CHAPTER 4

Nervous System

Learning objectives

At the end of the chapter the student should be able to

- ⇨ Explain the classification of nervous system and write the functions of organs of Nervous system
- ⇨ Describe autonomic nervous system and explain about sympathetic and parasympathetic nervous system
- ⇨ Explain about the structure and properties of neuron and neuroglia
- ⇨ Define a synapse, write its classifications and explain the excitatory and inhibitory post synaptic potentials
- ⇨ Understand the physiology of memory and learning
- ⇨ Explain about reflexes and its types

- ❑ The system that controls and coordinates all the functions of the body comprises the nervous system.
- ❑ Nervous system is divided into

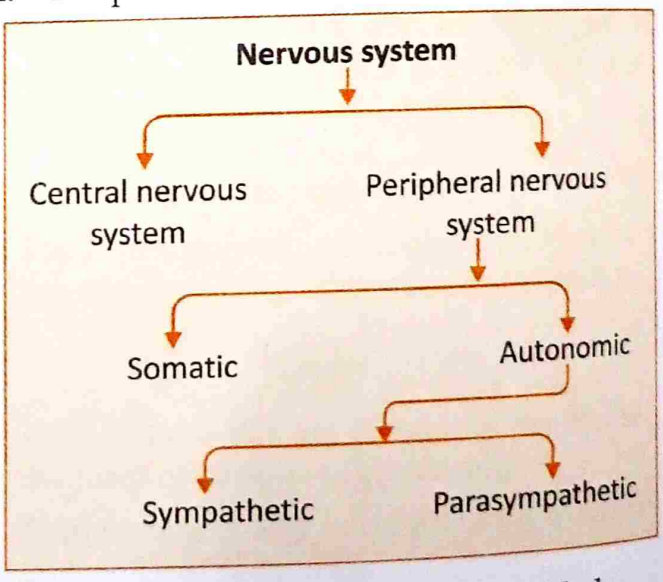
1. Central nervous system.
2. Peripheral nervous system.

- ❑ **Central nervous system** comprises the main core or the control point of the nervous system. It consists of the brain and spinal cord.
- ❑ **Peripheral nervous system** comprises the connections of the central nervous system to rest of the body or it is the connection between the control enter and the effectors of the body.
- ❑ It is made up of somatic nervous system and Autonomic nervous system.
- ❑ Autonomic nervous system is further divided into sympathetic and parasympathetic nervous system.

Nervous system

- ❑ Functionally nervous system can be divided into.

1. Central nervous system
2. Peripheral nervous



- ❑ Peripheral nervous system is divided

1. Somatic nervous system.
2. Autonomous nervous system.

- ❑ Autonomic nervous system is again divided.

1. Sympathetic nervous system.
2. Parasympathetic nervous system.

- ❑ Central nervous system is divided into brain and spinal cord.

- Brain is further subdivided into 3 divisions which are further subdivided as follows.

Based on embryological development brain is divided into.

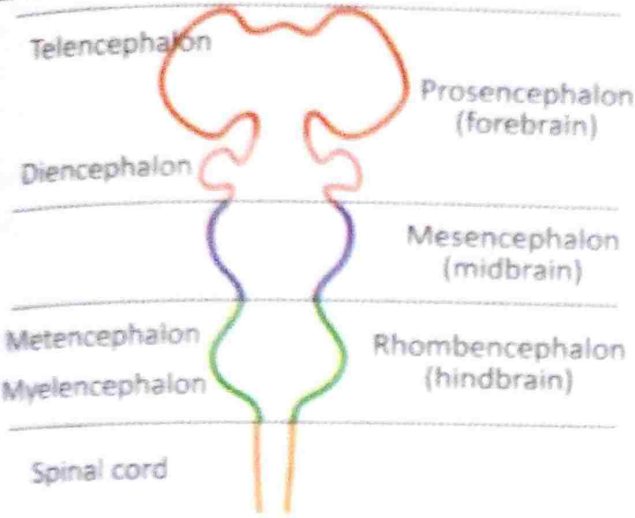


Figure 4.1 : Division of Brain

1. Proencephalon (Fore brain).
2. Mesencephalon (Mid brain).
3. Rhombencephalon (Hind brain).

1. Pro encephalon

It is the fore brain, it consists of

- **Telencephalon** : Cerebral hemisphere, Basal ganglia, Hippocampus.
- **Di encephalon**: Thalamus, Hypotha-lamus, Metathalamus, Subthalamus.

2. Mesencephalon

It is the midbrain.

3. Rhombencephalon (hind brain)

It consists of 2 parts.

- Myelencephalon (Medulla).
- Metencephalon : Pons, Cerebellum.

