Membrane Transport

Dr. Kornberg: "The Berlin Wall of the Cell"

Lecture 01.23.17 (21:04-23:52 & 35:27-38:29)-Berlin Wall (3 & 3 min)

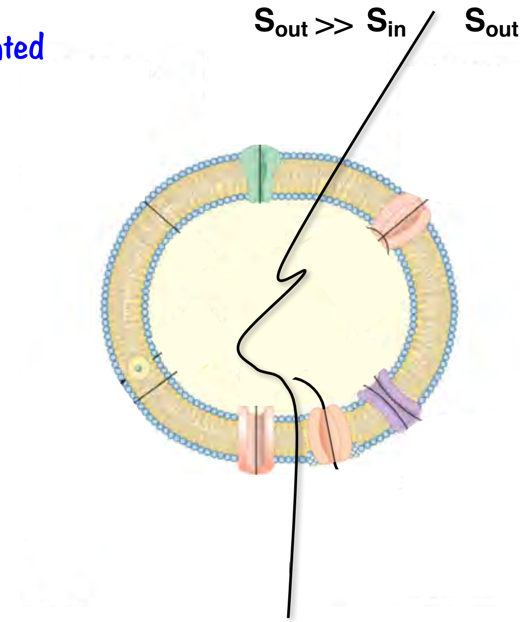
[BI422 videos: https://mymedia.bu.edu/channel/BI422/81224851]

- Cell membranes are permeable to small nonpolar molecules that passively diffuse through the membrane.
- Passive diffusion of polar molecules involves desolvation and thus has a high activation barrier, unless desolvation energy is lowered.
- Transport across the membrane can be facilitated by proteins that provide an alternative diffusion path.
- Such proteins are called transporters or permeases.

