Chapter 9
Nervous System

The nervous system is divided into two components: The CNS - the brain and spinal cord and the PNS - the nerves emanating from the spinal cord and brain that distribute to other areas of the body.

9.1. The Spinal Cord

The spinal cord is the pathway for the transmission of information from the brain to the rest of the body (efferent/motor) and from the body to the brain (afferent/sensory). Nerves enter and exit the spinal cord at regular intervals. Sensory nerves enter the spinal cord through the Dorsal Roots. Motor Nerves exit the spinal cord through the Ventral Roots. At a short distance from the spinal cord each pair of dorsal and ventral roots will fuse to form a Spinal Nerve that will carry "mixed"/ both sensory and motor information. The spinal cord is organized into distinct white and gray areas. The gray matter is organized into a roughly "H-shaped" central region. The gray area houses mostly unmyelinated structures such as perikarya and unmyelinated processes. The "arms" or "horns" of the gray area are designated the Dorsal Horns and Ventral Horns. The two sets of horns are connected by the "bar of the H", the Gray Commissure. Within the gray commissure is a hollow canal filled with Cerebral Spinal Fluid and lined by modified epithelial cells called Ependymal Cells . This canal is called the Central Canal. The ventral horns are motor/efferent areas. They contain the perikarya of multipolar alpha neurons called Somatic Motor Neurons which will innervate the skeletal muscles. The dorsal horns are sensory/afferent areas. They contain unmyelinated axons of Somatic Sensory Neurons whose cell bodies are located in an expansion of the dorsal root called the Dorsal Root Ganglion/Cranial-Spinal Ganglion.

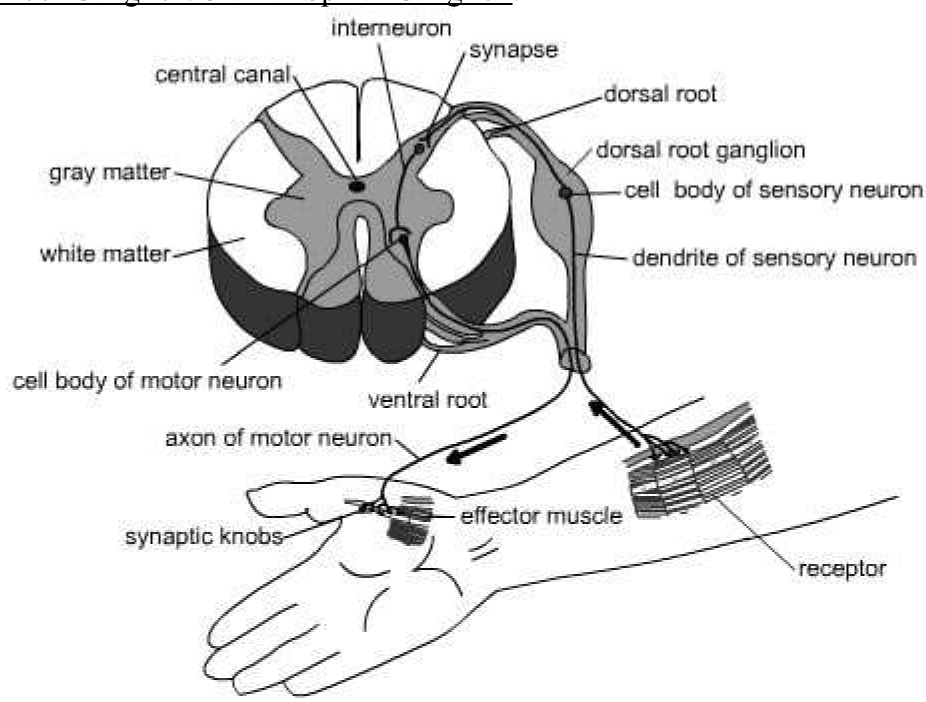

Fig.10.1. The C.S. of the Spinal Cord

A ganglion is a term for a collection of perikarya located outside of the CNS. In certain regions of the spinal cord, between T1 and L2, there are an extra pair of horns situated between the ventral and dorsal horns. These are the Lateral Horns/Intermediolateral Gray Horns . The lateral horns are also motor areas and are part of the ANS. So, the lateral horns contain the cell bodies of Visceral Efferent Neurons. Their axons will travel (with those of the ventral horns neurons) through the ventral root. The white matter surrounds the gray matter and is composed primarily of myelinated structures, especially descending and ascending myelinated axons. These axons are arranged into the Dorsal, Ventral, and Lateral Columns.