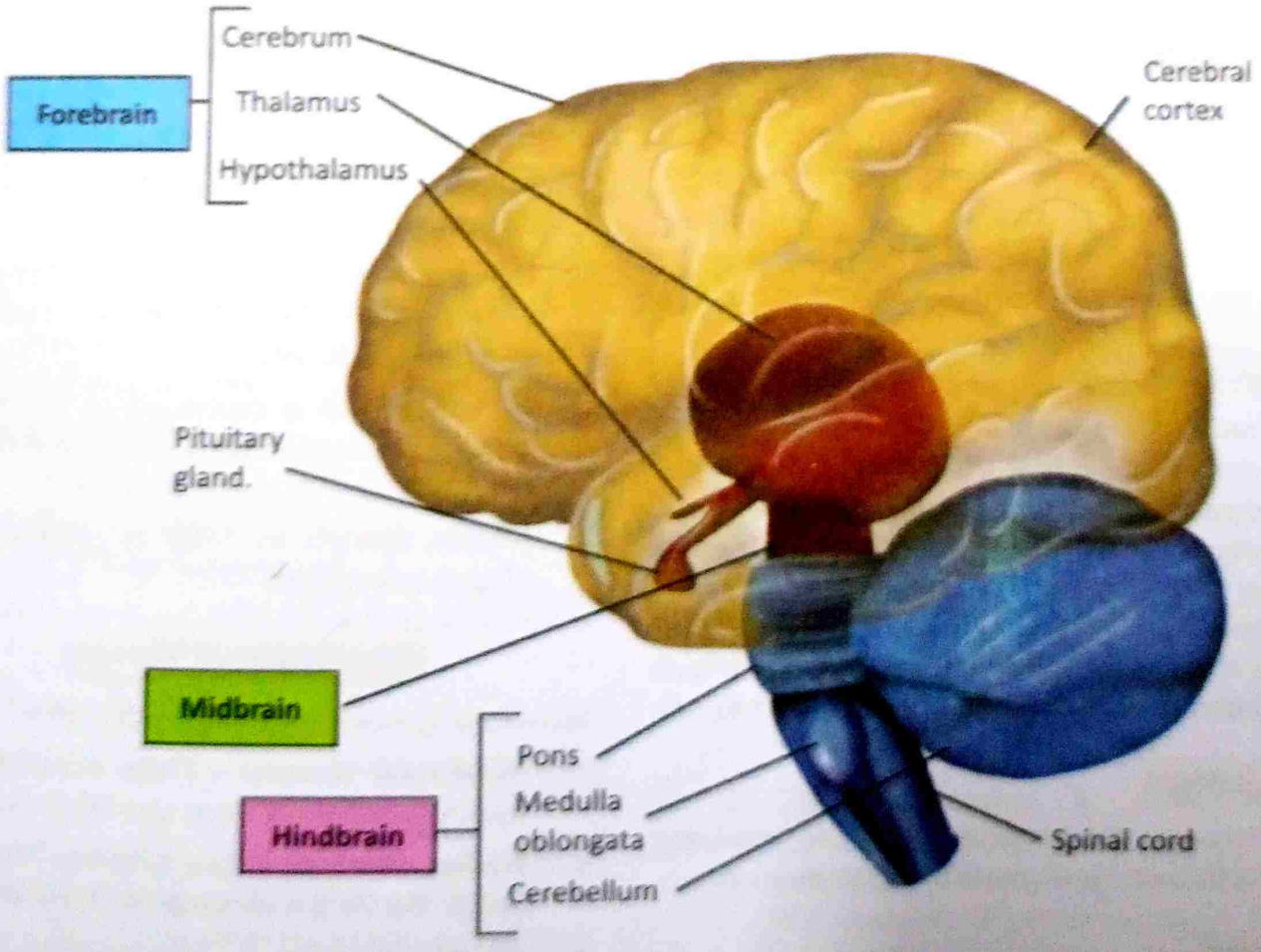


Figure 4.2 : Parts of Human Brain

Structural and functional unit of nervous system

- Histologically nervous system is composed of two types of cells.
  1. Neuron
  2. Neuroglia
- **Neuroglias** are the supporting cells of the nervous system which help in activities like metabolism, production of myelin sheath, production and circulation of CSF.
- **Neuron** is the structural and functional unit of nervous system.

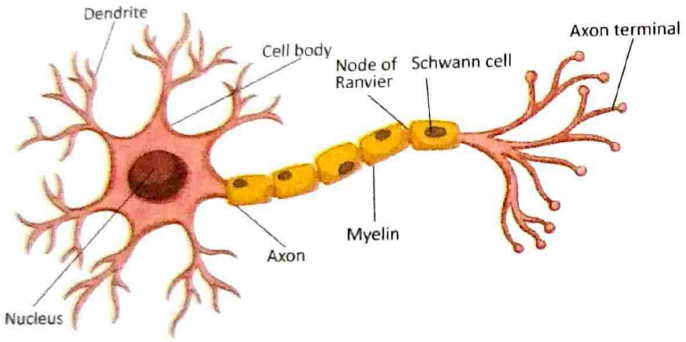


Figure 4.3 : Neuron

- It has three basic parts

1. Cell body

- Contains nucleus and surrounding cytoplasm that includes typical organelles like lysosomes, mitochondria, golgicomplex, nissl bodies (Nissl granules are modification of rough endoplasmic reticulum which serves as centre for production of proteins) neurofibrils which form cytoskeleton and gives support to cell.

