Nervous System - Chapt. 12

- I will discuss primarily membrane potentials.
- Please refer to text for nervous system overview, histology and circuitry.
- Today: Resting membrane potential and action potentials
- Monday: Impulse conduction and synapses/neurotransmitters

Nervous system organization
(see Fig 12.2)

- Role of the nervous system:
  - Communication, information processing and control (same as Endocrine System)
- Flow of information

![Flow of information diagram]

Information flow

- Depends on an event = action potential (a.p.) (open and close gated ion channels)
- Propagation of these repeated events (trains of a.p.) along the cell = conduction
- Propagation between cells at synapses
- Occurs in “excitable” cells = neurons and muscle cells (fibers)

Neural histology (see fig 12.3)

- Neuron
  - Dendrites
  - Cell body
  - Axon
  - Axon terminal
  - Synaptic end bulb - release neurotransmitters
- Neuroglia (refer to Table 12.1)
  - Examples: astrocytes in CNS, Schwann cells in periphery (myelin sheath)

Cell Membrane Potential

- Voltage potential difference across the membrane
- Lipid bilayer acts as insulator
- Necessary for communication
- Important in control of many reactions (often involve Ca++)

Resting membrane potential

- About -70 mV (millivolts)
- Depolarization (become less negative or even positive): one type of graded potential
- Hyperpolarize: become more negative another type of graded potential
- Threshold
- Due to movement of charged ions (Na+, K+, sometimes Ca++)
Basis of resting membrane potential

- Electrical Gradient (EG in mV)
  imbalance of cations (+) and anions (-)
  - unlike attract, like repel
- Due to (1) Concentration Gradient (CG in mM)
  - due to Na⁺/K⁺ pump
- (2) selective membrane permeability (conductance)
  - Due to # of “open” ion channels, at rest $P_{K^+} >> P_{Na^+}$

Why is this stuff important?

- Understanding membrane potentials explains why nerve action potentials can happen so FAST
- Understanding membrane potentials explains why plasma ion concentrations (especially potassium) are so important to health

Cross Section of a neuron

- High intracellular K⁺
- High intracellular fixed anions (proteins)
- High extracellular Na⁺ Cl⁻
- Any ions that cross membrane are eventually pumped back (CG DOESN’T USUALLY CHANGE!)

Hypothetical Case for K⁺

- If cell perfectly permeable to K⁺
- Initially no EG
- K⁺ efflux down CG
- Sets up EG
- No net movement at equilibrium potential

Actual State

- K⁺ not at equilibrium
- K⁺ equilibrium potential (= -90 mV)
- What way does K⁺ “want” to move?
- If increase $P_{K^+}$, cell will ___polarize
- BOTTOM LINE: there is a small electrochemical gradient for K⁺ to (EFFLUX or INFLUX?)

The effect of Na⁺

- High CG for Na⁺ influx
- High EG for Na⁺ influx
- What would membrane potential have to be for cell to be in Na⁺ equilibrium?
- Why doesn’t this occur?
  - LOW permeability to Na⁺
- BOTTOM LINE: there is a LARGE electrochemical gradient for Na⁺ to (EFFLUX or INFLUX?)
Reiterate: RMP due to:

- Concentration gradients for Na\(^+\) and K\(^+\)
  - Maintained by pumping
- Relative permeability to Na\(^+\) and K\(^+\)
  - \(P_{K^+} >> P_{Na^+}\)

What would happen if:

- Increase in ECF K\(^+\) (hyperkalemia)
  - Decrease K\(^+\) CG
  - Make K\(^+\) equilibrium potential less negative
  - Depolarize the membrane
  - Move toward threshold
  - Life threatening– cardiac arrhythmias

What would happen if:

- Increase in ECF Na\(^+\)
  - Increase Na\(^+\) CG
  - Increase Na\(^+\) equilibrium potential (more positive)
  - But little effect because of very low \(P_{Na^+}\)

What would happen if:

- Increased permeability to K\(^+\)
  - Hyperpolarize a little, further from threshold
- Increased permeability of Na\(^+\)
  - Huge electrochemical gradient for Na\(^+\) influx
  - Depolarize very quickly

What changes cell permeability to ions? (Fig 12.8)

- Opening and closing of gated ion channels
  - Voltage-regulated (VR) gates (in action potential)
  - Chemical-regulated gates (at synapses)

Excitable cells have special voltage regulated ion channels (see fig 12.12)

- Na\(^+\) VR gates: open when cell depolarized, but then shut and lock (inactivated) until cell repolarizes
- K\(^+\) VR gates: also open when cell depolarizes, but more slowly than Na\(^+\) channels.
Action Potential (Fig 12.11)
• Sudden and transient change in membrane potential
  – At rest
  – Stimulus --> depolarize to threshold
  – Reversal of polarization (positive inside)
  – Repolarize
  – Hyperpolarize
  – Return to rest

Action Potential (Fig 12.12)
• Order of VR gates opening important
• Which way do ions flux?
• What is effect on membrane potential?
• Why is this a POSITIVE feedback?
• What stops this positive feedback cycle?

Common misconceptions
• Don’t repolarize the membrane with the Na⁺/K⁺ pump
• Don’t usually change the CGs for Na⁺ and K⁺
• Don’t need Na⁺/K⁺ pump in SHORT run, but do need in LONG run to maintain the CG

Action potential is “all or none”
• Same amount of depolarization
• Same amount of time
• What codes information????
  – Not size i.e. not amplitude modulated (AM signal like a graded potential)
  – Rather frequency modulated (FM signal)
    • E.g. 5 AP/sec versus 100 AP/sec

Refractory periods (RP)
• Excitable cells can’t respond again until recover (Fig 12.11)
• Absolute RP (VR Na⁺ channels inactive=locked)
• Relative RP (VR K⁺ channels open)
• Significance:
  – Upper limit on frequency
  – A.P. can’t reverse direction when being propagated along axon.