Excitable tissue

What are the excitable tissue?

Electrical potentials exist across the membranes of virtually all cells of the body. Some cells, such as nerve and muscle cells, generate electrical impulses at their membranes when excited that transmit along the nerve or muscle membranes. These tissues are called **excitable** tissues.

Resting membrane potential

The resting membrane potential of a cell is defined as the electrical potential difference across the plasma membrane when that cell is in a non-excited state.

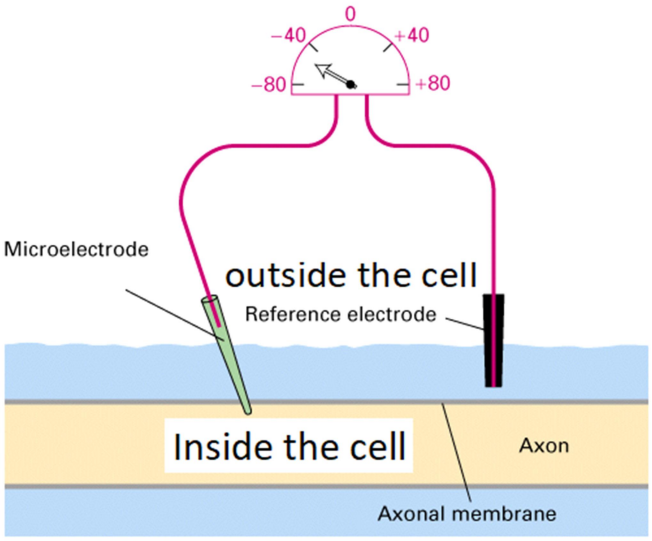


Figure: resting membrane potential

The resting membrane potential (RMP) range from -70 up to -90 mv(the potential inside the cells is 70 up to 90 mV more negative than the potential of the outside) this is due to build-up of negative charges inside the cells (excess K^+ & organic phosphates + proteins inside the cell) and an equal build-up of positive charges outside the cells (excess Na^+ and Cl^- ions out side the cell). RMP in Neuron = -70Mv and in Skeletal and cardiac muscle fibers = -90mV .

Factors contributing to RMP

- One of the main factors is K+ efflux.
- Contribution of Na influx is little .
- Na/K pump causes more negativity inside the membrane.
- Negatively charged protein ions remaining inside the membrane contributes to the negativity.

Action potentials

The membrane permeability of excitable cells can change in a fraction of a millisecond, as a result of activation of ion channels mainly Na^+ channels and K^+ channels leading to initiation of action potentials(AP) that propagated along the neighboring cell membranes. During the action potential the charge inside and outside the membrane reversed (depolarization) for short period then return to the resting state (repolarization), accordingly AP consist of 2 main phase:

1.Depolarization phase ,rapid opening of Na+ voltage-gated channels leads to Na+ inflow.

2. repolarization phase, rapid opening of K+ voltage-gated channels leads to K+ outflow.causes the resting membrane potential to be restored = (MP = -70mV)

Note : hyperpolarization, While the voltage-gated K^+ channels are open, a large enough outflow of K^+ may lead to after-hyperpolarization (Polarization more negative than the resting level (about -90mV) .