Types of Membrane Transport

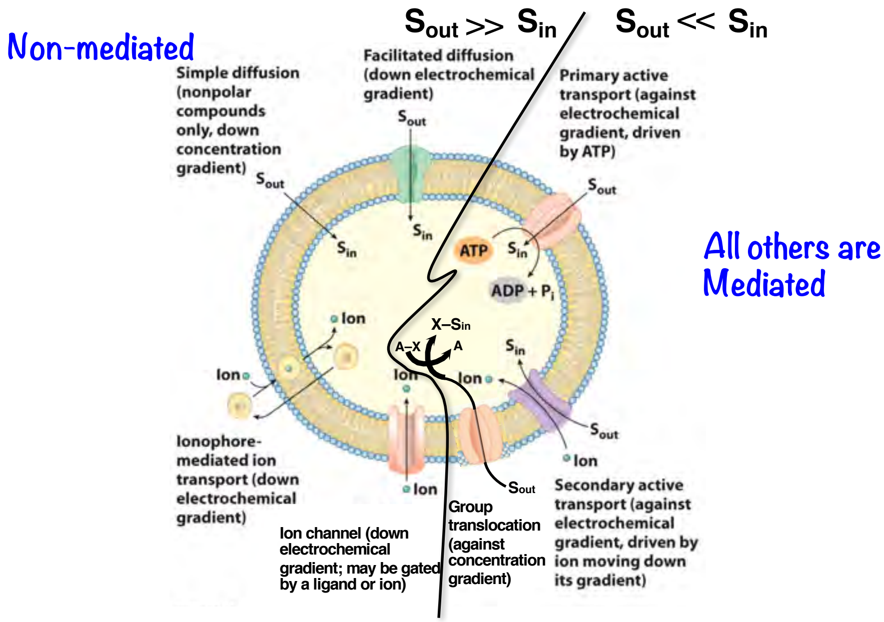
Non-mediated

$S_{out} >> S_{in}$ / $S_{out} << S_{in}$



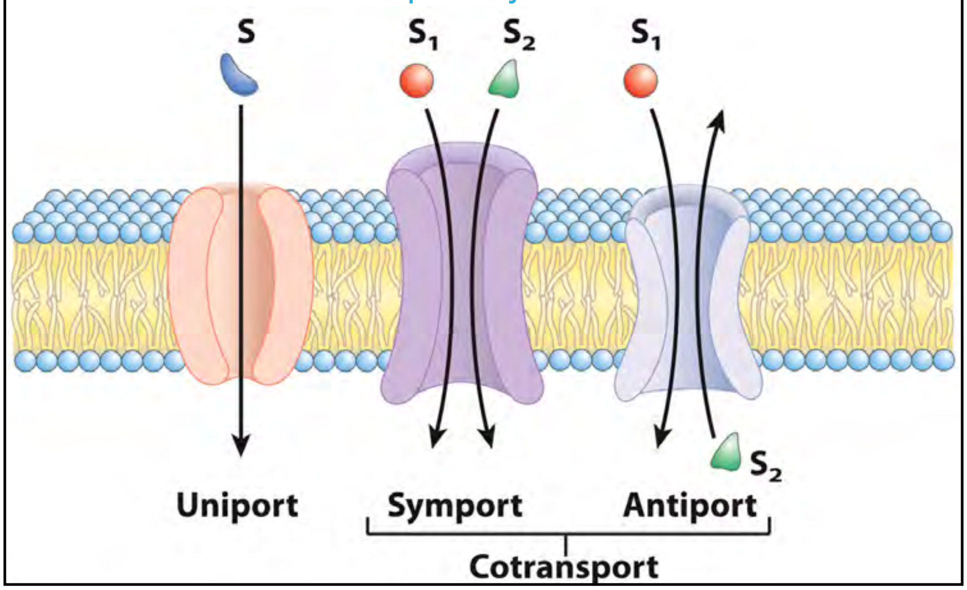
All others are Mediated

Types of Membrane Transport



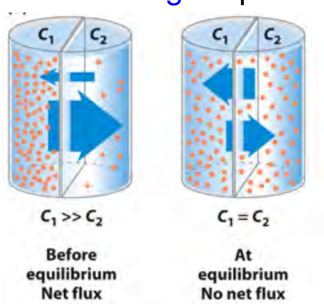
Membrane Transport

Three Classes of Transport Systems



Membrane Transport

- Transport across a membrane must be energetically favorable. There are two types of energies at play:
  - Concentration dependence: The solute moves toward chemical equilibrium across the membrane.
  - Electrical dependence: The solute moves toward charge equilibrium across the membrane.

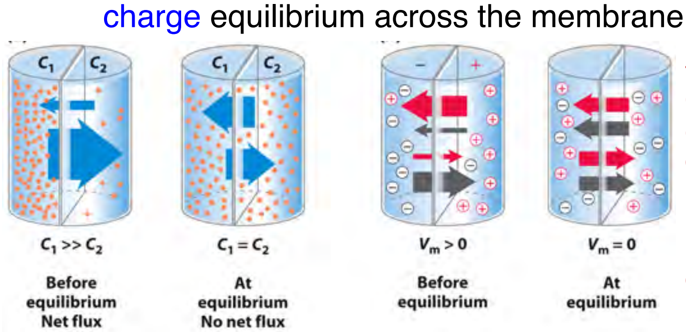


This is why we say "down" or "against" the electro-chemical gradient.

How is this gradient quantified?

Membrane Transport

- Transport across a membrane must be energetically favorable. There are two types of energies at play:
  - Concentration dependence: The solute moves toward chemical equilibrium across the membrane.
  - Electrical dependence: The solute moves toward charge equilibrium across the membrane.



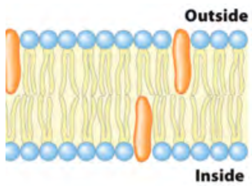
This is why we say "down" or "against" the electro-chemical gradient.

How is this gradient quantified?

Membrane Transport

Energetics

$[S_{out}]$



$[S_{in}]$

Transport can be considered like a chemical reaction of S_{out} to S_{in}

$$S_{out} \rightleftharpoons S_{in}$$

$$\Delta G' = \Delta \boldsymbol{G}^{o\prime} + RT\,ln\frac{[S_{in}]}{[S_{out}]}$$

But, $\Delta \boldsymbol{G}^{o\prime} = \mathbf{0}$ because there is no chemical reaction:

$$\Delta G' = RT\,ln\frac{[S_{in}]}{[S_{out}]}$$

If $[S_{in}] < [S_{out}]$, $\Delta \boldsymbol{G}'$ is $\ominus$

If $[S_{in}] > [S_{out}]$, $\Delta \boldsymbol{G}'$ is $\oplus$

But, if S is charged, we must account for this:

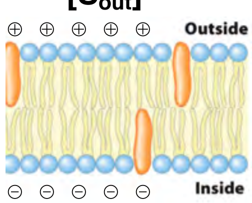
$$\Delta G' = RT\,ln\frac{[S_{in}]}{[S_{out}]} + z\mathscr{F}\Delta\psi$$

Where "z" is the charge on S, and $\Delta\psi$ is the membrane electrical potential in volts

Membrane Transport

Energetics

$[S^{\oplus}_{out}]$



$[S^{\oplus}_{in}]$

$$S_{out} \rightleftharpoons S_{in}$$

$$\Delta G' = RT\,ln\frac{S_{in}}{S_{out}} + z\mathscr{F}\Delta\psi$$

Where "z" is the charge on S, and $\Delta\psi$ is the membrane electrical potential in volts

$\Delta\psi$ = charge difference "in" versus "out"

So, if its more negative in than out, $\Delta\psi$ is $\ominus$ (as depicted)

And, if its more positive in than out, $\Delta\psi$ is $\oplus$

Now, if $\Delta\psi$ is negative, and S has a positive charge (z is +), then $z\mathscr{F}\Delta\psi$ makes a negative contribution to $\Delta \boldsymbol{G}'$ making it even more favorable.

