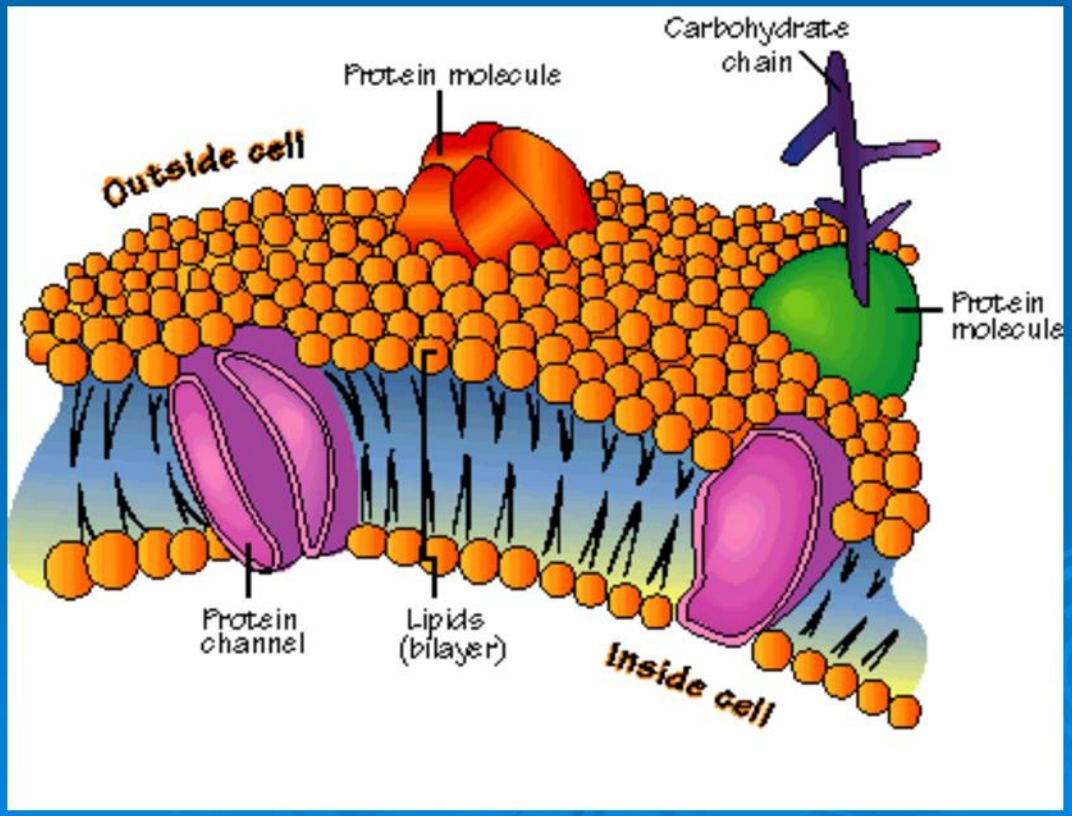
Transport Through the Cell Membrane

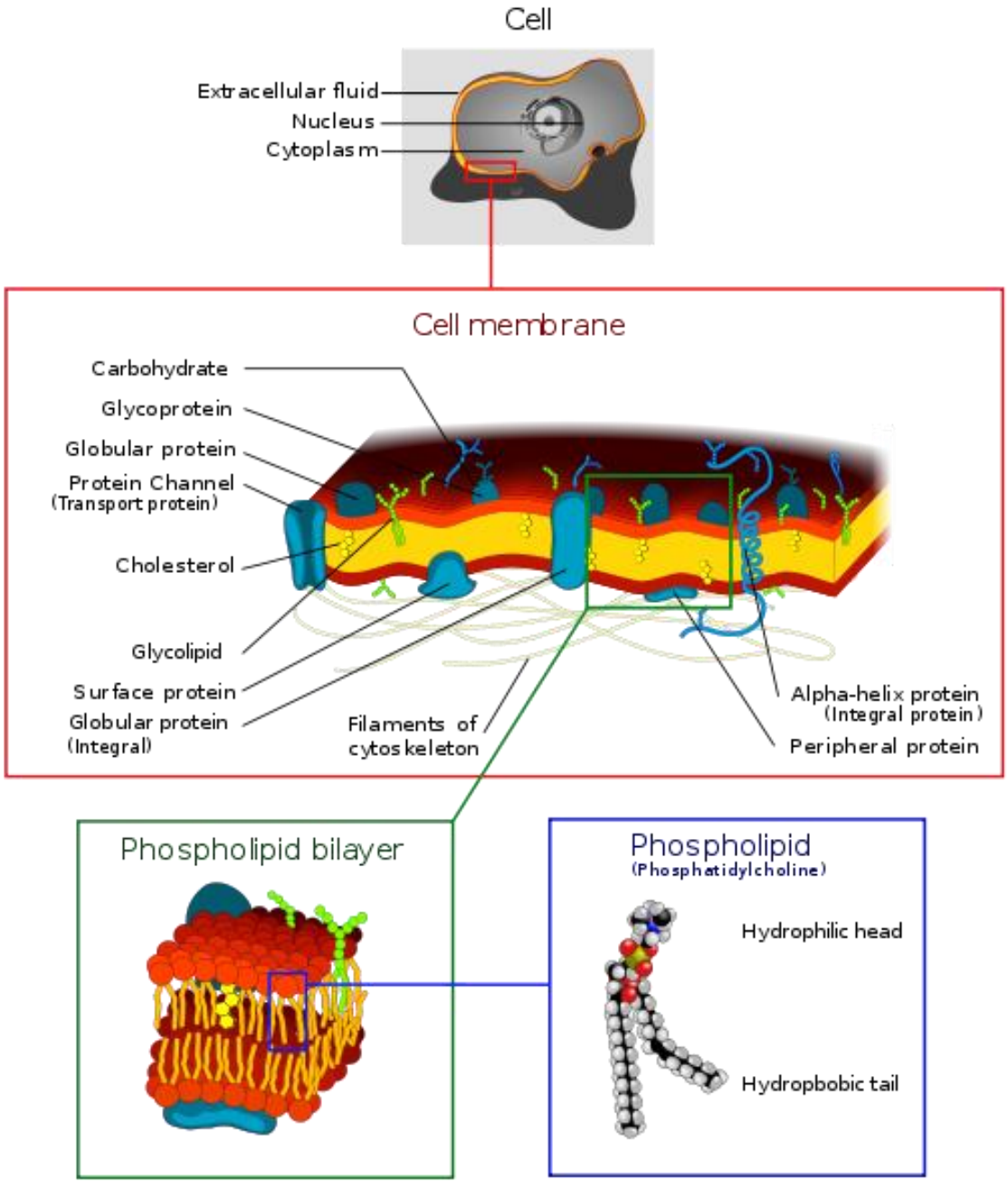
The Cell Membrane & Cell Transport



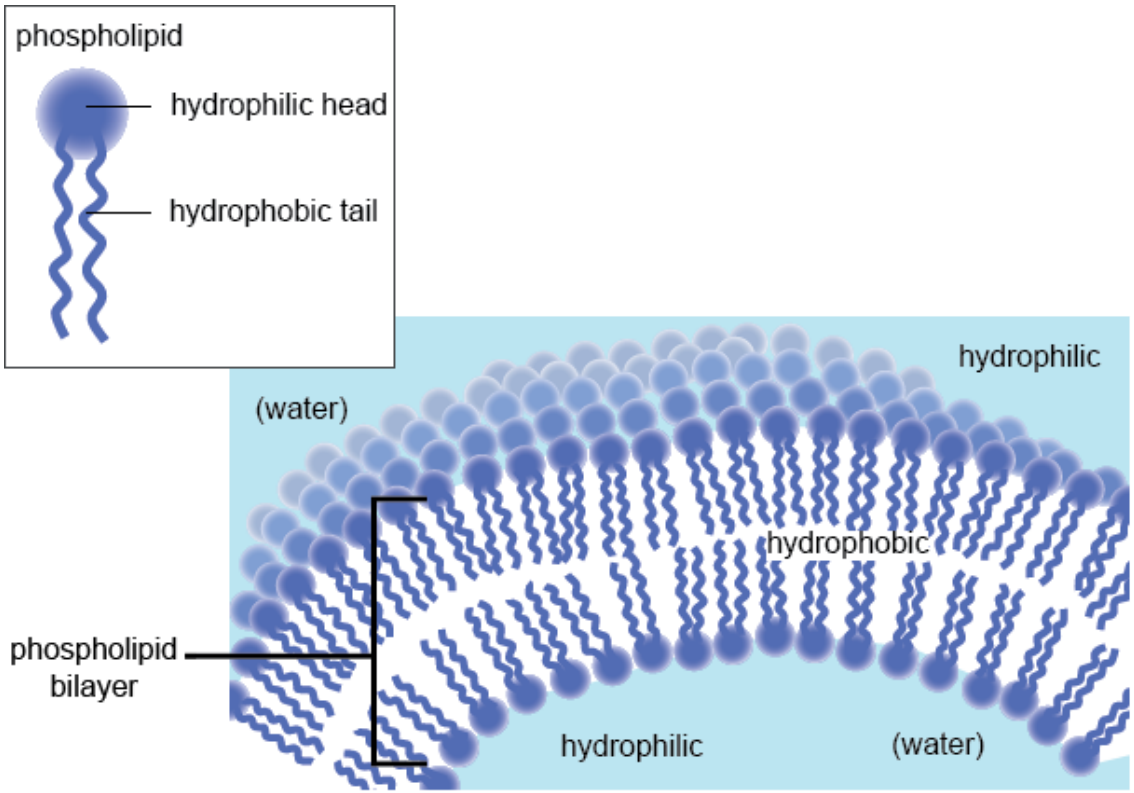
Cell membrane (plasma membrane)

