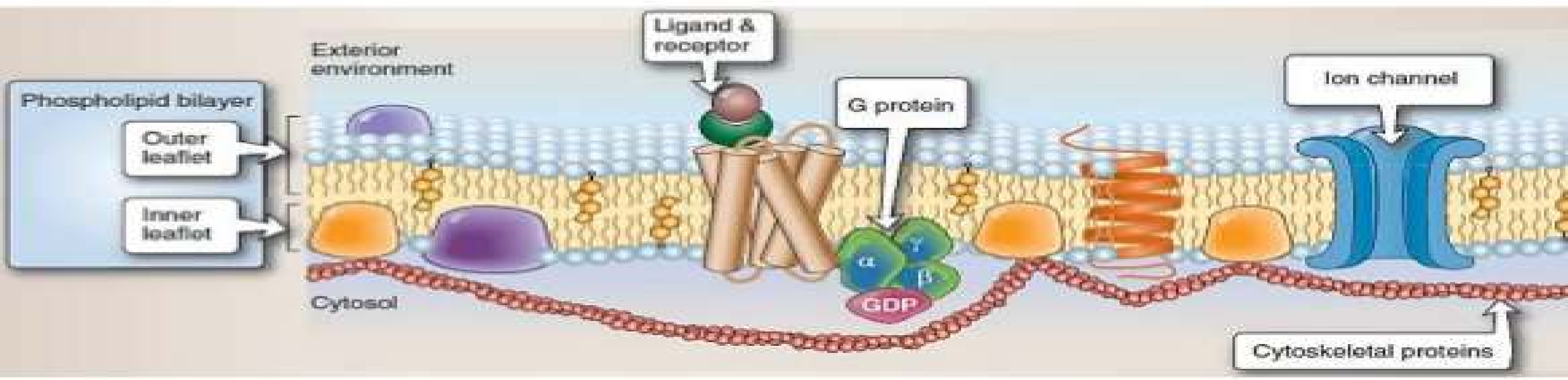
Attachment to the cytoskeleton and extracellular matrix (ECM)
Elements of the cytoskeleton (cell's internal supports) and the extracellular matrix (ECM) may be anchored to membrane proteins, which help maintain cell shape and fix the location of certain membrane proteins. Others play a role in cell movement or bind adjacent cells together.


Transporter
Enzyme
Anchor
Receptor


Peripheral membrane protein
Receptor
Enzyme
Transporter
Ion channel
α-helix
Extracellular space
Lipid bilayer
Intracellular space
Integral membrane protein
A
B

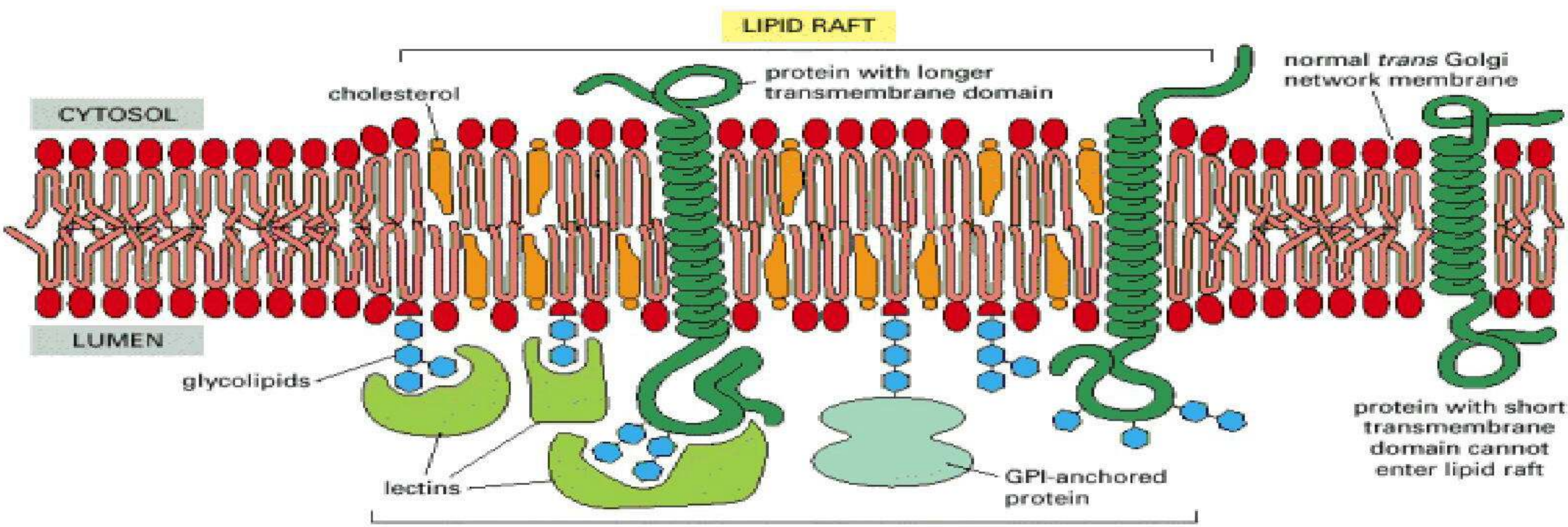
Plasma Membrane Surfaces

- **Differ in the kind and amount of lipids they contain**
- **Glycolipids are found only in the outer membrane surface**
- **20% of all membrane lipid is cholesterol**



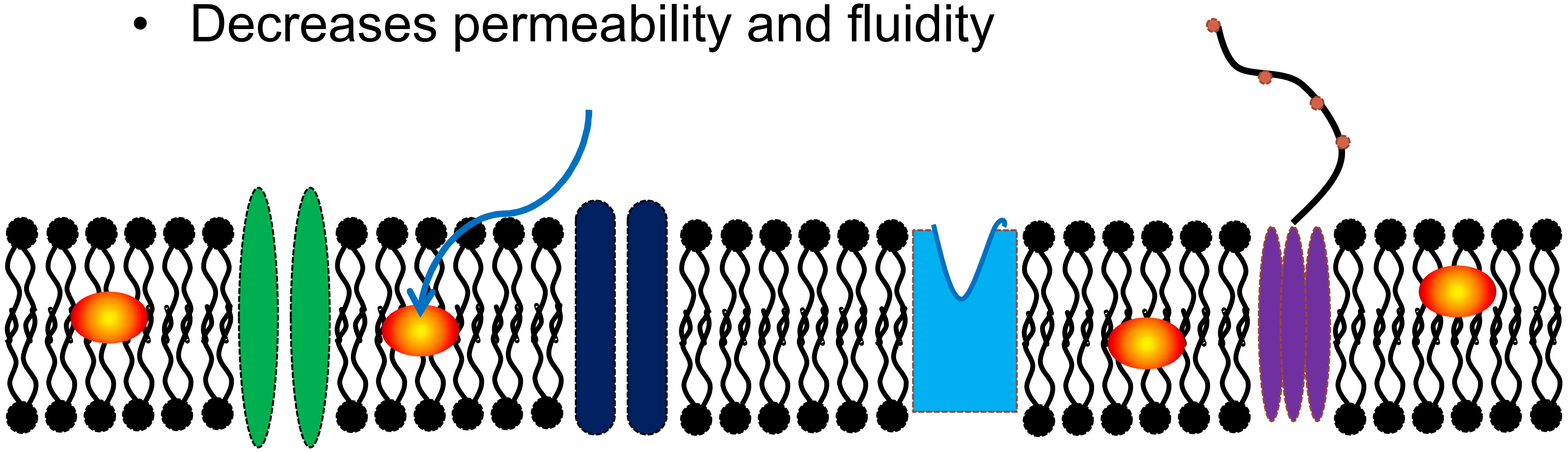
Lipid Rafts

- Make up 20% of the outer membrane surface
- **Composed of sphingolipids and cholesterol**
- **Are concentrating platforms for cell-signaling molecules**



Cholesterol:

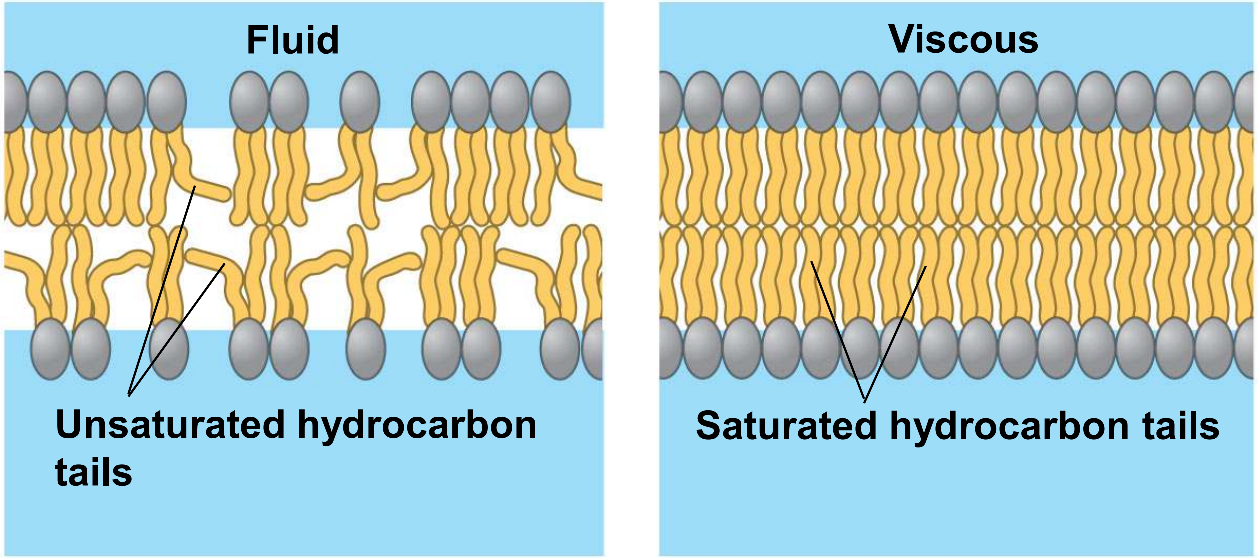
- animal cells incorporate cholesterol into their membranes to make them strong and flexible
- Decreases permeability and fluidity



Phospholipids are <u>not</u> cross-linked.

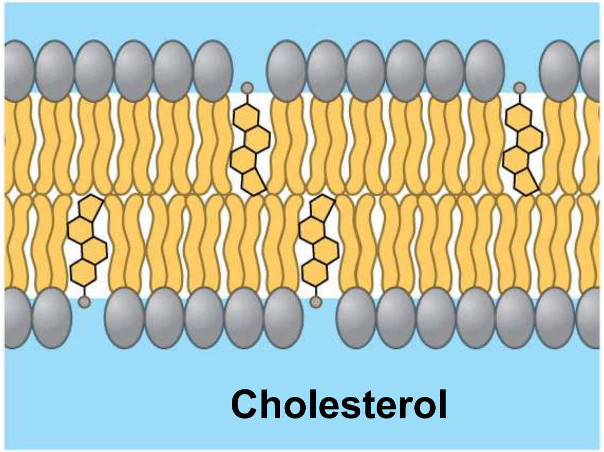
Membrane is a fluid!

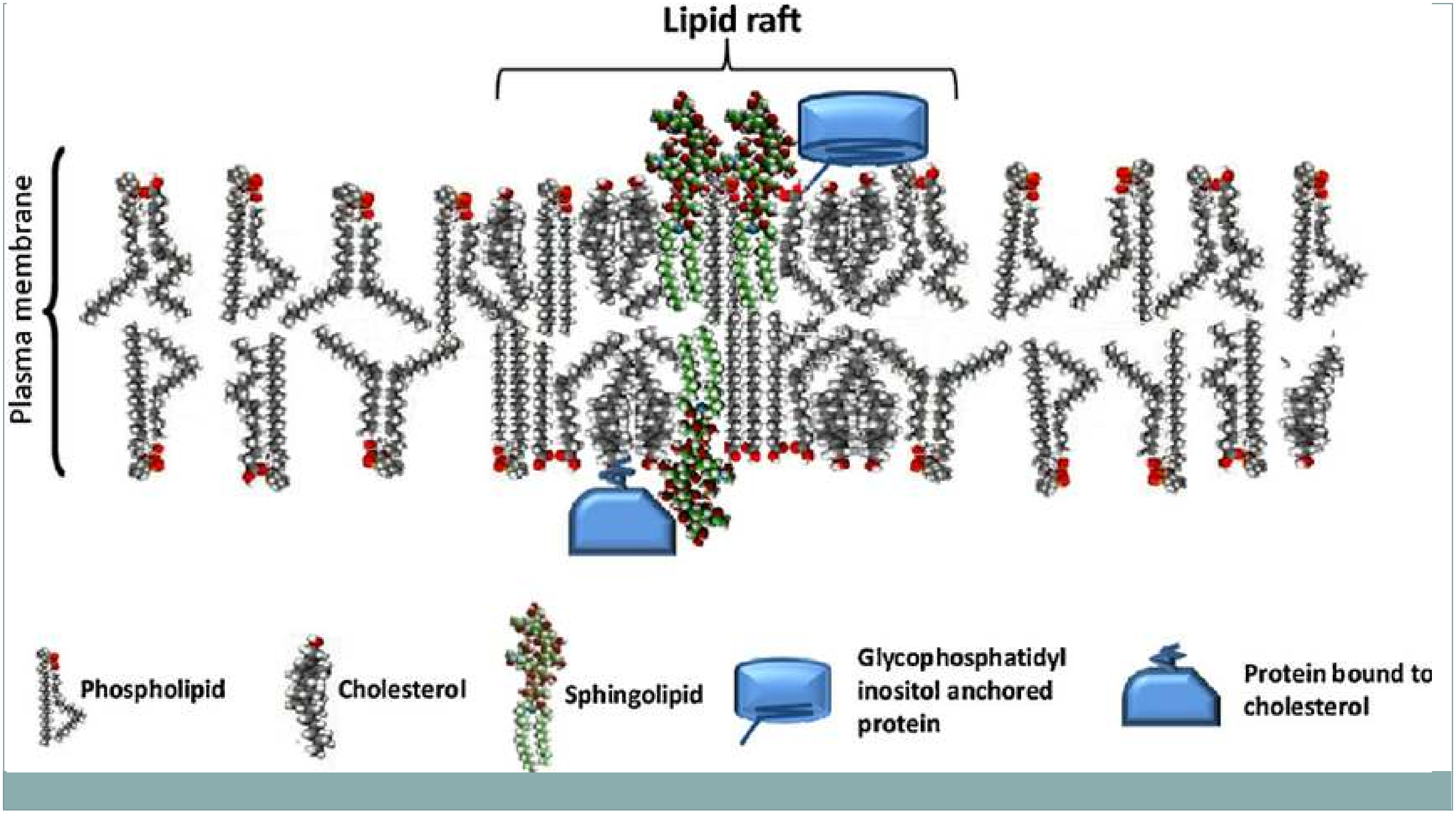
Figure 7.8



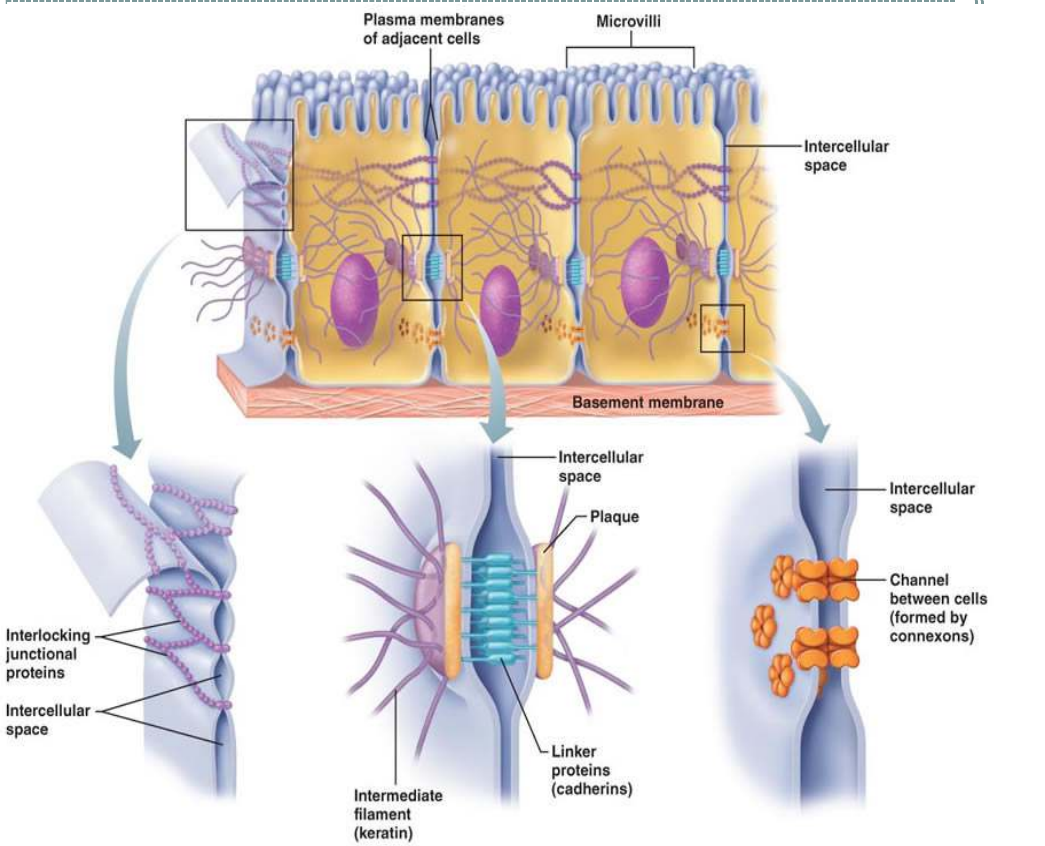
(a) Unsaturated versus saturated hydrocarbon tails

(b) Cholesterol within the animal cell membrane




Lipid raft
Plasma membrane
Phospholipid
Cholesterol
Sphingolipid
Glycophosphatidyl inositol anchored protein
Protein bound to cholesterol

Membrane Junctions

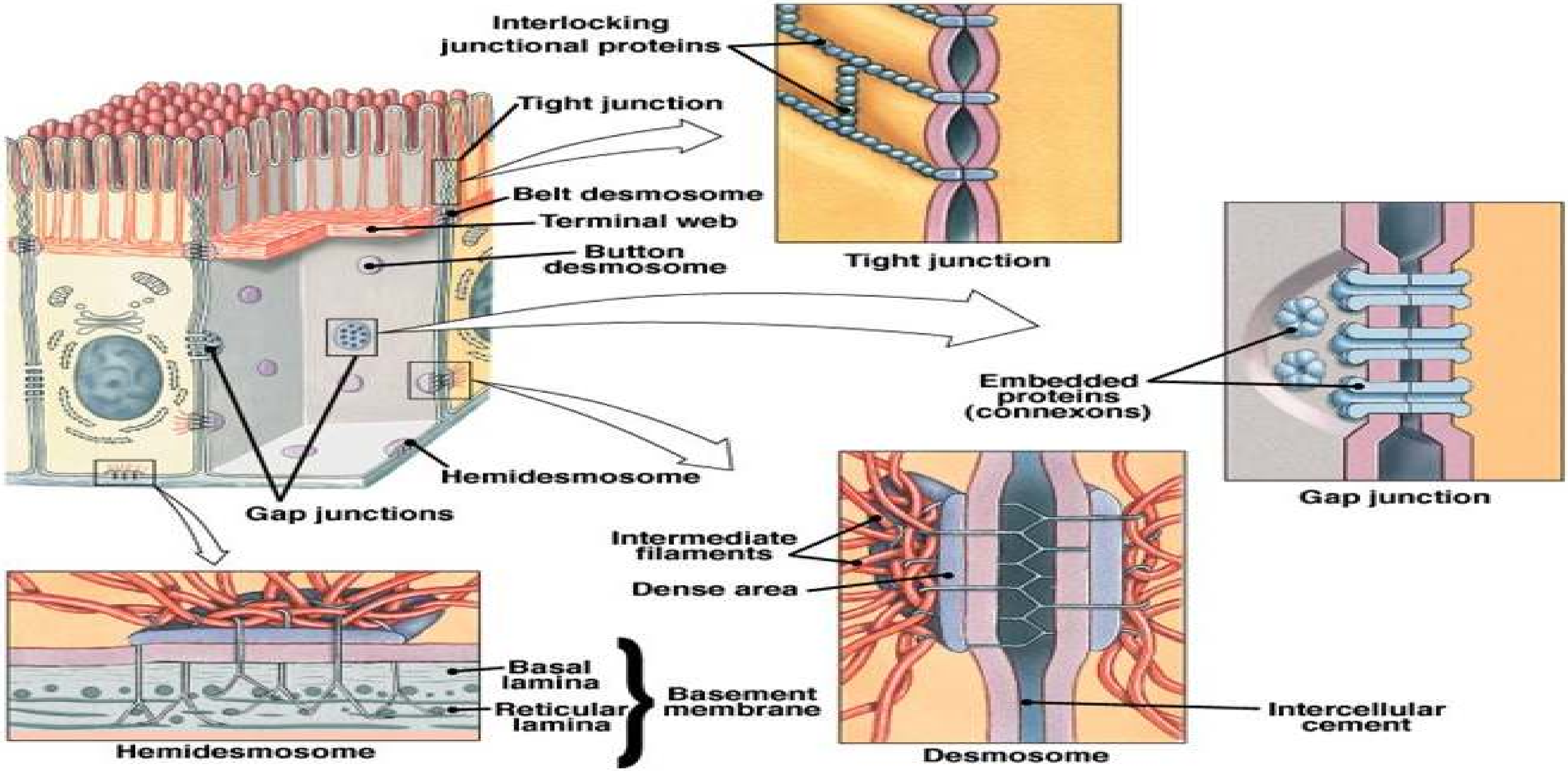


(a) Tight junctions: Impermeable junctions prevent molecules from passing through the intercellular space.

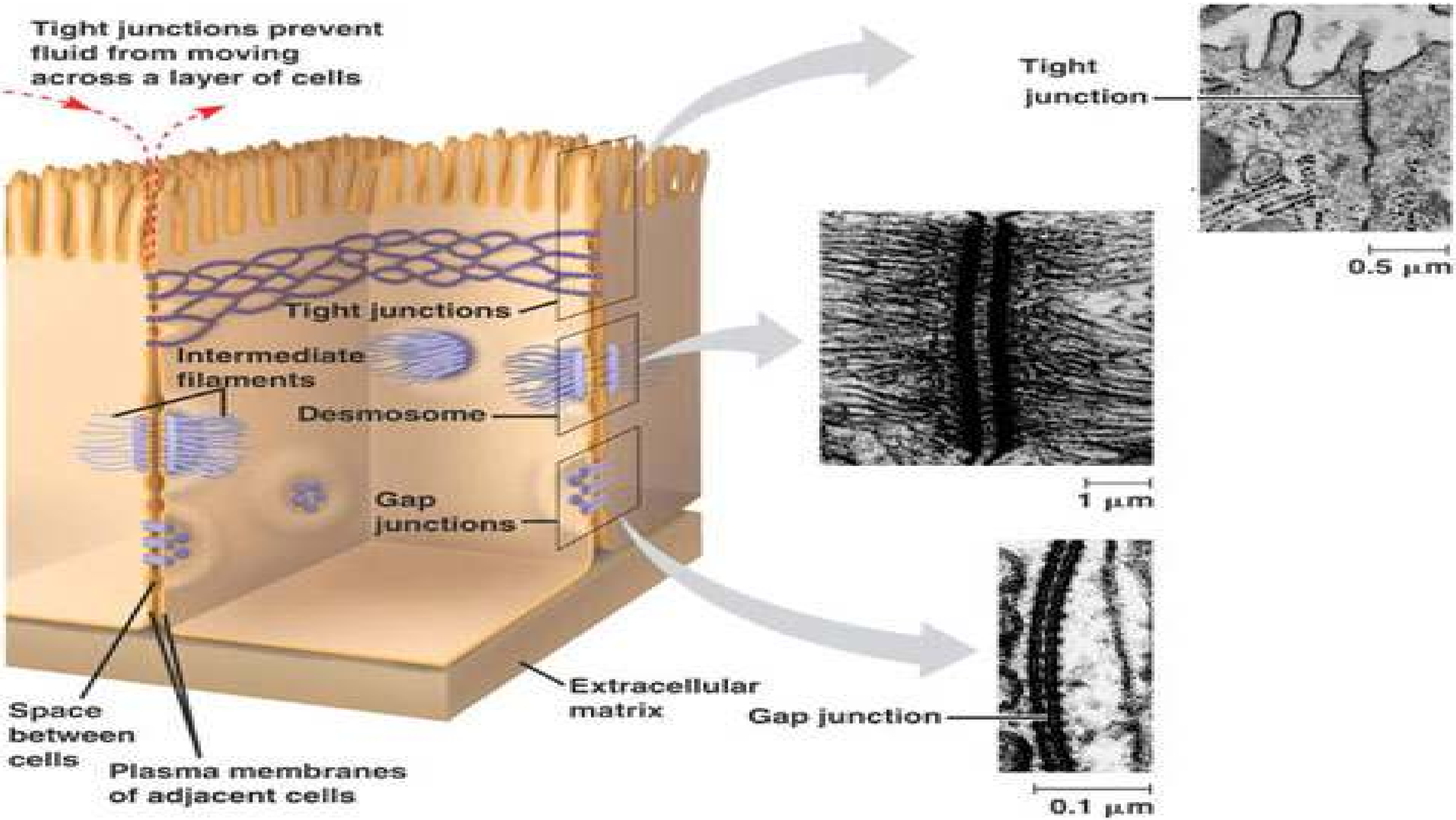
(b) Desmosomes: Anchoring junctions bind adjacent cells together like a molecular "Velcro" and help form an internal tension-reducing network of fibers.

(c) Gap junctions: Communicating junctions allow ions and small molecules to pass for intercellular communication.

- **Tight junction – impermeable junction that encircles the cell**
- **Desmosome – anchoring junction scattered along the sides of cells**
- **Hemidesmosomes : basalmembrane to cell**
- **Gap junction – a nexus that allows chemical substances to pass between cells**

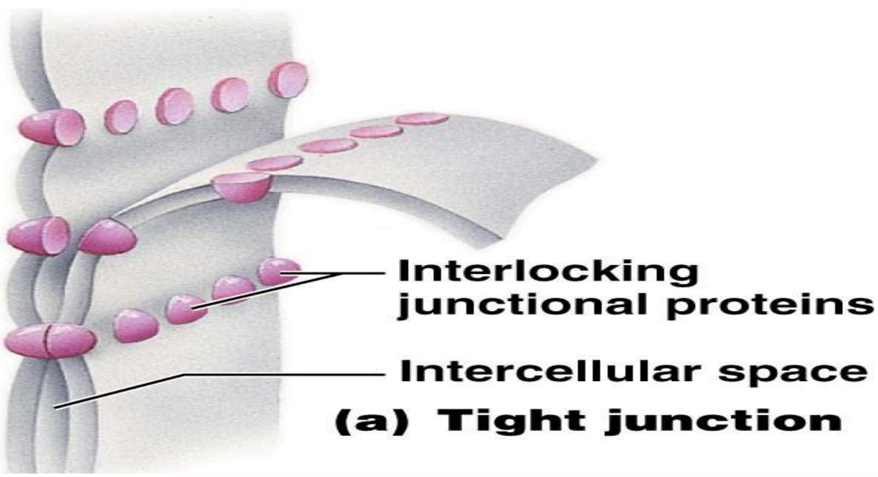


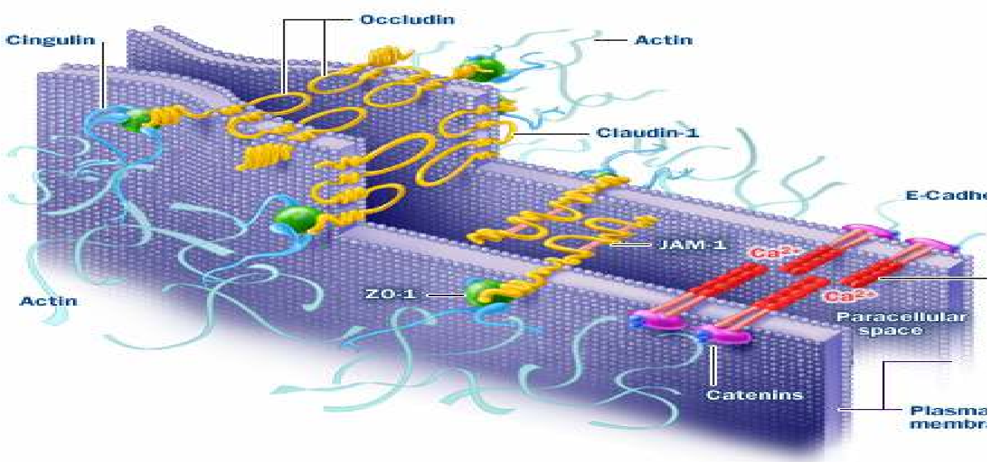
Interlocking junctional proteins
Tight junction
Belt desmosome
Terminal web
Button desmosome
Tight junction
Embedded proteins (connexons)
Gap junction
Hemidesmosome
Gap junctions
Intermediate filaments
Dense area
Basal lamina
Reticular lamina
Basement membrane
Hemidesmosome
Intercellular cement
Desmosome

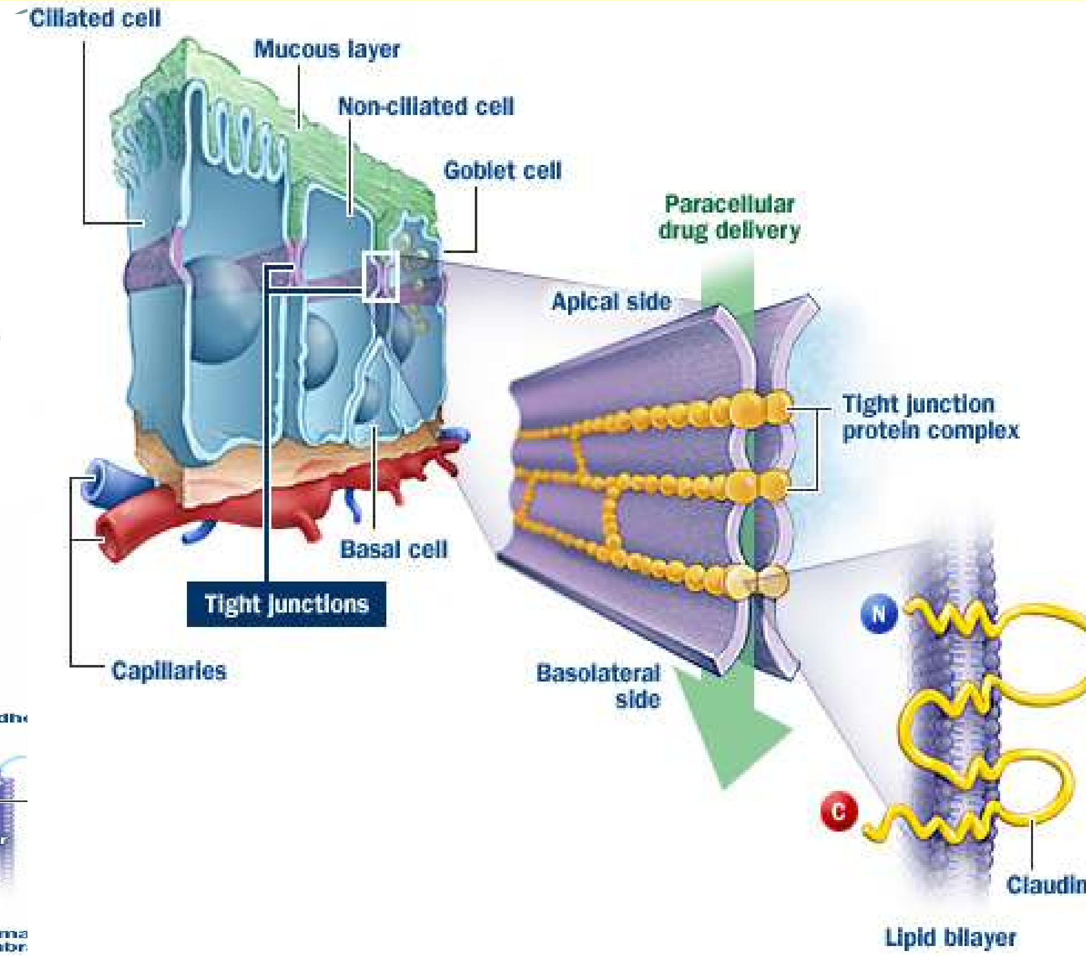


Tight junctions prevent fluid from moving across a layer of cells
Tight junctions
Intermediate filaments
Desmosome
Gap junctions
Space between cells
Plasma membranes of adjacent cells
Extracellular matrix
Tight junction
0.5 µm
1 µm
Gap junction
0.1 µm

