Electrical Signaling

Lecture Outline

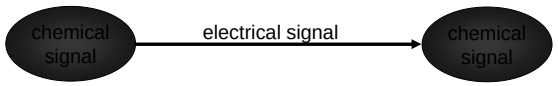
- Using ions as messengers
- Potentials in electrical signaling
  - Action
  - Graded
- Other electrical signaling
  - Gap junctions
- The neuron

Using Ions as Messengers

- **Important things to recall (and understand):**
  - ions are just atoms with a charge,
  - membrane potentials are established by ionic charges (electrochemical gradients),
  - changes in charge can affect membrane proteins such as channels,
  - other membrane channels allow for ions to flow down concentration gradients, creating a change that can affect other membrane potentials.
  - Excitable tissues have Na^+ & K^+ channels that operate at a threshold level

Potentials in Electrical Signaling

- Electrical signals
  - fast
  - specific / localized
  - shocking
  - sometimes used as conveyers of chemical signal



  - Sometimes used for coordination among cells
  - Sometimes used for integration

Potentials in Electrical Signaling

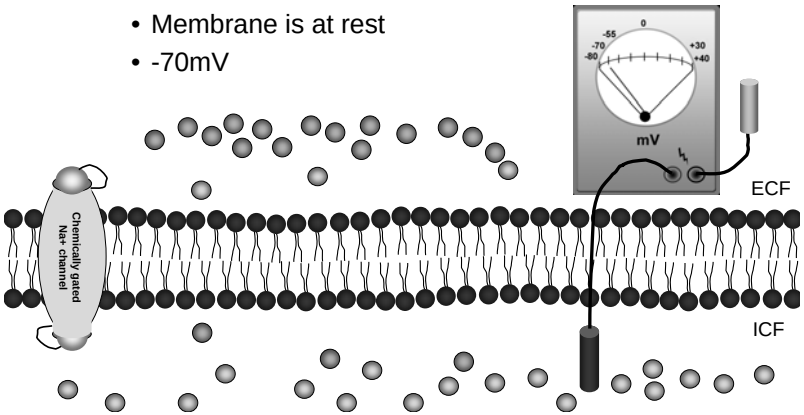
- Action Potential Characteristics
  - Traveling electrical charge
    - Non decremental over time & distance
    - All or none
    - Unidirectional
    - Occur only on tissues with voltage gated Na^+ channels
    - Send signal along:
      - Axon & associated axon collaterals of neurons
      - Sarcolemma & transverse tubules of muscle cells
      - Some glandular cell membranes
    - May travel in a “domino effect” style or in a “jumping” style
      - Local current flow = domino style (slower)
      - Saltatory conduction = jumping style (faster)

Potentials in Electrical Signaling

- Action Potentials
  - Basic process
    - Stimulus causes membrane potential to reach threshold level
    - Membrane depolarizes quickly as Na^+ voltage gated channels open en masse once threshold is reached
    - Membrane repolarizes as slow reacting K^+ voltage gated channels open en masse milimoments later
    - Resting membrane potential is restored