As a further consequence, if $\Delta\psi$ is maintained, then at equilibrium $\mathbf{[S_{in}] > [S_{out}]}$.

Membrane Transport

How do you experimentally determine the kind of transport?

Non-mediated	Simple diffusion
Mediated	Facilitated diffusion, ionophore mediated, active transport

Diffusion is governed by **Fick's law of diffusion**:

$$Q = DA\frac{P_1 - P_2}{L}$$

Q = rate of diffusion.

D = diffusion coefficient

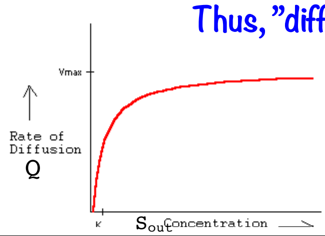
A = area across which diffusion occurs

[S_{out}] and [S_{in}] = concentrations on each side of membrane.

L = thickness of the membrane.

DA/*L* is the permeability coefficient.

Thus, "diffusion" is Non-mediated



Mediated behaves like saturation kinetics

$$C + S_{out} \rightleftharpoons CS \rightleftharpoons C + S_{in}$$

$$Q = \frac{Q_{max}\,[S_{out}]}{K_d + [S_{out}]}$$

Thus, "diffusion" is Mediated

Membrane Transport

Examples:

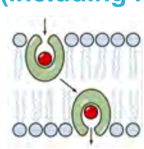
- Facilitative Diffusion
  - Ionophore
  - Maltoporins
  - GLUT1 transprter
  - Aquaporin
  - Selective ion channel for potassium (K-channels)
- Active Transport
  - Primary (1°)
    - Na/K
    - ABC
  - Secondary (2°)
    - Na/Glc
    - Bicarb/Cl
  - Group Translocation
    - Bacterial phosphotransferase system (PTS)

Membrane Transport

Facilitative Diffusion

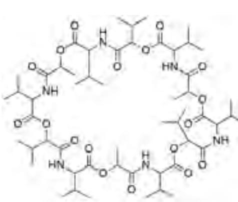
Membrane Transport

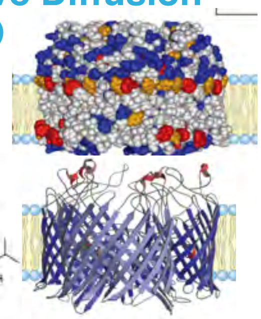
Examples of Facilitative Diffusion
(including ionophore mediated)



Ionophore

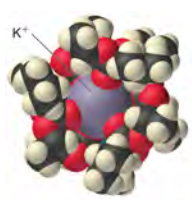
Valinomycin



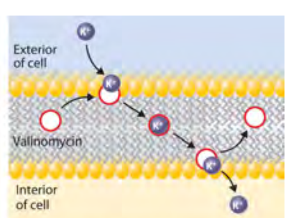


Maltoporin

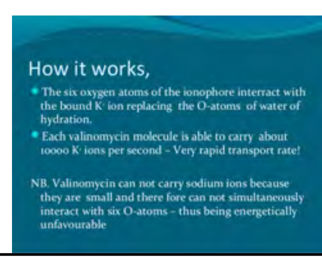
- Proteins of the *E. coli* outer membrane
- Maltoporin (derived from PDB ID 1MAL) is a maltose transporter (a trimer; each monomer consists of 16 β strands).