Membrane Junctions: Tight Junction





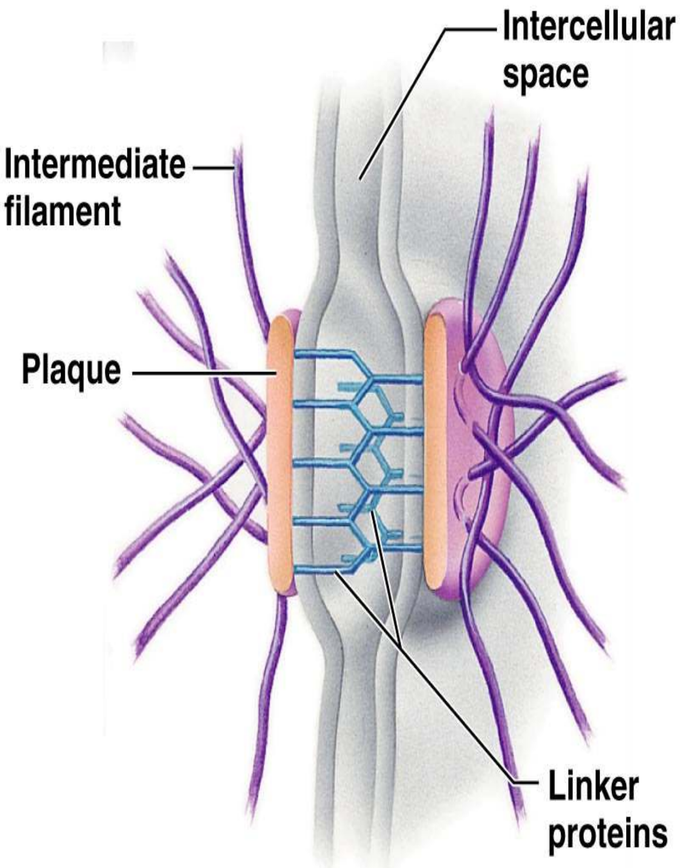


Tight junction

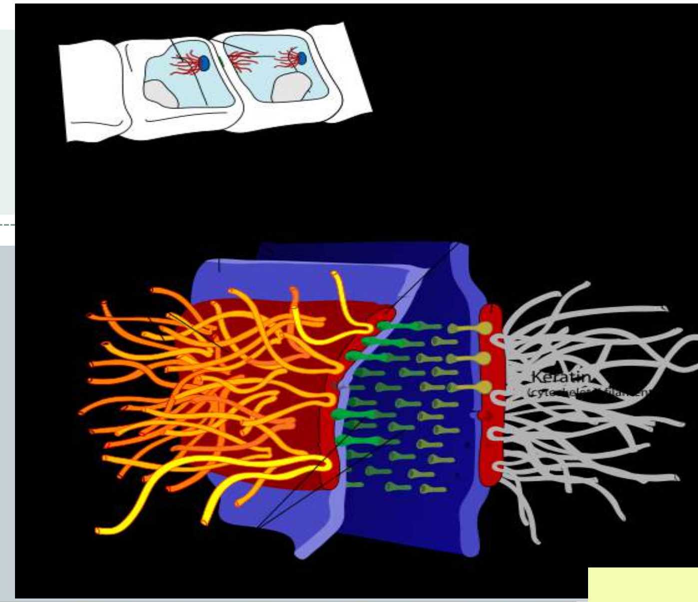
- Tight junctions are found in all tissues, but those of particular relevance to drug delivery include:
    - **Nasal tissue**
    - **Gastrointestinal tissue - where oral drugs are absorbed**
    - **Blood vessels**
    - **Blood-brain barrier**

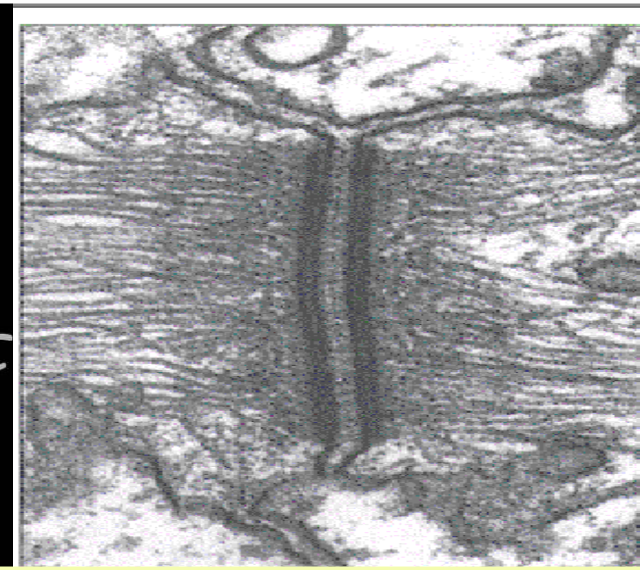
- Tight junctions consist of proteins, for example:
    - **claudins**
    - **occludins**
    - **junctional adhesion**

Membrane Junctions: Desmosome

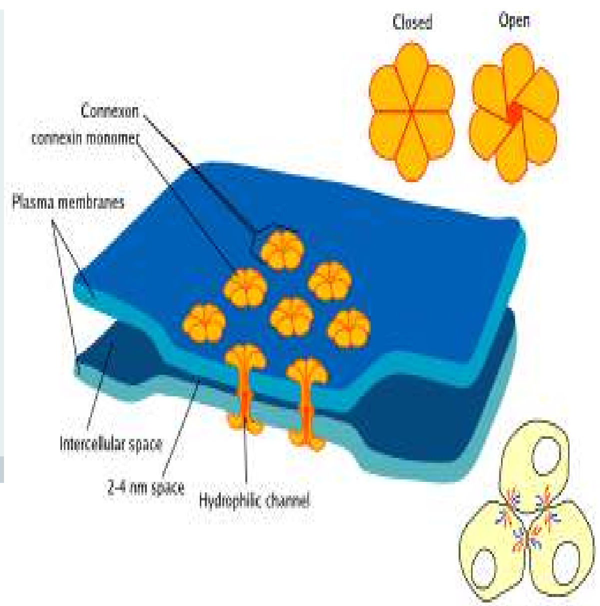


(b) Desmosome

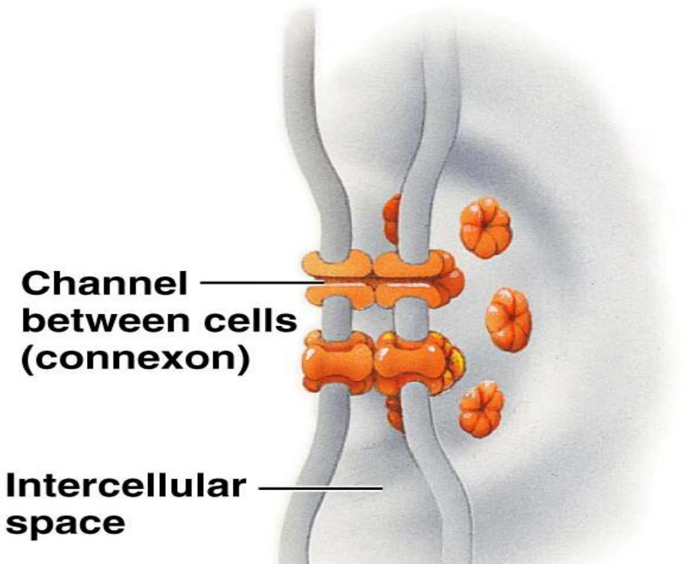




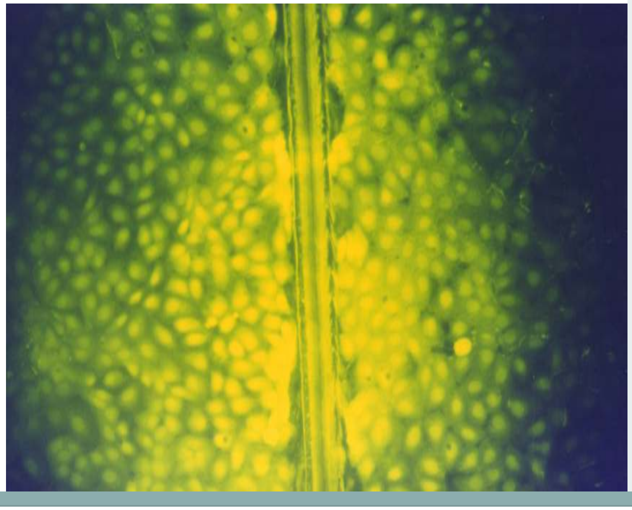
Membrane Junctions: Gap Junction = **nexus** or **macula communicans**



- **Protienaceous tubes that connect adjacent cells.**
- **These tubes allow material to pass from one cell to the next without having to pass through the plasma membranes of the cells.**
- **Dissolved substances such as ions or glucose can pass through the gap junctions.**
- **Large organelles such as mitochondria connot pass.**
- ***Ca++ control of gap junction opening***
- Gap junctions occur in virtually all tissues of the body, with the **exception of adult fully developed skeletal muscle and mobile cell types such as sperm or erythrocytes.**

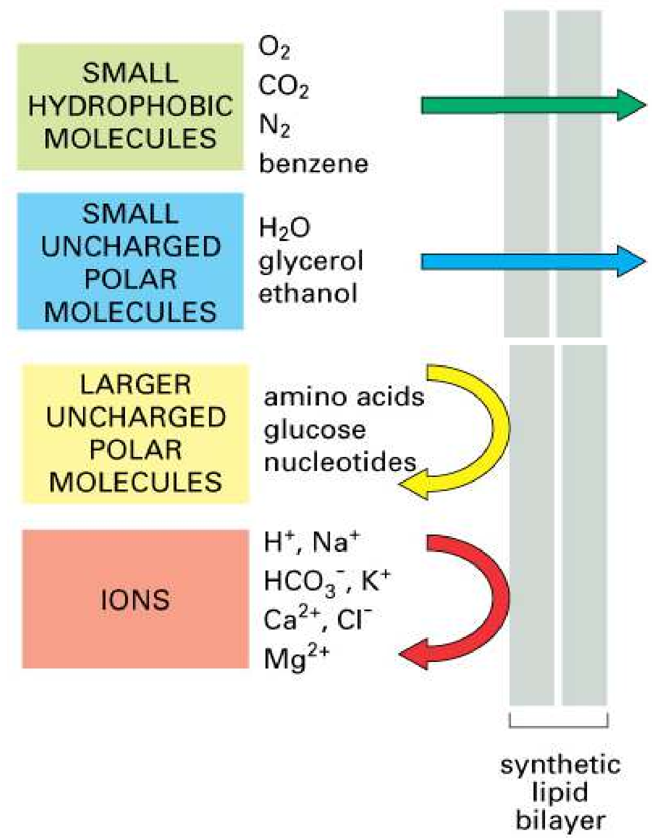


(c) Gap junction



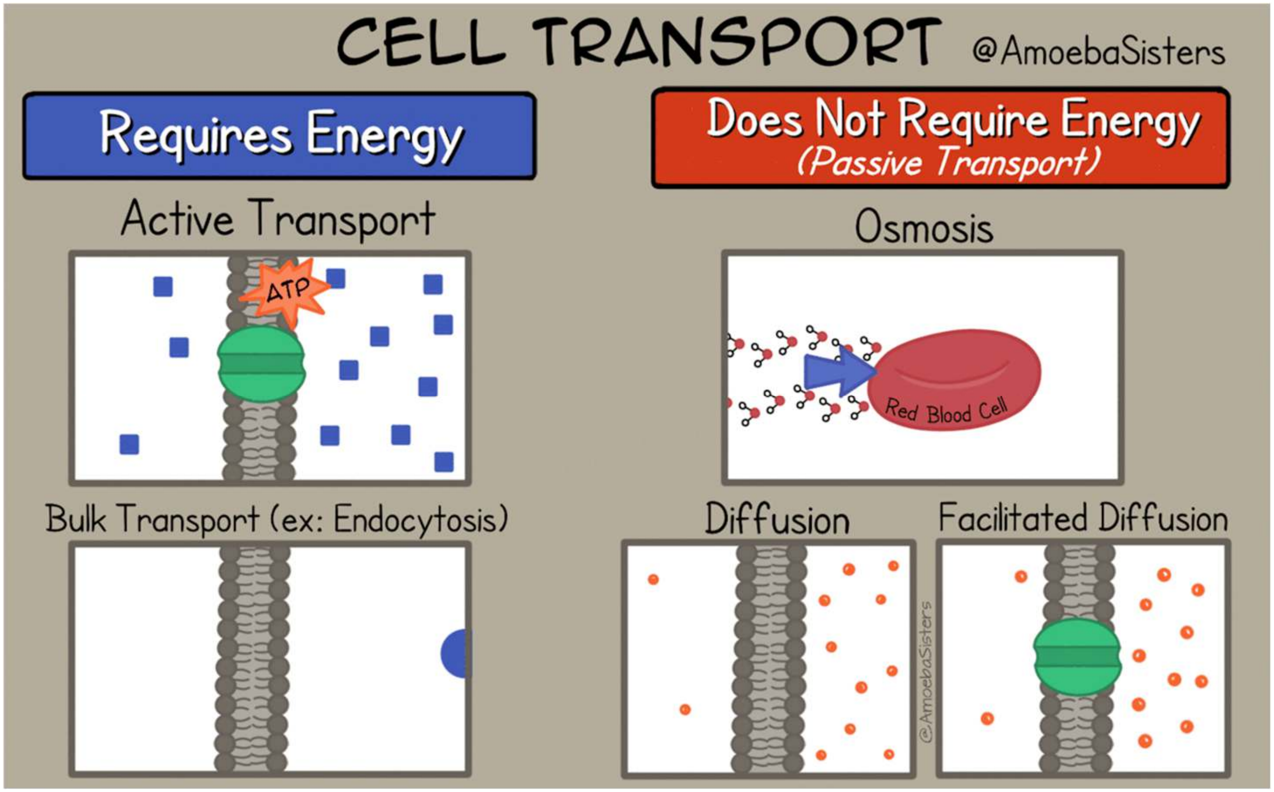
Membrane Permeability

- Ability to get things in and out of the cell!
  - Plasma membranes are **selectively permeable**
    - Small hydrophobic and/or uncharged molecules can pass through
    - Larger and charged/polar molecules cannot
  - Transport proteins are needed to move **large** and **charged/polar** molecules in/out of the cell.



Types of Cell Membrane Transport

- a. Passive Transport
- b. Active Transport



There are two ways that materials can move in/out of the cell

1. Passive Transport
   - Diffusion
   - Facilitated Diffusion
   - Osmosis

2. Active Transport
   - Protein Pumps
   - Endocytosis
   - Exocytosis

Passive Membrane Transport: Diffusion

I/ Simple diffusion

II/ Facilitated diffusion

Diffusion

- The movement of molecules from an area of higher concentration to an area of lower concentration until **equilibrium** is attained.

- Diffusion happens when there is a **concentration gradient .** The process by which molecules

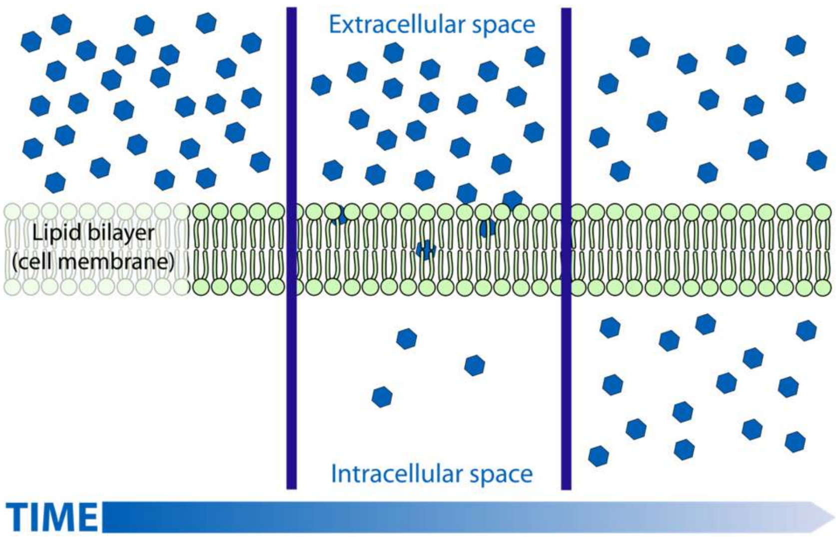
spread from areas of high concentration, to areas of low concentration (Moving across the concentration gradient)

- No energy is required
- When the molecules are even throughout a space - it is called **EQUILIBRIUM**

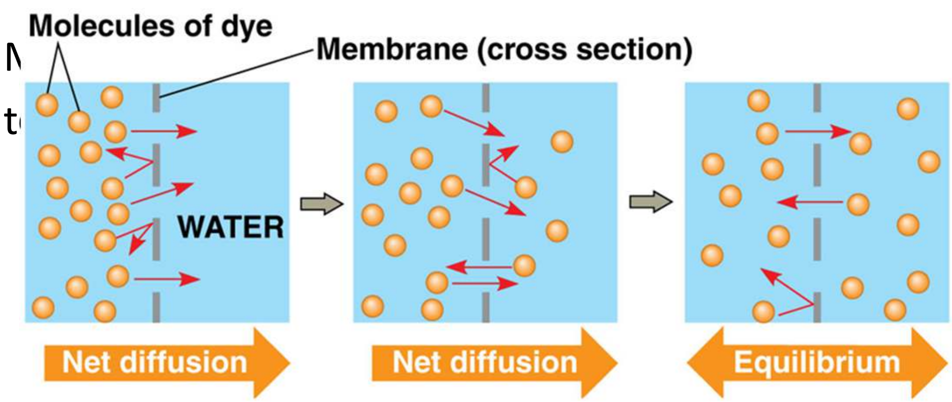
  - A difference in concentration of a substance

- N
  t

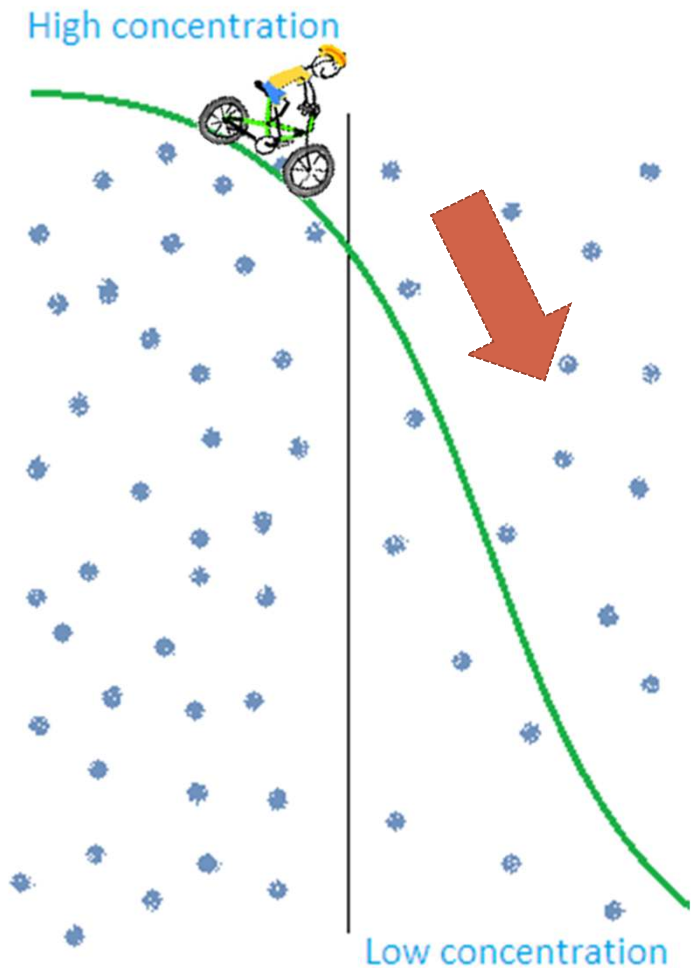
High Conc.



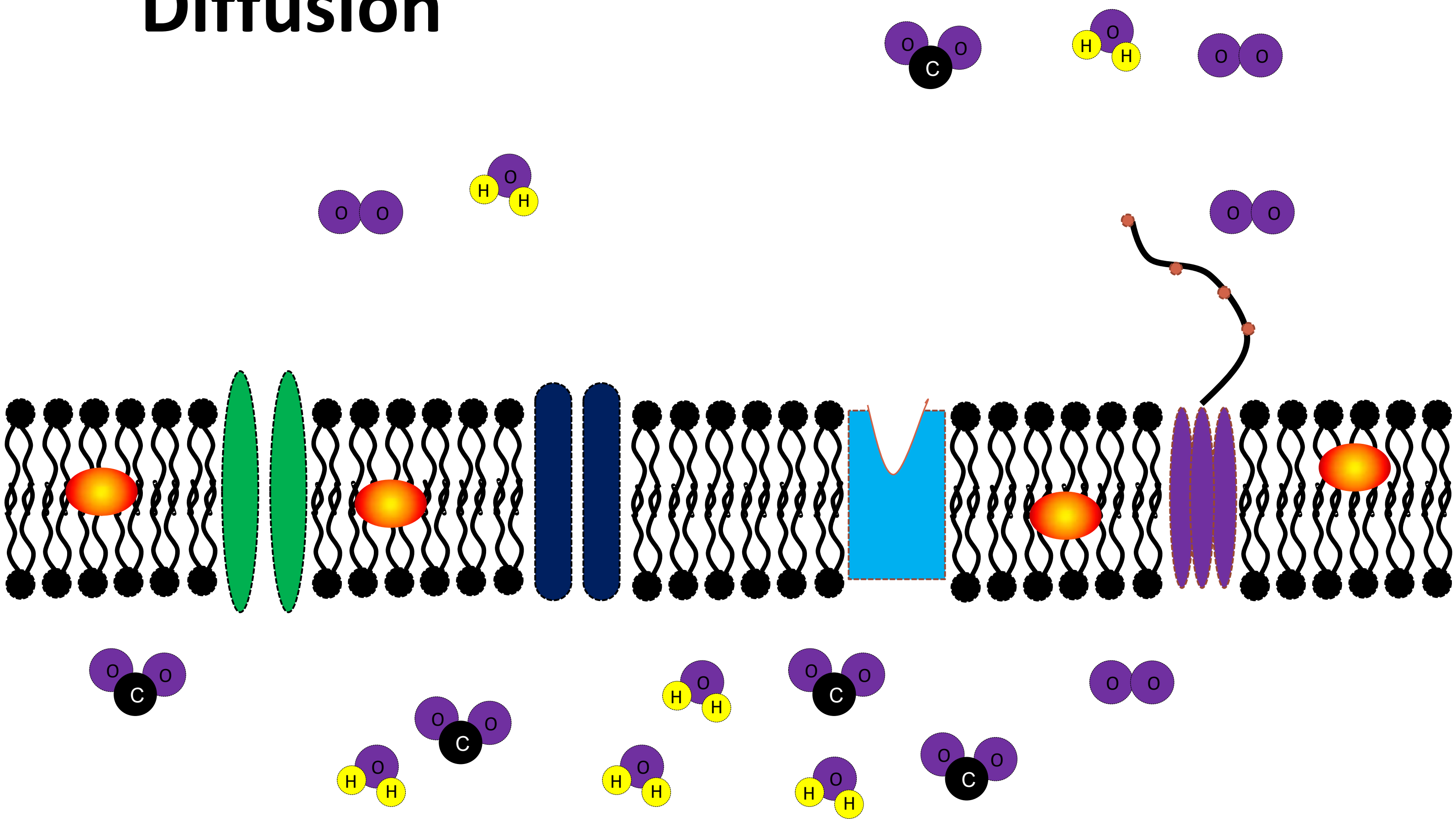
Low Conc.



Equilibrium means the concentrations are *uniformly distributed*


High concentration
Low concentration

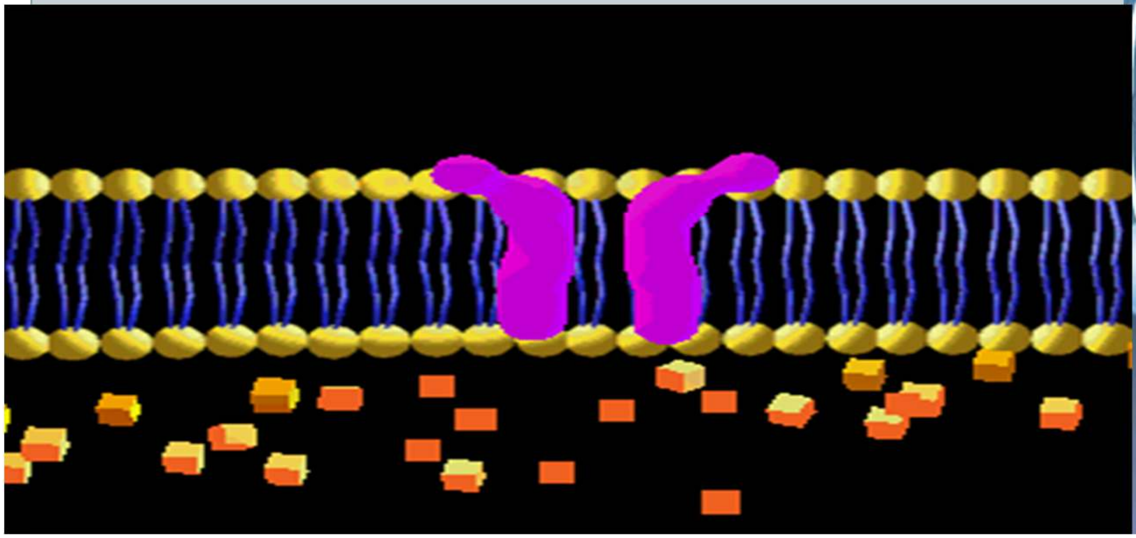
Diffusion

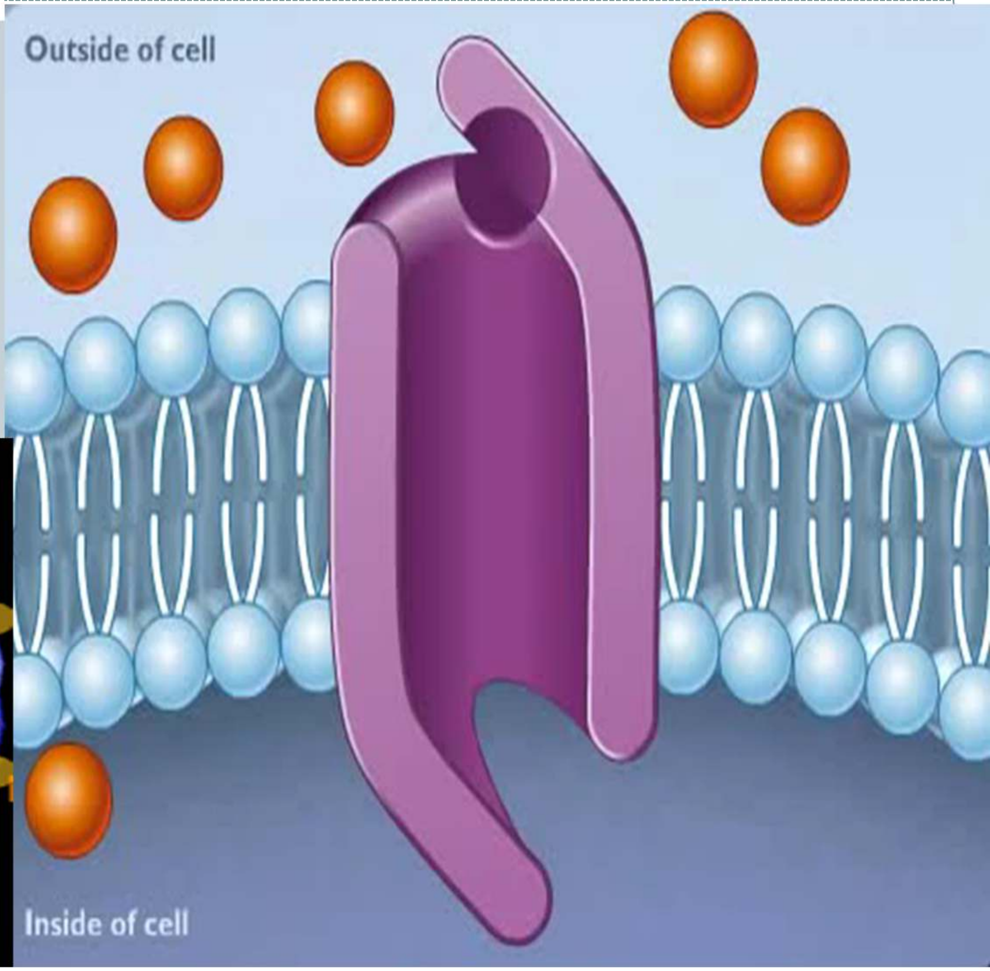


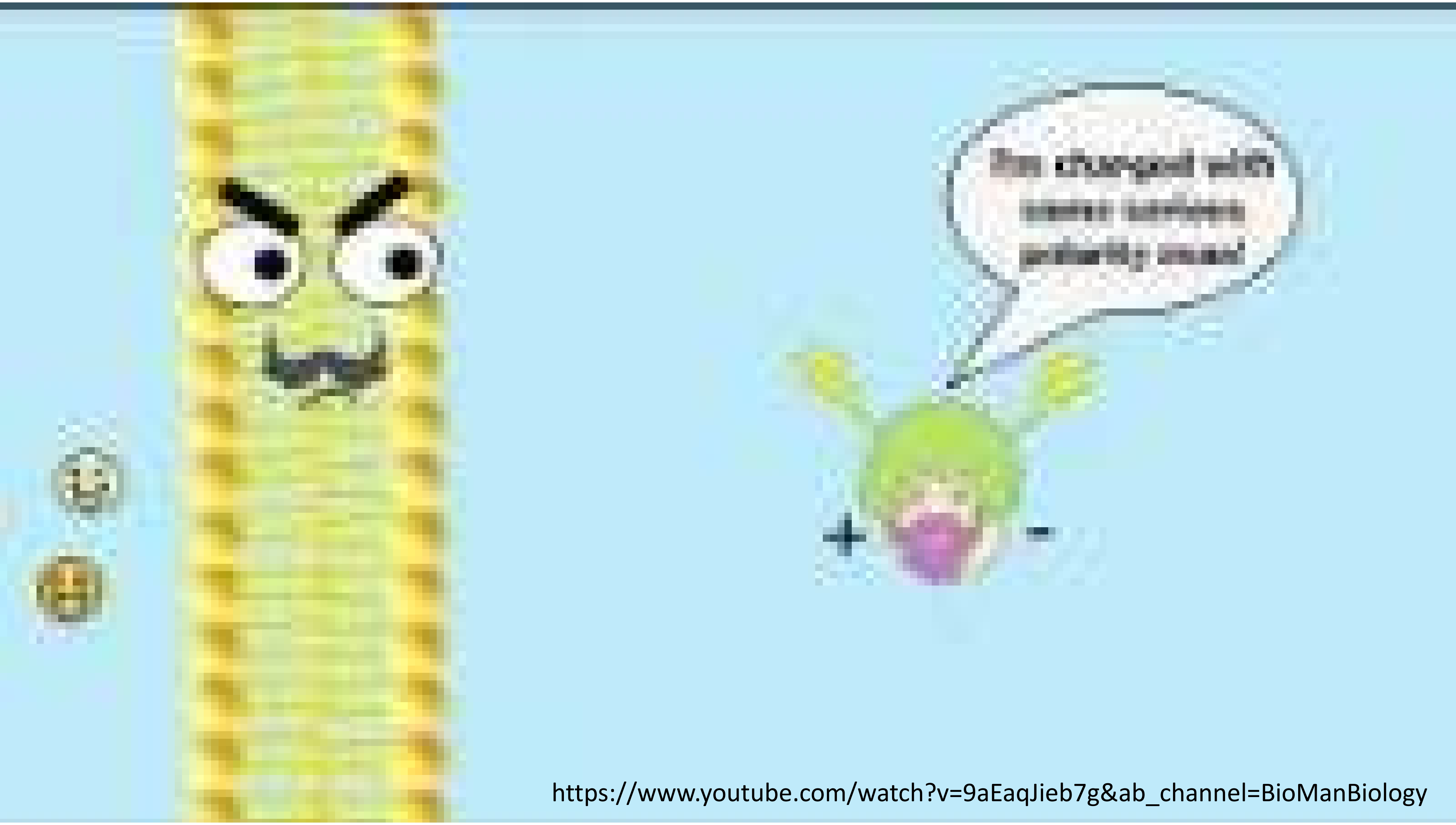
Oxygen, carbon dioxide, water (in small amounts), small lipids