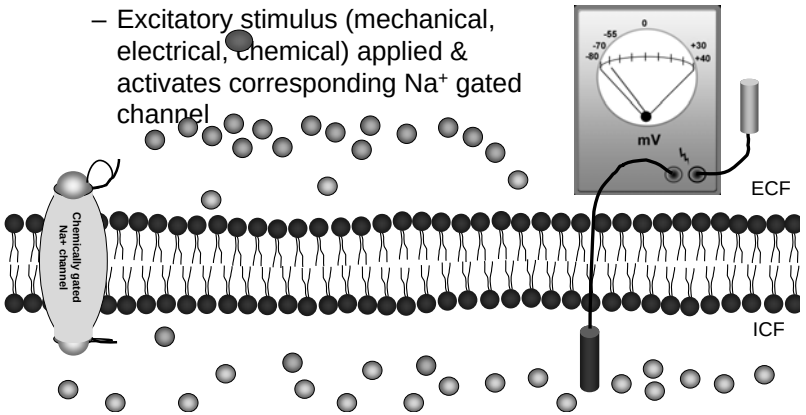
Potentials in Electrical Signaling

- The Process Action Potential Formation
  - Membrane is at rest
  - -70mV



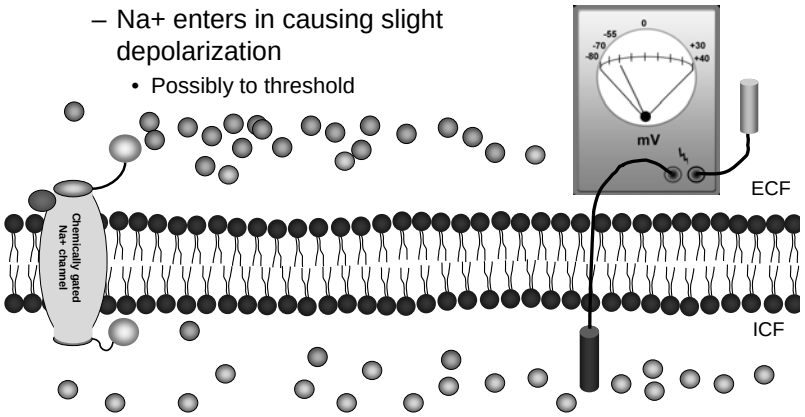
Potentials in Electrical Signaling

- Action Potentials – The process
  - Excitatory stimulus (mechanical, electrical, chemical) applied & activates corresponding Na^+ gated channel



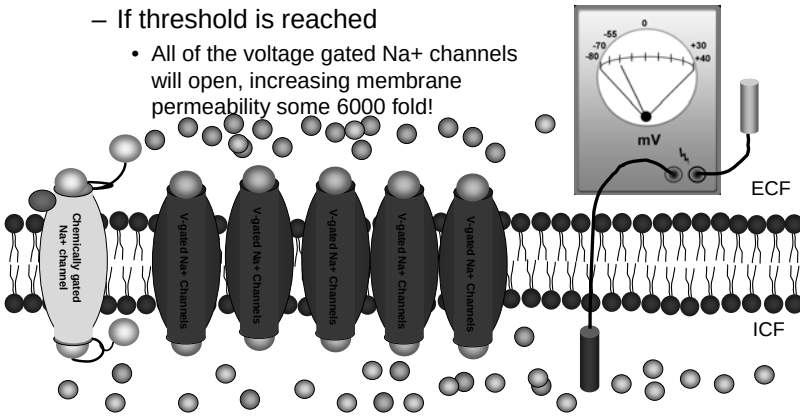
Potentials in Electrical Signaling

- Action Potentials – The process
  - Na+ enters in causing slight depolarization
    - Possibly to threshold



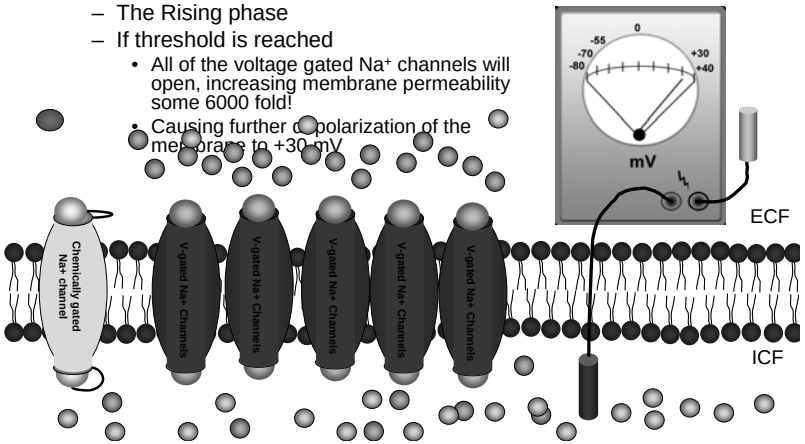
Potentials in Electrical Signaling

- Action Potentials – The process
  - If threshold is reached
    - All of the voltage gated Na+ channels will open, increasing membrane permeability some 6000 fold!



