Synaptic Signaling & The Action Potential

How Nerve Cells Communicate!

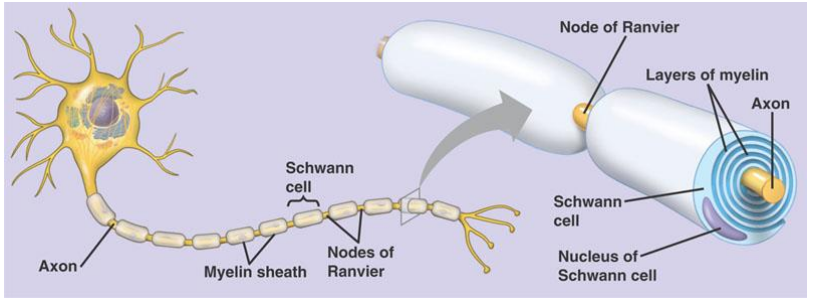
Packet #18

How Nerve Cells Communicate

Synaptic Signaling
The Action Potential

The Structure of the Nerve Cell

* Dendrites
* Cell Body
* Axon
* Myelin Sheath
* Axon Terminal
* Synapse



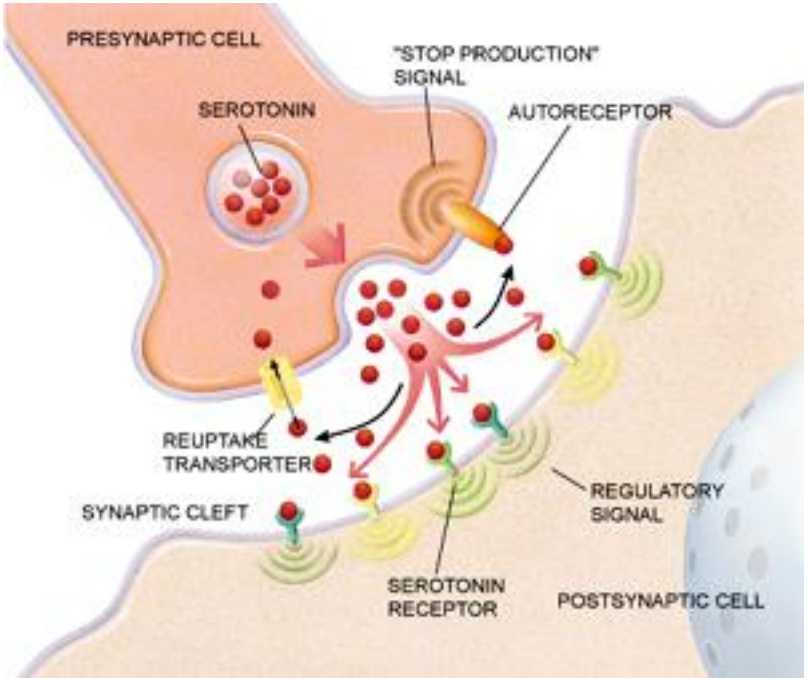
Introduction

* Axon of a neuron, nerve cell, terminates at specialized junctions called synapses.
  * Far away from the neuronal cell body.
* When activated by signals from the environment or from other nerve cells, the neuron sends electrical impulses along its axon at speeds up to 100 m/s.