2. Dendrites

- They are the processes that are receiving portion or input portion of the neuron.

3. Axon

- It is a cylindrical projection which carries nerve impulse to another neuron, gland or muscle fiber.
- An axon contains mitochondria microtubules neurofibrils but not rough endoplasmic reticulum.
- Its cytoplasm is called as axoplasm is surrounded by plasma membrane called axolemma.
- An axon ends by dividing into fine collaterals called axon terminals.
- Tips of axon terminals swell into bulb shaped structures called synaptic end bulbs.
- They contain membranous sacs called synaptic vesicles which contain chemical substance called neurotransmitters.

Myelin sheath

- Myelin sheath is the lipoprotein covering of the axon.
- It is responsible for faster conduction of action potentials and provides insulation to a nerve fiber/axon.
- Myelin sheath is produced by the special type of neuroglia called a Schwann cells in the CNS.
- Myelin sheath in PNS is produced by oligodendrocytes.

Classification of Neurons

Structurally neurons are classified into.

1. **Multi polar neurons** – These neurons have multiple poles for axon and dendrites.
2. **Bipolar neurons-** These neurons have two poles one for a axon and one for a dendrite
3. **Unipolar neurons** – These neurons have a single pole for both axon and a dendrite.

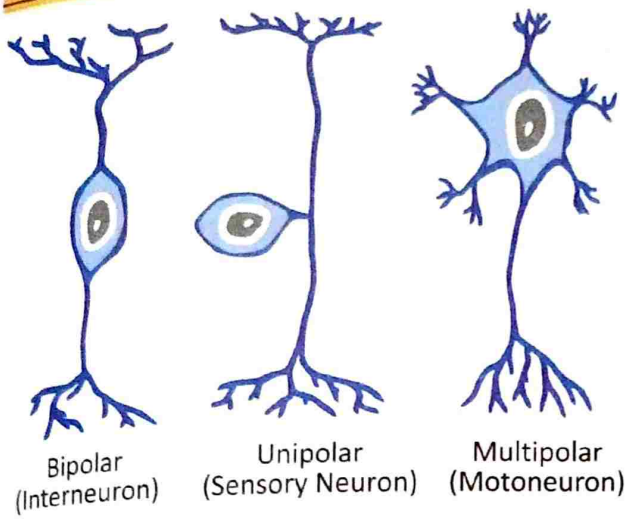


Figure 4.4 : Types of Neuron

Functionally the neurons are classified into three types.

1. Motor neurons
2. Sensory neurons
3. Association neurons

Properties of nerve fibers

1. **Excitability**
   - Nerve fibres respond to any external stimuli and cause an electric potential of cell.
   - Nerve fibers respond to all sort of stimuli like mechanical, electrical stimuli, thermal or chemical stimuli.
2. **All or none law**
   - When a stimulus is applied to a nerve fiber it either responds to the stimuli or it does not respond.
   - There is no half responses in a nerve fiber.
3. **Refractory period**
   - Every nerve fiber has a refractory period.
   - Refractory period is a period where in if two successive stimulus are applied to a nerve the nerve is unable to respond.
4. **Conductibility**
   - An action potential that is generated across a cell is propagated all along the axon till the axon terminal.
5. **Summation**
   - Application of a subthreshold stimulus in a nerve evokes no response where as, when many such stimulus are given in rapid succession, they are summated or added upon to produce a action potential.
6. **Accommodation**
   - Application of repeated stimuli decreases excitability of a nerve fiber.
7. **Infatigability**
   - A nerve fiber never undergoes fatigue even in continuos stimulation for long time.

Types of conduction

1. **Saltatory conduction**
   - It is a characteristic of myelinated fibers.
   - Here the action potential jumps across the node of Ranvier from one node to another.
   - Here the action potential is transmitted from one place of absence of myelin sheath to another place of absence of myelin sheath.
   - Hence this type of conduction is comparatively faster.
2. **Continuous conduction**
   - It is seen in unmyelinated nerve fibres.
   - Here the action potential travels across the neurilemma if a neuron.
   - This conduction is comparatively slower as there is no jumping or saltation of action potential across the node of Ranvier as seen in the salutatory conduction.

