Nervous System

- It is a complex network of nerves and cells that carry messages to and from the brain and spinal cord to various parts of the body.
- processing system, and the system that keeps us in contact with the outside world. It tells us that we exist, and along with the muscles allows us to move and react to stimuli.
- The nervous system includes both the Central nervous system and Peripheral nervous system. The Central nervous system is made up of the brain and spinal cord and The Peripheral nervous system is made up of the Somatic and the Autonomic nervous systems.

Function:
1. Sensory Input
2. Integration
3. Homeostasis
4. Mental Activity
5. Control of muscles and glands

Cells of the Nervous System

Neurons

- It is the basic unit in the nervous system. It is a specialized conductor cell that receives and transmits electrochemical nerve impulses. A typical neuron has a cell
body and long arms that conduct impulses from one body part to another body part.

There are three different parts of the neuron:

- the cell body
- dendrites
- axon

**Cell body of a neuron**
- conducts nerve impulses away from the cell body

**Dendrites**
- conduct nerve impulses towards the CELL BODY and AXON.
- highly branched, thick extensions that appear like cables.

**Axon**
- is a long, thin process that carries impulses away from the cell body to another neuron or tissue. There is usually only one axon per neuron.

**Axon Hillock**
- the area where the axon leaves the neuron cell body

**Schwann cells**
- surrounded by the neuroglia.

**Myelin Sheath**
- These are white segmented covering around axons and dendrites of many peripheral neurons. The covering is continuous along the axons or dendrites except at the point of termination and at the nodes of Ranvier.

**Neurilemma** is the layer of Schwann cells with a nucleus. Its function is to allow damaged nerves to regenerate.

**Nissl Bodies**
- the microscopic granules that appear when stained with a specific dye.

**Node of Ranvier**
- Gaps in the myelin sheath

**TYPES OF NEURONS**
1. **SENSORY NEURON**: (= afferent neuron) - takes a message from a sense organ to CNS. Has long dendrite and short axon.

2. **MOTOR NEURON**: (= efferent neuron) - takes message away from CNS to a muscle fiber or gland. Short dendrites, long axon.

3. **INTERNEURON**: (= association neuron or connector neuron): completely contained within CNS. Conveys messages between parts of the system. Dendrites, axons, may be long or short.

**According to structure:**

1. *Multipolar neurons* - have one axon and several dendrites. These are common in the brain and spinal cord.
2. *Bipolar neurons* - have one axon and one dendrite. These are seen in the retina of the eye, the inner ear, and the olfactory (smell) area.
3. *Unipolar neurons* - have one process extending from the cell body. The one process divides with one part acting as an axon and the other part functioning as dendrite. These are seen in the spinal cord.

**Neuroglia**

- Nonneuronal cells of the CNS and PNS
- Outnumber neurons by about 10 to 1, and they account for about half of the volume of the nervous system

- **Astrocytes**
  - Serves as the major supporting tissue in the CNS and participate with the blood vessel epithelium to form a permeability barrier.

- **Ependymal**
  - Line the fluid-filled cavities within the CNS

- **Microglia**
  - Helps remove bacteria and cell debris from the CNS
Electrical Signals and Neuronal Pathways

- **Resting Membrane Potential**

Unequal distribution of ions across the plasma membrane:
- $[\text{Na}^+]$ outside $10x >$ inside
- $[\text{K}^+]$ inside $20x >$ outside
- $[\text{Cl}^-]$ and $[\text{Ca}^{2+}]$ outside $>$ inside
- $[\text{Ca}^{2+}]$ high in some intracellular compartments

Resting membrane potential:

1. The $\text{Na}^+/\text{K}^+$ transporter (ATPase/pump) - active transport
   - Two $\text{K}^+$ into the cell
   - Three $\text{Na}^+$ out of the cell
   - Result: a net loss of positive charges within the cell
     - $\text{Ca}^{2+}$ pump
     - $\text{Na}^+/\text{K}^+$ pump

2. Some potassium channels (non-gated) in the plasma membrane are "leaky" allowing a slow facilitated diffusion of $\text{K}^+$ out of the cell.
3. $\text{Ca}^{2+}$ is removed via $\text{Ca}^{2+}$ pump

