NERVOUS SYSTEM
The PNS

- has two functional subdivisions
- The sensory, or afferent (“carrying toward”), division consists of nerve fibers that convey impulses to the central nervous system from sensory receptors located throughout the body. Sensory fibers conveying impulses from the skin, skeletal muscles, and joints are called somatic afferent fibers (soma = body), and those transmitting impulses from the visceral organs (organs within the ventral body cavity) are called visceral afferent fibers. The sensory division keeps the CNS constantly informed of events going on both inside and outside the body.
Nervous Tissue

- nervous tissue is made up of just two principal types of cells:

  I. supporting cells, smaller cells that surround and wrap the more delicate neurons also called neuroglia or glial cells

  II. neurons, the excitable nerve cells that transmit electrical signals.
Neuroglia

• There are six types of neuroglia—four in the CNS and two in the PNS
Neurons

• Also called nerve cells are the structural units of the nervous system.

• They are highly specialized cells that conduct messages in the form of nerve impulses from one part of the body to another. Besides their ability to conduct nerve impulses, neurons have some other special characteristics.
Myelin Sheath and Neurilemma

- a whitish, fatty (protein-lipoid), segmented. Myelin protects and electrically insulates fibers, and it increases the speed of transmission of nerve impulses. Myelinated fibers conduct nerve impulses rapidly, whereas unmyelinated fibers conduct impulses quite slowly.
Classification of Neurons

i. Structural Classification

i. Multipolar neurons have three or more processes

ii. Bipolar neurons have two processes—an axon and a dendrite—that extend from opposite sides of the cell body.

iii. Unipolar neurons have a single short process that emerges from the cell body and divides T-like into proximal and distal branches
Comparison of Structural Classes of Neurons

<table>
<thead>
<tr>
<th>Neuron Type</th>
<th>Relative Abundance and Location in Human Body</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multipolar</td>
<td>Most abundant in body. Major neuron type in the CNS.</td>
</tr>
<tr>
<td>Bipolar</td>
<td>Are found in some special sensory organs (olfactory mucosa, eye).</td>
</tr>
<tr>
<td>Unipolar (Pseudounipolar)</td>
<td>Found mainly in the PNS. Common only in dorsal root ganglia of the spinal cord and sensory ganglia of cranial nerves.</td>
</tr>
</tbody>
</table>

**Structural Variations**

- **Multipolar**
  - Purkinje cell of cerebellum
  - Cell body
  - Axon
  - Dendrites

- **Bipolar**
  - Pyramidal cell
  - Cell body
  - Axon
  - Cell body

- **Unipolar**
  - Olfactory cell
  - Axon
  - Cell body
  - Dendrite

- **Retinal cell**
  - Axon
  - Cell body

- **Dorsal root ganglion cell**
  - Receptive endings
  - Peripheral process (axon)
  - Central process (axon)
Resting Membrane Potential ($V_r$)

- The basis of potential in the plasma membrane is due to $\text{Na}^+$, $\text{K}^+$, $\text{Cl}^-$, and protein anions ($A^-\text{)}$ concentration in the intracellular and extracellular.

- The voltage across the membrane is usually $-70$ mV although it varies from -40 to -90 mV.

- In RMP the cell cytoplasm has lower $\text{Na}^+$ and higher $\text{K}^+$ than extracellular. the $\text{Na}^+$ (cations) in the extracellular is balance with $\text{Cl}^-$ (anions) while the $\text{K}^+$ in the intracellular is balanced with negatively charged protein ions.
Resting Membrane Potential ($V_r$)
Action Potential: Resting State

- **Na^+** and **K^+** channels are closed
- Leakage accounts for small movements of **Na^+** and **K^+**
- Each **Na^+** channel has two voltage-regulated gates
  - Activation gates – closed in the resting state
  - Inactivation gates – open in the resting state

**Figure 11.12.1**

Resting state: All gated **Na^+** and **K^+** channels closed (**Na^+** activation gates closed; inactivation gates open)
Propagation of an Action Potential
(Time = 0ms)

• Na⁺ influx causes a patch of the axonal membrane to depolarize

• Positive ions in the axoplasm move toward the polarized (negative) portion of the membrane

• Sodium gates are shown as closing, open, or closed
Propagation of an Action Potential
(Time = 0 ms)
Absolute Refractory Period

- It occurs when the membrane has reached the threshold potential and therefore cannot respond to any stimulus no matter its intensity.
Relative Refractory Period

• The interval following the absolute refractory period when:
  – Sodium gates are closed
  – Potassium gates are open
  – Repolarization is occurring

• It causes the membrane to restore to its membrane potential.
Conduction Velocities of Axons

- Once an action potential has been generated at a point it causes local flow of current to the adjacent regions of the membrane, this stimulates voltage gated Na channels to open and create a new action potential.