The Process at the Synapse

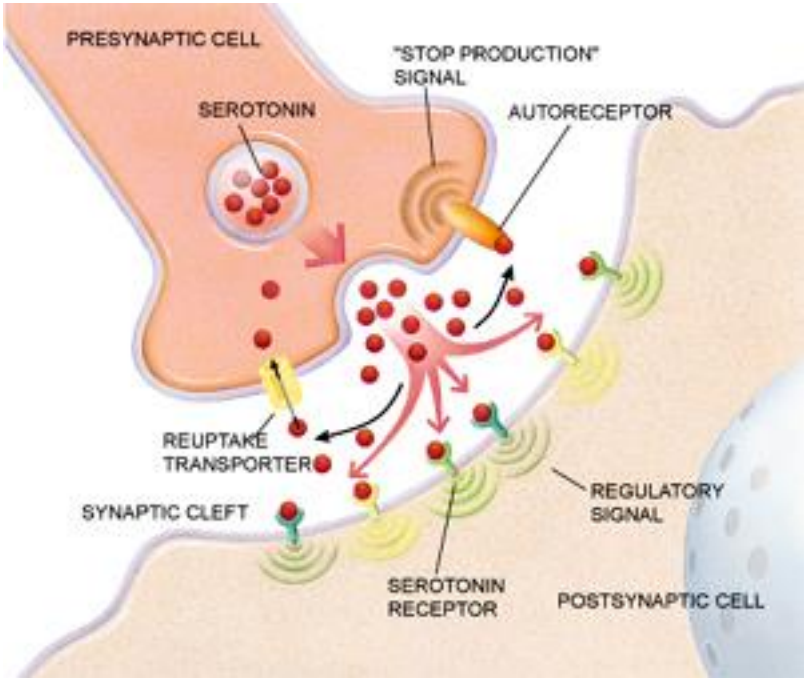
Signal Reception

Synaptic Signaling
The Triggering of an Action Potential



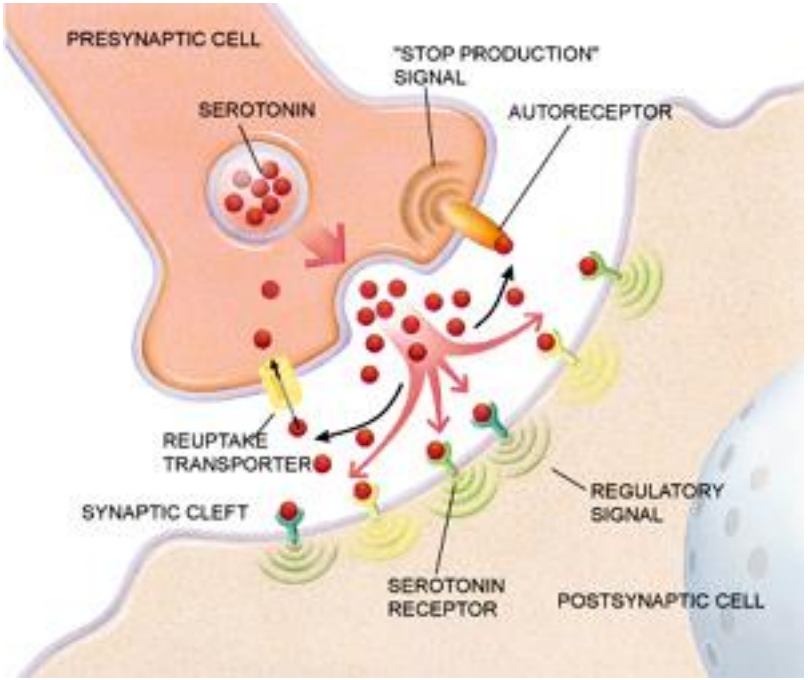
* Electrical signal, in the form of an action potential, reaches axon terminal and is converted into an extracellular chemical form
  * Electrical impulse opens the calcium voltage gated ion (Ca^{2+})
  * Calcium triggers the terminal to secrete a chemical signal, known as a neurotransmitter, within a vesicle.
  * Vesicle fuses to the membrane of the pre-synaptic cell
  * Vesicle, containing neurotransmitter, leaves the pre-synaptic cell via exocytosis.

Synaptic Signaling
The Triggering of an Action Potential



* Neurotransmitter crosses a small gap between axon-terminal membrane and membrane of target cell
  * Entire process occurs in less than a millisecond

Synaptic Signaling
The Triggering of an Action Potential



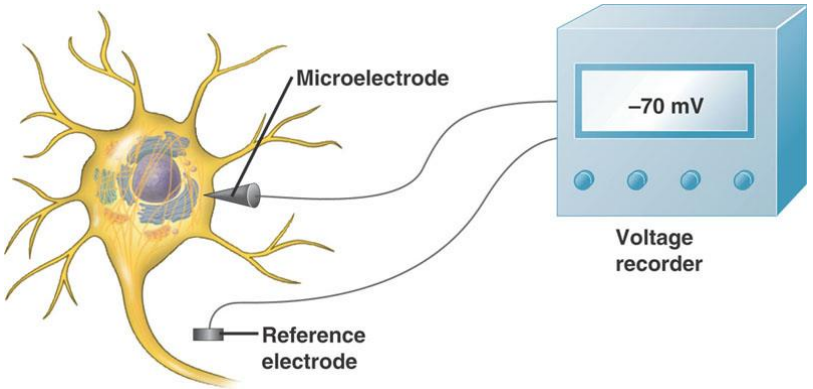
* The neurotransmitter binds onto receptors found on the postsynaptic cell.
* Results in a change in the postsynaptic cell resting potential—resulting in the formation of an action potential (beginning stages of an action potential in the post synaptic cell).

