Chapter 8
Nervous Tissue

The neuron is the functional and the structural unit of the nervous system. It displays two highly developed physiological traits:

1. Irritability - the capacity to generate a nervous impulse in response to various stimuli.
2. Conductivity - the ability to transmit these impulses along it's cellular processes.

Neurons allow for communication between the CNS and the rest of the body via the PNS. Nerve tissue also includes a class of nonneuronal cells called the Supporting Cells. Supporting cells assist the neurons in their functioning.

8.1. The Structure of a Neuron

The neuron is composed of three integral parts: the Perikaryon or nerve cell body, one or more Dendrites, Dendrites are, typically, receptive structures. Normally they will respond to a stimulus and conduct an impulse towards the perikaryon. Dendrites are branching structures having numerous secondary processes. and usually one Axon. Axons typically send information out from the axon towards another cell. Axons rarely branch along their length. In some cases one or even two branches may arise from the axon. These are called Axon Collaterals. Axon collaterals always branch at a right angle to the axon. At the end of the axon, near the site of synapse, there will be small branches radiating off from the end of the axon. This is termed the Telodendria.

Each branch of the telodenria is short and will end in a swollen knob called an Axon Terminal, Axonal Buoton, or End Bulb. The end bulb will be in contact with the cell that the axon is communicating with.

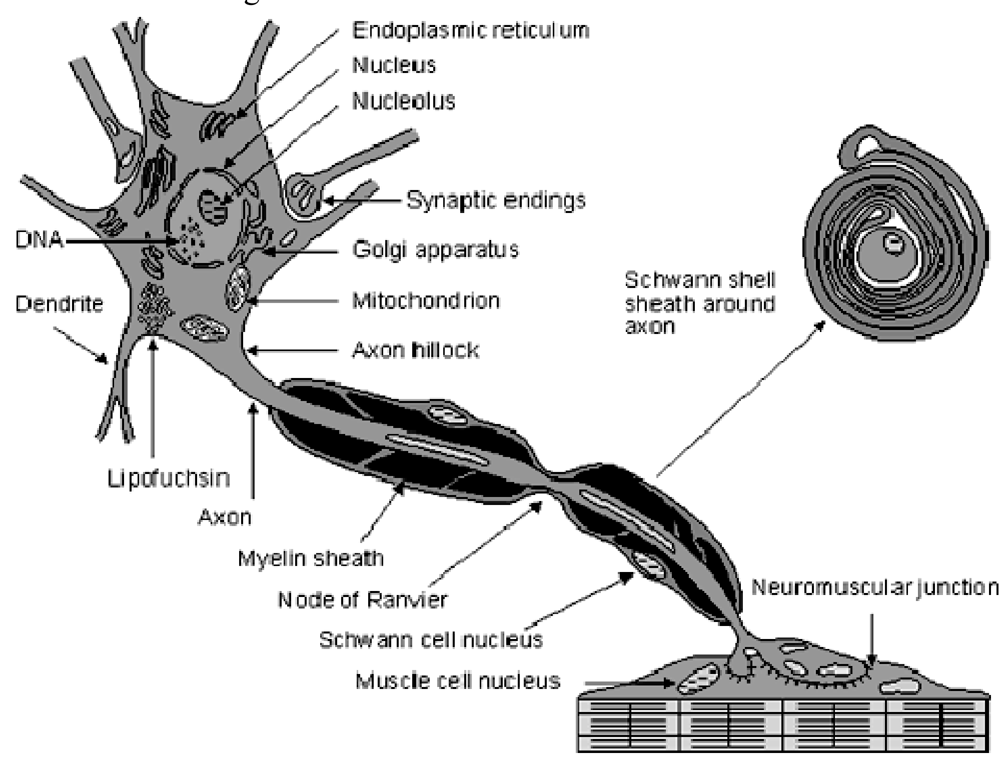

Fig.8.1. Structure of a motor neuron

8.2. Types of Neurons

Histologically neurons are classified based on the number of processes radiating from the perikaryon:

1. Unipolar Neurons (aka, pseudounipolar neurons) - these neurons have a single radiating process. Unipolar neurons are at their greatest numbers in the embryo before they develop into bipolar or multipolar neurons. In the adult, unipolar neurons are much less common and occur primarily in the sensory ganglia.
2. Bipolar Neurons - these neurons have two processes, one dendrite and one axon. Bipolar neurons are a rare class of neurons. They are found in places such as the olfactory mucosa, retina, and the inner ear where they serve a sensory role.
3. Multipolar Neurons - these neurons have three or more radiating processes, typically with one axon and two or more dendrites. These are by far the most numerous class of neuron. Multipolar neurons serve motor, sensory, and integration roles.

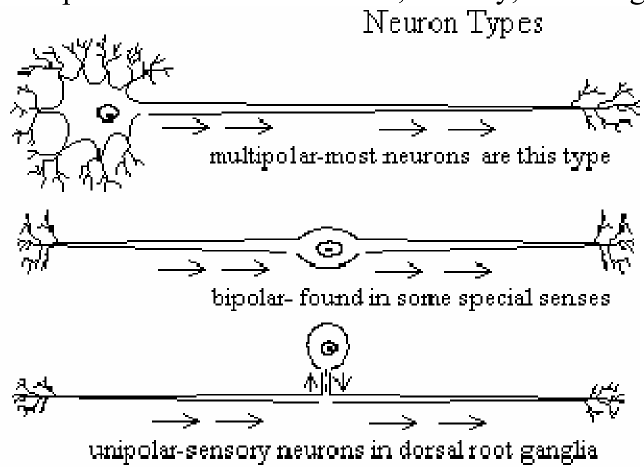

Fig.8.2. Types of Neurons

8.3. The Components of the Neuron

Although the shape of the perikaryon will vary between the various neurons, it will characteristically contain: a large, spherical nucleus having a prominent nucleolus, a well developed perinuclear Golgi complex, and many mitochondria scattered throughout the cytosol. Mitochondria are also scattered in the dendrites and axons. Neurons also have specialized intermediate filaments called Neurofilaments. These neurofilaments are organized into bundles to make up Neurofibrils which are visible in the cytoplasm. The neurofibrils are believed to give strength and resiliency to the neuron and it's processes as well as to play a role in the movement of neurotransmitters through the cell (i.e.; axonal transport). Endoplasmic reticuli are also present. SER is located throughout the neuron. RER is confined to the perikaryon and the dendrites. RER odes not extend into the axon beyond it's point of origin, the

8.3.1. Axonal Hillock.

As a result, the axon is dependent on the perikaryon for protein synthesis. These proteins are conveyed throughout the length of the axon by axonal transport. RER appears under the light microscope as clumps of darkly staining basophilic material called Chromatophilic Bodies or Nissl Bodies. The neuron also has cytoplasmic inclusions including:fat droplets, pigments, lipofuscin which is abundant in ganglionic neurons, melanin which is abundant in certain CNS neurons, glycogen is present **only** in the embryonic neuron. In the adult neuron there is a high dependency on oxidative metabolism and limited anaerobic capacity.

8.3.2. The Synapse

The synapse is the point of transfer of the impulse from one neuron to another cell, typically another neuron. Usually the synapse is between a presynaptic axon and a postsynaptic neuron (an axodendritic synapse) but not always. The synapse is where the Synaptic Transmission occurs. There are two physiological types of synapses: chemical synapses and electrical synapses. The impulse is electrical in nature. In a chemical synapse the electrical information of the impulse is converted into a chemical message and then converted back into an electrical impulse so as to cross the space between the two cells. The space between two synapsing cells is called the Synaptic Cleft. In an electrical synapse the electrical impulse simply jumps the synaptic cleft and continues along in the postsynaptic neuron.

a) The Chemical Synapse: Within the axon terminal are spherical, membrane-bound structures containing neurotransmitters called Synaptic Vesicles. During synaptic transmission the synaptic vesicles will be stimulated by the impulse to fuse with the axon membrane and release their chemicals into the synaptic cleft. The presence of synaptic vesicles on only one side of the synaptic cleft explains the unidirectional flow of information at a chemical synapse. The neurotransmitters will diffuse across the synaptic cleft and attach to receptor proteins on the dendritic membrane. These receptor proteins are attached to ion gateways which will open when the neurotransmitter has bound to the receptor protein. The opening of these ion channels will initiate and propagate a wave of depolarization which will conduct the generate and conduct the electrical impulse. Chemical synapses occur extensively in both the PNS and CNS. Ex; the neuromuscular junction where the neurotransmitter is acetylcholine.

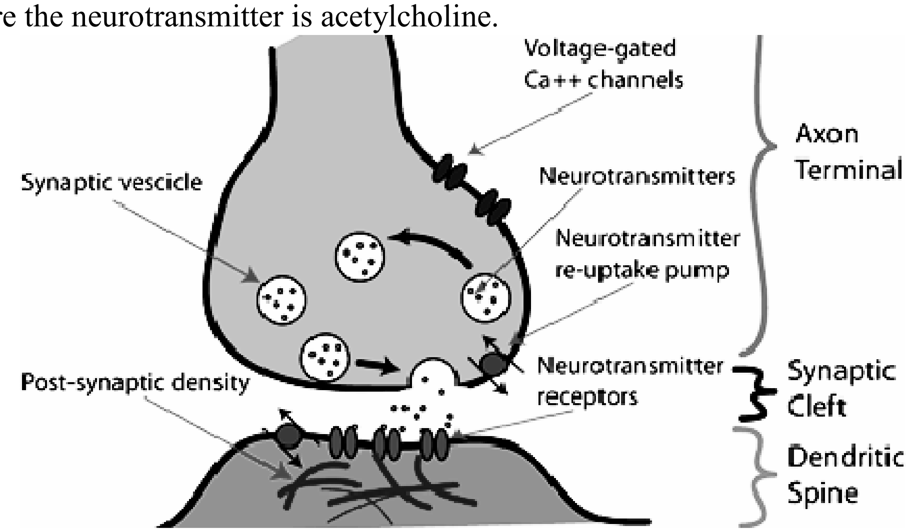

Fig.8.3. Synapse

b) The Electrical Synapse: The electrical synapse occurs predominantly in the CNS. The electrical synapse consists of a gap junction which structurally and electrically couples the presynaptic and postsynaptic membranes. The depolarization is mediated directly by ionic current instead of by chemical messengers. This type of synapse allows for a bidirectional flow of information.

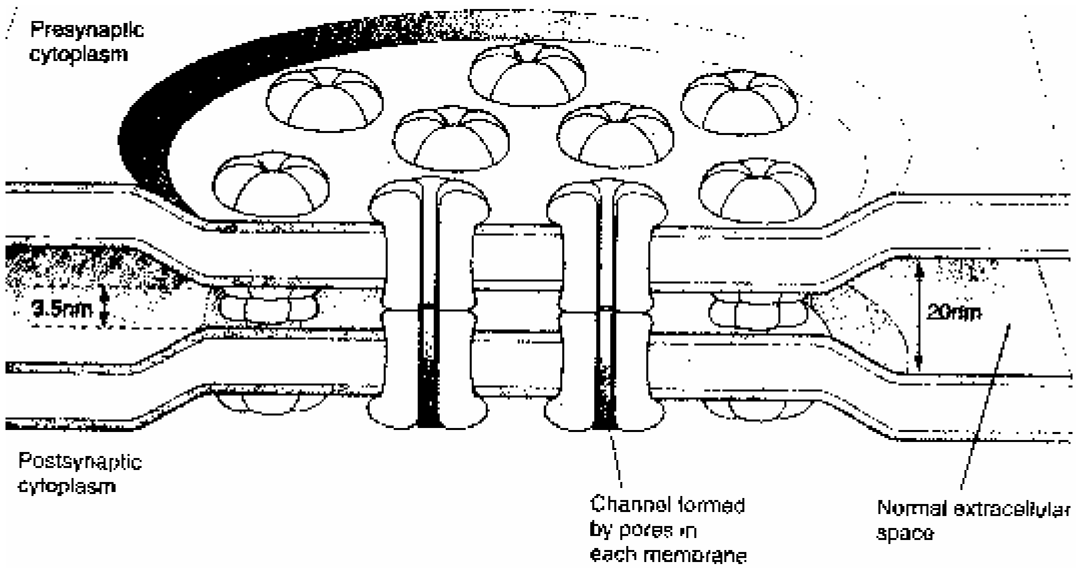

Fig.8.4. Electrical Synapse Gap Junction

8.3.3. Myelin

Myelin is a lipoprotein produced by supporting cells of the nervous system which serves to insulate neuronal processes, especially axons. This insulation allows the neuron to conduct the impulse more efficiently. Myelin is a modification of the supporting cell membrane. Myelin and PNS Neurons - all PNS axons and certain PNS dendrites are surrounded by myelin produced by Schwann Cells. These Schwann cells are arranged in sequence along the length of the neuronal process and form the Sheath of Schwann or Neurilemma. Schwann cells are derived from neural crest cells.

They insulate neurons from one another. They influence the conduction velocity of impulses transmitted along the axon. They participate in events associated with the regeneration of injured neurons. An axon can be ensheathed by Schwann cells in one of two configurations:

8.3.4. Unmyelinated Axons

Unmyelinated axons are slowly conducting (0.5m/s) axons. In unmyelinated axons several axons are associated with each Schwann cell of the neurilemma. Each axon has invaginated into a separate portion of the Schwann cell's plasmallema. Along it's length, portions of each axon are myelinated by a covering of the Schwann cell membrane and portions are uncovered.

8.3.5. Myelinated Axons

Myelinated axons are faster conducting axons (120m/s) due to their greater degree of insulation. Each Schwann cell is associated exclusively with only one axon. The Schwann cell is wrapped around the axon many times. These coils are so tight as to exclude the cytoplasm from all but the outermost layer of the Schwann cell. The outermost layer holds the nucleus and rest of the cytoplasmic components. So the myelin sheath is constructed of concentric revolutions of the Schwann cell plasmallema. These layers have absolutely nothing between them so the cell membranes are fused at their P faces. Under electron microscopy these fused cell membrane surfaces appear as dark lines called Major Dense Lines. Alternating with the major dense lines are are less darkly staining Interperiod Lines formed by the close association of opposing membrane E faces. The innermost and outermost revolutions of the Schwann cell plasmallema are connected by narrow channels of cytoplasm called Schmidt-Lanterman Clefts. Schwann cell plasmallemae have an unusually high lipid to proteinratio. This gives myelin it's insulating properties. As a result, myelinated axons can conduct impulses at a higher velocity. The Nodes of Ranvier represent small gaps between adjacent Schwann cells along an axon. Here minute portions of the axolemma are exposed to the extracellular space. The nerve impulse"leaps" over the insulated.portions of the axon from node to node. This is termed Saltatory Conduction. This allows for a faster rate of conduction. A small portion of the axon, called the Initial Segment, remains unmyelinated. The initial segment is where the axon originates at the axonal hillock and is where the impulse is generated.

Myelin and CNS Neurons - in CNS neurons another type of supporting cell, the Oligodendrocyte, is responsible for myelination. The oligodendrocyte extends multiple processes that will ensheath several axons in myelin. Unlike myelinated PNS neurons, one oligodendrocyte services more than one axon. Unlike unmyelinated PNS neurons, the axons do not invaginate into the insulating cell's plasmallema. Instead the oligodendrocyte sends out extensions to wrap around and insulate the axons.

8.3.6.Connective Tissue of the PNS Nerve Organ

All PNS nerve organs are made up of groups of neurons and their supporting cells. These groups of neurons have c.t. investments much like those of a skeletal muscle.

There are Three Levels of Connective Tissue Organization

a) Epineurium - is the outermost c.t. sheath and surrounds the entire nerve organ. The epineurium is composed of dense irregular c.t. rich in collagen fibers, elastic fibers, and fibroblasts. The epineurium extends into the nerve trunk separating it into axon bunches called Fascicles. The epineurium of a nerve organ can be followed back to the spinal cord where it is continuous with the dura mater.

b) Perineurium - the c.t. sheath encasing the individual fascicles. The inner layer of the perineurium is distinct from the outer layer. The outer layer is a dense irregular c.t continuous with that of the epineurium. The inner layer consists of a continuous sheet of flat epithelial cells supported by a basal lamina. These epithelial cells are called Perineurial Epithelium.

c) Endoneurium - is the innermost c.t. sheath and encases individual axons. The endoneurium is separated from the Schwann cells by a basal lamina. The endoneurium is a loose c.t rich in reticular fibers. The nervous tissues are well vascularized and the blood vessels travel through connective tissue investments. Arterioles and venules will be found in the epineurium and perineurium. Capillaries are found in the endoneurium.