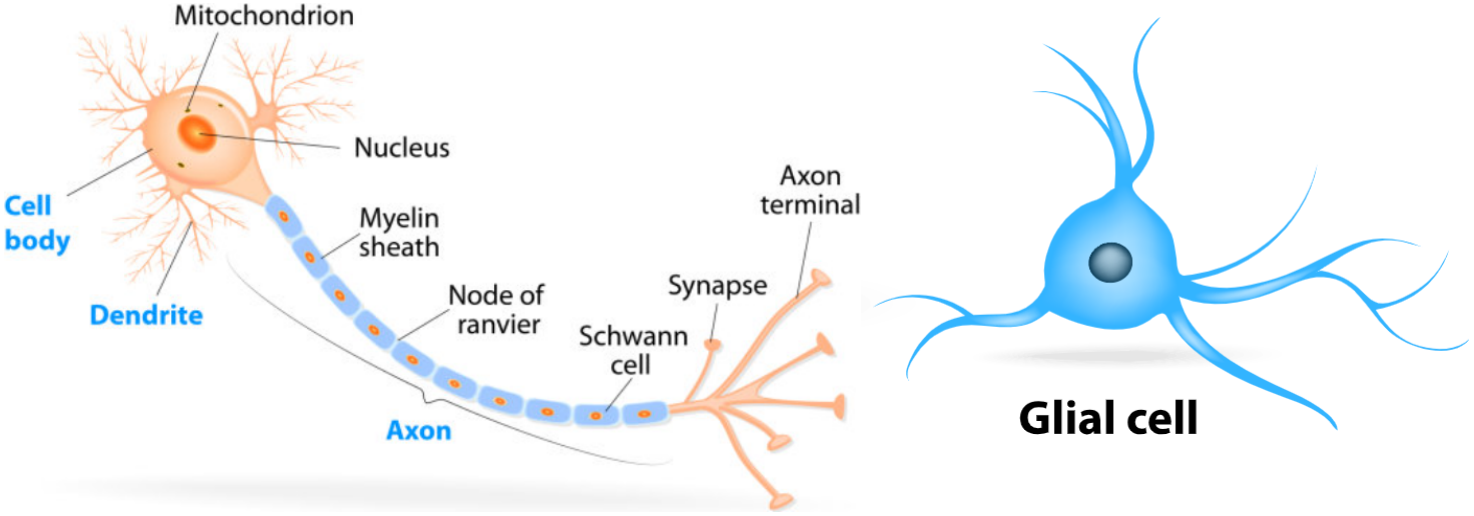
CONCEPT: NEURONS

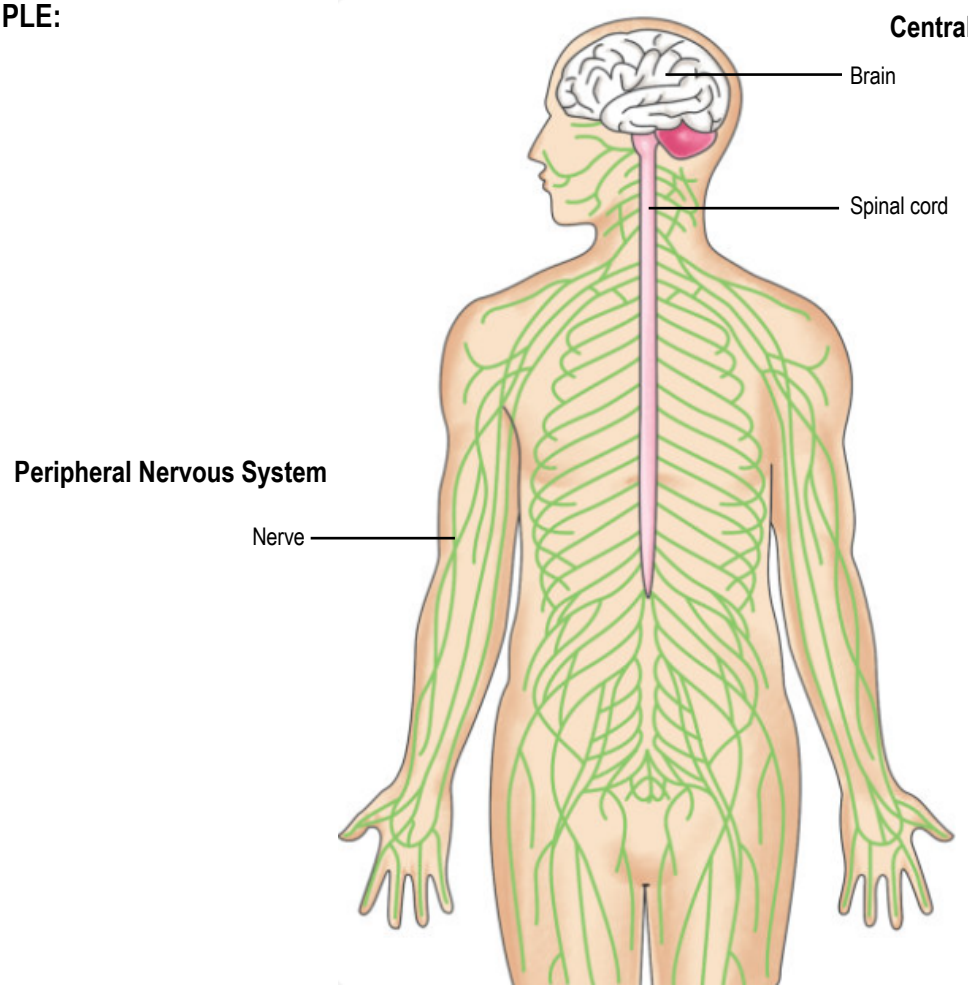
- ***Nervous system*** – network of nerve cells that transmit signals throughout the body
  - □ ***Neuron*** – major cell of the nervous system, capable of sending and receiving electrical and chemical signals
  - □ ***Glia*** – support and protect neurons, their role is still not well understood

EXAMPLE:



- ***Central nervous system*** (***CNS***) – division of the nervous system composed of the brain and spinal cord
- ***Peripheral nervous system*** (***PNS***) – nerves and ganglia outside of the brain and spinal cord

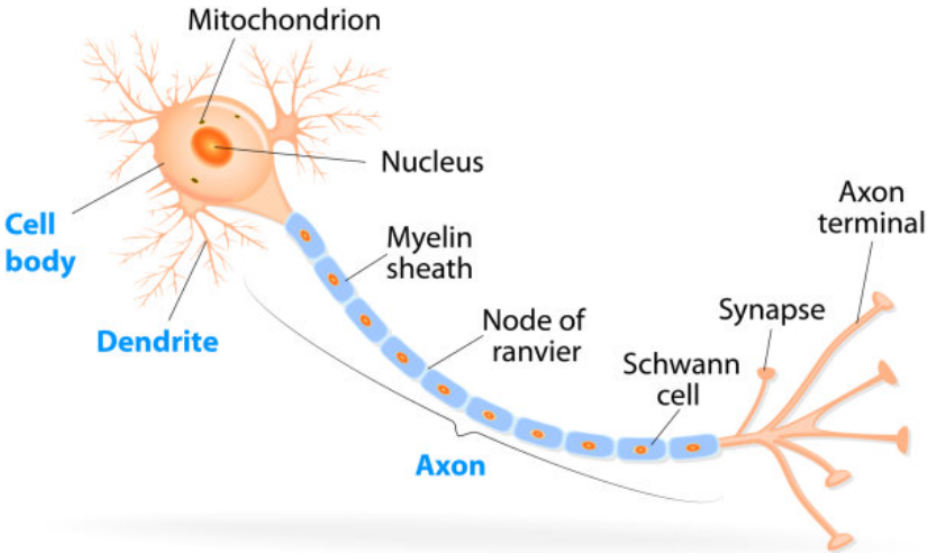
EXAMPLE:



CONCEPT: NEURONS

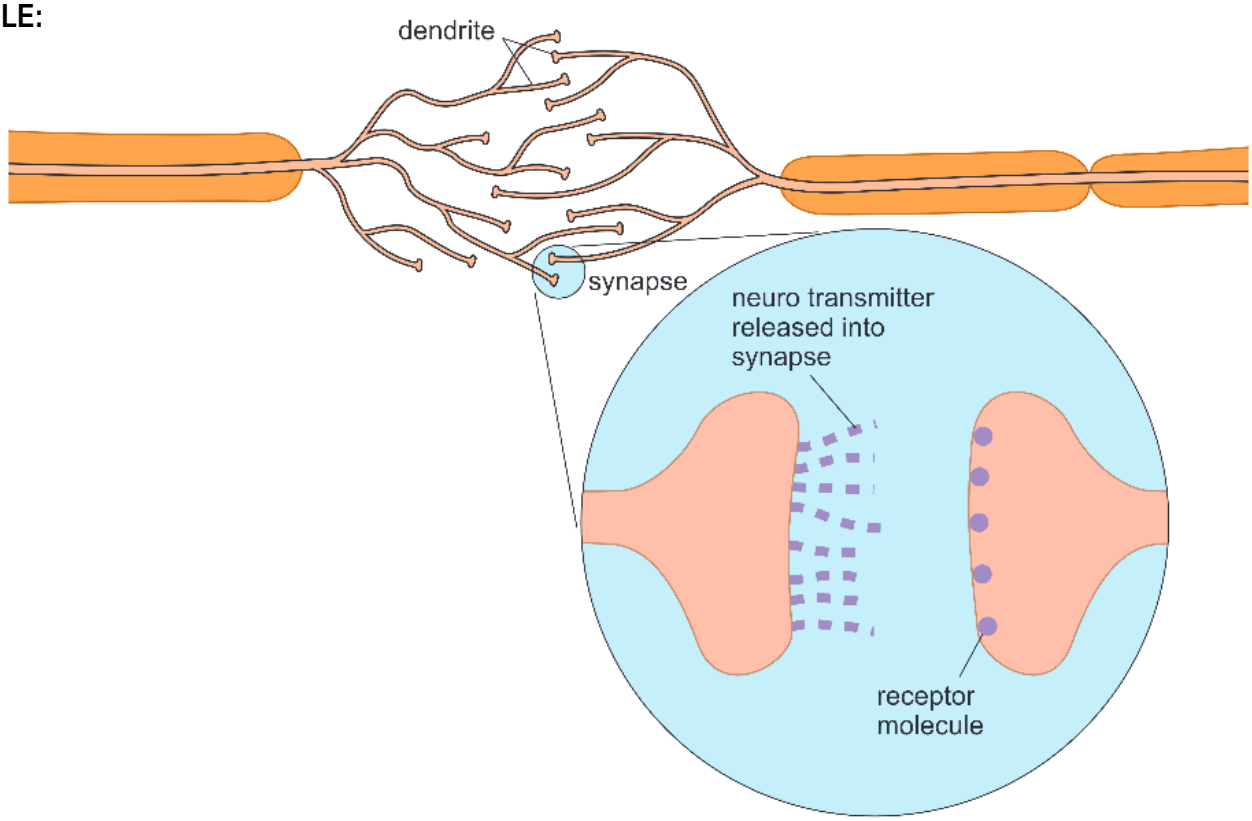
- Neurons transmit electrical signals, and can translate them into chemical signals that they release to other neurons
  - □ Neurons translate the chemical signals they receive into electrical signals
  - □ ***Cell body*** (***soma***) – contains the nucleus, and is the site of the majority of protein synthesis
  - □ ***Axon hillock*** – connects cell body to axon
  - □ ***Axon*** – long projection from the cell body that transmits electrical signal, like a wire
  - □ ***Dendrites*** – branched projections that receive signals from other neurons

EXAMPLE:



- ***Synapse*** – connection between an axon terminal and dendrites
- ***Neurotransmitters*** – chemical signal released from vesicles to the synapse

