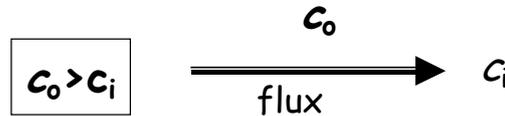


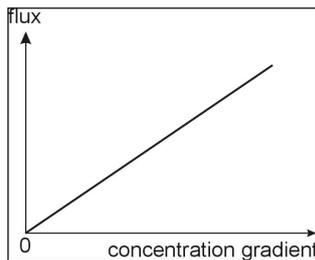
## PROBLEMS

### CATEGORIES OF TRANS-MEMBRANE TRANSPORT:

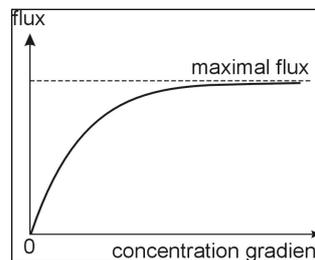
1. Simple diffusion: the Fick law, coefficient of diffusion, permeability, reflection coefficient  $\sigma$ .
2. Osmosis (the van't Hoff law, osmolarity, tonicity, osmotic behavior of red blood cells)
3. Filtration.



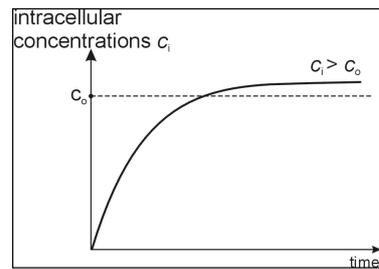
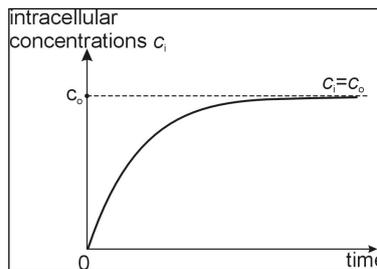
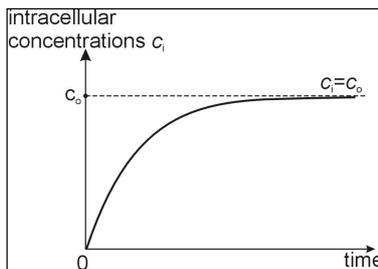
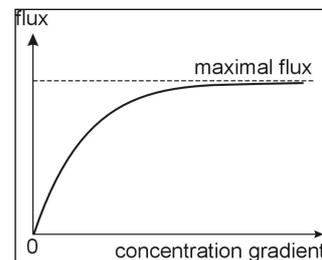
#### simple diffusion



#### facilitated diffusion



#### active transport



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### DIFFUSION

#### The Fick law:

The amount of substance  $dm$  (in moles or grams) crossing the surface area  $S$  in unit time  $dt$  is proportional to the concentration gradient  $dc/dx$ . The coefficient of proportionality is called the *coefficient of the diffusion*  $D$ .

$$\frac{dm}{Sdt} = -D \frac{dc}{dx} \quad [D] = \frac{\text{m}^2}{\text{s}} \quad \text{equivalent description:}$$

$$\frac{dm}{dt} = SP\Delta c \quad \text{where } P \text{ stands for membrane permeability with unit } \frac{\text{m}}{\text{s}}.$$

\*\*\*

**The reflection coefficient** (Staverman's coefficient)  $\sigma$  is the measure of membrane properties. It is defined as:

$$\sigma = \left( 1 - \frac{P_{\text{solute}}}{P_{\text{solvent}}} \right)$$

where  $P_{\text{solute}}$  - membrane permeability for solute molecules,

$P_{\text{solvent}}$  - membrane permeability for solvent molecules.

### OSMOSIS

**Osmosis** is the flow of water (solvent in general) across a *semipermeable* membrane from a compartment in which the solute concentration is lower to one in which the solute concentration is greater. A *semipermeable* membrane is defined as a membrane permeable to solvent but impermeable to solute. Osmosis take place because the presence of solute molecules results in decrease in *chemical potential* of water, and water tends to flow from place when its chemical potential is higher to where its chemical potential is lower.