9.2. The Autonomic Nervous System

The ANS consist of two neurons extending from the CNS to the structure innervated. These two neurons will meet/synapse outside of the CNS in an autonomic ganglion and so are designated the Preganglionic Neuron and the Postganglionic Neuron.

a] The Preganglionic Neuron : The preganglionic arises from the CNS; the exact location depends on which division of the ANS the nerve belongs to.The preganglionic neuron is myelinated. The preganglionic neuron will synapse with the postganglionic neuron in an autonomic ganglion through the neurotransmitter Acetylcholine.

b] The Postganglionic Neuron: The postganglionic neuron has it's cell body located in autonomicganglion and will extend it's axon into the target organ. The postganglionic neuron will be unmyelinated. The division of the ANS that the postganglionic neuron belongs to will determine what type of neurotransmitter is used to communicate with the target organ. The ANS has two divisions which often service the same organ but produce radically different responses:

9.2.1. The Parasympathetic Division

The parasympathetic nerves arise from the brain stem and the sacral portion of the spinal cord and so are called Craniosacral in their origin. This division uses acetylcholine as it's postganglionic-target organ neurotransmitter. Acetylcholine promotes the "house keeping" response. The parasympathetic ganglia are located near or within the structures innervated by their postganglionic axons.

9.2. 2. The Sympathetic Division

The sympathetic nerves arise only from the spinal cord, from the thoracic and lumbar portions of the spinal cord. So it is referred to as being Thoracolumber in it's origins. The perikarya of it's preganglionic neurons are located in the lateral horns of the spinal cord. This division uses epinepherine and norepinepherine as it's postganglionic-target organ neurotransmitter. Epinepherine and norepinepherine promotes the "emergency response". Their ganglia are located much closer to the spinal cord (than are those of the parasympathetic division) and display two patterns:

a] Chain Ganglia/Paravertebral Ganglia

These are paired ganglia running parallel on either side of the spinal cord. To be more exact, they are ventroloateral to the spinal cord. A chain ganglion is attached to the one above and below it by nerve trunks. This forms the Sympathetic Chain.

b] Prevertebral Ganglia/ Collateral Ganglia

These are singular ganglia located ventral/anterior to the spinal cord. They are located much closer to the target than are the chain ganglia. They will form nerve plexuses in the abdominopelvic region such as the celiac and hypogastric plexuses

9.3.3. The Histology of the Ganglion

All ganglia are contained within a connective tissue capsule that is continuous with the epineurium and perineurium of the nerves entering and exiting it. Within the ganglion each perikaryon is surrounded by Satellite Cells, the second of the two types of PNS supporting cells. Satellite cells separate the perikaryon from capillaries and so **may** serve to regulate metabolic exchange. This layer of satellite cells is continuous with the sheath of Schwann of the axon communicating with the neuron. External to the satellite cells is a basal lamina. External to the basal lamina is a connective tissue Capsule composed of collagen fibers and Capsule Cells. The capsule cells are modified fibroblasts. The capsule is continuous with the endoneurium of the axon.

a) The Dorsal Root Ganglion

The perikarya of the dorsal root ganglion are ovoid in shape with centrally located nuclei. These perikarya are located in the peripheral portion of the ganglion while their processes run through the central portion of the ganglion. The neurons of the dorsal root ganglion are unipolar. The axon-like portion of their singular process is myelinated and will enter into the spinal cord (one of the ascending pathways). The dendrite-like portion of the central process is also myelinated . The dendritic portion will terminate as a sensory receptor in either: the skin (Somatic Afferent Terminal), or the a visceral organ (Visceral Afferent Terminal). The dendritic portion will branch into dendritic endings so as to pick up stimuli along two patterns: as unencapsulated/free dendritic endings which are receptive to temperature, pressure, or pain. or as encapsulated dendritic endings which are mechanoreceptors for the sensation of touch and pressure.

b) The Autonomic Ganglia

Both parasympathetic and sympathetic ganglia contain multipolar neurons having a single, unmyelinated postganglionic axon. Their perikarya contain acentrically orientated nuclei.