The Formation of the Action Potential at the Membrane of the Post-Synaptic Cell

Transduction
Resting Potential

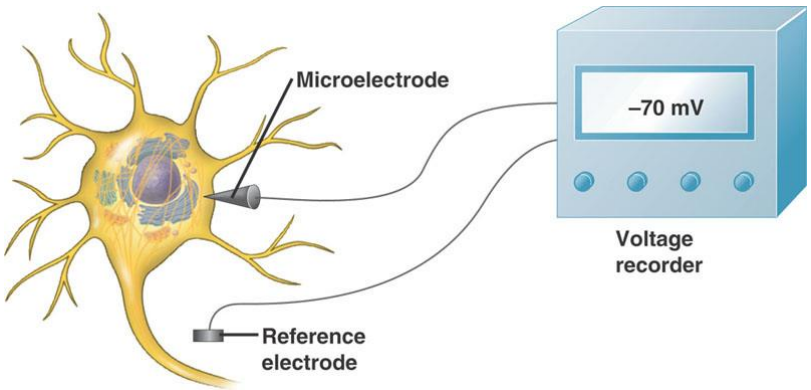
The Resting Potential

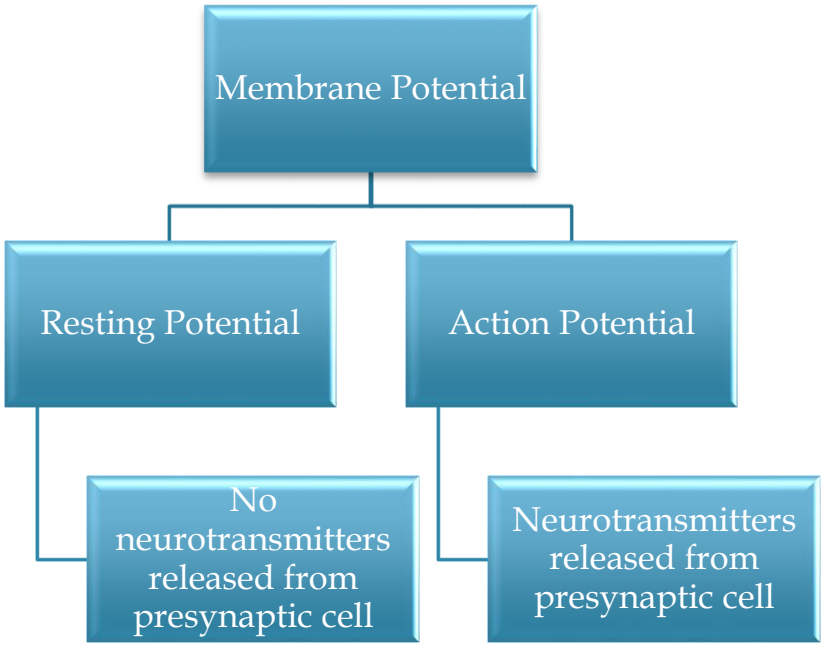
* The post synaptic cell is normally in a state of resting potential when no neurotransmitters have been released from the pre-synaptic cell.



The Resting Potential II

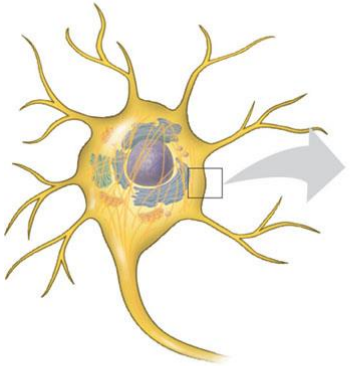
* The resting potential, measured in mV, is the membrane potential of a neuron that is not transmitting signals.
  * Not receiving a chemical signal in the form of a neurotransmitter.

