Nerve impulse
Transmembrane Potential
caused by ions moving through cell membrane at different rates
• Two main ions of concern
  • Na\textsuperscript{+} - Sodium
  • K\textsuperscript{+} - potassium

• Cell membrane not freely permeable
  • therefore uneven distribution of ions occurs
• even passive and active transport mechanisms don’t ensure equal distribution of ions

• it is easier for K\(^+\) to diffuse out through a potassium channel than it is for Na\(^+\) to diffuse in through its channel

• result inner surface has an excess of negative charges with respect to outer surface
Passive forces acting on membrane

- Chemical gradients
- Electrical gradients
- They can act to enhance each other or in oppose each other
Resting potential

If the cell membrane were freely permeable to potassium ions, the net electrochemical gradient would force potassium ions out of the cell.

If the cell membrane were freely permeable to sodium ions, the net electrochemical gradient would drive sodium ions into the cell.

The normal resting potential opposes the chemical gradient for potassium ions (K^+). The net electrochemical gradient tends to force potassium ions out of the cell.

The normal resting potential combined with chemical and electrical gradients drive sodium ions (Na^+) into the cell.

Electrochemical gradient for K^+ and Na^+
Active forces across membrane

- Sodium - potassium exchange pump
- exchanges
  - 3 intracellular sodium exchanged for 2 extracellular potassium
- ejects sodium as quickly as they enter
Changes in Transmembrane potential

- Membrane channels control movement of ions across cell membrane
- Channels either active channels (gated) or passive channels (leak channels)

- types
  - chemically regulated
  - voltage regulated
  - mechanical regulated
FIGURE 12–10  Gated Channels. Na⁺ channels are shown here, but comparable gated channels regulate the movements of other cations and anions. (a) A chemically regulated Na⁺ channel that opens in response to the presence of an activated binding site. (b) A voltage-regulated Na⁺ channel that is opened or closed depending on the membrane potential. At a normal resting potential, the channel is closed; at a membrane potential of −60 mV, the channel opens; at +30 mV, the channel is inactivated. (c) A mechanically regulated channel, which opens in response to distortion of the membrane.
Graded Potentials

- Local potentials
- do not spread far from site of stimulation
- any stimulus that opens a gated channel will produce a graded potential
any shift from the resting potential toward 0mV is a depolarization

resting open Na\(^+\) channels

local current depolarizes adjacent portions of membrane
Graded potentials cont.

- degree of depolarization decreases with distance away from stimulation site
- when chemical stimulus is removed then transmembrane potential returns to resting potential
- change is repolarization
Summary Graded Potentials

- Graded potentials, whether depolarizing or hyperpolarizing share 4 basic characteristics
- 1. The transmembrane potential is most affected at the site of stimulation, and the effect decreases with distance
- 2. The effect spreads passively, owing to local currents
3. The graded change in membrane potential may involve either depolarization or hyperpolarization. The nature of the change is determined by the properties of the membrane channels involved. For example, in a resting membrane, the opening of potassium channels will cause hyperpolarization.

4. The stronger the stimulus, the greater is the change in the transmembrane potential and the larger is the area affected.
Action Potentials

- AP’s are propagated changes in transmembrane potential that, once initiated, affect the entire excitable membrane
all or none principle

• The stimulus that initiates the AP is a depolarization large enough to open voltage-regulated sodium channels.

• opening occurs at threshold between -60mV and -55mV

• a stimulus from resting -70mV to -62mV will not produce an AP
Generation of Action Potential

**FIGURE 12-13**
The Generation of an Action Potential. For clarity, only gated channels are shown.

**RESTING STATE**
-70 mV

**STEP 1** Depolarization to threshold
-60 mV

**STEP 2** Activation of sodium channels and rapid depolarization
+10 mV

**STEP 3** Inactivation of sodium channels and activation of potassium channels
+30 mV

**STEP 4** The return to normal permeability
-90 mV

Information processing
Refractory Period

• from time AP begins till normal resting state regained (refractory period)-membrane normally will not respond to additional stimulus

• absolute RP - no activation can occur

• relative RP - activation can occur if stimuli is larger than normal
Sodium Potassium Exchange pump

- In an AP, depolarization results from influx of Na$^+$ and repolarization involves the loss of K$^+$.

