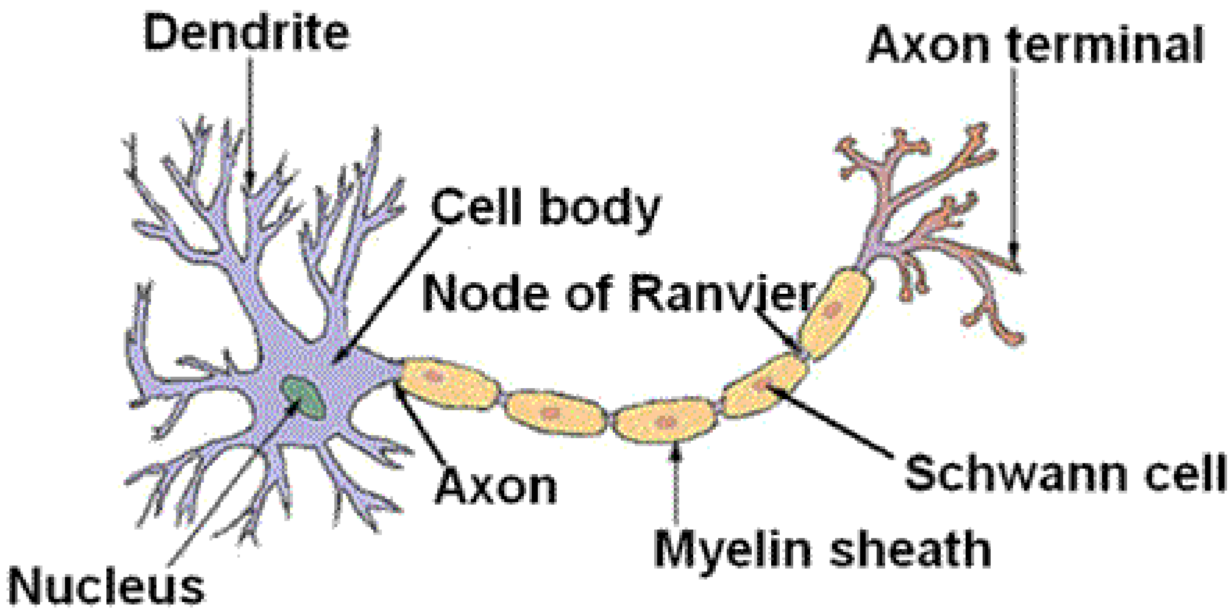
Section 8.2: Structure and Processes of the NS

SBI4UP

MRS. FRANKLIN

Neuron Structure



Dendrite:

Axon:

Node of Ranvier:

Myelin Sheath:

Axon Terminal:

Schwan Cell:

Neuron Structure

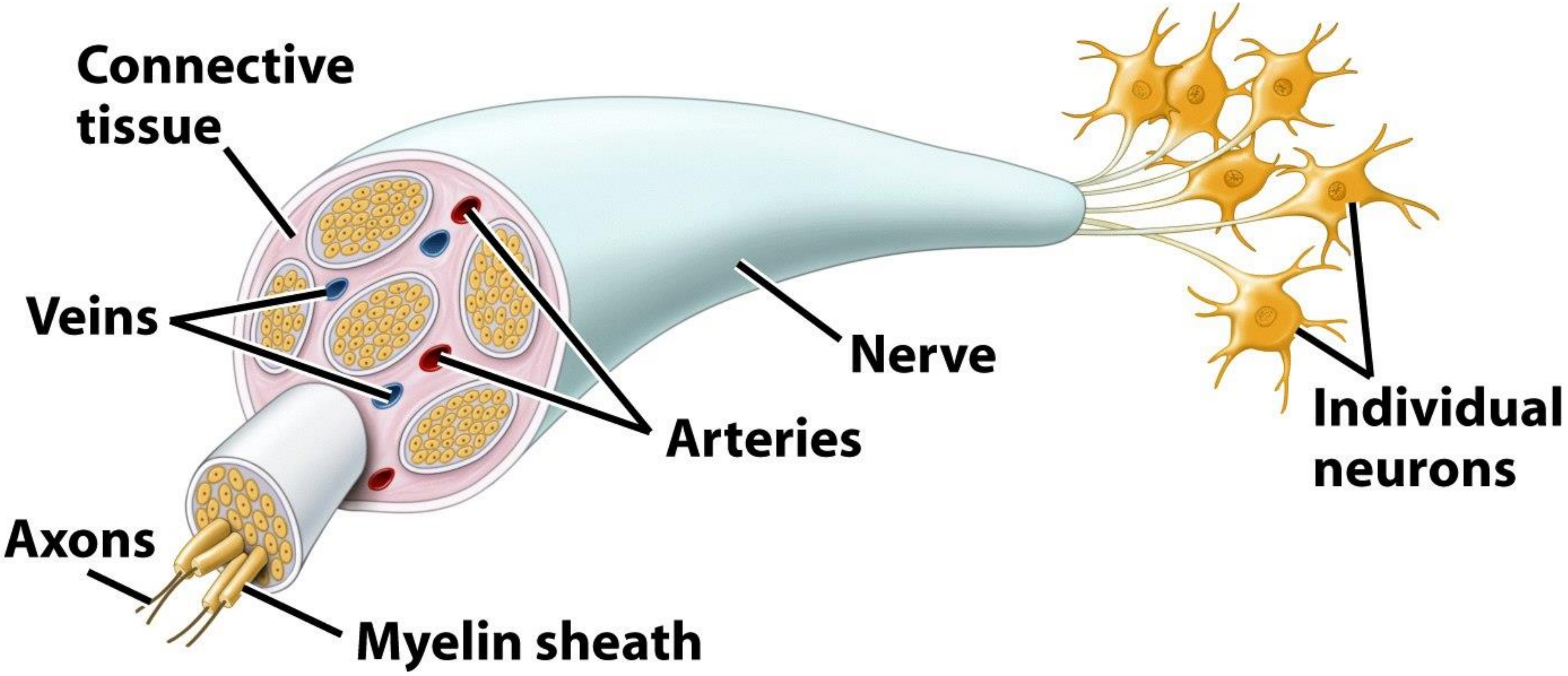


Figure 25-1b Discover Biology 3/e

Types of Neurons

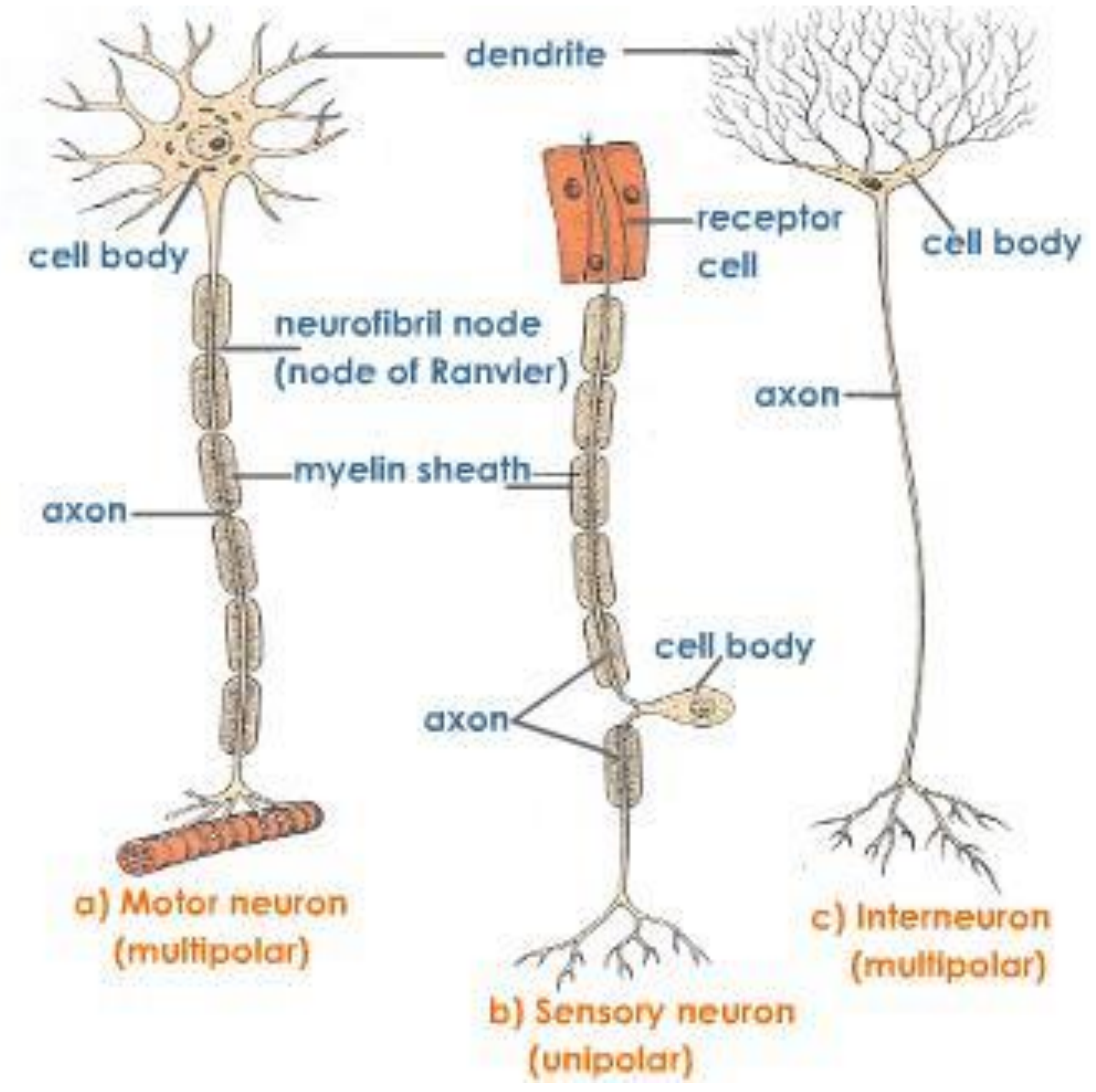
Glial Cells:

Sensory neurons:

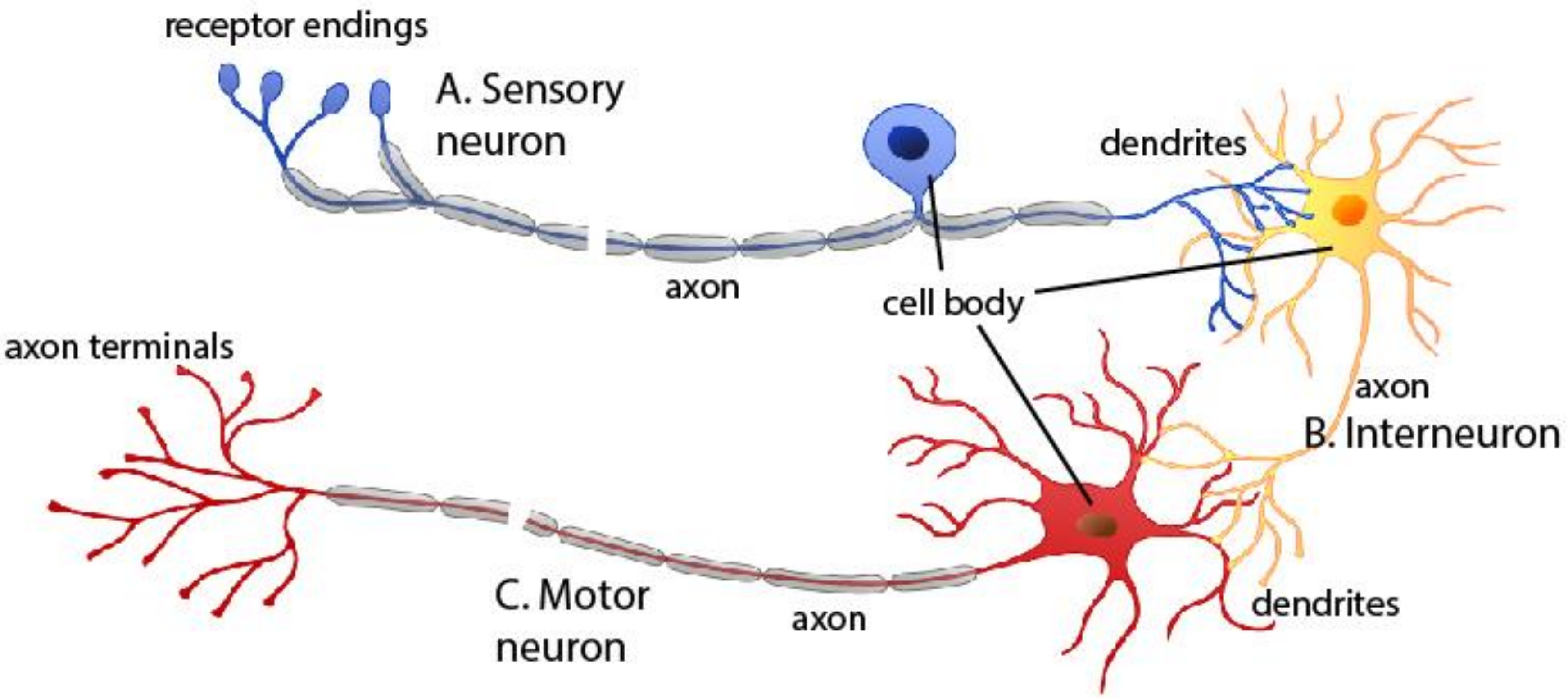
Motor neurons:

Types of Neurons

All three types of neurons are connected to one another to ensure that the signal is transmitted to and from the Central Nervous System.