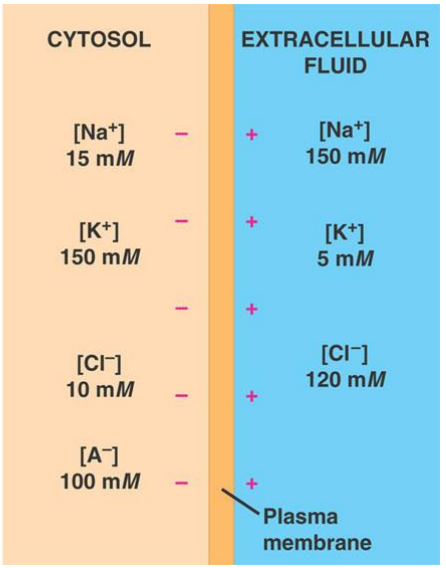




The Resting Potential III

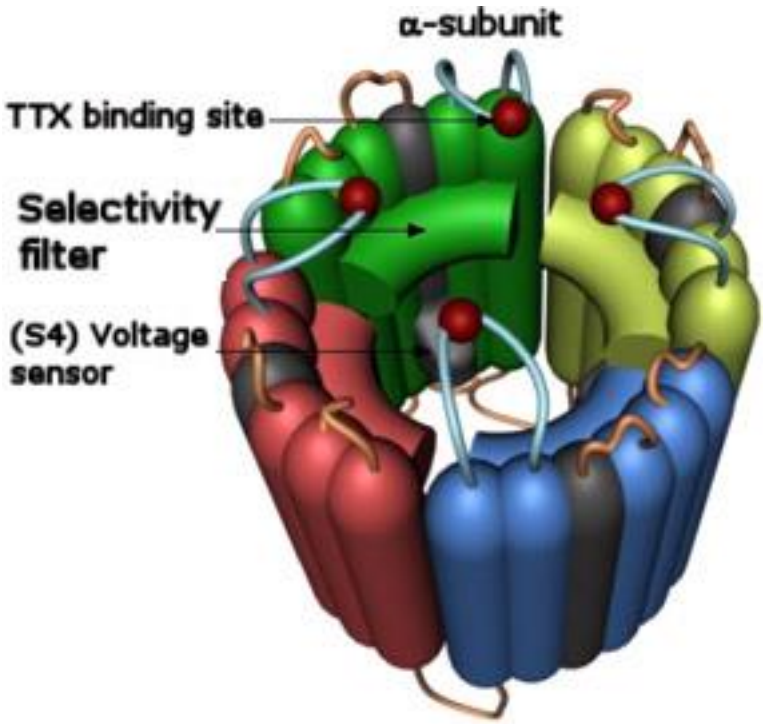
* The resting potential of a nerve cell is -70mV
* Maintained because the ion gated channels are closed.





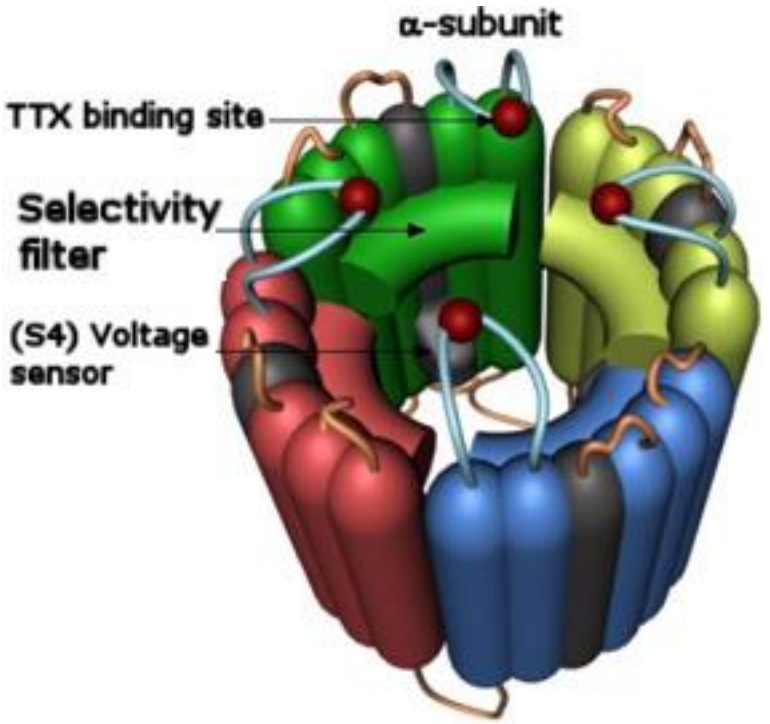
Types of Ion Channels Involved in Initiating Action Potential