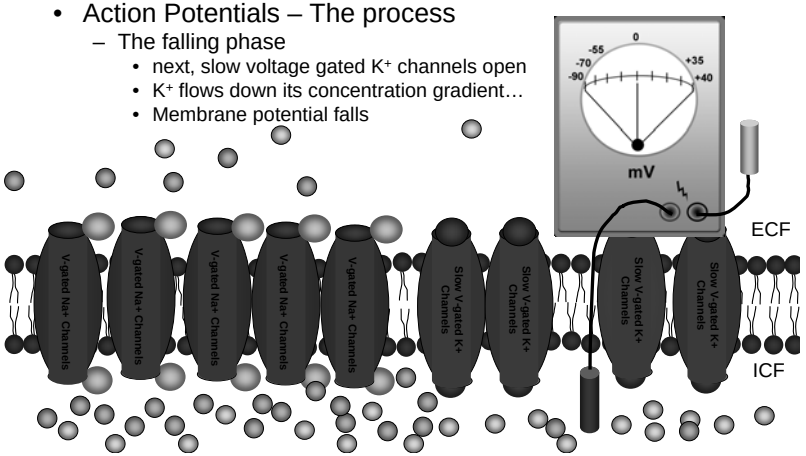
Potentials in Electrical Signaling

- Action Potentials – The process
  - The Rising phase
  - If threshold is reached
    - All of the voltage gated Na^+ channels will open, increasing membrane permeability some 6000 fold!
    - Causing further depolarization of the membrane to +30 mV



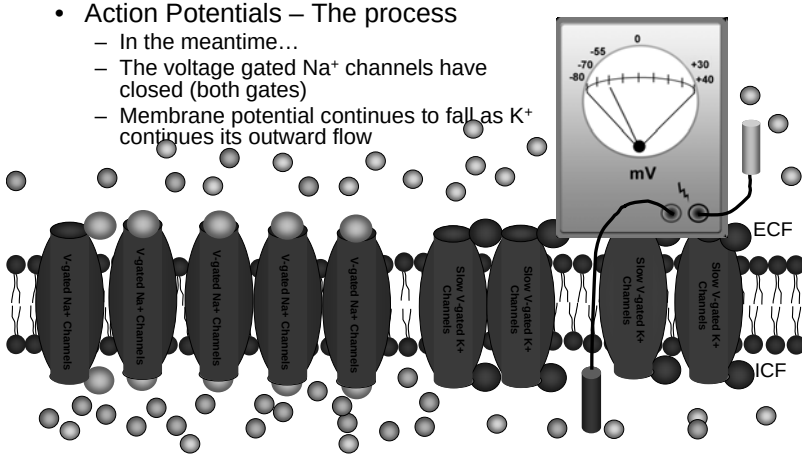
Potentials in Electrical Signaling

- Action Potentials – The process
  - The falling phase
    - next, slow voltage gated K^+ channels open
    - K^+ flows down its concentration gradient…
    - Membrane potential falls