Synapse

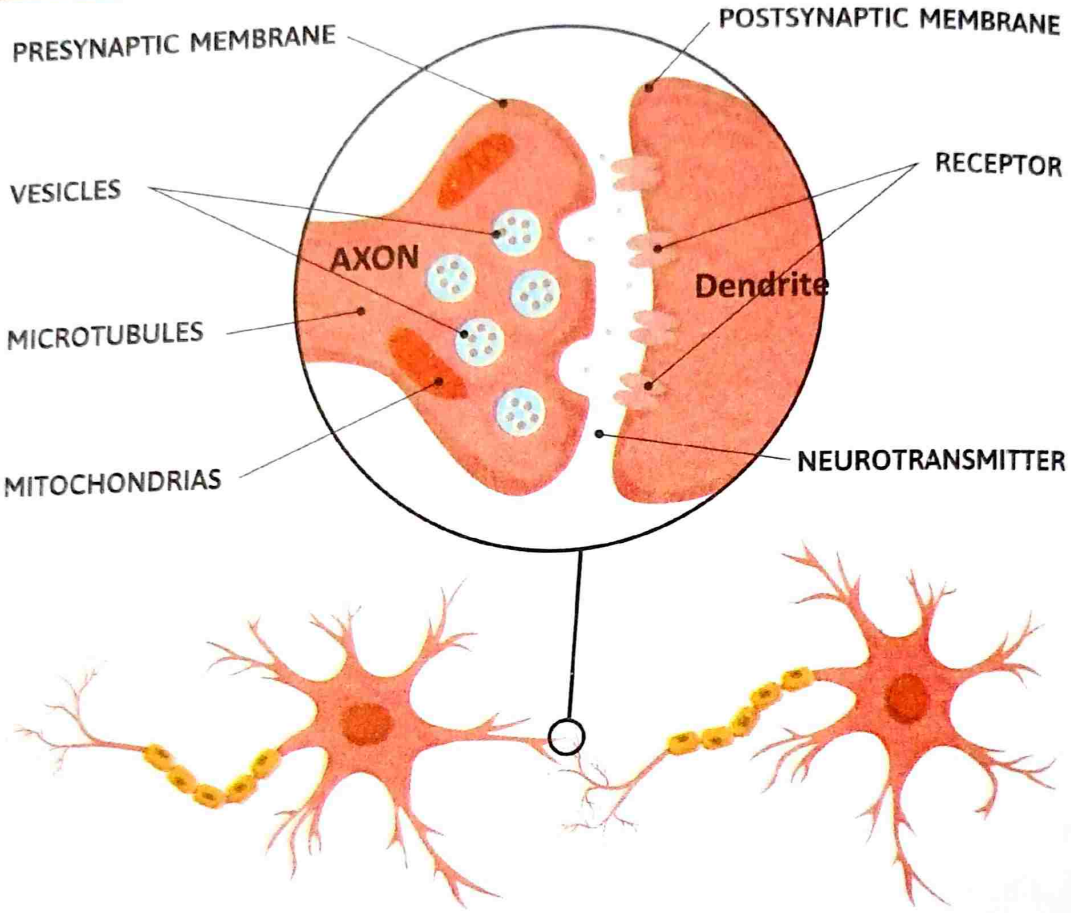


Figure 4.5 : Neuron Anatomy

- The site of functional contact between two neurons or between a neuron and an effector cell (muscle or gland) is called as synapse.
- Synapses are of 2 types.

1. Physiologically
   1. Electrical synapse
   2. Chemical synapse
2. Structurally synapses are of 3 types
   1. Axoaxonic synapse
   2. Axodendrite synapse
   3. Axosomatic synapse.

Electrical synapse

- Here the impulses are transmitted from one neuron to another through presence of gap junctions between two neurons.
- This physical connectivity between two neurons means that there is no synaptic delay in transmission of nerve impulses.
- Electrical synapses are present in junctions between neurons in cardiac muscles, smooth muscles of intestine and in the lens of eyes.

Chemical synapse

- This is a type of synapse where there is no physical connectivity between the two neurons.
- There will be space between the neurons

called as synaptic cleft.

- The action potential that reaches the presynaptic terminal will release a neurotransmitter into the synaptic cleft.
- The neurotransmitter upon reaching the post synaptic neuron will cause a change in the potential of the post synaptic neuron there by developing an action potential.

Conjoint synapse

- These are the synapses where electrical and chemical synapses co-exist.

Properties of a synapse

1. **Convergence and divergence**
   - Presynaptic neurons can converge on single post synaptic neuron and similarly presynaptic neurons diverge into many post synaptic neurons too.
2. **Law of forward conduction**
   - The transmission of an impulse happens from pre synaptic to post synaptic neuron in one way direction.
3. **Fatigue**
   - When a presynaptic neuron is stimulated repeatedly it may lead to fatigue and inability to transmit impulses.
4. **Synaptic delay**
   - The time interval between arrival of a synapse at the pre synaptic neuron and post synaptic neuron is called as synaptic delay.
5. **Occlusion**
   - The response seen during stimulation of more than one presynaptic neuron will be less than the sum total of the response that would have been seen if stimulated separately.
   - This due to overlapping of the afferent fibres in their central distribution.
6. **Summation**
   - Upon application of repeated stimuli at frequent intervals then the next stimulus will get a add on from the previous postsynaptic potential and will lead to a wider response.
   - This type of summation is called Temporal summation.
   - In the case where a post synaptic neuron receives impulses from a large number of presynaptic terminals at the same time then there will be a adding up effect eliciting a greater response.
   - This type of summation is called as Spatial summation.
   - When two different excitatory nerves to a muscle are stimulated simultaneously the tension developed in a individual muscle may be less than the tension that would have been generated if stimulated separately.
   - This decreased response is due to presynaptic fibers sharing post synaptic neurons.
7. **Reciprocal inhibition**
   - This is property seen in a synapse where an stimulus on the presynaptic neuron will result in excitatory effect in a group of muscles and at the same time cause inhibitory effect in another group of muscles.
8. **Learning and plasticity**
   - Plasticity refers to a special property in a synapse where the synaptic transmission can be increased or decreased based on past experiences.