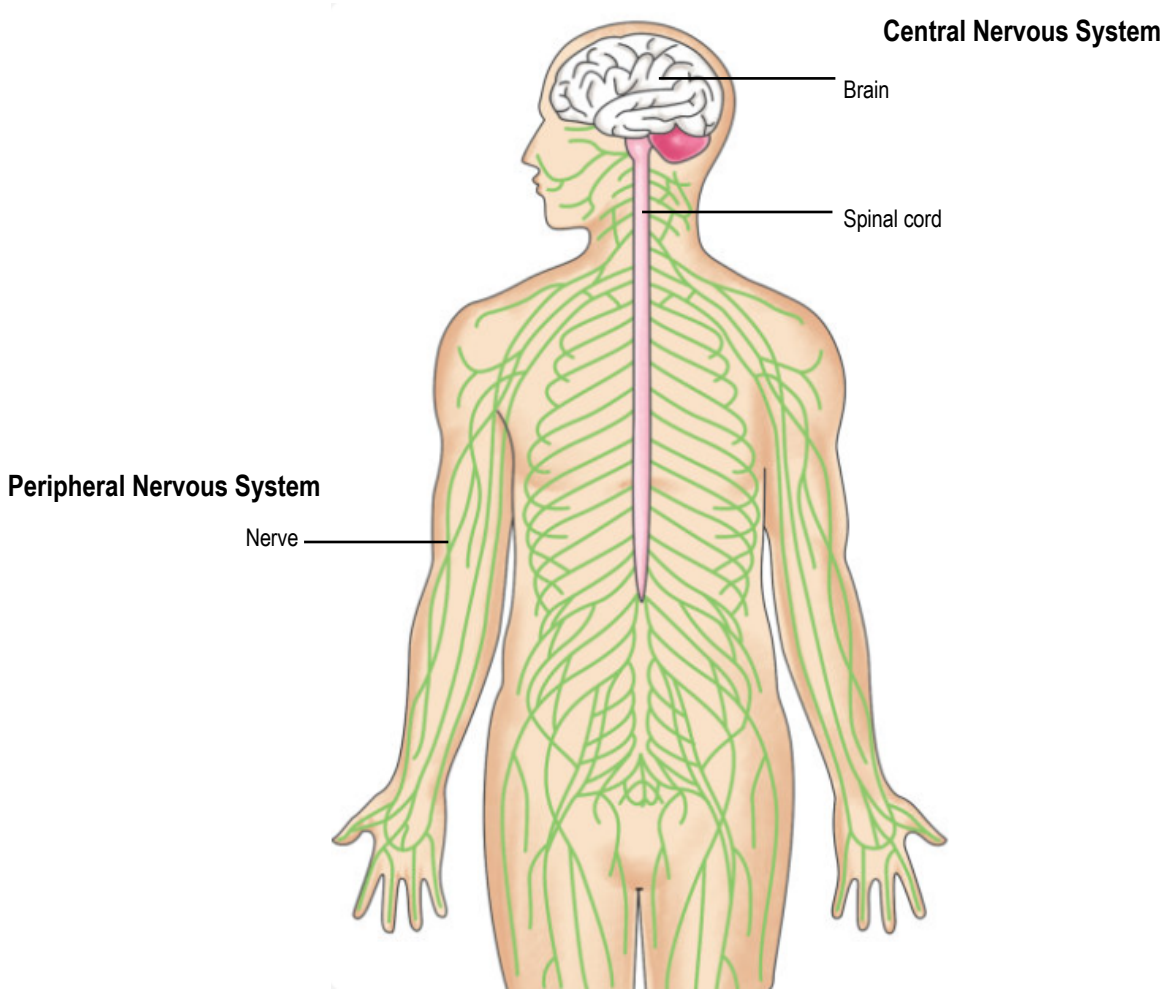
EXAMPLE:



CONCEPT: NEURONS

- ***Central nervous system*** (***CNS***) – integrates information it receives from the body, and coordinates responses
    - □ ***Brain*** – organ that acts as the center of the nervous system
    - □ ***Spinal cord*** – bundle of neurons and glia that extends from the brain down the back

EXAMPLE:

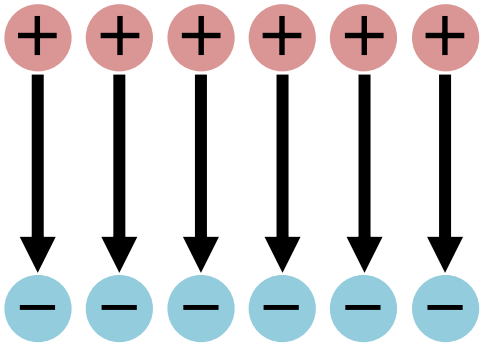


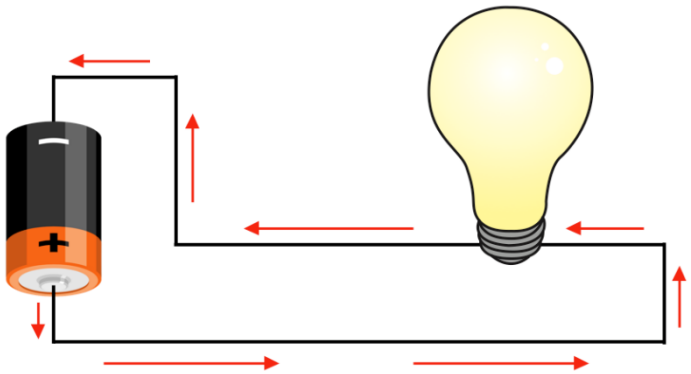
- ***Peripheral nervous system*** (***PNS***) – sends signals to and from the brain and spinal cord
    - □ ***Ganglion*** – cluster of neuron cell bodies (called nuclei in the CNS)
    - □ ***Nerves*** – bundle of axons in the PNS (called tracts in the CNS)
        - ***Sensory neurons*** – nerves that transmit sensory information, ultimately to the brain and spinal cord
        - ***Motor neurons*** – nerves that project from spine to stimulate effector organs like muscles and glands
- ***Interneurons*** – transmits information between neurons, connect sensory and motor neurons, main neuron in brain