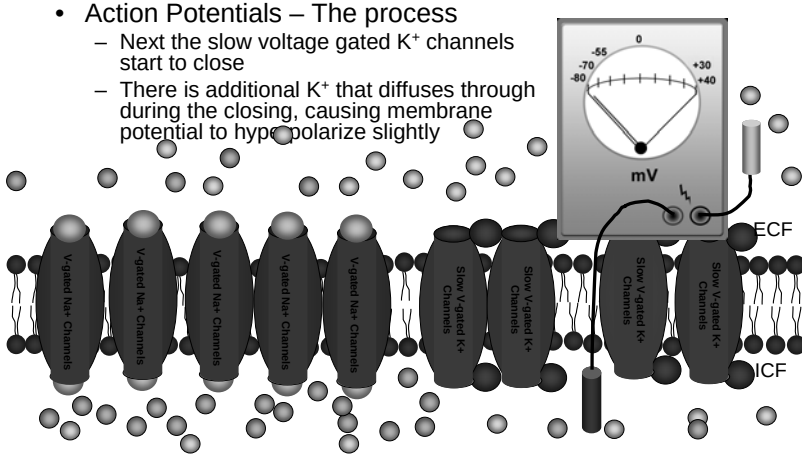
Potentials in Electrical Signaling

- Action Potentials – The process
  - In the meantime…
  - The voltage gated Na^+ channels have closed (both gates)
  - Membrane potential continues to fall as K^+ continues its outward flow



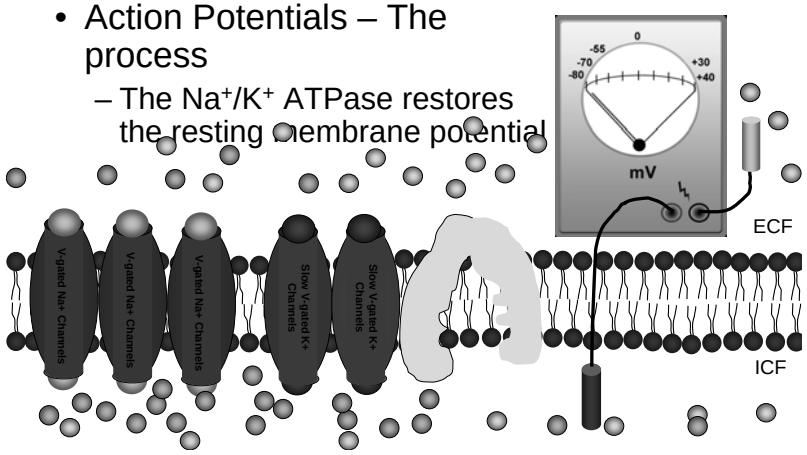
Potentials in Electrical Signaling

- Action Potentials – The process
  - Next the slow voltage gated K^+ channels start to close
  - There is additional K^+ that diffuses through during the closing, causing membrane potential to hyperpolarize slightly



Potentials in Electrical Signaling

- Action Potentials – The process
  - The Na^+/K^+ ATPase restores the resting membrane potential



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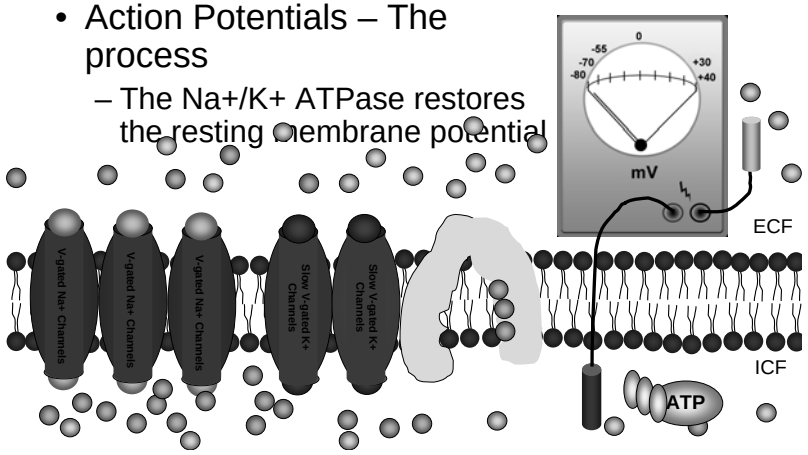