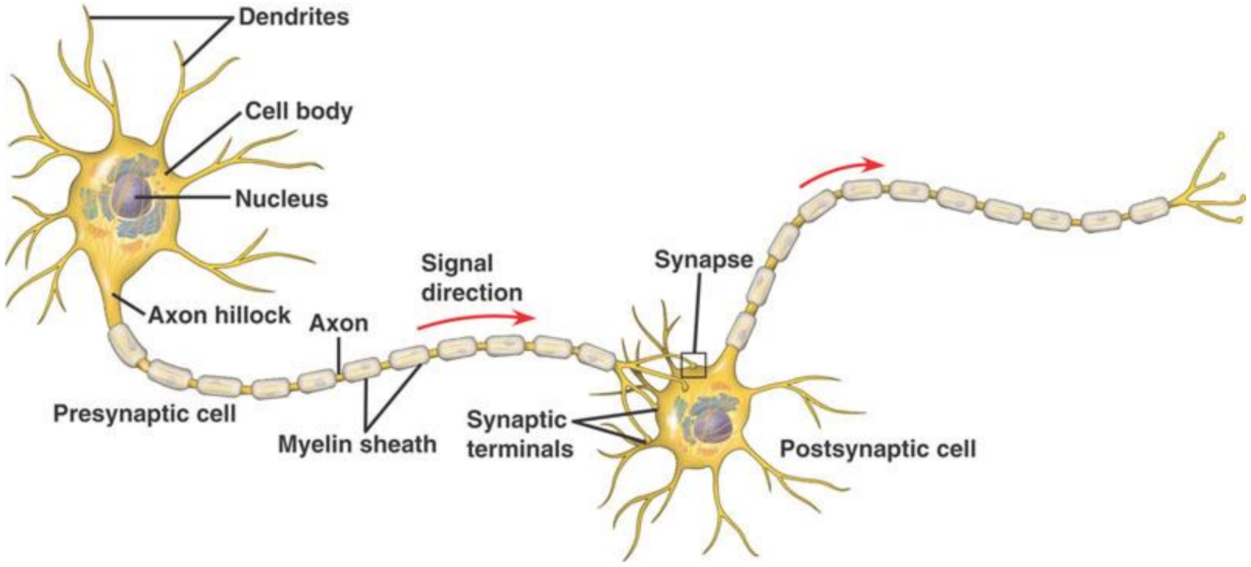


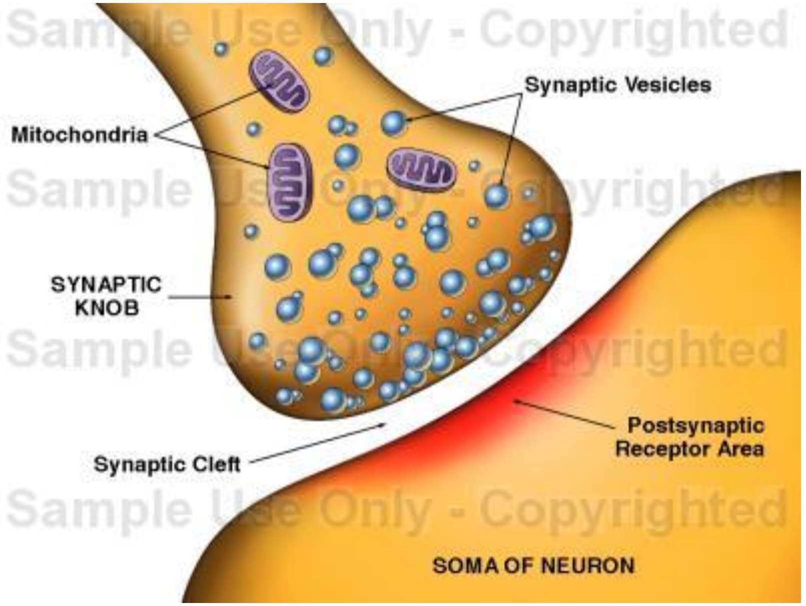
Types of Neurons



Synaptic Transmission

Nerve cells are not able to transmit the electrical signal directly from one neuron to the next. When the action potential reaches the ends of the terminal buds, there is a gap between that neuron and the dendrites of the new neuron. This gap is known as the ***'Synaptic Cleft'.***





Synapse: *Connection between two neurons (terminal buds of one and the dendrites of the other)*

Transmitting Signals in the Nervous System (NS)

When scientists places an electrode within the nerve cell of a squid and it was fired a large potential difference was detected. Without the excitation, the resting potential was -70 mV. When the nerve was excited it reached + 40 mV.

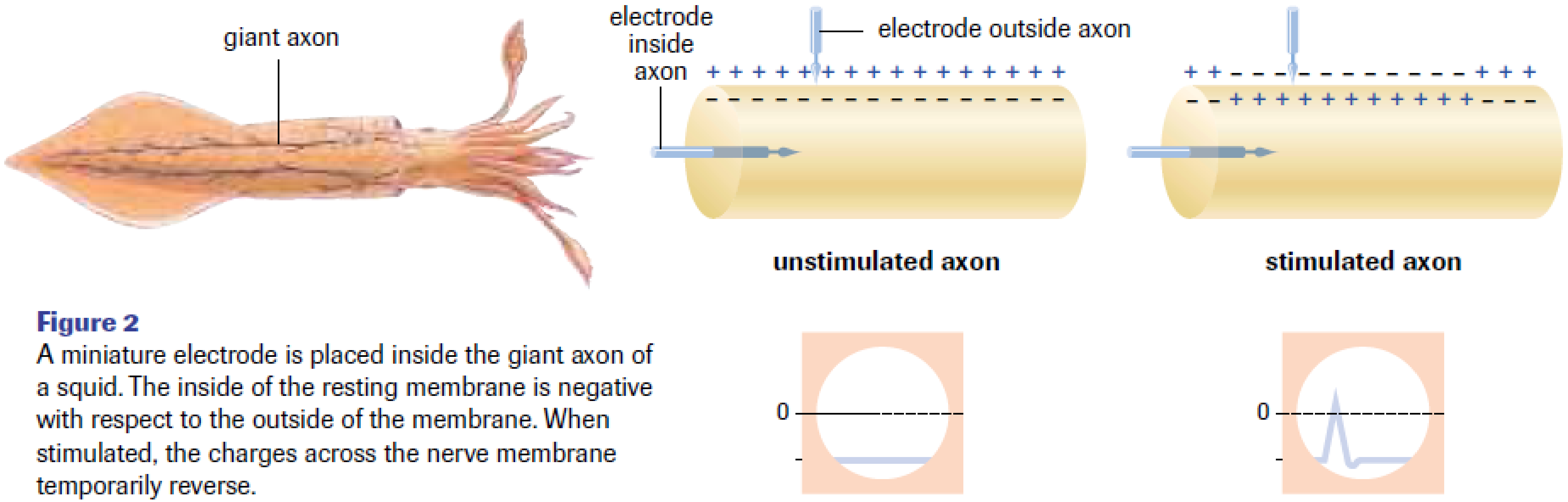
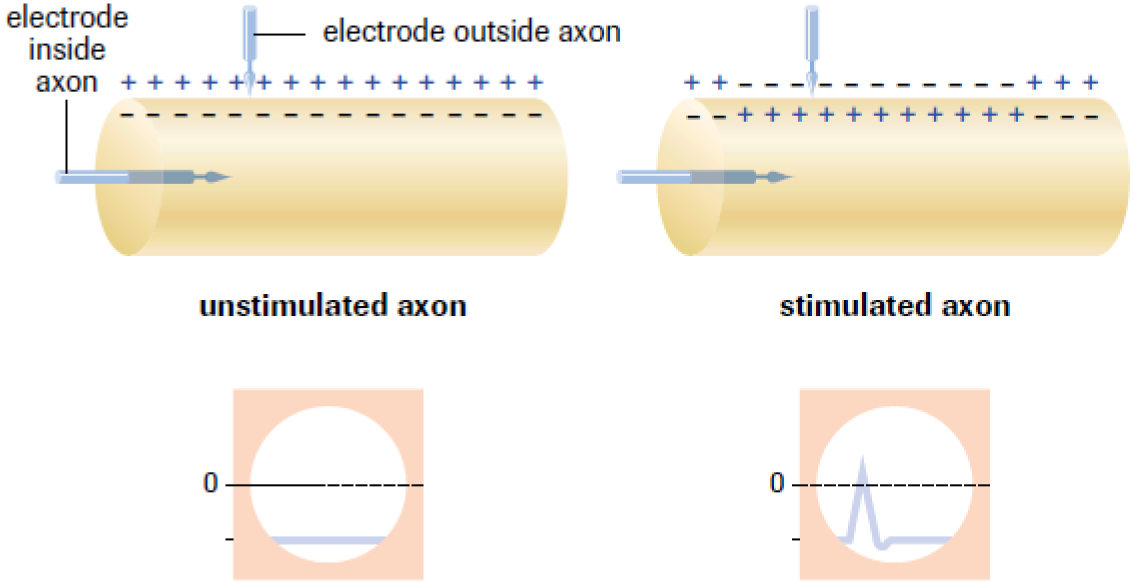


Figure 2
A miniature electrode is placed inside the giant axon of a squid. The inside of the resting membrane is negative with respect to the outside of the membrane. When stimulated, the charges across the nerve membrane temporarily reverse.

Transmitting Signals in the NS



*When the resting potential is -70 mV, this indicates that the inside of the cell is negatively charged in comparison to the outside of the cell. This charge I known as the **'Resting Potential'.***

When the potential changes from a negative to a positive state it is known as an 'Action Potential'

Transmitting Signals in the NS

There are 3 main reasons why most nerves cells tend to be negatively charged at ***'Resting Potential'***:

1) Large negative charged proteins that cannot cross the membrane and remain within the cell.

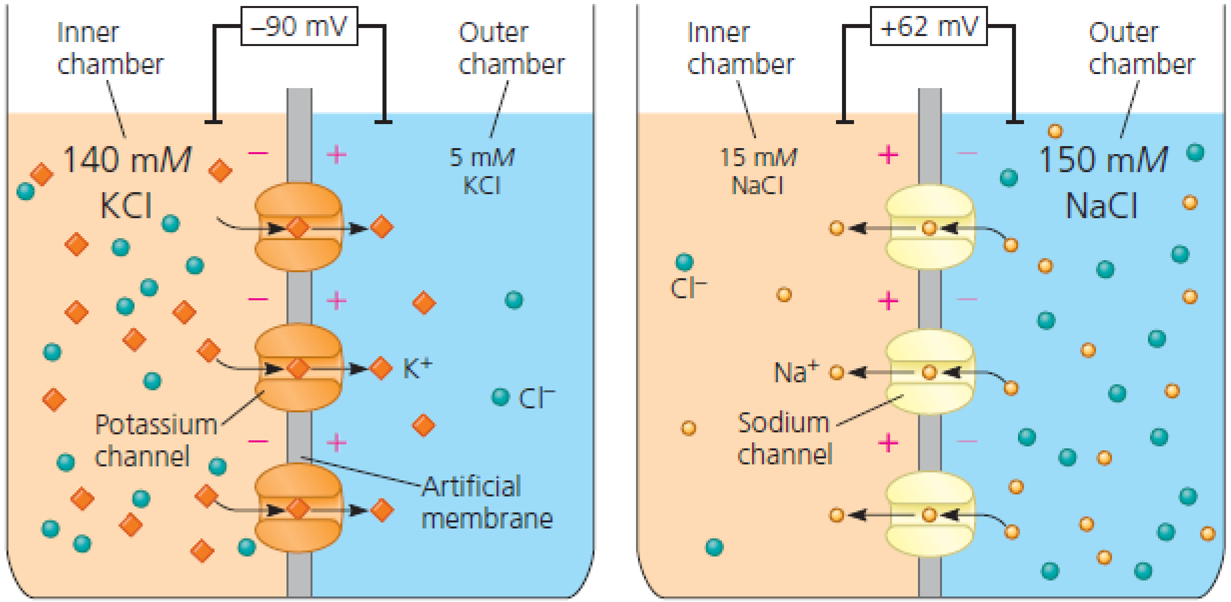
2) Ion-specific channels that are specific to the movement of potassium and sodium which are responsible for the production of an Action Potential

3) Sodium-potassium pumps which are responsible for maintaining the resting potential of the nerve cell.

Transmitting Signals in the NS

1) Large negatively charged proteins that cannot cross the membrane and remain within the cell.

There is a large concentration of negatively charged amino acids that make up certain proteins. These have a larger effect on the overall charge inside the cell. Thus creating a negative resting potential.



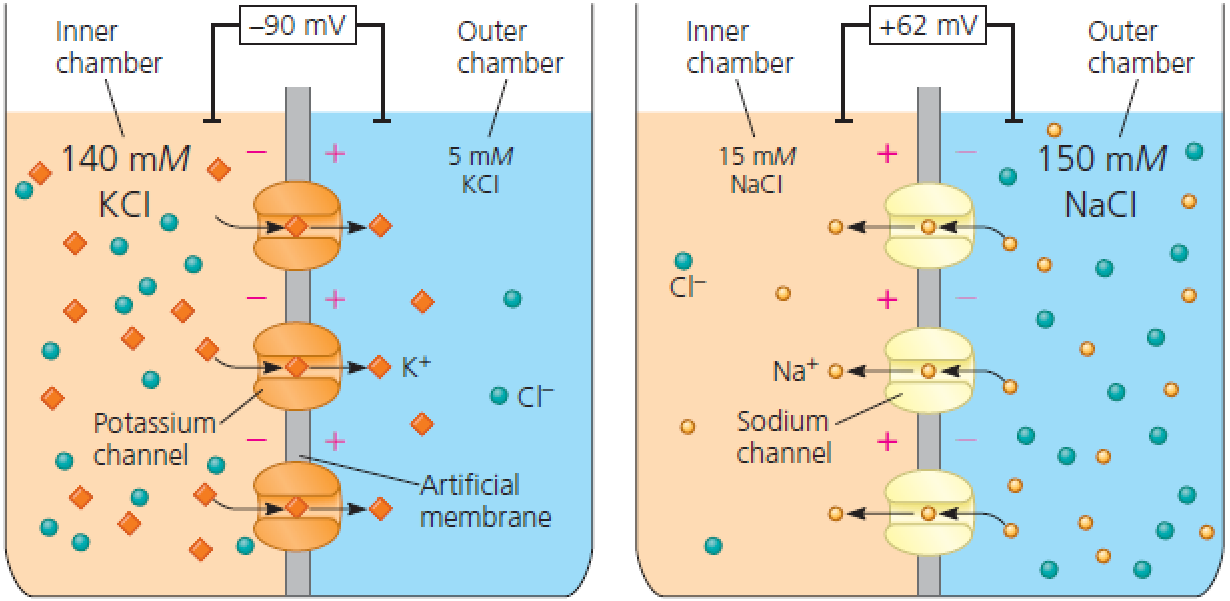
(a) Membrane selectively permeable to K^+ (b) Membrane selectively permeable to Na^+

Transmitting Signals in the NS

2) Ion-specific channels that are specific to the movement of potassium and sodium which are responsible for the production of an action potential.

a) The cell is impermeable to Cl- but permeable to K+. The movement of K+ across the cell creates a negatively charged environment.

