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Introduction

Coordination and Homeostasis

- **Coordination** is interaction and complementing functions of organs.
- Maintains *homeostasis* by synchronizing organ functions.
- Example: Physical exercise increases energy demand, oxygen supply, respiration rate, heartbeat, and blood flow.
- Post-exercise, organs like nerves, lungs, heart, kidneys return to normal.
- **Neural system** and **endocrine system** jointly coordinate body activities.
- Neural system: fast, point-to-point connections.
- Endocrine system: chemical coordination via hormones.

Memory Aids

- Coordination = organs working together for balance.
- Neural = fast signals; Endocrine = slow hormones.
- Exercise example: increased demand → increased supply.

Quick Checkpoints

- What is coordination in biology?
- How do neural and endocrine systems differ in coordination?
- Why does oxygen supply increase during exercise?

Neural System

Structure and Function

- Composed of specialized cells called **neurons**.
- Neurons detect, receive, and transmit stimuli.
- Lower invertebrates (e.g., *Hydra*) have simple neural networks.
- Insects have brains, ganglia, and neural tissues for better organization.

- Vertebrates possess highly developed neural systems.

Memory Aids

- Neurons = nerve cells for signal transmission.
- *Hydra* = simple nerve net.
- Insects = brain + ganglia; Vertebrates = advanced brain.

Quick Checkpoints

- What are neurons and their role?
- Describe neural organization in *Hydra*.
- How does neural complexity vary among animals?

Human Neural System

Structure and Divisions

- The human neural system has two parts: central neural system (CNS) and peripheral neural system (PNS).
- CNS includes the brain and spinal cord; it processes information and controls the body.
- PNS consists of all nerves outside the brain and spinal cord connected to CNS.
- PNS nerve fibers are afferent (to CNS) and efferent (from CNS).
- PNS divides into somatic neural system (to skeletal muscles) and autonomic neural system (to involuntary organs and smooth muscles).
- Autonomic system further splits into sympathetic and parasympathetic systems.
- Visceral nervous system is part of PNS controlling impulses between CNS and internal organs.

Memory Aids

- CNS = Brain + Spinal Cord (Control center)
- PNS = Nerves outside CNS (Communication lines)
- Afferent = Arrives at CNS; Efferent = Exits CNS

- Somatic = Skeletal muscles; Autonomic = Involuntary organs
- Sympathetic = Stress response; Parasympathetic = Rest and digest

Quick Checkpoints

- What are the two main parts of the human neural system?
- Which organs form the CNS?
- What types of fibers are in the PNS?
- How is the autonomic system subdivided?
- What is the role of the visceral nervous system?

Peripheral Neural System

Structure and Classification

- Peripheral neural system includes nerves outside brain and spinal cord.
- Two types of nerves: cranial nerves (12 pairs from brain) and spinal nerves (31 pairs from spinal cord).
- Cranial nerves include sensory, motor, and mixed types (e.g., olfactory, optic, facial, vagus).
- Spinal nerves classified into cervical (8 pairs), thoracic (12 pairs), lumbar (5 pairs), sacral (5 pairs), and coccygeal (1 pair).
- PNS subdivides into autonomic neural system and somatic neural system.
- Autonomic system controls involuntary organs; divided into sympathetic (stress response) and parasympathetic (rest) systems.
- Somatic system controls skeletal muscles.

Memory Aids

- Cranial nerves = 12 pairs from brain; Spinal nerves = 31 pairs from spinal cord.
- Autonomic = Involuntary control; Somatic = Voluntary control.
- Sympathetic = Thoracolumbar outflow; Parasympathetic = Craniosacral outflow.
- Sympathetic activates stress responses; Parasympathetic opposes it.

Quick Checkpoints

- What are the two types of peripheral nerves?
- How many pairs of cranial and spinal nerves exist?
- Which nerves are myelinated in PNS?
- What are the functions of sympathetic and parasympathetic systems?
- What does the somatic neural system control?

Neuron as Structural and Functional Unit of Neural System

Structure and Function

- A neuron has three parts: cell body, dendrites, and axon.
- Cell body contains cytoplasm, organelles, and Nissl's granules (rough ER with ribosomes) for protein synthesis.
- Dendrites are short, branched fibers transmitting impulses toward the cell body; they also contain Nissl's granules.
- Axon is a long fiber with branched distal ends ending in synaptic knobs containing synaptic vesicles with neurotransmitters.
- Axons transmit impulses away from the cell body to synapses or neuromuscular junctions.