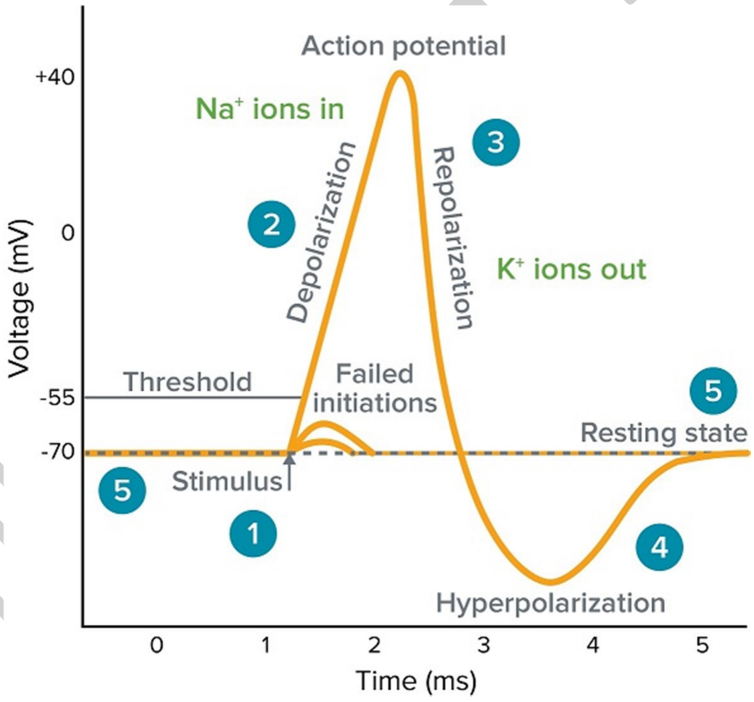


Figure: Action potential.

Refractory period

Refractory period is the period when excitable cells cannot generate another action potential when excited. There are two types of refractory periods:

- Absolute refractory period, refers to the time period during which a 2nd action potential cannot be initiated, even with a very strong stimulus.
- Relative refractory period, refers to the time period during which a 2nd action potential can be initiated, but only with a larger than threshold stimulus (supra threshold).

Propagation of action potential

An action potential elicited at any one point on an excitable membrane will excites adjacent portion of the membrane, resulting in propagation (conduction) of the action potential along the nerve or muscle cell. In the neuron an action potential (nerve impulse) carry information along the neuron to the central nervous system(sensory fiber) or they conduct signals from central nervous system to the periphery(motor fiber). In the muscle cell the action potential spread all over the muscle to initiate muscle contraction required for all our movement and activities.

The duration of action potential in skeletal muscle and neuron is about (5 msec) and it is actively transmitted along the nerve or muscle fiber.

Velocity of AP conduction

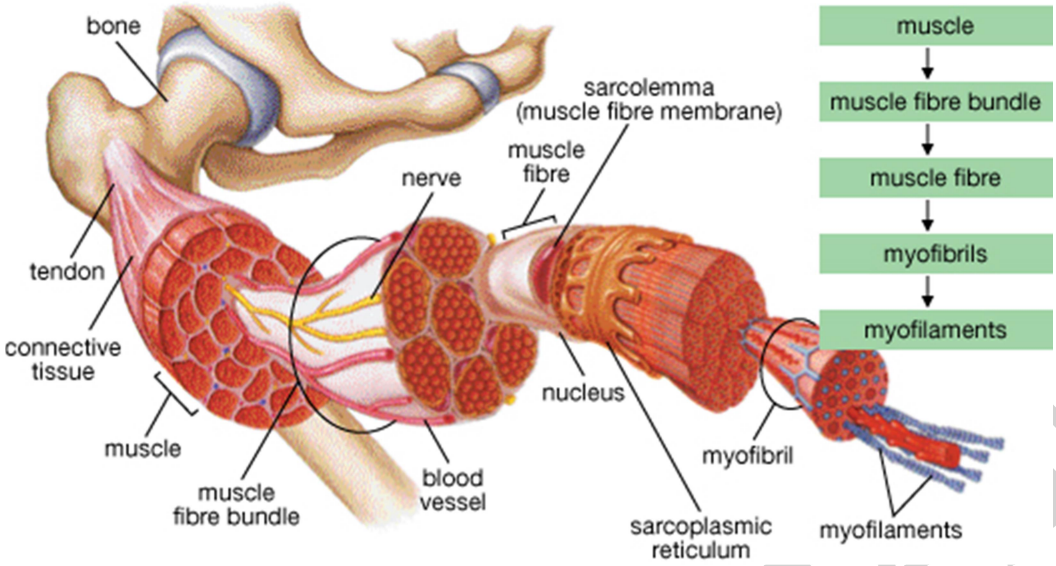
The speeds of AP conduction along nerve fiber range from 1 to 100 meters per second, depending on the properties of the fiber and its environment. In nerve cell the velocity of conduction depend on:

1.myelination, myelinated fibers had high velocity than non-myelinated nerve fiber.

2. **diameter of nerve fiber,** the larger the diameter the more the velocity of conduction of impulses.