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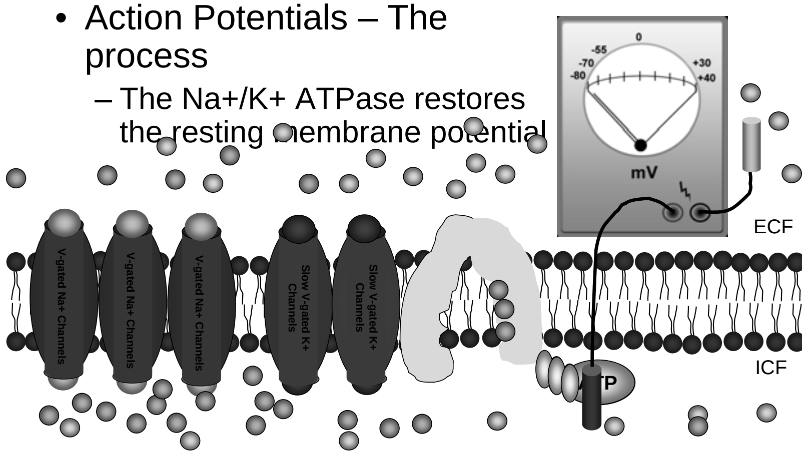

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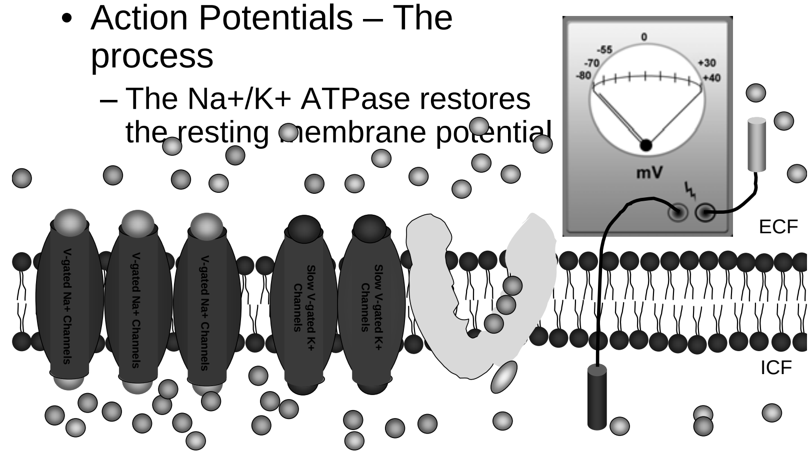

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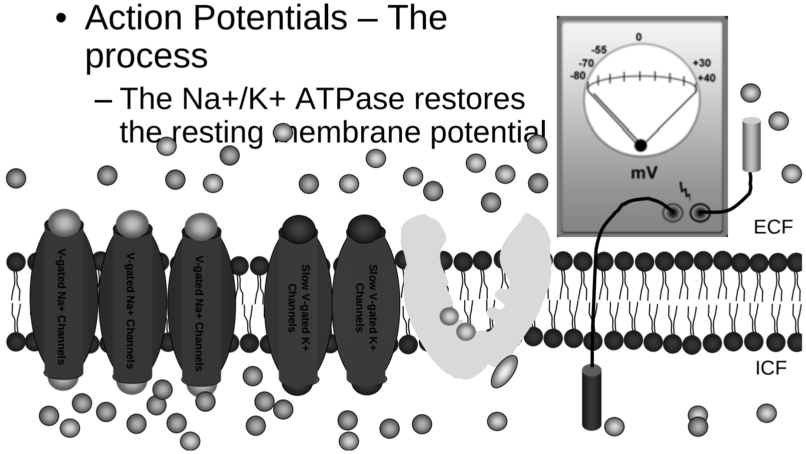