Passive Membrane Transport: Diffusion

- **Simple diffusion** – nonpolar and lipid-soluble substances
  - **Diffuse directly through the lipid bilayer**
  - **Diffuse through channel proteins**



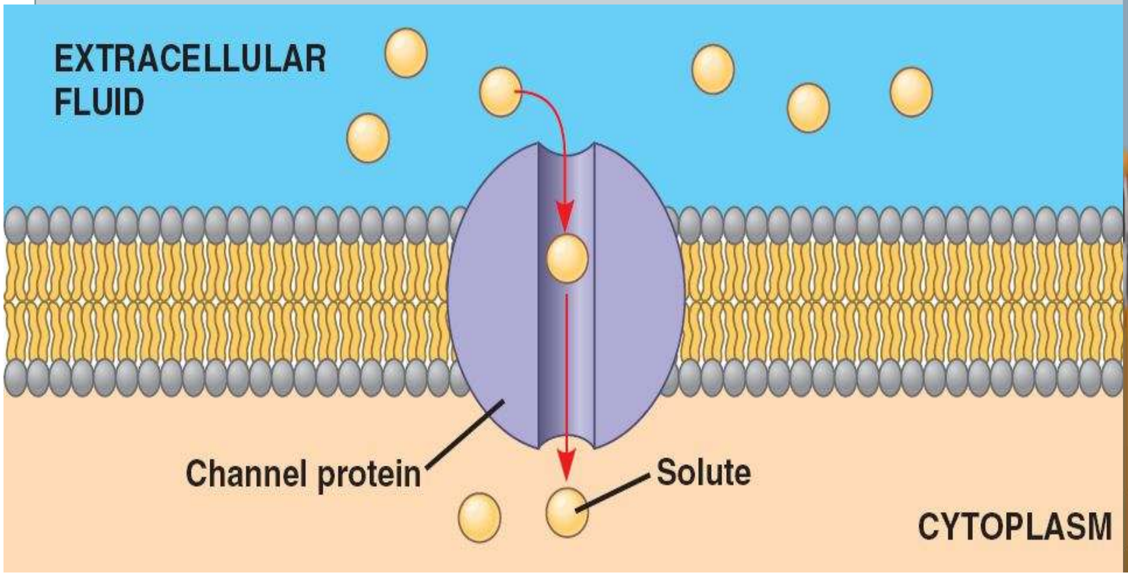


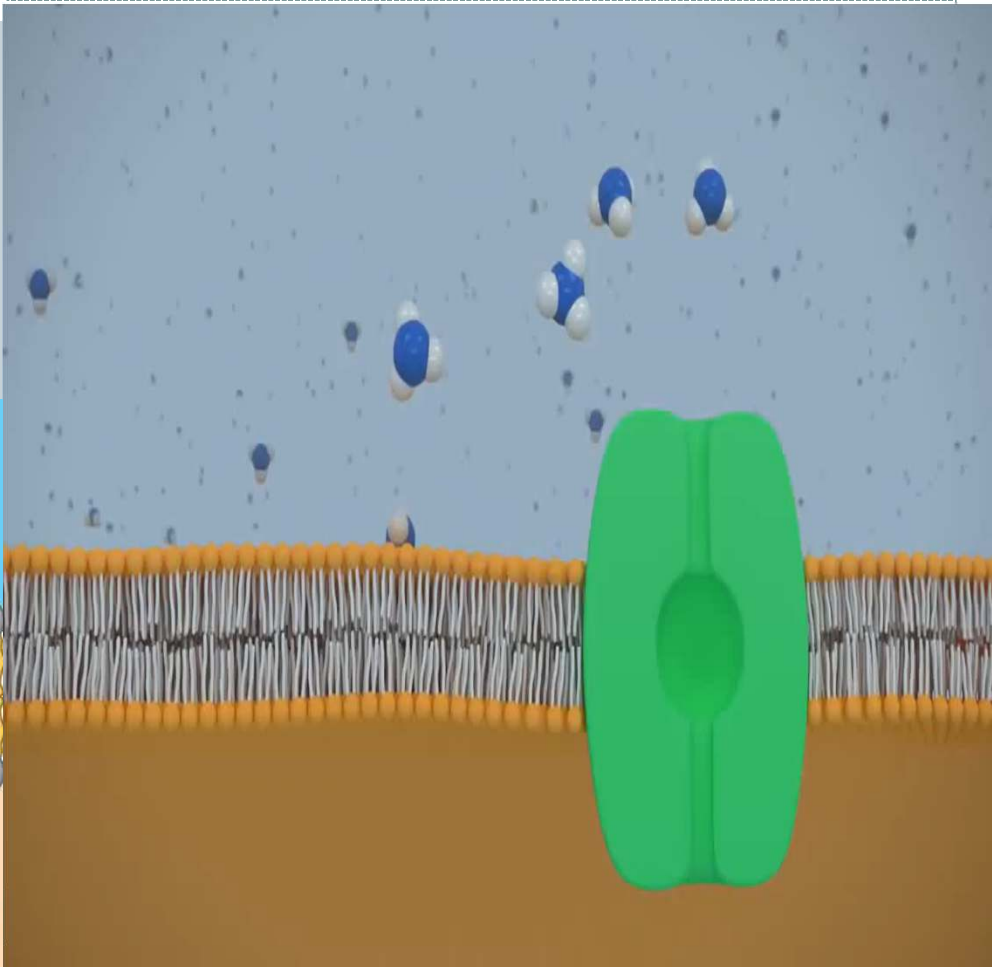


https://www.youtube.com/watch?v=9aEaqJieb7g&ab_channel=BioManBiology

Passive Membrane Transport: Diffusion

- **Facilitated diffusion**
  - Transport of glucose, amino acids, and ions
  - Transported **substances bind carrier proteins or pass through protein channels**





Mechanism of Facilitated Diffusion:

1. **Transport Proteins:** Facilitated diffusion involves the presence of specific proteins embedded in the cell membrane called carrier proteins or channel proteins.
   - These proteins create passageways, either channels or carriers, allowing certain molecules to move across the membrane.

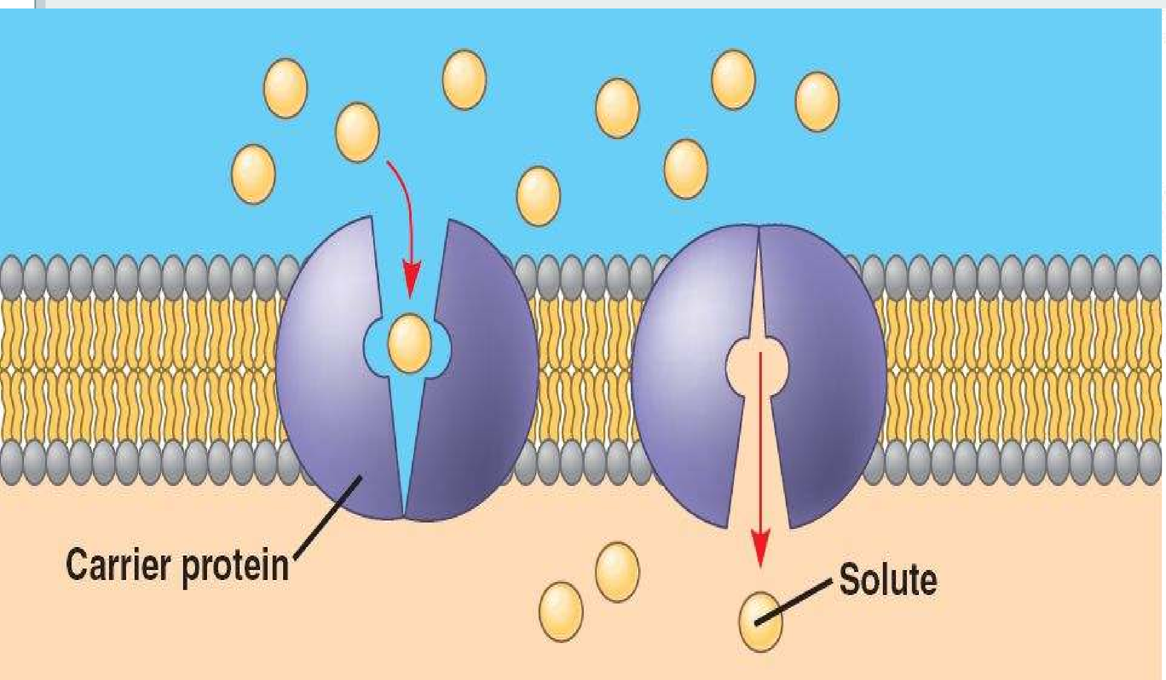
2. **Selectivity:** Transport proteins are selective in the substances they allow to pass through.
   - Each protein is designed to facilitate the movement of specific molecules or ions.
   - This selectivity ensures that only the necessary substances are transported into or out of the cell.

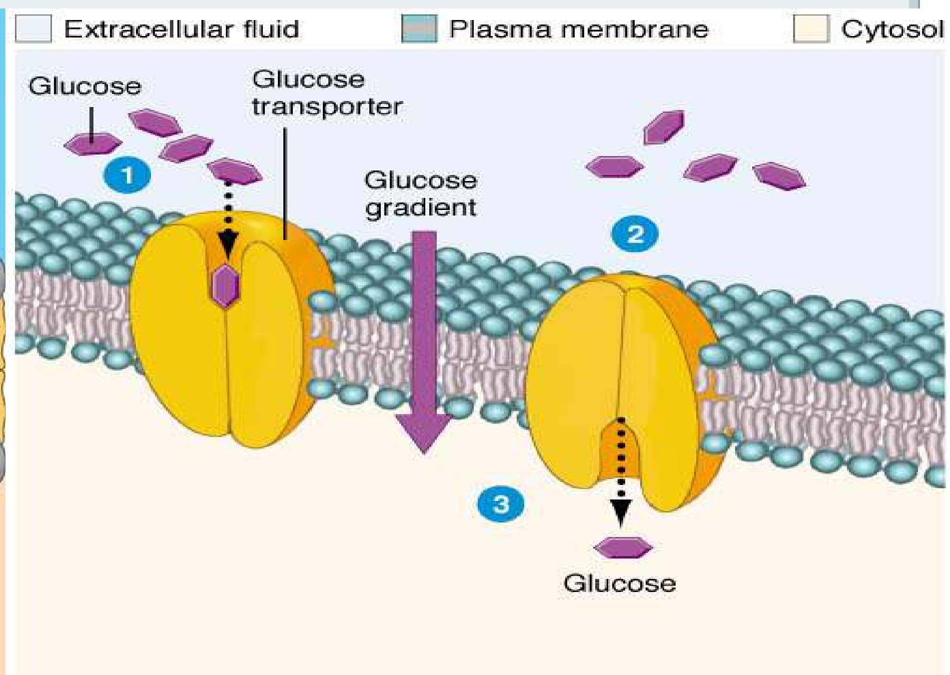
3. **Directionality:** Facilitated diffusion occurs down the concentration gradient, meaning that substances move from an area of higher concentration to an area of lower concentration.
   - This is a passive process, and no energy is expended by the cell.

4. **Saturation:** The rate of facilitated diffusion is limited by the number of available transport proteins.
   - Once all the proteins are in use, the rate of diffusion reaches a maximum, and further increases in substrate concentration do not result in increased transport.

Carrier Proteins

- Are integral transmembrane proteins
- Show specificity for certain polar molecules including sugars and amino acids

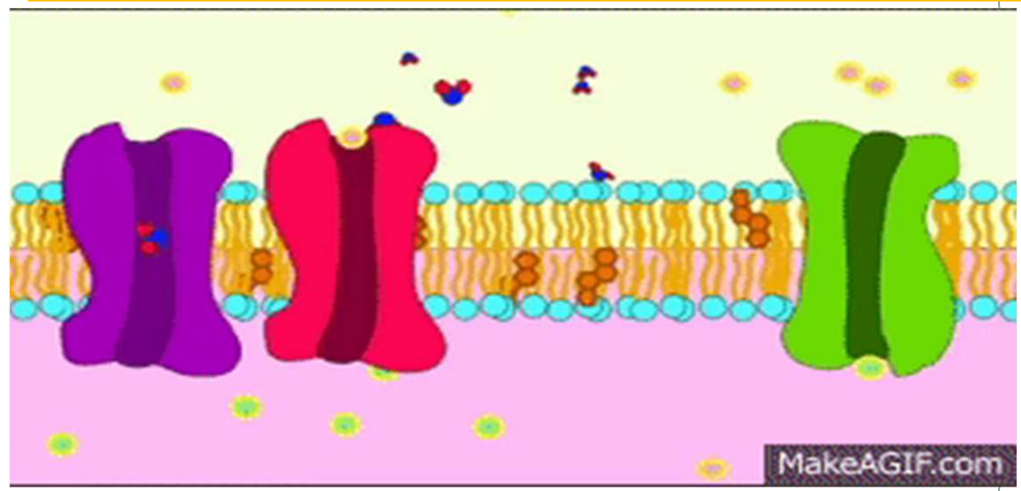


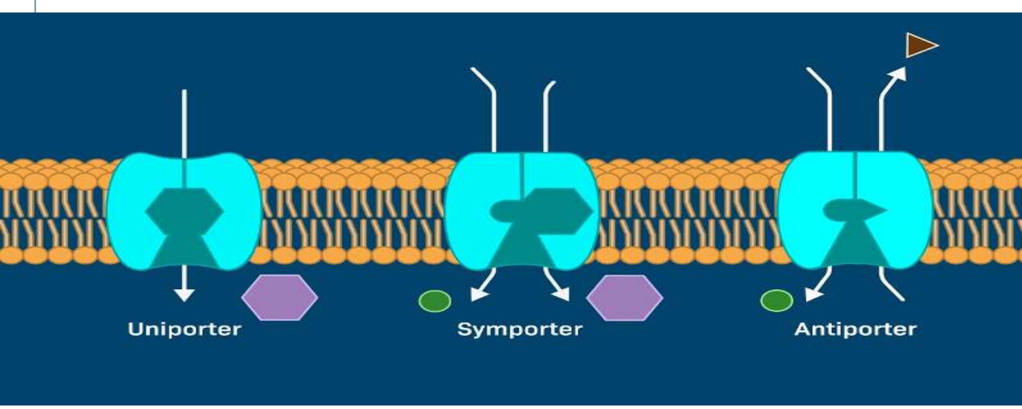


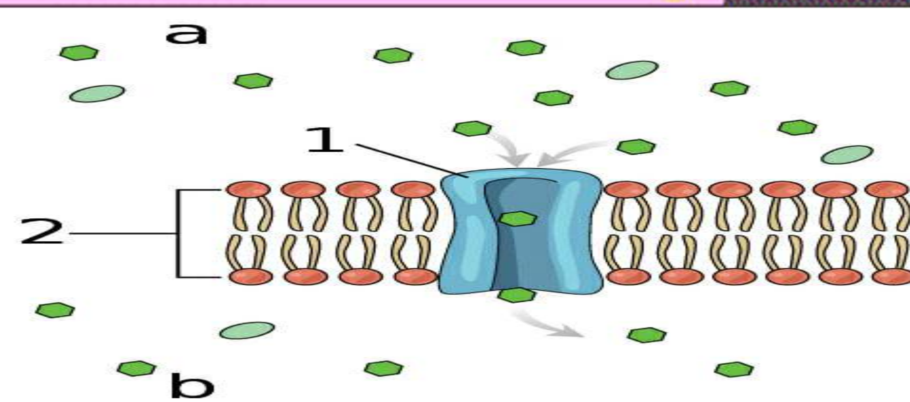
There are two main types of facilitated diffusion proteins:

- **Channel Proteins:** These form channels or pores in the membrane that allow specific ions or molecules to pass through.
  - Channel proteins are usually specific to certain types of substances, ensuring a high degree of selectivity.

- **Carrier Proteins:** These undergo a conformational change to transport a specific molecule across the membrane.
  - The carrier protein binds to the molecule on one side of the membrane, undergoes a change in shape, and releases the molecule on the other side.





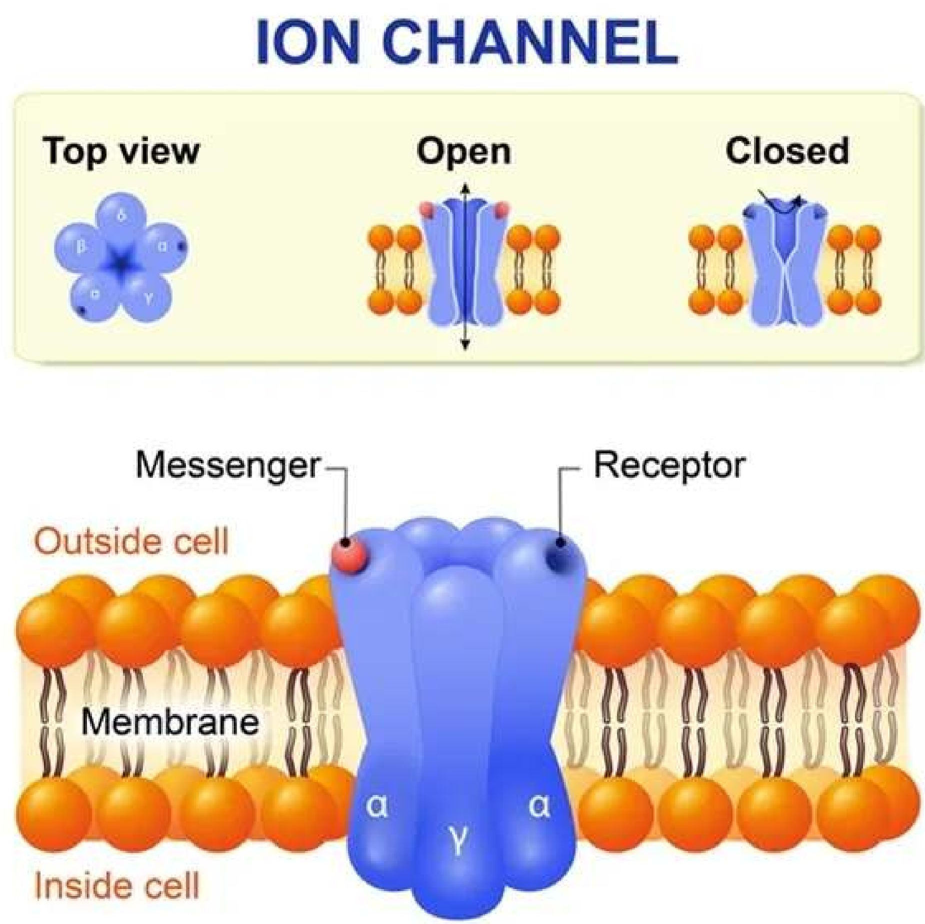


Facilitated Diffusion and Its Role

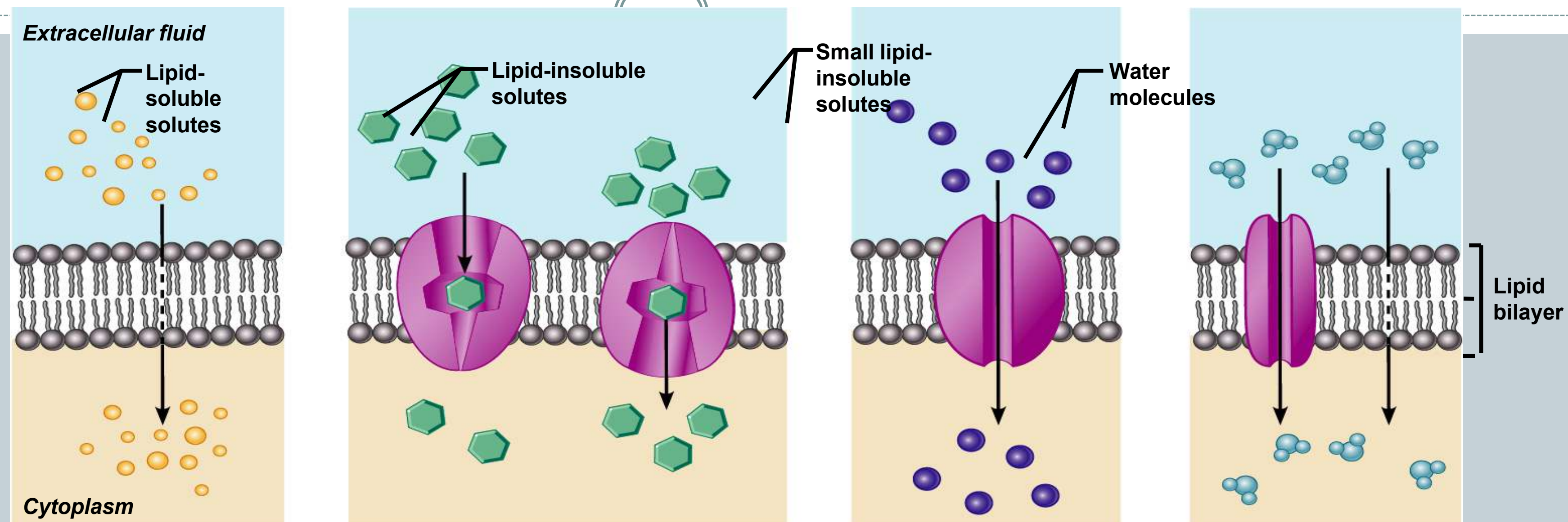
- **Examples of Facilitated Diffusion:**
- **Glucose Transporters:** Glucose transporters are carrier proteins that facilitate the movement of glucose across the cell membrane.
  - two main types—sodium–glucose linked transporters (SGLTs) and facilitated diffusion glucose transporters (GLUT))
- **Ion Channels:** Channel proteins, such as those for sodium (Na+), potassium (K+), and chloride (Cl-), allow the facilitated diffusion of these ions.

- Importance in nutrient uptake (glucose transporters in intestines)

Glucose transporters have also received much attention a therapeutic targets for various diseases



Diffusion Through the Plasma Membrane



(a) Simple diffusion directly through the phospholipid bilayer

(b) Carrier-mediated facilitated diffusion via protein carrier specific for one chemical; binding of substrate causes shape change in transport protein

(c) Channel-mediated facilitated diffusion through a channel protein; mostly ions selected on basis of size and charge

(d) Osmosis, diffusion through a specific channel protein (aquaporin) or through the lipid bilayer

Passive tra

1. Simple Diffusion:

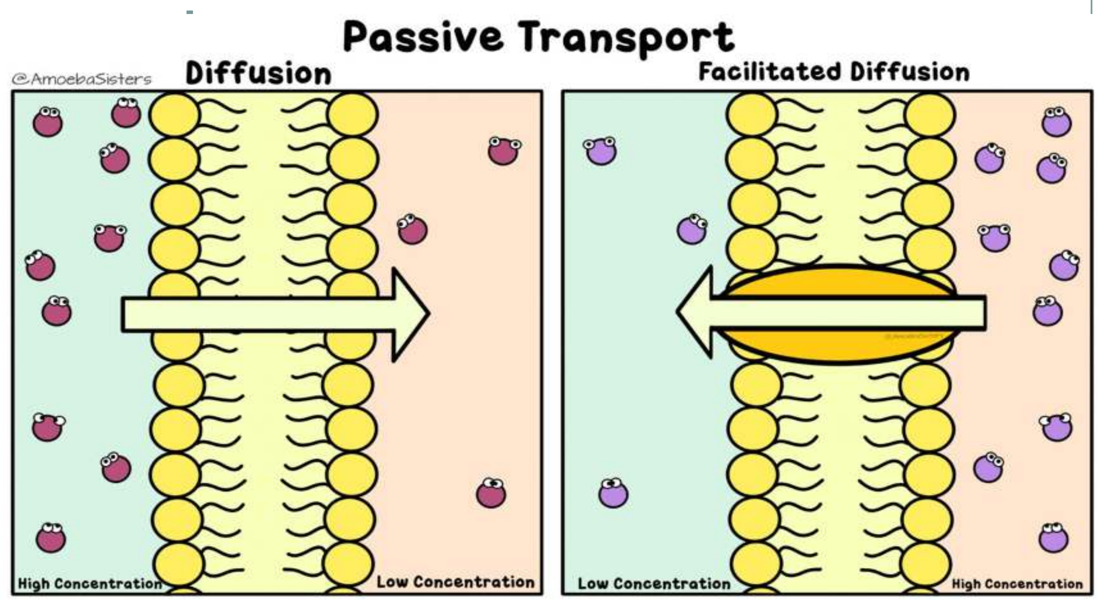
- **Definition:** The movement **of small, nonpolar molecules** (such as oxygen and carbon dioxide) **directly** through the lipid bilayer of the cell membrane.
- Driving Force: The concentration gradient of the substance.