**The van't Hoff law:**

$$\pi = iRTc_m$$

where:  $\pi$  - osmotic pressure

$i$  - number of ions formed by dissociation of a solute molecule

$R$  - gas constant,

$T$  - absolute temperature,

$c_m$  - molar concentration of solute.

The van't Hoff equation, however, does not predict precisely the osmotic pressure of real solutions. One way of correcting for the deviation of real solutions from the predictions of van't Hoff law is to use a correction factor called the *osmotic coefficient* ( $\phi$ ). Including the osmotic coefficient equation becomes:

$$\pi = \phi iRTc_m \quad \text{or} \quad \pi = (\phi i c_m)RT$$

where term ( $\phi i c_m$ ) is referred to as the *osmolar concentration* or **osmolarity** with units in **osmoles per liter**.

The flow of solvent (water) caused by osmosis is directly proportional to the osmotic pressure difference  $\Delta\pi$  of the solutions on the two sides of the membrane:

$$J_v = \sigma L_v \Delta\pi \quad \text{where} \quad J_v = \frac{dV}{Sdt}$$

where:  $\sigma$  - reflection coefficient,

$L_v$  - hydraulic conductivity,

$dV$  - volume of transported fluid,

$S$  - surface area,

$dt$  - time of flow.

## FILTRATION

If two solutions of equal concentration are separated by a membrane which is permeable for the solute and solvent molecules as well, and on both sides of the membrane a hydrostatic pressure difference  $\Delta p$  exists, the volume flow of solution across the membrane of surface area  $S$  is produced. Such a phenomenon is referred to as **filtration**.

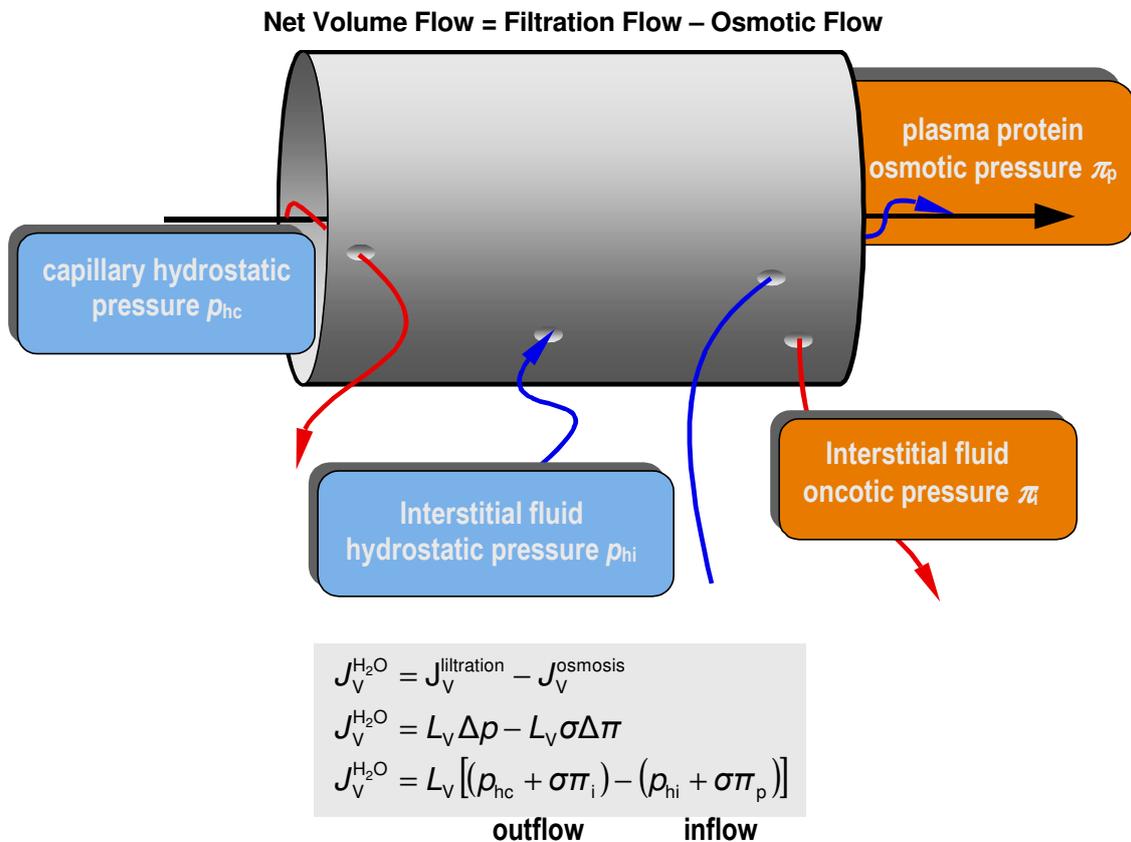
Equation describing the filtration process takes the form

