

**TRANSPORT PHENOMENON
FICK'S LAW OF DIFFUSION
ATP-POWERED PUMPS**

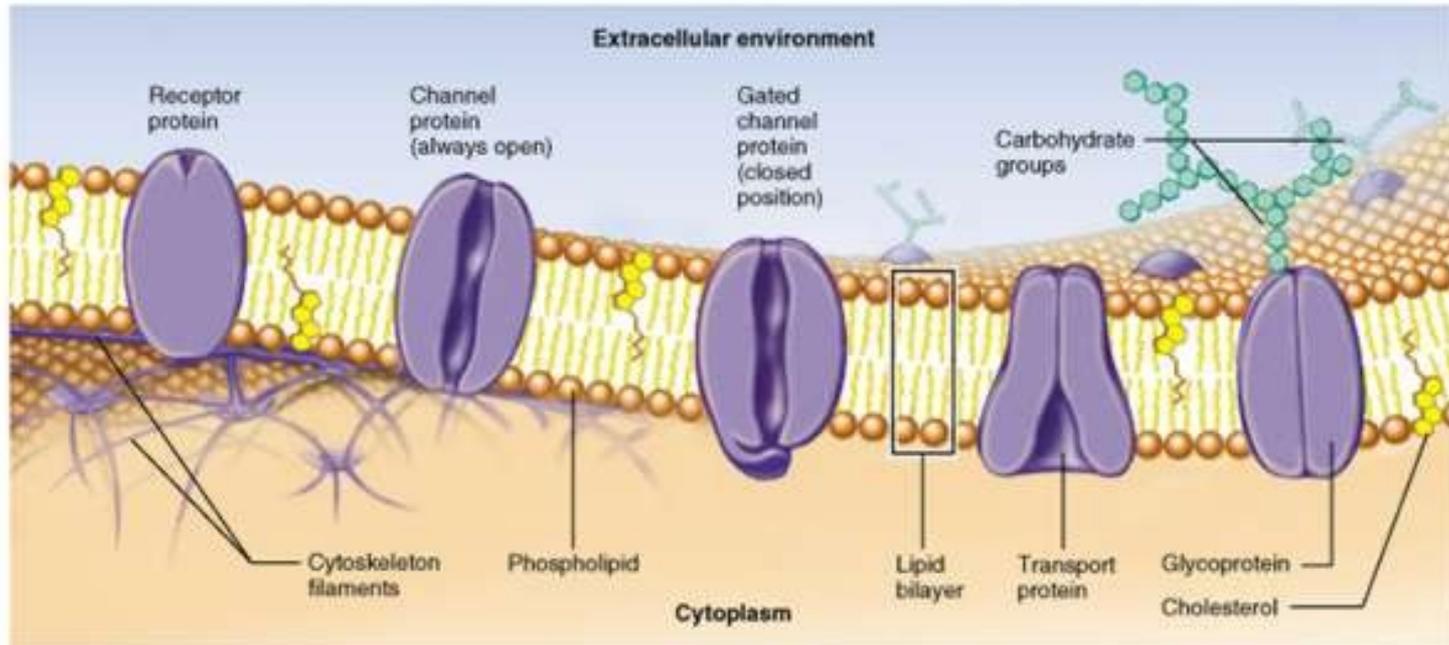
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<http://bealbio.wikispaces.com/Cell+Membrane>

Lipids form the barrier.

Proteins mediate distinct functions as :

- Detecting the signals from outside

- Transport biochemicals or other molecular substances across membranes

- Energy transduction

Between the two sides of the cell membrane

- A variety of molecules and ions differ in terms of intracellular and extracellular concentrations.
- The concentration difference between two area is termed as **concentration gradient**.
- As a result, between the two sides of the membrane
 - a **concentration gradient**
 - and a **potential gradient** of these substances occurs.

