Physiology of the Cell
Membrane

The main text for this lecture is:
Germann and Stanfield.
Some additions from Vander and Cooper's textbooks

If this was a cell membrane, which part of the Winnie The Pooh could be expected to be the most hydrophobic?

Total body water ~(60% of body mass):

Intracellular fluid ~2/3 or ~65%
Interstitial fluid ~28% of TBW (~80% of ECF)
Plasma of the blood ~7% of TBW (~20% of ECF)

Extracellular fluid ~1/3 or ~35%

Concentration of selected solutes in intracellular fluid and extracellular fluid in millimols

Inside the cell
In extracellular fluid

If the membrane was freely permeable to these molecules...

The first message: the cell membrane is NOT freely permeable to polarised/ionised/hydrophilic molecules
The second message: the cell is able to actively move certain molecules across its membrane. Proteins and ATP are synthesised inside the cell, therefore are highly concentrated there.

Forces which determine the direction of transport across the membrane

**Passive**
- along the concentration gradient and using the energy of this gradient

**Active**
- against the concentration gradient
- uses energy supplied by the cell to special proteins called PUMPS

Chemical and Electrical Driving Forces may combine to create the Electrochemical Driving Force

- Chemical driving force
- Electrical driving force

What will happen if the potential of this membrane decreases to -10 mV?

Electrical driving force
Conclusion: movement of charged particles such as ions, across the membrane depends on electro-chemical driving force (the sum of the force generated by chemical gradient and the force generated by electric field).

The Reversal Potential (same as equilibrium potential):
Potential of the membrane at which the electrical driving force is exactly equal the chemical driving force and therefore THE NET FLUX of charged particles (of one particular kind) is NIL.

The reversal (equilibrium) potential can be calculated using Nernst equation:

\[ E_{ion} = \frac{61.5 \text{mV}}{Z} \log_{10} \left( \frac{C_{out}}{C_{in}} \right) \]

IMPORTANT:
61.5 is a calculated constant derived from universal gas constant, the temperature (37°C and Faraday electrical constant. For 20°C it is 58.1; for 25°C it is 60. This is why different textbooks sometimes give you different values (In Vander's physiology it is 60!)

Z - is valence of an ion. Remember, for a negative ion it will be negative.
You MUST look through the relevant chapters in the textbooks:

E.g.:
- Chapter 6 in Vander’s Human Physiology (10th ed)

or
- Chapter 6 in Boron – Boulpaep Textbook

Be prepared to calculate the reversal potentials of the ions.

Also read about Goldman Equation which describes membrane potential when more than one ion is involved:

\[ V_m = 61.5 \times \log_{10} \left( \frac{P_{i,K} [K_i] + P_{i,Na} [Na_i] + P_{i,Cl} [Cl_i]}{P_{i,K} [K_o] + P_{i,Na} [Na_o] + P_{i,Cl} [Cl_o]} \right) \]

### Mechanisms of Passive Transport

- **Simple Diffusion**
- **Facilitated Diffusion**
- **Diffusion through Ion Channels**

### Factors affecting the speed of simple diffusion:

1. The magnitude of the driving force
2. Surface area of the membrane
3. Permeability of the membrane

**Fick’s law:**

\[ \text{Net flux} = P(\text{permeability}) \times A(\text{area}) \times (\Delta C) \]

For glucose the maximum rate can be ~ 10,000 molecules per second

### Factors affecting the speed of facilitated diffusion:

1. The magnitude of the driving force
2. Transport rate of the individual carriers
3. The number of available carriers

**Facilitated diffusion**
3. Diffusion through Ion Channels

Both leak and gated channels allow movement of molecules (mainly inorganic ions) down the electrochemical gradient. So, if the gradient reverses, the ions will flow in the opposite direction.

1. The channels are aqueous pores through the membrane.
2. The channels are usually quite selective, for example some only pass Na⁺, others K⁺, still others - Cl⁻.
3. Gated channels may be opened or closed by various factors (for example electrical potential of the membrane).

Factors affecting the speed of diffusion through ion channels:
1. The magnitude of the electro-chemical driving force
2. The transport rate of the individual channels (conductance)
3. The number of available channels
4. State of channels (open/close) in case they are gated (ADD TO YOUR HANDOUTS!!!)

Active transport

Key features:
1. Occurs irrespective of the chemical and/or electrical gradient
2. Requires an extra chemical source of energy, supplied by the cell. Directly or indirectly this is ATP

These guys are called pumps!