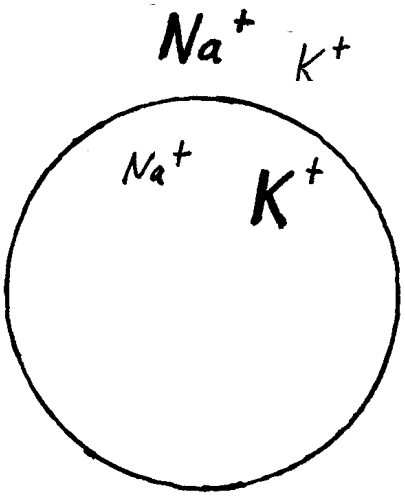
Neurophysiology

Resting membrane potential (Vr) - The resting membrane potential is a measurement of the voltage across a cell membrane. In this case a neuron. Usually, we will see a reading of approximately -70 mv. Note that the minus sign indicates that the inside of the cell, (cytoplasmic side of the membrane) is more negative than the extracellular side of the membrane.

The resting membrane potential varies from -40 mV, to -90 mV, depending on the neuron type.



All of this is due to differential permeability.

Remember that the membrane is slightly permeable to Na^+, and highly permeable to K^+ (75X higher than Na^+).

This means that K^+ diffuses out of the cell along its concentration gradient, faster than Na^+ can enter, along its concentration gradient. This results in more + ions moving out than in. This causes the inside of the cell to become negative compared to the outside.

To ensure that the two concentrations never reach equilibrium we utilize a sodium-potassium pump. This system removes 3 sodium ions from the cell and transports 2 potassium ions back in. Note that this requires ATP, (energy).

Membrane potentials are used to convey signals. Generally, there are two types of signals, 1) graded (short distance) and 2) action (long distance).

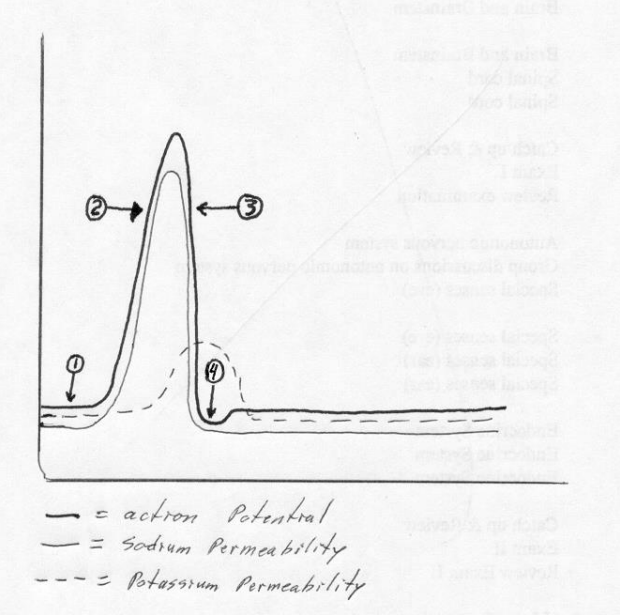
Graded potentials - are short lived local changes in membrane potential. They can be either depolarizations or hyperpolarizations. Here we see current flows which decrease with the distance traveled.

Action potentials - are found in cells with excitable membranes, such as neurons and muscle cells. Here we see a complete reversal of membrane potential with a total change of 100 mV (from -70 mV to 30 mV). This happens in a few milliseconds and, unlike graded potentials, does not decrease over distance.

Depolarization - a reduction in membrane potential. Here the inside of the cell becomes less negative (closer to zero) than the resting potential. On occasion this membrane potential can reverse and become greater than zero. Generally, this increases the probability of producing a nerve impulse.

Hyperpolarization – the membrane potential increases (becomes more negative) than the resting potential. Generally, this decreases the probability of producing a nerve impulse.