CONCEPT: NEURONS

- ***Electric current*** – flow of electric charge
- ***Electric potential*** – electric potential energy per unit of charge, measured in volts (V)
  - □ ***Voltage*** – difference in electric potential between two points, results from differences in charge

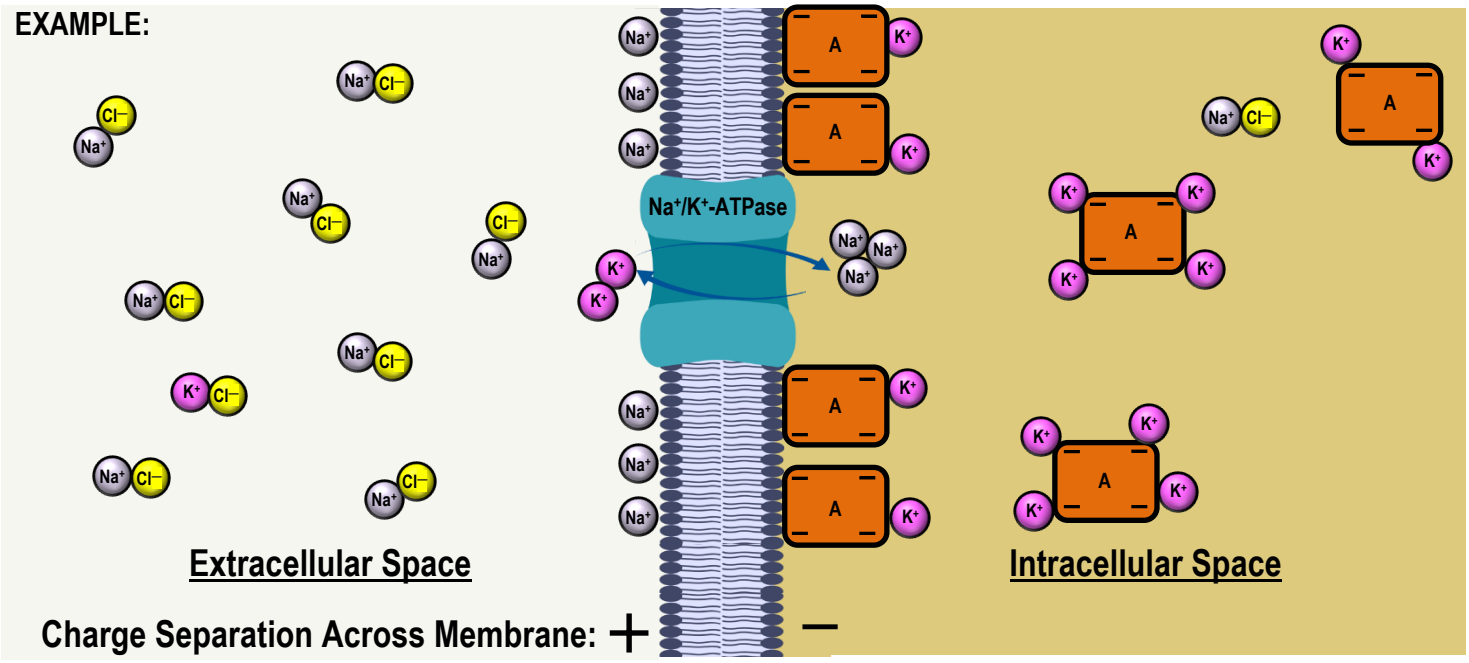
EXAMPLE:

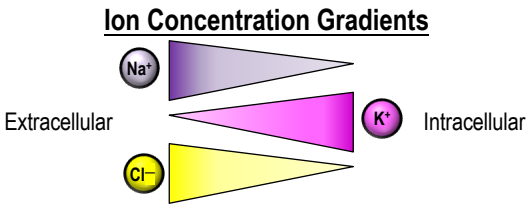




- ***Electrochemical gradient*** – chemical concentration gradient and electric potential gradient across a membrane
- ***Membrane potential*** – difference in electric potential between interior and exterior of a cell, separated by membrane
  - □ ***Resting potential*** – baseline membrane potential of a cell
  - □ ***Hyperpolarization*** – membrane potential becomes more negative
  - □ ***Depolarization*** – membrane potential becomes more positive

EXAMPLE:

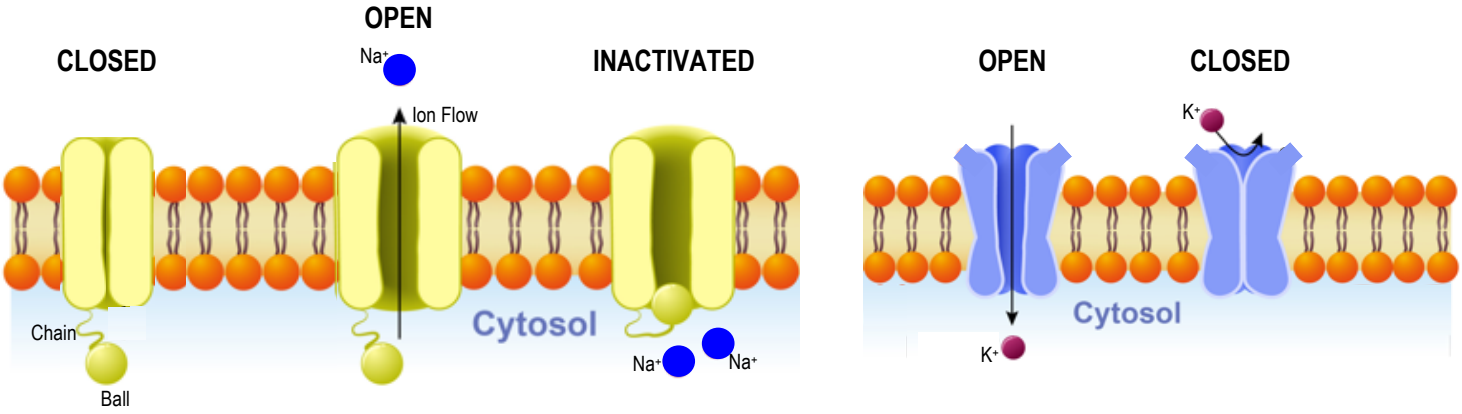




CONCEPT: NEURONS

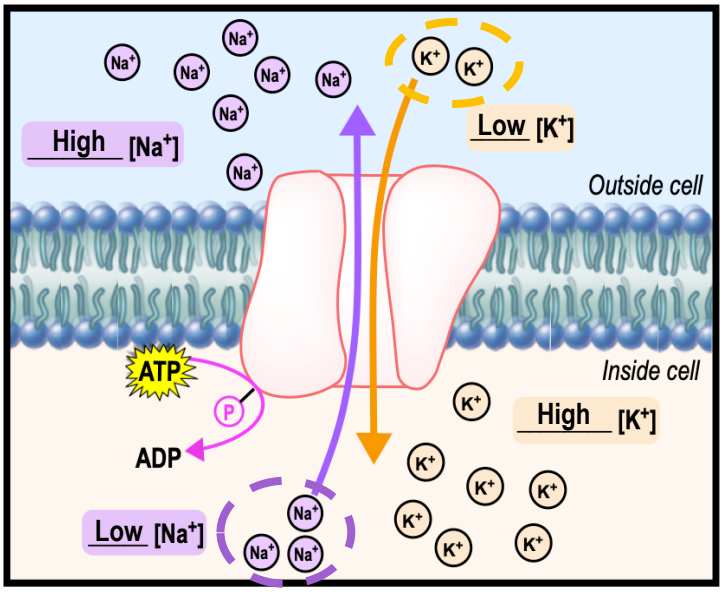
- ***Ion channels*** – protein channels that form a transmembrane pore, allowing for the passage of a specific ion
  - □ Critical in establishing membrane potentials, and transmission of electric signals in neurons
  - □ ***Leak channels*** – K^+ channels that help maintain the negative resting potential of neurons
  - □ ***Gated ion channels*** – ion channels that open or close in response to stimuli
    - ***Ligand-gated ion channel*** – opens in response to ligand binding
    - ***Voltage-gated ion channel*** – opens in response to a specific membrane potential

EXAMPLE:



- ***Na/K-ATPase*** (***sodium-potassium pump***) – actively pumps $3Na^+$ out of the cell, and brings $2K^+$ into the cell
  - □ Plays a crucial role in establishing resting potential of neurons
- ***Equilibrium potential*** (E_{ion}) – membrane potential at which there is no net movement of an ion in or out of the cell
  - □ Leak channels allow K^+ to leak out of cell along concentration gradient, until it reaches equilibrium potential

EXAMPLE:

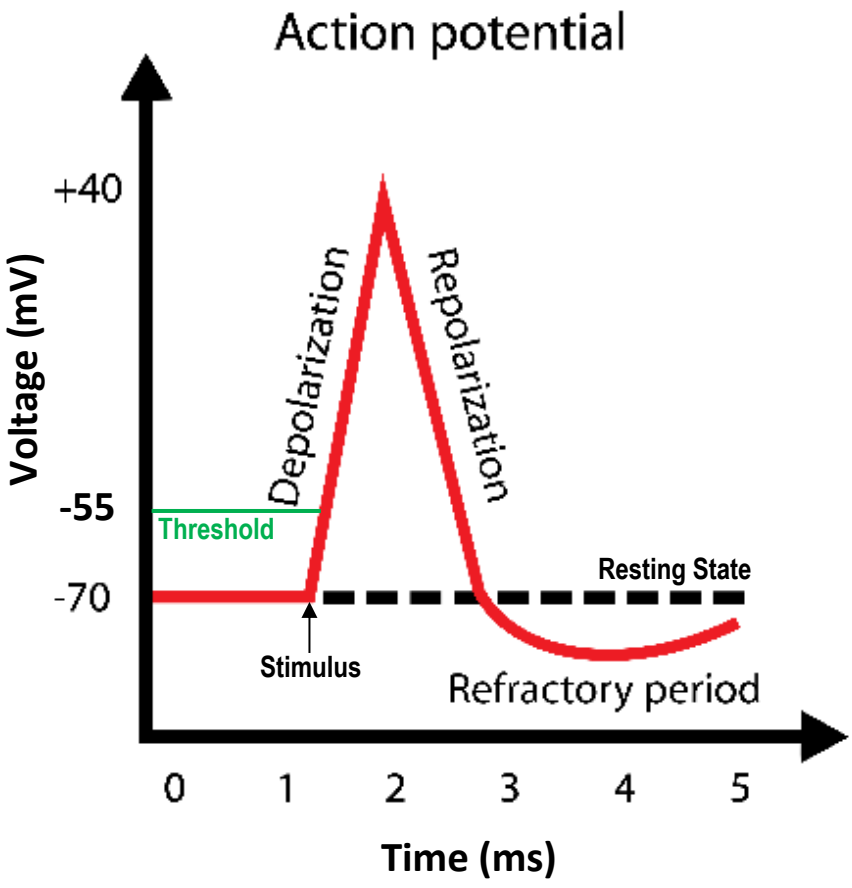


CONCEPT: NEURONS

- ***Graded potential*** – shifts in membrane potential that vary in magnitude, codes information in signal amplitude
- ***Action potential*** (***AP***) – transient shift in membrane potential, codes a binary, all-or-none signal
    - □ Signal intensity is coded by the frequency of action potentials
- Phases of the action potential:

1. Resting state – cell is at resting potential, voltage-gated Na^+ and K^+ channels are closed
2. Rising phase – depolarization of the membrane potential causes some voltage-gated Na^+ channels to open
    - □ ***Threshold*** – membrane potential at which action potential will be triggered
    - □ If threshold potential is reached, all voltage-gated Na^+ channels open, and Na^+ rushes into the cell
    - □ Influx of cations depolarizes membrane potential
3. Falling phase – Na^+ channels are inactivated, while voltage-gated K^+ channels open, causing K^+ to rush out of the cell
    - □ Efflux of cations causes repolarization of the membrane potential
4. Undershoot - Na^+ channels close, while some K^+ channels remain open causing hyperpolarization
    - □ ***Refractory period*** – time in which another action potential cannot be generated due to inactivated Na^+ channels