9.4. The Cerebellum and Cerebrum of the Brain

9.4.1. The Cerebellum

The cerebellum is primarily concerned with coordination and the refinement of skeletal muscle activity, the maintenance of equilibrium, and the maintenance of muscle tone. It only influences muscular activity. It does not initiate it. New studies indicate that the cerebellum may also serve as an extra storage bank for memories, particularly about movements.

a) The Cerebellar Cortex : The cerebellar cortex is the convoluted outer layer of gray matter surrounding a central core of white matter populated by small clusters of gray matter. The central core of white matter is called the Cerebellar White Matter and the small clusters of gray mater embedded in it are called Cerebellar Nuclei/Ganglia. This is the arrangement of white to gray matter which we see in the "higher" portions of the brain.

Histologically the cerebellar cortex is a trilaminar structure. The three layers are the Granular Layer, the Purkinje Layer, and the Molecular Layer. The Purkinje Layer - is the middle layer of this trilaminar arrangement. It consists of a single layer of flask-shaped cells called Purkinje Cells. These Purkinje cells sit on top of the granular layer. The

Purkinje cells have centrally orientated nuclei surrounded by Nissl bodies. Their apical dendrite extends into the molecular layer where it will arborize into a many branched dendritic tree. Their singular axon extends through the underlying granular layer and into the cerebellar white matter. The axon is myelinated. This is the pathway by which the influences of the cerebellar cortex are accomplished. The Granular Layer - is the deepest layer of the cortex, sitting on top of the white matter. It consists of a large population of densely packaged cells called Granule Cells. Granule cells have short dendrites which communicate with axons of the cerebellar white matter. Granule cells have a single, long axon that extends superficially, through the Purkinje layer and into the molecular layer. This axon is unmyelinated. In the molecular layer this axon bifurcates and establishes synapses with dendritic branches of Purkinje cells.

b] The Molecular Layer - is the superficial most layer of the cerebellar cortex. It consists mostly of the dendritic processes of Purkinje cells and the axons of granular cells. Amid these processes, however, there are two types of cells: Basket Cells and Stellate Cells.

9.4.2. The Cerebrum

This is by far the largest and most highly evolved portion of the primate brain. It is responsible for all of our "higher brain activities". The cerebral cortex, like the cerebellar cortex, is the convoluted outer layer of gray matter surrounding a central core of white matter populated by small clusters of gray matter. The central core of white matter is called the Cerebral White Matter and the small clusters of gray mater embedded in it are called Cerebral/Basal Nuclei/Ganglia. The cerebral cortex is responsible for analyzing sensory information, for initiating muscular activity, and for learning, memory, and the association of information. The cerebral cortex contains three major types of nerve cells named for the shape of their perikarya: Stellate Cells, Fusiform Cells, and Pyramidal Cells. Pyramidal cells are by far the most prominent.

These abundant cells have a pyramid shaped cell body. They have a large, central nucleus surrounded by many Nissl bodies. It has an apical dendrite extending superficially towards the brain's surface. It has a basal axon that extends deeper into the brain, into the cerebral white matter, towards the spinal cord. This is the principle path for information traveling from the cerebral cortex to the rest of the CNS.

It is the Pyramidal/Corticospinal Tract and is motor. Their are a variety of pyramidal cells recognized based on size and relative position in the cortex. The largest are the giant Betz Cells found in the motor cortex. The cerebral cortex is divided into six major layers of nerve cells. Pyramidal cells are located mostly in cortical layers II, III, V, and VI. Each layer is categorized by the pyramidal cells present and by their degree of axonal and dendritic branching.