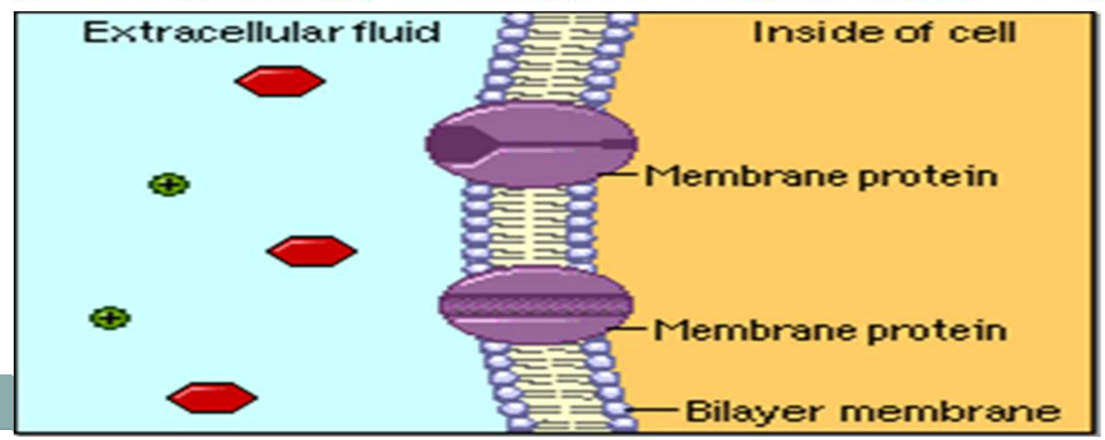
2. Facilitated Diffusion:

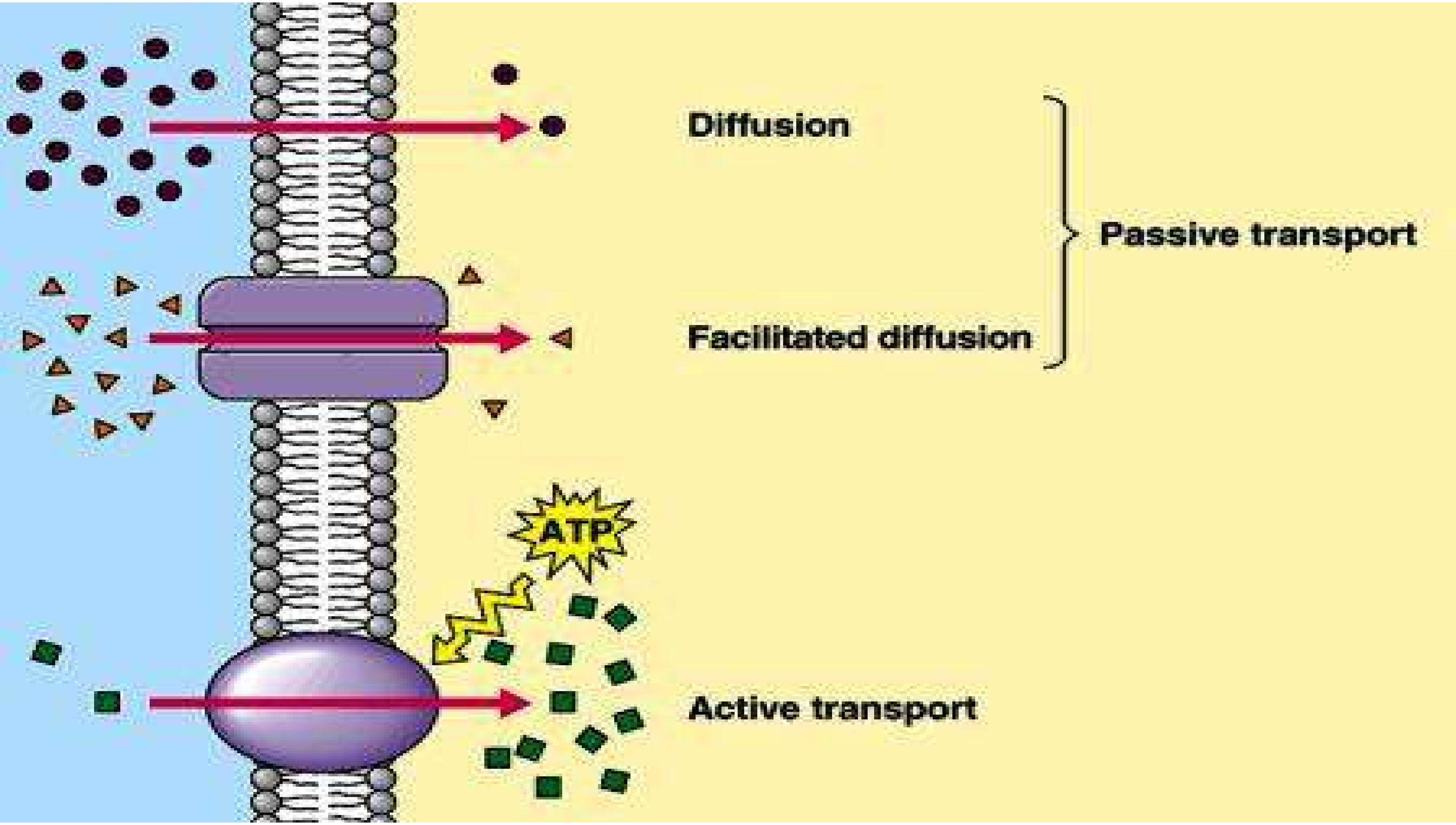
- **Definition:** The **assisted movement of substances across the cell membrane through protein channels or carriers.**

Proteins Involved:

- Channel Proteins: Form open channels allowing specific ions or molecules to pass through.
- Carrier Proteins: Bind to specific substances, undergo conformational changes, and transport the substances across the membrane.
- Driving Force: **Still follows the concentration gradient.**







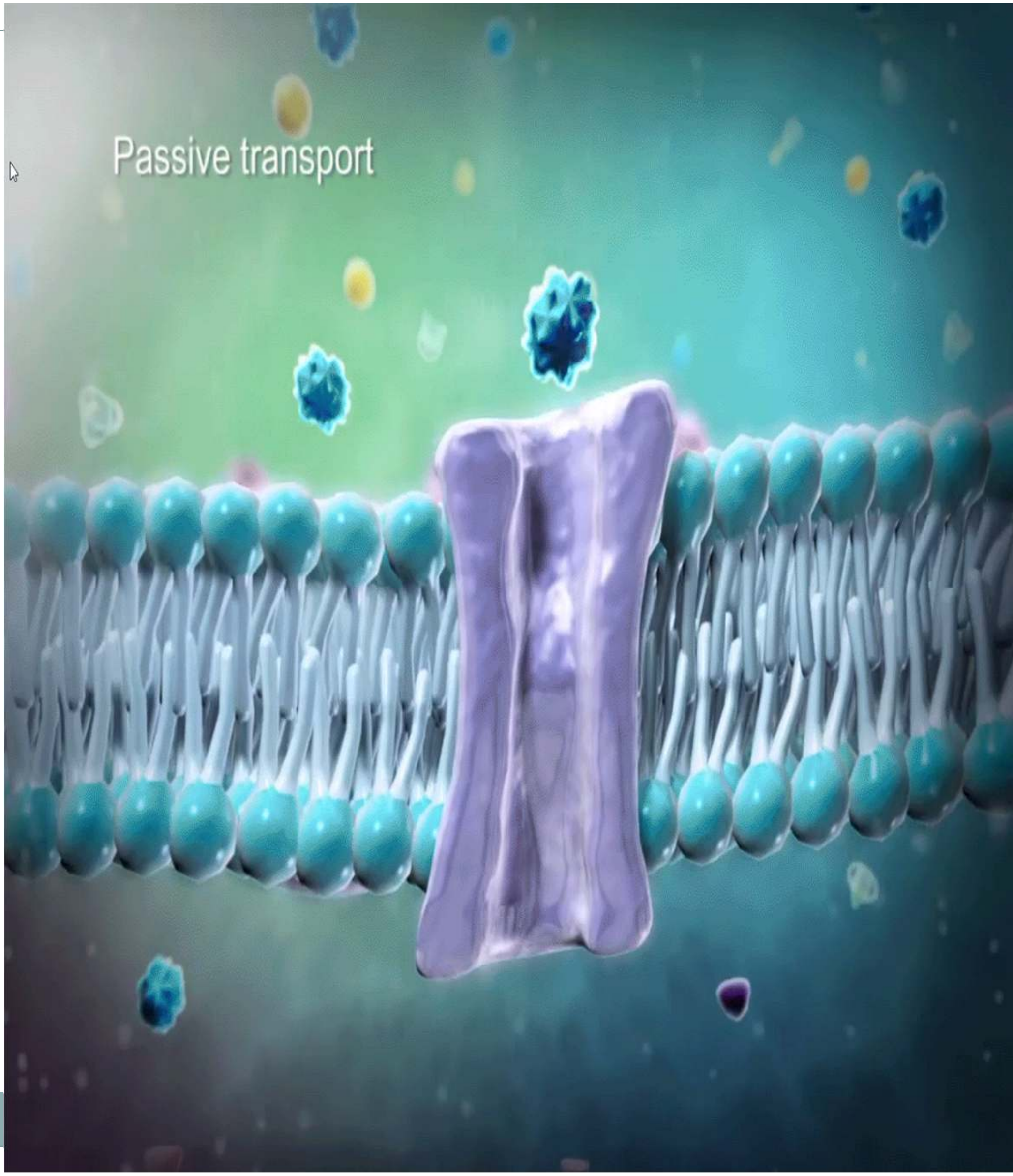
Diffusion
Facilitated diffusion
Passive transport
ATP
Active transport

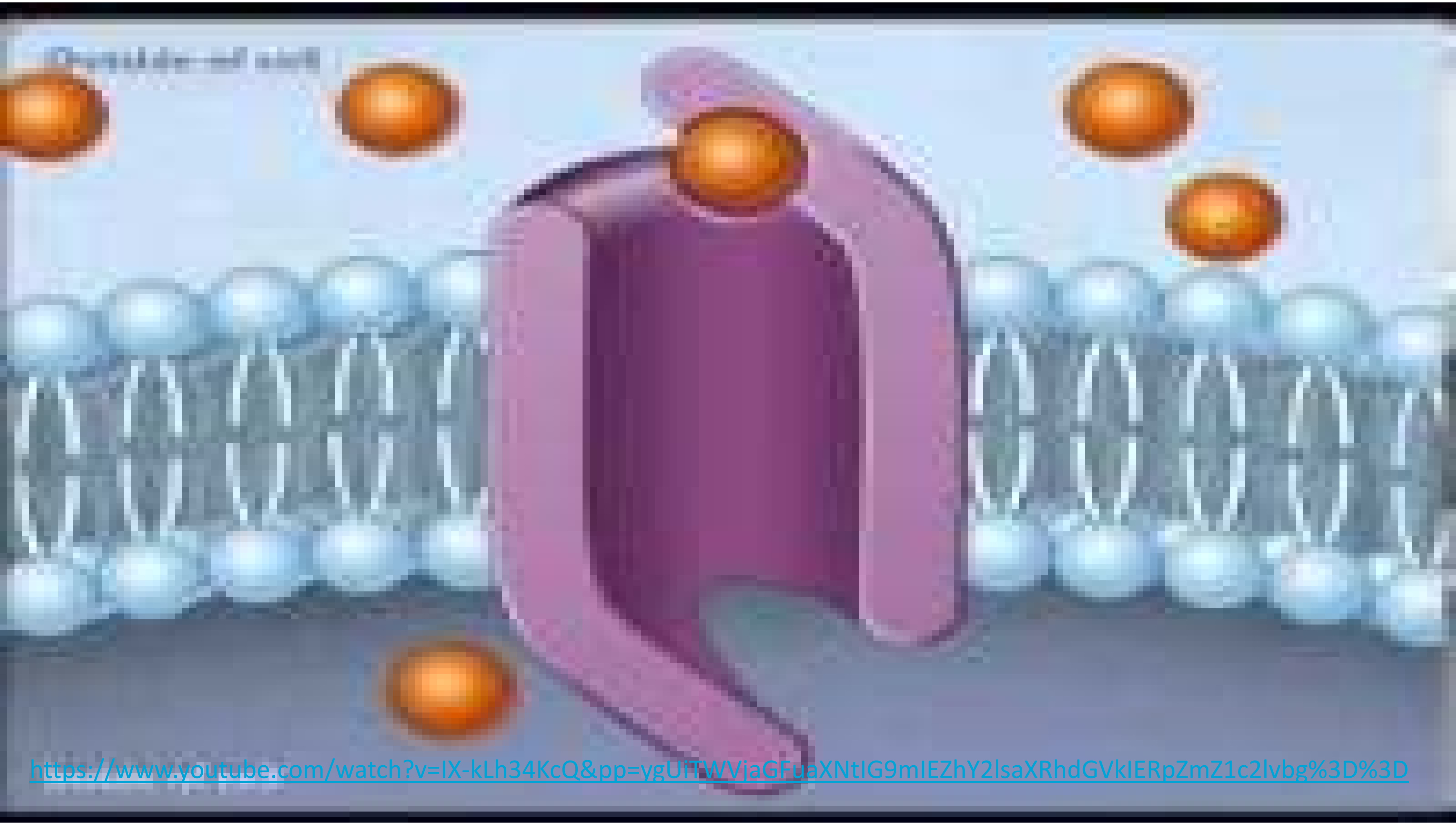
Passive transport

3. Osmosis:
Definition: **The passive movement of water** molecules across a selectively permeable membrane from an area of lower solute concentration to an area of higher solute concentration.
Special Term: **The movement of water** is influenced by the osmotic pressure created by solutes.

4. Ion Channels:
Definition: Proteins that form channels allowing the selective passage of ions based on size and charge.
Examples: Sodium channels, potassium channels.

5. Aquaporins:
Definition: Specialized protein channels that facilitate the rapid movement of water molecules.
Location: Found in cell membranes, especially in cells where water transport is essential.





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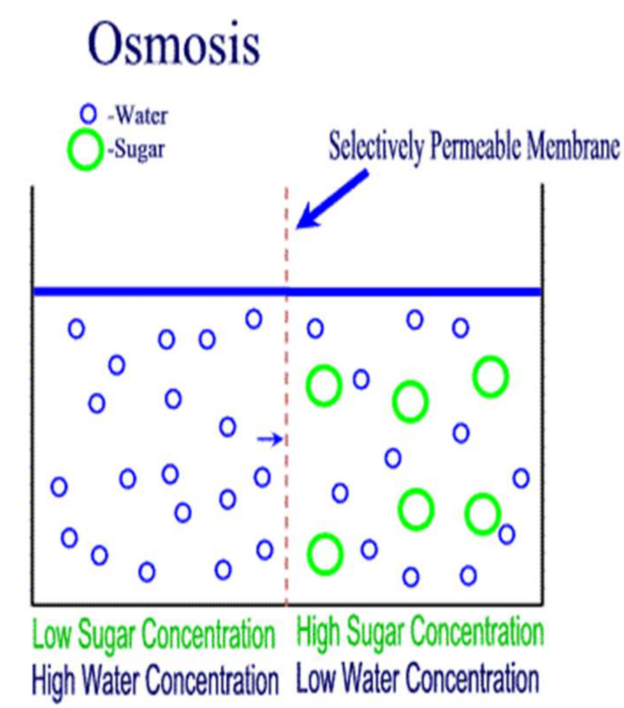
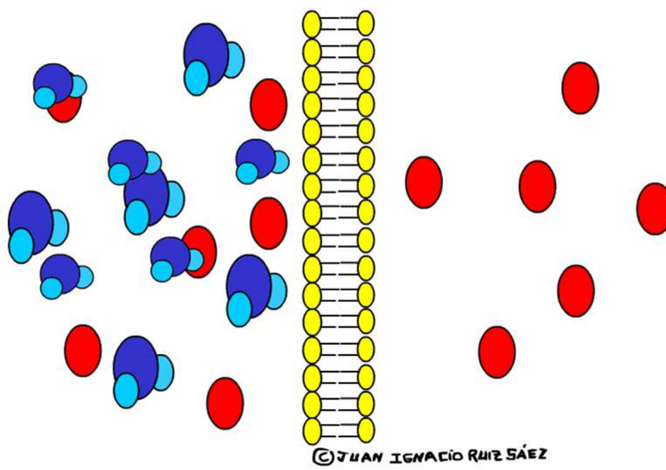
Effects of Solutions of Varying Tonicity

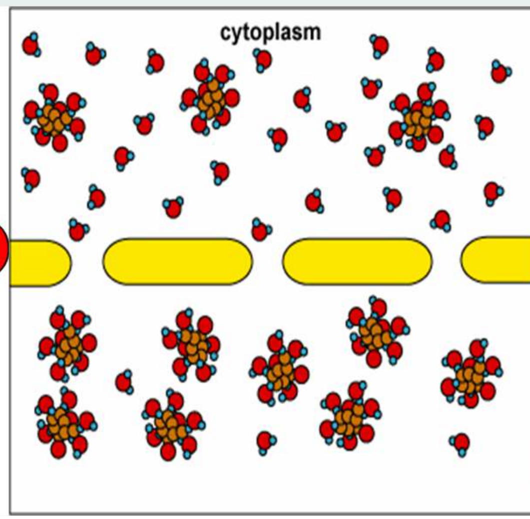
- **Isotonic** – solutions with the same solute concentration as that of the cytosol
- **Hypertonic** – solutions having greater solute concentration than that of the cytosol
- **Hypotonic** – solutions having lesser solute concentration than that of the cytosol

Passive Membrane Transport: **Osmosis**

- **Osmosis is the diffusion of water** through a cell membrane from a solution *of* ***low*** **solute concentration to a solution with high solute** concentration, up a solute concentration gradient.
- It is a **physical process** in which a **solvent moves, without input of energy**, across a **semi permeable membrane (permeable to the solvent, but not the solute)** separating two solutions of different concentrations.
- **Osmosis releases energy, and can be made to do work, as when a growing tree-root splits a stone**.







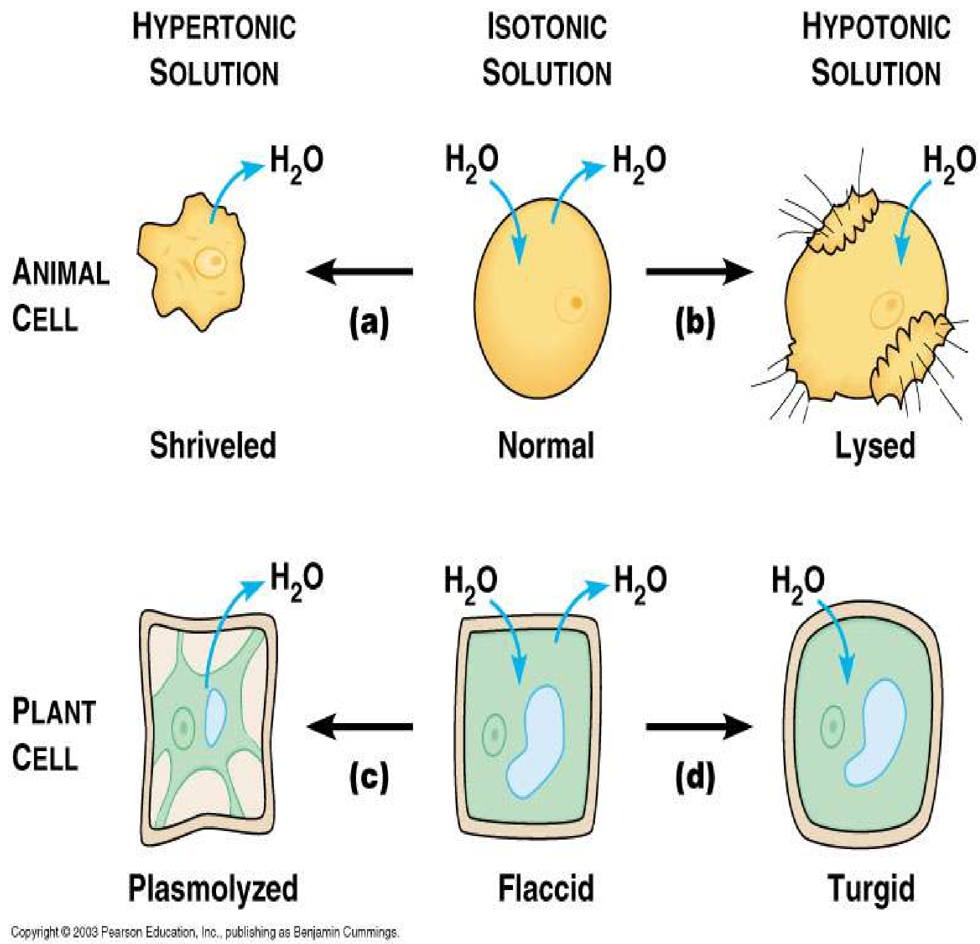
Passive Membrane Transport: Osmosis

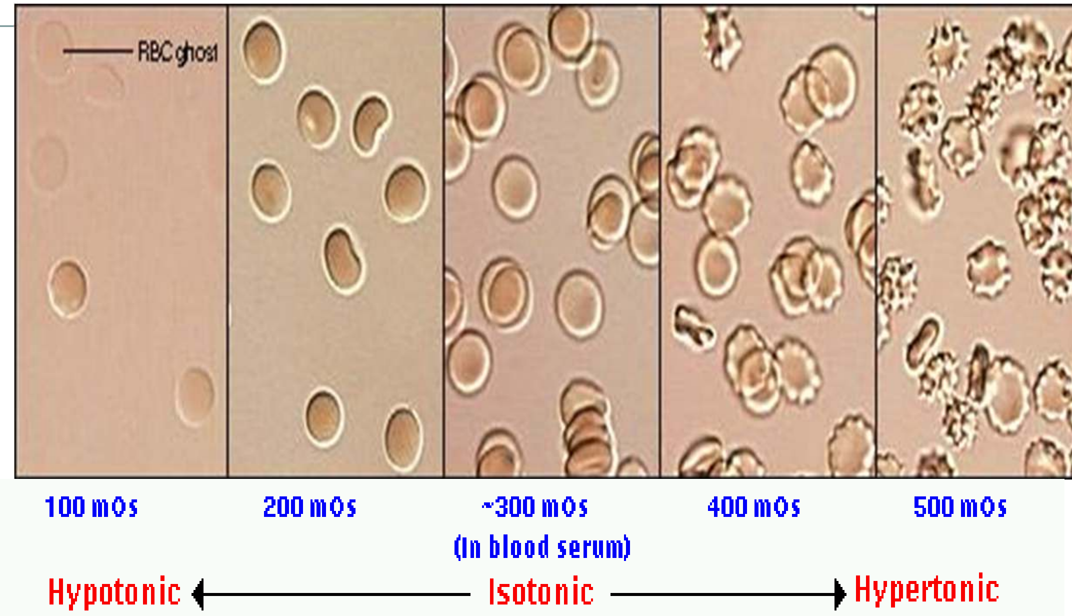
- **Occurs when the concentration of a solvent is different on opposite sides of a membrane**
- **Diffusion of water across a semipermeable membrane**

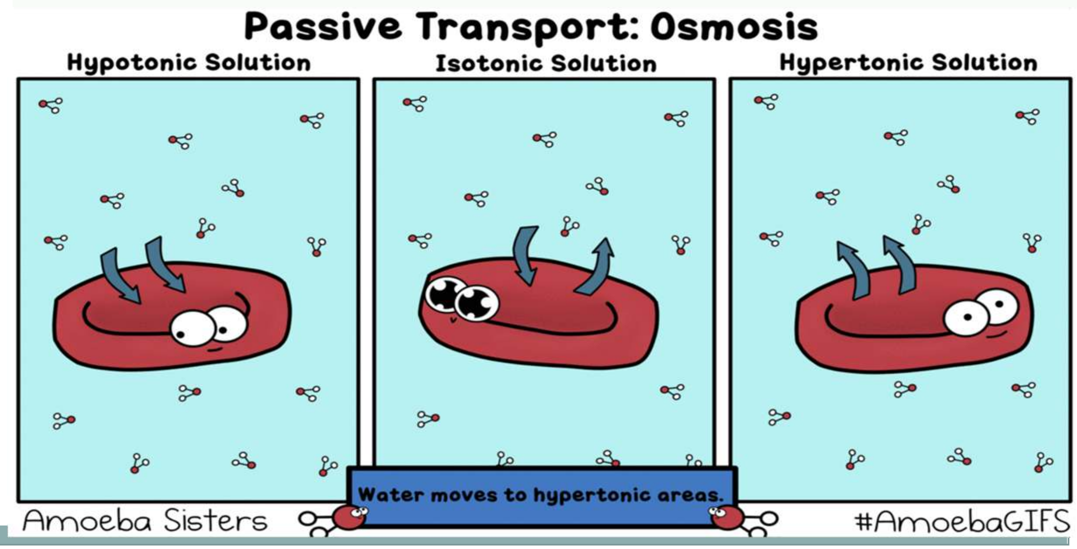
- **Osmolarity – total concentration of solute particles in a solution**
- **Tonicity – how a solution affects cell volume**

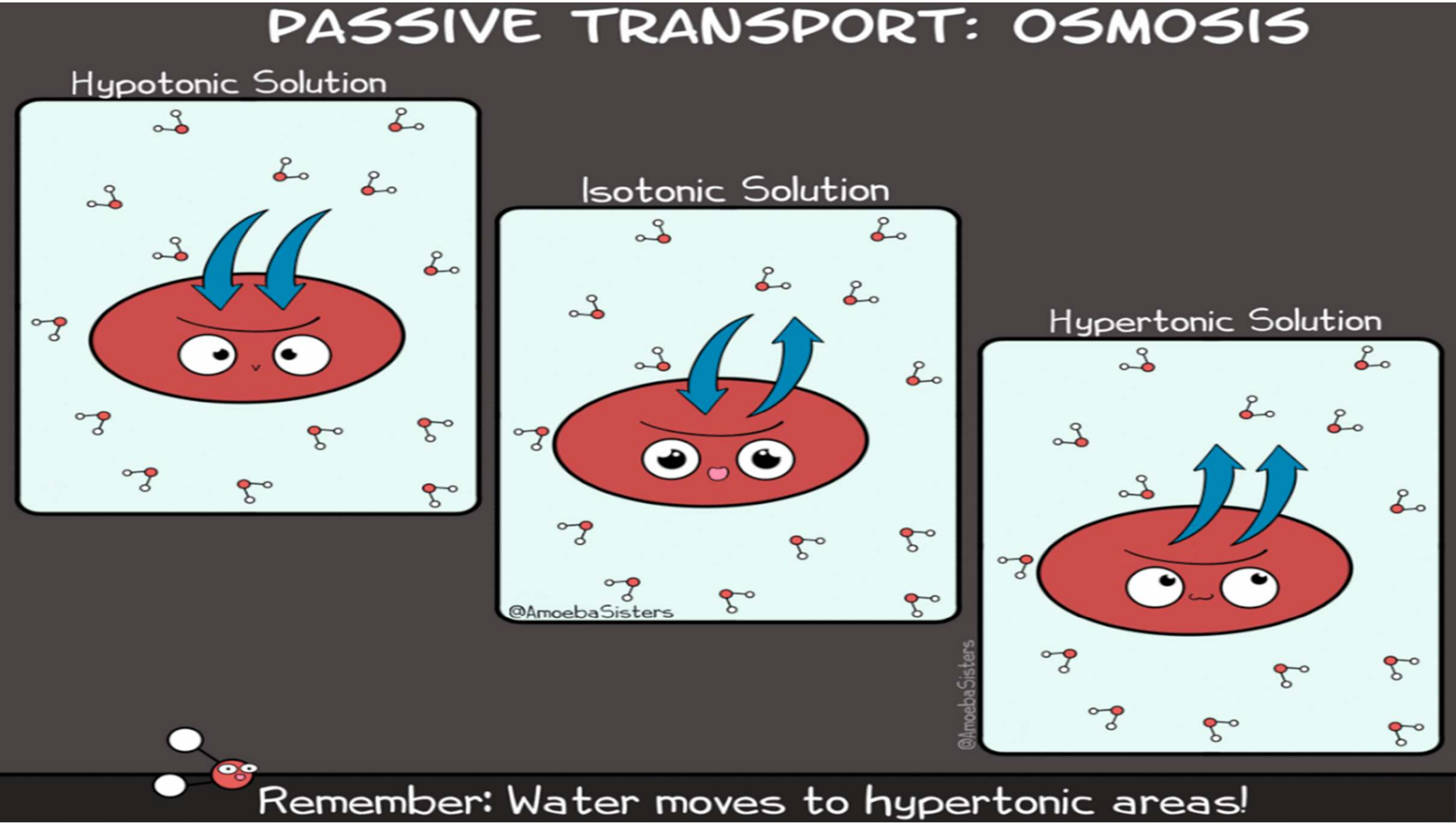
It has been estimated that an amount of water equivalent to roughly 250 times the volume of the cell diffuses across the red blood cell membrane *every second*; the cell doesn't lose or gain water because equal amounts go in and out.

Osmotic pressure affects cell shape and life








PASSIVE TRANSPORT: OSMOSIS
Hypotonic Solution
Isotonic Solution
Hypertonic Solution
@AmoebaSisters
@AmoebaSisters
Remember: Water moves to hypertonic areas!

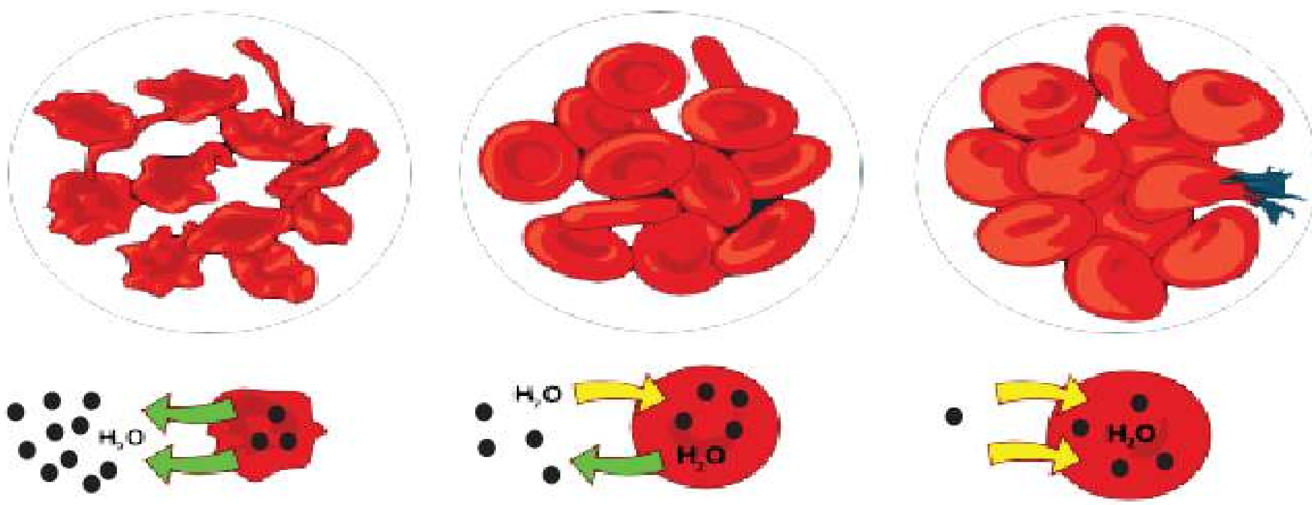
Red Blood Cells in Saline Solutions

- Plasma membranes of RBCs are very permeable to water
- Sensitive to **osmotic pressure gradients** (e.g. NaCl concentration in surrounding fluid)

Crenated RBCs

Normal RBCs

Hemolyzed RBCs
(if they lyse or burst)



Hypertonic Solution:
Net Lose of Water
300 mM>[NaCl] externally

Isotonic Solution:
No Lose or Gain of Water
Normal [NaCl]= **300mM**

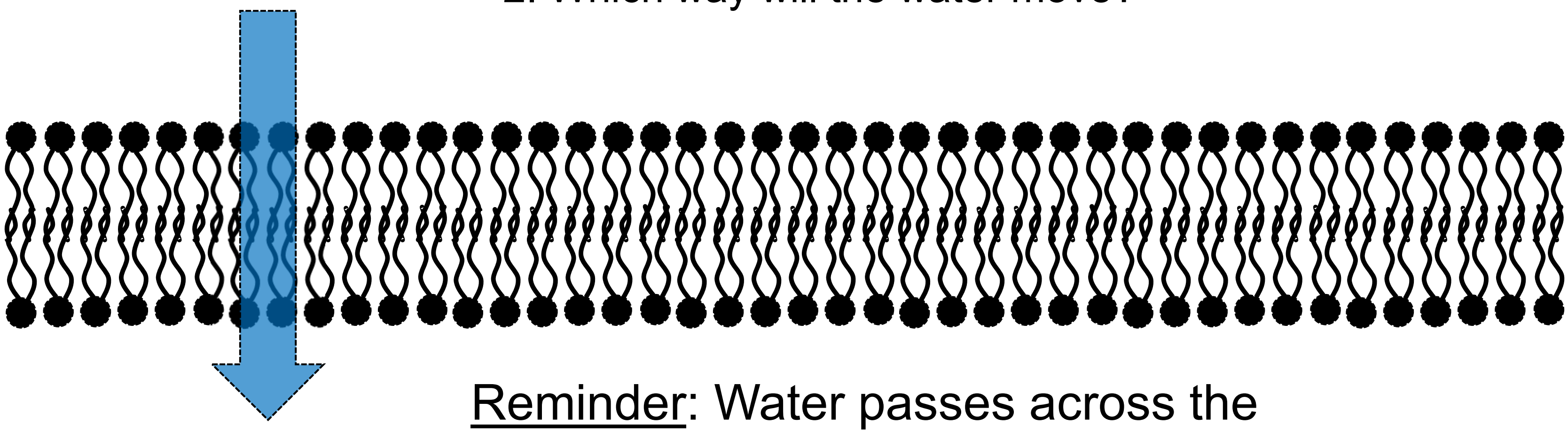
Hypotonic Solution:
Net Gain of Water
300mM <[NaCl] externally

1. What is the concentration of water on each side of the membrane?

2. Which way will the water move?

3% solute

97% H_2O



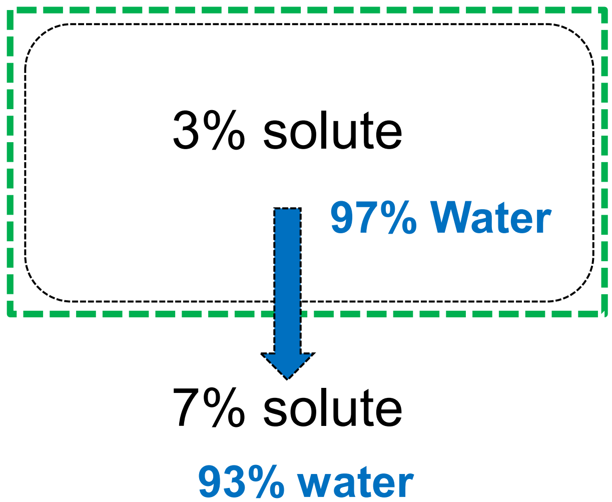
5% solute

95% H_2O

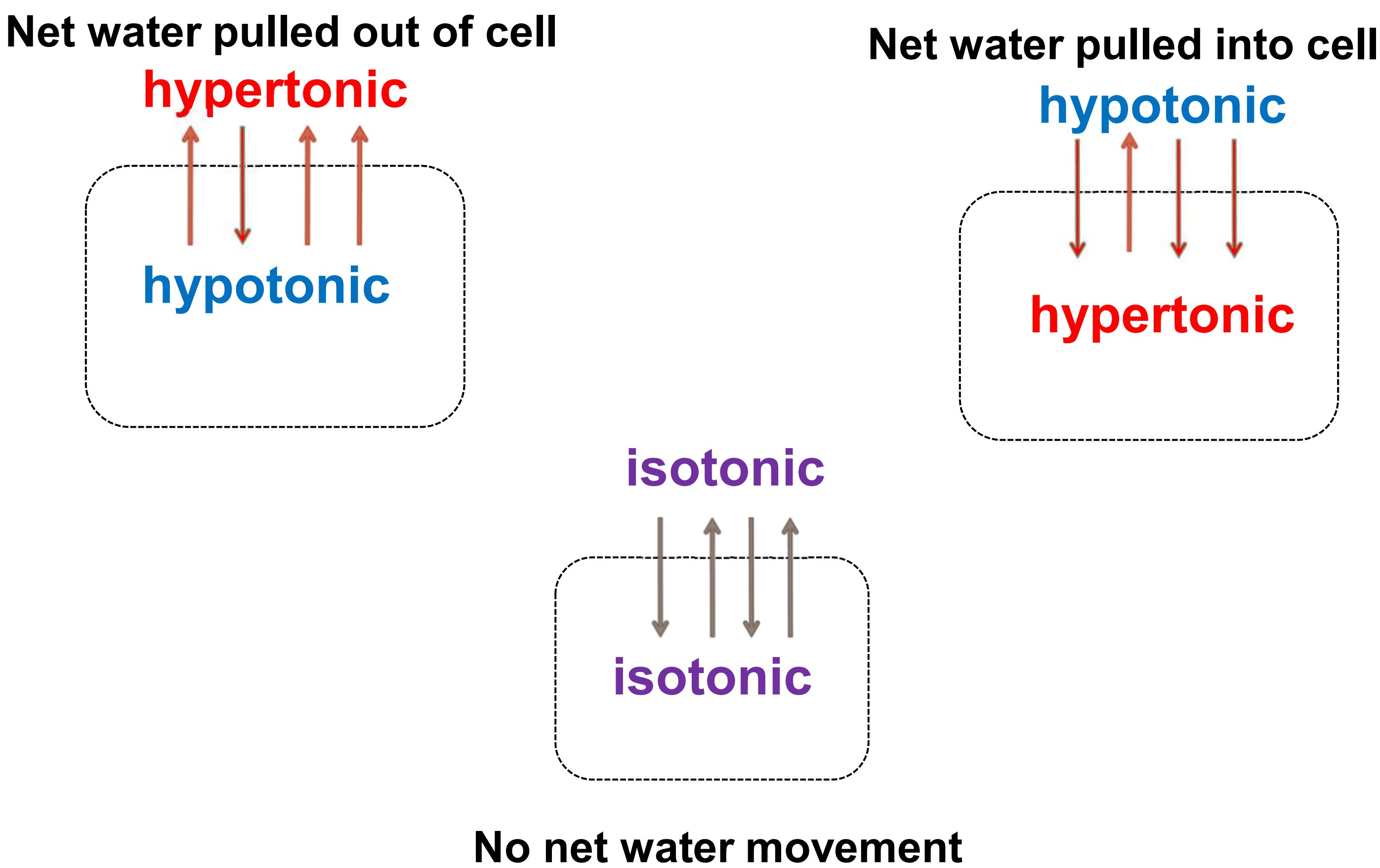
Reminder: Water passes across the membrane, but **solute (particles) cannot**!