- Over time the SPEP returns ion concentrations back to resting levels.
Propagation of AP

- Two types
  - Continuous propagation
    - occurs over unmyelinated axons
  - Saltatory propagation
    - occurs over myelinated axons
continuous propagation

**STEP 1** As an action potential develops in the initial segment, the transmembrane potential depolarizes to +30 mV

**EXTRACELLULAR FLUID**

- Action potential
- +30 mV
- -70 mV

**Cell membrane**

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**CYTOSOL**

**STEP 2** A local current depolarizes the adjacent portion of the membrane to threshold

**Graded depolarization**

- -60 mV
- -70 mV

**Local current**
STEP 3  
An action potential develops at this location, and the initial segment enters the refractory period.

STEP 4  
A local current depolarizes the adjacent portion of the membrane to threshold, and the cycle is repeated.
saltatory propagation

**STEP 1**
Action potential at initial segment

**STEP 2**
Depolarization to threshold at node 1
STEP 3: Action potential at node 1

Repolarization (refractory)

STEP 4: Depolarization to threshold at node 2

Local current
propagation speed

- myelin greatly increases speed of propagation of AP
- Diameter of axon
  - larger diameter is faster
Neural Communication

• action potential travels length of axon to end of axon

• transfer of information to another neuron or effector cell

• neurotransmitters (ex. Ach) released from synaptic terminal

• if synapse to another neuron could go to dendrite, cell body or axon
Structure Synapse

- synaptic knob of presynaptic neuron
- at end of axon
- synaptic cleft
- space between pre and post synaptic neuron
Sequence of events
(at the typical cholinergic synapse)

- Step 1
- An arriving action potential depolarizes the synaptic knob and the presynaptic membrane
• Step 2

• Calcium ions enter the cytoplasm of the synaptic knob.

• Ach release occurs through exocytosis of neurotransmitter
• Step 3 - Ach diffuses across the synaptic cleft and binds to receptors on the postsynaptic membrane

• Sodium channels on the postsynaptic surface are activated producing a graded depolarization

• Ach release stops because calcium ions are removed from the cytoplasm of the synaptic knob
• Step 4

• The depolarization ends as Ach is broken down into acetate and choline by AchE

• The synaptic knob reabsorbs choline from the synaptic cleft and uses it to resynthesize Ach.
• other neurotransmitters
• noradrenaline (NE)
• dopamine (DO)
• gamma aminobutyric acid (GABA)
• serotonin
• nitric oxide (NO)
• carbon monoxide (CO)
- Neurotransmitters can be excitatory or inhibitory

- Where an action potential appears post-synaptic depends on balance between inhibitory and excitatory stimulation
Neuronal Pools

- A neuronal pool is a group of interconnected interneurons with specific functions

- **divergent pattern**
  - when you step on a sharp object - stimulates divergent pool -
  - pull foot away, feel pain and say ouch
• **convergent pool**

  • several neurons synapse on a single post synaptic neuron.

  • makes possible both voluntary and involuntary control over some body processes. ex. breathing
Types of Nerve

• Definitions
  • The nerve fiber is an extension of a neuron.
  • A nerve is a bundle of nerve fibers
• Sensory nerves
  • impulses to brain or spinal cord
• Motor nerves
  • impulses to muscles or glands
• mixed nerves
  • both sensory and motor
Nerve Pathways

- Nerve pathway is the route the impulse travels
- simplest one is reflex arc
  - consists few neurons
• Reflex arc

• has receptor at on sensory nerve fiber

• SNF leads to interneurons in CNS

• CNS serves as processing center or reflex center

• interneurons link to motor neurons

• Motor neurons lead to effectors
• Reflexes

• automatic subconscious responses to stimuli (changes in or out of body) enacted to maintain homeostasis

• may control things like

• hear rate / breathing rate/ blood pressure / digestion
Withdrawal Reaction

Interneuron
Axon of sensory neuron
Cell body of sensory neuron
Dendrite of sensory neuron
Direction of impulse
Spinal cord
Axon of motor neuron

Effector—flexor muscle contracts and withdraws part being stimulated

Cell body of motor neuron

Pain receptors in skin

Tack