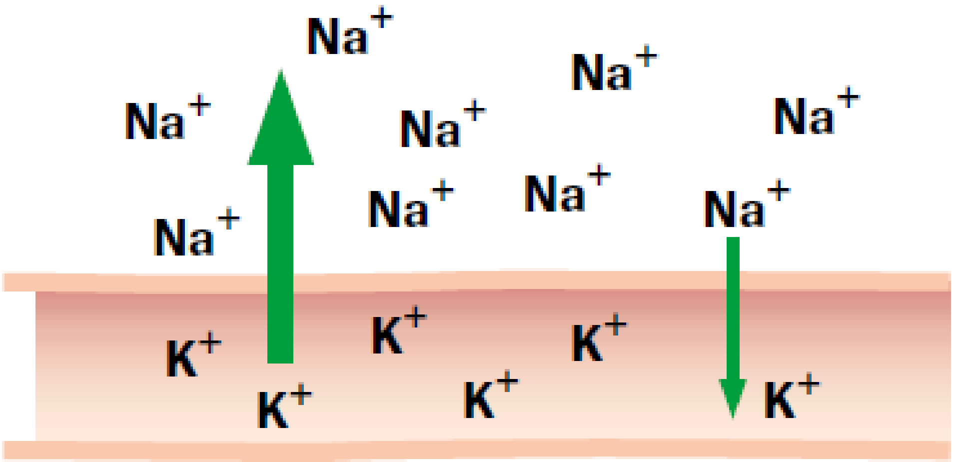
b) The cell is now permeable to Na+ and not K+. The movement of Na+ into the cell creates a positive environment within the cell.



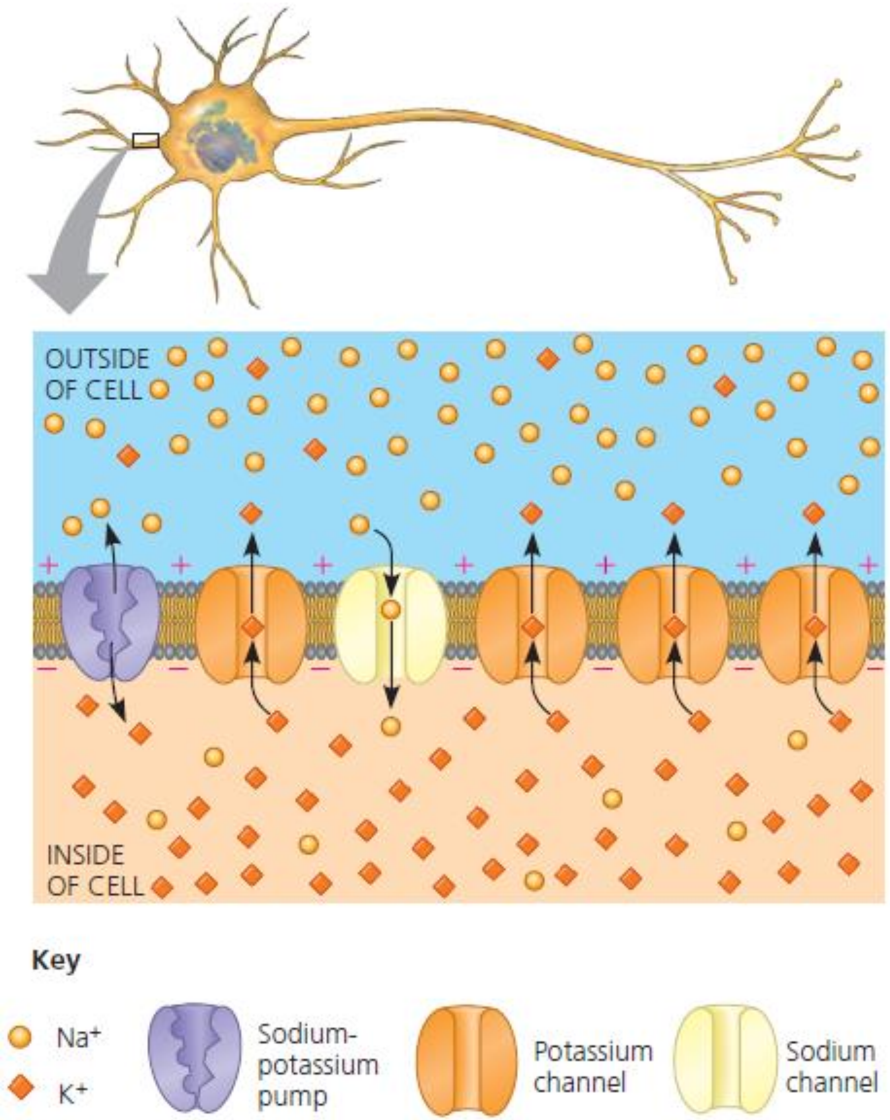
(a) Membrane selectively permeable to K^+ (b) Membrane selectively permeable to Na^+

Transmitting Signals in the NS

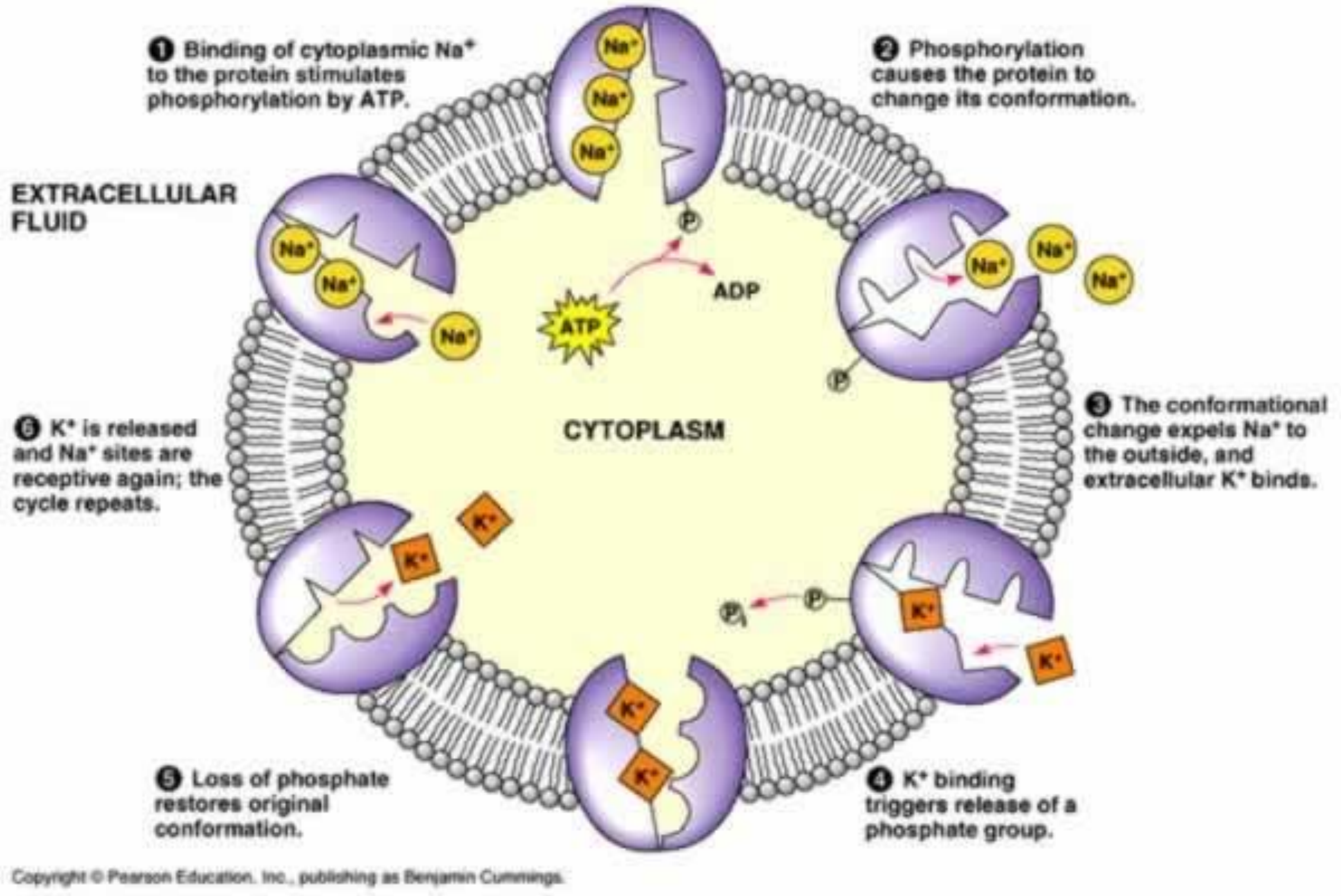
3) Sodium-potassium pumps which are responsible for maintaining the resting potential of the nerve cell.

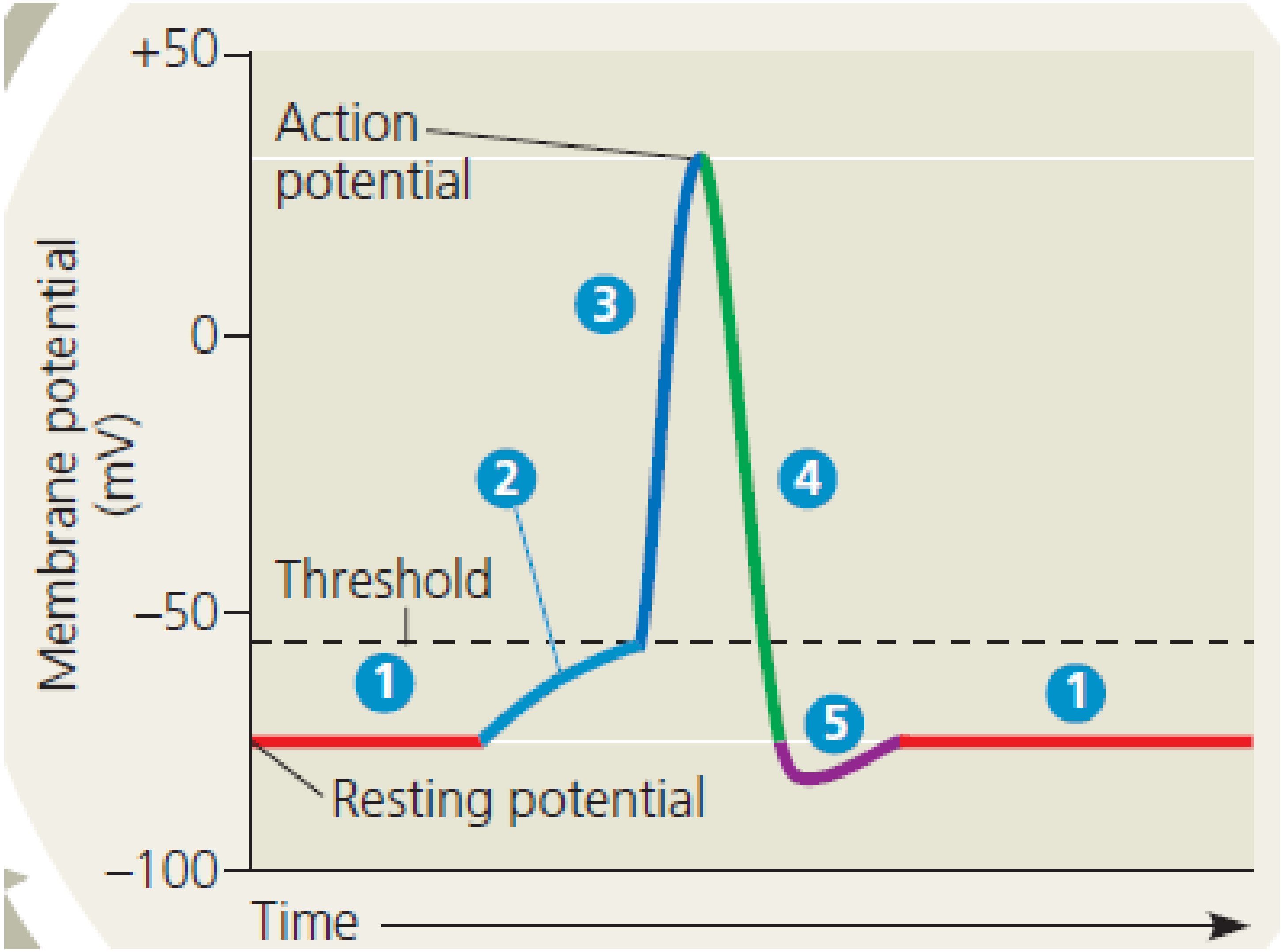


Potassium diffuses out of the nerve cell faster than sodium diffuses into the nerve cell.

