Q15 Discuss the important factors in exchange of gases and substrates between capillaries and tissue cells (March 2010)

As per **Fick's law,** flow of gas through a membrane (J) $\propto$ $\frac{\text{Area of membrane x Diffusion constant x (P1-P2)}}{\text{Thickness of membrane}}$

$$\text{Diffusion constant} \propto \text{Solubility}/\sqrt{\text{MW}}$$

Hence, factors to consider in the exchange of gas across a membrane are the membrane surface area and thickness, difference in partial pressures of gas on either side of the membrane, gas solubility and molecular weight.

Movement of fluids across a membrane depends on the **balance of Starling forces:** $k[(Pc-Pi)-\varepsilon(\pi_c - \pi_i)]$ where:

- k = filtration coefficient
- ε = reflection coefficient
- P_c = hydrostatic pressure in the capillary
- P_i = hydrostatic pressure in the tissues
- π_c = oncotic pressure in the capillary
- π_i = oncotic pressure in the interstitial tissues.

Osmotic pressure must also be considered in the movement of substrates between capillaries and tissue cells, and may be calculated using a derivation of the ideal gas law. $\pi = MRT$ where:

- π = Osmotic Pressure
- M = molar concentration (in mol/L)
- R = gas constant
- T = temperature in Kelvins

The **Gibbs-Donnan effect** will also regulate substrate movement → in the presence of a nondiffusable ion, the diffusible ions move down the concentration gradient until a significant opposing electrical potential has developed. This prevents further movement of ions, and an electrochemical equilibrium is reached. There is now osmotic disequilibrium, because there are more osmotically active particles on the side of the nondiffusible proteins, and water will move into the intravascular space. The result is opposing osmotic and electro-chemical gradients.

Transport mechanisms:

- Diffusion through the cell membrane:
  - Simple diffusion → occurs through the interstices of the lipid bilayer if the diffusing substance is lipid soluble, or through watery channels that penetrate all the way through some of the large transport proteins
  - Facilitated diffusion → diffusion through the membrane using a specific carrier protein to help
- Active transport → means movement of ions or other substances across the membrane in combination with a carrier protein against an energy gradient. May be primary (energy derived directly from ATP) or secondary (occurs via co-transport or counter transport)
- Endocytosis → engulfment of particle by cellular contents
- Exocytosis → extrusion of the contents of secretory vesicles through the cell membrane