Will water flow into or out of this cell?

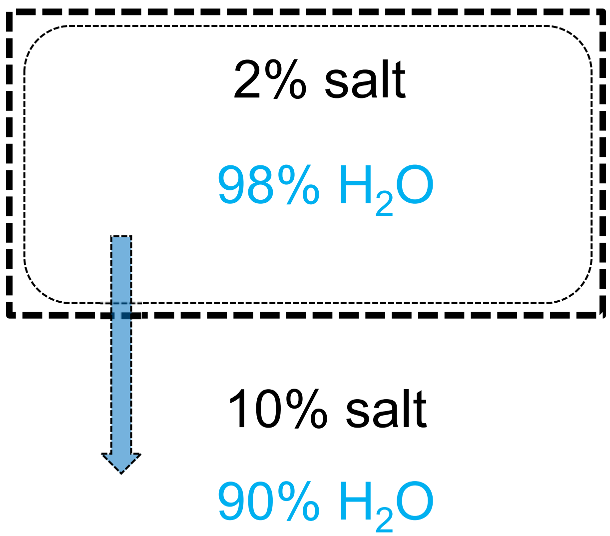
Plant cell



Out of the cell


Net water pulled out of cell
hypertonic
hypotonic
Net water pulled into cell
hypotonic
hypertonic
isotonic
isotonic
No net water movement

Plant cell



1. % water inside and outside the cell?

2. Does the water flow into or out of the cell?

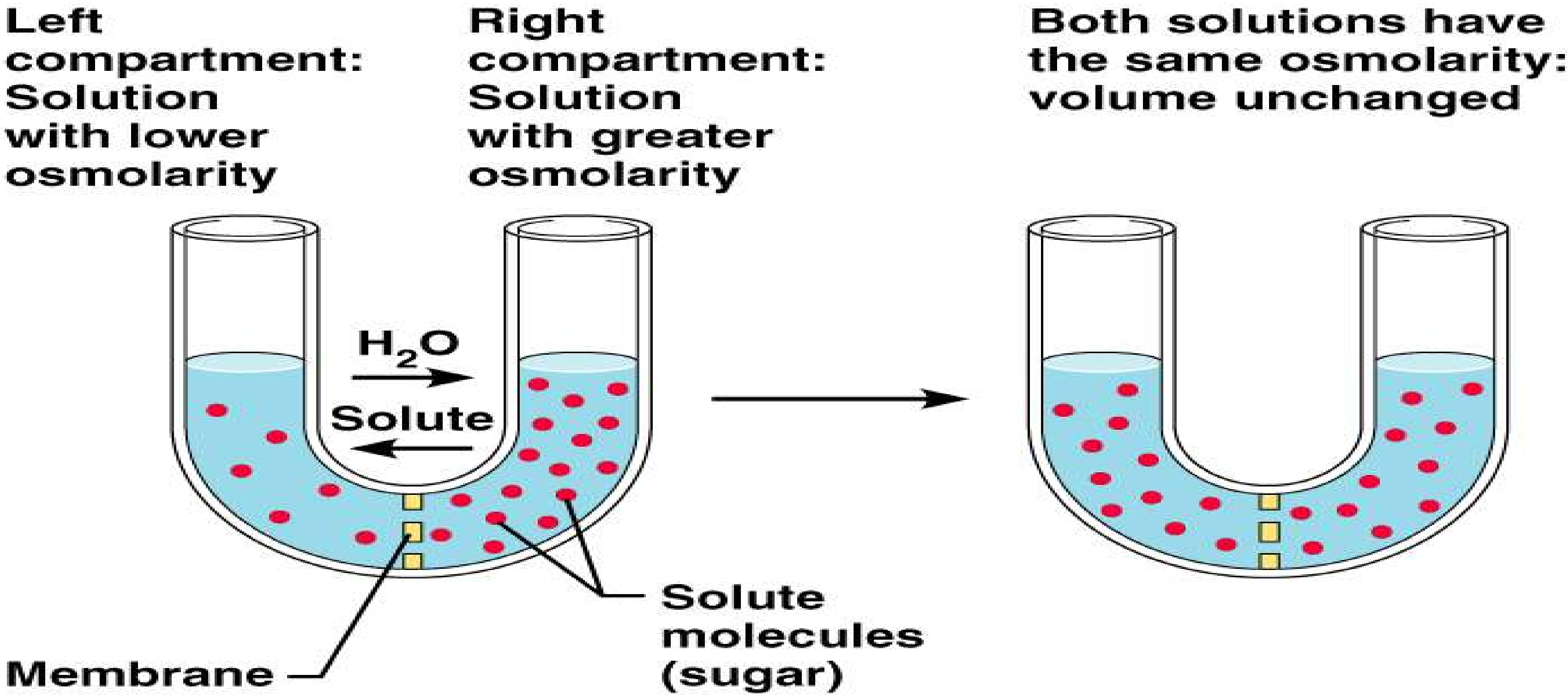
Out of the cell

3. Is the solution *surrounding the cell* **hypertonic, hypotonic** or **isotonic** with respect to the interior of the cell?

HYPERTONIC

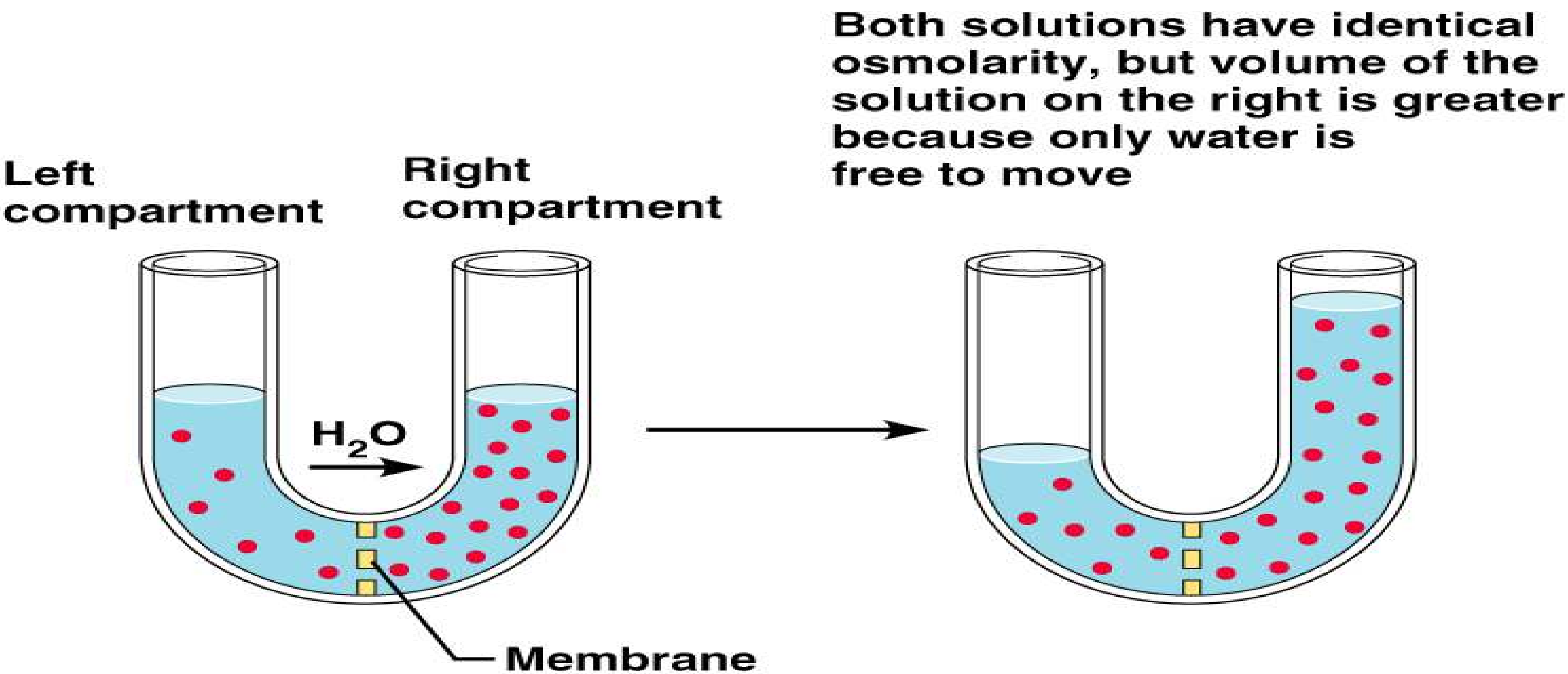
*Salt pulls water out

Effect of Membrane Permeability on Diffusion and Osmosis



(a) Membrane permeable to both solute molecules and water

Effect of Membrane Permeability on Diffusion and Osmosis



(b) Membrane impermeable to solute molecules, permeable to water

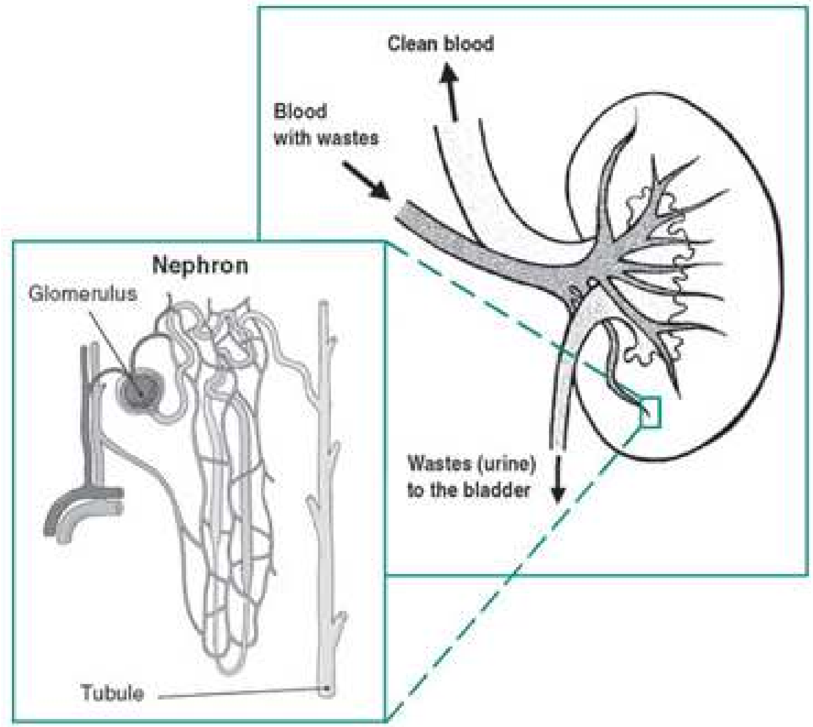
Osmosis in Physiology

- Role of osmosis in maintaining water balance.
- Relevance to kidney function and urine concentration.

Passive Membrane Transport: Filtration

- In biological terms, "filtration" through a cell membrane typically refers to **the selective passage of substances across the cell membrane** based on their size, charge, and other properties.
- the plasma membrane, acts as a **semi-permeable barrier** that controls the entry and exit of substances into and out of the cell.
- **The passage of water and solutes through a membrane by hydrostatic pressure**
- **Pressure gradient pushes solute-containing fluid from a higher-pressure area to a lower-pressure area.**

Why this is important biologically



Kidney function is dependent upon ion and water transport

Key points about osmosis in physiology include:

1.Semi-permeable Membrane:

- Osmosis occurs through a semi-permeable membrane, which allows the passage of water molecules but restricts the movement of solutes (such as ions or molecules).

2.Concentration Gradient:

- Osmosis always occurs down a concentration gradient. Water moves from areas of lower solute concentration (higher water concentration) to areas of higher solute concentration (lower water concentration).

3.Role in Cell Physiology:

- Osmosis is crucial for the functioning of cells.
- Cells are surrounded by membranes that are selectively permeable, and the movement of water in and out of cells helps maintain cell shape, regulate cell volume, and facilitate the transport of nutrients and waste products.

4. Tonicity:

- Tonicity refers to the ability of a solution to cause a cell to gain or lose water.
- There are three main types of tonicity: hypertonic, hypotonic, and isotonic.
  1. **Hypertonic Solution:** A solution with a higher solute concentration than the cell.
     - Water moves out of the cell, causing it to shrink or undergo crenation.
  2. **Hypotonic Solution:** A solution with a lower solute concentration than the cell.
     - Water moves into the cell, causing it to swell or undergo lysis.
  3. **Isotonic Solution:** A solution with the same solute concentration as the cell.
     - There is no net movement of water, and the cell maintains its shape.

5. Osmotic Pressure:

- Osmotic pressure is the pressure exerted by the movement of water across a semi-permeable membrane due to osmosis.
- It is influenced by the concentration of solutes and the temperature.

Osmosis plays a crucial role in various physiological processes within the human body, and its understanding is fundamental in the field of medicine.

Here are some key aspects highlighting the importance of osmosis in medicine:

1.Cellular Physiology:

1. **Cellular Homeostasis:** Osmosis is vital for maintaining the balance of water and solutes within cells.
2. Cells need to regulate their internal environment to ensure proper functioning, and osmosis helps achieve this balance.

2.Renal Physiology:

1. **Kidney Function:** Osmosis is integral to the formation of urine in the kidneys.
2. The selective reabsorption and secretion of water and solutes in different parts of the renal tubules are orchestrated through osmotic processes.

3.Blood Physiology:

1. **Osmotic Pressure:** Osmosis contributes to the maintenance of blood osmotic pressure.
2. Proteins in the blood, such as albumin, help regulate osmotic pressure by attracting water into the bloodstream, preventing excessive fluid leakage into tissues.

1.Clinical Applications:

1. **Intravenous Fluids:** Understanding osmosis is crucial when administering intravenous fluids.
2. Different solutions have varying osmotic pressures, and selecting the appropriate fluid is essential for preventing complications such as cell lysis or excessive fluid shift.

2.Disease Mechanisms:

1. **Edema:** Disorders affecting osmotic balance can lead to conditions like edema, where an abnormal accumulation of fluid occurs in tissues.
2. This is seen in various medical conditions, such as heart failure or liver disease.

3.Drug Absorption and Distribution:

1. **Pharmacokinetics:** Osmosis influences the absorption and distribution of drugs within the body.
2. Medications may move across cell membranes through osmotic processes, impacting their efficacy and duration of action.

4.Biological Membranes:

1. **Cell Membrane Integrity:** Osmosis is essential for maintaining the integrity and structure of cell membranes.
2. Changes in osmotic pressure can affect cell shape and function.

5.Digestive System:

1. **Nutrient Absorption:** Osmosis is involved in the absorption of nutrients in the digestive system.
2. The movement of water and nutrients across the gastrointestinal tract is influenced by osmotic processes.

Clinical example

A 65-year-old patient presents to the emergency department with significant swelling in the lower extremities. The patient has a history of heart failure, a condition that compromises the pumping efficiency of the heart, leading to fluid retention.

- Edema is a medical condition characterized by the abnormal accumulation of fluid in the interstitial spaces, leading to tissue swelling.

- This condition often involves disruptions in the balance of passive transport mechanisms, specifically related to osmosis and the movement of water across cell membranes.

Passive transport key words

•**Concentration Gradient:** **The difference in concentration of a substance between two areas.**

•**Equilibrium:** When the concentration of a substance is the same on both sides of the membrane, and there is no net movement.

•**Selective Permeability:** The property of the cell membrane to allow certain substances to pass through while restricting others.

Passive Membrane Transport: Filtration

- The passage of water and solutes through a membrane by hydrostatic pressure
- Pressure gradient pushes solute-containing fluid from a higher-pressure area to a lower-pressure area

Importance of Passive Transport

- Essential for nutrient uptake, waste removal, and maintaining cellular homeostasis.
- Ensures the continuous exchange of gases (like oxygen and carbon dioxide) across cell membranes.
- Facilitates the movement of water, ions, and other essential molecules without the expenditure of energy by the cell.

https://www.youtube.com/watch?v=oFZZncLteXc&ab_channel=MrPollock

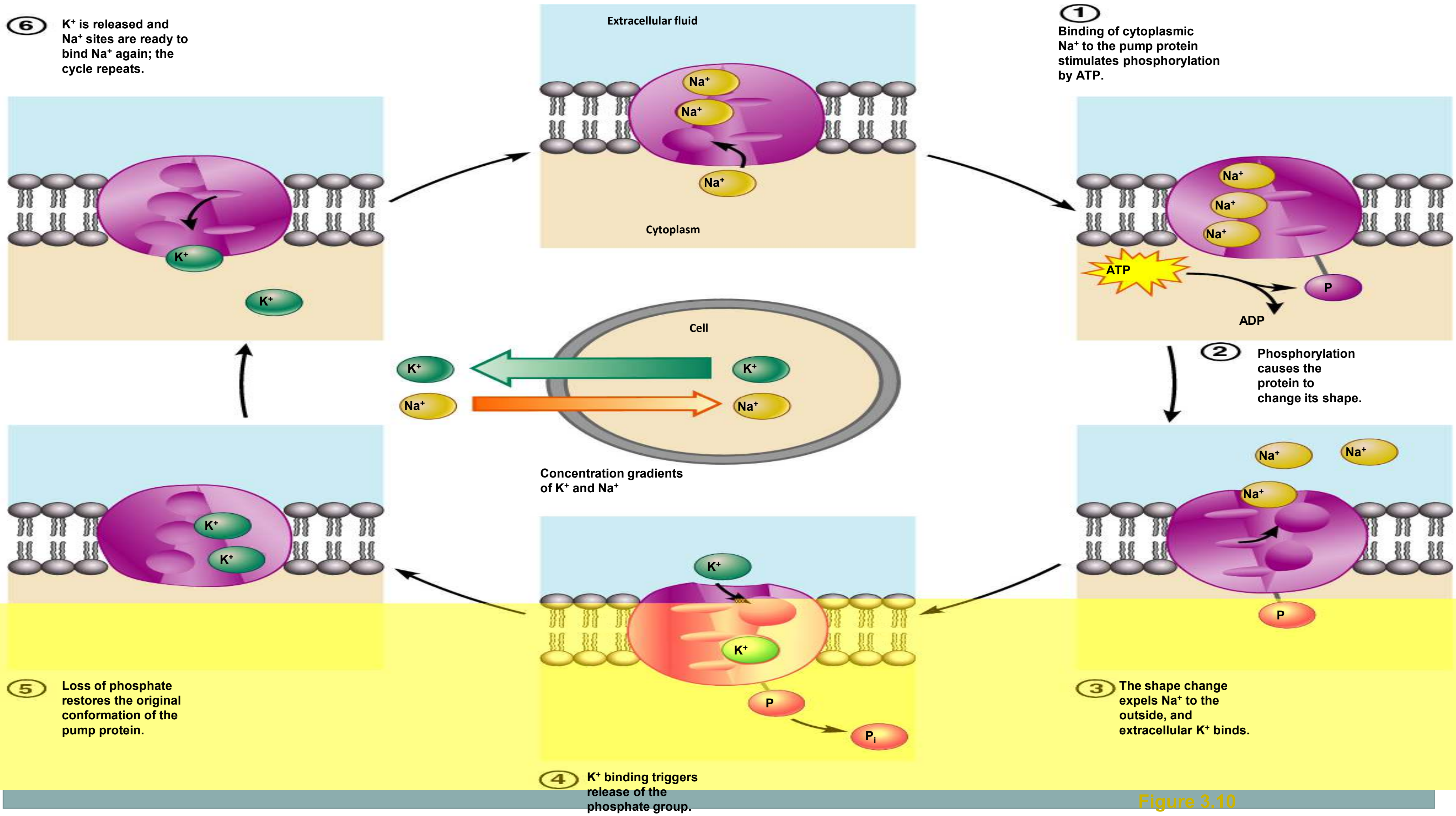

Extracellular fluid
Cytoplasm
Na+
K+
Cell
ATP
ADP
P
Pi
1 Binding of cytoplasmic Na+ to the pump protein stimulates phosphorylation by ATP.
2 Phosphorylation causes the protein to change its shape.
3 The shape change expels Na+ to the outside, and extracellular K+ binds.
4 K+ binding triggers release of the phosphate group.
5 Loss of phosphate restores the original conformation of the pump protein.
6 K+ is released and Na+ sites are ready to bind Na+ again; the cycle repeats.
Concentration gradients of K+ and Na+

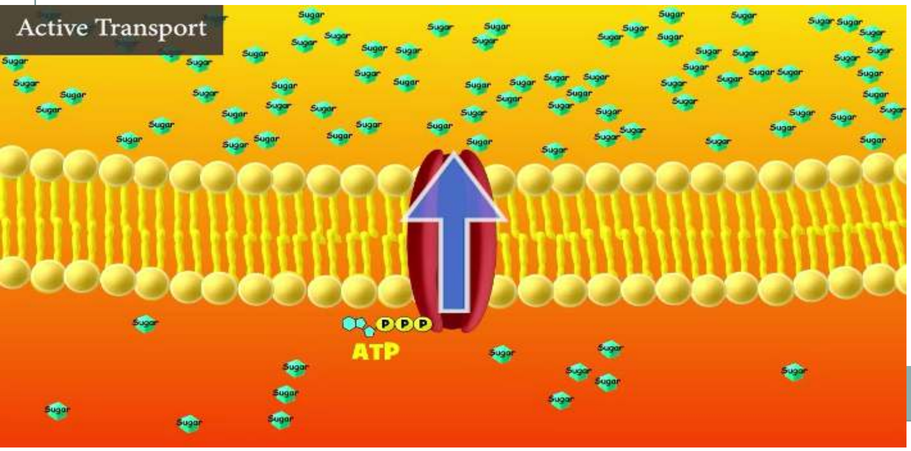
Figure 3.10

Active Transport

- **Uses ATP** to move solutes across a membrane
- **Requires carrier proteins**

Active Transport in Cellular Physiology

- Active transport is a cellular process that requires energy to move substances against their concentration gradient, from an area of lower concentration to an area of higher concentration.
- Examples related to human physiology (e.g., sodium-potassium pump).
- **his process is essential for maintaining specific intracellular concentrations of ions and molecules, and it plays a crucial role in various physiological functions.**



Here are key aspects of active transport in cellular physiology:

1. **Energy Expenditure:**
2. **Protein Pumps**
3. **Against the Concentration Gradient**
4. **Ion Pumping**

5. **Sodium-Potassium Pump**

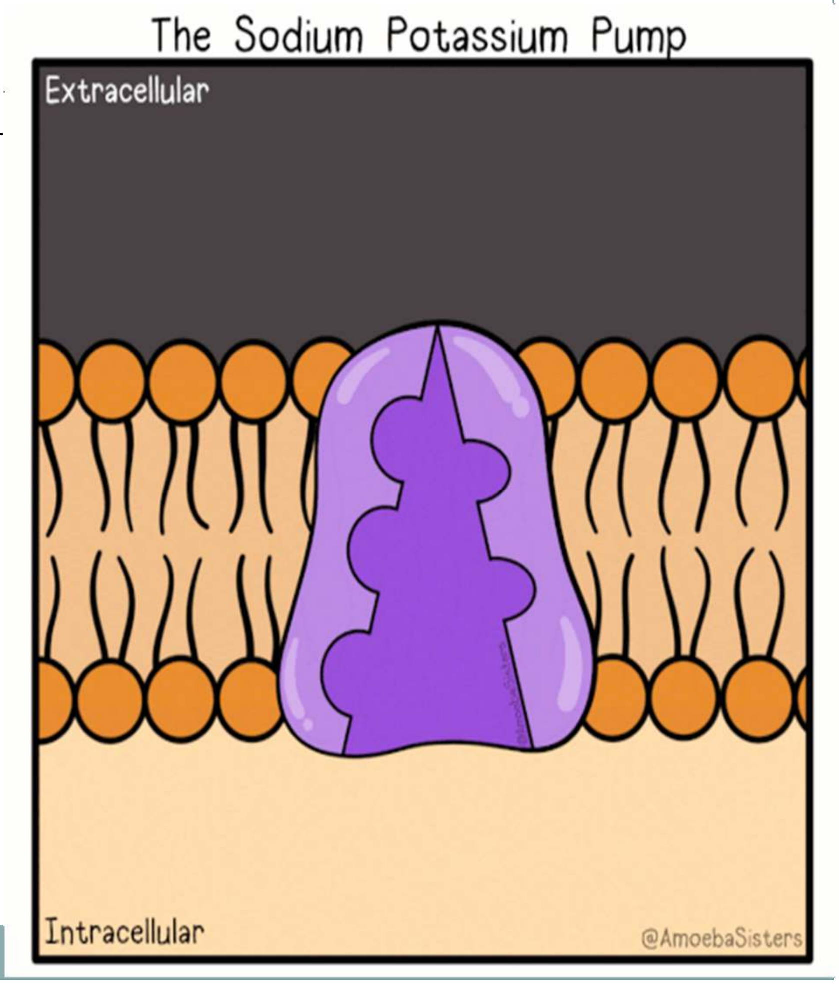
6. **Endocytosis and Exocytosis**

7. **Primary Active Transport vs. Secondary Active Transport:** In primary active transport, energy directly comes from the hydrolysis of ATP. In secondary active transport, the energy is derived from the electrochemical gradient established by primary active transport. Symporters and antiporters are examples of secondary active transport proteins.

8. **Role in Cellular Homeostasis:** Active transport is crucial for maintaining the proper balance of ions and molecules inside and outside the cell. This is essential for cell function, signaling, and overall cellular homeostasis.

Active Transport

- Uses ATP to move solutes across a mem
- **Requires carrier proteins**



Here are key aspects of active transport in cellular physiology:

1.Energy Expenditure: Active transport mechanisms utilize energy, usually in the form of adenosine triphosphate (ATP), to pump substances across the cell membrane against their natural gradient.

2.Protein Pumps: Active transport is often facilitated by specific membrane proteins, such as pumps or transporters, that actively move substances across the membrane.

- Examples include the sodium-potassium pump and the proton pump.

3.Against the Concentration Gradient: Unlike passive transport, which follows the concentration gradient, active transport **moves substances in the opposite direction, against the gradient.**

4.Ion Pumping: Many active transport processes involve the movement of ions, such as sodium (Na+), potassium (K+), calcium (Ca2+), and hydrogen ions (H+).

- **These ions are crucial for cellular functions like maintaining membrane potential and regulating pH.**

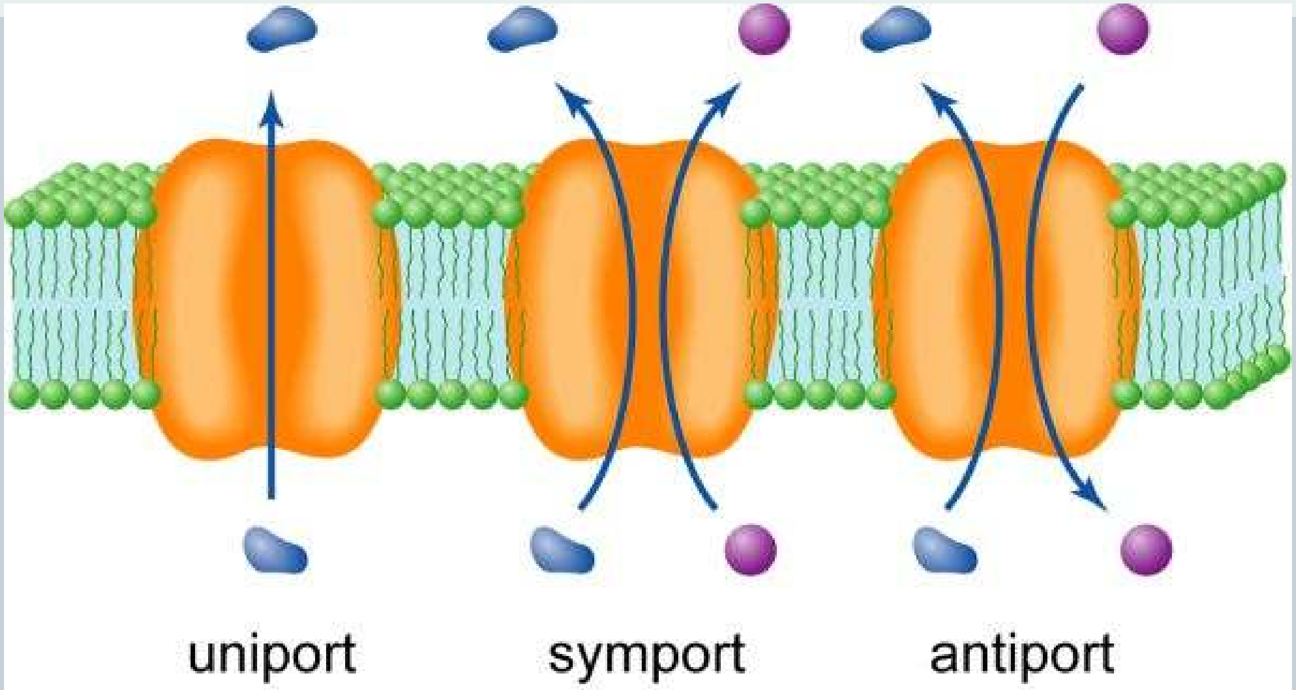
5.Sodium-Potassium Pump: A well-known example of active transport is the sodium-potassium pump, which actively transports three sodium ions out of the cell and two potassium ions into the cell against their respective concentration gradients.