- The cycle continues producing a wave like conduction of the action potential from point to point along the axon.

- In myelinated neurons electrical charge can only occur at the nodes of Ranvier as the sheath insulates the cell from current. This type of conduction is called saltatory Conduction
• Depending on the particular neurotransmitter, the terminating mechanism may be:
  – Degradation by enzymes associated with the postsynaptic membrane or present in the synapse, as with acetylcholine
  – Reuptake by astrocytes or the presynaptic terminal, where the neurotransmitter is stored or destroyed by enzymes, as with norepinephrine
  – Diffusion away from the synapse
Functional Classification of Neurotransmitters

- Some neurotransmitters have both excitatory and inhibitory effects
  - Determined by the receptor type of the postsynaptic neuron
  - Example: acetylcholine
    - Excitatory at neuromuscular junctions with skeletal muscle
    - Inhibitory in cardiac muscle
• The middle layer, which forms a loose brain covering

• It is separated from the dura mater by the subdural space which contains lubricating serous fluid.

• Beneath the arachnoid is a wide subarachnoid space filled with CSF and large blood vessels

• Arachnoid villi protrude superiorly and permit CSF to be absorbed into venous blood
Figure 12.23a

Arachnoid Mater

Superior sagittal sinus
Subdural space
Subarachnoid space

Skin of scalp
Periosteum
Bone of skull
Periosteal Meningeal
Dura mater
Arachnoid mater
Pia mater
Arachnoid villus
Blood vessel
Falx cerebri (in longitudinal fissure only)
cerebral cortex

- Superficial gray matter; accounts for 40% of the mass of the brain.
- It enables sensation, communication, memory, understanding, and voluntary movements.
Functional Areas of the Cerebral Cortex

- Primary motor area
- Premotor cortex
- Frontal eye field
- Working memory for spatial tasks
- Executive area for task management
- Broca's area
- Working memory for object-recall tasks
- Solving complex, multi-task problems
- Prefrontal cortex

- Central sulcus
- Primary somatosensory cortex
- Somatosensory association cortex
- Gustatory cortex
- Wernicke's area (outlined by dashes)
- General interpretation area (outlined by dots)
- Primary visual cortex
- Visual association area
- Auditory association area
- Primary auditory area

Somatic sensation
Taste
Vision
Hearing

Figure 12.8a
Somatosensory Association Cortex

- Located posterior to the primary somatosensory cortex
- Integrates sensory information i.e., forms a comprehensive understanding of the stimulus.
- Damage to this area means the person cannot recognize without looking.
Fiber Tracts in White Matter

Figure 12.10b
Midbrain

- Located between the diencephalon and the pons
- Midbrain structures include:
  - Cerebral peduncles – two bulging structures that contain descending pyramidal motor tracts
  - Cerebral aqueduct – hollow tube that connects the third and fourth ventricles
  - Various nuclei
Midbrain Nuclei

- Nuclei that control cranial nerves III (oculomotor) and IV (trochlear) i.e.
  - Corpora quadrigemina – four domelike protrusions of the dorsal midbrain made up of pairs of Superior colliculi – visual reflex centers and Inferior colliculi – auditory relay centers

- Substantia nigra – functionally linked to basal nuclei releases dopamine for fine muscle control.