(a) K^+–valinomycin complex



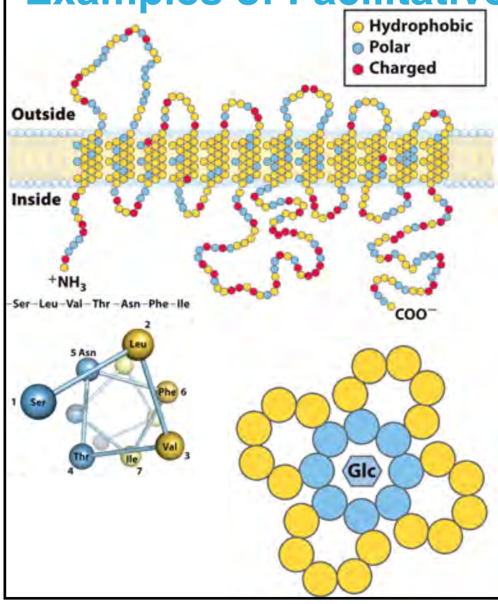
(b) Transport of K^+ across a membrane

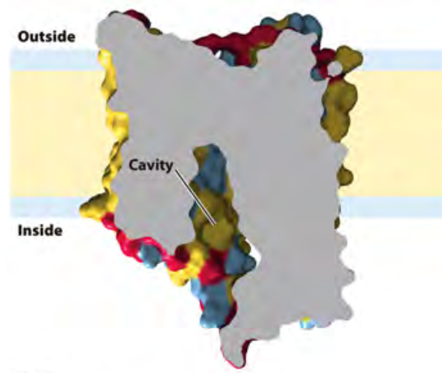


Membrane Transport

Examples of Facilitative Diffusion

Glucose Transporter (GLUT1)

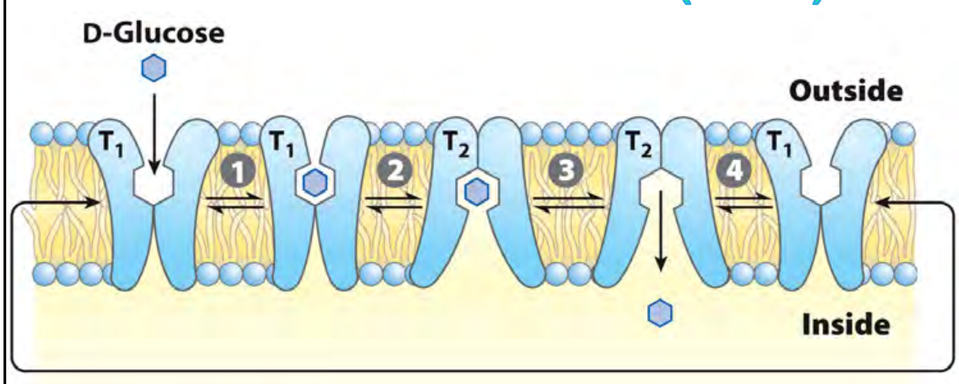




Membrane Transport

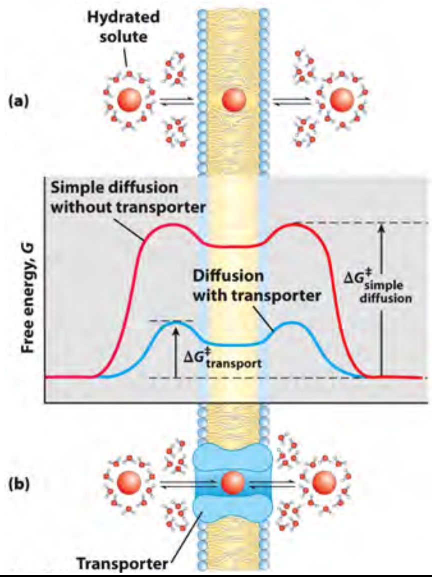
Examples of Facilitative Diffusion

Glucose Transporter (GLUT1)

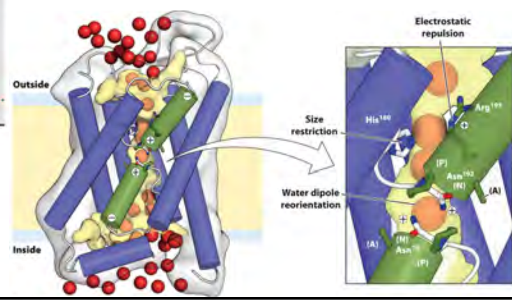


Membrane Transport

Examples of Facilitative Diffusion

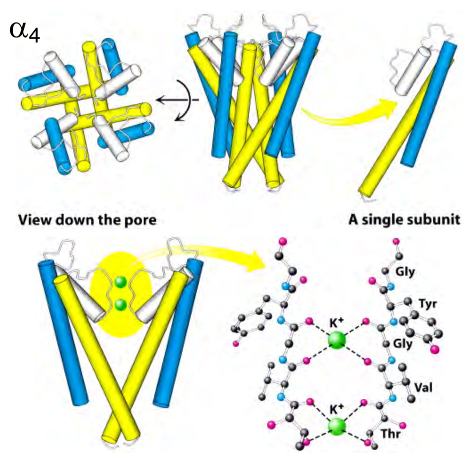


Aquaporins Allow Rapid Water Passage Through Membranes



Membrane Transport

Examples of Facilitative Diffusion



Potassium Channel KcsA K^+ allows specific passage of this ion through membranes