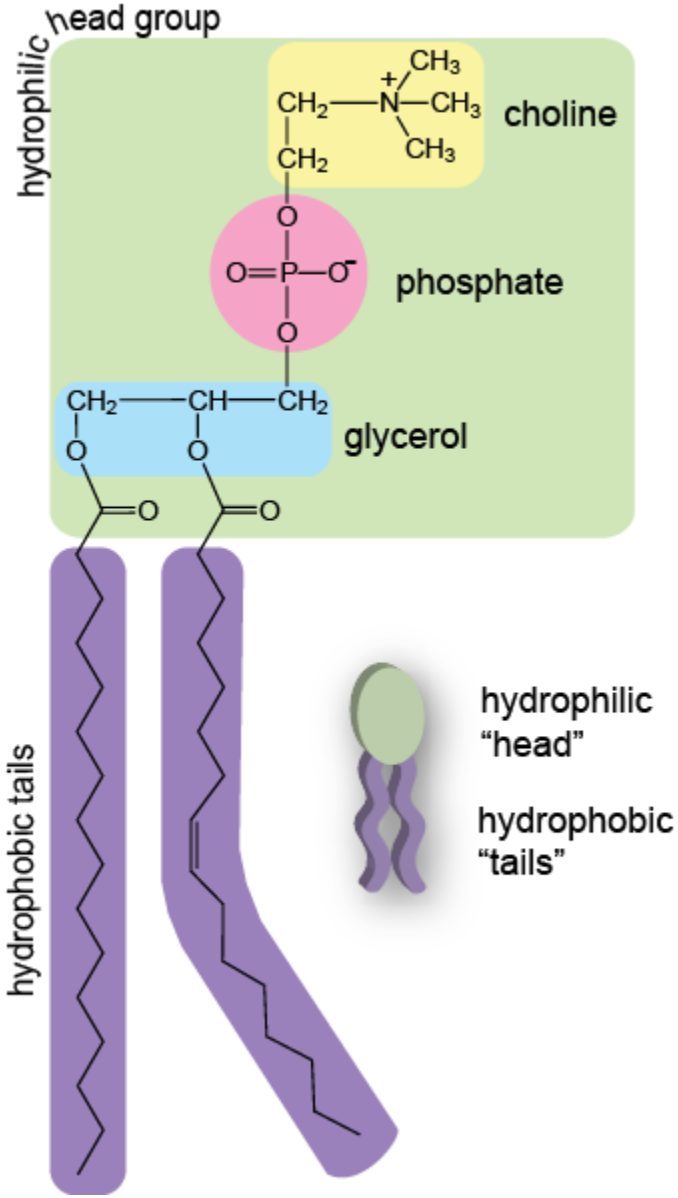
- separates the interior of all cells from the outside environment
- The cell membrane keeps the cytoplasm from leaking out.
- The cell membrane is selectively permeable to ions and organic molecules and controls the movement of substances in and out of cells.
- It basically protects the cell from outside forces.
- It consists of the lipid bilayer with embedded proteins.
- Cell membranes are involved in a variety of cellular processes such as cell adhesion, ion conductivity and cell signaling and serve as the attachment surface for several extracellular structures, including the cell wall, glycocalyx, and intracellular cytoskeleton.

Cell membrane : Phospholipid bilayer

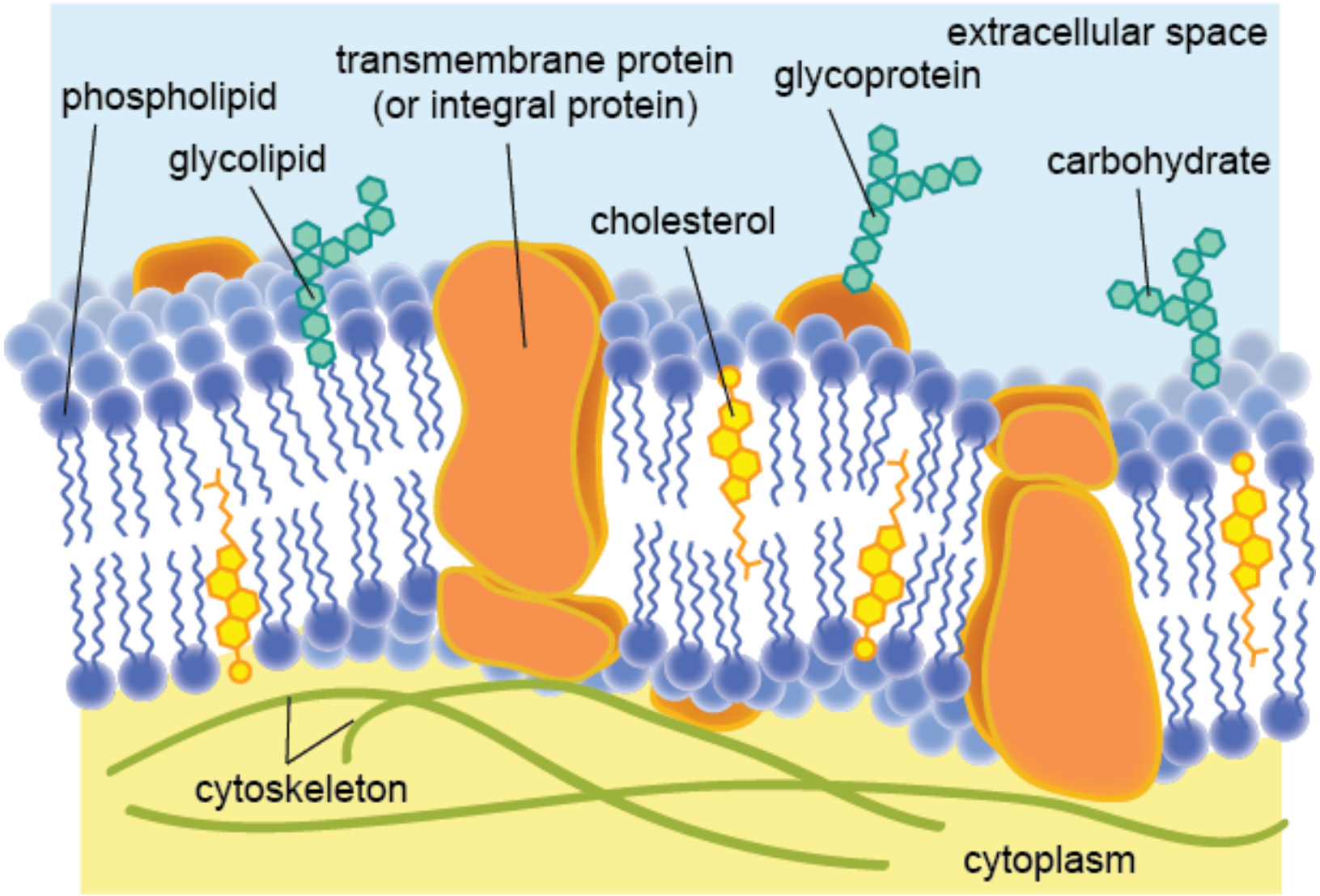


Cell membrane : Phospholipid bilayer





The Plasma Membrane



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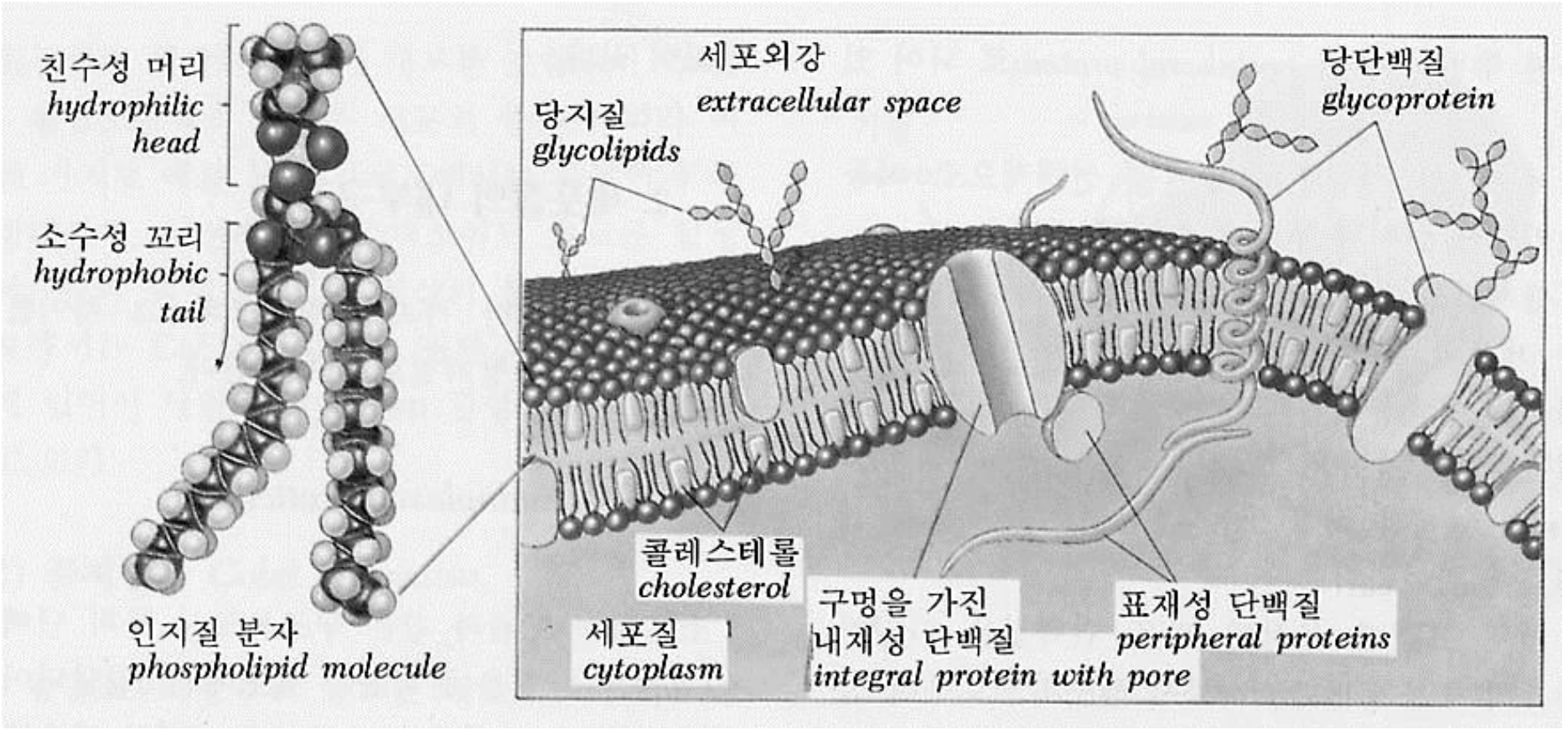
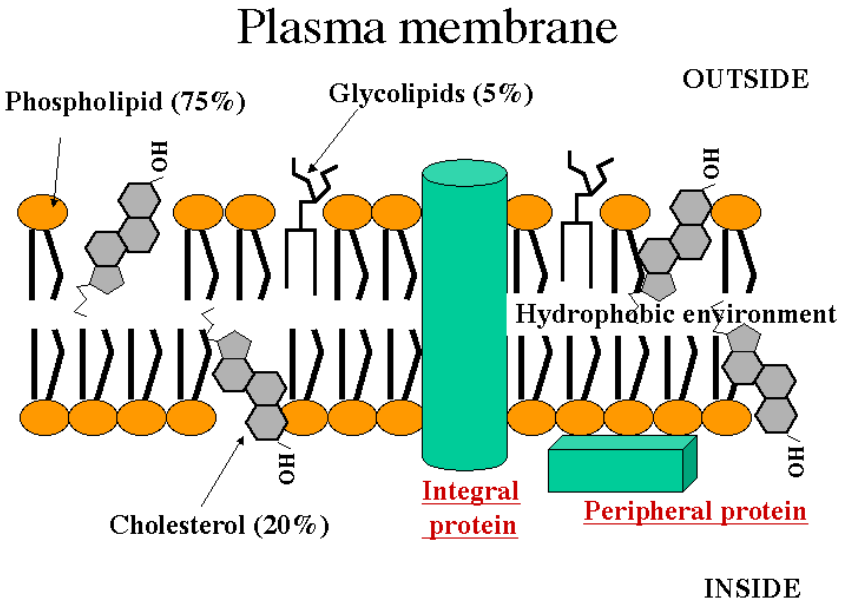