- Red nucleus – largest nucleus of the reticular formation; red nuclei are relay nuclei for some descending motor pathways
Medulla Oblongata

(c) Medulla oblongata

- Hypoglossal nucleus
- Dorsal motor nucleus of vagus
- Inferior cerebellar peduncle
- Fourth ventricle
- Choroid plexus
- Solitary nucleus
- Vestibular nuclear complex
- Cochlear nuclei
- Reticular formation
  - Lateral nuclear (small cell) group
  - Medial nuclear (large cell) group
  - Raphe nucleus
- Medial lemniscus
- Pyramid
- Nucleus ambiguus
- Inferior olivary nucleus

Figure 12.16c
Medulla Nuclei

• Inferior olivary nuclei – gray matter that relays sensory information

• Cranial nerves VII (vestibulocochlear) IX (glossopharyngeal) X (vagus), XI (accessory), and XII (hypoglossal) are associated with the medulla

• It forms the following centres for reflexes ie
  – cardiovascular centre which controls rate and force of heart and BP
  – Respiratory centre that control rate and depth of breathing
  – Other centres include vomiting, hiccuping, swallowing, coughing and sneezing
Functional Brain System

• Networks of neurons working together and cannot be localized to specific areas of the brain.

• The two systems are:
  – Limbic system
  – Reticular formation
Limbic System

Figure 12.18

- Cingulate gyrus
- Septum pellucidum
- Anterior commissure
- Septal nuclei
- Hypothalamus
- Olfactory bulb
- Mammillary body
- Hippocampus
- Corpus callosum
- Fornix
- Anterior thalamic nuclei (flanking 3rd ventricle)
- Amygdala
- Parahippocampal gyrus
- Dentate gyrus (deep to the parahippocampal gyrus)
Peripheral Nervous System (PNS)

- PNS – all neural structures outside the brain and spinal cord
- Includes sensory receptors, peripheral nerves, associated ganglia, and motor endings
- Provides links to and from the external environment
Cranial Nerve I: Olfactory

Figure I from Table 13.2
Cranial Nerve III: Oculomotor

- Fibers extend from the ventral midbrain, pass through the superior orbital fissure, and go to the extrinsic eye muscles.
- Functions in raising the eyelid, directing the eyeball, constricting the iris, and controlling lens shape.
- It is motor.
Cranial Nerve VII: Facial

• Fibers leave the pons and travel to the lateral aspect of the face.

• Mixed nerve with five major branches: temporal, zygomatic, buccal, mandibular, and cervical.

• Motor functions include facial expression, and the transmittal of autonomic impulses to lacrimal and salivary glands.

• Sensory function is taste from the anterior two-thirds of the tongue.
Cranial Nerve IX: Glossopharyngeal

- Fibers emerge from the medulla, leave the skull via the jugular foramen, and run to the throat.
- Nerve IX is a mixed nerve with motor and sensory functions.
  - Motor – innervates part of the tongue and pharynx, and provides motor fibers to the parotid salivary gland.
  - Sensory – fibers conduct taste and general sensory impulses from the tongue and pharynx.
Cranial Nerve XI: Accessory

Figure XI from Table 13.2
Figure XII from Table 13.2

Cranial Nerve XII: Hypoglossal

Intrinsic muscles of the tongue
Hypoglossal canal
Hypoglossal nerve (XII)
Extrinsic muscles of the tongue
Spinal Nerves: Roots

- Each spinal nerve connects to the spinal cord via two medial roots, i.e.,
  - Ventral roots arise from the anterior horn and contain motor (efferent) fibers to the skeletal muscles and the glands.
  - Dorsal roots contain sensory fibers carrying impulses from the peripheral located receptors to the spinal cord.
Cervical Plexus

- The cervical plexus is formed by ventral rami of C1-C4.
- Most branches are cutaneous nerves of the neck, ear, back of head, and shoulders.
- The most important nerve of this plexus is the phrenic nerve which is the major motor and sensory nerve of the diaphragm.
Brachial Plexus

- Formed by C5-C8 and T1 (C4 and T2 may also contribute to this plexus)
- It gives rise to the nerves that innervate the upper limb
Sympathetic Division

- It is also called thoracolumbar division as its preganglionic neurons arise from the thoracic and lumbar regions of the spinal cord ie T1-L2.
- It supplies visceral organs and also blood vessels and sweat gland located superficially.
- It has short preganglionic neurons which release acetylcholine and long post ganglionic neurons which produce norepinephrine hence called adrenergic fibers.
- Preganglionic fibers pass through the white rami communicantes and synapse in the paravertebral ganglia.
- Postganglionic fibers innervate the numerous organs of the body.
- The ganglia is formed a few cms off the CNS forming a sympathetic chain.
- It has gray and white communicantes.
Visceral Reflexes

• Visceral reflexes have the same elements as somatic reflexes
• They are always polysynaptic pathways
• Afferent fibers are found in spinal and autonomic nerves