Impulses formation :

Impulse: Electrical (Charge exchange on each side of the axon membrane), Physical (Change in membrane permeability) and chemical changes (energy production and release).It is simply the movement of action potentials along a nerve cell.

- All cells in the body maintain differences (Voltage) across the membrane , or (resting membrane potential) , in which the inside of the cell is negatively charged in comparison to the outside of the cell , in neurons it is equal to -70 mv , in muscle it is equal to – 85 mv.

- **In resting potential** , the cell membrane is High permeability to K+ , Less permeability to Cl- and Na+ and the presence of organic big negatively charged molecules (Proteins) inside the axon, makes the inside negatively charged and the outside positively charged.

- **After stimulation, the membrane become in action potential** and said to be (depolarized) , the membrane become High permeability to Na+ , Less permeability to K.+

✱Action potential are localized (only affect a small area of nerve cell membrane) .So, when one occurs, only a small area of membrane depolarizes. As a result, for a split second, areas of membrane adjacent to each other has opposite charges (The depolarized membrane is negative on the outside and positive on the inside). An electrical circuit or mini-circuit develops between these oppositely charged areas). The mini- circuit stimulates the adjacent area and, therefore, an action potential occurs. This process repeats itself and action potentials move down the nerve cell membrane.

✤**Action potential** is a very rapid change in membrane potential that occurs when a nerve cell membrane is stimulated. Specifically, the membrane potential goes from the resting potential (typically -70 mV) to some positive value (typically about +35mV) in a very short period of time (just a few milliseconds).

Action potential occurs only when the membrane is stimulated (depolarized) enough so that sodium channels open completely. The minimum stimulus needed to achieve an action potential is called the threshold stimulus.

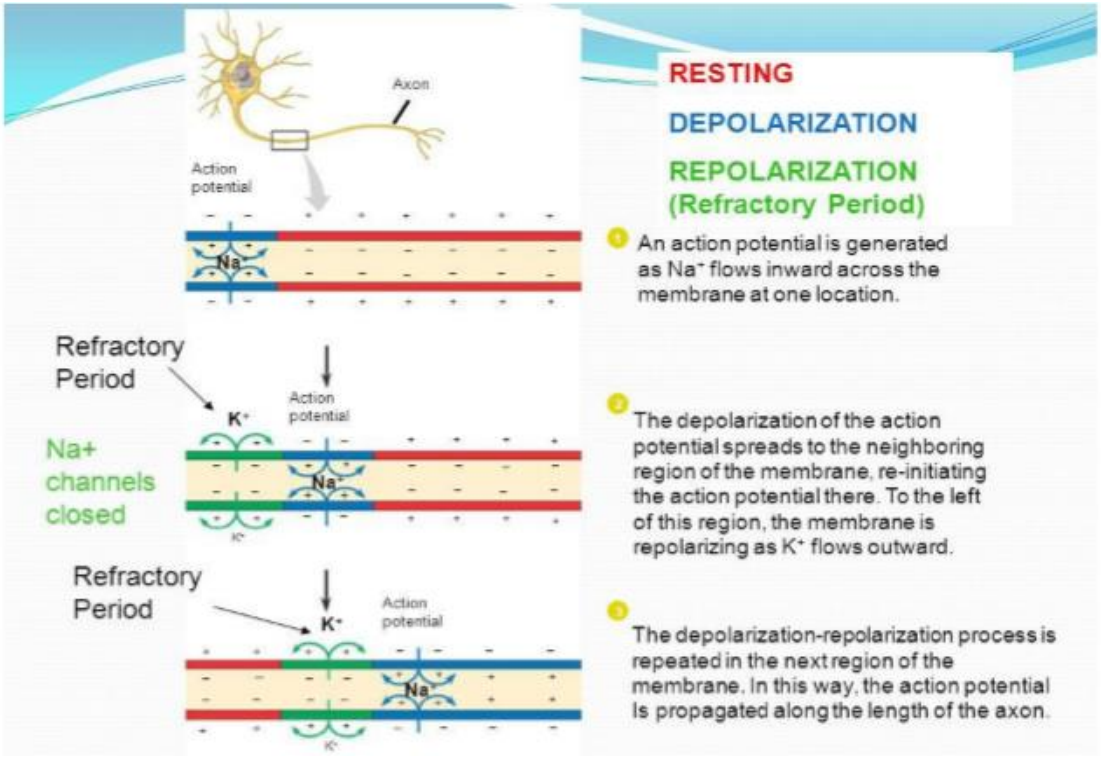
The length of time that the Na+ and K+ channels stay open is independent of the strength of the depolarization stimulus. The amplitude (size) of action potentials is therefore all or none.

Polarization ..... Depolarization ..... Repolarization

Resting potential Action potential

The permeability of the axon membrane to Na+ and K+ is regulated by gates, which open in response to stimulation. Net diffusion of these ions occurs in two stages: first Na+ moves into the axon. Then K+ moves out. This flow of ions, and the changes in the membrane potential that result, constitute an event called an **action potential**.

The action of Na+ /K+ pumps , help to maintain a potential differences because , they pump out 3 Na+ for every 2 K+ into the cell . As a result the Na+ became at high concentration in extracellular fluid than inside the cell and K+ at high concentration within the cell. The physiologic ability of neurons and muscle cells to produce and conduct changes in membrane potential known as excitability or irritability.



Changes in the potential differences across the membrane can be measured (by the voltage developed between 2 electrodes, one placed inside the cell, the other placed outside the membrane. The voltage between these 2 electrodes can be visualized by connecting them to an **Oscilloscope.**

When the axon membrane has been depolarized to threshold level, the Na+ gates open and the membrane becomes permeable to Na+. Since the gates for the Na+ channels of the axon membrane are voltage- regulated, this additional depolarization opens more Na+ channels and makes the membrane even more permeable to Na+. As a result, more Na+ can enter the cell and indices a depolarization that opens even more voltage - regulated Na+ gates.

Since the myelin sheath prevents inward Na+ current. Action potential can be produced only at gaps in the myelin sheath called the node of Ranvier. This leaping of the action potential from node to node is known as **Saltatory conduction**.

The How of the Action Potential Sodium-Potassium Pump

1. A stimulus opens the Sodium-Potassium Pump gates

2. Sodium gates open first, so positively charged ions flow into the axon, changing the membrane potential from -70 to +35mV

3. Membrane potential change is called depolarization, charge changes from negative to a positive

4. Potassium gates open second, so potassium flows out and the action Potential changes from +35 to - 70mV.

5. The resting potential resumes and this is called repolarization

Other types of action potential in the human body:

1. Cardiac action potential: plays an important role in coordinating the contraction of the heart .The cardiac cells of the sinoatrial node (SA node) provide the pacemaker potential that synchronizes the heart.

2. Muscular action potential: the action potential in a normal skeletal muscle cell is similar to the action potential in neurons. Action potential result from the depolarization of the cell membrane (the sarcolemma) ,which opens voltage –sensitive sodium channels ; these became inactivated and the membrane is repolarized through the outward current of potassium ions.

 Refractory period:

During the time that a patch of axon membrane is producing an action potential, it is incapable of responding – or refractory – to further stimulation. If a second stimulus is applied during the time that an action potential is being produced, the second stimulus will have no effect on the axon membrane .The membrane is thus said to be in a refractory period; it cannot respond to any subsequent stimulus.

 Cable properties of neurons:

The term cable properties refer to the ability of a neuron to transmit changes through its cytoplasm. These cable properties are quite poor because there is a high internal resistance to the spread of changes and because many charges leak out of the axon through its membrane.

Synapses:

Is the functional connection between a neuron and a second cell? In CNS, this other cell is also a neuron. In PNS, this other cell may be a neuron or an effectors cell (gland or muscle).

Synaptic Transmission: is the process whereby one neuron communicates with other neurons or effectors, such as a muscle cell. A typical neuron has a cell body; branching processes specialized to receive incoming signals (dendrites), and a single process (axon) that carries electrical signals away from the neuron toward other neurons or effectors.

Electrical signals carried by **axons** are **action potentials**. Axons often have thousands of terminal branches, each ending as a bulbous enlargement, the **Synaptic knob or Synaptic terminal**. At the synaptic knob, the action potential is converted into a chemical message which, in turn, interacts with the recipient neuron or effectors.

Synapses are junctional complexes between presynaptic membranes (synaptic knobs) and postsynaptic membranes (receptor surfaces of recipient neurons or effectors). The gap between them known as Synaptic cleft. Synaptic knobs contain many membrane-bounded synaptic **vesicles**, 40 to 100 **nanometers** in diameter, contain the **Neurotransmitter**. Synaptic knobs also contain mitochondria, microtubules, and other organelles.

In brief, the impulses transmit from cell to another by 2 ways:

1. Electrical synapses (Gap junctions)

2. Chemical synapses (Neurotransmitters)

Electrical Synapses (Gap junctions)

Gap junctions are a specialized intercellular connection between multitudes of animal cell-types. They directly connect the cytoplasm of two cells, which allows various molecules, ions and electrical impulses to directly pass through a regulated gate between cells. One gap junction channel is composed of two connexons (or hemichannels), which connect across the intercellular space. **Properties include**:

1. The presynaptic and postsynaptic membranes are partially fused. This allows the action potential to cross from the membrane of one neuron to the next without the intervention of a neurotransmitter.

2. Electrical synapses often lack the directional specificity of chemical synapses and may transmit a signal in either direction.

3. Gap junctions present in cardiac muscle, some smooth muscles, between glial cells and various regions in the brain. It is also present in embryonic tissue, but disappears as the tissue became more specialized.

Chemical synapses (Neurotransmitters)

Neurotransmitter include: Acetylcholine, Monoamines, Serotonin, Dopamine, and Norepinephrine, others (Amino acids, polypeptides and Nitric oxide).

Action potentials arriving at synaptic knobs trigger the release of neurotransmitter into the synaptic cleft. Action potentials open calcium channels in the membrane of the synaptic knob, which causes an inward movement of calcium ions. Calcium ions trigger the release of neurotransmitter from synaptic vesicles into the synaptic cleft. The synaptic vesicles fuse with the presynaptic membrane during this process of exocytosis. The membranes of old vesicles become part of the presynaptic membrane and new vesicles pinch off from an adjacent area of membrane. These new vesicles are subsequently refilled with newly synthesized or "recycled".

Once released into the synaptic cleft, neurotransmitters remain active until they are either altered chemically or taken back into the synaptic knob by special carrier systems and recycled. At cholinergic synapses, Acetylcholinesterase is present in the synaptic cleft. This enzyme cleaves the neurotransmitter into acetate and choline, neither of which is active. Serotonin and epinephrine, on the other hand, are taken up into the presynaptic terminal and recycled.