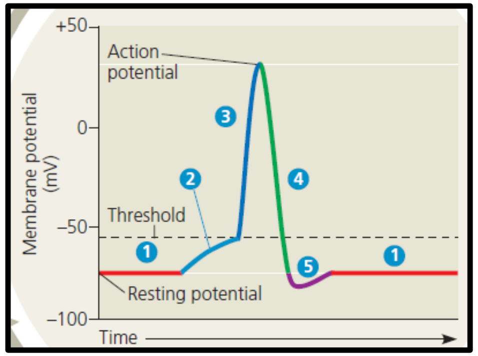


Remember . . . Na+-K+ pump



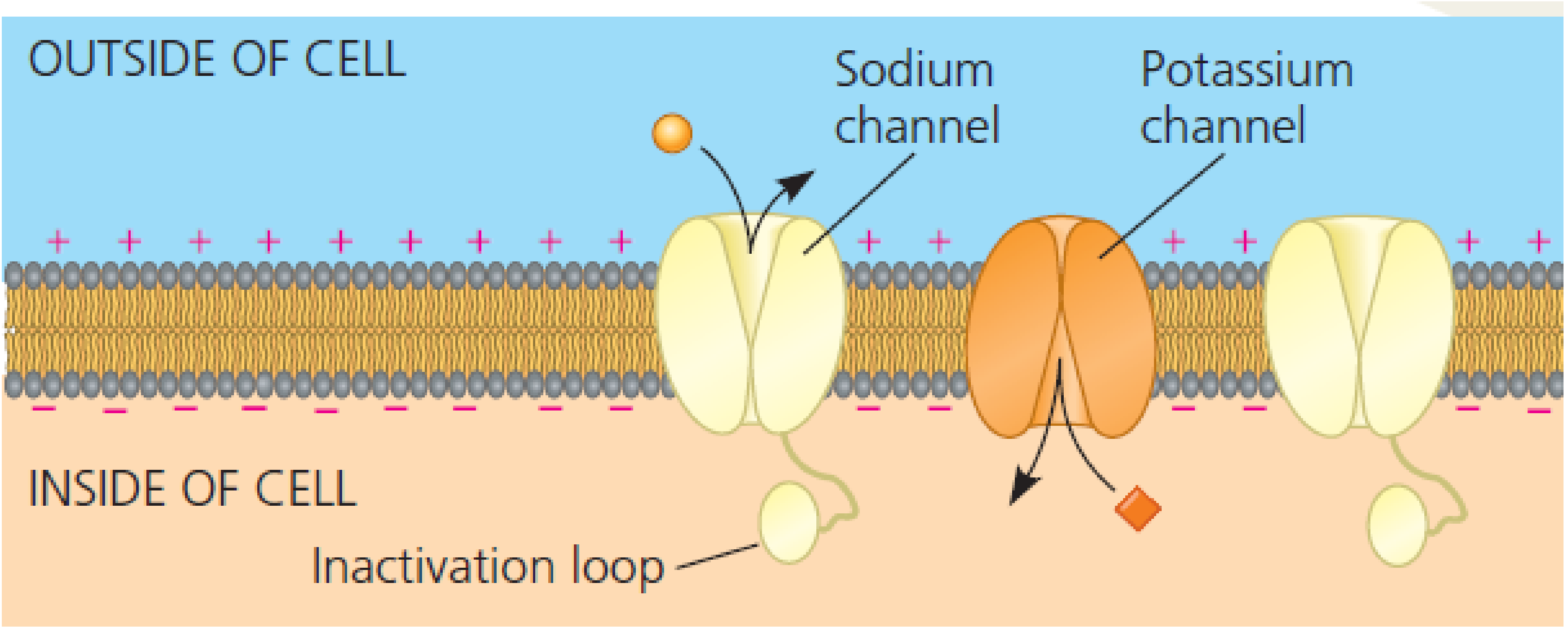


+50
0
−50
−100
Membrane potential (mV)
Action potential
Threshold
Resting potential
1
2
3
4
5
1
Time



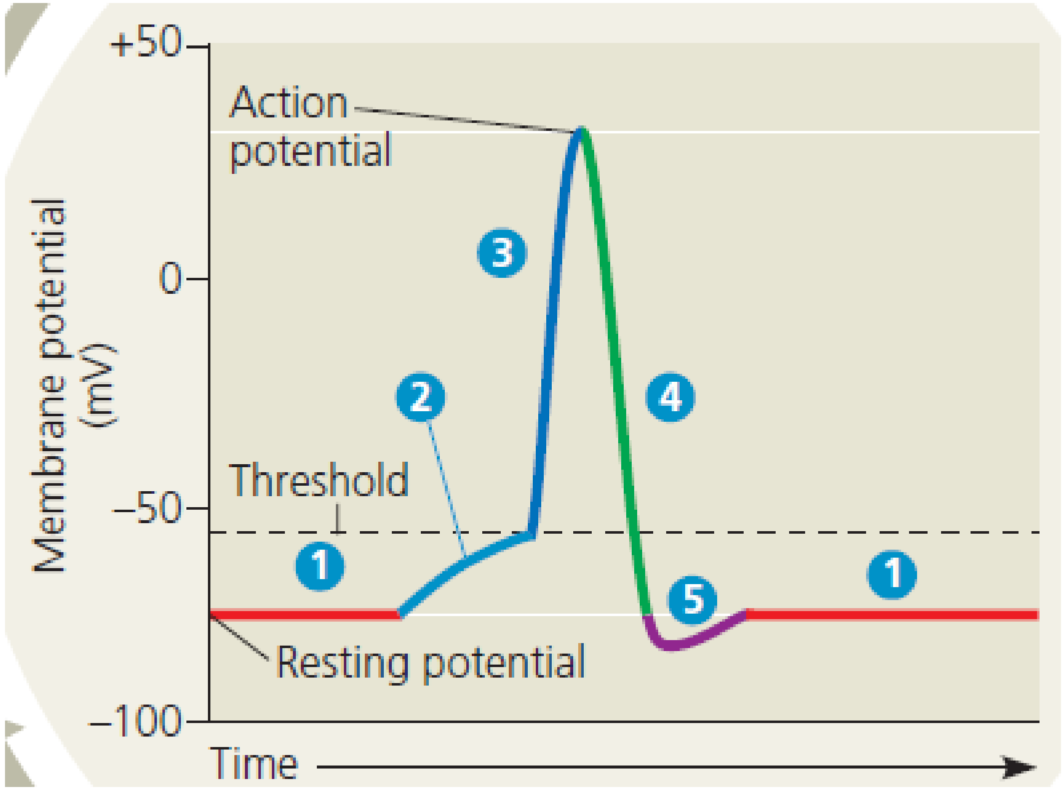
Step 1: Resting Potential (No Stimulus)

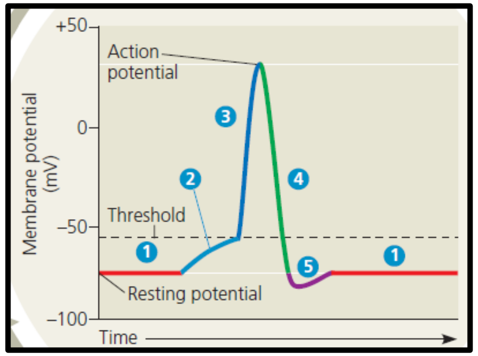
Both the K+ and the Na+ channels are closed. It is only the Na+/K+ pump that is maintaining the -70 mV within the nerve cell.



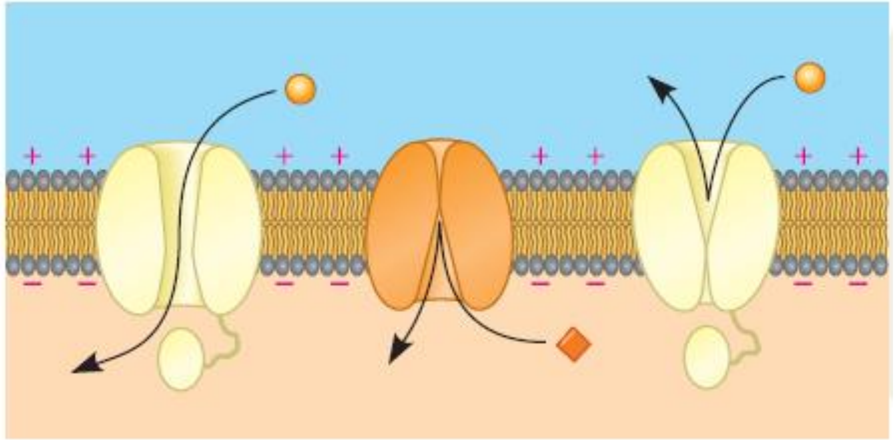
Step 1: Resting Potential (No Stimulus)

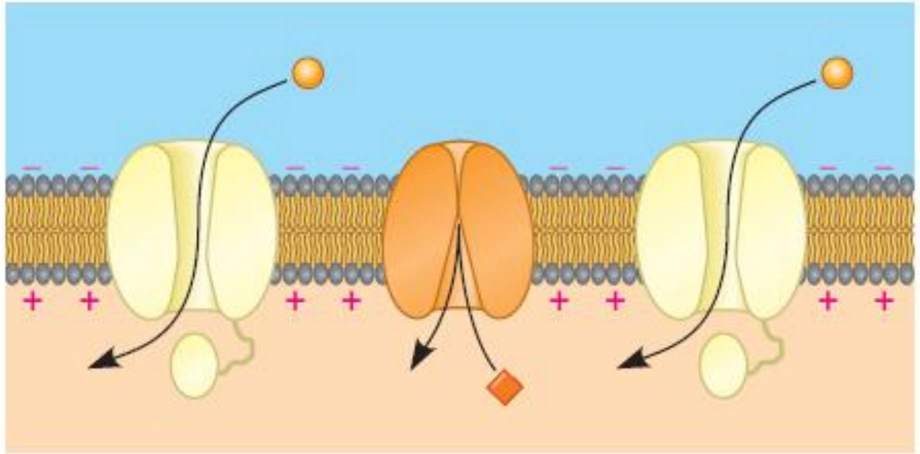
Due to the negatively charged proteins inside the nerve cell, the Na+/K+ pumps and the closing of K+ and Na+ channels the resting potential is maintained at -70 mV.





Step 2 & 3: Depolarization





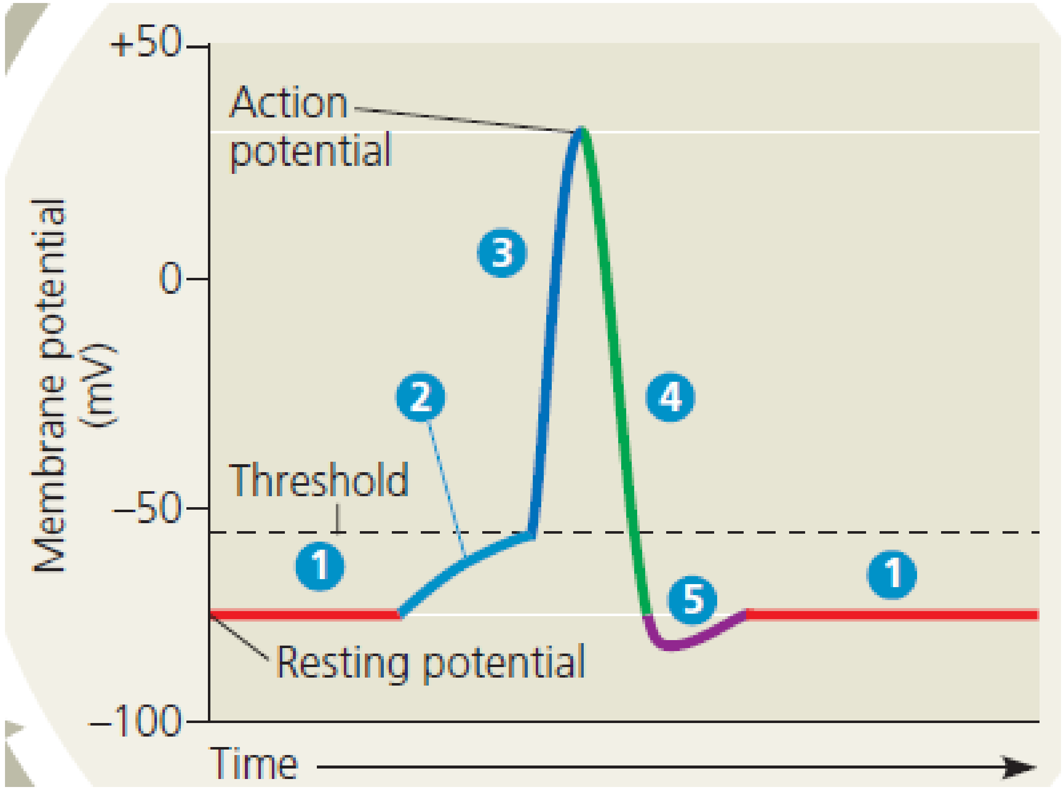
In response to a stimulus, a few Na+ channels are activated and the charge becomes more positive inside the cell.

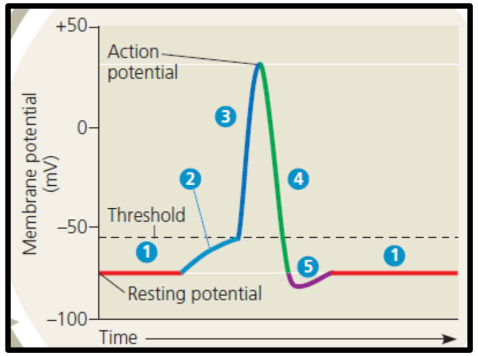
Only once it reaches a threshold do the rest of the Na+ Channels open.