- **Transmission of impulses across Synapses**

- **Synapse**: junction where the axon of neuron or an effector organ such as muscles or glands.
- **Synaptic Endings**: swollen terminal knobs on the ends of axon terminal branches.
- **Presynaptic Membrane**: the membrane of the axon synaptic ending.
- **Postsynaptic Membrane**: the membrane of the next neuron just beyond the axon's synaptic membrane.
- **Synaptic Cleft**: the space separating the presynaptic and the postsynaptic membranes.
- **Neurotransmitter Substances (neurotransmitters)**: chemicals that transmit the nerve impulses across a synaptic cleft.
- **Synaptic Vesicles**: where a chemical substance called neurotransmitter are stored. Contained near surface of synaptic endings.
- The inside of the post synaptic cells tend to become more negative or **hyperpolarized** causing the ACTION potential to be inhibited
- **Acetylcholine (Ach), Noradrenalin (NA), Serotonin, Adrenalin (epinephrine)** are some important neurotransmitters.
• Transmission across a synapse is one-way because only the ends of axons have synaptic vesicles that are able to release neurotransmitters to affect the potential of the next neurons.

• **STIMULATION or INHIBITION** of postsynaptic membranes can occur.

• A neuron is on the receiving end of many synapses -- some may be giving inhibitory and some may give stimulatory impulses. Whether or not the neuron they are attached to fires depends on the **SUMMARY EFFECT** of all the excitatory neurotransmitters received.

• If amount of excitatory neurotransmitters received is sufficient to overcome the amount of inhibitory neurotransmitters received, the neuron fires. If not, only local excitation occurs. The total process allows neurons to fine-tune to the environment.

• Neurotransmitters take nerve impulses across synapses. Neurotransmitters are small molecules. They can be single amino acids, short chains of amino acids, or derivatives of protein.

• Proper brain and nervous system function depends on the proper balance of excitatory and inhibitory synaptic transmitters. Excitatory transmitters: include ACETYLCHOLINE (ACh), ADRENALIN (epinephrine), NORADRENALIN (norepinephrine), SEROTONIN (derived from the amino acid tryptophan), and DOPAMINE.

• Inhibitory transmitters: include GABA (gamma aminobutyric acid - a type of amino acid), glycine (an amino acid). Serotonin can also act as an inhibitory neurotransmitter.

• Neurotransmitters include endorphins and enkephalins (a 5 amino-acid chain that functions as a natural pain reliever in brain). Opium and heroin mimic the action of natural endorphins and enkephalins.

• A single neuron may receive information from thousands of neighbouring neuron through thousands of synapse. Some of the messages are excitatory (i.e. they tell the neuron to “fire”) while others may be inhibitory (i.e. they tell the neuron not to fire).

• Whether or not a neuron “fires” off an action potential at any particular instant depends on its ability to integrate these multiple positive and negative inputs.

### Divisions Of The Nervous System

**A. Central nervous system (CNS)**

- It is divided into two major parts: the brain and the spinal cord.

**The brain**

- The brain lies within the skull and is shaped like a mushroom. The brain consists of four principal parts: the brain, cerebrum, cerebellum and diencephalon.
- Weighs approximately 1.3 to 1.4 kg. It has nerve cells called the neurons and supporting cells called the glia.

**Two Types of Matter in the Brain:**
- Grey matter - receives and stores impulses (dorsal cell bodies).
  - send along primarily motor information (ventral cell bodies).
  - containing cell bodies of neurons and short fibers. Looks kind of like the butterfly with open wings.
- White matter - carries impulses to and from grey matter.
  - containing long fibers of interneurons that run together in bundles called tracts that connect the cord to the brain.

**Brain stem**
- also known as the Medulla oblongata.
- It is located between the pons and the spinal cord and is only about one inch long.
- Controls heart rate, breathing, blood pressure, reflex reactions like coughing, sneezing, vomiting, hiccoughing, swallowing.

