Membrane Potential

1. When separated by distance, oppositely charged particles tend to attract one another
   a. When separated charged particles have potential energy i.e. force of attraction can be coupled to a device to do work
   b. Potential energy is measure in volts
      1. 1 mv = .001 volts = 1/1000\textsuperscript{th} volt

Membrane Voltage = mv

Membrane Potential

• Plasma membrane of all living cells has a membrane potential (membrane voltage)
  – Separation of charges across plasma membrane
  – Due to differences in concentration and permeability of key charged ions
• Can be measured by a volt meter
  – Difference in charge between two locations is measured by a voltage meter in millivolts

REFERENCE POINT IS ALWAYS INSIDE THE CELL
(a) Membrane has no potential

(b) Membrane has potential
(c) Separated charges responsible for potential

(d) Separated charges forming a layer along plasma membrane
Membrane Potential

- Nerve and muscle cells
  - Excitable cells
  - Have ability to produce rapid, transient changes in their membrane potential because charged particles can move by diffusion through ion channels
Membrane Potential

- Nerve and muscle cells
- Resting membrane potential
  - The measured membrane potential (voltage) present in cells of nonexcitable tissues and those of excitable tissues when they are “at rest” (ion channels closed) vs. “excited” (ion channels open)

Table 3-3

<table>
<thead>
<tr>
<th>Ion</th>
<th>Extracellular Concentration*</th>
<th>Intracellular Concentration*</th>
<th>Relative Permeability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Na⁺</td>
<td>150</td>
<td>15</td>
<td>1</td>
</tr>
<tr>
<td>K⁺</td>
<td>5</td>
<td>150</td>
<td>25–30</td>
</tr>
<tr>
<td>A⁻</td>
<td>0</td>
<td>65</td>
<td>0</td>
</tr>
</tbody>
</table>

*Concentration expressed in millimoles per liter, mM
Membrane Potential

- Effect of sodium-potassium pump on membrane potential
  - Makes only a small direct contribution to membrane potential through its unequal transport of positive ions
  - Maintains overall a constant ion composition in ECF and ICF

Fig. 3-19, p. 65
When at Resting Membrane Potential (RMP) in an excitable cell, if a route (channel) for K+ opens long enough, and only K+ can move, then membrane potential will move from -70mV to the \( E_{K^+} \) of -90mV.

\[ E_{K^+} = -90 \text{ mV} \]

\( E_{K^+} \) = voltage measured when \( K^+ \) is in electrochemical equilibrium (potassium equilibrium potential)
The concentration gradient for Na⁺ tends to move this ion into the cell.

2. The inside of the cell becomes more positive as Na⁺ ions move to the inside down their concentration gradient.

3. The outside becomes more negative as Na⁺ ions move in, leaving behind in the ECF unbalanced negatively charged ions, mostly Cl⁻.

4. The resulting electrical gradient tends to move Na⁺ out of the cell.

5. No further net movement of Na⁺ occurs when the outward electrical gradient exactly counterbalances the inward concentration gradient. The membrane potential at this equilibrium point is the equilibrium potential for Na⁺ ($E_{Na^+}$) at +60 mV.

$E_{Na^+} = +60 \text{ mV}$
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The Na–K pump actively transports Na+ out of and K+ into the cell, keeping the concentration of Na+ high in the ECF and the concentration of K+ high in the ICF.

Given the concentration gradients that exist across the plasma membrane, K+ tends to drive membrane potential to the equilibrium potential for K+ ($E_K$); whereas Na+ tends to drive membrane potential to the equilibrium potential for Na+ ($E_{Na^+}$).

However, K+ exerts the dominant effect on resting membrane potential because the membrane is more permeable to K+. As a result, resting potential (~70 mV) is much closer to $E_K$ than to $E_{Na^+}$.

During the establishment of resting potential, the relatively large net diffusion of K+ outward does not produce a potential of ~90 mV because the resting membrane is slightly permeable to Na+ and the relatively small net diffusion of Na+ inward neutralizes (in gray shading) some of the potential that would be created by K+ alone, bringing resting potential to ~70 mV, slightly less than $E_K$.

The negatively charged intracellular proteins (A-) that cannot cross the membrane remain unbalanced inside the cell during the net outward movement of the positively charged ions, so the inside of the cell is more negative than the outside.

Fig. 3-21, p. 67
Resting membrane potential = $-70 \text{ mV}$

Relatively large net diffusion of $K^+$ outward establishes an $E_{K^+}$ of $-90 \text{ mV}$

No diffusion of $A^-$ across membrane

Relatively small net diffusion of $Na^+$ inward neutralizes some of the potential created by $K^+$ alone