Step 2 & 3: Depolarization

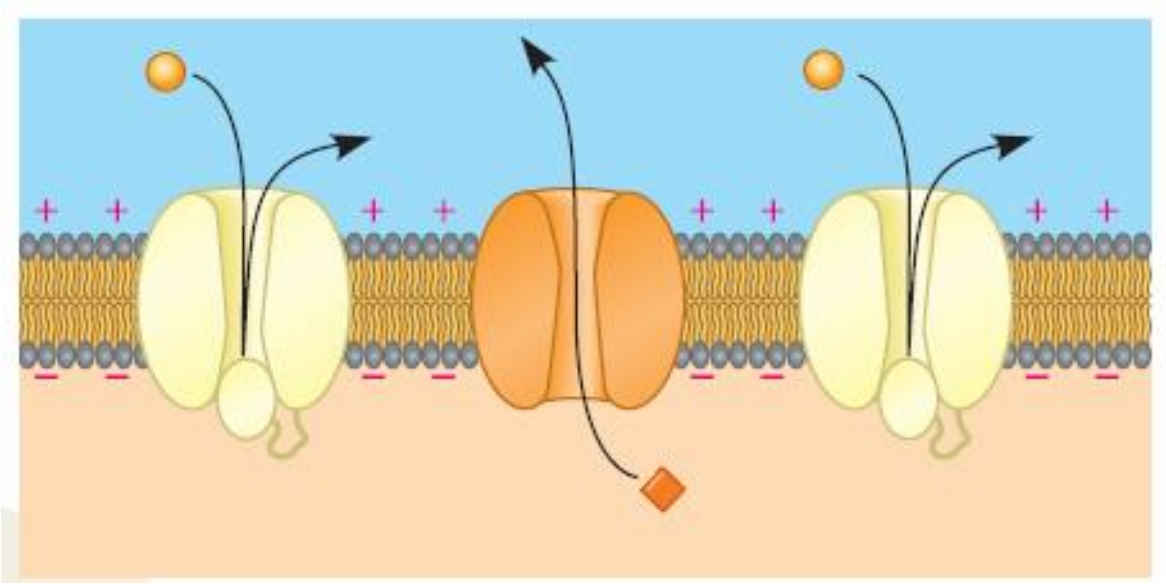
Once the cell reaches threshold, the voltage-gated Na+ channels open and a large influx of Na+ rushes into the cell.

The charge within the nerve cell's potential quickly rises to a + 40 mV.





Step 4: Hyperpolarization

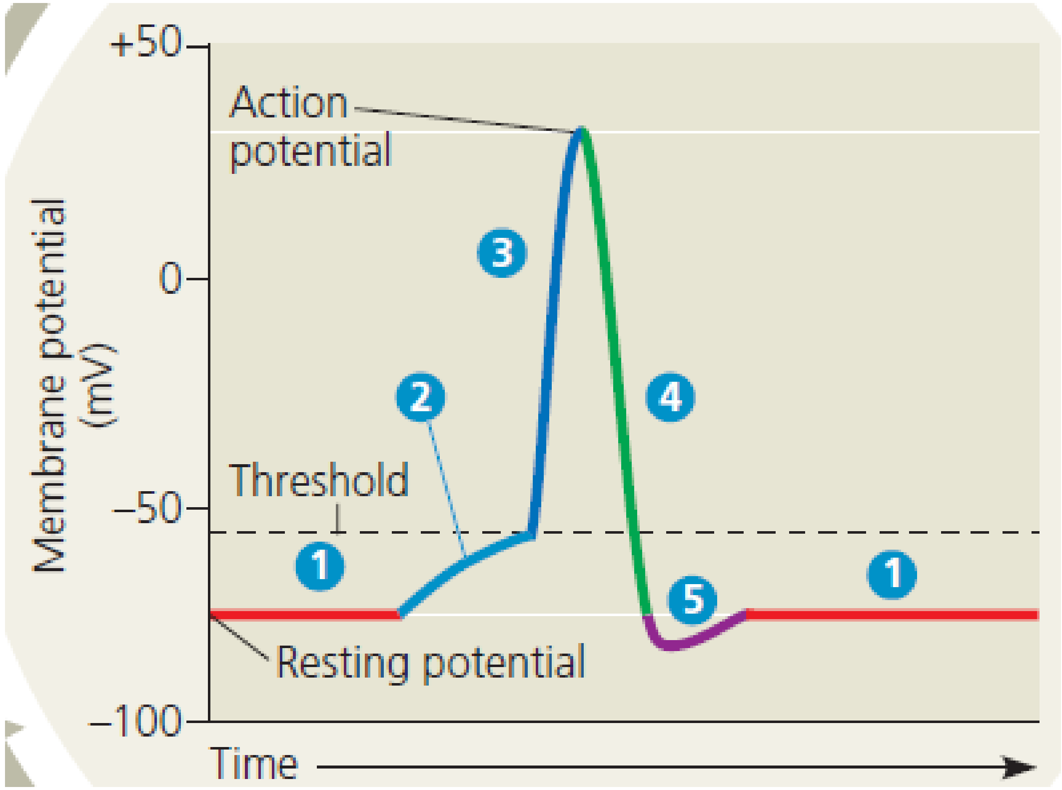


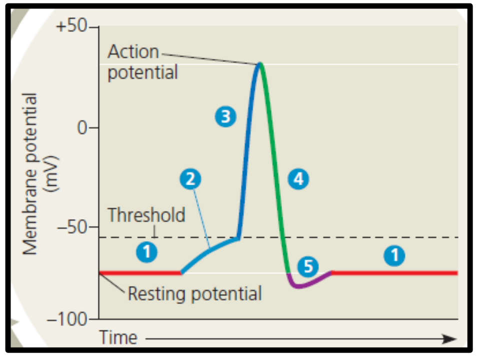
When the nerve cell reaches its maximum voltage of +40 mV (this may vary depending on the nerve cell), the Na+ channels close.

The voltage-gated K+ channels open. This causes a large efflux of K+ out of the cell and the voltage will fall below the Resting Potential of -70 mV.

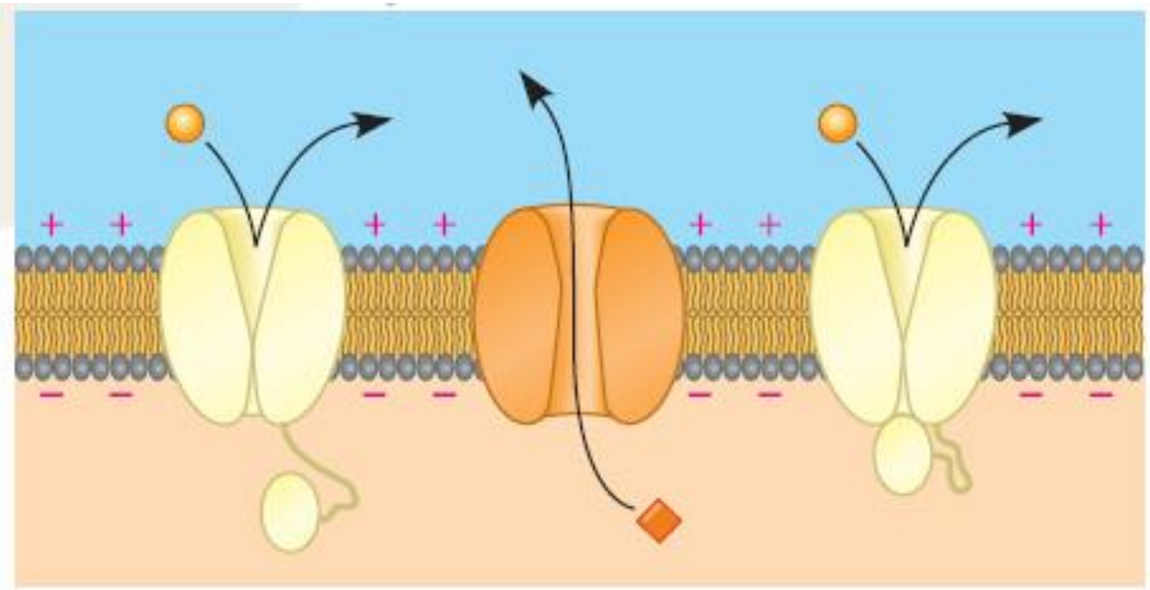
Step 4: Hyperpolarization

Due to the closing of the Na+ channels and the opening of the K+ channels, this causes a large concentration of K+ ions to exit the nerve cell, thus leading to hyperpolarization.





Step 5: Repolarization

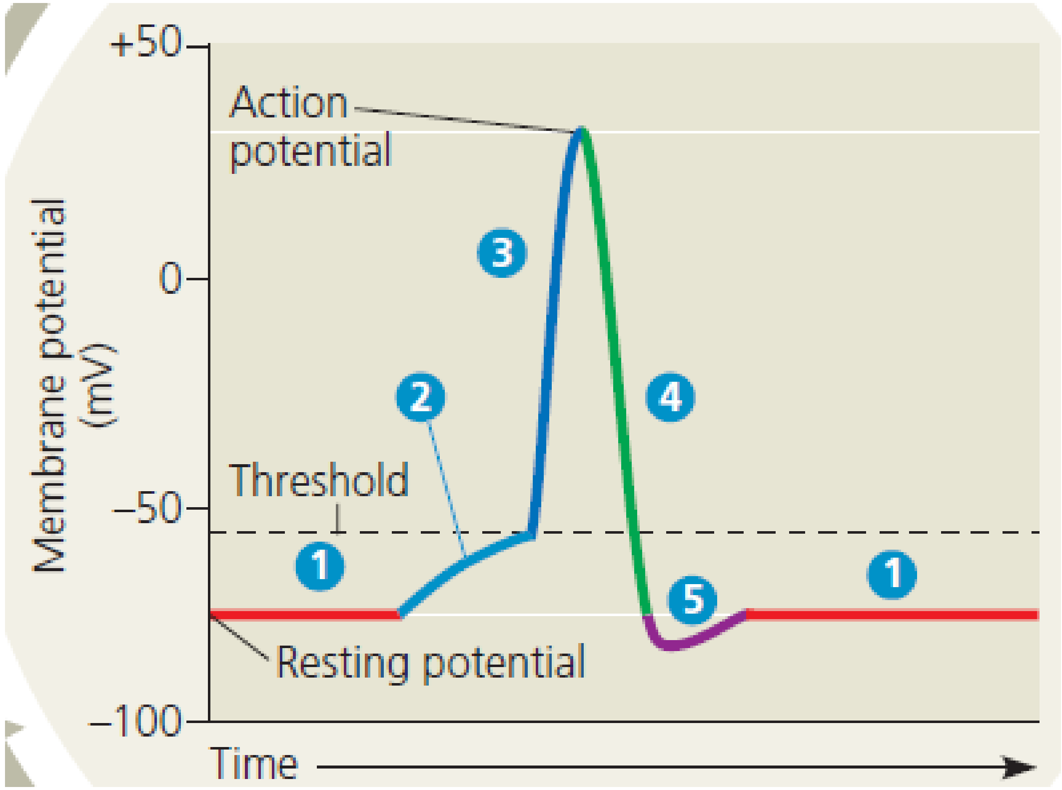


All other channels in the cell close. Only the Na+/K+ pump is working to repolarize the nerve cell to its resting potential.

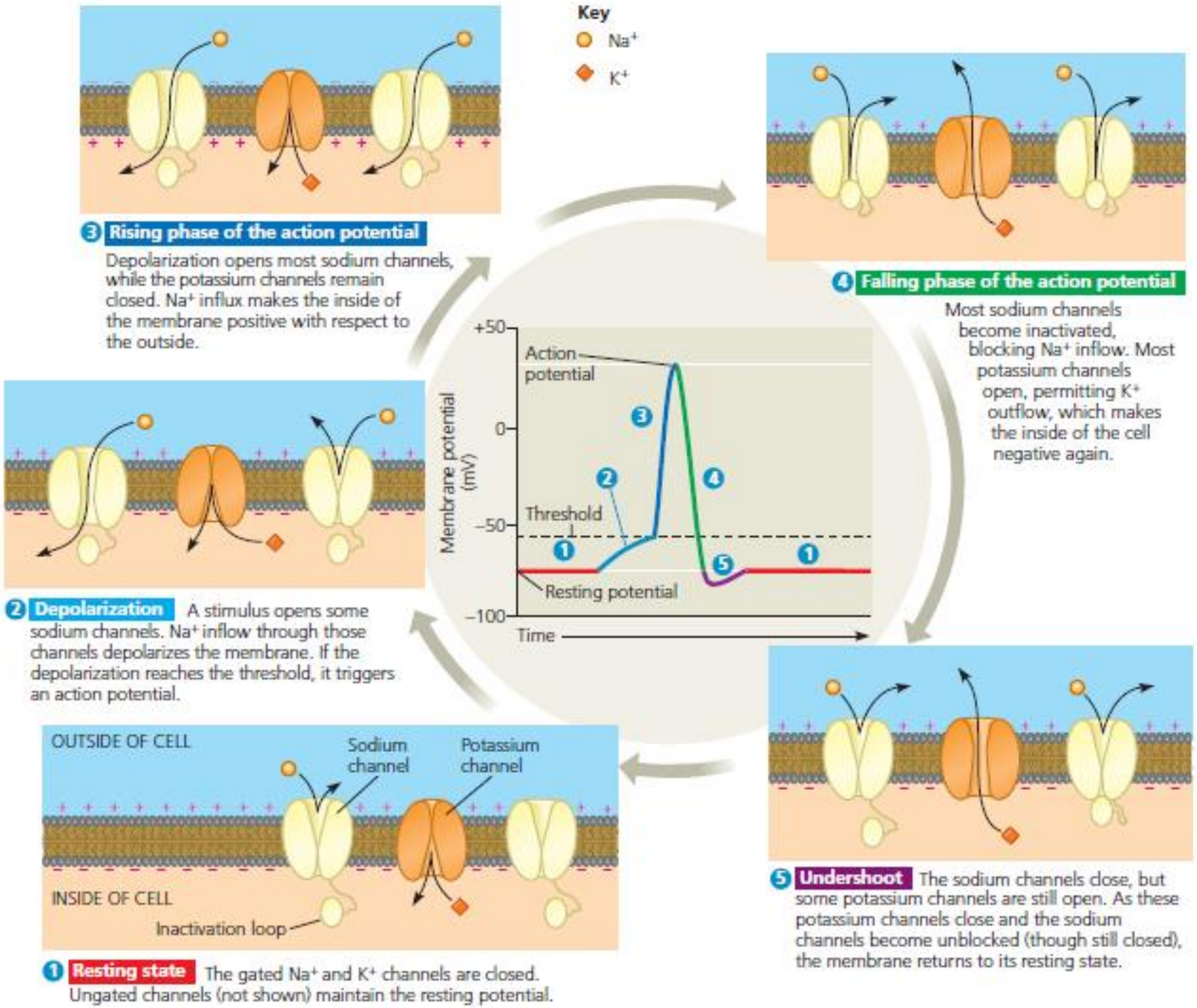
Step 5: Repolarization

Due to the Na+/K+ pump, the voltage within the nerve cell can be brought back to resting potential. Once back to its original state, the cell must go into a 'Refractory Period'.