**Cerebrum**
- forms the bulk of the brain and is supported on the brain stem.
- Consciousness resides only in this part of the brain.
- Intellect, learning, memory, sensations are formed here.
- The cerebrum is divided into two hemispheres. Each hemisphere controls the activities of the side of the body opposite that hemisphere.
  
  The hemispheres are further divided into four lobes:

  ✓ Frontal lobe - movement, higher intellectual processes (e.g. problem solving, concentration, planning, judging the consequences of behavior, moving your tongue and mouth to speak (left side only).
  ✓ Temporal lobes - processing of visual information, although their main function is auditory reception. It is also linked to understanding speech and retrieving visual and verbal memories
  ✓ Parietal lobe - receive and process sensory information from the skin and hearing, smelling, interpretation of experiences, memory of visual scenes, music, and complex sensory patterns.
  ✓ Occipital lobe - vision, combining visual experiences with other sensory experiences. This are needed for recognition of what is being seen.
Cerebellum
- It is located behind and below the cerebrum.
- Controls balance and complex muscular movement.
- Responsible for maintaining normal muscle tone, posture, balance. It receives sensory information from the inner ear (which senses balance).

Diencephalon
- It is also known as the fore brain stem. It includes the thalamus and hypothalamus. The thalamus is where sensory and other impulses go and coalesce.
  - **Thalamus**- sits at the base of the forebrain. It consists of neurons that provide connections between various part of the brain
  - **Hypothalamus**- one of the most important sites for the regulation of homeostasis. It maintains internal environment, contains centers for hunger, sleep, thirst, body temperature, water balance, blood pressure -this controls the pituitary gland.

**Pituitary Gland** - serves as a link between the nervous system and the endocrine systems.

Midbrain
- provides conduction pathways to and from higher and lower centers
- It relays visual and auditory information between areas of the hindbrain and forebrain

Pons
- acts as a pathway to higher structures; it contains conduction pathways between the medulla and higher brain centers.
- serves as a relay center between the neurons of the right and left halves of the cerebrum, the cerebellum, and the rest of the brain

Cranial Nerves

<table>
<thead>
<tr>
<th>Nerves</th>
<th>Type</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>I Olfactory</td>
<td>sensory</td>
<td>olfaction (smell)</td>
</tr>
<tr>
<td>II Optic</td>
<td>sensory</td>
<td><strong>vision</strong></td>
</tr>
<tr>
<td>III Oculomotor</td>
<td>motor*</td>
<td>eyelid and eyeball muscles</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(Contain 38% of all the axons connecting to the brain.)</td>
</tr>
</tbody>
</table>
### Cranial Nerves

<table>
<thead>
<tr>
<th>Number</th>
<th>Name</th>
<th>Type</th>
<th>Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>IV</td>
<td>Trochlear</td>
<td>motor*</td>
<td>eyeball muscles</td>
</tr>
<tr>
<td>V</td>
<td>Trigeminal</td>
<td>mixed</td>
<td>Sensory: facial and mouth sensation, Motor: chewing</td>
</tr>
<tr>
<td>VI</td>
<td>Abducens</td>
<td>motor*</td>
<td>eyeball movement</td>
</tr>
<tr>
<td>VII</td>
<td>Facial</td>
<td>mixed</td>
<td>Sensory: taste, Motor: facial muscles and salivary glands</td>
</tr>
<tr>
<td>VIII</td>
<td>Auditory</td>
<td>sensory</td>
<td>hearing and balance</td>
</tr>
<tr>
<td>IX</td>
<td>Glossopharyngeal</td>
<td>mixed</td>
<td>Sensory: taste, Motor: swallowing</td>
</tr>
<tr>
<td>X</td>
<td>Vagus</td>
<td>mixed</td>
<td>main nerve of the parasympathetic nervous system (PNS)</td>
</tr>
<tr>
<td>XI</td>
<td>Accessory</td>
<td>motor</td>
<td>swallowing; moving head and shoulder</td>
</tr>
<tr>
<td>XII</td>
<td>Hypoglossal</td>
<td>motor*</td>
<td>tongue muscles</td>
</tr>
</tbody>
</table>

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**Wernick's Area**

- One of the two parts of the cerebral cortex linked since the late nineteenth century to speech (the other is Broca's area).
- It is involved in the understanding of written and spoken language.
- It is traditionally considered to consist of the posterior section of the superior temporal gyrus in the dominant cerebral hemisphere (which is the left hemisphere).
hemisphere in about 97% of people).