- **This process is vital for maintaining the cell's resting membrane potential and controlling cell volume**.

6.Endocytosis and Exocytosis: While not strictly active transport across the cell membrane, endocytosis and exocytosis involve the energy-dependent movement of large molecules or particles into and out of the cell through vesicles.

Types of Active Transport

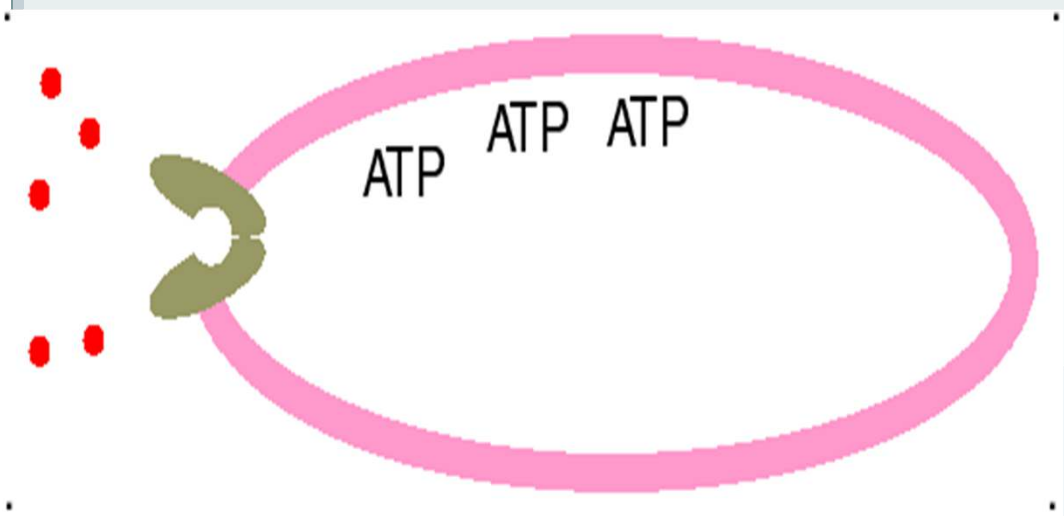
- **Symport system** – two substances are moved across a membrane in the ***same direction***
- **Antiport system** – two substances are moved across a membrane in ***opposite directions***

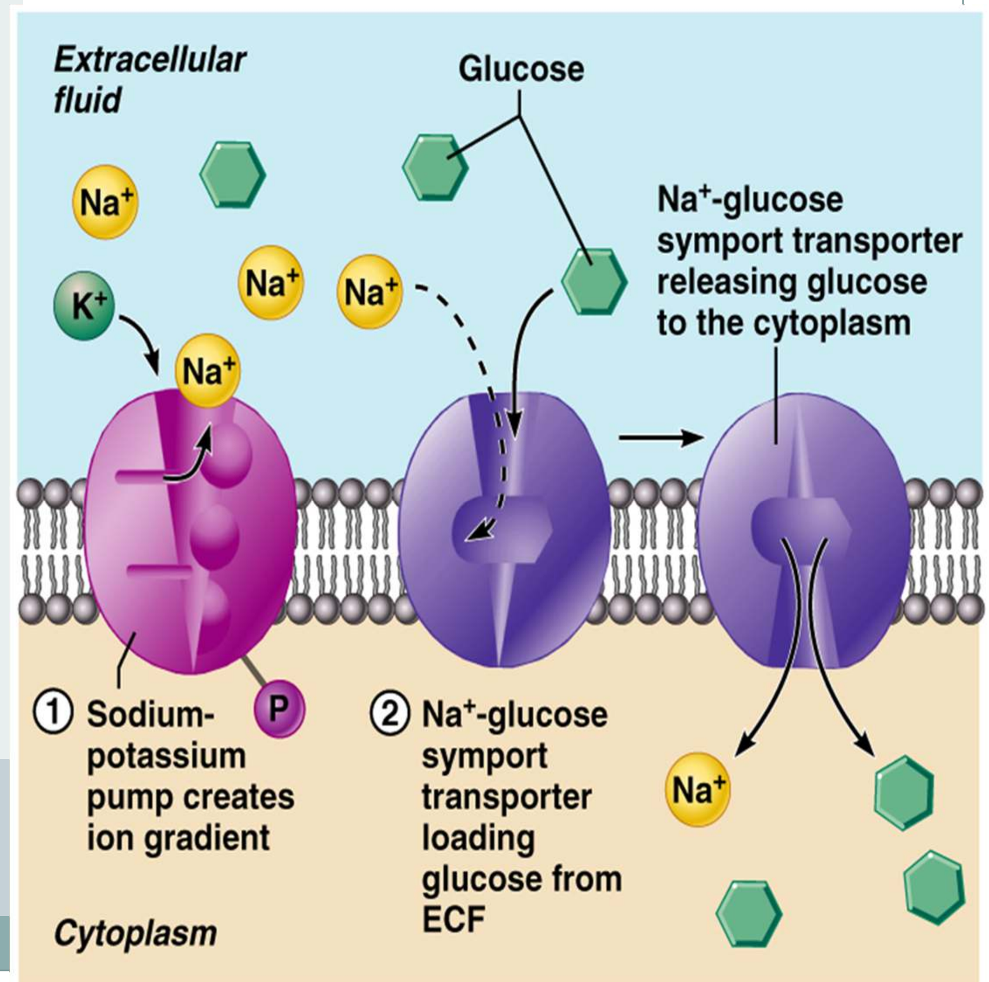


Types of Active Transport

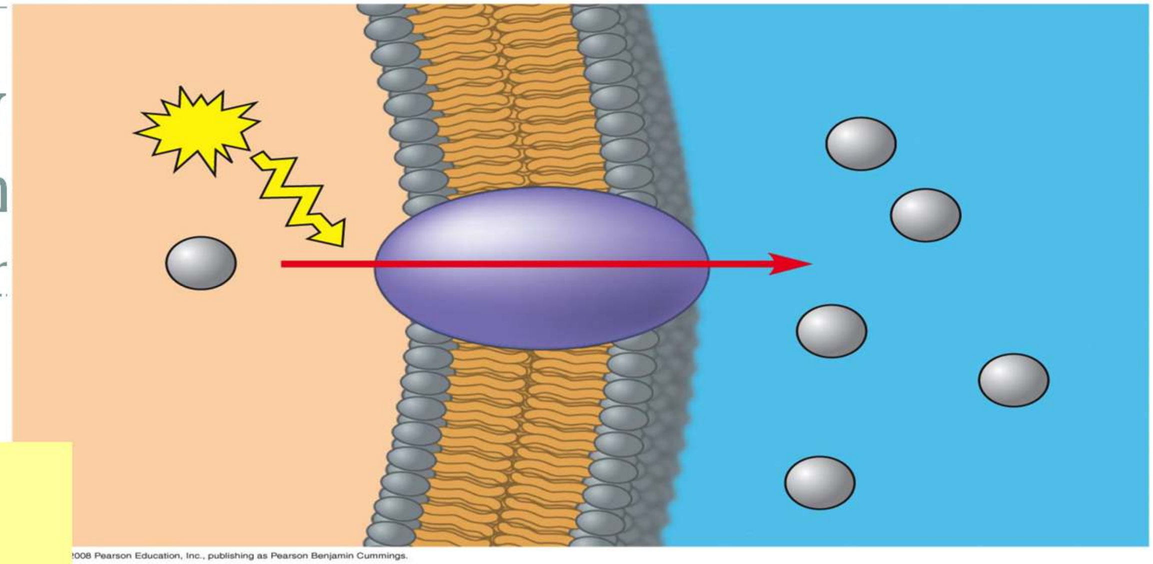
- **Primary active transport – hydrolysis of ATP phosphorylates the transport protein causing conformational change**

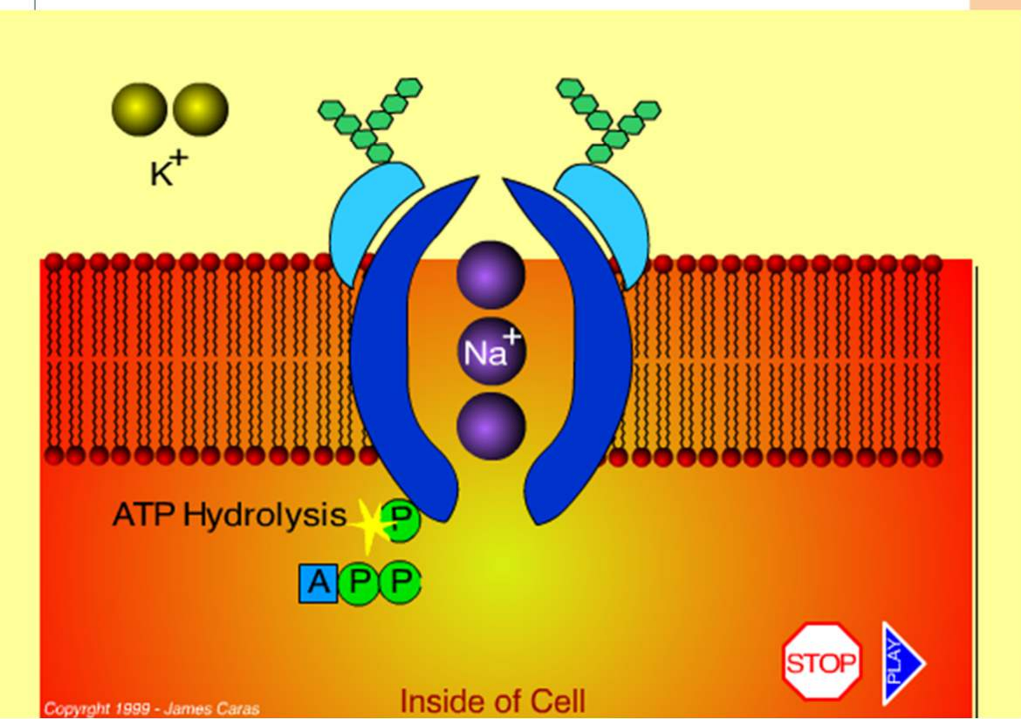
- **Secondary active transport – use of an exchange pump (such as the Na^+-K^+ pump) indirectly to drive the transport of other solutes[ATP-ASE]**





Protein Pumps use energy (ATP, electrons) to increase th concentration on one side of th membrane





The Sodium-Potassium (Na^+/K^+) Pump uses ATP to move Na+ out and K+ into nerve, muscle and many other cells.

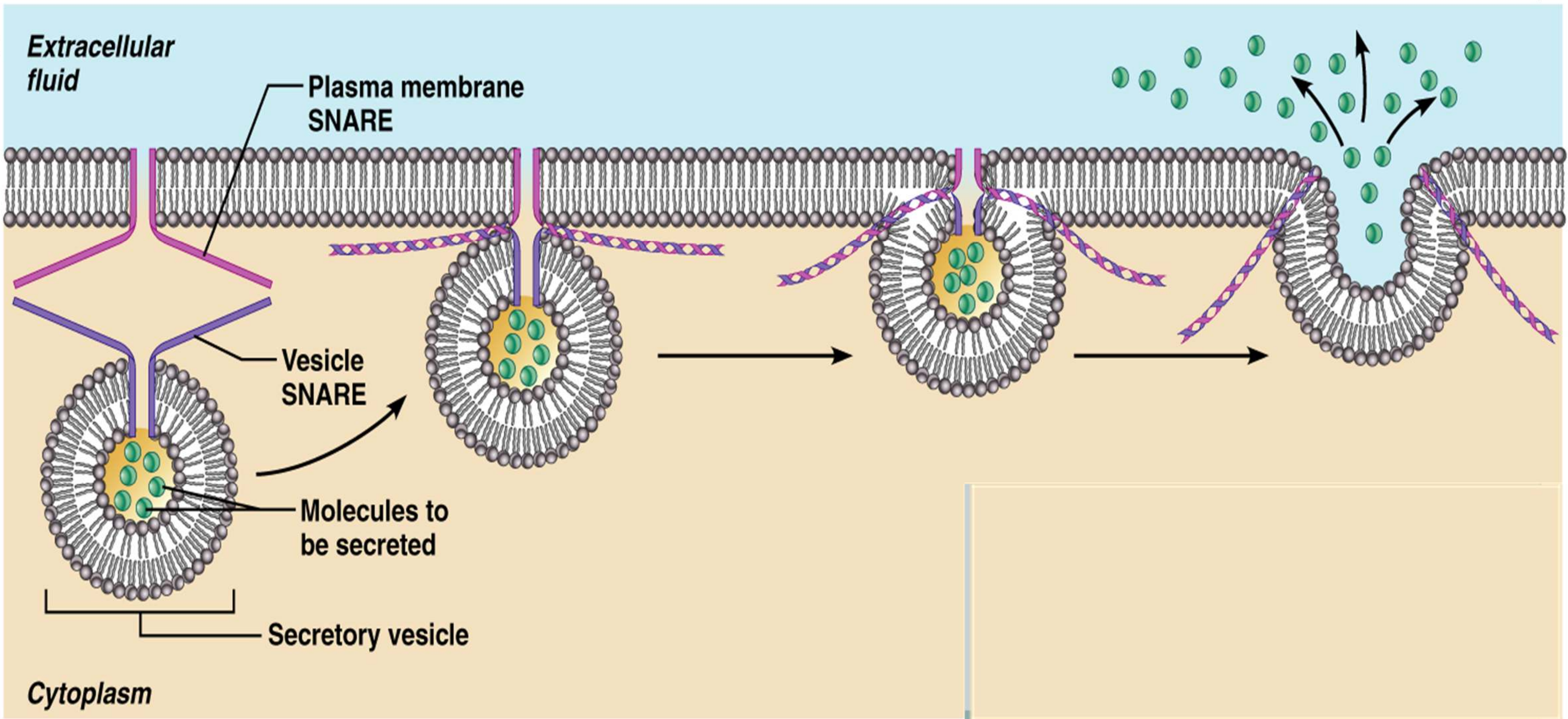
Vesicular Transport

- **Transport of large particles and macromolecules across plasma membranes**
  - Exocytosis – moves substance from the cell interior to the extracellular space
  - Endocytosis – enables large particles and macromolecules to enter the cell
    - Phagocytosis – pseudopods engulf solids and bring them into the cell's interior
    - PINOCYTOSIS
    - Receptor-mediated endocytosis – clathrin-coated pits provide the main route for endocytosis and transcytosis
  - Transcytosis – moving substances into, across, and then out of a cell

- Fluid-phase endocytosis – the plasma membrane infolds, bringing extracellular fluid and solutes into the interior of the cell
- Vesicular trafficking – moving substances from one area in the cell to another
- Non-clathrin-coated vesicles – caveolae that are platforms for a variety of signaling molecules

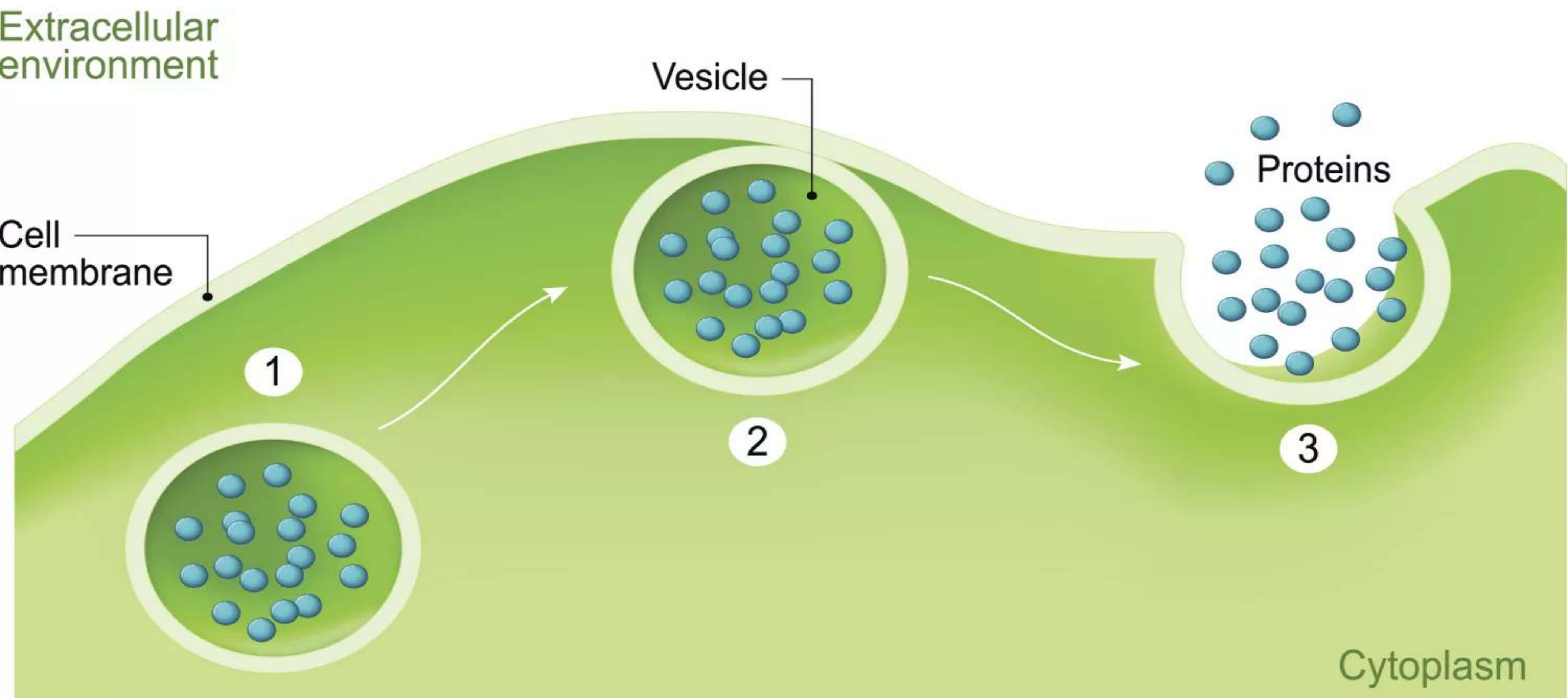
Endocytosis	Both	Exocytosis
•Molecules *enter* cell	•Involve vesicles, which are made of phospholipids	•Molecules *leave* cell
•Cell membrane pinches in, creating vesicle	•Large amount of molecules transported	•Vesicle approaches cell membrane, and merges with it, releasing molecules
•Ex: cell taking in nutrients	•Golgi complex controls process	•Ex: Cell releasing hormones
	•Requires energy	

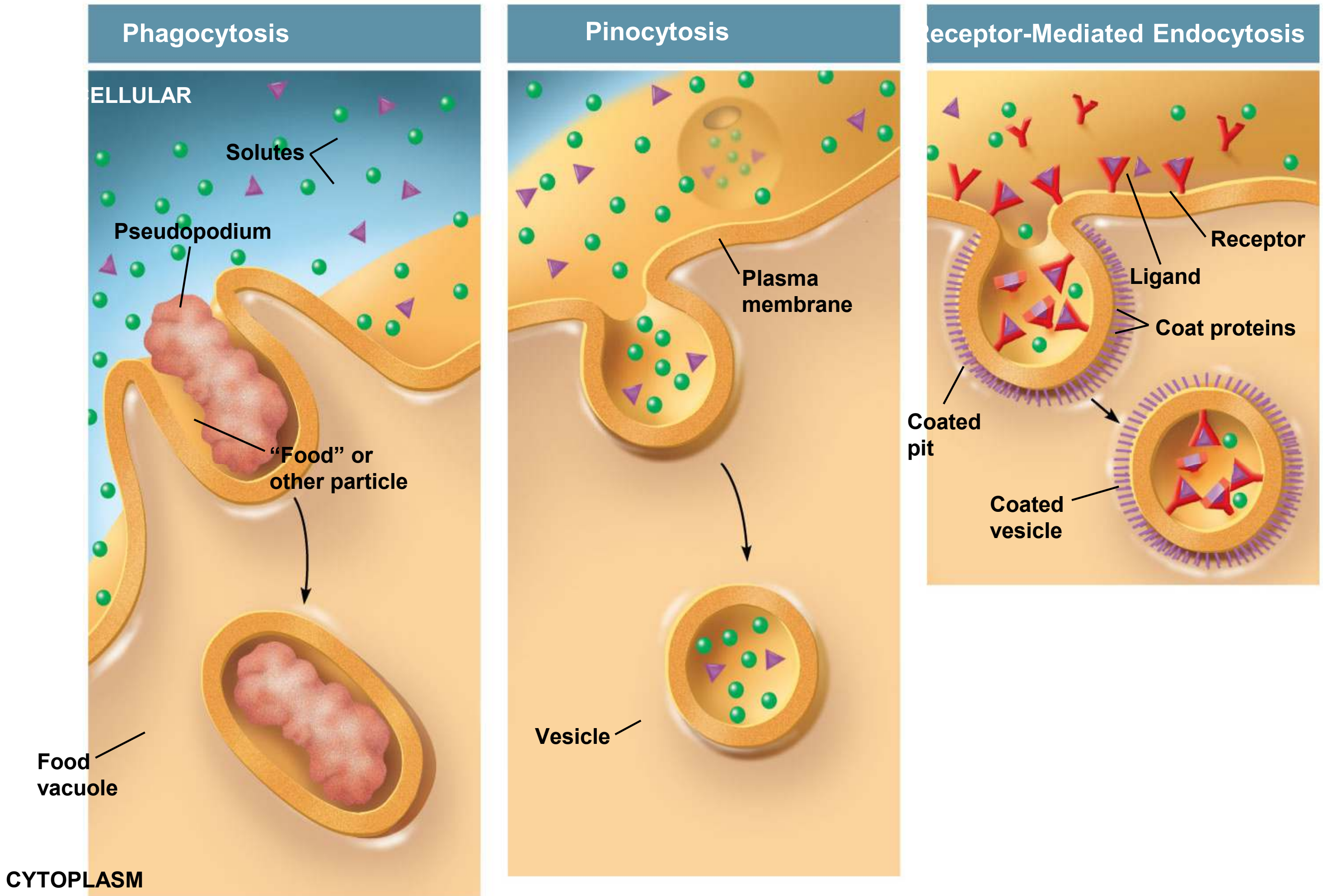
Exocytosis



Extracellular fluid
Plasma membrane SNARE
Vesicle SNARE
Molecules to be secreted
Secretory vesicle
Cytoplasm

EXOCYTOSIS


Extracellular
environment
Vesicle
Proteins
Cell
membrane
1
2
3
Cytoplasm

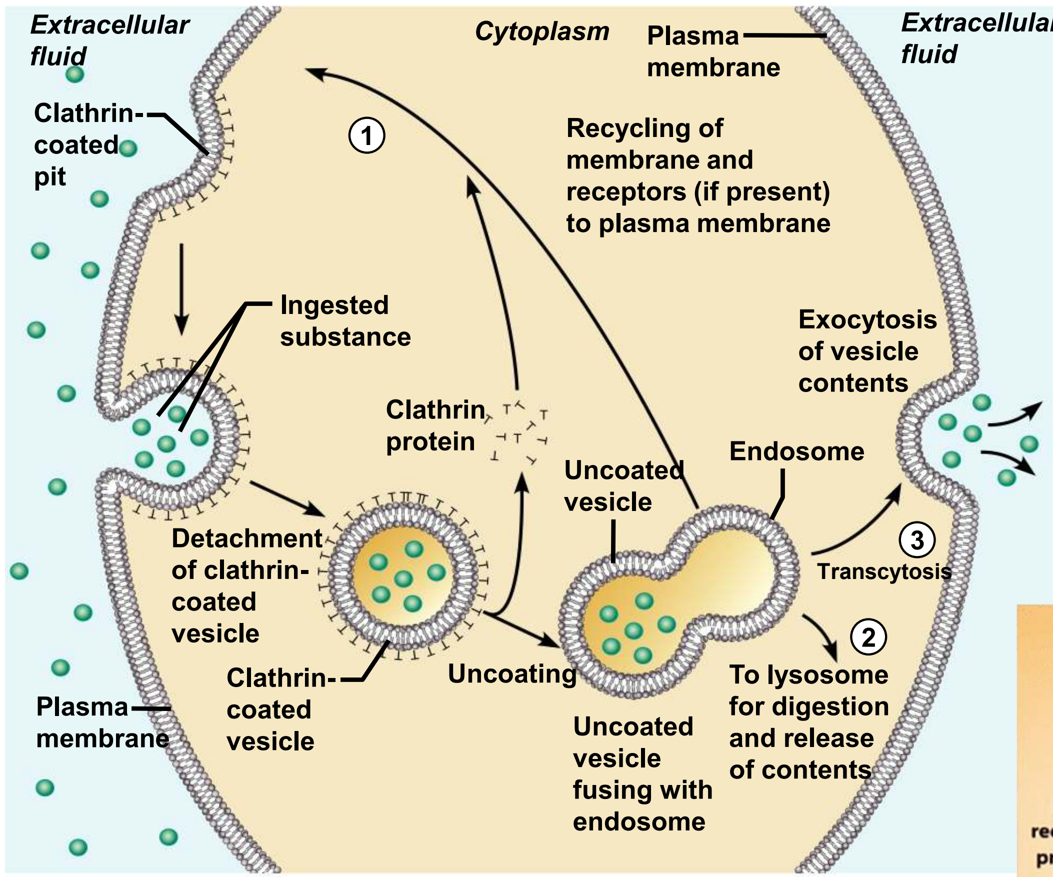


Phagocytosis
Pinocytosis
eceptor-Mediated Endocytosis
ELLULAR
Solutes
Pseudopodium
"Food" or
other particle
Food
vacuole
CYTOPLASM
Plasma
membrane
Vesicle
Receptor
Ligand
Coat proteins
Coated
pit
Coated
vesicle

Clathrin-Mediated Endocytosis

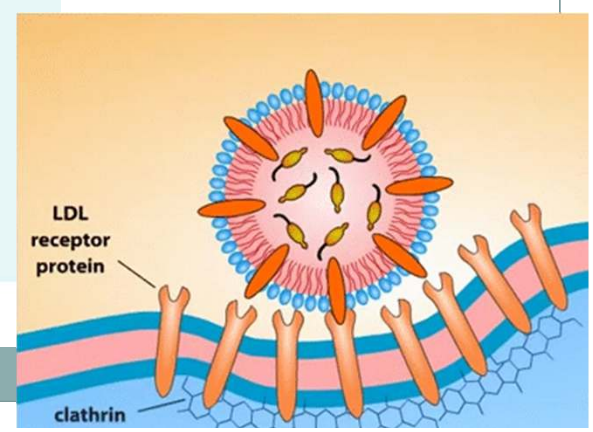
his mechanism is essential for various cellular functions, including nutrient uptake, receptor internalization, and the regulation of cell signaling.

1. **Initiation:
2. **Formation of Clathrin-Coated Pits:
3. **Binding of Adaptor Proteins:
4. **Invagination of the Membrane:
5. **Pinching Off of the Vesicle:
6. **Uncoating and Fusion:
7. **Cargo Delivery and Recycling:



(a) Clathrin-mediated endocytosis

Example of action : Clathrin-mediated endocytosis allows cells to regulate their cholesterol levels by taking up LDL particles from the extracellular environment.



1. **Initiation:

- The process begins with the recognition of specific molecules or ligands on the cell membrane that need to be internalized.
- These molecules often include nutrients, signaling receptors, or other substances that the cell needs.

2. **Formation of Clathrin-Coated Pits:

- Clathrin is a protein that assembles into a lattice-like structure on the inner surface of the cell membrane, forming structures known as clathrin-coated pits.
- These pits are regions where endocytosis will take place.

3. **Binding of Adaptor Proteins:

- Adaptor proteins, such as adaptin, help link clathrin to the receptors on the cell membrane that are associated with the molecules to be internalized.
- These adaptors help in the recruitment of clathrin to the specific sites.

4. **Invagination of the Membrane:

- The clathrin-coated pit invaginates, causing the cell membrane to fold inward and form a vesicle.
- This process encloses the target molecules within the vesicle.

5. **Pinching Off of the Vesicle:

- The vesicle, now fully enclosed and coated with clathrin, pinches off from the cell membrane.
- The clathrin coat is shed, leaving a free vesicle containing the internalized cargo.

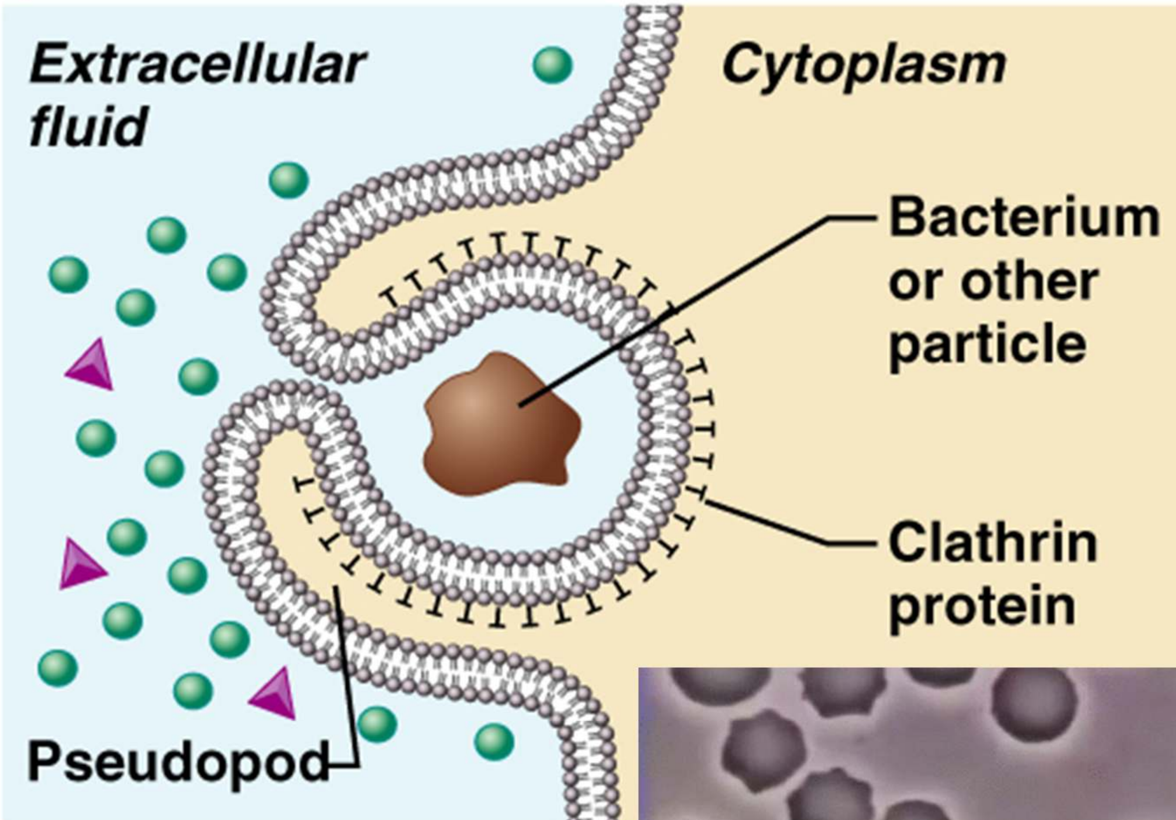
6. **Uncoating and Fusion:

- Once the vesicle is formed, it loses its clathrin coat.
- The uncoated vesicle then moves into the cell's interior, where it may fuse with other vesicles or undergo further processing.