Memory Aids

- Neuron parts: Cell body, Dendrites (toward), Axon (away).
- Nissl's granules = protein synthesis sites.
- Synaptic knob = neurotransmitter release point.

Quick Checkpoints

- What are the three main parts of a neuron?
- Where are Nissl's granules found and their function?
- Direction of impulse transmission in dendrites and axons?

Types of Neurons

Classification

- Based on axon and dendrites:
  - Unipolar: One axon, found in embryo.
  - Bipolar: One axon, one dendrite, found in retina.
  - Multipolar: One axon, multiple dendrites, found in cerebral cortex.
- Pseudounipolar: One axon divides into two, e.g., dorsal root ganglion.
- Non-polar: All processes equal, impulse conduction in any direction, e.g., coelenterates.
- Based on function:
  - Afferent (sensory): Carry impulses from receptors to CNS; dendrites form receptors.
  - Efferent (motor): Carry impulses from CNS to effectors; axon terminals form neuromuscular junction.

Memory Aids

- Unipolar = embryo, Bipolar = retina, Multipolar = brain.
- Afferent = arrive CNS, Efferent = exit CNS.

Quick Checkpoints

- How are neurons classified by structure?
- What is the function of afferent and efferent neurons?
- Examples of pseudounipolar and non-polar neurons?