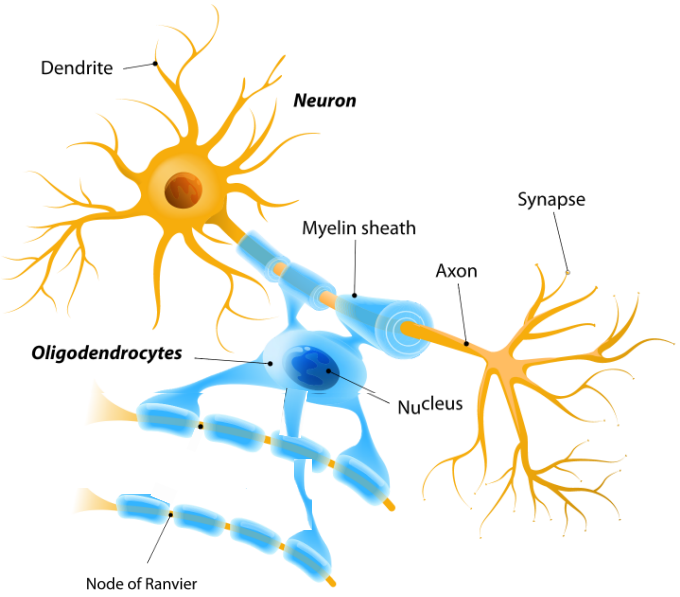
EXAMPLE:

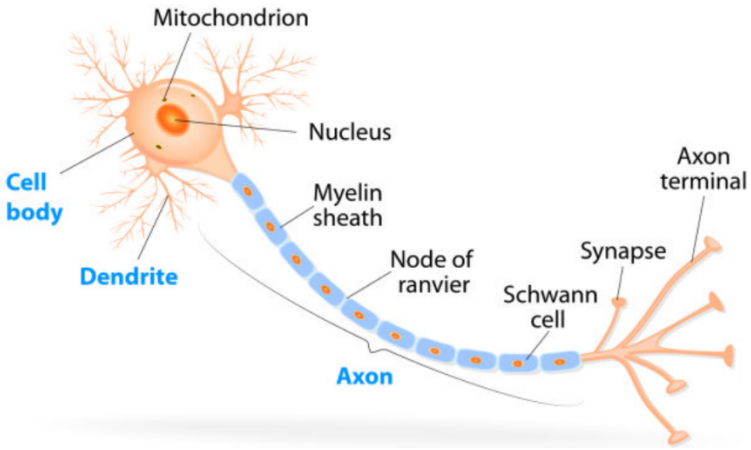


CONCEPT: NEURONS

- Axon diameter influences the speed of propagation of an action potential, larger diameters have lower resistance
- ***Myelin*** – fatty substance used to insulate axons and speed up action potential propagation
    - □ ***Myelin sheathe*** – myelin covering over an axon, neither continuous nor generated by a single glial cell
    - □ ***Node of Ranvier*** – gap in myelin sheathe that allows ion channels to exchange ions with the extracellular fluid
- ***Oligodendrocyte*** – glial cell of the CNS that can myelinate multiple axons
- ***Schwann cell*** – glial cell of the PNS that myelinates a single axon

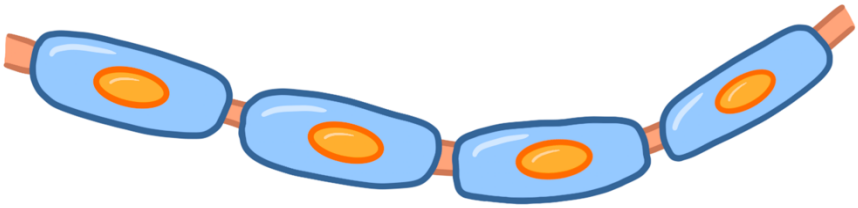
EXAMPLE:

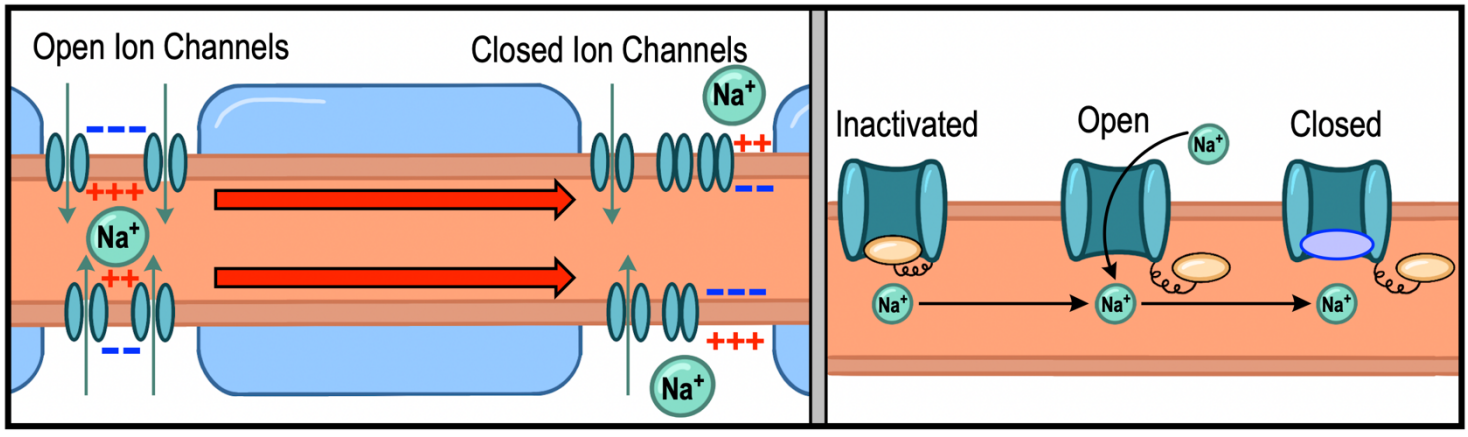




- ***Saltatory conduction*** – propagation of the action potential along myelinated axons, from one node of Ranvier to the next