* There **are two types of ion channels** involved in the process of initiating the action potential at the plasma membrane of the post-synaptic cell
  * Ligand Gated Ion Channel
    * Na^+
  * Voltage Gated Ion Channels
    * Na^+
    * K^+



Types of Ion Channels Involved in Initiating Action Potential

* Voltage Gated Ion Channels
  * Na^+
    * Has two gates
      * Activation
      * Inactivation
  * K^+
    * Has one gate

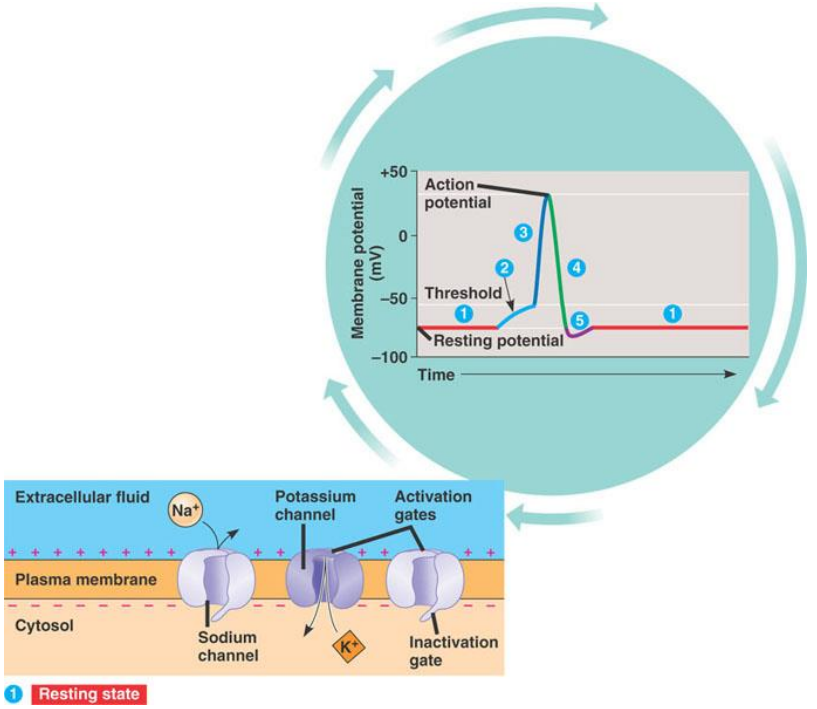


The Formation of the Action Potential at the Membrane of the Post-Synaptic Cell

Transduction
Action Potential

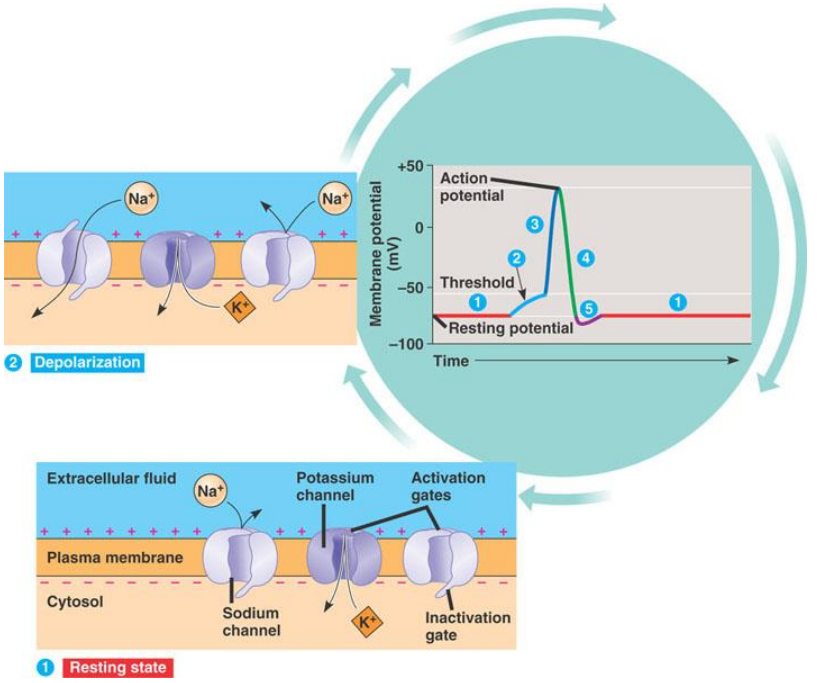
Stages of the Action Potential I Resting Potential

* Resting potential
  * Ion channels are closed
    * Na^+ channels are closed
      * Ligand gated channel is closed
      * Voltage gated channel is closed
        * Activation gate is closed
        * Inactivation gate is open
    * K^+ channels are closed
      * Remember, this is a voltage gated ion channel.



