Action Potential

Lesson 12
Learning Goals

1. What is an **action potential**

2. How does **electrical impulse** move across a neuron
Action potential

**Action potential**
- A temporary shift in the *membrane potential*
- Results from the *voltage difference* across a membrane when the nerve is excited
- The electrical current (impulse) travels the length of an axon

**Membrane potential (voltage)**
- Differences in electrical potential across a membrane (charge separation)
- Unequal *sodium* (Na+) and *potassium* (K+) ions inside and outside the cell
Membrane Resting potential (MRP)

- Membrane potential of a neuron at rest (-70 mV)

Sodium-potassium pump
- Active transport that moves 3 Na+ out of the cell and 2 K+ into the cell across their concentration gradients
Resting Membrane Potential

- At rest, the membrane **inside** a neuron has a **negative** charge.
- At rest, **outside** of the neuron membrane is **positively** charged.

*Section of an axon during the resting potential.*
Axon hillock

Axon Hillock

- Specialized part of the cell body that connects it to the axon
- The site where the axon begins
Threshold level

• Incoming Na+ from a stimulus raises membrane potential until it reaches the threshold potential of -50 to -55 mV

Threshold level

• Minimum level of a stimulus required to produce a response (depolarization)

• Cause all voltage-gated Na+ channels to open
The magnitude of a potential stays the same as it travels along an axon.

The all-or-nothing characteristic of the AP means that the intensity or stimulus is reflected in the frequency of AP rather than in their magnitude.

The greater the stimulus, the faster the AP.
Depolarization

- Diffusion of sodium ions into the nerve cell resulting in a charge reversal
- Inside the cell briefly becomes positive
Repolarization

• When the membrane potential reaches +30 mV, the Na+ voltage-gated ion channels close

Repolarization

• Process of restoring the original polarity of the nerve membrane

• **K+ voltage-gated channels** open and K+ ions exit along its concentration gradient

  • Depolarization and repolarization only takes about 5 milliseconds!
Hyperpolarization

- Process of restoring the original polarity of the nerve membrane
- K+ channels close \textit{slowly} = K+ outflow = -80 mV

Refractory Period

- \textit{Recovery time} required before a neuron can produce another action potential
  - Threshold to depolarize the neuron is harder to reach
Resting Membrane Potential

- **Na+/K+ pump** returns the neuron to resting potential
- Neuron is ready for a new action potential
“All-or-Nothing” response

- An action potential is only produced if the stimulus is strong enough to cause depolarization at the threshold level (-55 mV)

- Neurons will fire maximally or not at all

- Intensity of impulse and speed of transmission is independent of stimulus strength once threshold is reached
Action Potential Propagation

• Depolarization of one site causes nearby voltage-gated Na$^+$ channels to open $\rightarrow$ resulting in depolarization of an adjacent site

• Action potential “travels” by repeated regeneration along axon

• Refractory period ensures the action potential travels in one direction only = unidirectional
Speed of Transmission?

**Axon diameter**
- Larger = faster conduction
- Less resistance

**Myelination (myelin sheath)**
- Voltage-gated ion channels only in nodes of Ranvier
- Axons only exposed to ions in extracellular fluid (ECF) nodes
- No action potential in regions between nodes
Unmyelinated Conduction

(a) Resting

(b) Initiation

(c) Propagation

(d) Propagation continues
Myelinated Conduction

• Current generated by action potential at a node “leaps” to next node

• Na+ and K+ exchange can only occur where the axons are exposed to the ECF

• Allows for faster signal conduction along the axon
Synapse

- A small region that controls communication between two neurons or between neurons and effectors

- Action potential is transmitted through the synapse by neurotransmitters that are received by receptors on the other side of the synapse

- **Neurotransmitters** = chemical messengers contained in vesicles
  - Released from the presynaptic neuron and depolarizes the postsynaptic neuron

- More synapses = slower transmission
  - Very few synapses in a reflex arc, but MANY involved in problem solving!
Action Potential Summary

- The magnitude of a potential stays the same as it travels along an axon.
- The all-or-none characteristic of the AP means that the intensity or stimulus is reflected in the frequency of AP rather than in their magnitude.
- The greater the stimulus, the faster the AP.

Diagram:

1. Resting Potential
   - Na⁺/K⁺ pump
2. Depolarisation
   - Voltage-gated Na⁺ channel
3. Repolarisation
   - Voltage-gated K⁺ channel
4. Resting Potential
   - Na⁺/K⁺ pump
Homework

1. Worksheet questions

2. Unit Task Research: Due Tuesday
   • Computer lab will be open on Monday at lunch

3. Reproductive (female) assignment: Due Monday