Ionic basis of excitatory synapse and inhibitory synapse

- Excitatory synapse is a synapse which results in transmission of a nerve impulse further.
- Inhibitory synapse is a synapse that results in the inhibition of the transmission of action potential.

Excitatory post synaptic potential

- Arrival of action potential at axon terminal
- Opening of calcium channels in presynaptic membrane
- Entry of calcium ions from ECF to axon terminal
- Stimulation of synaptic vesicles and release of acetylcholine
- Acetyl choline moves into synaptic cleft
- Gets attached to the receptors in the post synaptic neuron
- Opening of Na^+ channels and entry of Na^+ ions in the post synaptic neuron
- Development of excitatory post synaptic potential (EPSP)
- Spread of action potential

Inhibitory post synaptic potential

- Arrival of action potential at axon terminal
- Opening of calcium channels in presynaptic membrane
- Entry of calcium ions from ECF to axon terminal
- Stimulation of synaptic vesicles and release of GABA
- GABA moves into synaptic cleft
- Opening of K^+ channels and movement of K^+ ions out of the post synaptic neuron
- Opening of Cl^- channels and entry of Cl^- ions in the post synaptic neuron
- Inhibition of synaptic transmission

Neuroglia

Neuroglias are basically of 6 types.

1. **Astrocytes:** Help in the metabolism of neurotransmitters and take part in forming blood brain barrier.
2. **Oligodendrocytes:** They help in production of myelin sheath in CNS.
3. **Microglia:** They are small phagocytic cells. They acts as scavengers of nervous system.
4. **Ependymal cells:** They line the ventricles and help in the production of CSF.

The other two types of Neuroglia are found in PNS namely.

5. **Schwann cells:** They help in production of myelin in PNS.
6. **Satellite cells:** Supporting cells of PNS.

Neurotransmitter

- Chemical mediators liberated from the nerve endings that are responsible for transmission of a nerve impulse is called as a neurotransmitter.
- Some of the important neurotransmitters employed by the neurons are Epinephrine, Norepinephrine, Acetylcholine, Dopamine, GABA (gamma amino butyric acid).

Brain

Brain is conventionally divided into four principal parts.

1. Brain stem
2. Dincephalon
3. Cerebellum
4. Cerebrum

Coverings of brain

- Brain is protected by the cranial bones and cranial meninges.
- Three cranial meninges cover the brain
  1. Outer durameter
  2. Middle arachnoid meter
  3. Inner piameter
- An extension of duramater called as **falx cerebri** separates two hemispheres of cerebrum.
- An extension of duramater called as **falx cerebelli** separates two lobes of cerebellum.
- An extension of duramater called as **tentorium cerebelli** separates cerebrum from cerebellum.