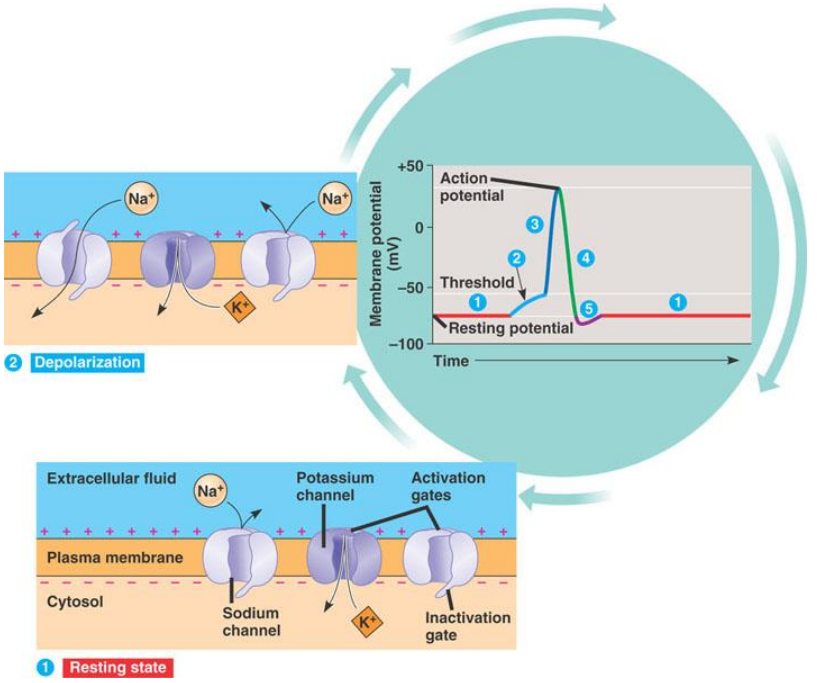
Stages of the Action Potential II Depolarization I

* Depolarization
  * Stimulus opens the activation gates of some Na^+ channels.
    * K^+ channels remain closed.
  * Results in an increase in membrane potential



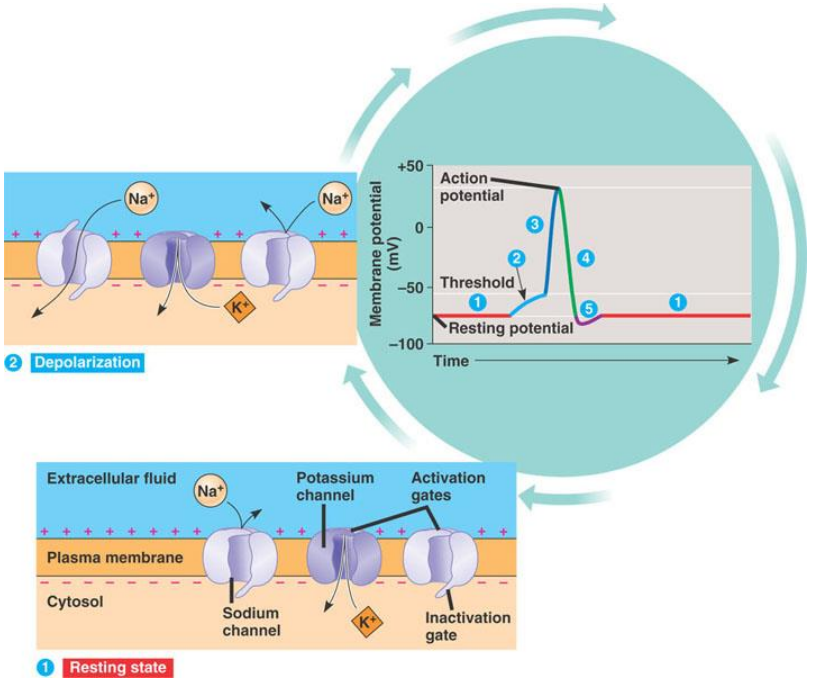
Stages of the Action Potential II Depolarization II