*** Brocas Area

- Broca's area is one of the main areas of the cerebral cortex responsible for producing language.
- This region of the brain was named for French neurosurgeon Paul Broca who discovered the function of Broca's area while examining the brains of patients with language difficulties.
- This brain area controls motor functions involved with speech production. Persons with damage to Broca's area of the brain can understand language but cannot properly form words or produce speech.

The spinal cord

- It is along tube like structure which extends from the brain.
- It is composed of a series of 31 segments. A pair of spinal nerves comes out of each segment. The region of the spinal cord from which a pair of spinal nerves originates is called the spinal segment. Both motor and sensory nerves are located in the spinal cord.
- It is about 43 cm long in adult women and 45 cm long in adult men and weighs about 35-40 grams. It lies within the vertebral column, the collection of bones (back bone).
- The spinal nerves carry information from different levels (segments) in the spinal cord. Both the nerves and the segments in the spinal cord are numbered in the same way as the bones:
  - So the cervical nerves and spinal cord segments are called C1-C8, the thoracic are T1-T12, lumbar are L1-L5 and sacral are S1-S5.

** MYOTOMES

Each muscle in the body is supplied by a particular level or segment of the spinal cord and by its corresponding spinal nerve. The muscle, and its nerve make up a myotome. This is approximately the same for every person:

- C3,4 and 5 supply the diaphragm (the large muscle between the chest and the belly that we use to breath)
- C5 also supplies the shoulder muscles and the muscle that we use to bend our elbow
- C6 is for bending the wrist back
- C7 is for straightening the elbow
- C8 bends the fingers
- T1 spreads the fingers
- T1 – T12 supplies the chest wall and abdominal muscles
- L2 bends the hip
- L3 straightens the knee
- L4 pulls the foot up
- L5 wiggles the toes
- S1 pulls the foot down
- S3, 4 and 5 supply the bladder, bowel and sex organs and the anal and other pelvic muscles

**Spinal Nerves**

**Other parts of the central nervous system**

- **The meninges**
  - They are three layers or membranes that cover the brain and the spinal cord. The outermost layer is the dura mater. The middle layer is the arachnoid, and the innermost layer is the pia mater. The meninges offer protection to the brain and the spinal cord by acting as a barrier against bacteria and other microorganisms.

- **Cerebrospinal Fluid (CSF)**
  - This circulates around the brain and spinal cord. It protects and nourishes the brain and spinal cord.

**B. The Peripheral nervous system**

The Peripheral nervous system is made up of two parts:

- **Somatic nervous system**
  - pick up sensory information or sensations from the peripheral or distant organs (those away from the brain like limbs) and carry them to the central nervous system.
- includes all the nerves that serve the musculoskeletal system and the exterior sense organs (including skin). Exterior sense organs are RECEPTORS. Muscle fibers are EFFECTORS that react to the stimulus.

** Receptor - receive environmental stimuli and begin nerve impulses.
** Effectors - A nerve ending that carries impulses to a muscle, gland, or organ and activates muscle contraction or glandular secretion.

- Autonomic nervous system

- These also consist of motor nerve fibers that come out of the brain and take the messages for movement and necessary action to the skeletal muscles.
- This nervous system controls the nerves of the inner organs of the body on which humans have no conscious control. This includes the heartbeat, digestion, breathing (except conscious breathing) etc.
- It has three parts:

a) Sympathetic Nervous System
   - is especially important during EMERGENCY SITUATIONS and is associated with "FIGHT OR FLIGHT" reaction. For example, in an emergency, it causes the following:
   - energy directed away from digestion
   - pupils dilate
   - heart rate increases
   - perspiration increases
   - salivation decreases
   - breathing rate increases
   - the neurotransmitter released by the postganglionic axon of the Sympathetic nervous system is NORADRENALIN (which is closely related to adrenalin -- a known heart stimulant). Noradrenalin is released by postganglionic axon --> heart rate accelerates
   - fibers for this system arise from middle part (thoracic-lumbar) of the spinal cord. Preganglionic fiber is short, postganglionic fiber (which contacts the organ) is long