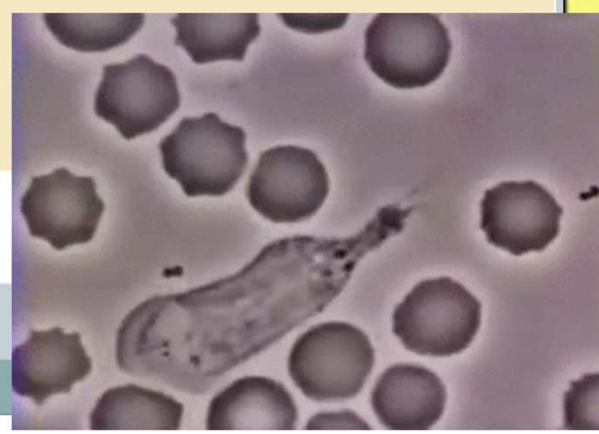
7. **Cargo Delivery and Recycling:

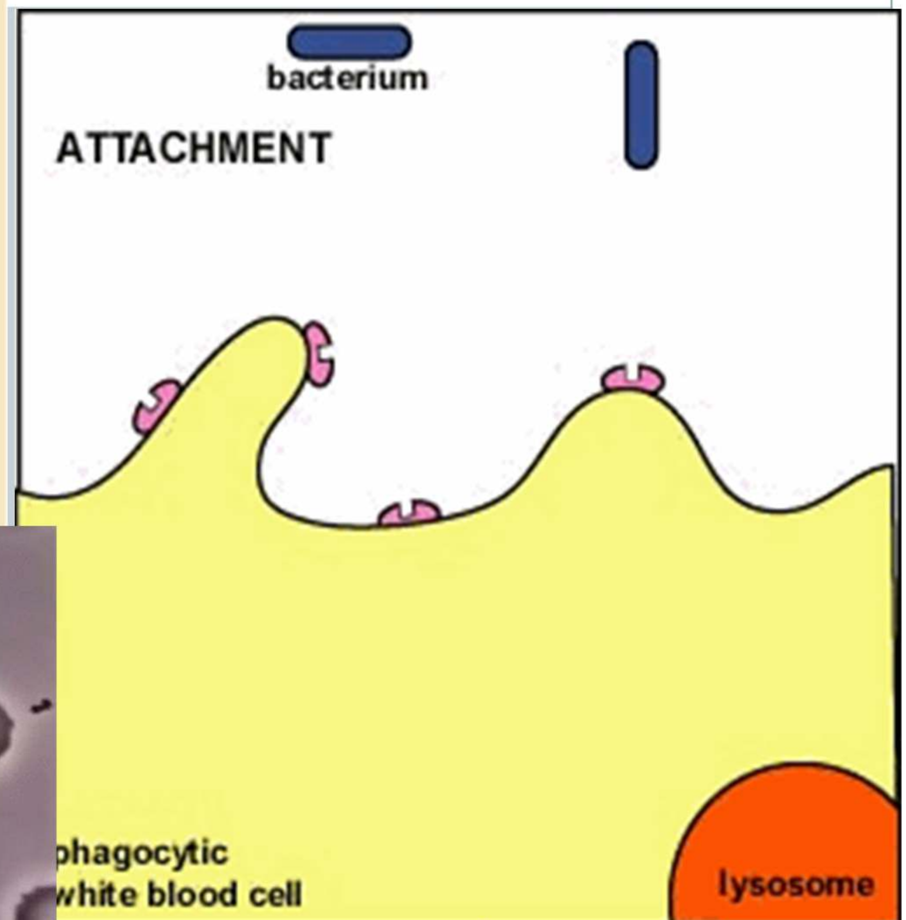
- The internalized cargo is transported to its destination within the cell.
- The clathrin molecules can be recycled and used for future endocytic events.

Phagocytosis

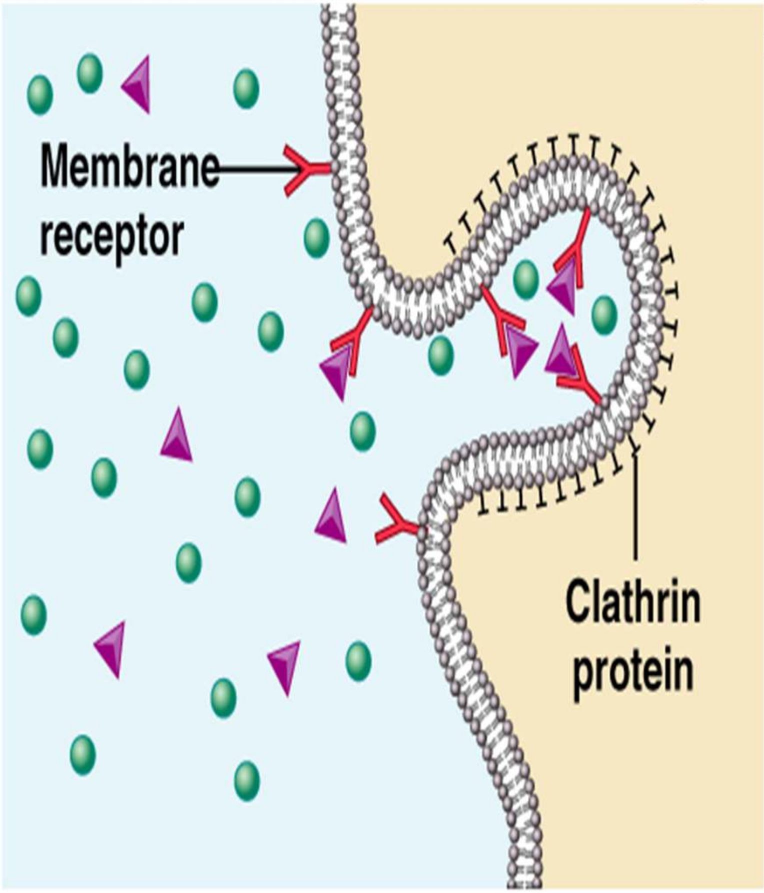


(b) Phagocytosis

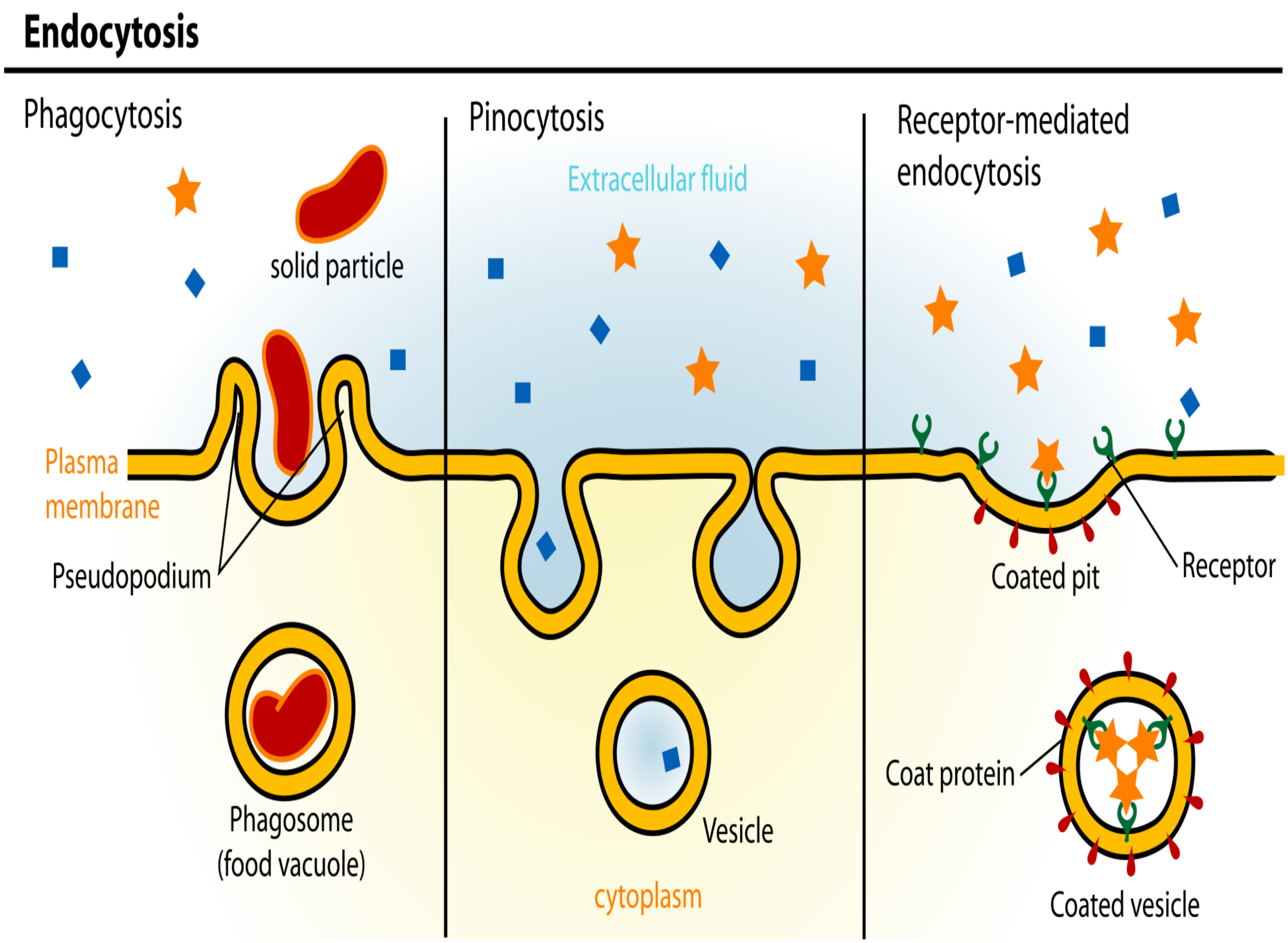




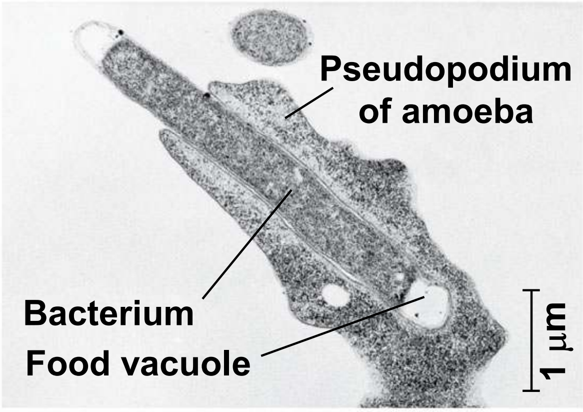
Receptor Mediated Endocytosis



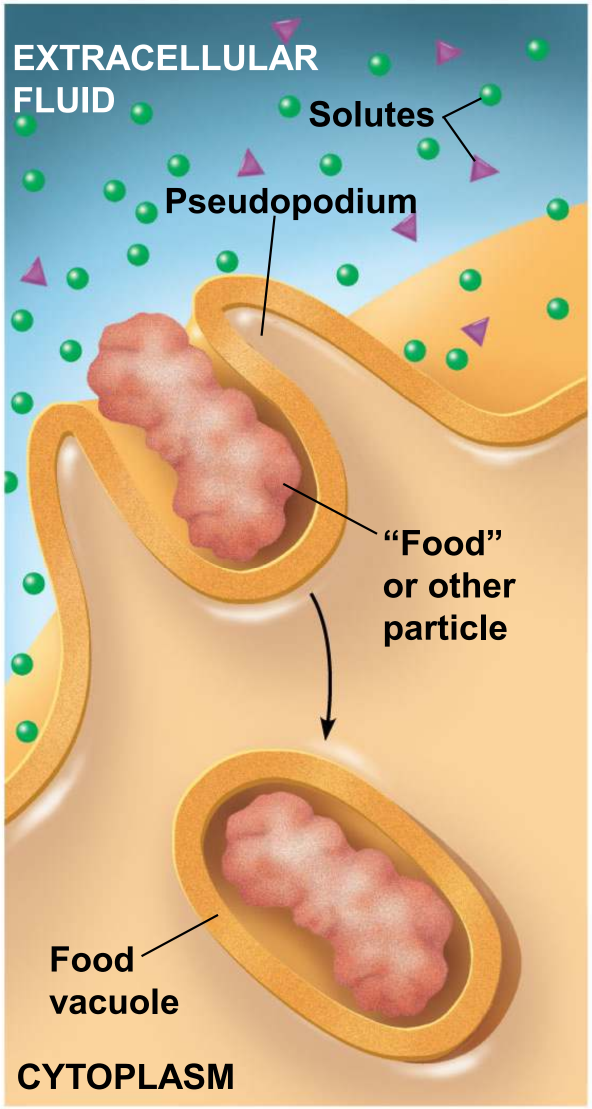
(c) Receptor-mediated endocytosis



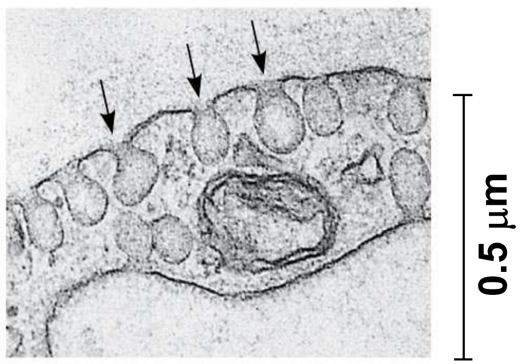
Phagocytosis



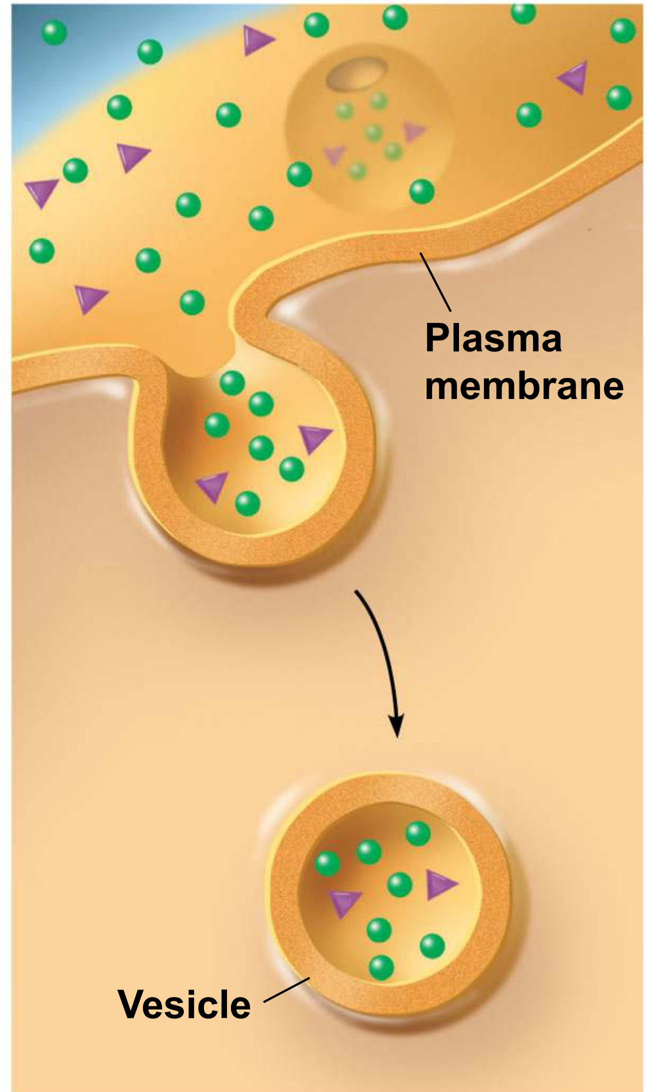
An amoeba engulfing a bacterium via phagocytosis (TEM).



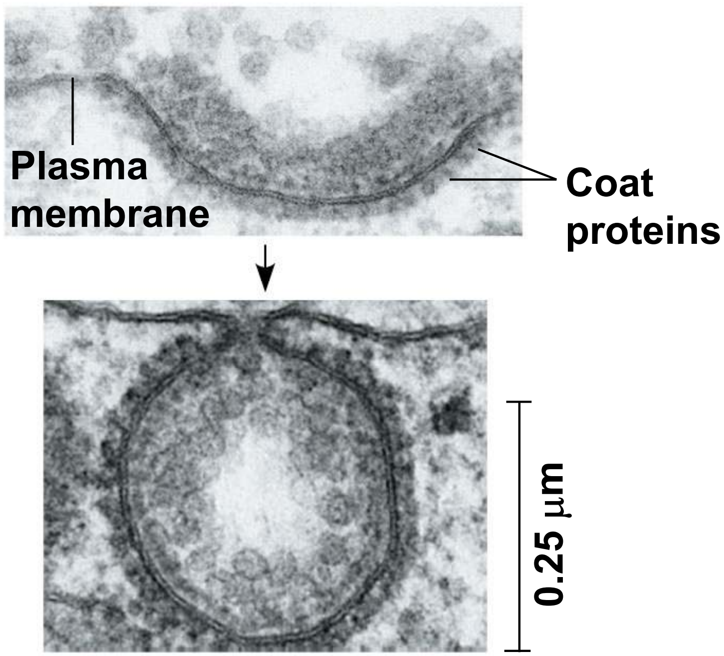
Pinocytosis

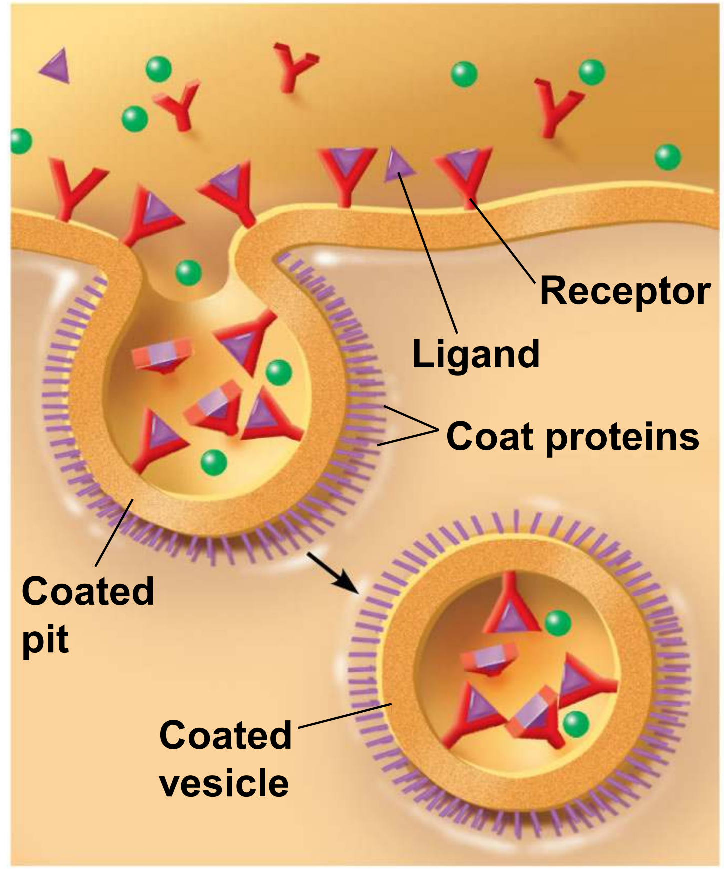


Pinocytosis vesicles forming in a cell lining a small blood vessel (TEM).



Receptor-Mediated Endocytosis





Top: A coated pit. *Bottom:* A coated vesicle forming during receptor-mediated endocytosis (TEMs).

Magnif. : x400
Speed: x2

Passive (Physical) Processes

- Require no cellular energy and include:
  - Simple diffusion
  - Facilitated diffusion
  - Osmosis
  - Filtration

Active (Physiological) Processes

- Require cellular energy and include:
  - Active transport
  - Endocytosis
  - Exocytosis
  - Transcytosis

Passive Membrane Transport – Review

Process	Energy Source	Example
Simple diffusion	Kinetic energy	Movement of O_2 through membrane
Facilitated diffusion	Kinetic energy	Movement of glucose into cells
Osmosis	Kinetic energy	Movement of H_2O in & out of cells
Filtration	Hydrostatic pressure	Formation of kidney filtrate

Active Membrane Transport – Review

Process	Energy Source	Example
Active transport of solutes	ATP	Movement of ions across membranes
Exocytosis	ATP	Neurotransmitter secretion
Endocytosis	ATP	White blood cell phagocytosis
Fluid-phase endocytosis	ATP	Absorption by intestinal cells
Receptor-mediated endocytosis	ATP	Hormone and cholesterol uptake
Endocytosis via caveoli	ATP	Cholesterol regulation
Endocytosis via coatomer vesicles	ATP	Intracellular trafficking of molecules

Clinical Relevance

Cell membrane transport plays a critical role in maintaining cellular homeostasis and ensuring proper functioning of cells and tissues. Disruptions in membrane transport processes can have significant impacts on cellular function and contribute to the development or progression of various disease conditions. Here are some examples:

1.Cystic Fibrosis:

- **Defective Ion Transport:** Cystic fibrosis is a genetic disorder caused by mutations in the CFTR gene, leading to defective chloride ion transport across cell membranes. This disrupts the balance of ions and water in the respiratory and digestive systems, resulting in thick and sticky mucus. This mucus impairs the function of the lungs and pancreas, leading to respiratory and digestive problems.

2.Diabetes:

- **Glucose Transport Issues:** In diabetes, particularly type 2 diabetes, there is a reduced responsiveness of cells to insulin (insulin resistance). Insulin facilitates the uptake of glucose into cells by promoting the insertion of glucose transporters (GLUT4) into the cell membrane. Insulin resistance disrupts this process, leading to elevated blood glucose levels and contributing to the development of diabetes.

3.Hemolytic Anemias:

- **Impaired Ion Transport in Red Blood Cells:** Certain types of hemolytic anemias result from defects in ion transport mechanisms in red blood cells. For example, hereditary spherocytosis is caused by mutations affecting membrane proteins involved in maintaining the shape and stability of red blood cells. This can lead to premature destruction of red blood cells and anemia.

4.Hypertension:

- **Ion Transport in Blood Vessels:** The regulation of ion transport across the membranes of blood vessel cells is essential for maintaining blood pressure. Dysregulation of ion transport, such as increased sodium retention, can contribute to hypertension (high blood pressure). This is often associated with conditions like kidney disease.

5.Cancer:

- **Altered Transport in Tumor Cells:** Cancer cells often exhibit changes in membrane transport processes. For example, upregulation of certain ion channels and transporters can promote the survival and proliferation of cancer cells. Disruptions in ion transport may also contribute to changes in the microenvironment that support tumor growth.

6.Neurological Disorders:

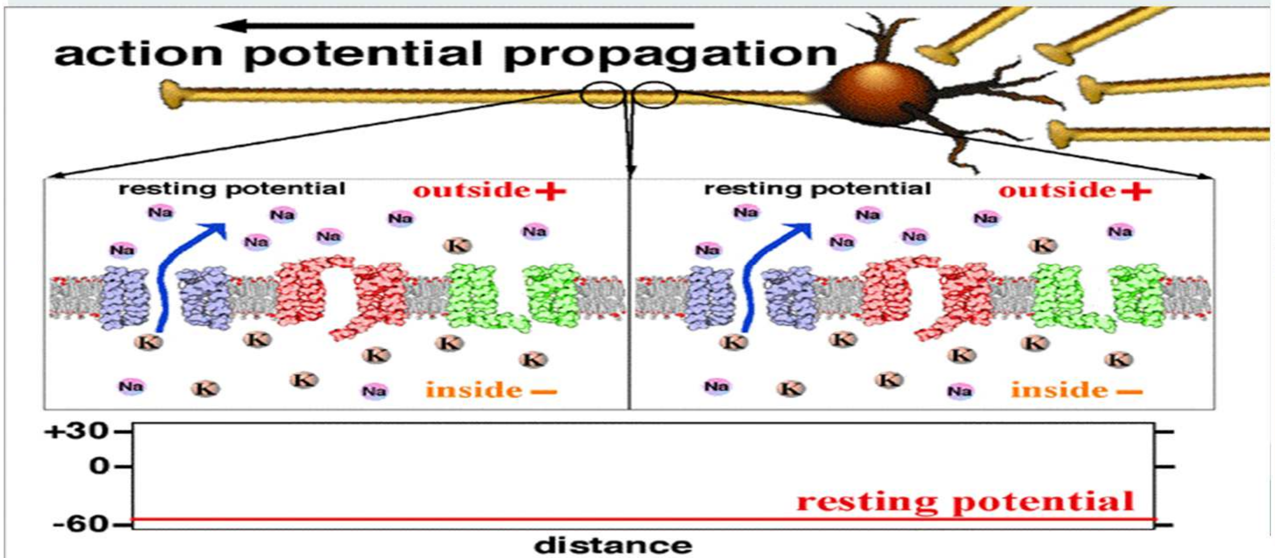
- **Ion Transport in Neurons:** Neurological disorders, such as epilepsy and certain movement disorders, can be influenced by abnormalities in ion transport across neuronal membranes. Ion channels and transporters play a crucial role in maintaining the electrical excitability of neurons, and disruptions can lead to abnormal neuronal activity.

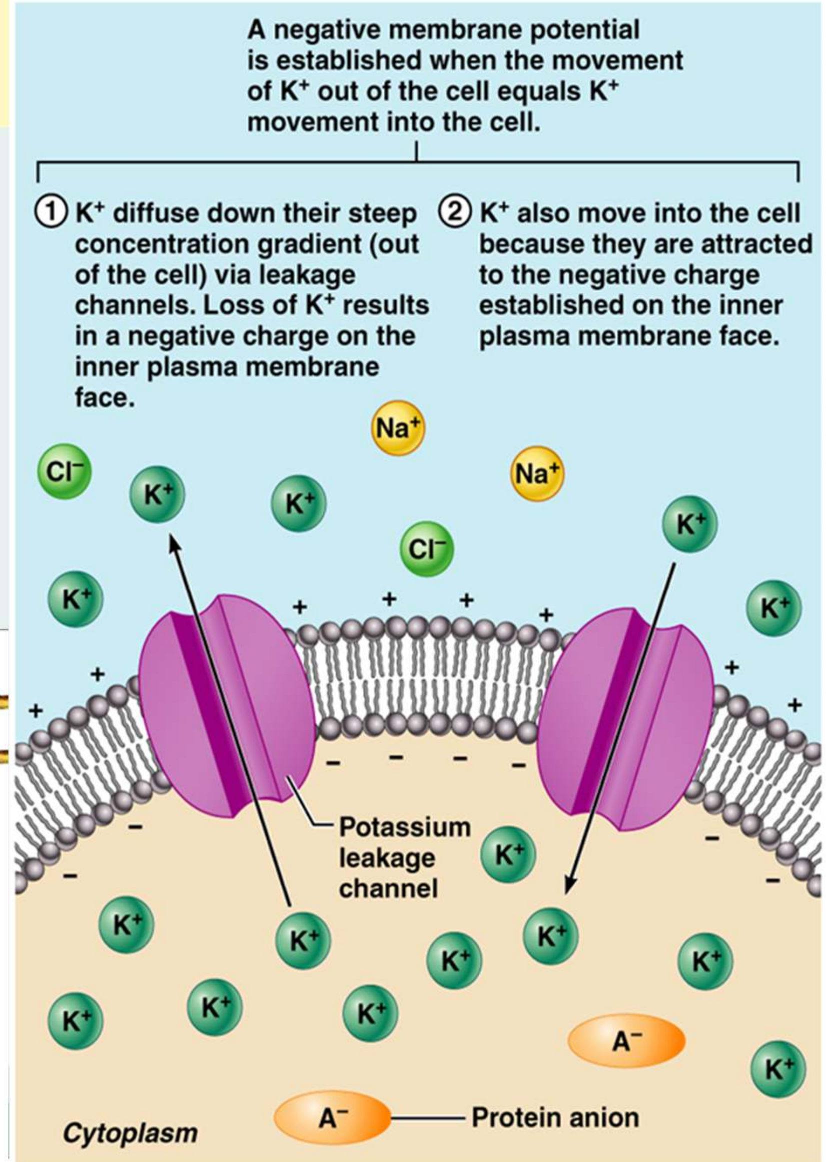
Activity

	Diffusion	Facilitative Diffusion	Active Transport
Concentration Gradient	• Down the gradient	• Down the gradient	• Against the gradient
Energy	• No energy needed	• No energy needed	• Needs energy (ATP)
Proteins	• No proteins needed	• Uses proteins	• Uses proteins
Types of molecules	• Small (CO_2, H_2O, O_2, lipids)	• Larger charged/polar molecules	• Larger charged/polar molecules

Membrane Potential

- Voltage across a membrane
- Resting membrane potential – the point where K^+ potential is balanced by the membrane potential
  - Ranges from –20 to –200 mV
  - Results from Na^+ and K^+ concentration gradients across the membrane
  - Differential permeability of the plasma membrane to Na^+ and K^+
- Steady state – potential maintained by active transport of ions