$$A \quad \frac{dV}{dtS} = L_V \Delta p \quad \text{or} \quad J_V = L_V \Delta p$$

where  $J_V$  - volume flow  
 $L_V$  - hydraulic conductivity

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**NET TRANSPORT (VOLUME FLOW)  $J_V$  DUE TO FILTRATION AND OSMOSIS:**  
the relationship between hydrostatic pressure and osmotic pressure and the role of these factors in regulating fluid passage across the capillary endothelium (Starling hypothesis):



### An example:

- assume that:
- capillary hydrostatic pressure ( $p_{hc}$ ) is 30 mmHg,
  - interstitial fluid pressure ( $p_{hi}$ ) adjacent to the capillary is 1 mmHg,
  - colloid osmotic pressure ( $\pi_p$ ) (oncotic pressure) of the blood is 27 mmHg,
  - colloid osmotic pressure of ( $\pi_i$ ) interstitial fluid is 2 mmHg,

Calculate the net pressure moving fluid through the capillary wall (take  $L_V = 1$  and  $\sigma = 1$ ):

$$J_V = L_V [(p_{hc} + \sigma \pi_i) - (p_{hi} + \sigma \pi_p)] = (30 \text{ mmHg} + 2 \text{ mmHg}) - (1 \text{ mmHg} + 27 \text{ mmHg}) = 32 \text{ mmHg} - 28 \text{ mmHg} = 4 \text{ mmHg}$$

The net fluid pressure is equal to 4 mmHg and drives fluid out of the capillary.

**About the reflection coefficient:**

It is a measure of an impediment to the passage of a substance through the capillary membrane and can take values from 0 through 1:

- 1<sup>0</sup>  $\sigma = 1$  - the membrane is perfectly semipermeable (impermeable for solutes ( $P_{\text{solute}} = 0$ ) and permeable for solvent molecules) - the reflection occurs. In this case the net fluid flow ( $J_v$ ) is equal to  $J_v = L_v(\Delta p - \Delta\pi)$ . When *both* pressure differences  $\Delta p$  (*hydrostatic*) and  $\Delta\pi$  (*osmotic*) are equal, the net fluid flow is equal to zero - it corresponds to the equilibrium state which is not accepted in living organisms.
- 2<sup>0</sup>  $\sigma = 0$  - there is no reflection - the membrane is equally permeable for solvent and solute as well - solute particles pass through like water ( $P_{\text{solute}} = P_{\text{solvent}}$ ). In this case the simple filtration occurs and the equalization of concentrations occurs in the way of simple diffusion.

**EXAMPLES:**

- **Permeability of kidney's late distal tubules and collecting ducts: the role of the anti-diuretic hormone, vasopressin (ADH) in the control of osmolarity of body fluids.**
- **Discussion of the role of osmosis and filtration in the filtrating functions of kidneys.**