b) Parasympathetic Nervous System
   - The parasympathetic System promotes all the internal responses associated with a RELAXED state. For example:
   - causes the pupils to contract
   - energy diverted for digestion of food
   - heart rate slows
   - Important neurotransmitter in this system is ACETYLCOLINE.
fibers for this system arise from upper and lower part of spinal cord (cranial and sacral nerves).
- Preganglionic fiber is long, postganglionic fiber is short because the ganglia lie near or within the organ.

c) Enteric Nervous System
- is a complex network of nerve fibers that innervate the organs within the abdomen like the gastrointestinal tract, pancreas, gall bladder etc. It contains nearly 100 million nerves.

Neurons in the peripheral nervous system

- Preganglionic neuron - fibers from the CNS to the ganglion. That is like a central controlling body for numerous neurons going out peripherally.
  - located in either the brain or the spinal cord.
- Postganglionic neuron- this run to the effector organ (cardiac muscle, smooth muscle, or a gland).

Clinical Disorders

- HUNTINGTON’S CHOREA - causes a progressive deterioration of nervous system culminating in insanity and death. Thought to be due to GABA malfunctions. A genetic disorder -- children have a 50% chance of developing Huntington's chorea if one of their parent has it. No cure yet.

- TABES DORSALIS – is a progressive disorder occurring as a result of a syphilis infection. Tabes means wasting away, and dorsalis refers to the dorsal root and dorsal region of the spinal cord. Eventually paralysis develops as the infections spreads.

- ALZHEIMER’S DISEASE - a severe form of senility marked by advanced memory loss. Affects 5 to 10% of people over 65. Is a disorder of the limbic system, as it affects both emotion and memory. Protein plaques build up in the brain and destroy brain cells. Ach secretion is considerably below normal in the brains of Alzheimer’s patients. Some drugs show limited success in forestalling advancement of disease in some patients. No cure yet.

- PARKINSON’S DISEASE - characterized by tremors of limbs (especially hands), muscular rigidity. Thought to be due to a lack of dopamine. Some modern medicines are symptomatically effective. No cure yet.
• EPILEPSY - caused by disturbances of normal communication between RAS and cerebral cortex. Causes episodes of convulsions known as seizures. There are "grand mal" and "petite mal" seizures. In a grand mal seizure, the cerebrum becomes extremely excited, the individual may lose consciousness. The seizure only stops when the neurons become fatigued. Medicines (like Dilantin) are effective in treating and preventing seizures. There is still no cure for this disease.

• CEREBRAL PALSY - characterized by spastic weakness of arms and legs. Caused by lack of oxygen during birth which damages motor areas of cerebral cortex. Some symptoms are related to basal nuclei disfunction, such as increased muscle tone and resting tremors.

• SCHIZOPHRENIA: severe mental illness is probably linked, in part, to a surplus of dopamine.

TRIVIAS:

1. The human brain consists of approx 100 billion neurons
2. The cerebral cortex is the smallest part of the brain, but it is the largest portion of the nervous system
3. When the baby is in utero a mass of cells develops that begin the process of creating the brain and nervous system.
4. Our 30-foot long gut is embedded with cells of the enteric nervous system, the ENS, a complex system of around 100 million nerves which is often referred to as our "second brain".
5. The average adult male brain weighs 1375 g while the average adult female brain weighs 1275 g according to MedIndia.
6. the right side of the brain controls the left side of the body and the left side of the brain controls the right side of the body
7. Rate of neuron growth during development of a fetus (in the womb)= 250,000 neurons/minute
8. Diameter of a neuron= 4 to 100 microns
9. Longest axon of a neuron= around 15 feet (Giraffe primary afferent axon from toe to neck)
10. Velocity of a signal transmitted through a neuron= 1.2 to 250 miles/hour
12. There are 43 different pairs nerves which connect the central nervous system to every part of our body. Twelve of these nerve pairs are connected to the brain, while the remaining 31 are connected to the spinal cord.

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