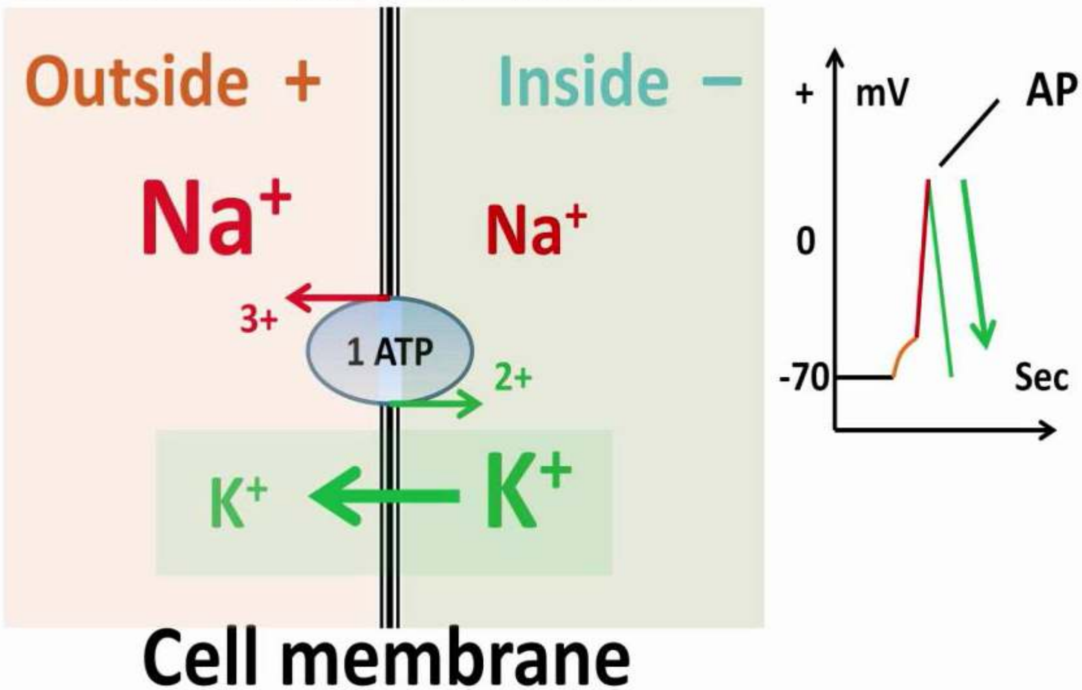


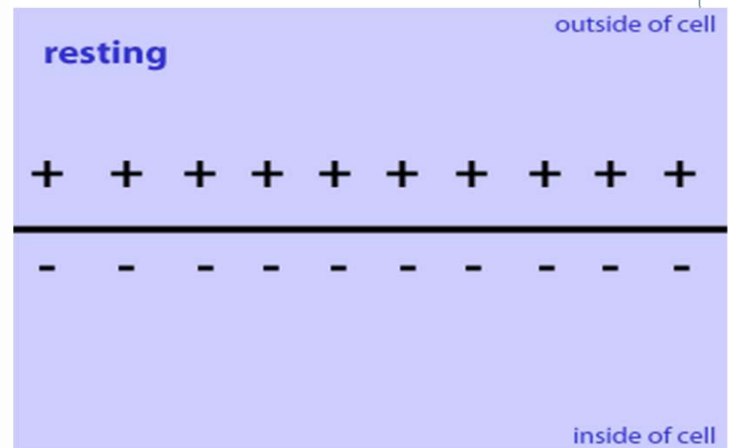


Action Potential (AP): Repolarization

Na^+ channels close, K^+ channels open; K^+ diffusion

TP: +30 mV back to -70 mV

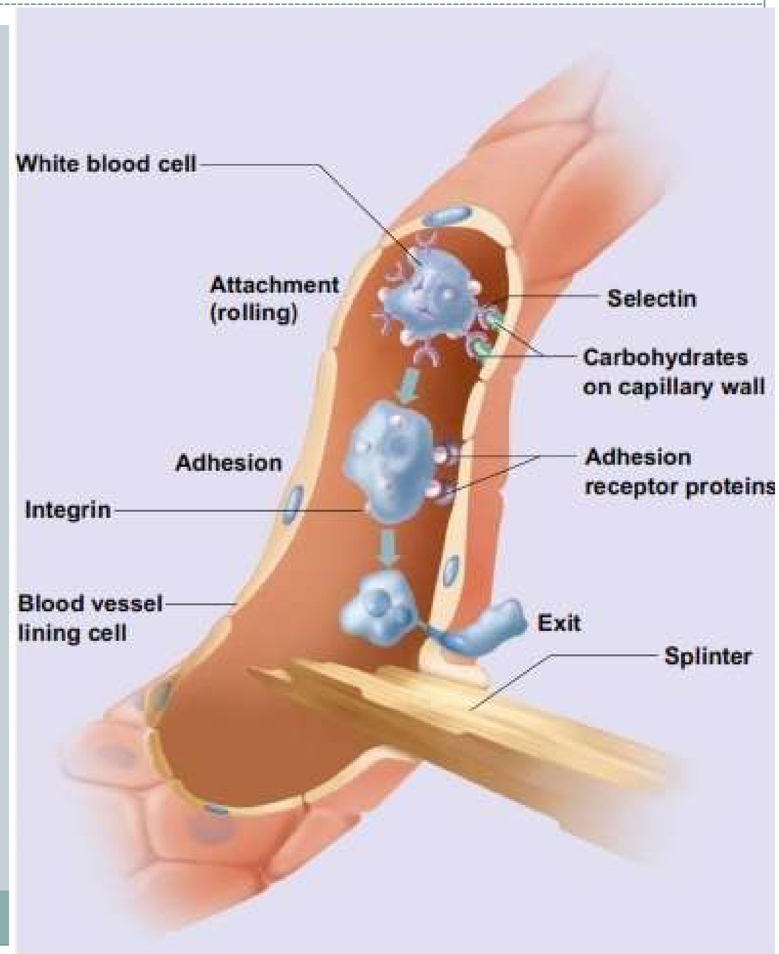




Faulty Ion Channels Cause Disease

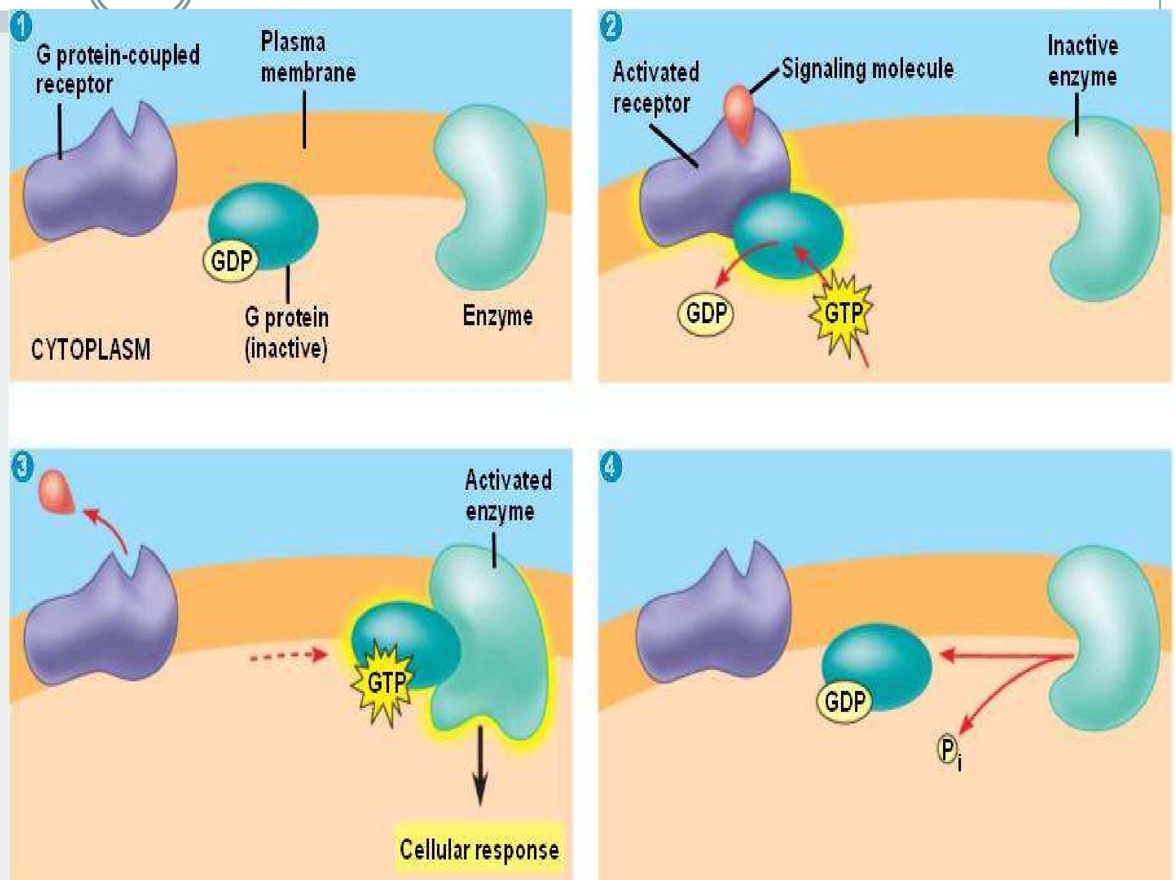
Cell Adhesion Molecules (CAMs)

- Anchor cells to the extracellular matrix
- Assist in movement of cells past one another
- Rally protective white blood cells to injured or infected areas
- Guide cells on the move
- Selectin – allows white blood cells to "anchor"
- Integrin – guides white blood cells through capillary walls
- Important for growth of embryonic tissue
- Important for growth of nerve cells



Roles of Membrane Receptors

- **Contact signaling** – important in normal development and immunity
- **Electrical signaling** – voltage-regulated "ion gates" in nerve and muscle tissue
- **Chemical signaling** – **neurotransmitters** bind to chemically gated channel-linked receptors in nerve and muscle tissue
- **G protein-linked receptors** – ligands bind to a receptor which activates a G protein, causing the release of a second messenger, such as cyclic AMP



Operation of a G Protein

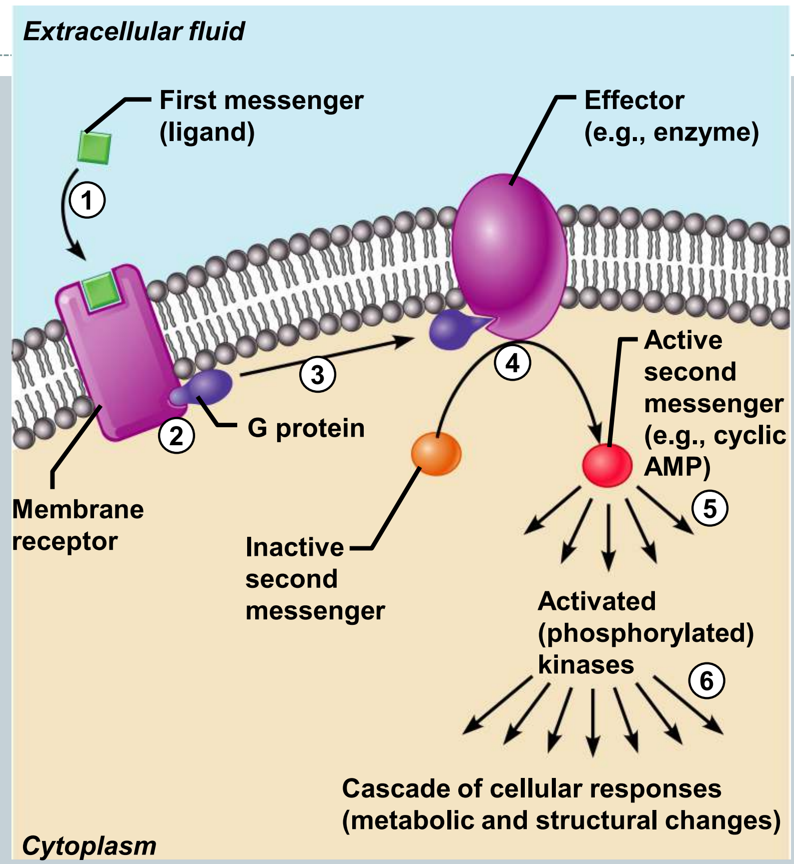


Figure 3.16

Cytoplasm

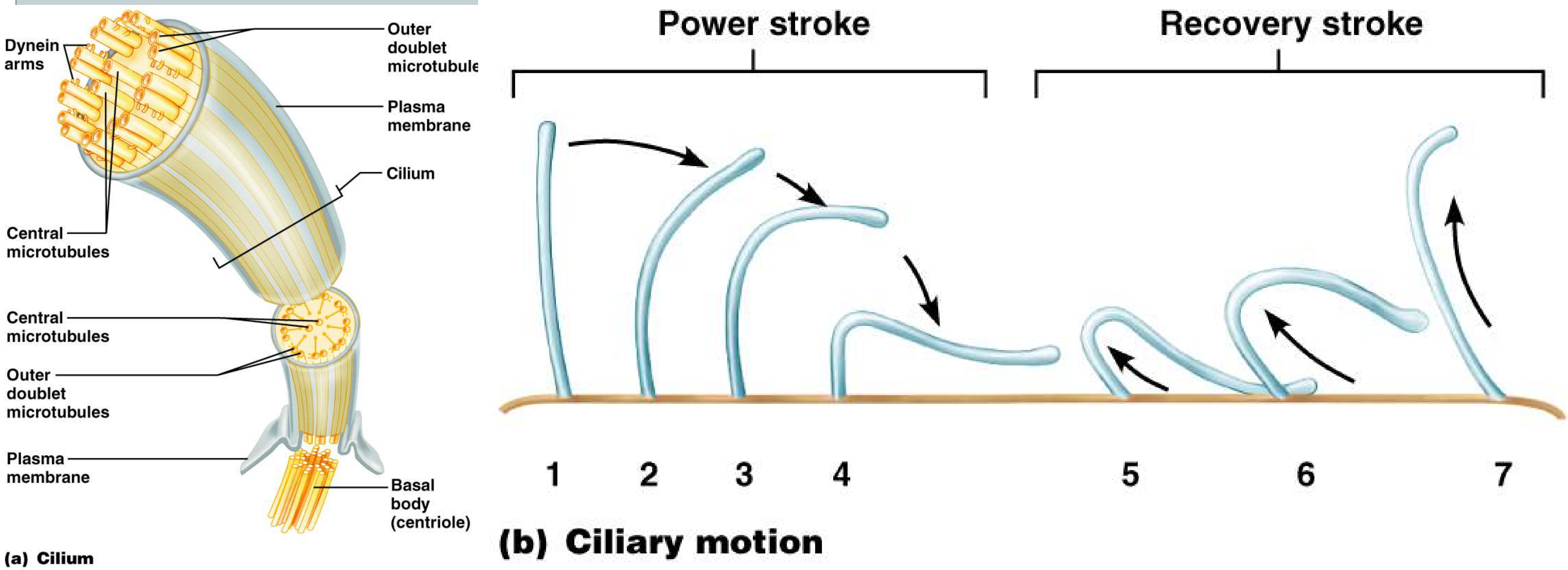
- Cytoplasm – material between plasma membrane and the nucleus
- Cytosol – largely water with dissolved protein, salts, sugars, and other solutes
- The cytosol (cf. *cytoplasm*, which also includes the organelles) is the internal fluid of the cell, and where a portion of cell metabolism occurs.
  - Proteins within the cytosol play an important role in signal transduction pathways and glycolysis.
  - They also act as intracellular receptors and form part of the ribosomes, enabling protein synthesis.

- Cytoplasmic organelles – metabolic machinery of the cell
- Inclusions – chemical substances such as glycosomes, glycogen granules, and pigment

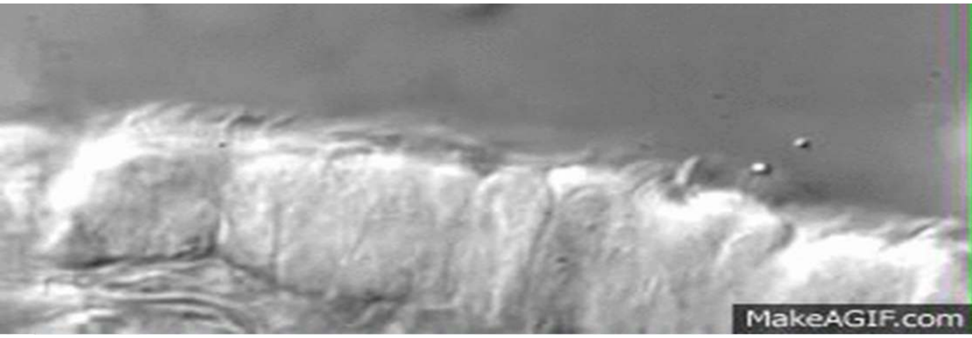
- Cytosol = water
- Organelles = solids

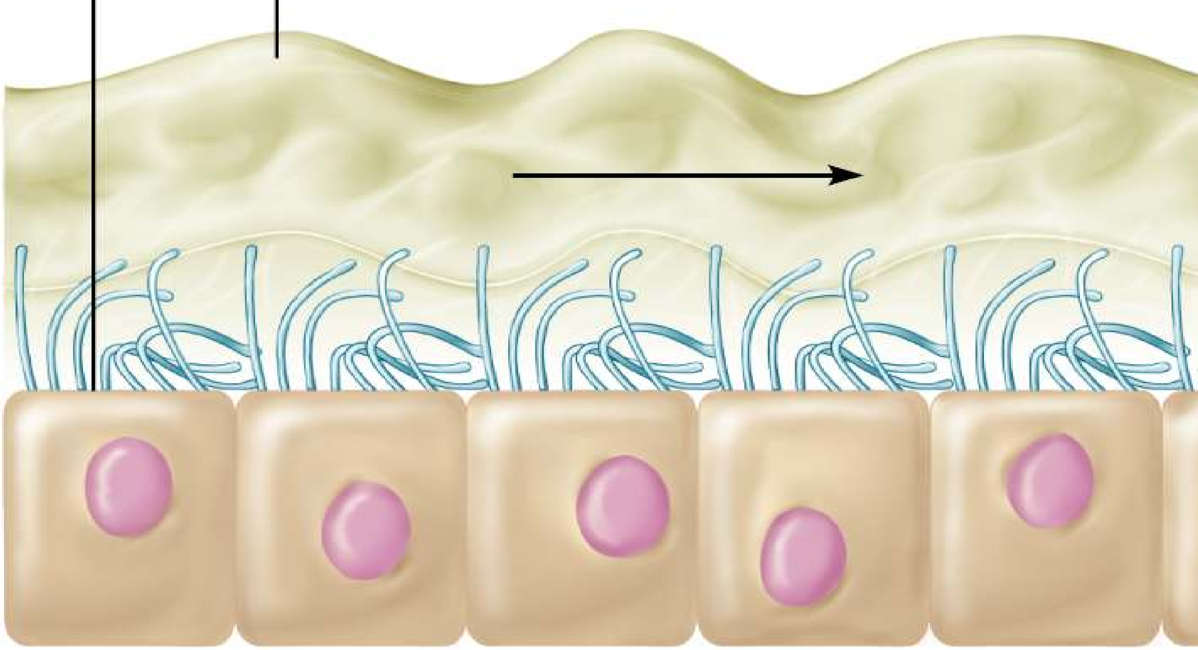
Cilia

- Whip-like, motile cellular extensions on exposed surfaces of certain cells
- Move substances in one direction across cell surfaces

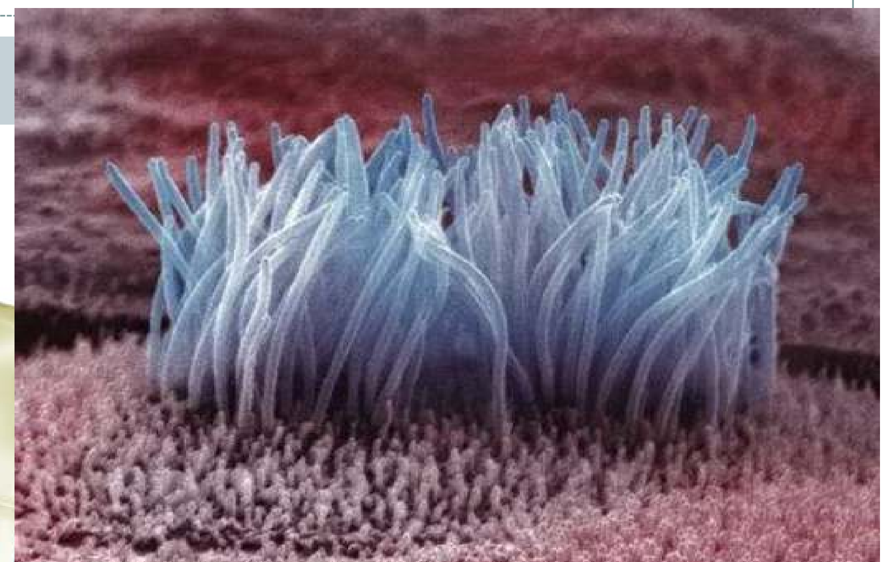


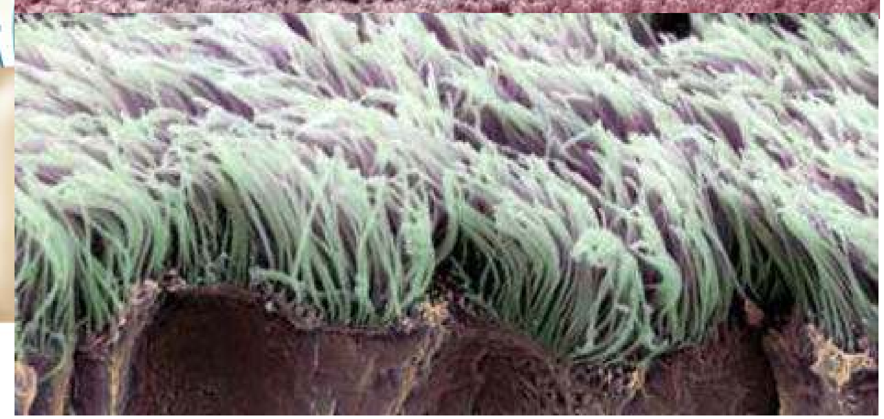
Cilia

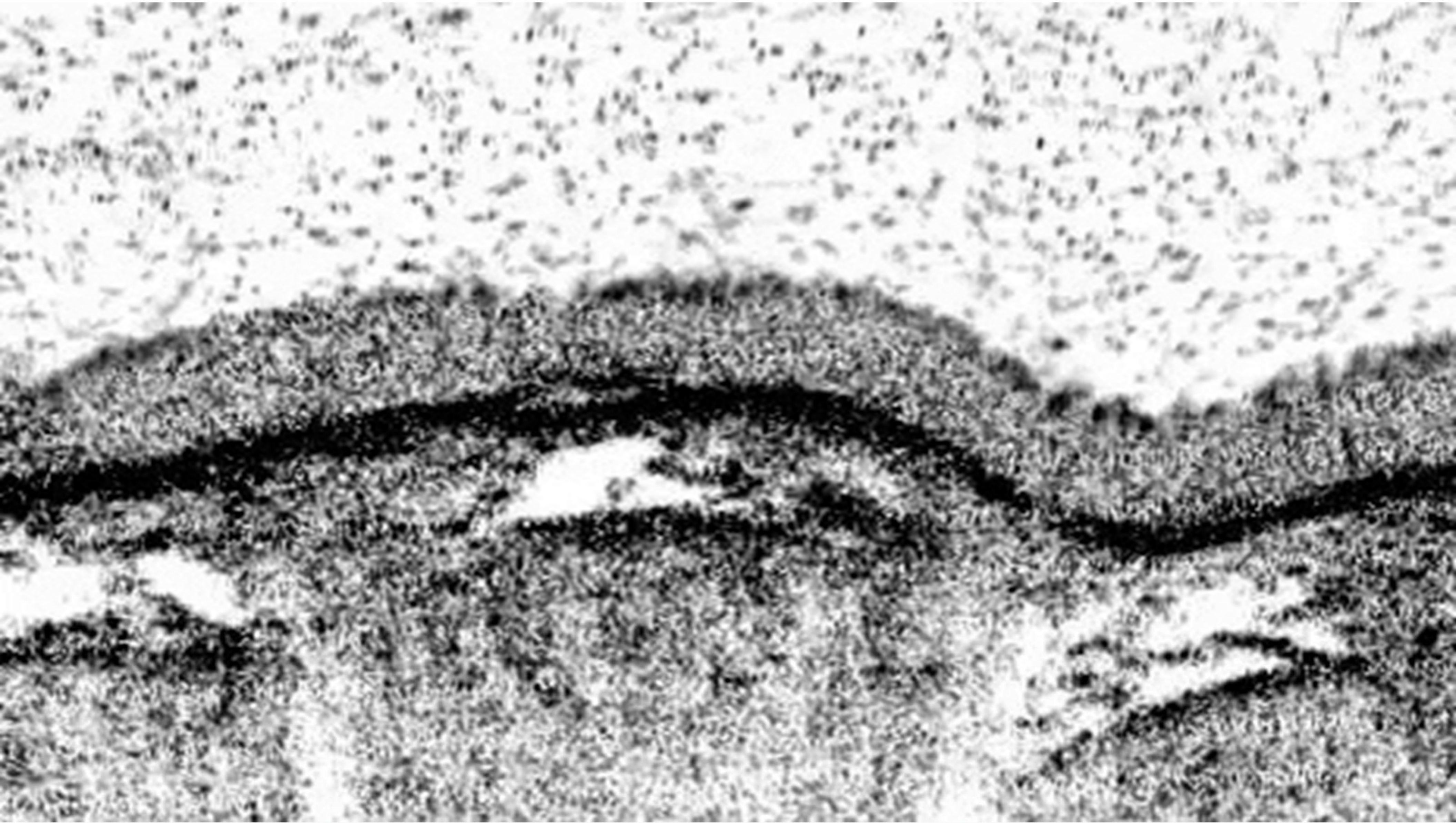


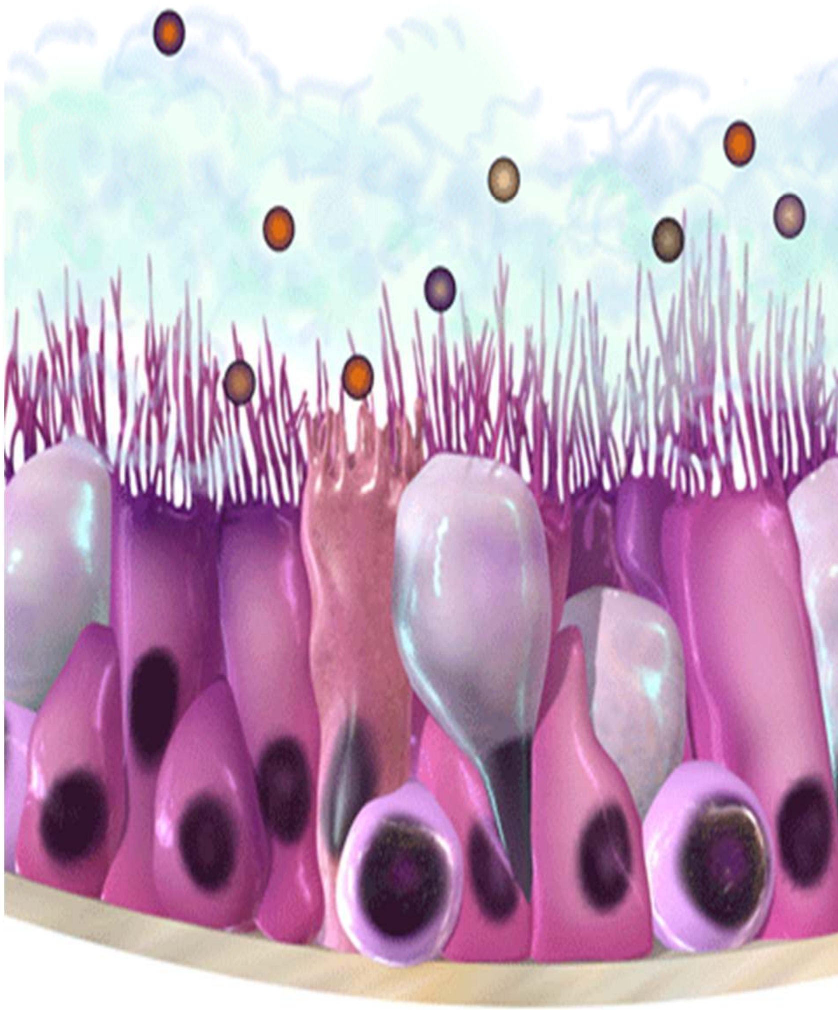


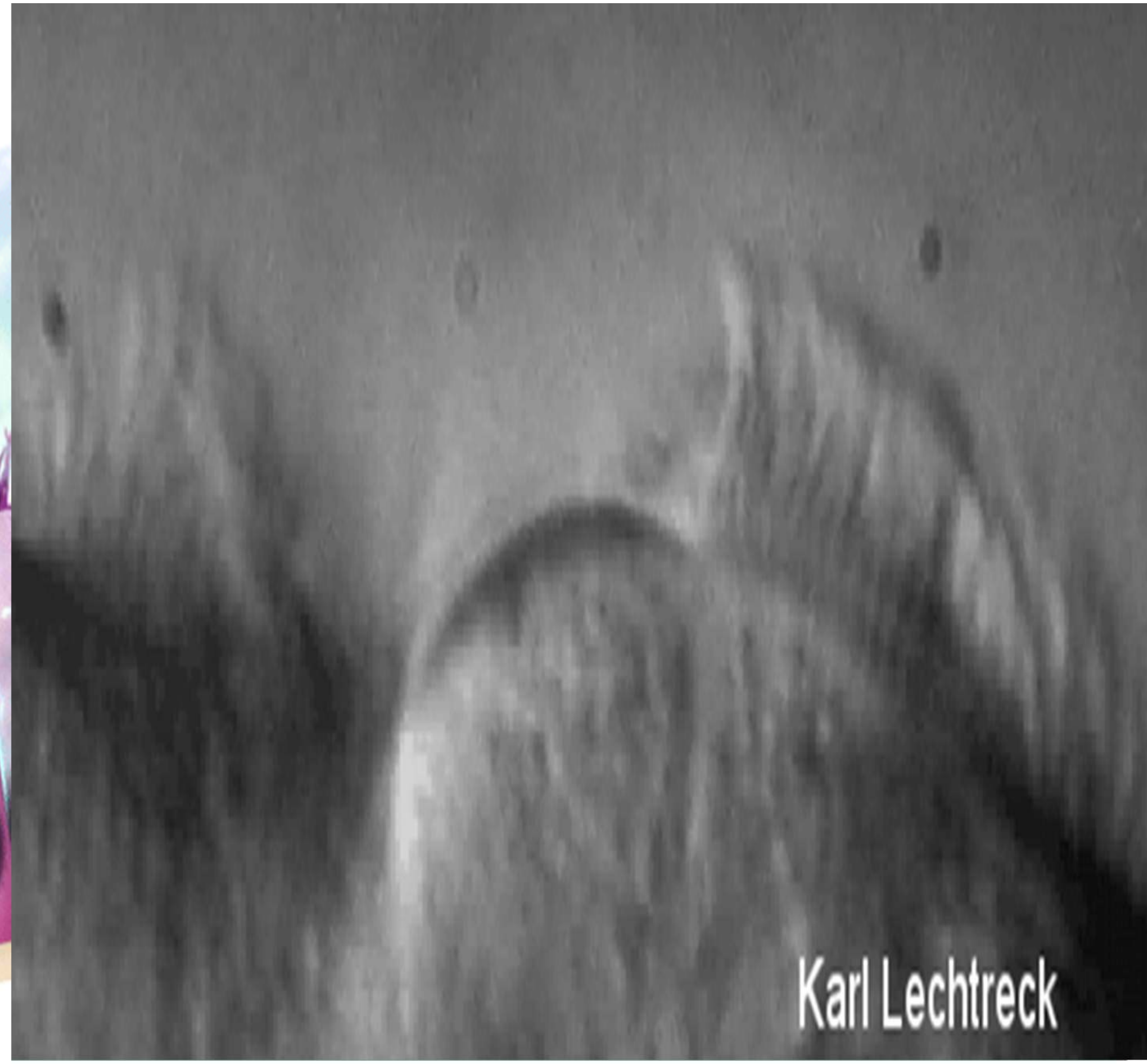
(c) Movement of mucus across cell surfaces










Karl Lechtreck

Interactive Simulation

- Introduction to an online simulation demonstrating cell membrane transport.
- https://contrib.pbslearningmedia.org/WGBH/conv19/tdc02-int-membraneweb/index.html
- Guided exploration: Participants interact with the simulation to understand transport processes.
- https://www.youtube.com/watch?v=2CNGe3jMej0
- https://www.youtube.com/watch?v=S3xulvstq90
- https://www.youtube.com/watch?v=masD8IuzN0M
- https://www.labxchange.org/library/pathway/lx-pathway:52bb8fb7-0c76-4863-8f7c-3bd90d0d79fa/items/lb:LabXchange:340f1f89-6346-3be5-b7e5-8c4ba0c868c4:html:1/53420