Mammalian Cell Ion Concentrations

COMPONENT	INTRACELLULAR CONCENTRATION (mM)	EXTRACELLULAR CONCENTRATION (mM)
Cations		
Na ⁺	5–15	145
K ⁺	140	5
Mg ²⁺	0.5	1–2
Ca ²⁺	10 ⁻⁴	1–2
H ⁺	7 × 10 ⁻⁵ (10 ^{-7.2} M or pH 7.2)	4 × 10 ⁻⁵ (10 ^{-7.4} M or pH 7.4)
Anions [*]		
Cl ⁻	5–15	110

Active and Passive Transport

- In terms of thermodynamics, transport systems whether mediated or unmediated are studied under two titles:
 - **Passive transport**
 - **Active transport**

Passive Transport

- In passive transport, molecules or ions can transport to the other side of the membrane
 - by themselves
 - or by the help of mediator membrane protein moleculesunder the influence of concentration gradient.
- It does not require an input of metabolic energy.
- **Passive transport**
 - Moves downhill, with the concentration gradient
 - Does not require metabolic energy
 - The free energy of the system is reduced

The thermodynamic **free energy** is the amount of work that a thermodynamic system can perform.

Active Transport

- Active transport is the movement of biochemicals across a cell membrane
 - against their concentration gradient (from low to high concentration)
 - and by the help of a mediator protein molecule.
- Active transport
 - Moves uphill, against the concentration gradient
 - Requires metabolic energy to occur
 - The free energy of the system increases

Cell Membrane Transport

- Mediated Transport
 - refers transport mediated by a membrane transport protein
- Unmediated (Nonmediated) Transport
 - the movement of a substance across a barrier is done by diffusion

General Classification of Transport Systems

	Passive	Active
Mediated	glucose transport through erythrocyte membranes	Na ⁺ , K ⁺ and Ca ⁺² pumps
Unmediated	Na ⁺ input (transport in) K ⁺ output (transport out)	- (?)

Morphological Types of Transport Systems

Three types of morphological transport systems found in animal tissues:

- Homocellular transport
- Intracellular transport
- Transcellular transport

Homocellular Transport

- The most common type of transport
- Seen in both eukaryotes and prokaryotes
- Organic substances or ions are transported inside or outside of the cell membrane
 - Glucose and amino acid uptake
 - Na⁺ ion transportation from the cell
 - Keeping a high concentration of K⁺ ions within the cell

Intracellular Transport

- Cell nuclei and some cellular organelles, such as mitochondria and chloroplasts are able to accumulate or release dissolved substances.
- Just as the cells, organelles have transport systems in their membranes in order to keep the composition of inner cavity substances.
- Intracellular Transport is the transportation of biochemicals and biomolecular substances through intracellular organelle membranes.

Transcellular Transport

- In this type of transport, substances transported all the way through a cellular layer instead of simply through the cell membrane.