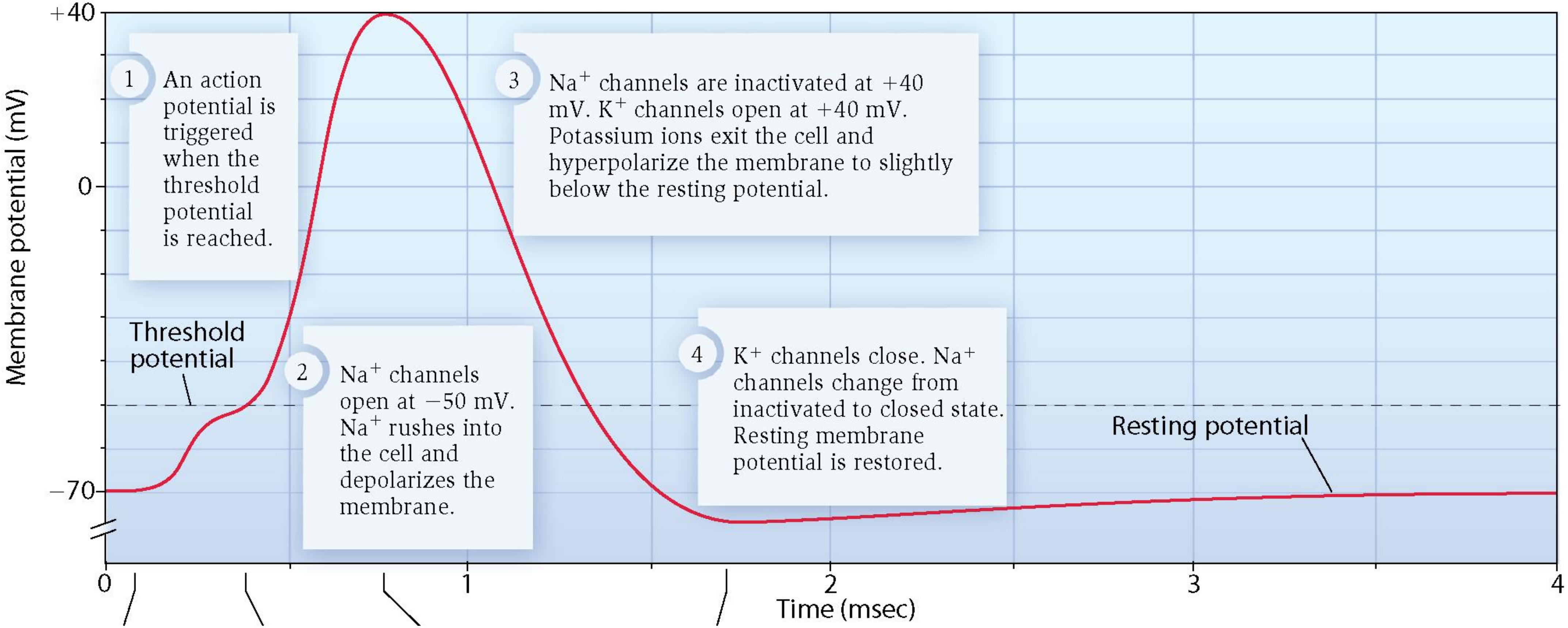
<u>Refractory period:</u> *state in which the axon cannot initiate another action potential for a brief period of time.*



Summary of the Nerve Stimulus

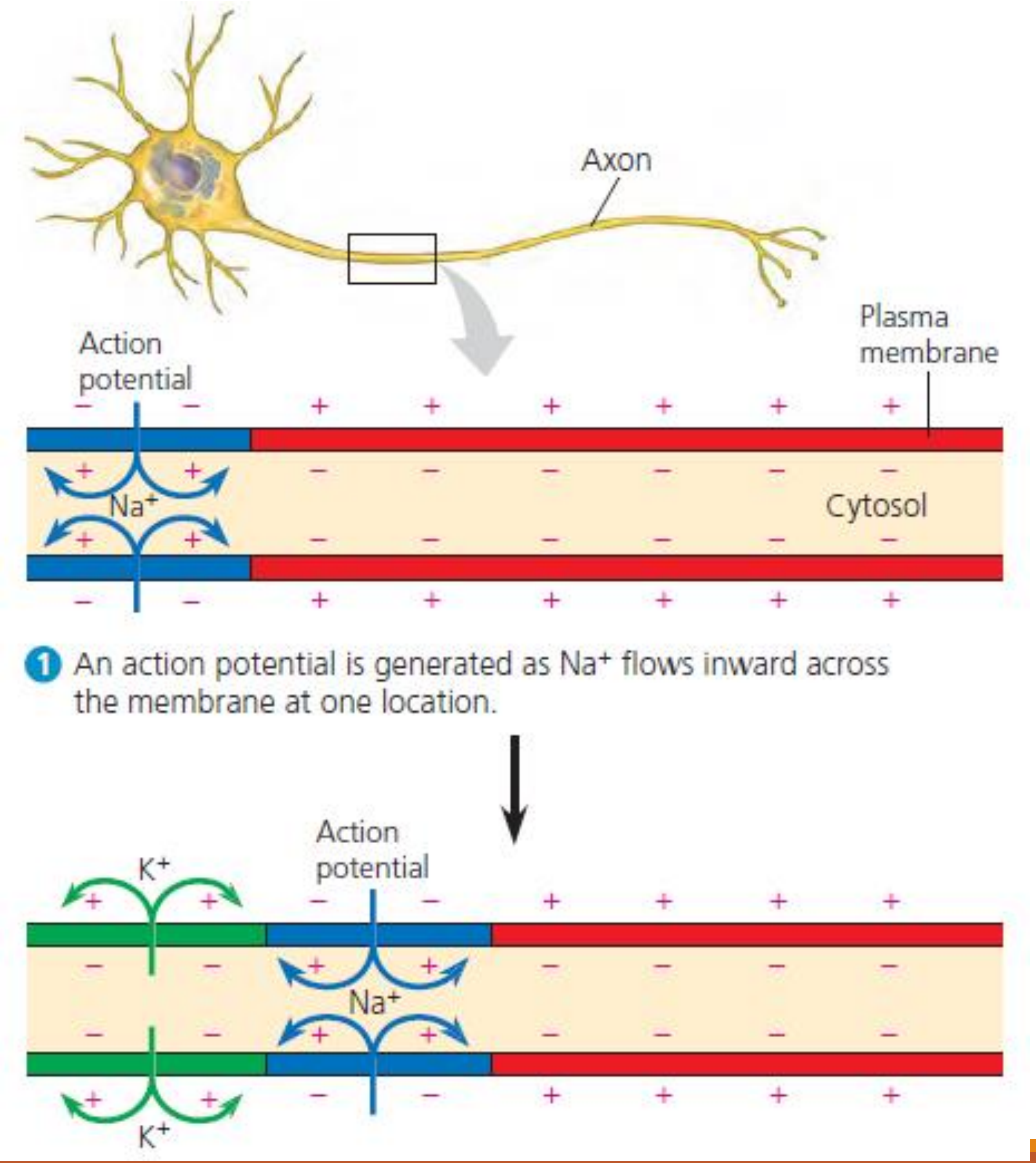


Nerve Impulse Summary

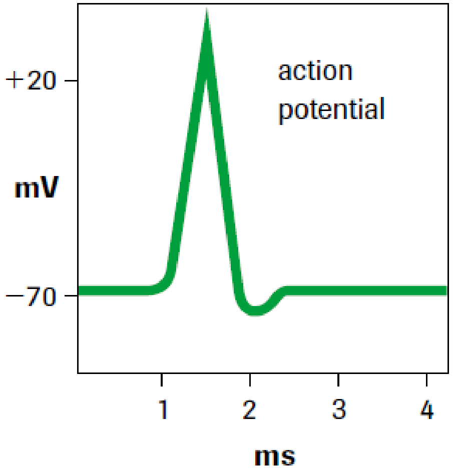


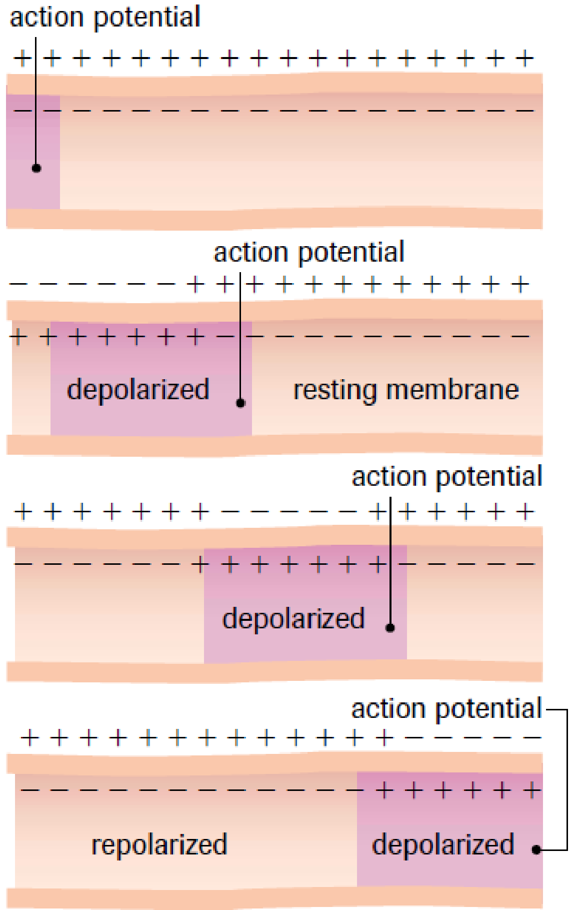
Movement of the Action Potential

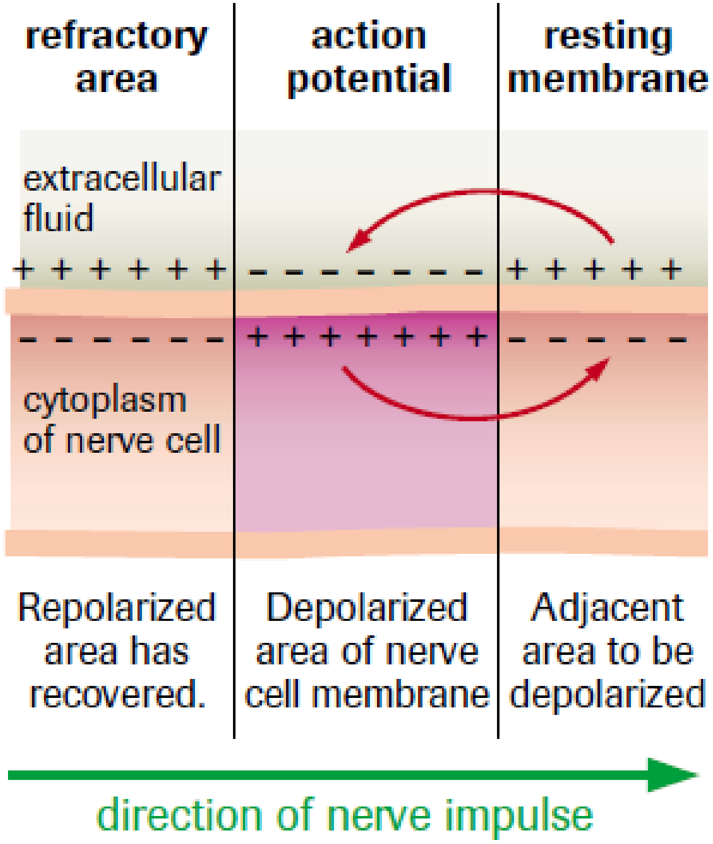
When there is an influx of positive charge into the cell due to the opening of Na+ channels, all of the positive charge is attracted to the adjacent negative charge. This causes the next area of the axon to be depolarized.



Movement of the Action Potential

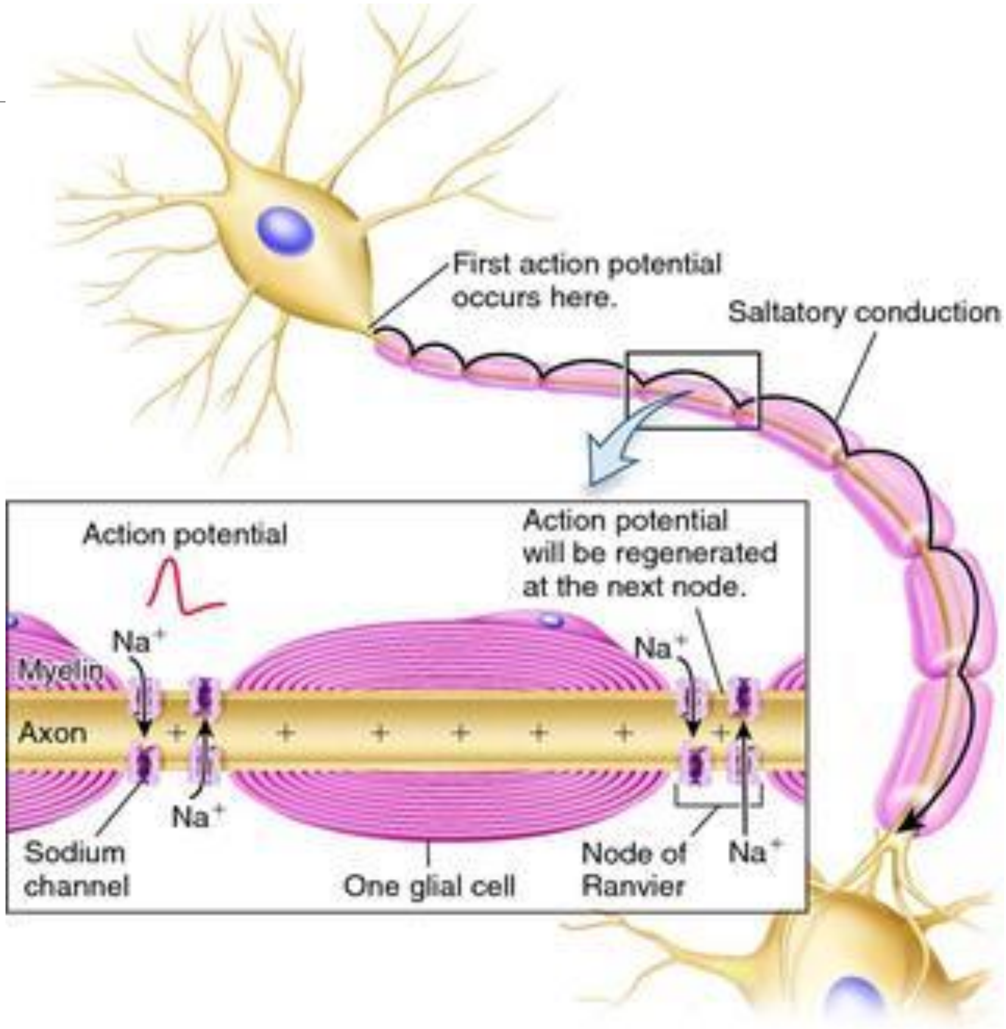






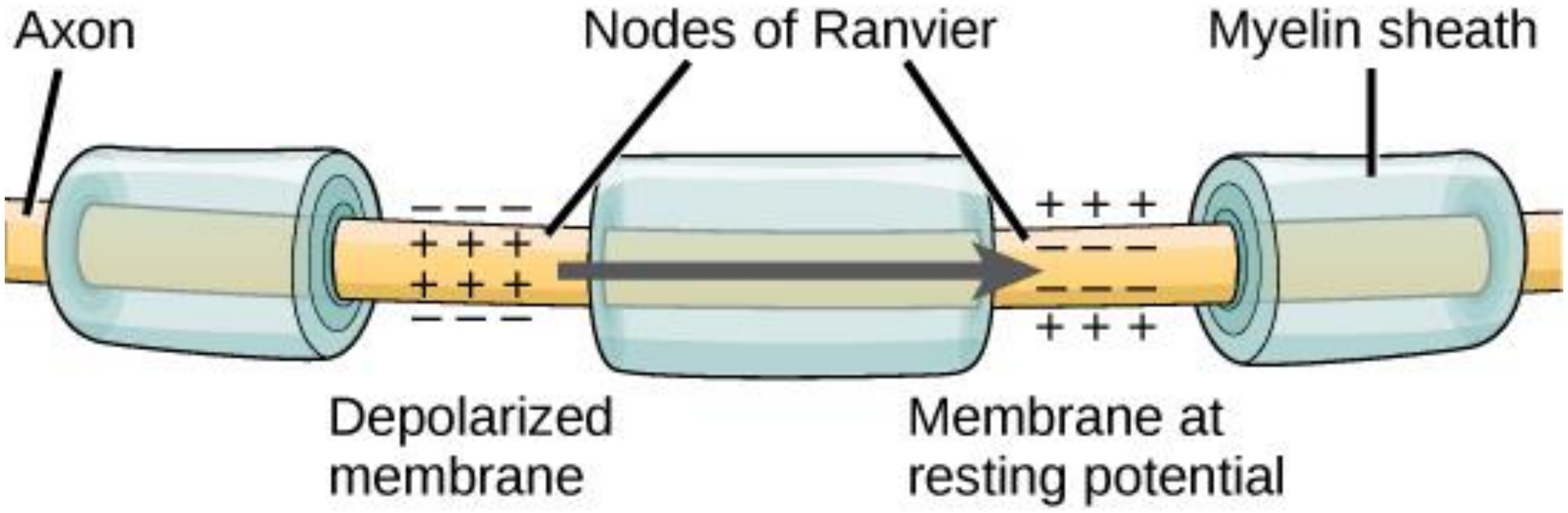
Myelinated Nerve Impulse

Nerve cells that contain myelin rely on the depolarization at the Nodes of Ranvier. When depolarization occurs, the myelin is able to insulate the charge and propagate until it reaches the next Node of Ranvier.



Myelinated Nerve Impulse

When the positive charge of the Na+ ions travels across the myelin sheath and reaches the Node of Ranvier, this causes the Node to reach a threshold. Thus stimulating the opening of all the Na+ channels in that area, creating another action potential that can be propagated across to the next myelin towards the following Node of Ranvier.

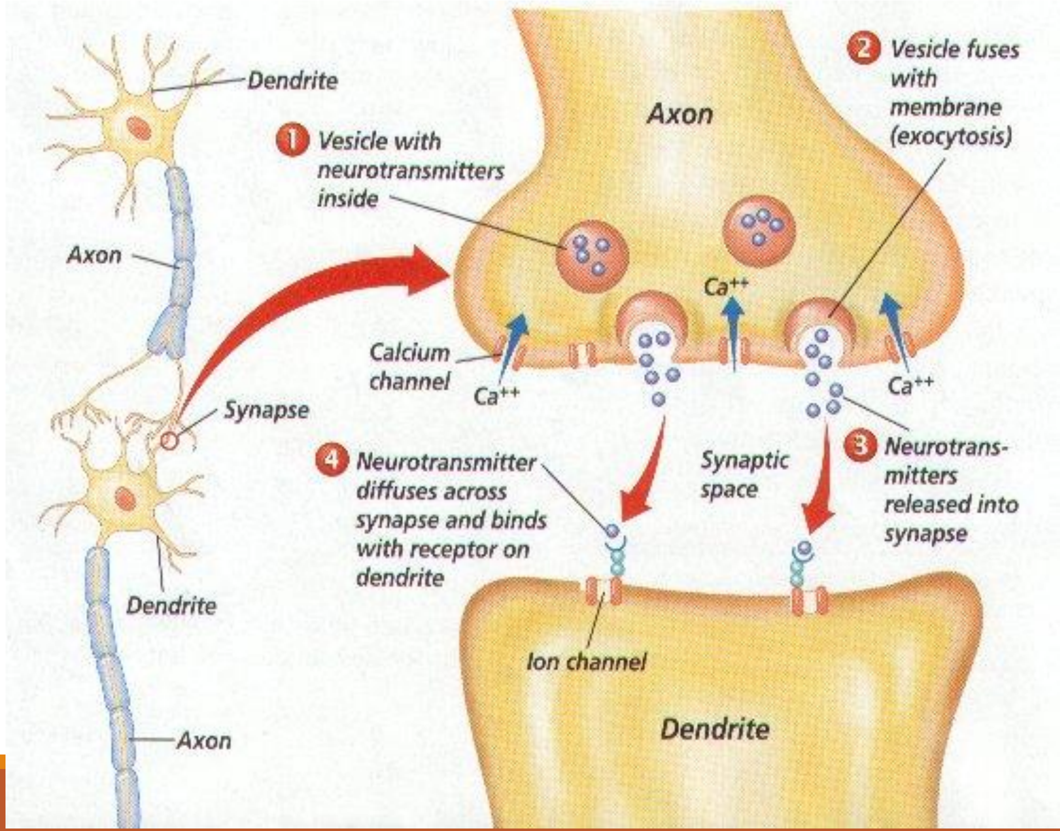


Homework

Textbook: pg. 362 # 2, 3, 4, 6 & 7

Synaptic Transmission

Considering that the electrical signal cannot be directly transferred to the following neuron, a chemical message needs to be used to relay the message through the synaptic cleft towards the next neuron.



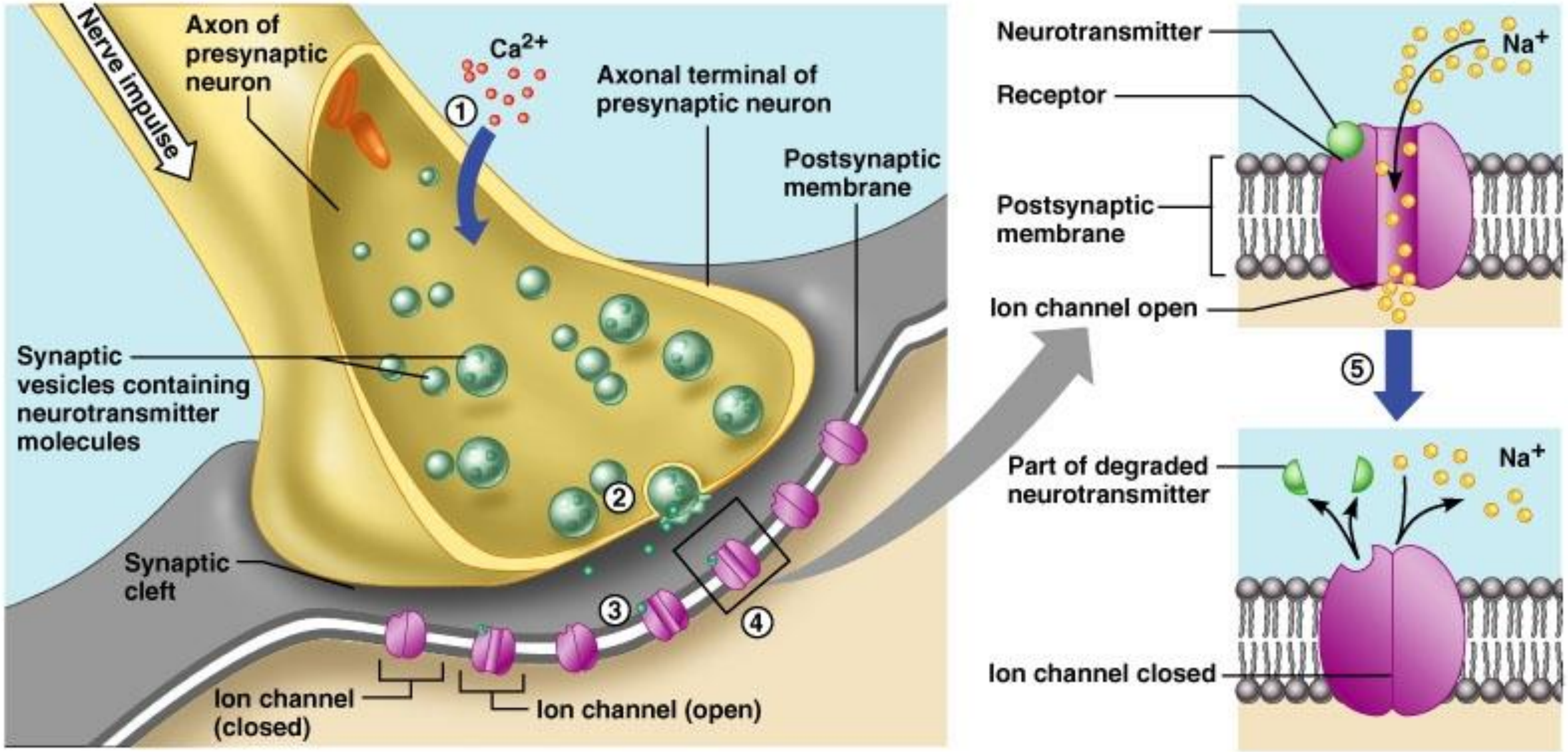
Neurotransmitter:

Synaptic Vesicle:

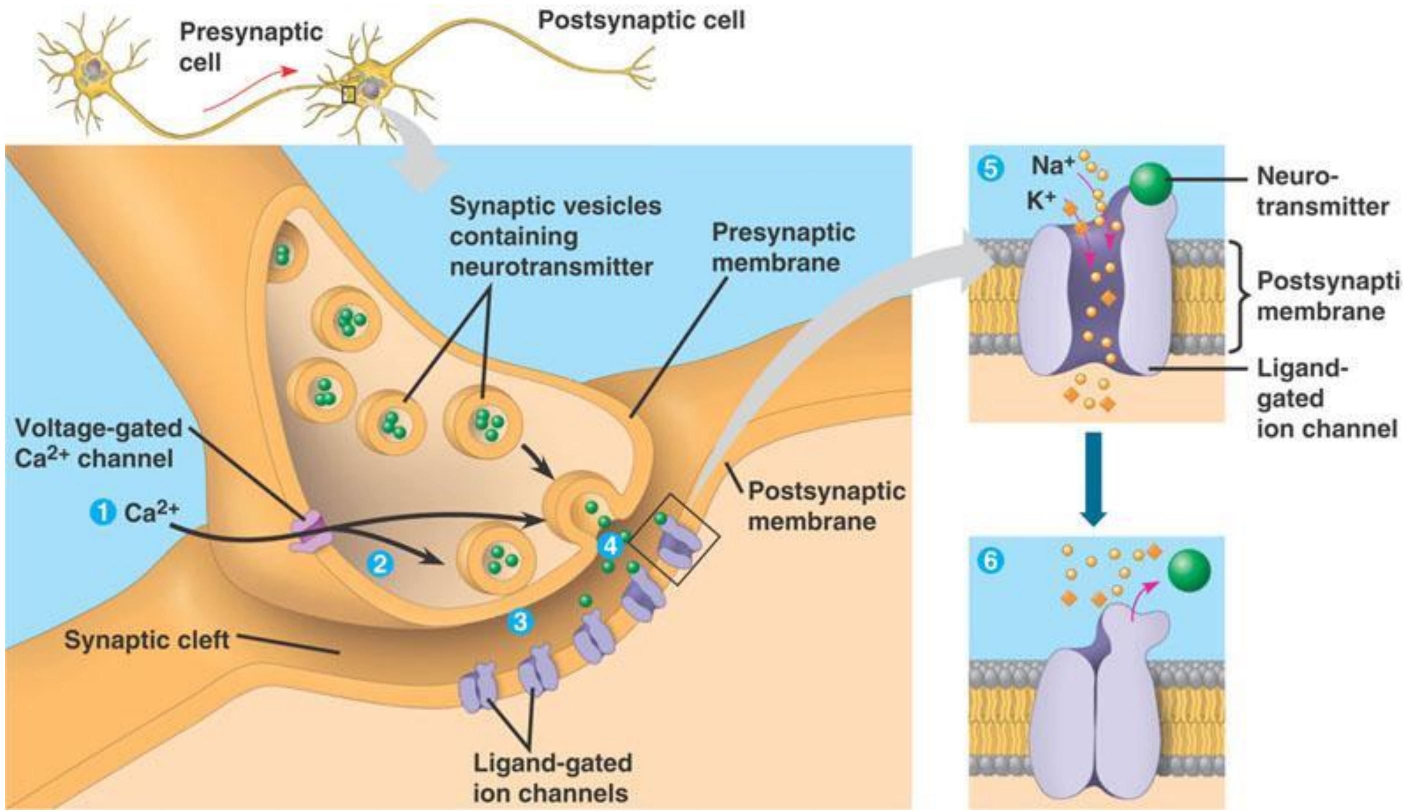
Dendrites:

Receptors:

Action Potentials and Neurotransmitters



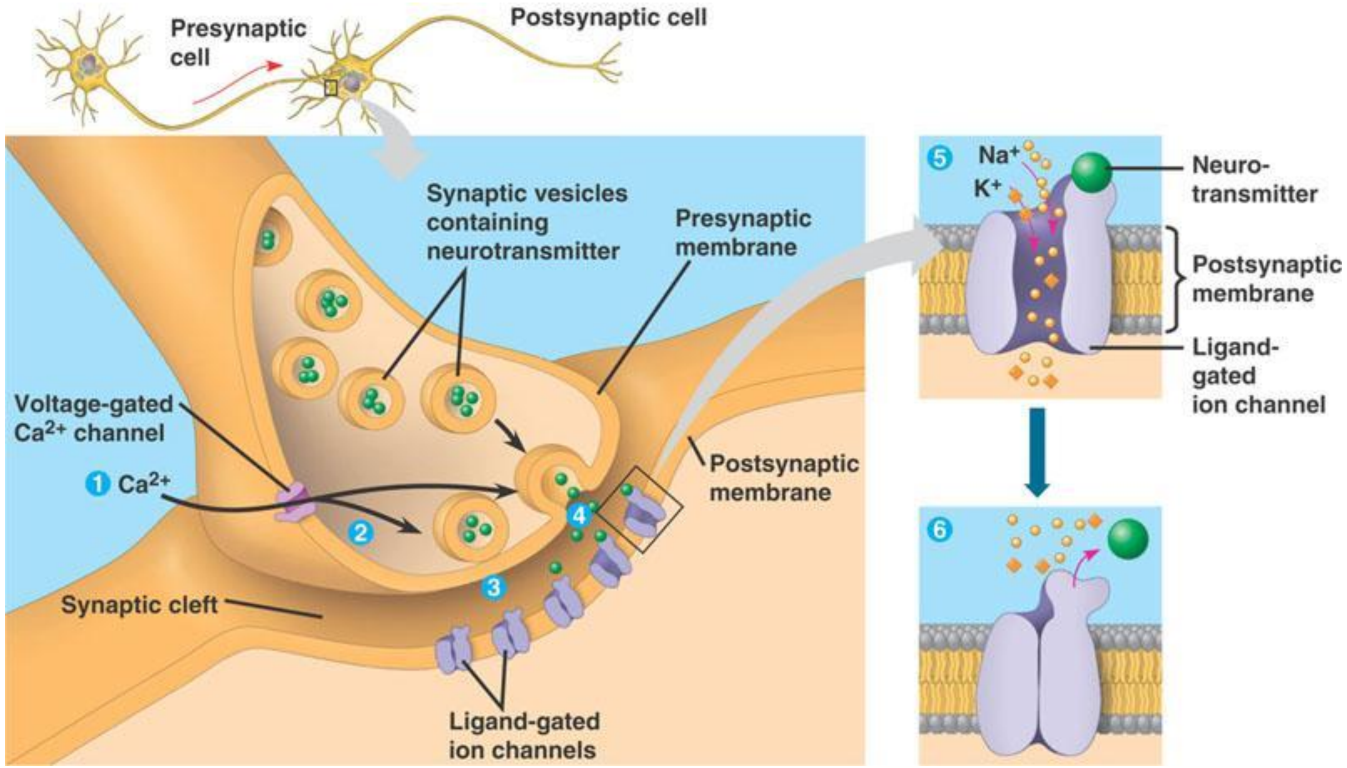
Synaptic Transmission



Step 1: When the action potential reaches the terminal buds of the presynaptic cells, it opens the Ca^{2+} channel.

Step 2 & 3: The influx of Ca^{2+} triggers the fusion of synaptic vesicles to the terminal bud, thus releasing the neurotransmitters into the synaptic cleft through exocytosis.

Synaptic Transmission

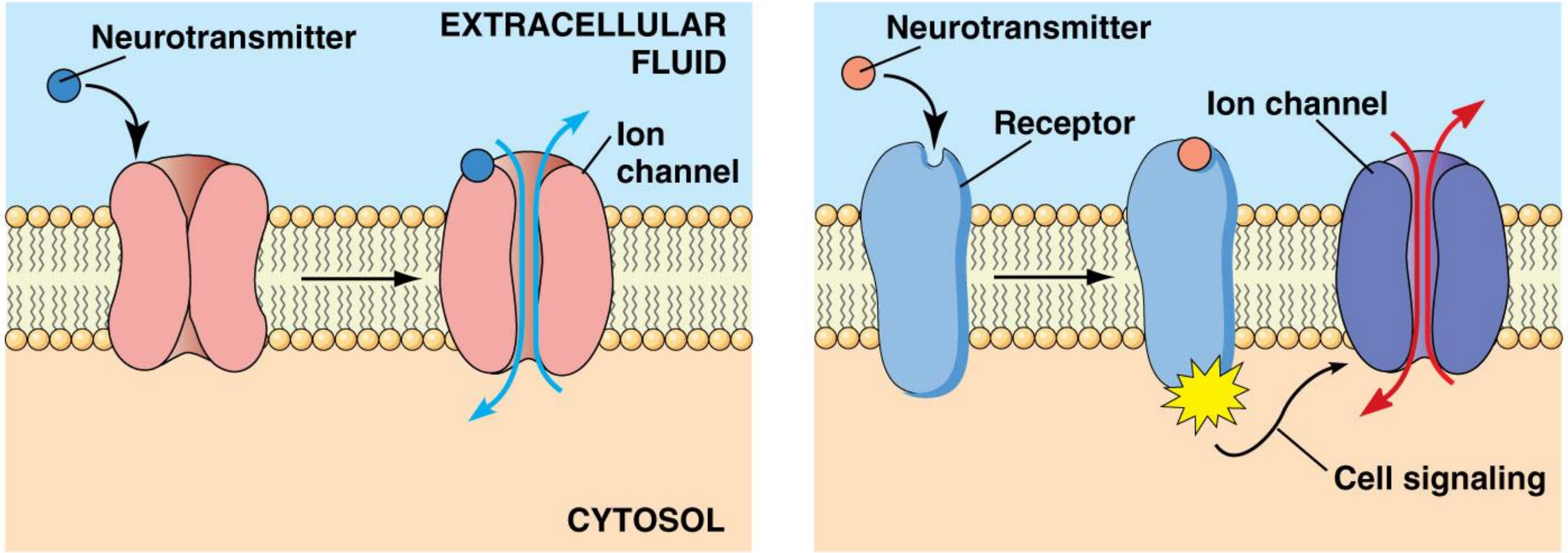


Step 4: There are channels located on the dendrite surface that recognize specific neurotransmitters and open in response to the binding of the neurotransmitter.

Step 5: When the neurotransmitter binds, the channel opens and allows a large influx of Na+ into the post synaptic cell. This changes the membrane potential until is reaches the threshold.

Synaptic Transmission

Step 6: When the neurotransmitter is released from the channel on the dendrite, the channel closes. The rest of the neurotransmitters in the synaptic cleft are recycled and taken back into the terminal bud.



(a) Direct neurotransmitter action (ionotropic receptor)

(b) Indirect neurotransmitter action (metabotropic receptor)

Neurotransmitters

Neurons can be excitatory or inhibitory.

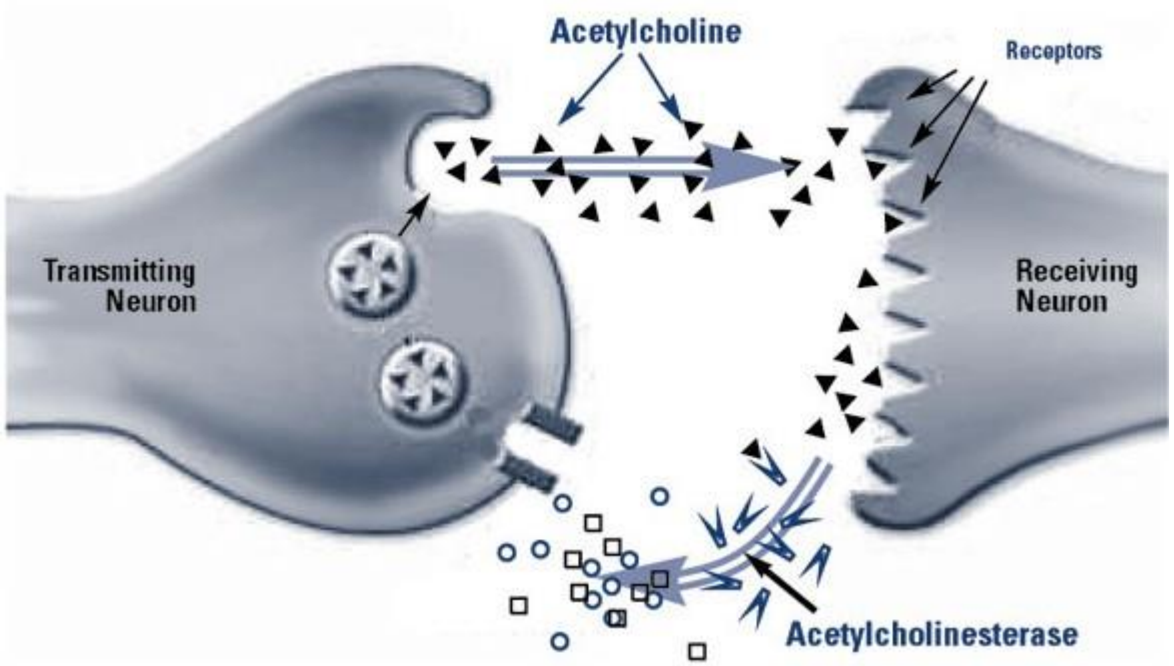
Excitatory Neurons:

Inhibitory Neurons:

Types of Neurotransmitters

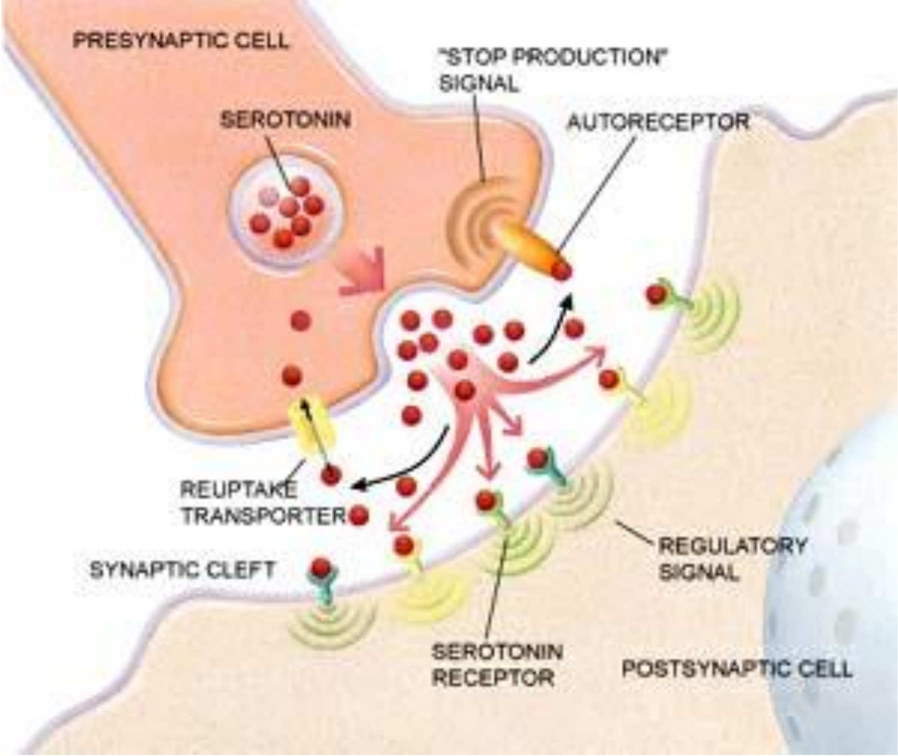
Acetylcholine: neurotransmitter released from vesicles in the end plates of neurons that open Na+ channels.

Acetylcholinesterase: *is an enzyme that destroys the acetylcholine once it is no longer required. Only once acetylcholine is destroyed will the Na+ channels close.*



Types of Neurotransmitters

Serotonin: *neurotransmitter that helps regulate temperature in the body and mood control. When there is a low amount of serotonin available, it is thought to be associated with depression.*



Types of Neurotransmitters

Endorphins: neurotransmitter that is a natural pain killer and affects emotional areas of the brain. Many opiate drugs are thought to imitate endorphins and bind to their receptors, leading to similar effects.

Dopamines: neurotransmitters involved in the sensation of pleasure. Some drugs are thought to induce a constant release of dopamine which leads to dependency.

Homework

Textbook: pg. 362 # 8, 9 & 10