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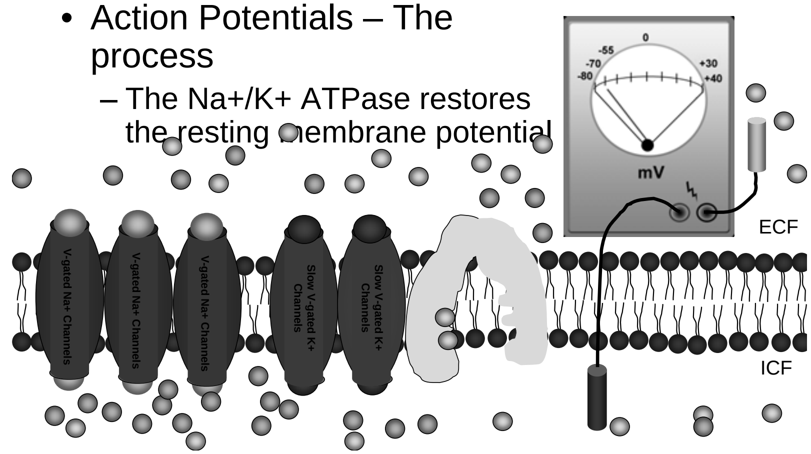
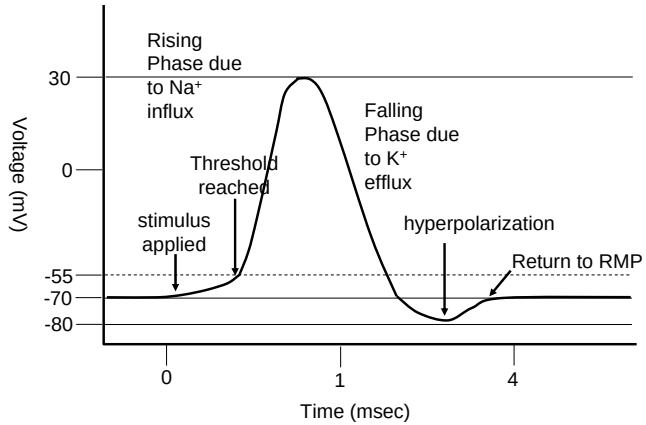
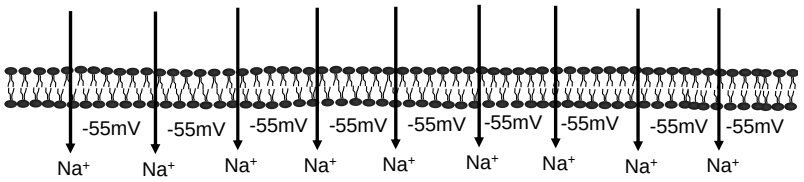


Action Potential Graph



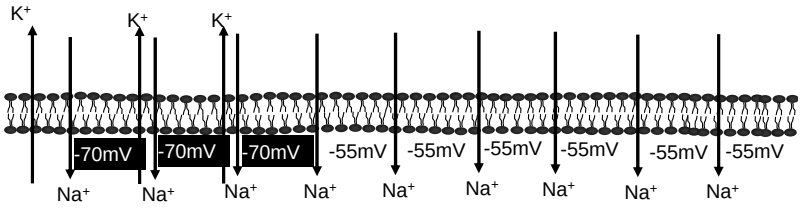
Potentials in Electrical Signaling

- Action Potentials – The process
  - This process, will occur along the entire length of the excitable cell membrane
    - As long as it has…
  - The local influx of Na+ will cause the next adjacent voltage gated channels to open, cascading to the end of the membrane



Potentials in Electrical Signaling

- Action Potentials – The process
  - What happens when it gets to the end of the membrane?
  - The signal is transduced
    - And a chemical signal is generated
  - The prior sections of membrane are finishing up, getting back to resting membrane potential as K^+ effluxes



Some Potential Questions!

- Why are potentials all or none
  1. Can't increase beyond **all** open!
  2. If threshold isn't reached, no channels **open**

- This creates refractory periods
  1. absolute refractory period
  2. relative refractory period

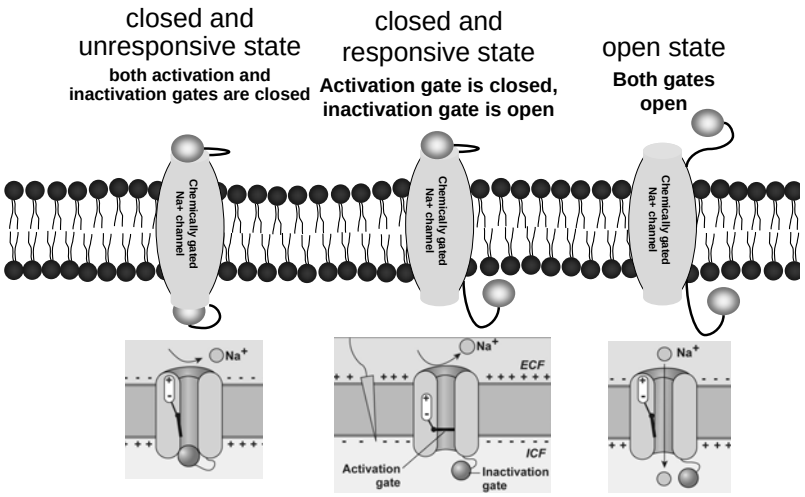
- Why are they unidirectional?

  the voltage gated channels when closed just after depolarization enter into a state of inactivity…

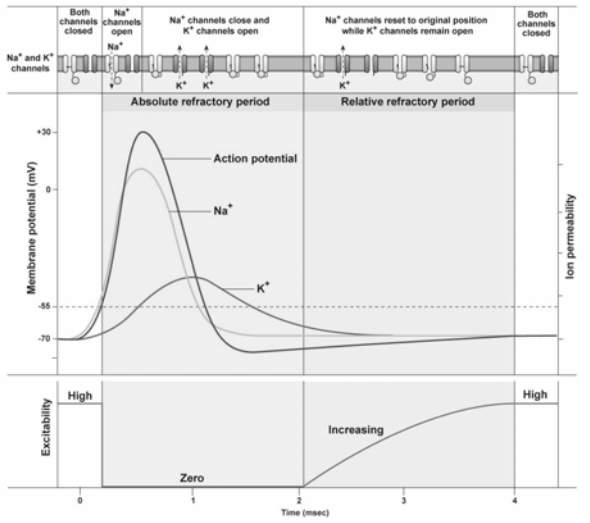
  "closed and unable to open"

  this prevents ions from influxing into the cell from regions that were just affected

Channel States



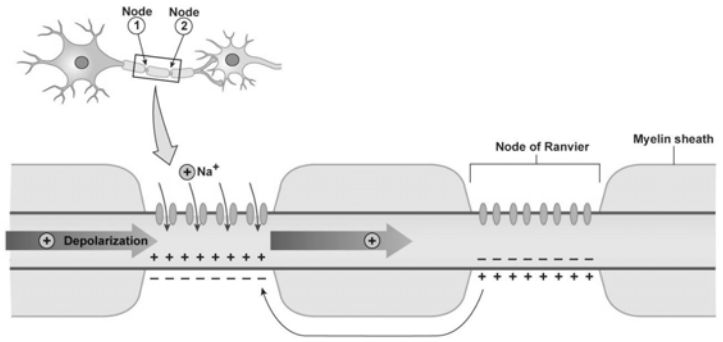
Refractory Periods



Action Potential Speed

- The speed of transmission depends on:
  - Membrane/cell characteristics
    - Thicker = faster
  - Presence of insulation around cell
    - Myelin around axon portion of neuron
    - Insulation = faster
      - Conduction of depolarization jumps to the nodes of exposed membrane between the insulation

Myelinated Axon



(a) Action potentials appear to jump from one node of Ranvier to the next. Only the nodes have Na^+ voltage-gated channels.

Next Week

- Graded Potentials vs. Action Potentials
- Synaptic Transmission
- Nervous System (CNS)