친수성 머리
hydrophilic head
소수성 꼬리
hydrophobic tail
인지질 분자
phospholipid molecule
세포외강
extracellular space
당지질
glycolipids
당단백질
glycoprotein
콜레스테롤
cholesterol
세포질
cytoplasm
구멍을 가진
내재성 단백질
integral protein with pore
표재성 단백질
peripheral proteins

세포막의 화학적 성분 조성

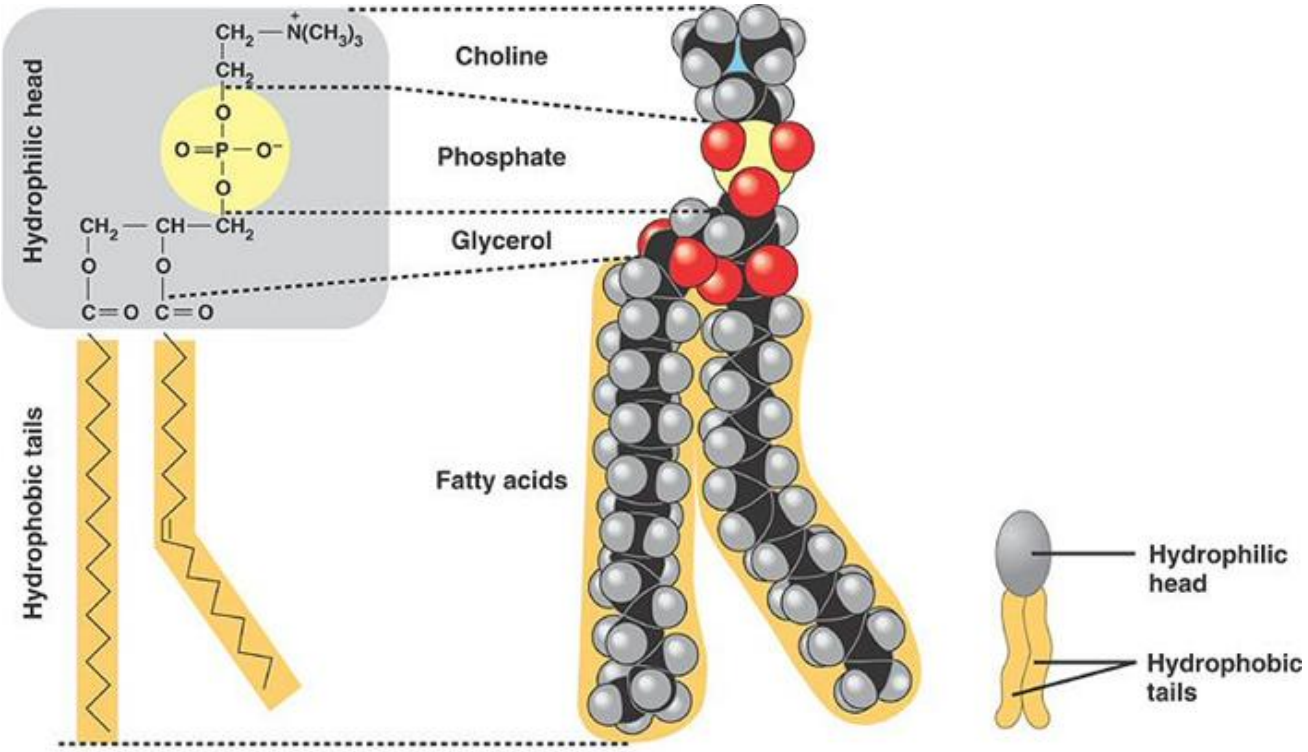
1. 단백질: membrane proteins
   : 60-70 % 당단백 (glycoprotein)
2. 지질 20-40%
   a. 인지질: phospholipids : 지질량의 약70%
   b. 당지질: glycolipids 세포막에 존재
   c. 콜레스테롤: cholesterols
3. 탄수화물: carbohydrates
   : 세포막의 약 1-5%차지



Phospholipids in the membrane

- Phospholipids form the lipid bilayer
  : Structural basis of the cell membrane
- Each phospholipid molecule
  : One polar head group, Two non-polar fatty acid tail groups

Polar head groups prefer water molecules and they face the intracellular and extracellular fluids



Proteins in the membrane

- Two major types of membrane proteins
  - integral membrane proteins ; are often involved in the *transport of materials.*
  - peripheral membrane proteins ; generally function in *cellular communication*.

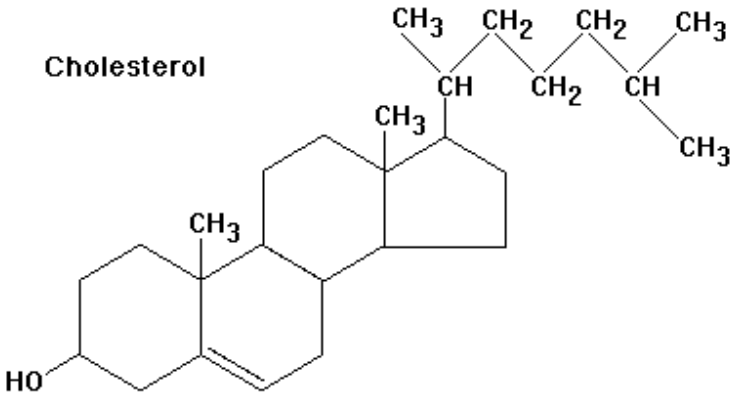
- Some proteins are fairly free to diffuse in the plane of the membrane while others are anchored by cytoskeletal elements

http://www.youtube.com/watch?v=ULR79TiUj80&feature=player_embedded

Cholesterol in the membrane

- Cholesterols enhance fluidity
- Cholesterols prevent fatty acid chains from crystallizing

Cholesterol molecules are primarily responsible for giving the membrane the **rigidity** it needs to hold the cell's shape. Without cholesterol, cells would be nothing more than useless, flattened bags of mush. Balloons with all of the air let out. If you look at the chemical shape of cholesterol, you will notice that is has a lot of ring-like structures, which tend to be very rigid.



Carbohydrate in the membrane

- Carbohydrates are usually attached to the membrane proteins or sometimes to the phospholipids.
- Proteins with carbohydrates attached are called glycoproteins, while phospholipids with carbohydrates attached are called glycolipids.
- The carbohydrates are short polysaccharides composed of a variety of different monosaccharides, and form a cell coat or glycocalyx outside the cell membrane.
- The glycocalyx is involved in protection and cell recognition, and antigens such as the ABO antigens on blood cells are usually cell-surface glycoproteins.

Plasma Membrane

- Phospholipids
- **Basic structure of membrane**
- **Barrier to passage of water-soluble substances between ICF and ECF**
- **Provides fluidity to membrane**

- Cholesterol
- **Adds fluidity to membrane**
- **Interferes with hydrophobic interactions between phospholipids**
- **Prevents crystallization of phospholipid**
- **Decreases permeability of membrane to water**

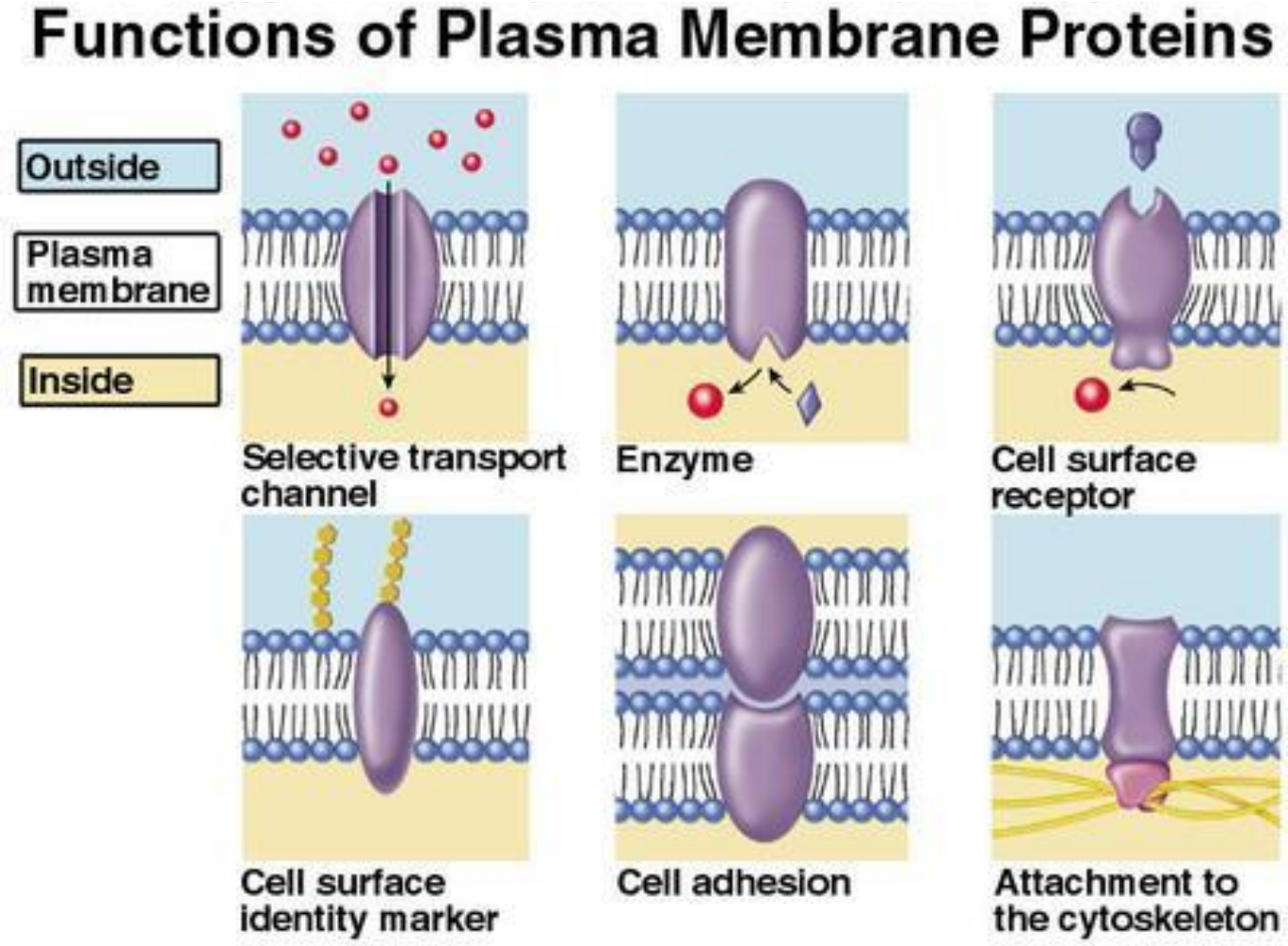
- Membrane Proteins
- **Integral membrane proteins**
- **Peripheral membrane proteins**

Membrane Proteins

- **Integral Membrane Proteins**
  - **To isolate, the membrane must be disrupted**
  - **Amphipathic (have hydrophilic and hydrophobic parts)**
  - **Some are transmembrane proteins**
  - **Channels**
  - **Carrier proteins**
  - **Some are located on one side of membrane**
  - **Enzymes**
  - **Receptors**
- **Peripheral Membrane Proteins**
  - **Easily dissociated from membrane**
  - **Most located on cytosolic side**
  - **Most are part of cytoskeleton**

Membrane Carbohydrates

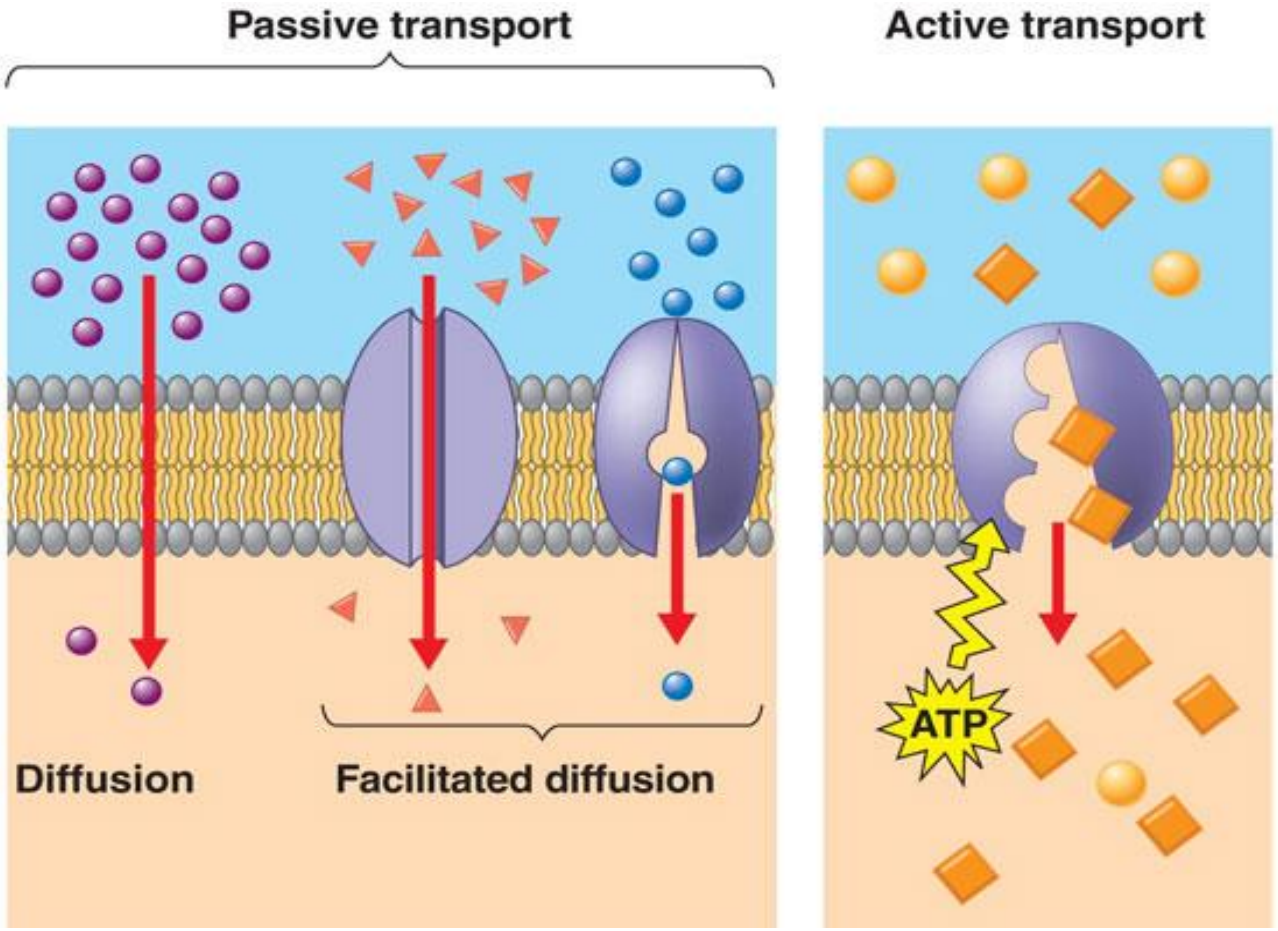
- **Carbohydrates covalently bound to membrane lipids or proteins**
- **Glycolipids**
- **Glycoproteins**
- **Functions**
- **Glycocalyx**
- **Cell recognition**


Functions of Plasma Membrane Proteins
Outside
Plasma membrane
Inside
Selective transport channel
Enzyme
Cell surface receptor
Cell surface identity marker
Cell adhesion
Attachment to the cytoskeleton

세포막의 기능

1. 물질의 운반
2. 외부환경과의 경계
3. 항상성
4. 여러 가지 효소 존재 → 화학반응촉진
5. 세포와 세포사이 인지능력
6. 세포와 세포사이의 결합상태 유지
7. 특정물질과 결합하는 수용기 receptor 가 존재

Membrane Transportation



Why do we study membrane transport?

- Cells need to interact with environments
  - Take in nutrients
  - Eliminate waste products
- Cellular transport functions
  - Maintenance of intracellular composition
  - Water homeostasis
  - Secretion and absorption

Chemical compositions of ECF and ICF

	Extracellular fluid	Intracellular fluid
Na^+	142 mM	10 mM
K^+	4 mM	140 mM
Cl^-	103 mM	4 mM
Mg^{++}	3 mM	58 mM
Amino acid	2 mM	8 mM
Glucose	5.6 mM	1 mM
Protein	0.2 mM	4.0 mM

Normal pH value for body fluid 7.35 - 7.45

세포막을 통한 물질이동

물리적 이동 **(passive process)**

1. 확산 **(diffusion)**

2. 삼투 **(osmosis)**

3. 여과 **(filter)**

생리적 이동 **(active process)**

1. 능동적 운반 **(active transport)**

2. 용적운반 **(bulk transport)**

- **phagocytosis**
- **pinocytosis**

세포막 투과성

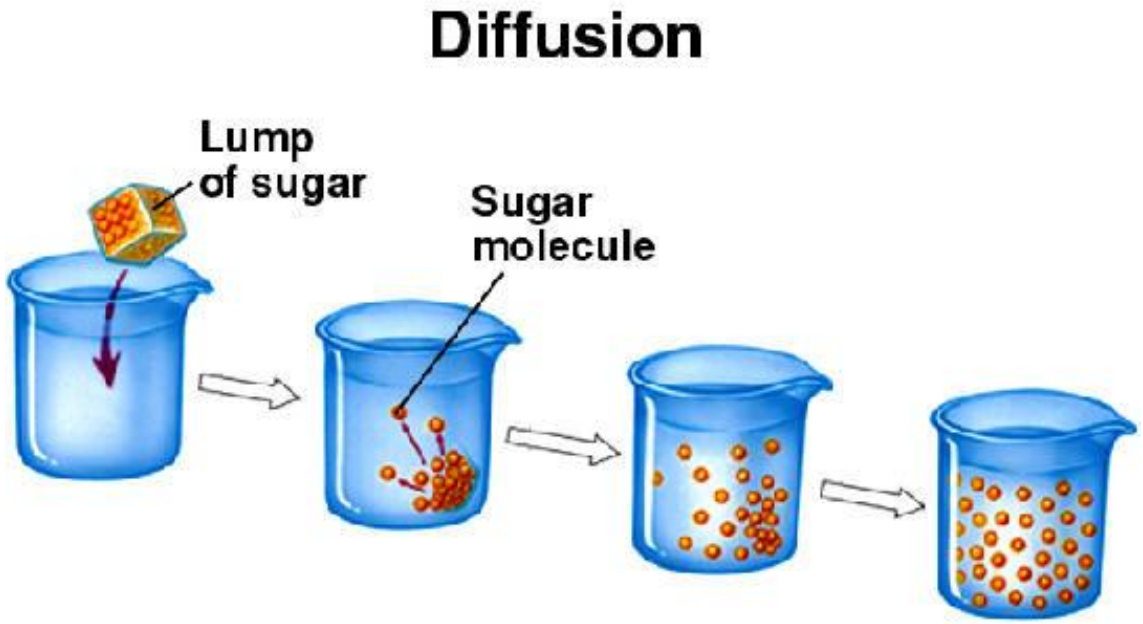
- 지질용해도가 높을수록 투과성이 높다
- **K^+, Cl^-**이온에 대해서는 비교적 높은 투과성
- **Na^+** 에 대해서는 낮은 투과성
- 세포 내 음이온의 중심이 되는 단백질 및 **PO_4^{2-}**에 대해서는 투과성이 거의 없음

1. Diffusion (확산)

Some substances (small molecules, ions) such as carbon dioxide (CO_2), oxygen (O_2), and water, can move across the plasma membrane by diffusion, which is a passive transport process.

- Diffusion is important since cells need to bring in nutrients and eliminate waste products
- **Random** movements of substances of interest caused by their **thermal energy** (Brownian motion)

Passive transport: Diffusion - the movement of a substance from an area of high concentration to an area of lower concentration (a concentration gradient).



Net diffusion

"**Net**" diffusion continues from the high concentration area to the low concentration area until the concentration is the same everywhere (**equilibrium** is reached).

- "**Net**" diffusion does not happen from the low concentration to the high concentration area even though individual molecules/substances may diffuse from the low concentration area to the high concentration area.

- "Net" diffusion stops when equilibrium is reached but diffusion itself does not stop.

Diffusion coefficient

Diffusion coefficients (D) are used to describe how easily (how far) given molecules in a specific condition can diffuse. Loosely speaking,

- the smaller the molecule, the greater the diffusion coefficient
- the less viscous the medium, the greater the diffusion coefficient
- the higher the temperature, the greater the diffusion coefficient

Diffusion of molecules

- Net diffusion rate is proportional to
  - area
  - concentration **difference** between the two sides

- Greater net diffusion rate could be obtained by
  - increasing area
  - increasing concentration difference between the two sides
  - increasing diffusion coefficient

"**Fick's Law of Diffusion**"

$$J = - DA \frac{\Delta C}{\Delta X}$$

J = net diffusion rate (moles/s)
D = diffusion coefficient (cm2/s)
A = membrane area (cm2)
C = concentration difference across the membrane
x = thickness of the membrane (cm)

- **확산 (diffusion)**
  - 농도가 높은 곳에서 낮은 곳으로 이동 ; 정수압은 일정
  - 확산 속도 : 거리의 반비례
  - 확산 촉진 요인
    1. 농도경사가 클 때
    2. 분자의 직경이 작을 때
    3. 지질 용해성이 높을 때
    4. 확산 거리가 짧을 때
    5. 온도가 높을 때
    6. 전기력이 반대일 때

passive process

What goes across the lipid bilayer?

- **Small uncharged and lipophilic molecules cross biological membranes well by simple diffusion**

- **Other biologically important molecules do not cross the membrane by simple diffusion at appreciable rates**

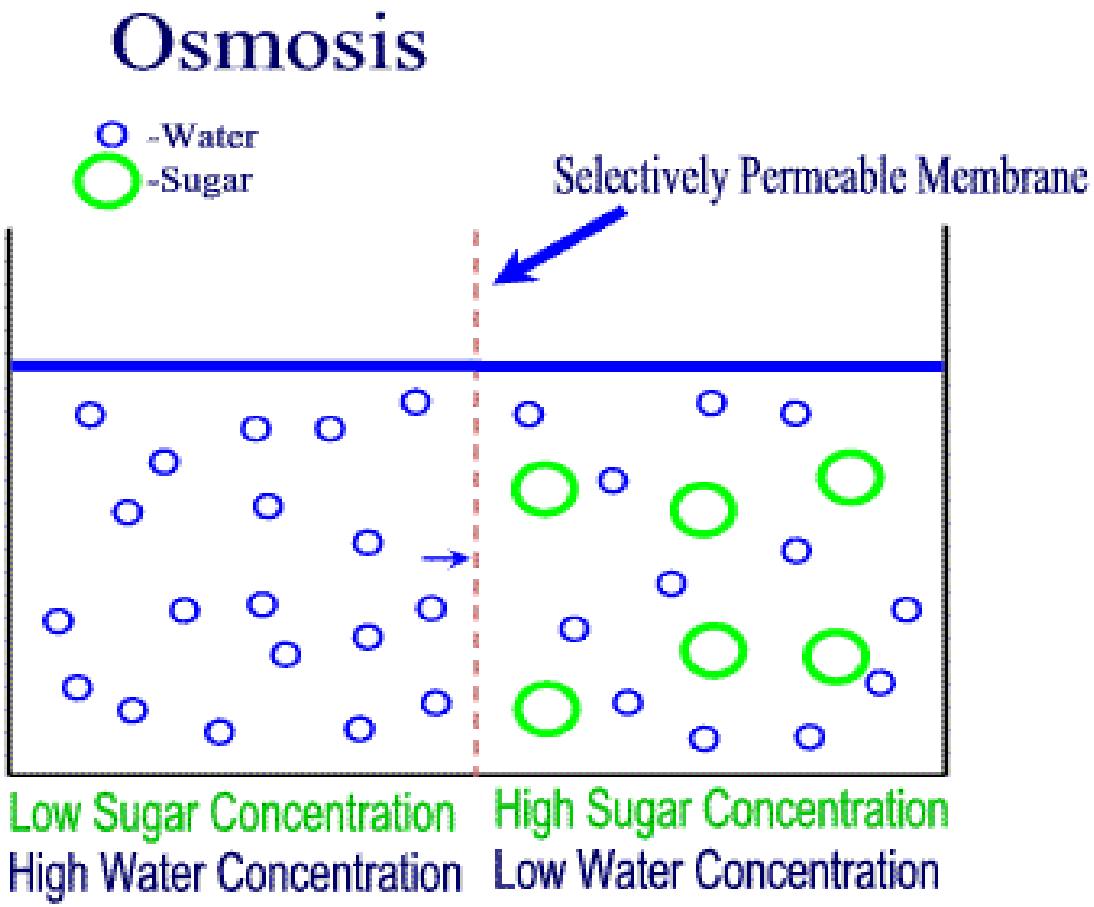
  - They are often large and hydrophilic
  - Cells use membrane transport proteins

2. Osmosis (삼투)

- **Because the membrane acts as a barrier for certain molecules and ions, they can occur in different concentrations on the two sides of the membrane.**
- **Such a concentration difference across a semipermeable membrane can set up a osmotic flow for the solvent, in this case water.**
- **Water can thus be transported across the membrane by osmosis.**

- **Net diffusion of water molecules (more precisely, solvent) across its concentration gradient through a semipermeable membrane**
- **Osmotic transport of solvent (water, for example) is in the direction to reduce the solute concentration gradient**
- **Important in cell volume regulation**

passive process



- Osmotic pressure

- Van't Hoff law describes the pressure gradient generated by a difference in solute concentrations across a membrane permeable to water but not to the solute:

$$\pi = RT\,(C_2 - C_1)$$

pi = osmotic pressure
R = gas constant
T = temperature (& deg; K)
C_1 = total solute concentration side 1
C_2 = total solute concentration side 2

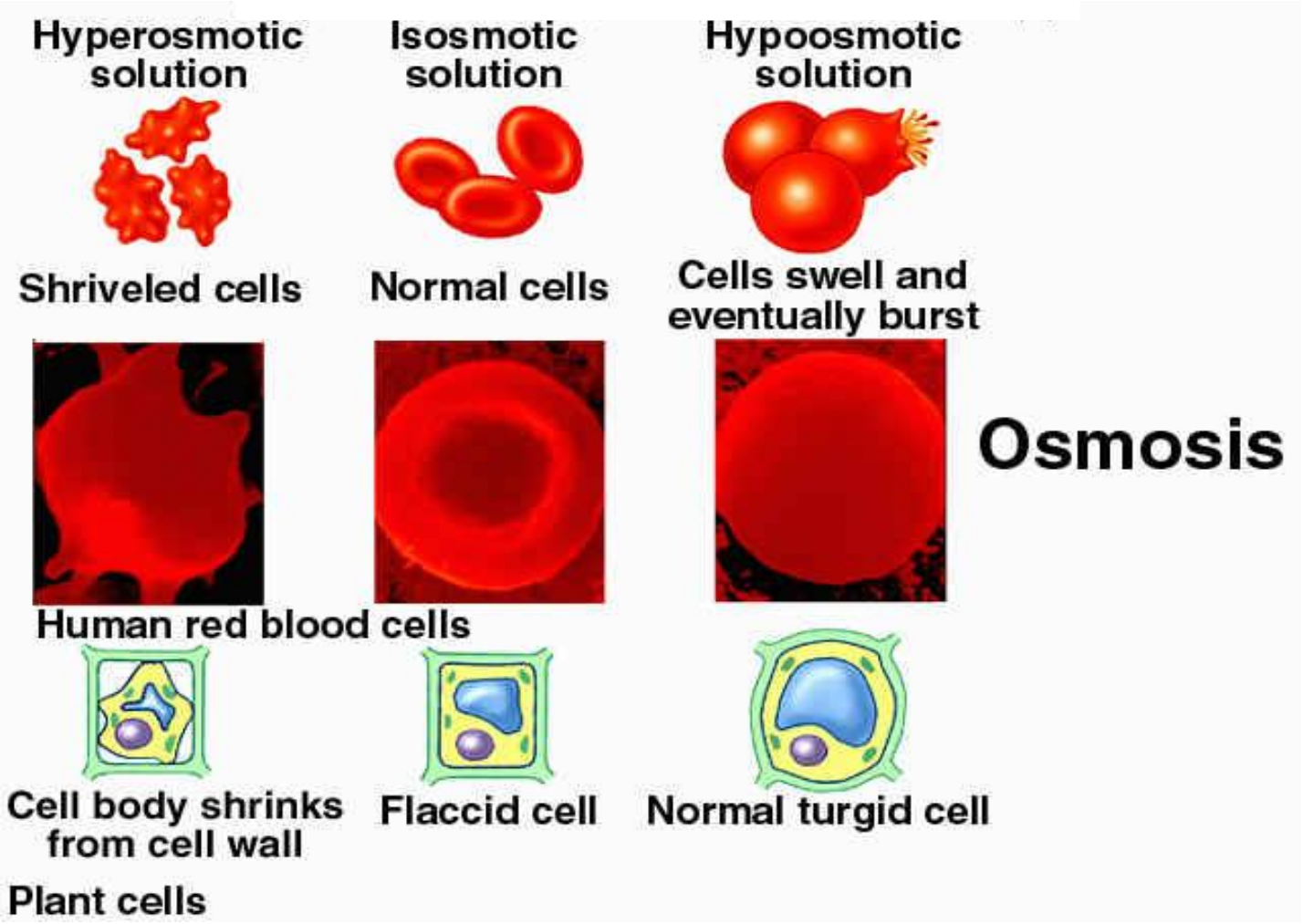
- When the membrane is equally permeable to both solute and solvent, no net volume flow (no osmotic pressure)

– 삼투

- 용질 농도가 높은 곳으로 용매(물)의 이동 현상
- 삼투압은 용질의 종류, 크기와는 무관하고 용질 개수에만 비례
  예: 대부분의 물의 이동, 적혈구-저장액에서 용혈현상

- 생리적 식염수(등장액): 0.92% NaCl 용액
- 혈장 삼투압 (mosm/l): 290
- 교질 삼투압 (colloidal pressure) : 단백질이 통과하지 못하여 생기는 낮은 삼투압

passive process



•삼투와 살아있는 세포

passive process

Why do we need membrane transport proteins?

- Many biologically important molecules are charged and they do not diffuse across the membranes well
- To increase the transport rates, cells use specialized membrane transport proteins

- Net diffusion occurs from the high concentration side to the low concentration side
- Cells need to "accumulate" some substances above the extracellular concentration

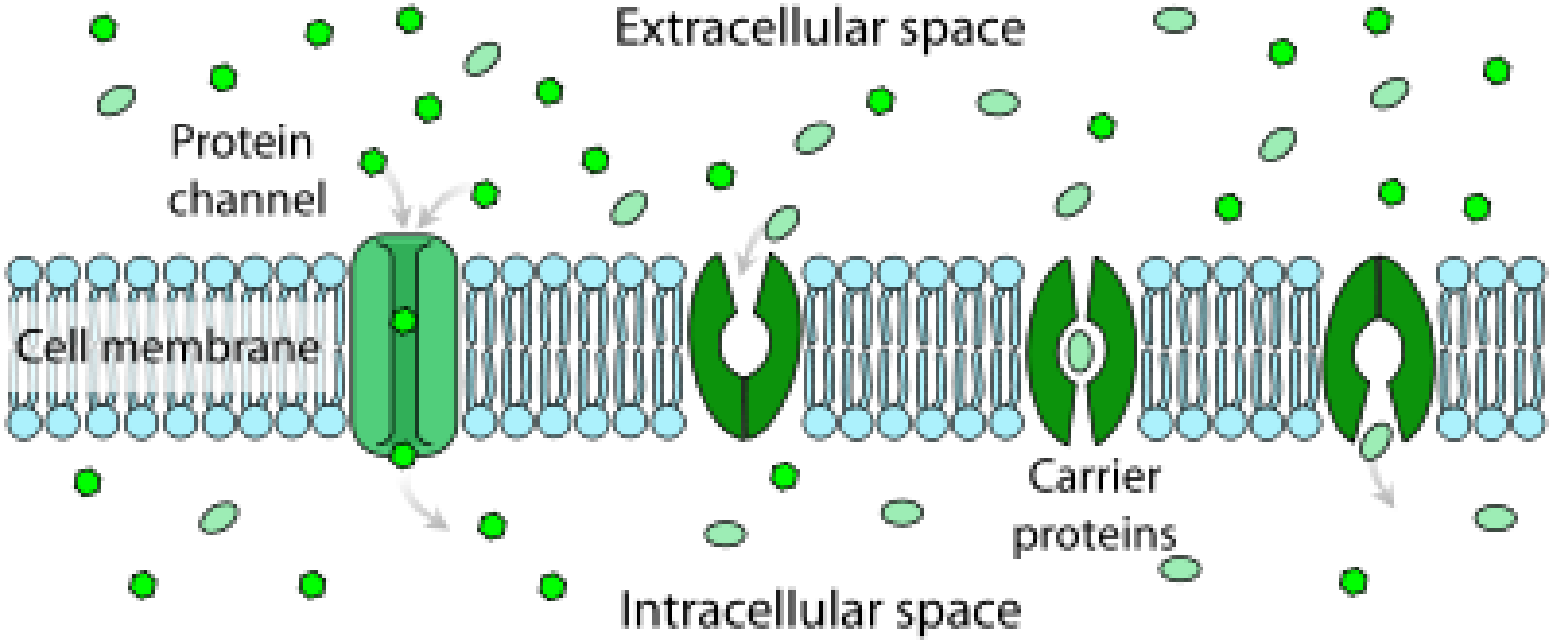
- Osmotic/volume regulation
  - intracellular proteins

3. Membrane transport proteins

- **a membrane protein involved in the movement of ions, small molecules, or macromolecules, such as another protein across a biological membrane.**
- **Transport proteins are integral membrane proteins; that is they exist within and span the membrane across which they transport substances.**
- **The proteins may assist in the movement of substances by facilitated diffusion or active transport. These mechanisms of action are known as carrier-mediated transport.**

- **Three major types of membrane transport proteins**
  - **Channel**
  - **Carrier**
  - **Pump (active transportation)**

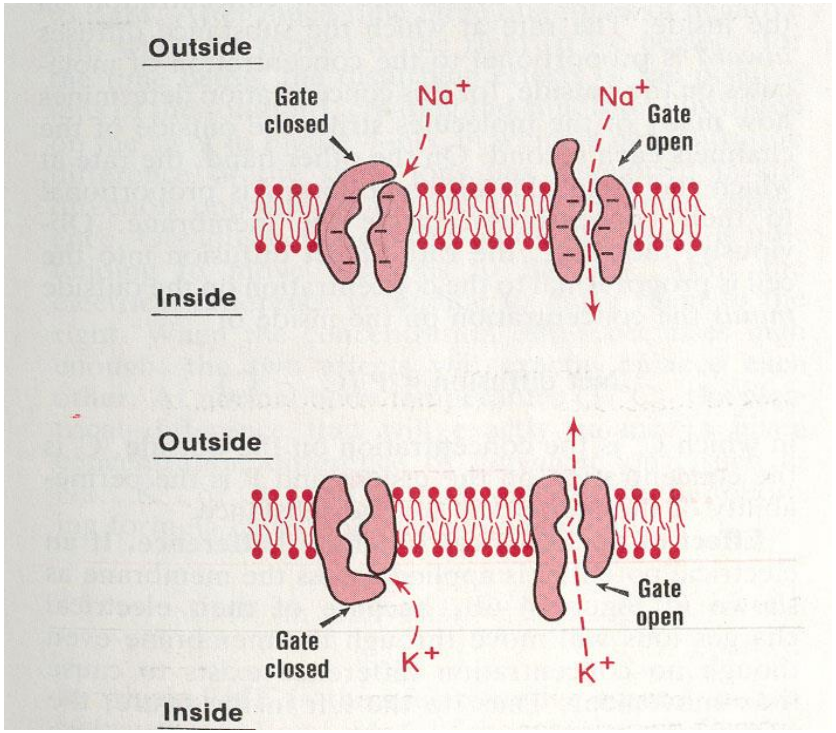
passive process



Brief definitions of membrane transport proteins

- Channels

- Small, dynamic "hole"-like proteins in the membrane
- Channels may be closed or open
- Compared with other transporters, the transport rates are typically much higher



passive process

Ion channel

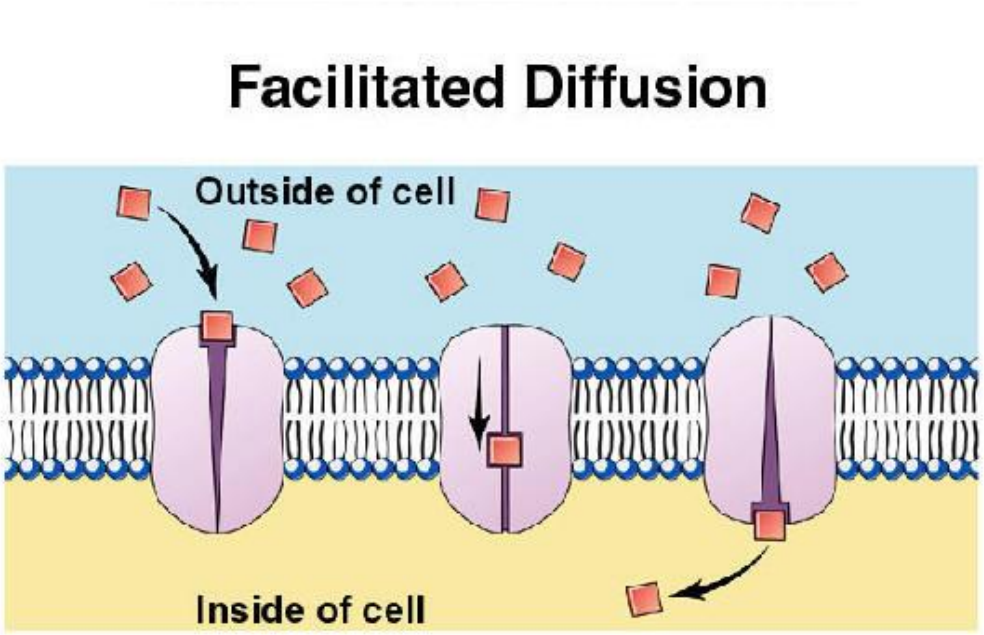
- pore-forming proteins that help establish and control the small voltage gradient across the plasma membrane of cells (see cell potential) by allowing the flow of ions down their electrochemical gradient.
- They are present in the membranes that surround all biological cells.
- Ion channels regulate the flow of ions across the membrane in all cells.
- Ion channels are integral membrane proteins; or, more typically, an assembly of several proteins.

Ion channel

- Because channels underlie the nerve impulse and because "transmitter-activated" channels mediate conduction across the synapses, channels are especially prominent components of the nervous system.
- Indeed, most of the offensive and defensive toxins that organisms have evolved for shutting down the nervous systems of predators and prey (e.g., the venoms produced by spiders, scorpions, snakes, fish, bees, sea snails and others) work by modulating ion channel conductance and/or kinetics.

Exchangers (Carriers)

- Exchangers are transport proteins which are not channels and which are not pumps.
- For each molecule (i.e. one ion) transported, a carrier must under go a complete sequence of conformational change.



passive process

Facilitated diffusion

- Facilitated diffusion is the passage of molecules or ions across a biological membrane through specific carrier proteins and requires no energy.
- Facilitated diffusion is used especially in the case of large polar molecules and charged ions; once such ions are dissolved in water they cannot diffuse freely across cell membranes due to the hydrophobic nature of the fatty acid tails of the phospholipids that make up the bilayers.
- The type of carrier proteins used in facilitated diffusion is slightly different than in active transport. They are still transmembrane carrier proteins, but these are gated transmembrane channels, meaning they do not internally translocate, nor require ATP to function.
- The substrate is taken in one side of the gated carrier, and without using ATP the substrate is released into the cell.

Active transport

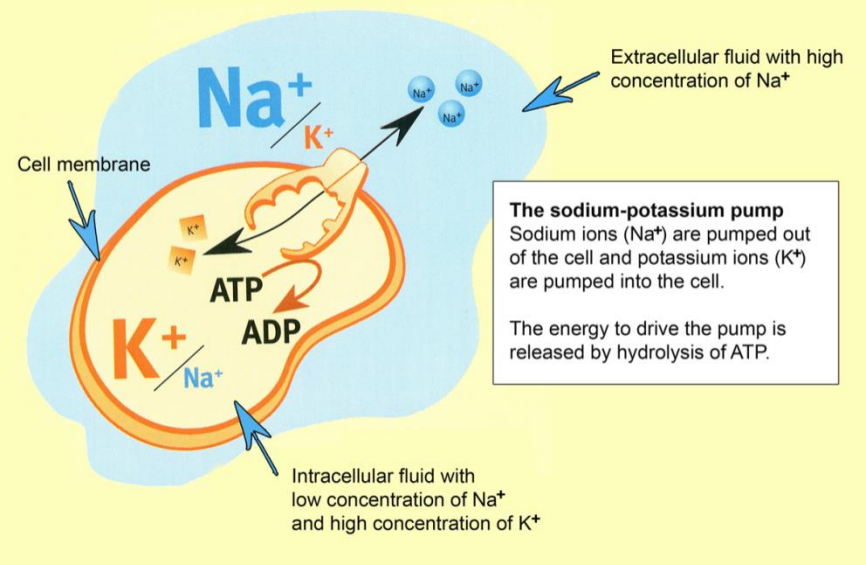
- Primary active transport system directly utilizes chemical energy (usually hydrolysis of ATP)
- Transport of substances against the electrochemical gradient ("uphill" transport).

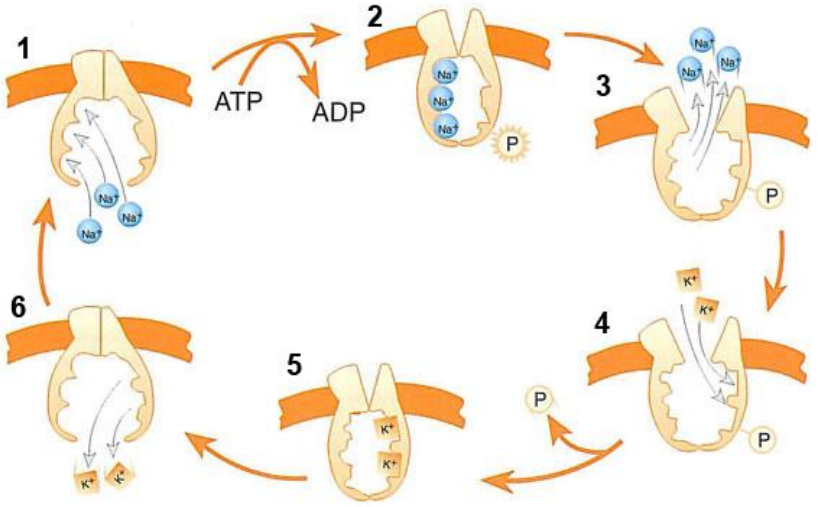
  Ex) Na^+ -K^+ pump :

  Transport Na^+ out of the cell and K^+ into the cell
- Active transport systems are responsible for the long-term maintenance of the ionic concentration gradients
- Differential ionic compositions inside and outside

- Pumps

- Membrane transport ATPase
- Pumps hydrolyze ATP and use the released energy to mediate transport

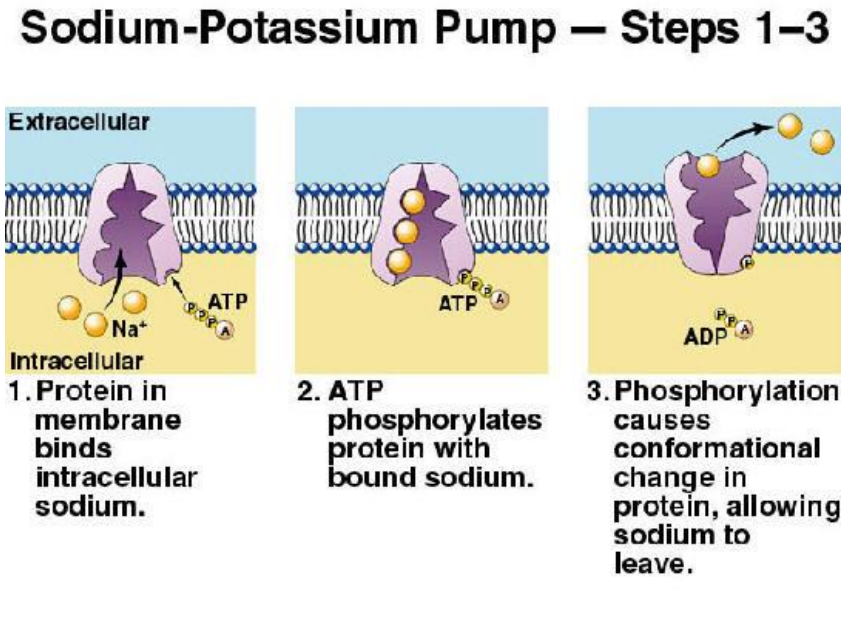


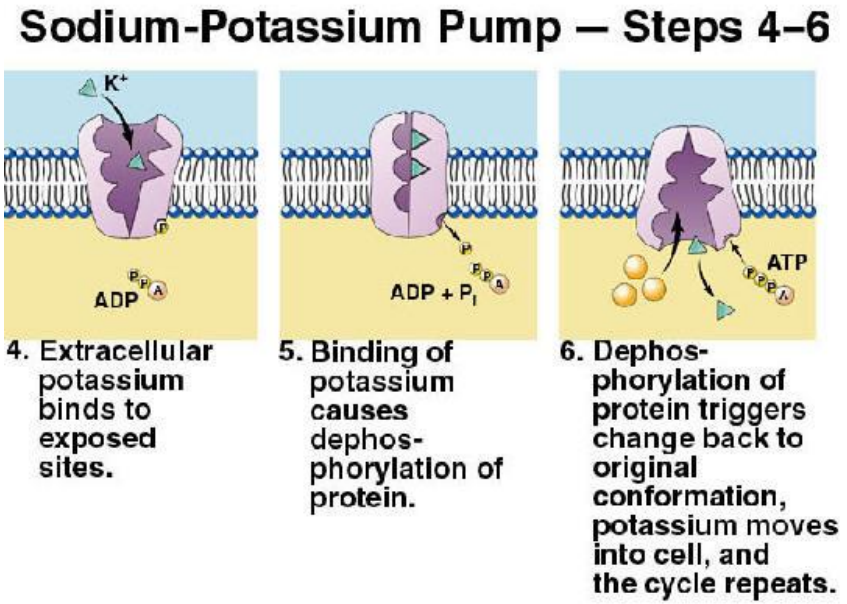


Na^+ -K^+ pump

Active process

- Transport Na^+ and K^+ ions
- Under physiological conditions, 3 Na^+ outward and 2 K^+ inward for each molecule of ATP hydrolyzed
- **integral membrane protein**
- **two major different polypeptides (alpha and beta)**
- binding sites for Na^+ and ATP on its intracellular surface
- binding sites for K^+ and ouabain on its extracellular surface





Active process

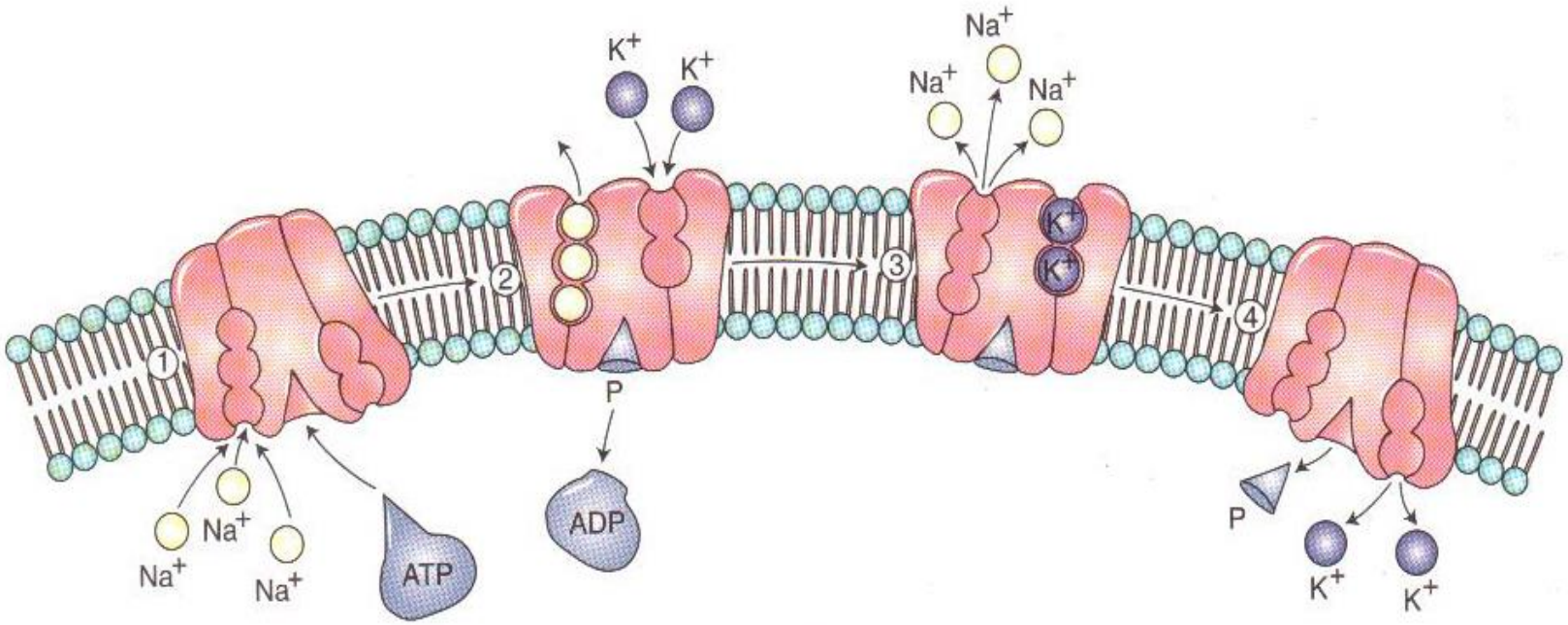


그림 3-5. 근육세포와 신경세포에서 세포막의 나트륨-칼륨 펌프의 단백질 속성

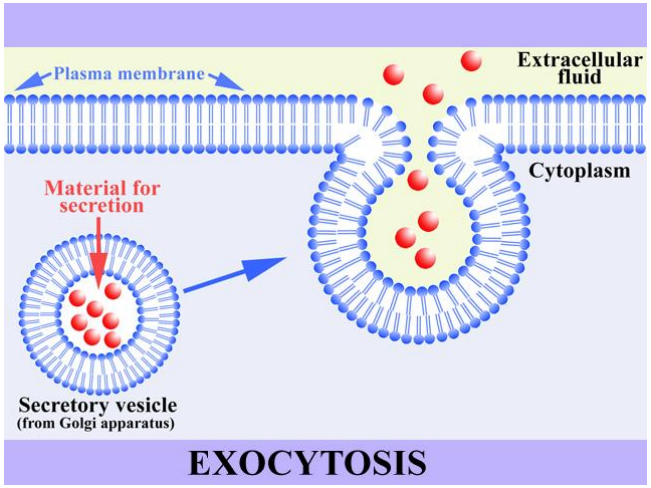
Bulk (vesicular) transportation

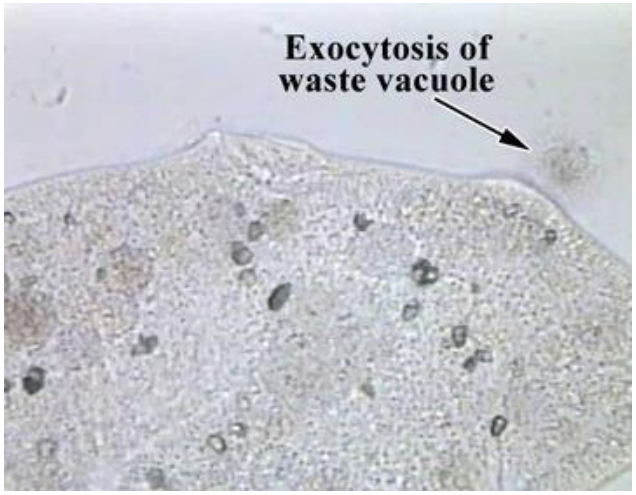
- Bulk transport (vesicular transport) is the term given to the movement of substances into and out of the cell by membranous organelles called vesicles (vesicular transport).
- Bulk transport includes endocytosis and exocytosis.