Structure of Skeletal Muscle

Each skeletal muscle made of a number of fascicles(bundle of muscle fiber) and each bundle contain a number of muscle fibers(muscle cell) within each muscle cell there are a large number of myofibrils .The myofibrils in turn consist of a large number of myofilament .These myofilaments arrange in the form of building and functional structure called sarcomere. The sarcomere consist a number of contractile filaments called the actin and myosin which produce the muscle contraction and relaxation.



skeletal muscle cell

The plasma membrane of skeletal muscle cell, called the sarcolemma,the cytoplasm, called sarcoplasm.The cell is occupied mainly by long protein bundles called **myofibrils** about 1 µm in diameter. The (endoplasmic reticulum) **sarcoplasmic reticulum** of skeletal muscles form a network of membranous channels, that extends throughout the cytoplasm of the fiber. The **sarcolemma**(cell membrane) that surround muscle fiber send into cytoplasm of muscle fiber a system of **transverse tubules** (T tubules) where they come into contact with expanded portions of the sarcoplasmic reticulum. The expanded portions of the sarcoplasmic reticulum contain calcium ions (Ca^{2+}), which are essential for muscle contraction.

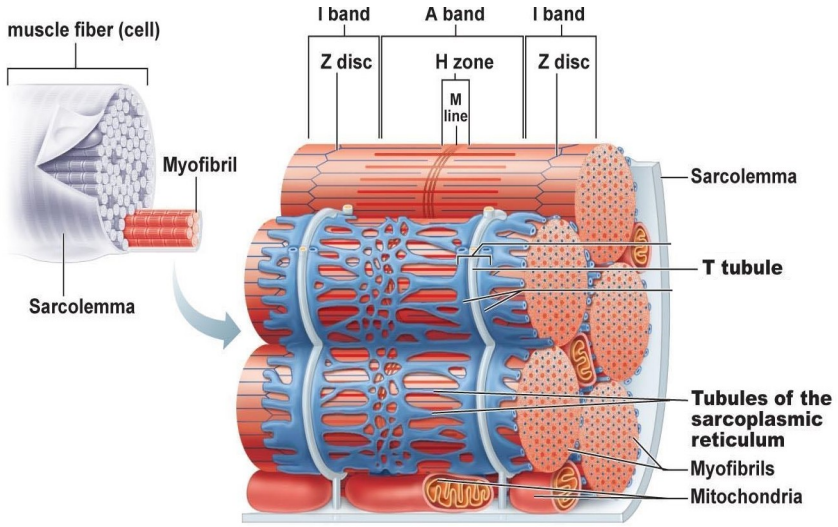


Figure:muscle cell

SYNAPTIC TRANSMISSION

Synapse

Synapse, also called **neuronal junction**, the site of transmission of electric nerve impulses between two nerve cells (neurons) or between a neuron and a gland or muscle cell (effector). A synaptic connection between a neuron and a muscle cell is called a neuromuscular junction.

Types of synapses

There are two types of synapses:

1. Electrical synapses occur where two cells are joined by gap junctions, which conduct current from cell-to-cell via nonselective pores.
2. Chemical synapses involve the release of a chemical transmitter by one cell that acts upon another cell. Chemical synapses have the following functional characteristics:

- Presynaptic terminals contain neurotransmitter chemicals stored in vesicles.
- Synaptic cleft is a space between two neurons.
- Post synaptic neuron

Action potentials in a presynaptic cell cause the release of the chemical transmitter, which crosses a narrow cleft to interact with specific receptors on a postsynaptic cell. Excitatory neurotransmitters produce an excitatory postsynaptic potential. Inhibitory neurotransmitters produce an inhibitory postsynaptic potential.

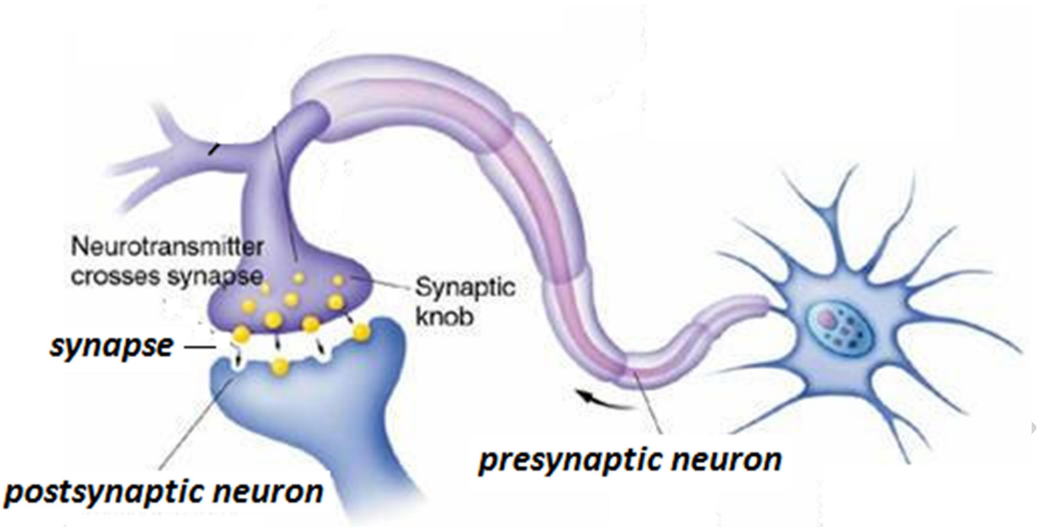


Figure: synapse.

The Neuromuscular Junction

The skeletal-muscle fiber are voluntary muscles supplied by motor neuron. Upon reaching a muscle, the axon of a motor neuron loss their myelin sheath and divides into many branches, each branch forming a single junction with a muscle fiber. The junction of motor neuron and the muscle fibers called the neuromuscular junction. When an action potential in a motor neuron arrives at the axon terminal, it cause releasing of acetylcholine (Ach) which bind muscle plasma membrane leading to opening of sodium channels and producing an action potential on muscle membrane that propagation to all part of muscle fiber by T-tubules and initiate muscle contraction(Excitation-contraction coupling).

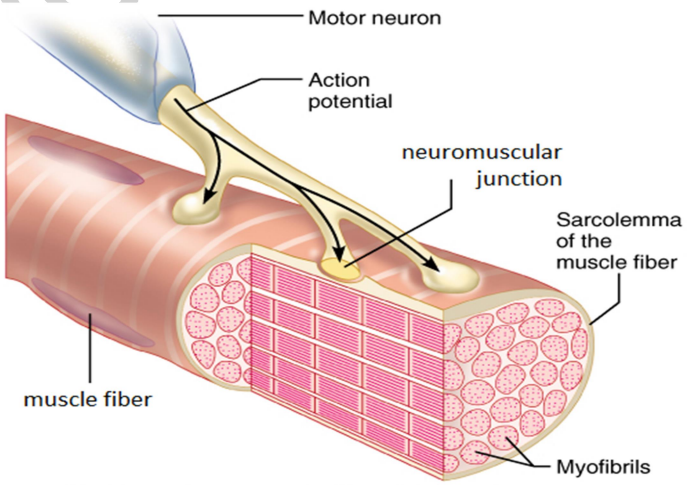


Figure: Neuromuscular Junction

Excitation-contraction coupling

The stimulus for skeletal muscle contraction is the action potentials developed in neuromuscular junction in response to motor nerve impulses. The action potentials carried by T tubules which extend deep into the cell to form blind-ended tubes containing extracellular fluid. These blind end are in close contact with sarcoplasmic reticulum that surrounded the myofibrilis and contain Ca2+. Action potentials in T tubules induce Ca2+ release from the sarcoplasmic reticulum. Ca2+ ion bind with tropomyosin as a result tropomyosin shift their position, and myosin binding sites are exposed to actin. The heads of a myosin filament have ATPase enzymes, which act to split ATP into ADP and P. The energy released by ATP causes binding of actin and myosin by cross-bridges that pulls the thin filaments actin toward the middle of the sarcomere. The cross-bridge is then broken and new cycle begins again; the actin filaments move nearer the center of the sarcomere each time the cycle is repeated. Contraction continues until nerve impulses cease and calcium ions are returned to their storage sites in the sarcoplasmic reticulum by Ca2+-ATPases of sarcoplasmic reticulum.