Action potential

The neuron:

It is the nerve cell which is able to transmit messages between the nervous system and all parts of the body. Neuron is composed of three main parts: the dendrites or nerve endings, the axon and the cell body. Nerve cells that conduct impulses from the central nervous system toward the periphery are termed motor neurons while the ones which transmit impulses from the periphery to the higher centers are called sensory neurons.

The axon:

It is a long extension of the neural cytoplasm encased in a thin sheath called the nerve membrane of the axolemma.

- Afferent (Ascending) – transmit impulses from the periphery to the brain
  - First Order neuron
  - Second Order neuron
  - Third Order neuron
- Efferent (Descending) – transmit impulses from the brain to the periphery

First Order Neurons

- Stimulated by sensory receptors
- End in the dorsal horn of the spinal cord
- Types of nerve fibers
  - A-alpha – non-pain impulses
  - A-beta – non-pain impulses
    - Large, myelinated
    - Low threshold mechanoreceptor; respond to light touch & low-intensity mechanical info
  - A-delta – pain impulses due to mechanical pressure
    - Large diameter, thinly myelinated

        - Short duration, sharp, fast, bright, localized sensation (prickling, stinging, burning)
    - C – pain impulses due to chemicals or mechanical
        - Small diameter, unmyelinated
        - Delayed onset, diffuse sensation (aching, throbbing)

Second Order Neurons

- Receive impulses from the first order neuron in the dorsal horn
    - Lamina II, Substantia Gelatinosa (SG) - determines the input sent to T cells from peripheral nerve
    - Travel along the spinothalmic tract
    - Pass through Reticular Formation
    - Ends in thalamus

Third Order Neurons

- Begins in thalamus
- Ends in specific brain centers (cerebral cortex)
    - Perceive location, quality, intensity
    - Allows to feel pain, integrate past experiences & emotions and determine reaction to stimulus

Neurotransmitters

- They are chemical substances that allow nerve impulses to move from one neuron to another
- Found in synapses
- Examples include:
    - Substance P - thought to be responsible for the transmission of pain-producing impulses
    - Acetylcholine – responsible for transmitting motor nerve impulses
    - Enkephalins – reduces pain perception by bonding to pain receptor sites

- Can be either excitatory or inhibitory

Resting membrane potential:

- Resting membrane Potential: a chemical and electrical balance with a pump to aid in return to homeostasis.
  - The resting membrane potential for a neuron is approximately -70vmV
  - At rest it is permeable to sodium ions
  - Freely permeable to potassium ions
  - Freely preamble to chloride ions
  - At rest the ions are distributed as in the following table:

Ion	Intracellular (mEq/L)	Extracellular (mEq/L)
Potassium	110-170	3-5
Sodium	5-10	140
Chloride	5-10	110

Depolarization:

Excitation of a nerve segment leads to rapid influx of sodium into the nerve cell which causes depolarization of the nerve from its resting state to a firing threshold of approximately -50 to -60 mV. When the firing threshold is reached a massive increase in the influx of sodium occurs. At the end of depolarization (peak of the action potential), the electrical potential of the nerve is actually reversed. The entire depolarization process takes around 0.3 ms.

Repolarization:

Repolarization is caused by inactivation of membrane permeability to sodium to return the nerve cell to its resting stage. In order to move sodium against its concentration gradients the sodium potassium pump plays an important role in the repolarization step. The entire repolarization process takes around 0.7 ms.

Threshold

The minimum amount of stimulus that is necessary to start an action potential. The threshold can be affected by many factors including experience and local anesthesia.

The firing threshold is the reduction in membrane potential that can start an action potential.

Refractory periods

- Refractory period: membrane potential goes below the resting potential of -70mV and may not be stimulated for a given period of time. This limits how many action potentials may be produced
  - Absolute refractory period: NO stimulus will create a response no matter how strong
  - Relative refractory period: resting potential is much lower, therefore a higher stimulus is needed

Theories of local anesthetic action:

1- Acetylcholine theory
2- Calcium displacement theory
3- Surface charge theory
4- Membrane expansion theory
5- Specific receptor theory

The most favored theory is the specific receptor theory. It proposes that local anesthetic acts by binding to specific receptors on the sodium channel. The action of the local anesthetic is direct and not mediated by some changes in the general properties of the cell membrane.