EXAMPLE:

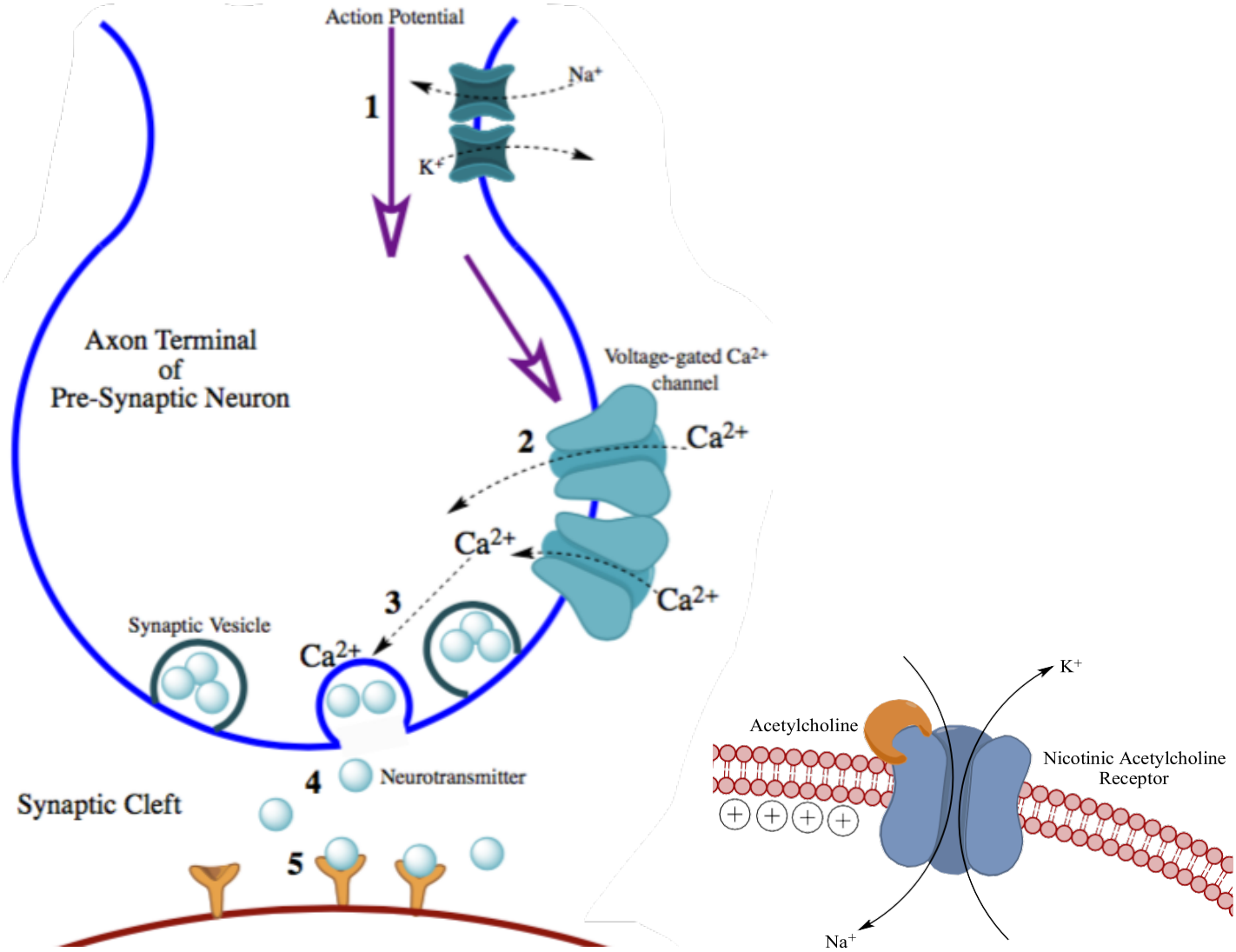




CONCEPT: NEURONS

- ***Synapse*** – junction between neurons that allows them to pass signals between cells
  - □ Signals (almost) always travel from the presynaptic cell to the postsynaptic cell
  - □ Signals can be chemical (neurotransmitters), or electrical (gap junction)
  - □ Voltage-gated Ca^{2+} channels on presynaptic axon terminal open in response to depolarization from AP
  - □ ***Synaptic vesicles*** – store neurotransmitters and release the into the synapse in response to Ca^{2+}
  - □ ***Synaptic cleft*** – small space between the axon terminal of the presynaptic cell and the postsynaptic cell

EXAMPLE:

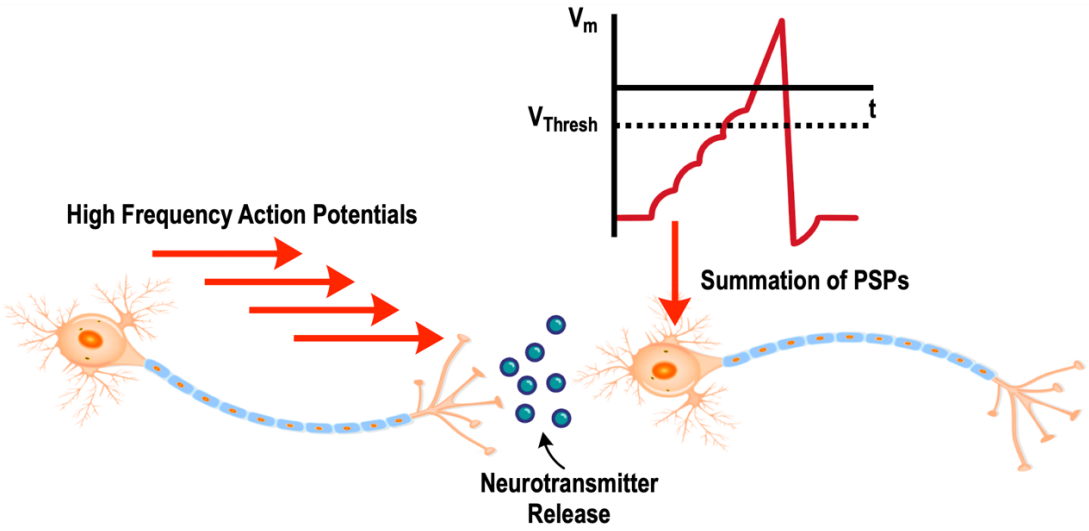


- Ionotropic receptor – membrane receptor that acts by opening an ion channel
  - □ ***Ligand-gated ion channels*** – open in response to ligand binding, like neurotransmitters
- Metabotropic receptor – membrane receptor that acts through second messengers
  - □ Often G protein coupled receptors, can have a wide variety of effects

CONCEPT: NEURONS

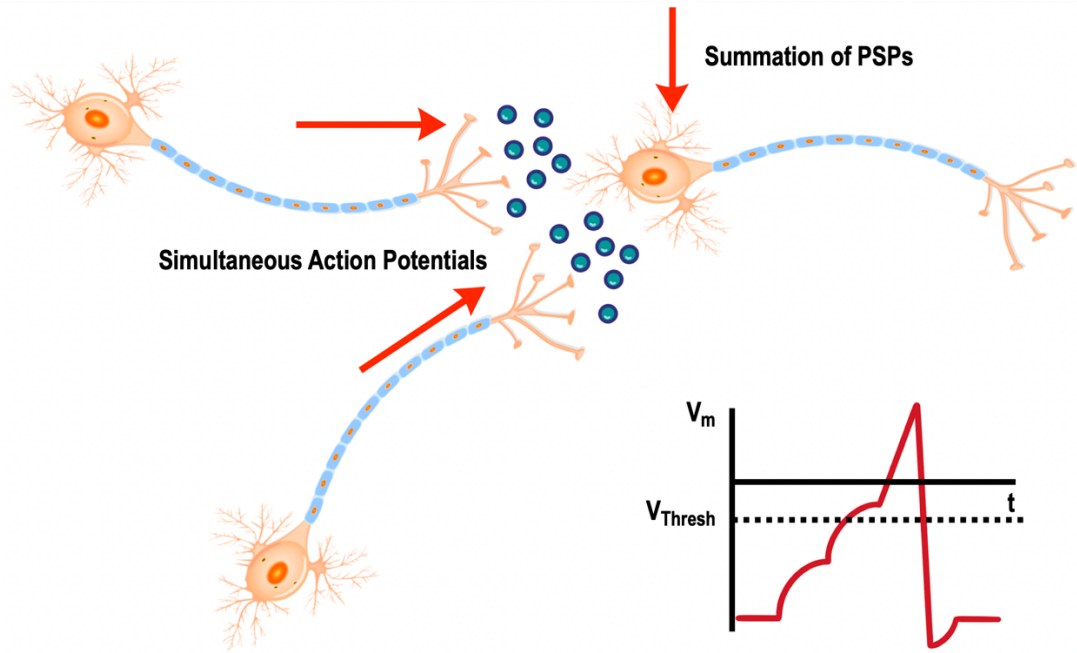
- Neuron signals frequently result in a change in membrane potential of the postsynaptic cell
  - □ ***Excitatory postsynaptic potential*** (***EPSP***) – depolarization of the membrane potential, increasing chance of AP
    - EPSPs that sum together can depolarize membrane potential to the threshold of an action potential
    - Na^+ channels that will trigger an action potential are located in the axon hillock
  - □ ***Inhibitory postsynaptic potential*** (***IPSP***) – hyperpolarization of membrane potential, decreasing chance of AP
- ***Temporal summation*** – PSPs occur in succession, and adding together to a larger depolarization

EXAMPLE:



- ***Spatial summation*** - PSPs occur in close proximity, and adding together to a larger depolarization

EXAMPLE:



CONCEPT: NEURONS

- Neurotransmitters are signaling molecules that cross the synapse and bind to receptors
    - □ Neurotransmitters exert their effects based on the receptors they bind
        - - A single neurotransmitter will have different types of receptors that can bind it
    - □ Neurotransmitters must be cleared from the synapse after release, either degraded or reabsorbed
- ***Acetylcholine*** – neurotransmitter used by parasympathetic nervous system, and at neuromuscular junction
    - □ ***Neuromuscular junction*** – synapse between motor neurons and muscles, have ionotropic nicotine receptors
        - - Acetylcholine has excitatory effect at neuromuscular junction, causing muscle contraction
    - □ Heart muscle has muscarinic metabotropic receptors, innervated parasympathetic nervous system
        - - Acetylcholine has inhibitory effect in some parts of parasympathetic nervous system and heart
    - □ Acetylcholinesterase digests acetylcholine in the synapse
- ***Amino acids*** – includes glutamine, glycine, and GABA
    - □ ***Glutamate*** – major excitatory neurotransmitter of the CNS
    - □ ***GABA*** (γ-aminobutyric acid) – major inhibitory neurotransmitter of the CNS

EXAMPLE:

- ***Monoamines*** – contain an amine and an aromatic ring, derived from aromatic amino acids
    - □ ***Serotonin*** – major neurotransmitter of the enteric nervous system, involved in feelings of happiness
    - □ ***Dopamine*** – catecholamine involved in reward pathways of the brain
    - □ ***Norepinephrine*** – catecholamine hormone and neurotransmitter used in sympathetic nervous system
- ***Neuropeptides*** – peptide neurotransmitters including substance P, neuropeptide Y, ghrelin, and endorphins
    - □ ***Endorphins*** – endogenous opioids, suppress pain and induce euphoria
- NO can act as a neurotransmitter, and diffuses widely, doesn't obey pre- to postsynaptic transmission rule
- ***Neurotoxins*** – poisons that are destructive to nerve tissue

EXAMPLE: