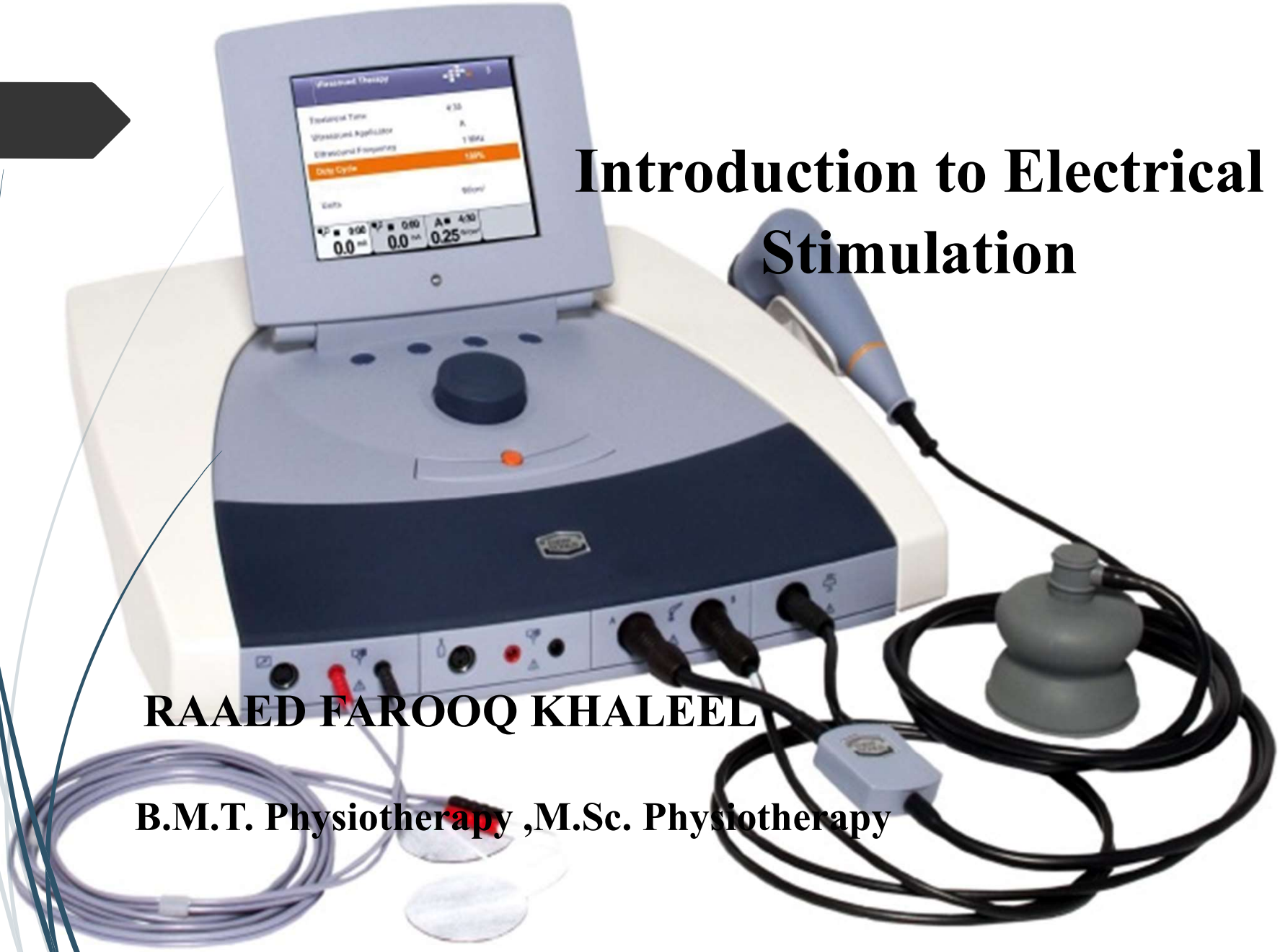
Introduction to Electrical Stimulation



RAAED FAROOQ KHALEEL

B.M.T. Physiotherapy ,M.Sc. Physiotherapy

An **electrical current** is a flow of charged particles. The charged particles may be electrons or ions. Electrical currents have been applied to biological systems to change physiological processes.

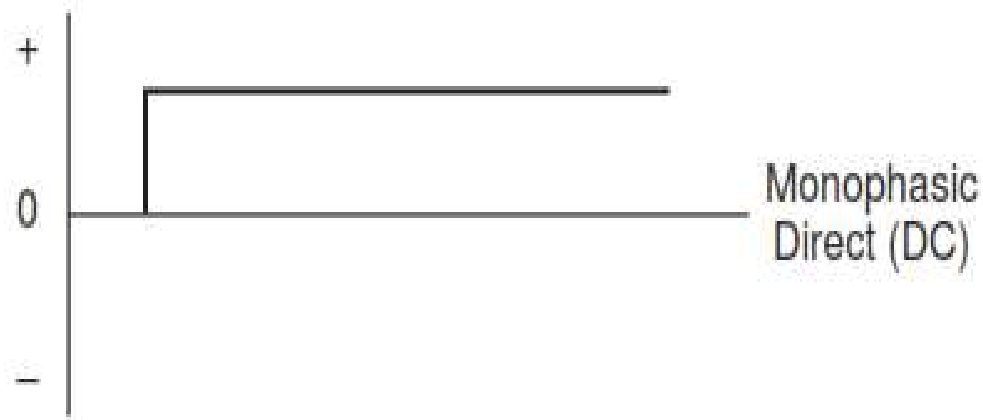
ELECTRICAL CURRENT PARAMETERS

The characteristics of electrical currents can be described as parameters. Following are descriptions and explanations of commonly available and often adjustable electrical current parameters used for clinical electrical stimulation.

WAVEFORMS

Electrical current waveforms can be considered to be of three types: **monophasic or direct current (DC), biphasic or alternating current (AC),** and **pulsatile current (PC)**.

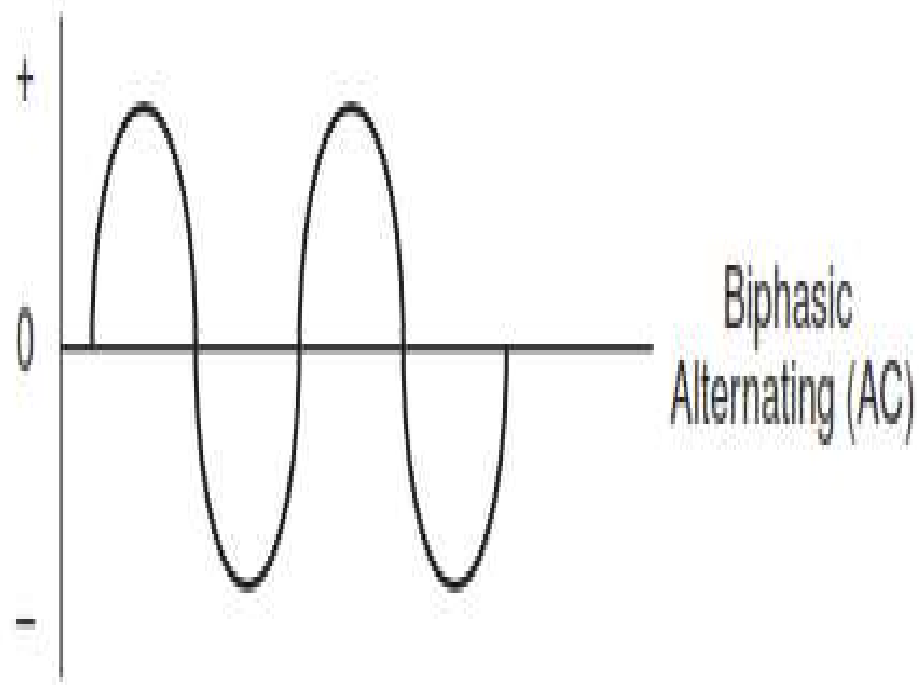
1. **Direct current (DC): -** DC is a **continuous** unidirectional flow of charged particles .On most modern direct current devices, the polarity and thus the direction of current flow can be reversed. It is most commonly used for iontophoresis and for stimulating contractions in denervated muscle.



2. **Alternating current (AC):** - the continuous flow of electrons is bidirectional, constantly changing direction or, stated differently, reversing its polarity.

Electrons flowing in an alternating current always move from the negative to positive pole.

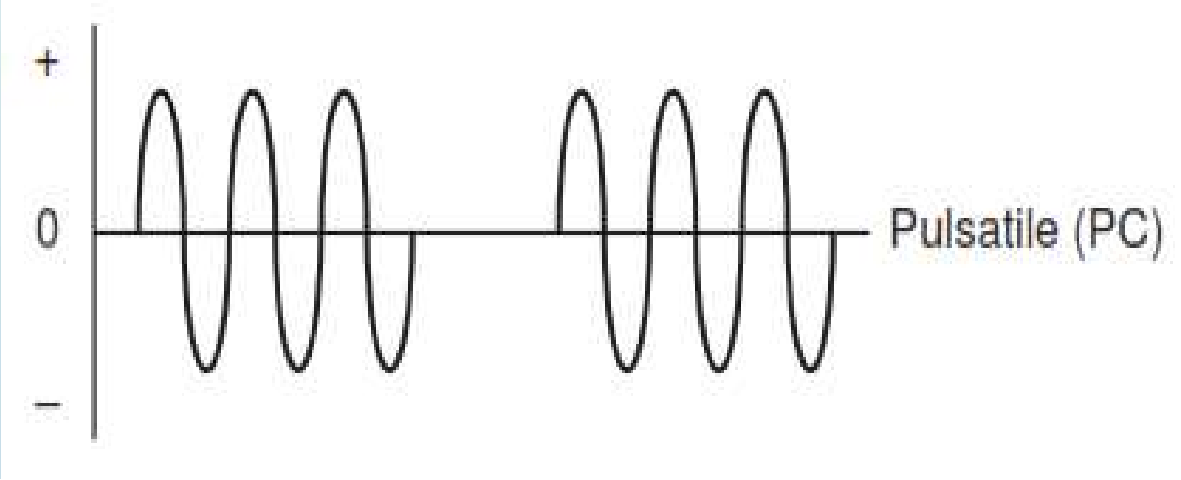
AC can be used for pain control (e.g., interferential) and for muscle contraction (e.g., Russian current).



3. **Pulse currents (PC):-** PC is an interrupted flow of charged particles where the current flows in a series of **pulses** separated by periods where no current flows.

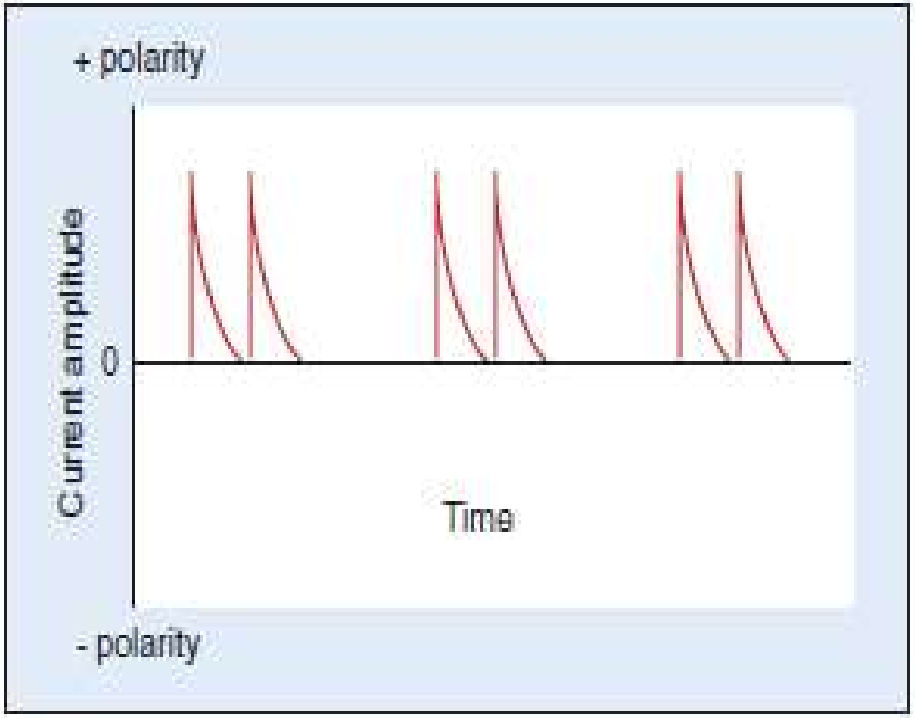
Usually contain three or more pulses grouped together and may be unidirectional or bidirectional.

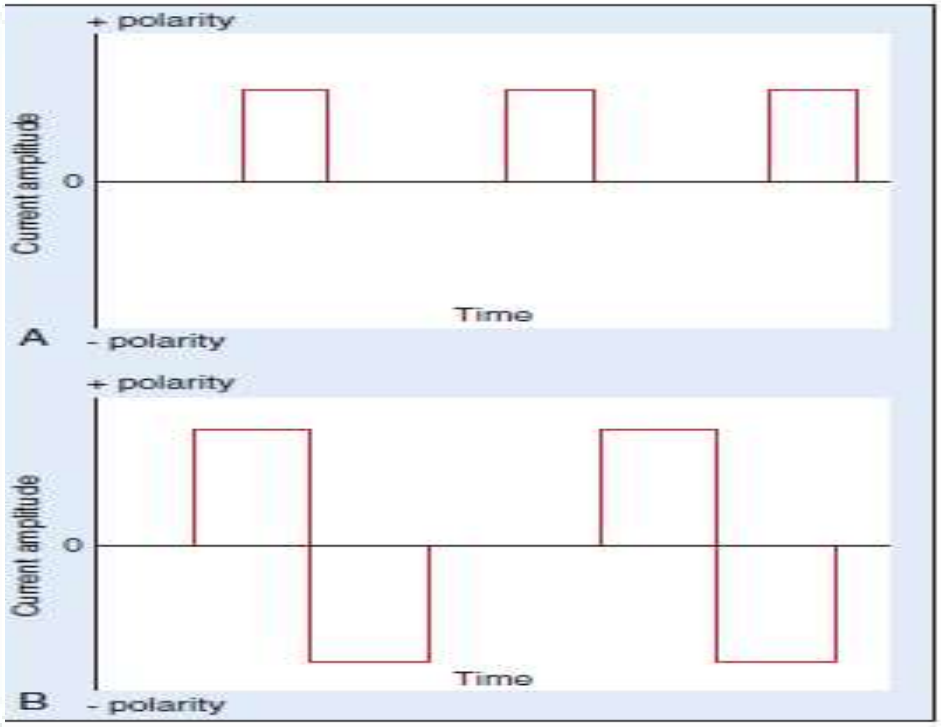
These groups of pulses are interrupted for short periods of time. PC is used in many applications, including pain control, tissue healing, and muscle contraction.



Monophasic pulsed currents: - may be used for any clinical application of electrical stimulation but are most commonly used to promote tissue healing and for acute edema management.

The most commonly encountered monophasic pulsed current is high-volt pulsed current (HVPC), also known as *pulsed galvanic current*.

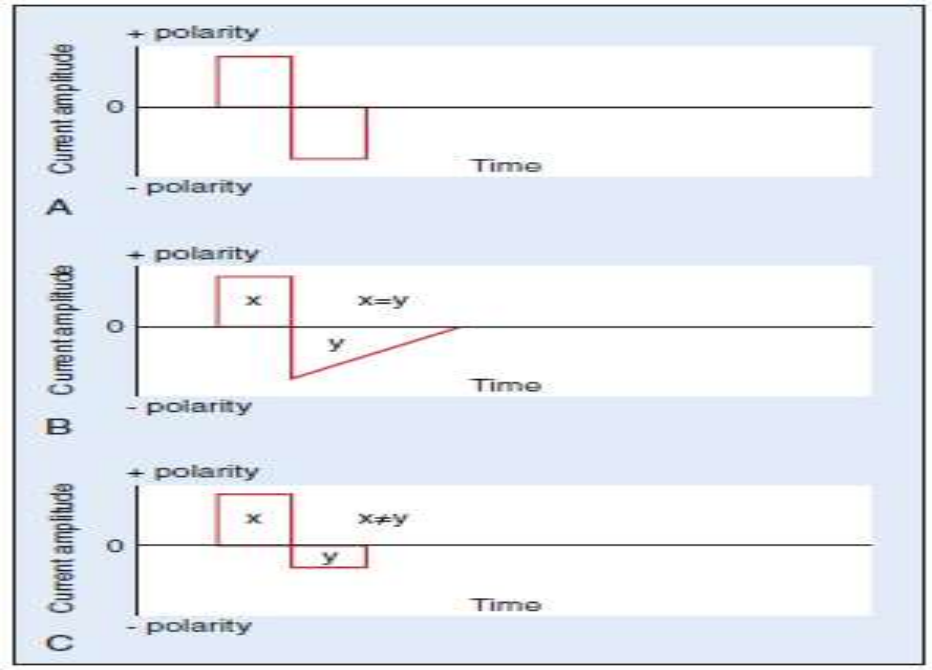




Biphasic pulsed current:- may be symmetrical or asymmetrical, and if asymmetrical, may be balanced or unbalanced.

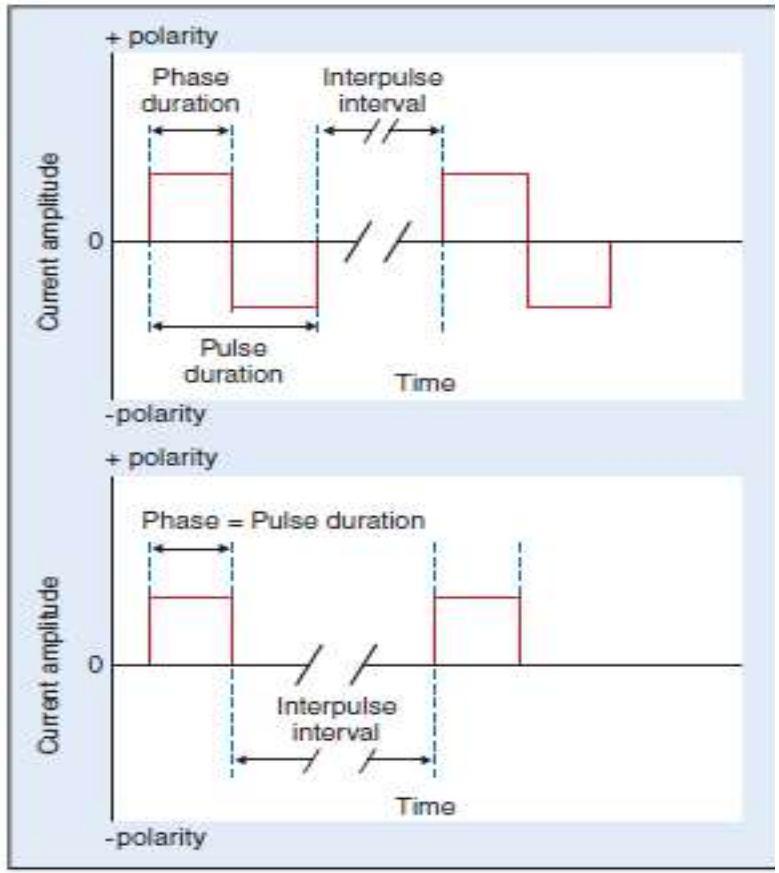
With a symmetrical or a balanced asymmetrical biphasic pulsed current, the charge of the phases are equal in amount and opposite in **polarity**, resulting in a net charge of zero.

With an unbalanced asymmetrical biphasic current, the charge of the phases are not equal, and there is a net charge



TIME-DEPENDENT PARAMETERS

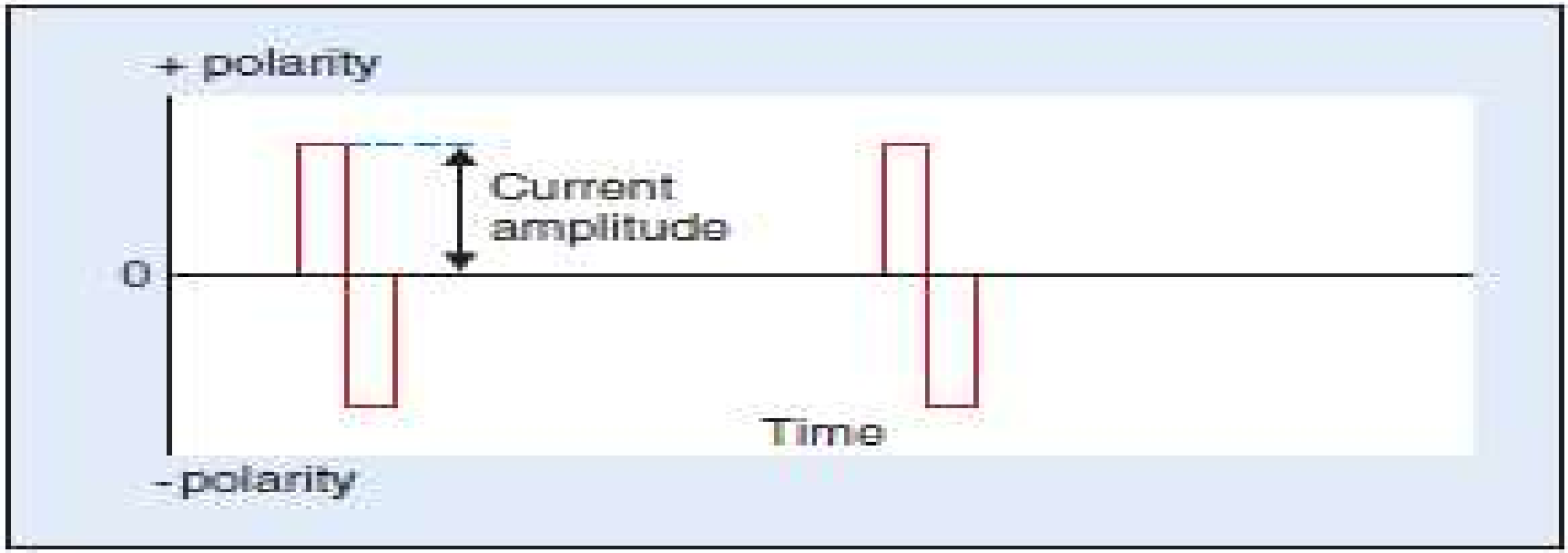
1. **Pulse duration** is how long each pulse lasts (the time from the beginning of the first phase of a pulse to the end of the last phase of a pulse). Pulse duration is usually measured in microseconds (10^{-6} seconds). Shorter pulse durations are usually used for pain control, and longer pulse durations are needed to produce muscle contractions.
2. **Phase duration** is the duration of one phase of the pulse. It is equal to the pulse duration with a monophasic pulsed current and is less than the pulse duration in a biphasic pulsed current. When a pulse is made up of two phases of equal duration, the phase duration is half the pulse duration.
3. **Interpulse interval** is the amount of time between pulses.



OTHER ELECTRICAL CURRENT PARAMETERS

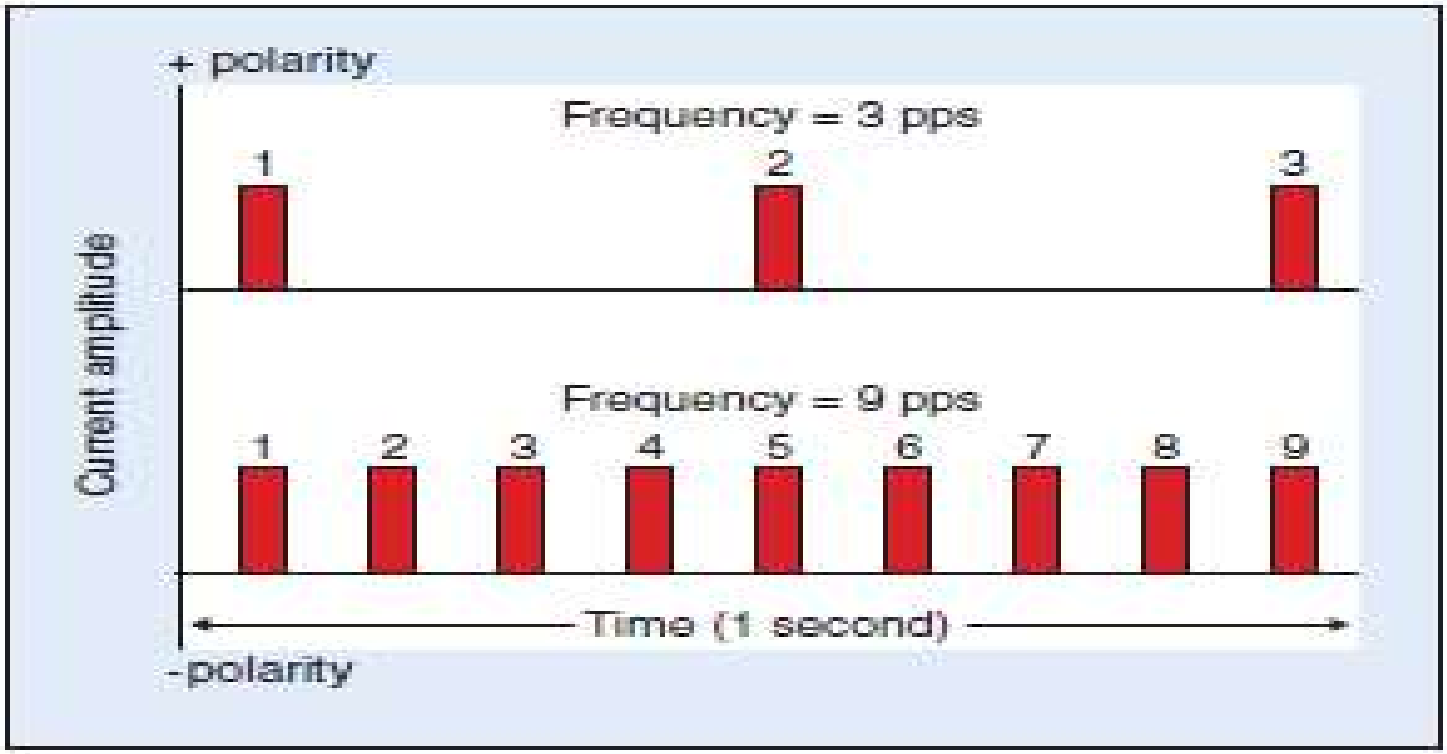
•The **amplitude** is the magnitude of the current or **voltage** and is often also called the “intensity” or the “strength” of the current .

•This parameter is usually controlled by the patient or the therapist and can affect how intense the stimulation feels, as well as what types of nerves are activated by the current.



Frequency is the number of cycles or pulses per second and is measured in Hertz (Hz) or pulses per second (pps).

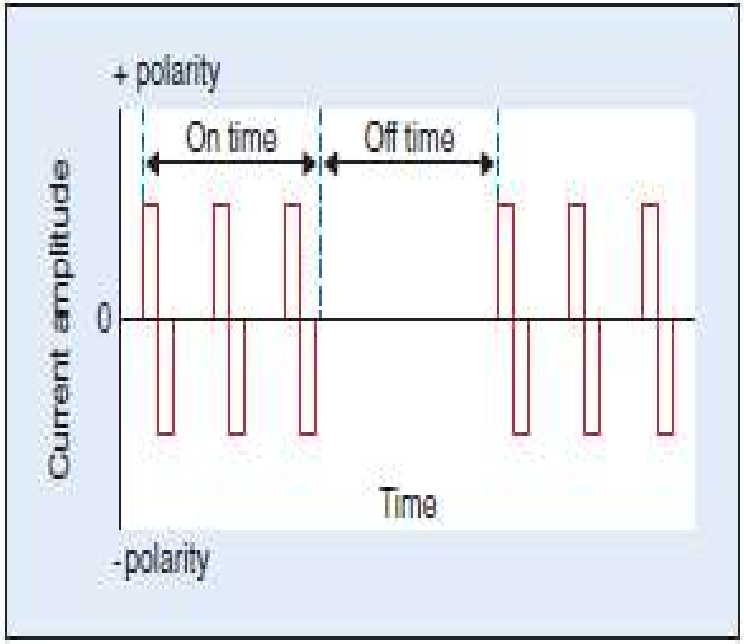
Different frequencies are chosen depending on the goal of the treatment.



The **on time** is the time during which a train of pulses occurs. The **off time** is the time between trains of pulses where no current flows.

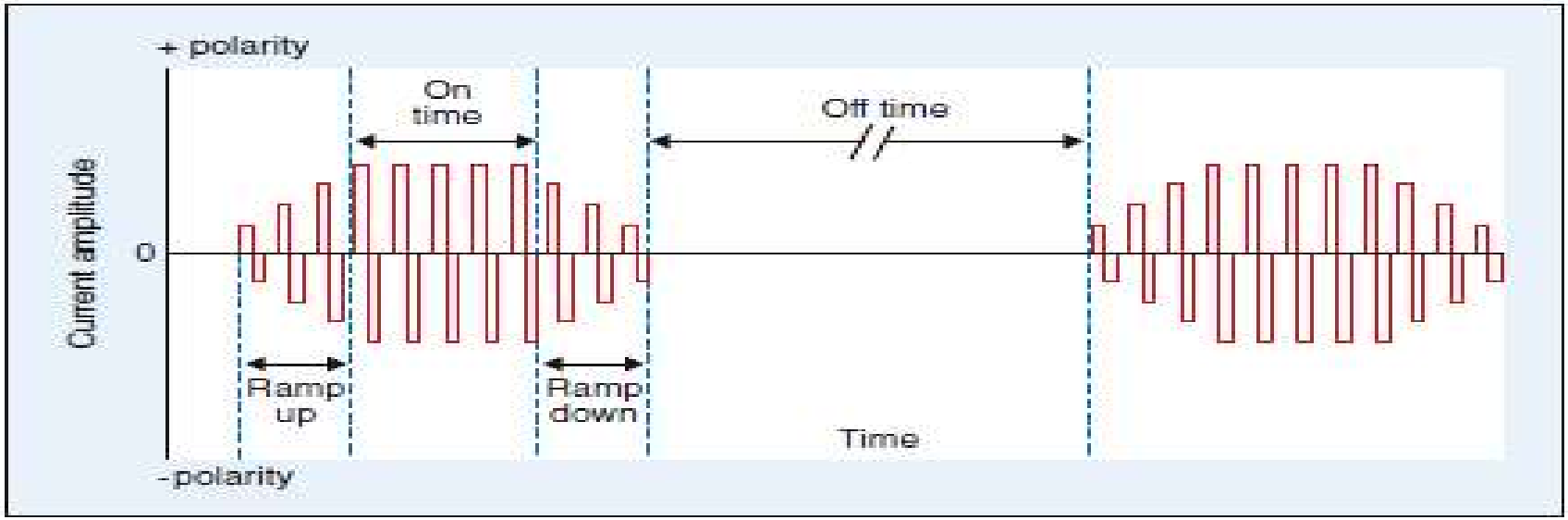
On/Off timers are used when electrical stimulation is used to produce muscle contractions to simulate the voluntary contract and relax phases of normal physiological exercise and to reduce muscle fatigue.

The on time produces the muscle contraction, and the off time allows the muscle to relax.



1. The **ramp up** is the amount of time it takes for the current amplitude to increase from zero during the off time to its maximum amplitude during the on time.

2. The **ramp down** is the time it takes for the current amplitude to decrease from its maximum amplitude during the on time to zero during the off time. Ramps are used to improve patient comfort when electrical currents are used



EFFECTS OF ELECTRICAL CURRENTS

- **STIMULATION OF ACTION POTENTIALSIN NERVES**

Electrical currents exert their physiological effects by depolarizing nerve membranes, thereby producing action potentials, the message unit of the nervous system.

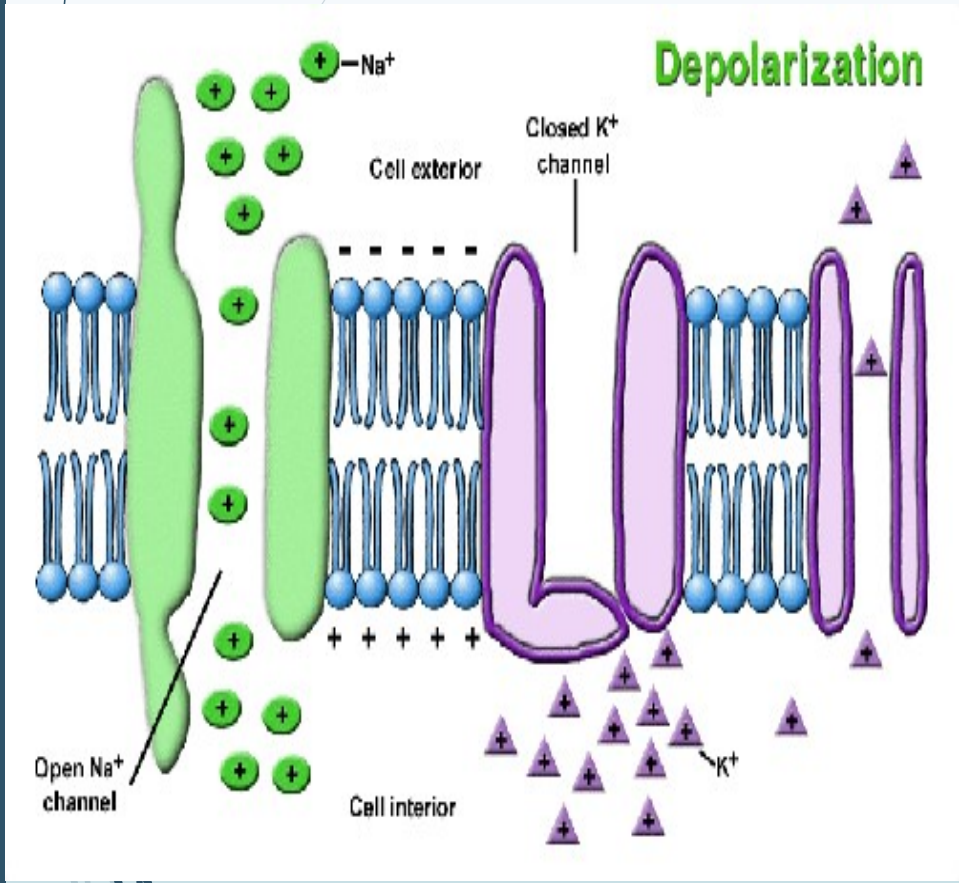
Electrical currents with sufficient amplitude that last for a sufficient length of time will cause enough of a change in nerve membrane potential to generate an **Action Potential**.

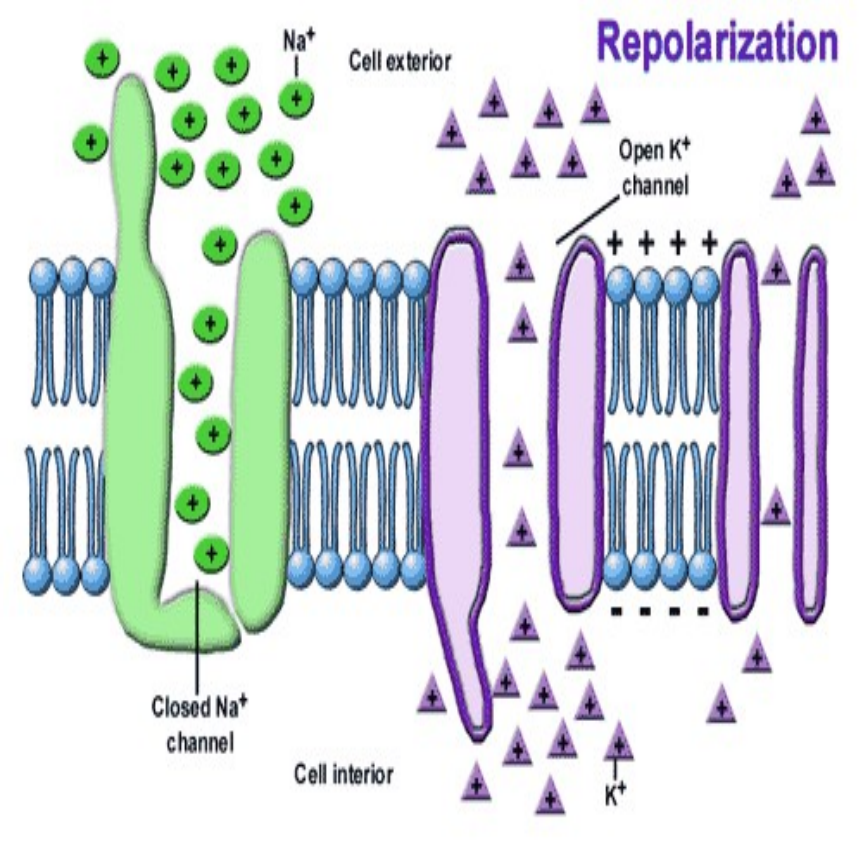
Resting Membrane Potential:-When a nerve is at rest, without physiological or electrical stimulation, the inside is more negatively charged than the outside by -60 to -90 mV.

- The resting membrane potential is maintained by having more sodium ions outside the cell and fewer potassium ions inside the cell, making the inside negative relative to the outside.

- When a sufficient stimulus is applied, sodium channels in the cell membrane open rapidly, whereas potassium channels open slowly.

- Because of the high extracellular concentration of sodium, sodium ions rush into the cell through the open channels.
- This makes the inside of the cell more positively charged, reversing the membrane potential.
- When the membrane potential reaches +30 mV, the permeability to sodium decreases and potassium channels rapidly open, increasing the permeability to potassium.
- Because the intracellular concentration of potassium ions is high, potassium ions then flow out of the cell, returning the membrane polarization to its resting state of -60 to -90 mV.
- This sequential depolarization and repolarization of the cell membrane caused by the changing flow of ions across the cell membrane is the AP .


Depolarization
Na+
Cell exterior
Closed K+ channel
Open Na+ channel
Cell interior
K+


Repolarization
Na+
Cell exterior
Open K+ channel
Closed Na+ channel
Cell interior
K+

Action Potential Propagation

Once an Action Potential is generated it triggers an Action Potential in the adjacent area of the nerve membrane.

This process is called propagation or conduction of the Action Potential along the neuron.

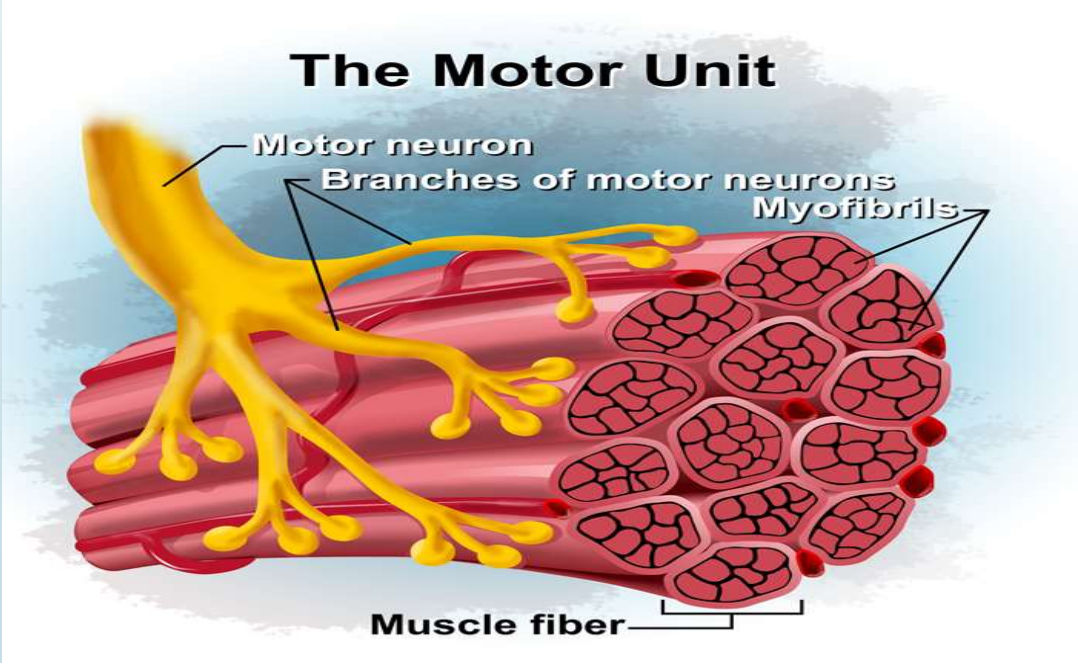
With physiological stimulation, Action Potential propagation occurs in only one direction.

With electrically stimulated APs, propagation occurs in both directions from the site of stimulation.

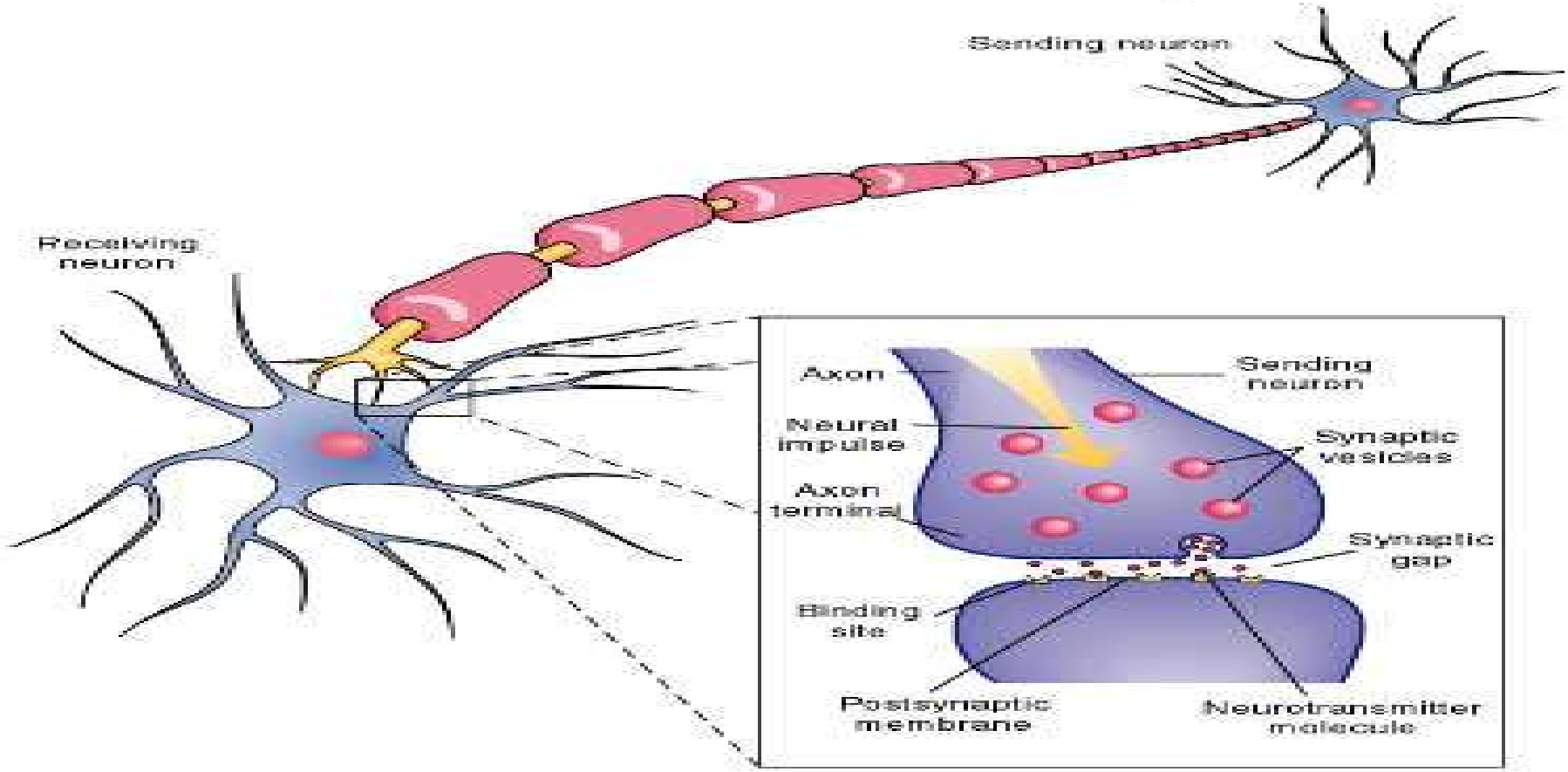
Motor Unit

A **motor unit** is made up of a motor neuron and the skeletal muscle fibers innervated by that motor neuron's axonal terminals.

Groups of motor units often work together to coordinate the contractions of a single muscle ; all of the motor units within a muscle are considered a motor pool .



Neurotransmitters and the Synapse



The neurotransmitter is released into the synaptic gap. There it may bind with receptors on the postsynaptic membrane.

ACCOMODATION

The nerve and muscle tissue possess the property to adapt to slowly increasing intensities

This cause a decrease of excitability of the membrane, and thus requiring more intensity of stimulating current

Nerve fiber has high accommodation rate.

	Positive pole(anode)		negative pole(cathode)
1	attract negative ions ,oxygen	1	attract positive ions ,hydrogen
2	acid	2	alkaline
3	dehydrates tissues	3	liquefies tissues
4	vasoconstrictor	4	vasodilator
5	cause ischemia	5	cause hyperemia
6	stop bleeding	6	cause bleeding
7	more germicidal	7	less germicidal
8	sedative	8	stimulant
9	relieve pain in congestion	9	cause pain
10	corrodes metals by oxidation	10	do not corrodes metals
11	repels bases ,metals, alkaloids	11	Repels acid ,acid radicals ,halogens

Refrences

1. **Clayton's Electrotherapy (Physiotherapy Essentials) Paperback – Import, 24 Nov 1995 by Sheila Kitchen MSc PhD DipTP MCSP Professor (Author), Sarah Bazin MCSP (Author)**
2. **Physical Agents : Theory and Practice**,3rd Edition ,**Barbara J. Behrens** PTA, MS ,**Holly Beinert** PT, MPT
3. **Physical Agents in Rehabilitation: *From Research to Practice* ,Fourth Edition,** by Michelle H. Cameron, MD, PT, OCS
4. **Therapeutic Modalities For Sports Medicine and Athletic Training**, Sixth Edition by William E. Prentice , Ph.D., A.T.C., P.T.
5. **Textbook of Electrotherapy Kindle Edition by Singh Jagmohan (Author)**
6. **Practical Electrotherapy: A Guide to Safe Application ,by** John Fox and Tim Sharp**,** 2007