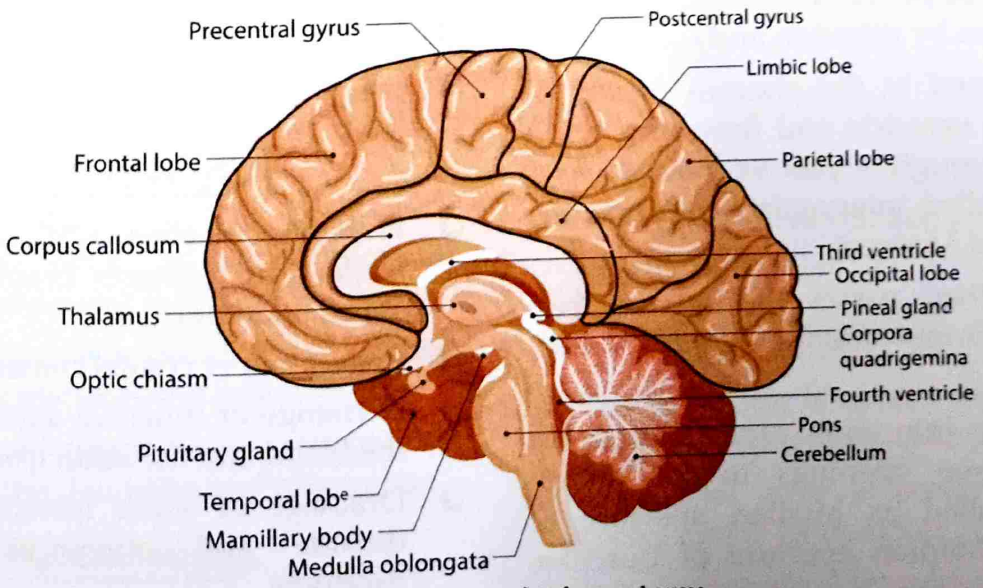


Figure 4.6: Human brain anatomy

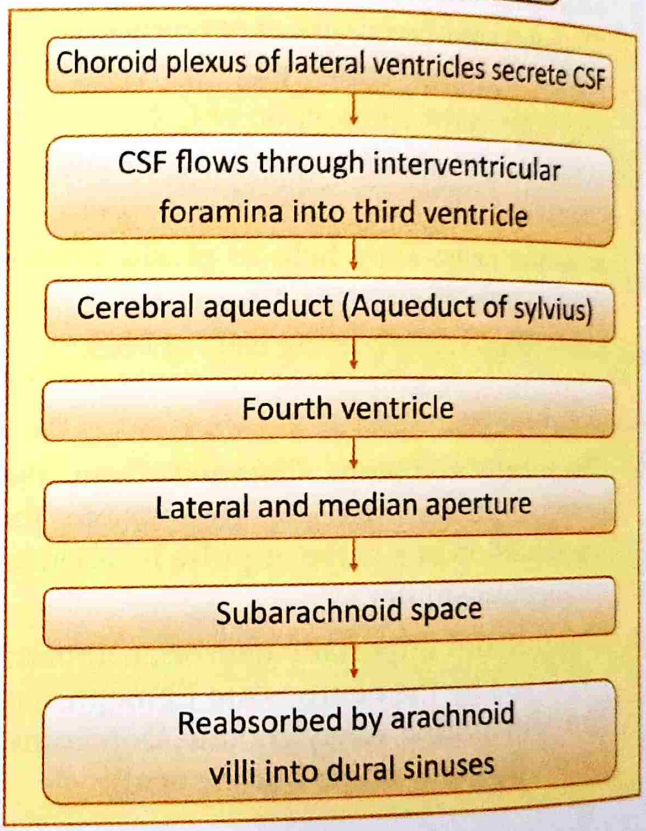
Cerebrospinal fluid

- Brain and spinal cord are protected against physical or mechanical injury by a fluid called as cerebrospinal fluid.
- This fluid continuously circulates across subarachnoid space (between arachnoid and pia meter) and in central canal and cavities in brain and spinal cord.
- Four cavities within brain namely two lateral ventricles, third ventricle, and fourth ventricle play a role in formation and circulation of cerebrospinal fluid.
- Entire nervous system contains about 80-150 ml of CSF at one time where as the total production of CSF is about 450 – 500ml/24 hrs.
- It is a clear colourless fluid containing glucose, proteins, lactic acid, urea, cations and anions.

Formation of CSF

- CSF is formed in the choroid plexus which are a network of capillaries in the walls of ventricles of the brain.
- The capillaries are covered by ependymal cells which form cerebrospinal fluid from blood plasma by filtration and secretion.
- CSF is formed in the choroid plexus of each lateral ventricle and flows into third ventricle through a pair of narrow oval openings called interventricular foramina (Foramina of Monroe).
- The fluid then passes through cerebral aqueduct from midbrain into fourth ventricle.
- CSF enters into sub arachnoid space through three openings in the fourth ventricle called as Median aperture of Magendie, Median aperture of Luschka, and rest of it passes through central canal into spinal cord.
- It is gradually reabsorbed back into the blood through arachnoid villi.

Formation and circulation of CSF



- Volume – 150 ml
- Specific gravity – 1.005

Functions of CSF

- **Protective function:** CSF acts like a fluid buffer and protects brain from external shock and injury.
- Regulation of cranial content volume.
- Exchange of nutritive substances between the blood and the brain tissues.
- Drainage of waste materials like carbon dioxide and other metabolic waste products.

Blood brain barrier

- A special barrier exists between the brain and the blood.
- This barrier called as blood brain barrier selectively permits small molecules, uncharged molecules and lipids to enter into the system.
- It does not allow large molecules; plasma protein bound substances and water soluble substances to pass through it.
- Blood brain barrier is formed due to astrocytes. Astrocytes surround the capillaries of brain and form a sheath around the capillaries and form a barrier.
- In the endothelium of capillaries of brain, cells are joined by "tight junctions".
- These tight junction prevent excess permeability there by strengthening the blood brain barrier and protecting the brain.