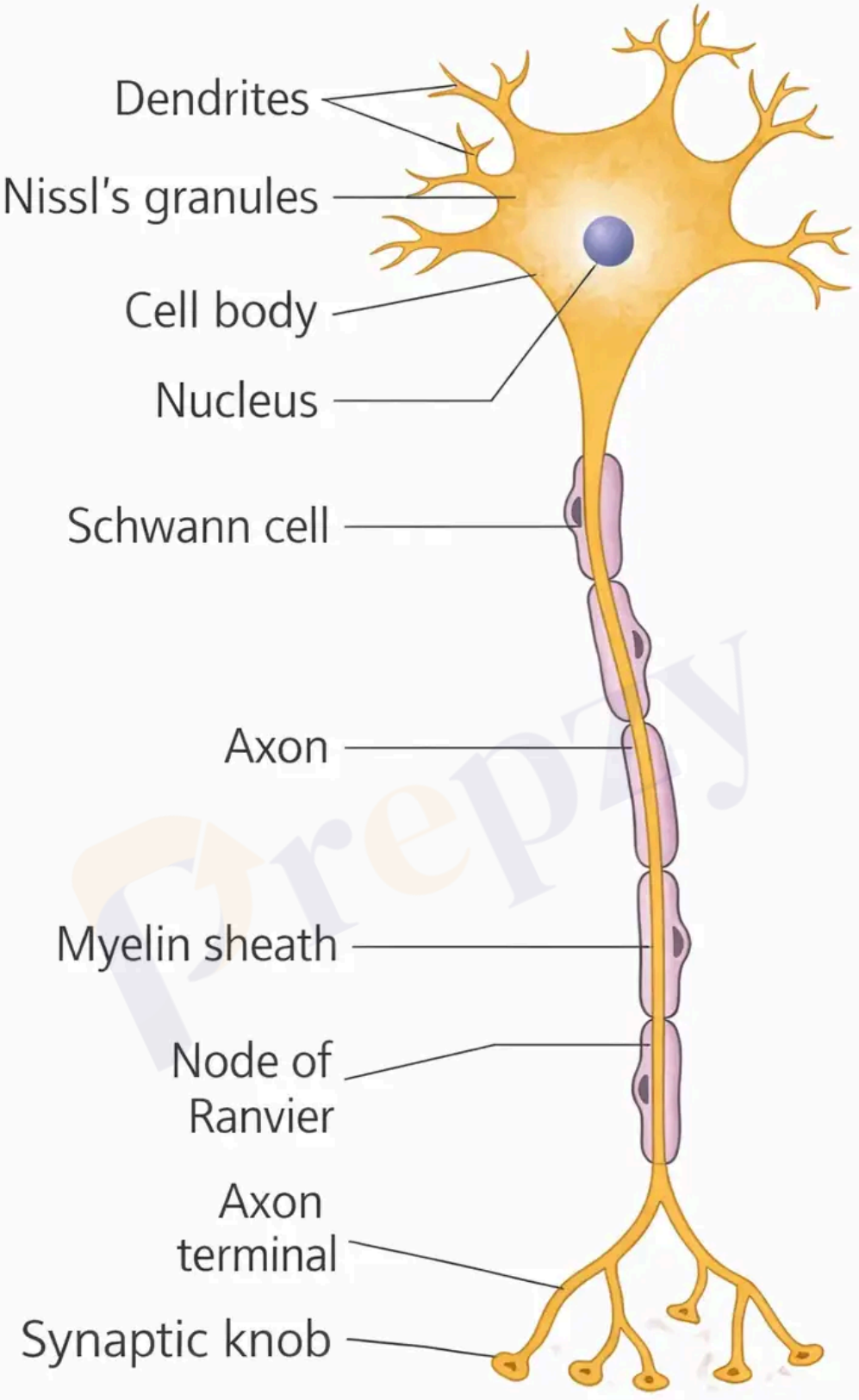


Fig. : Structure of a neuron

Types of Axons

Classification and Features

- Two types: myelinated and non-myelinated.
- Myelinated axons are wrapped by Schwann cells forming myelin sheath with nodes of Ranvier; found in spinal and cranial nerves.
- Non-myelinated axons are enclosed by Schwann cells without myelin sheath; found in autonomic and somatic systems.

Memory Aids

- Myelinated = fast, nodes of Ranvier aid impulse speed.
- Non-myelinated = slow, no myelin sheath.

Quick Checkpoints

- What is the role of Schwann cells?
- Where are myelinated and non-myelinated axons found?
- What are nodes of Ranvier?

Generation and Conduction of Nerve Impulse

Resting State and Ionic Gradients

- Neurons are excitable due to polarized membranes with selective ion channels.
- At rest, membrane is more permeable to K^+, less to Na^+; inside axon has high K^+ and negative proteins, outside has high Na^+.
- Sodium-potassium pump maintains gradients by pumping 3 Na^+ out and 2 K^+ in.
- Resting potential is about -70 mV (inside negative, outside positive).

Action Potential and Impulse Conduction

- Stimulus opens Na^+ channels, Na^+ influx reverses polarity (depolarization) creating action potential (+30 to +45 mV).
- Current flows to adjacent membrane, triggering action potential there; impulse moves along axon.
- After Na^+ influx, K^+ channels open, K^+ efflux restores resting potential (repolarization).
- Conduction is unidirectional; refractory period prevents backward impulse.
- In myelinated axons, impulse jumps node to node (saltatory conduction), faster than continuous conduction in non-myelinated axons.

Memory Aids

- Resting potential = -70 mV, action potential = +30 to +45 mV.
- Na^+ in = depolarization, K^+ out = repolarization.
- Saltatory conduction = jump nodes, faster impulse.

Quick Checkpoints

- What ions are involved in resting and action potentials?
- How does the sodium-potassium pump maintain resting potential?
- What is saltatory conduction?