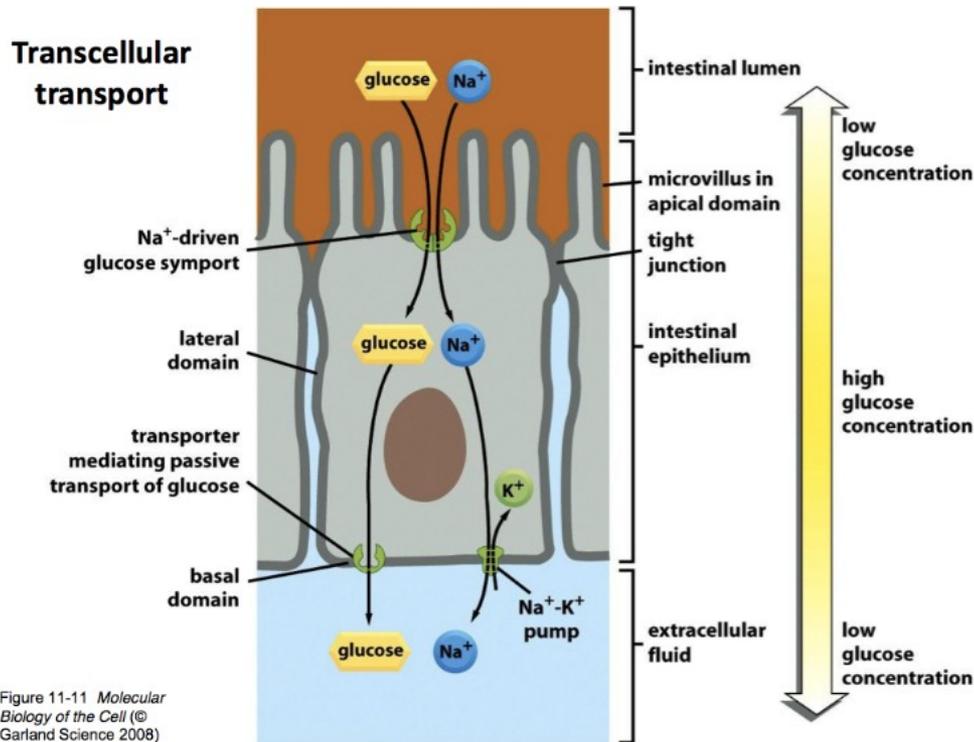


Figure 11-11 *Molecular Biology of the Cell* (© Garland Science 2008)

- This type of transport occurs through the epithelial cells of
- gastrointestinal mucosa and renal tubules
 - H⁺ ions are transported from the blood through the gastrointestinal mucosa epithelial cells

TRANSPORT SYSTEMS

UNMEDIATED-MEDIATED TRANSPORT

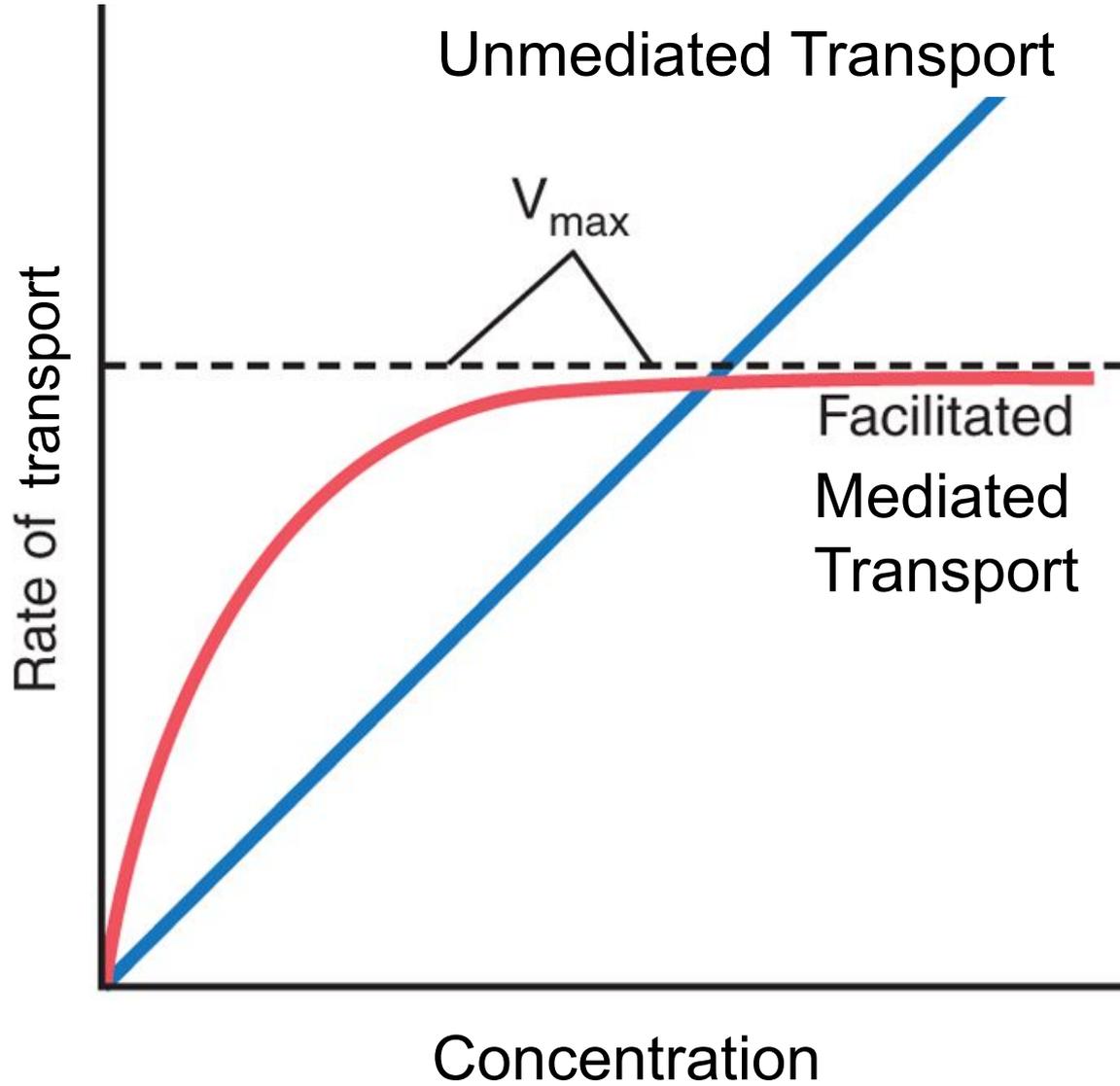
Unmediated Transport

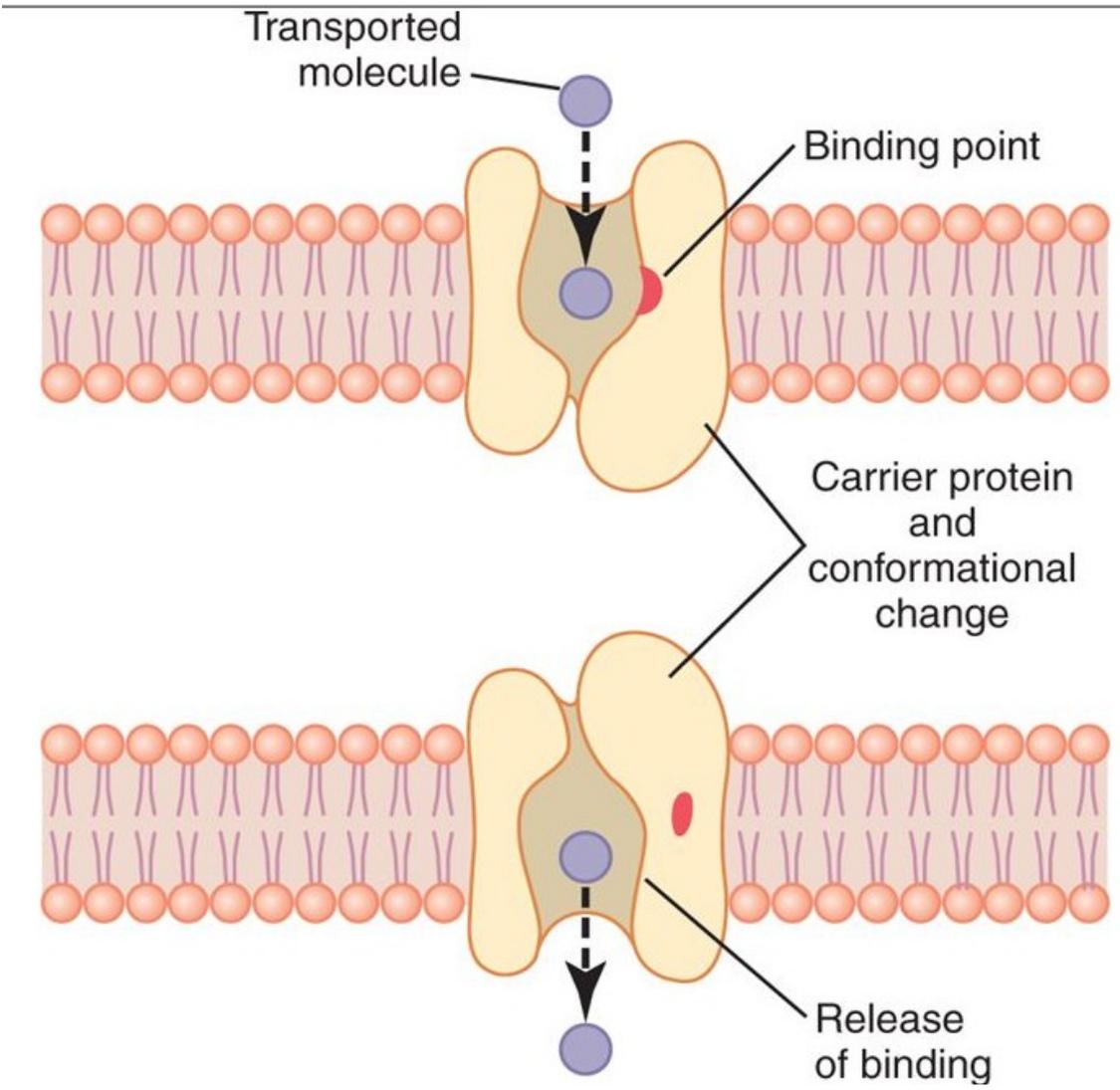
- Is a result of simple physical diffusion of solute molecules
 - The driving power of diffusion is the concentration/potential gradient
- transport rate is directly proportional with the concentration of solute
- solute molecules do not undergo a chemical change during transport

Mediated Transport

Facilitated Diffusion

- Shows saturation kinetics
 - The mediator may reach a saturation point for solute molecules.
 - In this case, transport rate is independent of the concentration of solute molecules
 - transport system has an active region (receptor) which can bind substrate in a reversible way
 - Transport rate can never be greater than the
 - binding rate of the substrate
 - rate of the transition substrate in the receptor
 - release rate of binding on the other side of the receptor





Mediated Transport

- Specific for the transported substance
 - Carrier system only shows activity for a particular substance or close equivalents
- Specific inhibition
 - agents which has similar structures as substrate can bind to the receptor (competitive inhibition) or
 - agents can block or alter the functional group of proteins
- Among the most important substances that cross cell membranes by facilitated/mediated transport are *glucose* and most of the *amino acids*.

Active and Passive Mediated Transport

- A transport system can be specified as active or passive according to the following factors:
 - Transport downhill with the concentration gradient or uphill against the concentration gradient
 - Requires metabolic energy or not
 - Transport only in one direction

Active Transport Systems

- There are three major active transport systems in animal cells;
 - Na⁺- K⁺ pump
 - Transport system for glucose and other carbohydrates
 - Transport system for amino acids

Na⁺- K⁺ pump

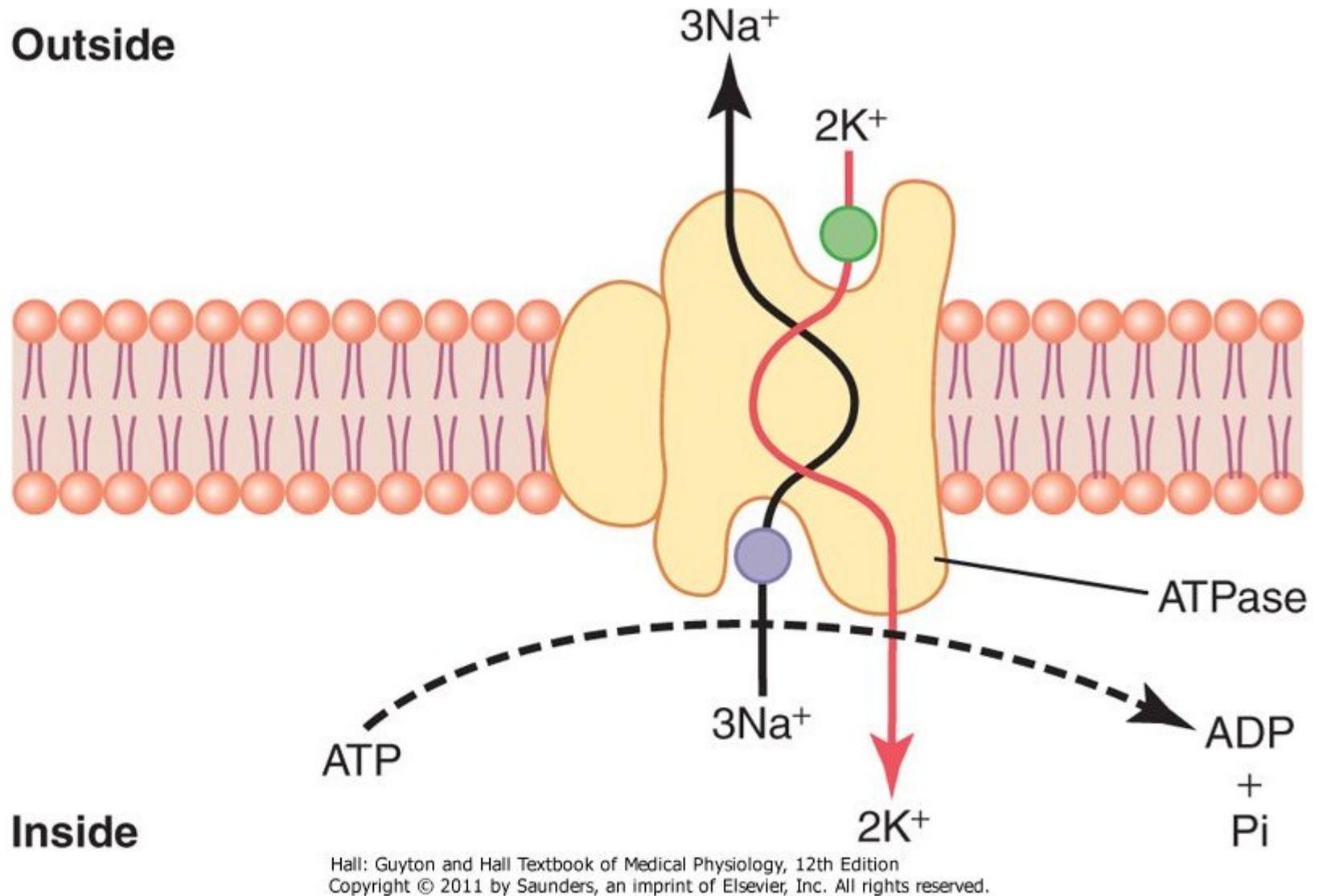
- It is the most active and widespread transport system among active transport systems.
- Found in almost all animal cell membranes.
- Low intracellular Na⁺ concentration and high extracellular Na⁺ concentration
 - intracellular Na⁺ concentration ~10 mM
 - extracellular Na⁺ concentration ~150 mM
- High intracellular K⁺ concentration and low extracellular K⁺ concentration
 - intracellular K⁺ concentration ~ 120 to 160 mM
 - extracellular K⁺ concentration ~ 4 mM

Na⁺- K⁺ pump

- Distribution of intra-and extracellular Na⁺ and K⁺ ions is vital in terms of some cellular processes.
- High intracellular K⁺ concentration is essential for;
 - the synthesis of protein in the ribosomes
 - the maximum activity level of some enzymes
 - the production of the necessary impulse in excitable cells such as nerve and muscle cells. Because the membrane potential depends on the concentration gradients of Na⁺ and K⁺ ions, stimulating a cell will suddenly change the permeability of the membrane and thus impulse generation occurs for the information transmission between cells.

Na⁺- K⁺ pump

- Intracellular K⁺ concentration is kept high by means of the enzyme Na⁺K⁺-ATPase
 - (Na⁺-K⁺) pump, pumps 3 Na⁺ outward through the cell membrane of all cells and at the same time pumps 2 K⁺ from the outside to the inside
 - Required energy -for the work done against the electrochemical gradient- is derived directly from breakdown of adenosine triphosphate (ATP).
 - Because the energy is derived directly from ATP, this kind of transport mechanisms are called *primary active transport*.

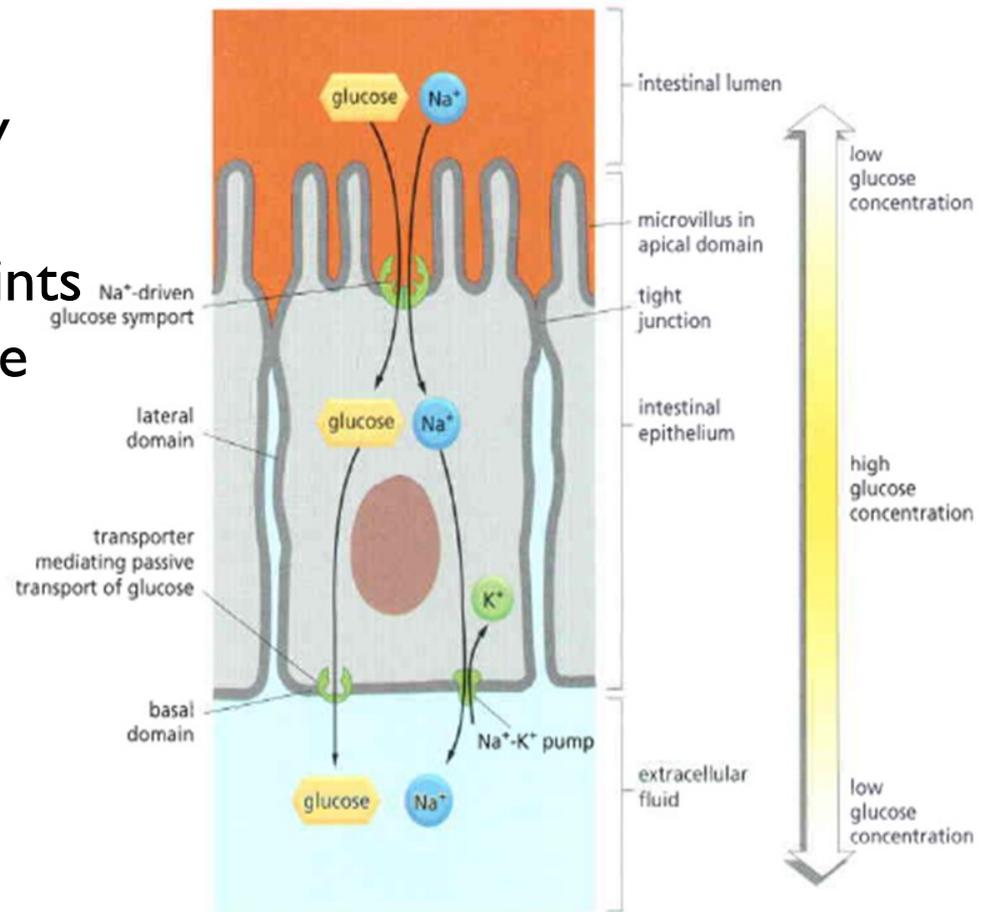


Mechanism of the sodium-potassium pump.

ADP, adenosine diphosphate; ATP, adenosine triphosphate; Pi, phosphate ion.