Cerebrum

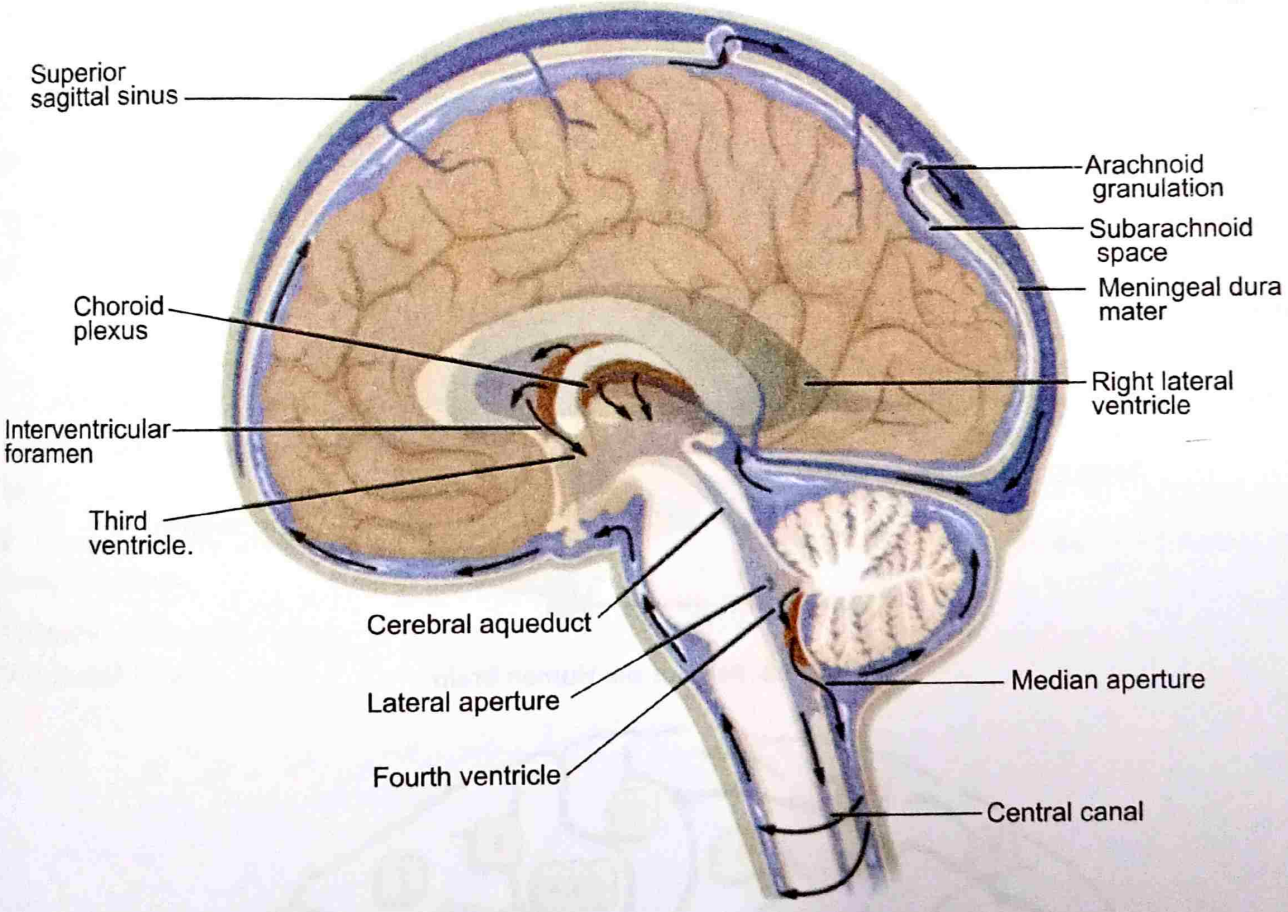


Figure 4.7: Cerebrum

Gray and white matter

- **White matter** refers to aggregation of myelinated processes from many neurons.
- The colour of myelin sheath is responsible for the white matter being called so.
- **The gray matter** of nervous system contains both cell bodies dendrites and neuroglia.

Ganglia and nuclei

- The collection of cell bodies in central nervous system is called as nuclei.
- The collection of cell bodies outside central nervous system is called as ganglion.

Cerebrum

- The cerebrum is spread over a wide area over diencephalon and brainstem.
- Superficial layer of cerebrum is cerebral cortex and is made up of grey matter.
- It is characterized by sulcus and Gyrus.

- Gyri are elevated ridges "winding" around the brain.
- Sulci are small grooves dividing the gyri.
- It is divided into right and left hemispheres by a fissure called as longitudinal fissure.
- Between the hemispheres is an extension of duramater called falx cerebri.
- The hemispheres are connected internally by a bundle of transverse fibres called as corpus callosum.
- Cerebral cortex is composed of 6 layers namely the
  1. Molecular layer
  2. External granular layer
  3. Outer pyramidal layer
  4. Internal granular layer
  5. Ganglionic layer
  6. Fusiform cell layer
- Each cerebral hemispheres is divided into lobes namely
  1. Frontal
  2. Parietal
  3. Temporal
  4. Occipital