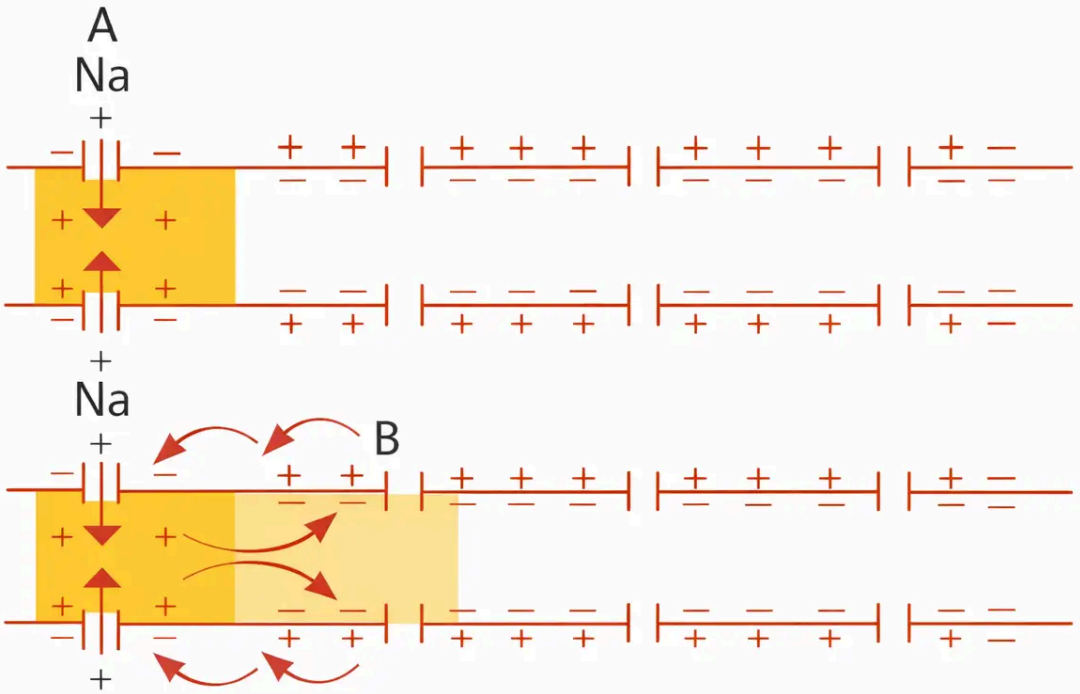


Fig. : Diagrammatic represention of impulse conduction through an axon at points A and B

Transmission of Impulses

Synapses and Types

- Impulse transmission occurs at synapses between neurons.
- Synapse = junction of pre-synaptic and post-synaptic neurons, may have synaptic cleft.
- Two types: electrical (direct current flow, rare) and chemical (neurotransmitter-mediated).

Chemical Synapse Mechanism

- Axon terminals contain vesicles with neurotransmitters (excitatory: acetylcholine; inhibitory: GABA).
- Impulse arrival causes vesicles to fuse with membrane, releasing neurotransmitters into synaptic cleft.
- Neurotransmitters bind receptors on post-synaptic membrane, opening ion channels to generate new potential.
- New potential can be excitatory or inhibitory.

- Impulse transmission is slower than electrical synapses.

Memory Aids

- Synapse = signal transfer point.
- Neurotransmitters: acetylcholine (excitatory), GABA (inhibitory).
- Chemical synapse slower than electrical.

Quick Checkpoints

- What are the two types of synapses?
- How do neurotransmitters transmit impulses?
- Difference between electrical and chemical synapses?

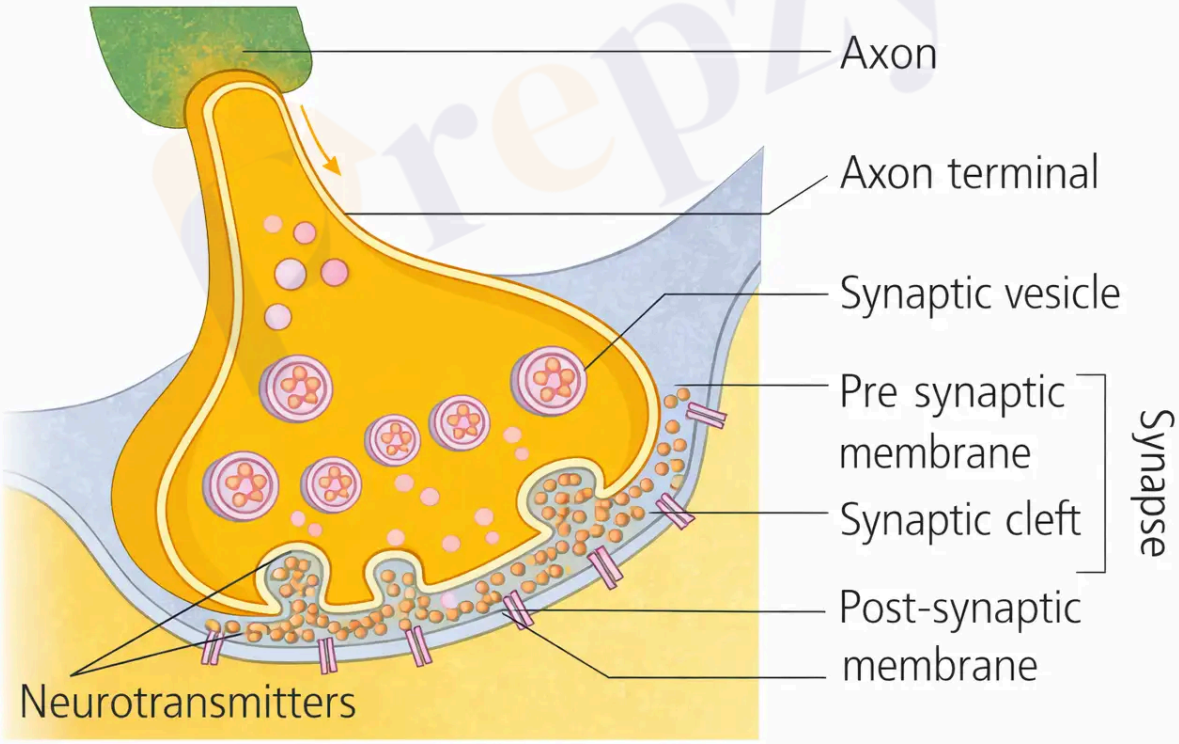


Fig.: Diagram showing axon terminal and synapse

Ultrastructure of a Neuron Showing Transmission of Nerve Impulse at Synapse

Cell body (Soma)
It contains typical cell organelles, a prominent spherical nucleus and cytoplasm called **neuroplasm**. It also has **neurofibrils** (play role in transmission of impulses), **neurotubules** (maintain shape) and **Nissl's granules** (synthesise proteins).