9.5. The Neuroglia

The neuroglia are the supporting cells of the CNS. They include the astrocytes, oligodendrocytes, microglia, and ependymal cells.

9.5.1. Astrocytes

Astrocytes are star-shaped cells of the CNS. There are two types of astrocytes currently recognized (although they may really both be the same type of cell):

a) Fibrous Astrocytes - are found primarily in white matter. They have several long, infrequently branching cytoplasmic processes. They have an ovoid nucleus. They have many filaments running throughout the cytoplasm called Glial Filaments.

b) Protoplasmic Astrocytes - are found primarily in gray matter. They have shorter, more frequently branching cytoplasmic processes. They have an ovoid nucleus also. They have many filaments running throughout the cytoplasm called Glial Filaments also. Astrocytes have many "foot processes" which are the dilated terminal portions of their cytoplasmic extensions. Some of these foot processes extend into the pia mater, some extend to the neurons or their processes, and some extend to the capillaries of the CNS.

Astrocytes may play a role in the blood-brain barrier. They may help to regulate the exchange of materials between the blood stream and the neurons. Astrocytes are now known to play a major role in neurotransmitter regeneration.

9.5.2. Oligodendrocytes

Oligodendrocytes have many cytoplasmic extensions which wrap around and insulate CNS neurons in myelin. They act as the Schwann cells of the CNS.

9.5.3. Microglia

Microglia are odd cells. Their origin is still undetermined but it is known that they are **not** derived from neuroepithelium as are the other neuroglia.

a) Appearance - small cells with deeply staining nuclei and having a few, sort cytoplasmic extensions.

b) Functions: Microglia act as macrophages of the CNS. They phagocytosize foreign invaders and dead neurons.

9.5.4. Ependymal Cells

Ependymal cells are derivatives of embryonic neuroepithelium and make up the Ependyma of the adult. The ependyma is a single layer of ependymal cells that lines the hollow spaces of the CNS (i.e.; the brain ventricles, the central canals, and all of the communicating passageways). Ependymal cells will appear as either cuboidal or columnar, ciliated epithelial cells depending on their location. The cilia are responsible for the circulation of CSF (cerebrospinal fluid). CSF is a plasma filtrate that nourishes and protects the CNS. CSF is found in all of the hollow spaces of the CNS and within the surrounding meninges. CSF is produced by special capillaries beds called the Choroid Plexus.

9.6. Comparison of Afferent and Efferent Nerves

9.6.1. Efferent/Motor Nerve Endings

Efferent nerve endings are axon terminals on synaptic contact with myofibers and secretory epithelial cells. They stimulate contraction and secretion respectively.

9.6.2. Afferent/Sensory Nerve Endings

Afferent nerve endings are dendritic terminals which act as sensory receptors. They are capable of the transduction of various stimuli into nerve impulses that are sent back towards the CNS for processing and evaluation. These various stimuli include: temperature, touch, pressure, pain, odor, etc. Examples of sensory receptors include: neuromuscular spindles, Golgi tendon organs, and special senses such as taste, smell, hearing, and vision. Sensory receptors come in two classes:

a) (Complete Cell) Receptor Cells - these are neuroepithelial cells responsible for the detection of some of the special senses. They are typically modified columnar epithelial cells with elongate stereocilia for the detection of stimuli. They are in close association with a dendritic extension of a sensory neuron which will pick up the stimulus

and conduct it towards the CNS.
i) Dendritic Endings - these are the terminal portions of dendrites which directly pick up the stimulus. They are divided into two morphologically distinct classes:
ii) Free/Unencapsulated Dendritic Endings:
These dendritic endings are unmyelinated, lacking Schwann cells, and are not covered by a connective tissue capsule. They typically monitor the general senses such as temperature, pain, and pressure.

b) Encapsulated Dendritic Endings:

These dendritic endings occur at the terminus of myelinated dendrites but are themselves unmyelinated. They are covered, however, by a many layered connective tissue sheath. They also monitor general senses and often act as mechanoreceptors. They occur frequently in the skin. Ex; Pacinian corpuscles and Meissner's corpuscles.