Threshold and the all or none phenomenon



1. resting phase: all Na^+ and K^+ gates are closed

2. depolarizing phase: Na^+ gates open

3. repolarizing phase: Na^+ gates closing, K^+ gates opening

4. undershoot: K^+ gates still open, Na^+ gates closed, Na+ inactivation gate is opening.

Not all local depolarizations produce action potentials. The depolarization must reach threshold levels if the axon is to "fire." We believe that this is due to an exchange of Na^+ and K^+ ions across the cell membrane and occurs when the outward current carried by K^+ is exactly equal to the inward current of Na^+. Usually this is seen when the membrane has a depolarization change of 15 - 20 mV.

The action potential is an all or none phenomenon. It is dependent upon the strength and duration of the stimulus. (like a match to a twig).

Once initiated all action potentials are alike. How can the CNS determine whether a stimulus was intense or weak? Strong stimuli cause nerve impulses to be generated more often in a given time interval. Stimulus intensity is coded for by the frequency of impulse transmissions.

Refractory periods

Absolute refractory period - the period from the opening of the voltage gated Na^+ channels to the closing of the sodium inactivation gates. **No** new action potential can be generated during this time.

Relative refractory period - sodium gates are closed and most have returned to their resting state. Potassium gates are open and repolarization is occurring.

Conduction Velocities

Conduction velocities of neurons vary greatly and are usually associated with the axon's anatomical function. Where speed is essential, such as in postural reflexes, we see fast conduction neurons (approx. 100 m/s). Slow conducting neurons are generally found in areas where speed is not essential, such as in the gut, glands, & blood vessels.

Conduction velocity generally depends on two factors:

1. axon diameter - in general, the larger the axon diameter the faster the conduction velocities.
2. myelination - the presence of a myelin sheath greatly increases the rate of impulse propagation because myelin acts as an insulator to prevent almost all leakage of charge from the axon. The myelination is caused by cells wrapped around the axon. These cells are called neurolemmocytes, or Schwann cells. Adjacent neurolemmocytes do not actually touch each other, so there are bare areas along the axon. These areas are known as axonal nodes, or nodes of Ranvier. In a myelinated axon, the charge appears to jump along the axon from node to node. This is referred to as saltatory conduction.

Multiple sclerosis is an autoimmune disease that demyelinates axons. The myelin sheath is gradually reduced to nonfunctional hardened sheaths called scleroses. This slows down the conduction impulse. Once the sclerotic plaques become extensive enough, conduction in that axon may be completely blocked. Note that in multiple sclerosis, the axons themselves are not damaged.

Axons terminate by forming a synapse with another neuron, with a muscle, or with a gland. When an axon synapses with another neuron, a neurotransmitter is released and the impulse will be passed to that second neuron. An axon that terminates at a muscle, forms a synapse known as a neuromuscular junction. At this junction, neurotransmitter is released into the synaptic cleft to bind to receptors on the muscle cell at the motor end plate. This will cause the muscle cell to contract. If an axon terminates on a gland, neurotransmitter is released that will bind to receptors on the gland, and the gland will secrete its glandular product.

A review of various synapses can be found in the neurohistology lecture.

There are over 50 neurotransmitters in the human body. These can be classified according to structure or function:

1. structure.

    a. acetylcholine – the first neurotransmitter to be identified. Found at neuromuscular junctions and in the CNS.

    b. biogenic amines.

        1. catecholamines.
            dopamine, epinephrine, norepinephrine.
        2. indolamines.
            seratonin, histamine.

    c. amino acids.

        GABA, glycine, aspartate, glutamate.

    d. peptides.

        substance P, endorphins, enkephalins.

    e. novel messengers.
        ATP, nitric oxide, carbon monoxide.

2. function.

    a. excitatory.

b. inhibitory.

Note that some neurotransmitters can be excitatory in one location yet inhibitory in another. A well-known example is Ach. Ach is excitatory at the neuromuscular junction with skeletal muscle, yet is inhibitory on cardiac muscle.