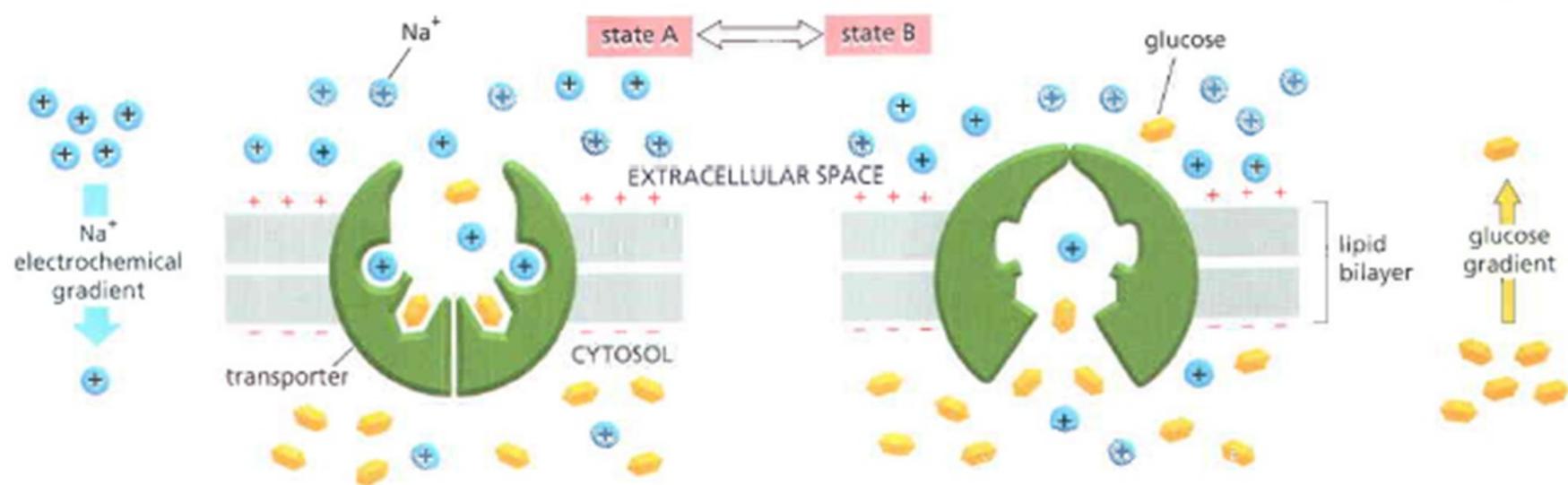
Active transport of glucose

- During the absorption of carbohydrates from small intestine into the blood, glucose transport is done against the glucose concentration gradient.
- This transport is achieved by means of a carrier protein which serves attachment points for both Na^+ ion and glucose molecule.



Active transport of glucose

- When Na^+ ions are transported out of cells by primary active transport, a large concentration gradient of Na^+ ions across the cell membrane usually develops-high concentration outside the cell and low concentration inside. This gradient represents a storehouse of energy because the excess Na^+ outside the cell membrane is always attempting to diffuse to the interior.
- This diffusion energy of Na^+ can pull glucose along with the Na^+ through the cell membrane.
- This phenomenon is called **co-transport** or **symport**.
- Thus, a glucose gradient develops towards the outside of the cell.
- In this case, for the transport of glucose against the concentration gradient, ATP energy is used indirectly. This type of transport is called as *secondary active transport*.
- The same transport mechanism is valid for amino acids.



References

- Prof. Dr. Grbz elebi. *Biyofizik. Tıp ve Diř Hekimlięi ęrencileri iin. Barıř Yayınları Faklteler Kitabevi, Cilt I, III.Baskı, İzmir, 2005.*
- Prof. Dr. Ferit Pehlivan. *Biyofizik. Hacettepe Tař. 4. Tıpkı Basım, Ankara, 2009.*
- <http://www.eng.utah.edu/~lzang/images/lecture-3.pdf>
- <http://www.eng.utah.edu/~lzang/images/lecture-4.pdf>