* Depolarization {Details}
  * Stimulus (neurotransmitter) binds onto the ligand gated ion Na^+) channel.
  * Ligand gated ion (Na^+) channel opens
  * Na^+ enters into the post-synaptic cell.
  * Electrochemical gradient changes
    * Inside the post-synaptic cell becomes more positive.
    * **Voltage changes (starts to increase)**
  * Voltage gated Na^+ channels open
    * **Activation gates open.**



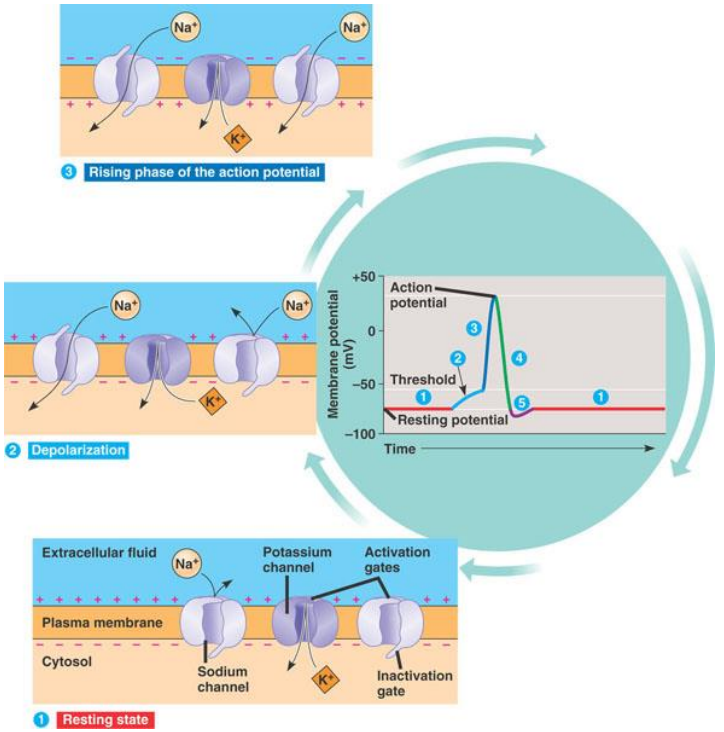
Stages of the Action Potential II Depolarization III

* Depolarization {Details}
  * Large amounts of Na^+ enter the cell.
  * **Reminder**
    * **The K^+ gates remain closed.**



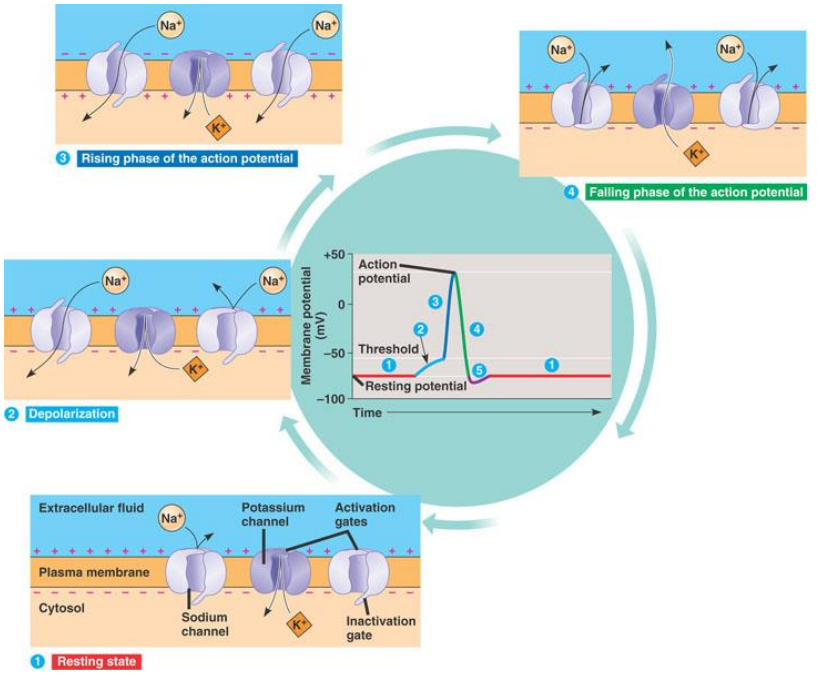
Stages of the Action Potential III
Rising Phase of Action Potential

* Rising phase of action potential.
  * Voltage increases
  * Voltage inside the cell is higher than outside.
* Threshold is reached and action potential is triggered.
* Remember
  * Na^+ channels are open.
  * K^+ channels are closed.