Axon
It is a single, long process of uniform thickness which conducts nerve impulses away from the cell body.

Cell membrane

Dendrites
These are highly branched extensions that receive incoming nerve impulses and conduct them towards cell body.

Myelin sheath
It is a sheath around axon laid down by Schwann cells and plays a role in protection and insulation of nerve fibre. It increases the rate of transmission of impulses.

Axon hillock
It is the area of origin of axon and is considered as the most sensitive part of the neuron.

Node of Ranvier
These are gaps occurring at regular intervals in myelin sheath which allow nerve impulses to move along the neuron through a process of depolarisation and repolarisation of membrane.

Synapse

Terminal arborisations
They form junctions with other neurons.

Fig.: Ultrastructure of a neuron

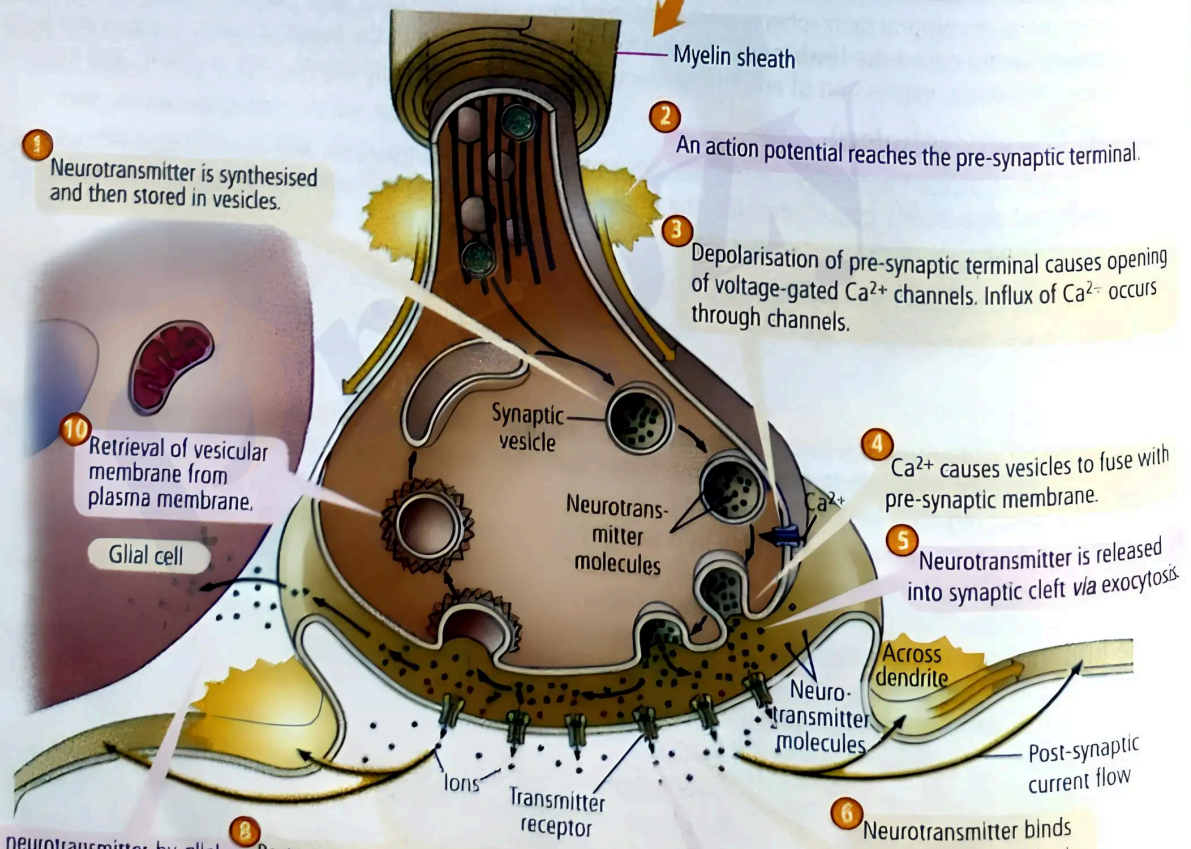


Fig.: Transmission of nerve impulse at a chemical synapse

Central Neural System

Overview