Exocytosis

Active process

- Exocytosis is the movement of materials out of the cell.
- Exocytosis includes cellular excretion (release of waste substances) and secretion (release of useful substances) and involves the fusion of vesicles with the plasma membrane for release into the extracellular environment.
- 세포막 운동에 의하여 세포 내 물질을 세포 밖으로 방출하는 현상
- 세포 내의 수분, 세포분비물질, 점액 등 방출
- 소포(小胞)막이 세포막과 융합하게 되어 소포의 내부가 세포 밖으로 열리면서 내부물질 방출

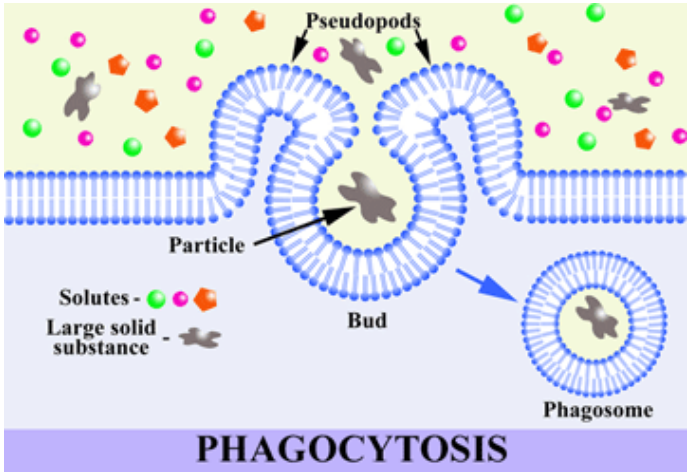


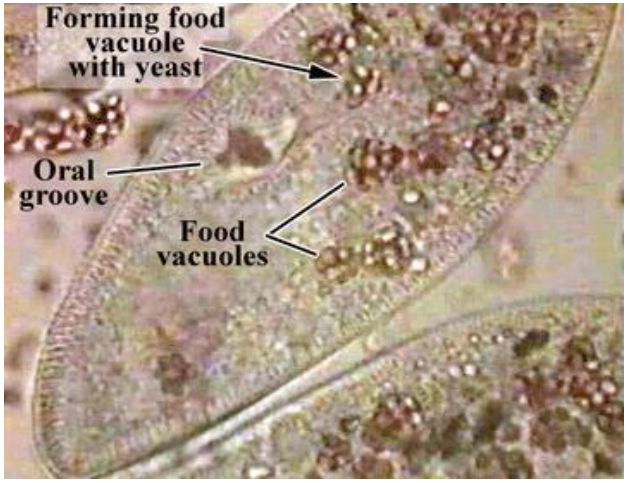


Endocytosis

Active process

- Endocytosis is the movement of materials into the cell by the invagination of the plasma membrane.
- Endocytosis includes phagocytosis, and pinocytosis.
- Phagocytosis is the movement of solid particles into the cell,
  - 식세포작용(phagocytosis)
    - ✓고형물이나 세포 부스러기를 받아들이는 과정
- Pinocytosis is the movement of fluid (liquid in extracellular environment) into the cell.
  - 음세포작용(pinocytosis)
    - ✓물이나 용질 상태의 물질을 받아들이는 과정

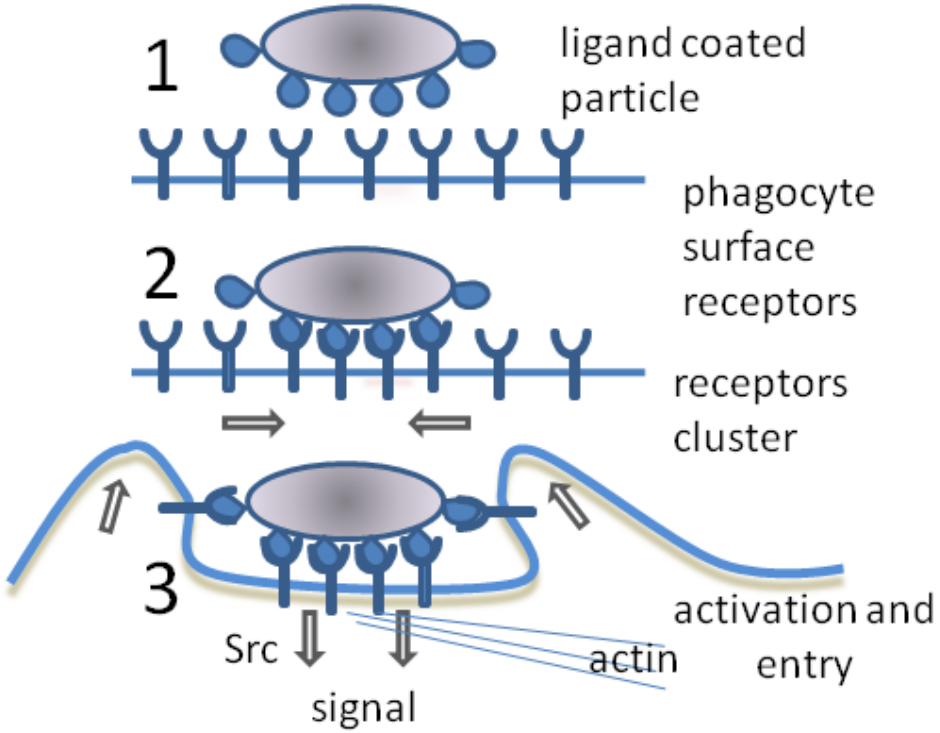


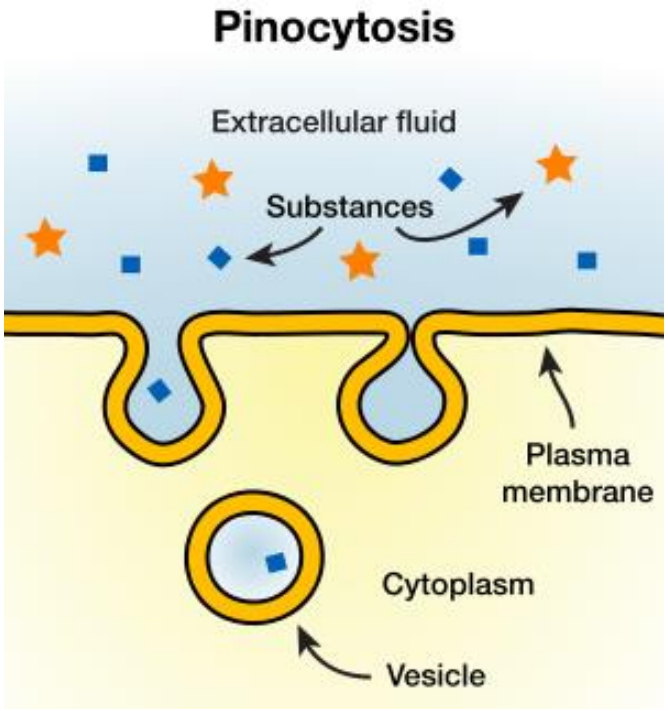


http://www.youtube.com/watch?v=4gLtk8Yc1Zc&feature=player_embedded

Phagocytosis in three steps:

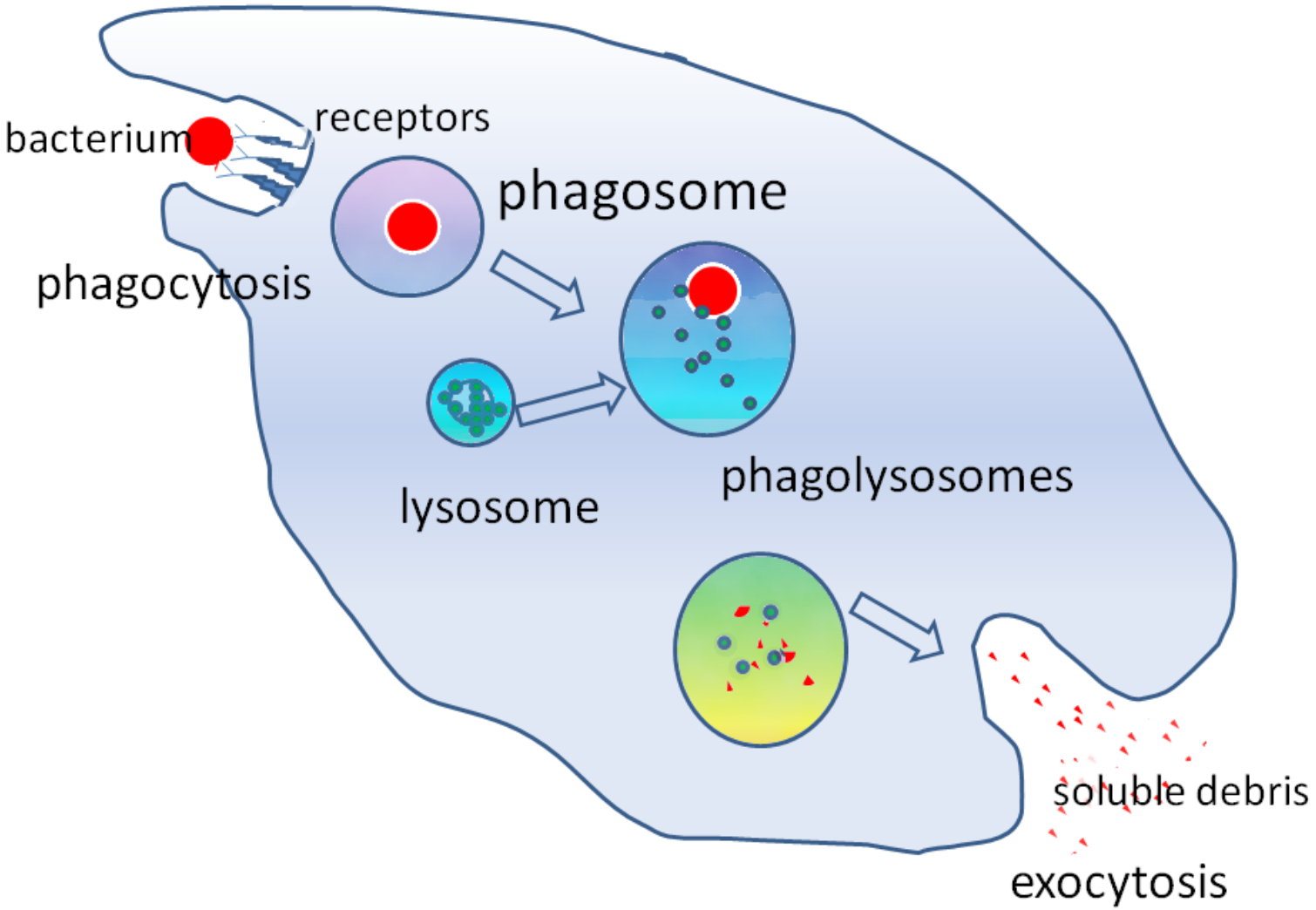
1. Unbound phagocyte surface receptors do not trigger phagocytosis.
2. Binding of receptors causes them to cluster.
3. Phagocytosis is triggered and the particle is taken up by the phagocyte.





- Pinocytosis is non-specific and non-absorptive. Molecule-specific endocytosis is called receptor-mediated endocytosis.
- Pinocytosis is otherwise known as **cell-drinking**, **fluid endocytosis**, and **bulk-phase pinocytosis**.

Active process



물질이동 방식의 주요 특성 비교

기전		특징	이동물질
확산		용질분자의 이동 농도경사 분자직경 전하 지용성 여부 따라 속도 변화	무기이온, 지용성 물질
삼투		물분자의 이동 농도경사에 따라 속도 결정	물
여과		정수압에 의한 물과 용질의 이동 압력 및 여과공의 크기에 따라 속도 결정	물, 용질
운반체 매개이동	촉진확산	운반체에 의한 수동수송 포화성, 상경적 억제, 운반체의 특이성 있음	포도당, 아미노산
	능동수송	운반체에 의한 능동수송 포화성, 상경적 억제, 운반체의 특이성, ATP이용성	Na^+, K^+, Ca^{2+}, Mg^{2+}
용적운반	세포 내 이입	이동물질을 수용하는 소포 형성 ATP가 필요함	체액, 양분, 파편, 병원체
	세포 외 유출	이동물질을 수용하는 소포와 세포막의 융합 ATP가 필요함	체액, 파편

누가 제일 클까요 !!! – 지구와 금성은 비슷하네여...