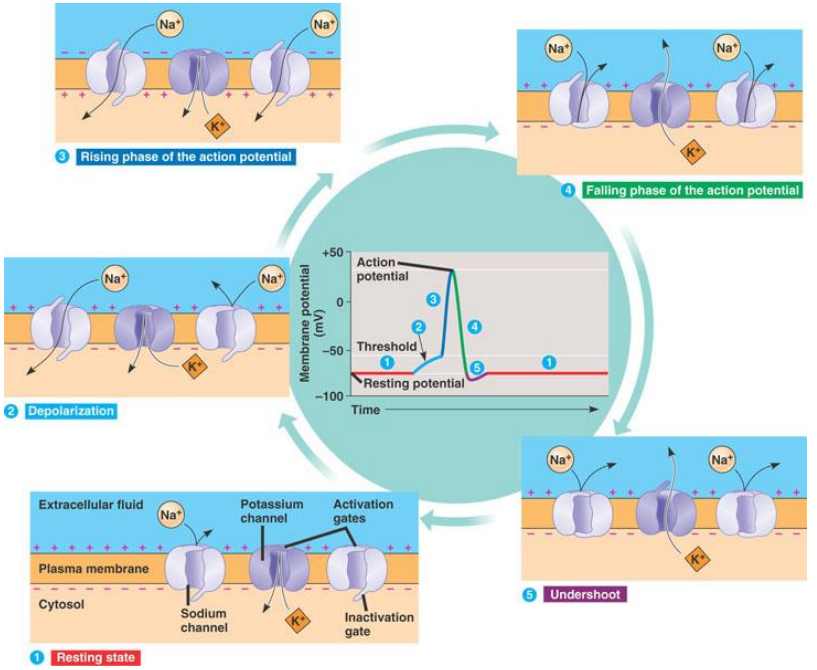
Stages of the Action Potential IV Falling Phase of Action Potential

* Falling phase of action potential.
  * Ligand leaves ligand gated ion (Na^+) channel
  * Inactivation gates on Voltage gated Ion (Na^+) channels close
    * Na^+ is blocked from entering.
  * K^+ channels open
    * K^+ leaves the cell
  * The voltage becomes more negative



Stages of the Action Potential V

* Undershoot
  * **The voltage goes below the original resting potential**
    * Aka…the K^+ gates do not close fast enough
  * Eventually, the K^+ gates close.
    * However, there is a need to get the cell back to a resting potential
  * The sodium potassium pump allows for the exchange of Na^+ and K^+ ions to return back to the resting potential.
    * However, the action potential now proceeds towards the cell body and eventually the axon.

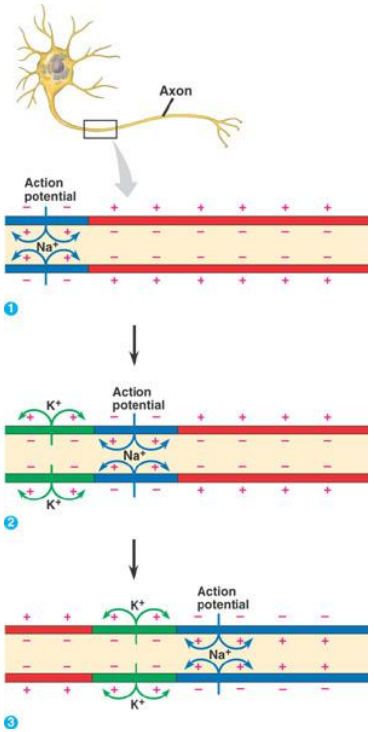


The Action Potential at the Cell Body and the Axon

Transduction
The Action Potential

Action Potential at the Axon

* The action potential conducts and moves down the axon of the nerve cell.
  * Voltage gated Na^+ and K^+ ions open and close as the message moves along the axon.
* The movement is sped up by the presence of the Myelin sheath
  * Myelin sheath is produced by Schwann cells
    * Saltatory conduction.
* **STUDENTS MUST VIEW ANIMATION ONLINE.**



Review