- The brain is the central processing organ, controlling voluntary movements, balance, vital involuntary organs, thermoregulation, hunger, thirst, circadian rhythms, endocrine activities, and behavior.
- Processes vision, hearing, speech, memory, intelligence, emotions, and thoughts.
- Protected by the skull and covered by cranial meninges: dura mater (outer), arachnoid (middle), pia mater (inner).
- Divided into forebrain, midbrain, and hindbrain.
- Cerebrospinal fluid (CSF) cushions the brain, present in ventricles and subarachnoid space.

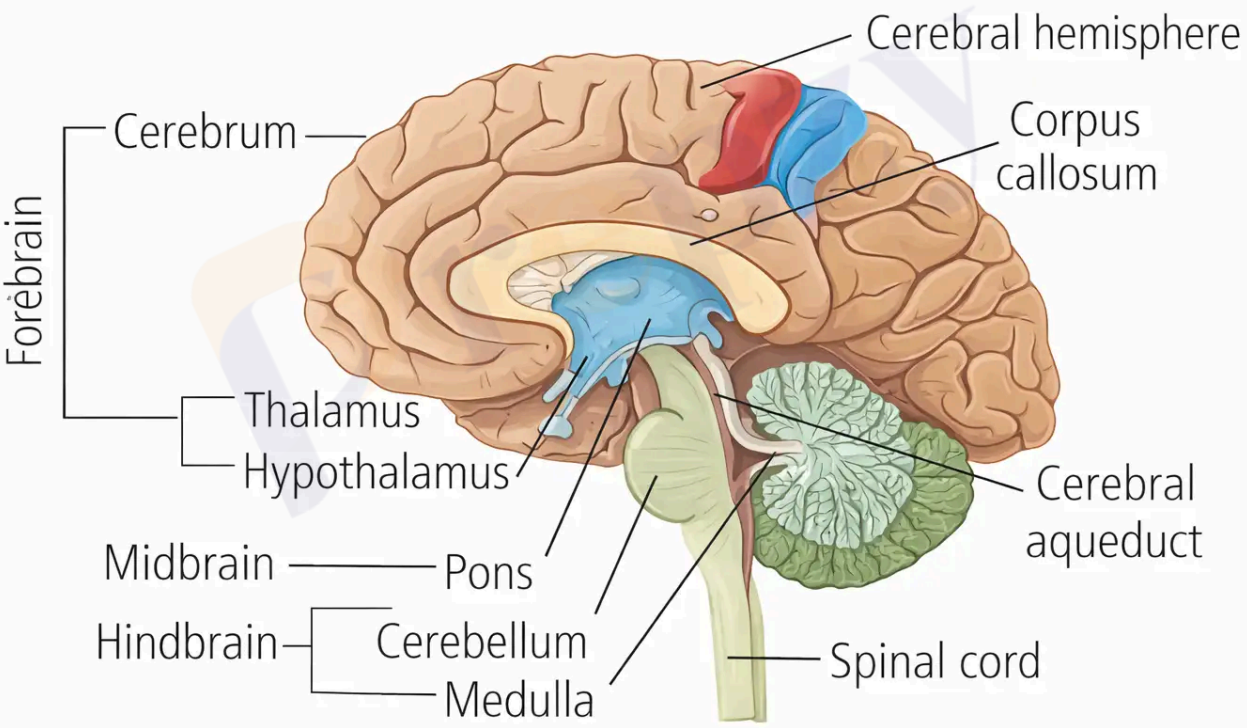


Fig. : Diagram showing sagittal section of the human brain

Memory Aids

- Brain parts: Forebrain (thinking), Midbrain (relay), Hindbrain (balance & vital functions).
- Meninx layers: Dura (durable), Arachnoid (spider-like), Pia (delicate).

Quick Checkpoints

- What are the three main parts of the brain?
- Which meninges layer is the thinnest?
- What is the role of cerebrospinal fluid?

Brain

Structure and Functions

- Forebrain includes olfactory lobes, cerebrum, and diencephalon.
- Cerebrum: largest part, two hemispheres connected by corpus callosum, cerebral cortex with gyri and sulci.
- Diencephalon: epithalamus (melatonin secretion), thalamus (sensory relay except smell), hypothalamus (controls hunger, thirst, hormones).
- Limbic system (amygdala, hippocampus) regulates emotions, sexual behavior, motivation.
- Midbrain: between forebrain and hindbrain, contains cerebral aqueduct and corpora quadrigemina (superior colliculi for sight, inferior colliculi for hearing).
- Hindbrain: pons (fiber tracts, breathing regulation), cerebellum (movement coordination, balance), medulla oblongata (controls respiration, cardiovascular reflexes).
- Brain stem (midbrain, pons, medulla) connects brain to spinal cord, entry/exit for 10 cranial nerves.
- Spinal cord: extends from medulla to second lumbar vertebra, conducts impulses, controls reflexes, has grey (inner) and white (outer) matter, ends as conus medullaris with filum terminale.

Forebrain

Olfactory lobes

- Paired club shaped structure, forming anterior part of brain, concerned with sense of smell.
- Each lobe consists of two parts– anterior bulb and posterior **olfactory tract.**

Cerebrum

- Largest and most complex part of human brain, consists of left and right cerebral hemispheres, connected by **corpus callosum** (tract of nerve fibres).
- **Cerebral cortex** forms outermost portion of cerebrum and makes up the grey matter that gives greyish appearance.
- The surface of cortex is highly folded, forming **gyri** (upward folds) alternating with **sulci** (downward grooves).
- The cerebral cortex contains motor area, sensory areas and large regions that are neither clearly sensory nor motor in function. These regions are called **association areas.**
- Beneath the grey matter of frontal, parietal, temporal and occipital lobes.
- Each hemisphere consists of association areas.
- Association areas are responsible for functions like intersensory associations, memory and communication.

Diencephalon

Epithalamus (Roof)

- Forms anterior choroid plexus.
- Short pineal stalk, have pineal body, secretes **hormone melatonin.**

Thalamus (sides)

- Lies superior to midbrain.
- Composed primarily of grey matter.
- It serves as a **switching station** for sensory input including sound and balance. With the exception of smell, each sense channels its sensory nerves through thalamus.

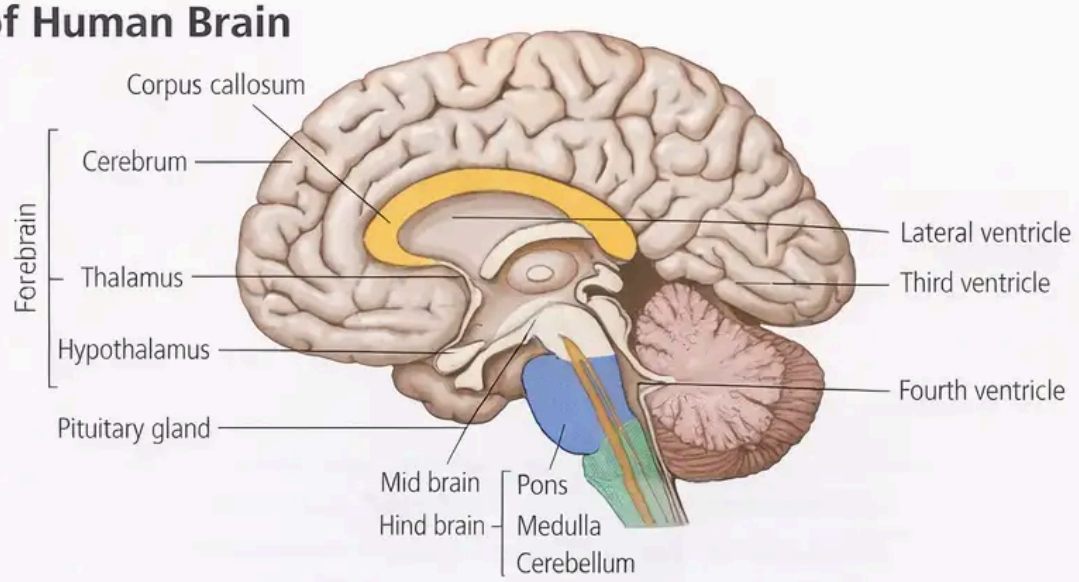
Hypothalamus (floor)

- Hypothalamus lies above the pituitary gland and is attached to it by a stalk called **infundibulum.**
- Maintains homeostasis, controls urge for eating and drinking.
- Contains neurosecretory cells, which secrete hormones called hypothalamic hormones.

Fig. : Transmission of nerve impulse at a chemical synapse

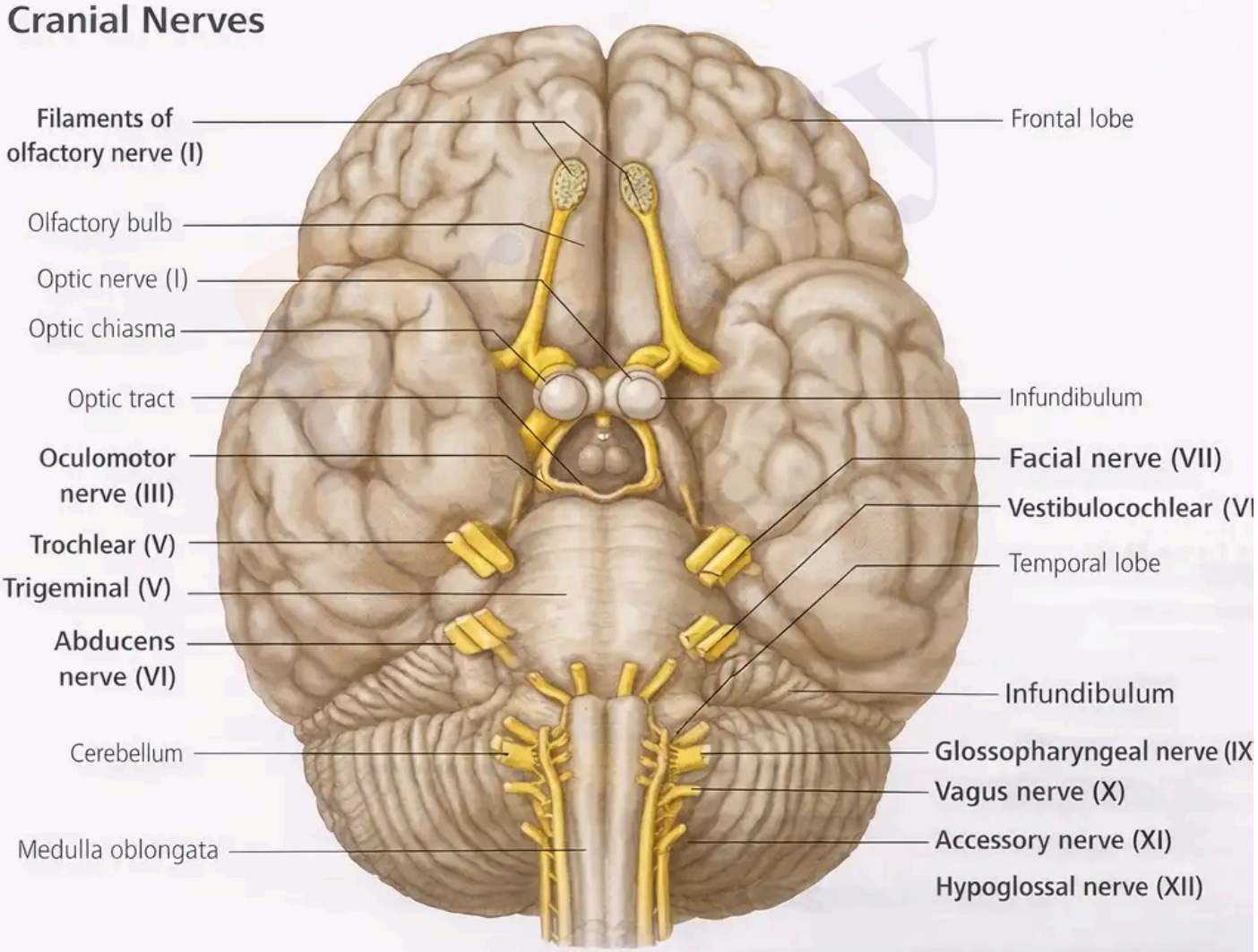
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Parts of Human Brain



Lateral view of brain

Cranial Nerves



Ventral view of brain

Memory Aids

- Forebrain = Olfactory + Cerebrum + Diencephalon.
- Corpora quadrigemina: Superior = Sight, Inferior = Hearing.
- Brain stem = Midbrain + Pons + Medulla.
- Limbic system controls emotions and motivation.

Quick Checkpoints

- What are the main parts of the forebrain?
- Which part of the brain controls balance and coordination?
- What is the function of the thalamus?
- Where is the cerebral aqueduct located?
- What does the medulla oblongata regulate?
- What connects the two cerebral hemispheres?
- What is the role of the spinal cord?