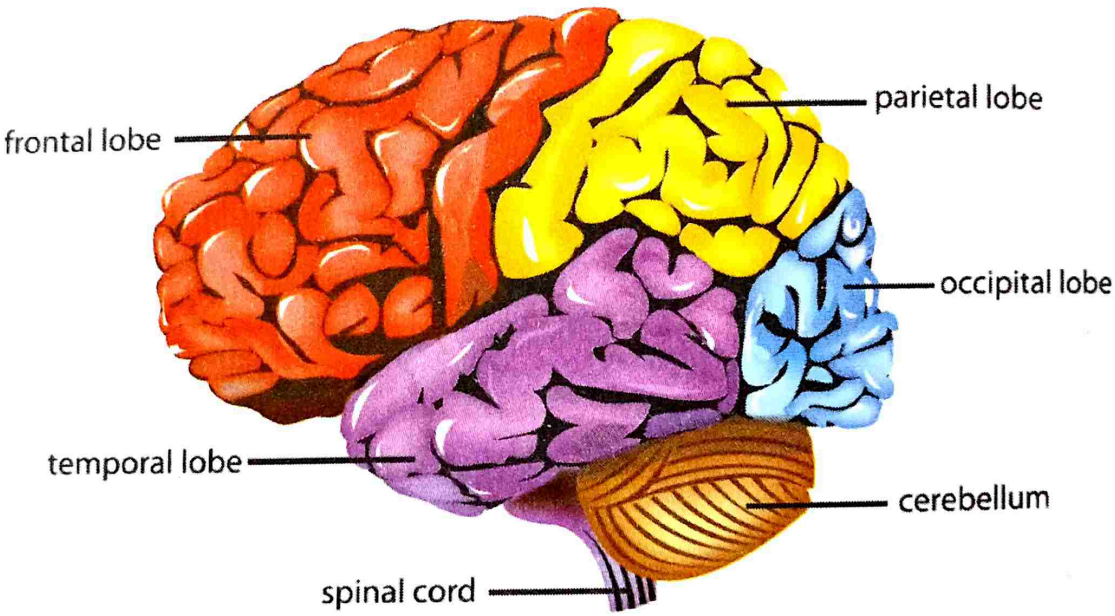


Figure 4.8: Parts of the Human Brain

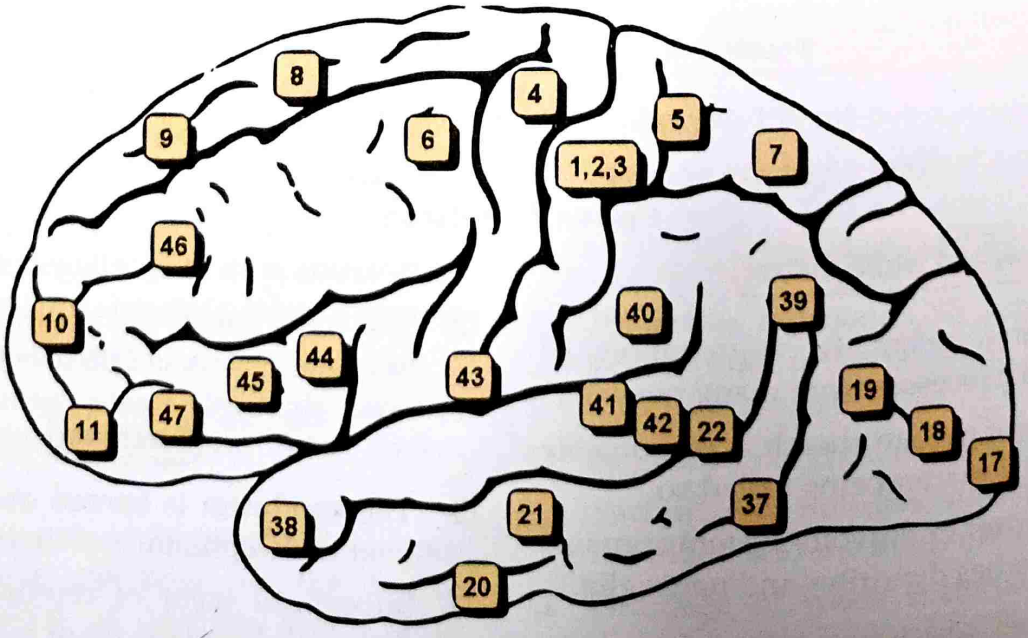


Figure 4.9: Functional areas (Brodman's areas) of Cerebrum

- A central sulcus separates frontal lobe from parietal lobe.
- A lateral sulcus separates frontal lobe from temporal lobe and also temporal lobe from parietal lobe.
- A parieto occipital sulcus separates parietal parietal lobe from occipital lobe.

The functional areas (Brodmans areas) of cerebrum can be divided into.

1. Sensory areas
2. Motor areas
3. Association areas

Sensory areas

- **Primary somesthetic area:**
  - Also called Area 1, Area 2 and Area 3.
  - It is present in the parietal lobe.
  - It receives sensory impulses of touch, pressure, pain, heat cold and discriminative touch.
- **Primary visual area:** Area 17 in the occipital lobe.
- **Primary auditory area:** Area no 41, 42 in the temporal lobe.
- **Primary olfactory area:** Present in the temporal lobe.
- **Primary gustatory area:** Area 43 Present in the parietal lobe of cerebral cortex.

Motor area

- **Primary motor area:** Located in the prefrontal area of frontal lobe.
- **Brocas area (Area no 44 and 45)**
  - It is the motor area for speech located in the dominant hemisphere of the frontal lobe.
  - It coordinates the movements of organs of voice production like tongue, lips and larynx.

Association areas

- **Gnostic area:** Common integrative area among somatosensory, visual and auditory association areas.
- **Visual association area** Area 18, 19 located in the occipital lobe.
- **Wernickes area** (Auditory association area) Area no 22- temporal lobe.
- **Premotor area** (Area no 6) - Frontal cortex.
- **Frontal eyelid area** (Area 8) – Frontal cortex.

Brain Stem

It comprises of

1. Medulla oblongata
2. Pons
3. Mid brain

1. Medulla oblongata

- It starts at Foramen magnum where spinal cord ends and extends till pons.

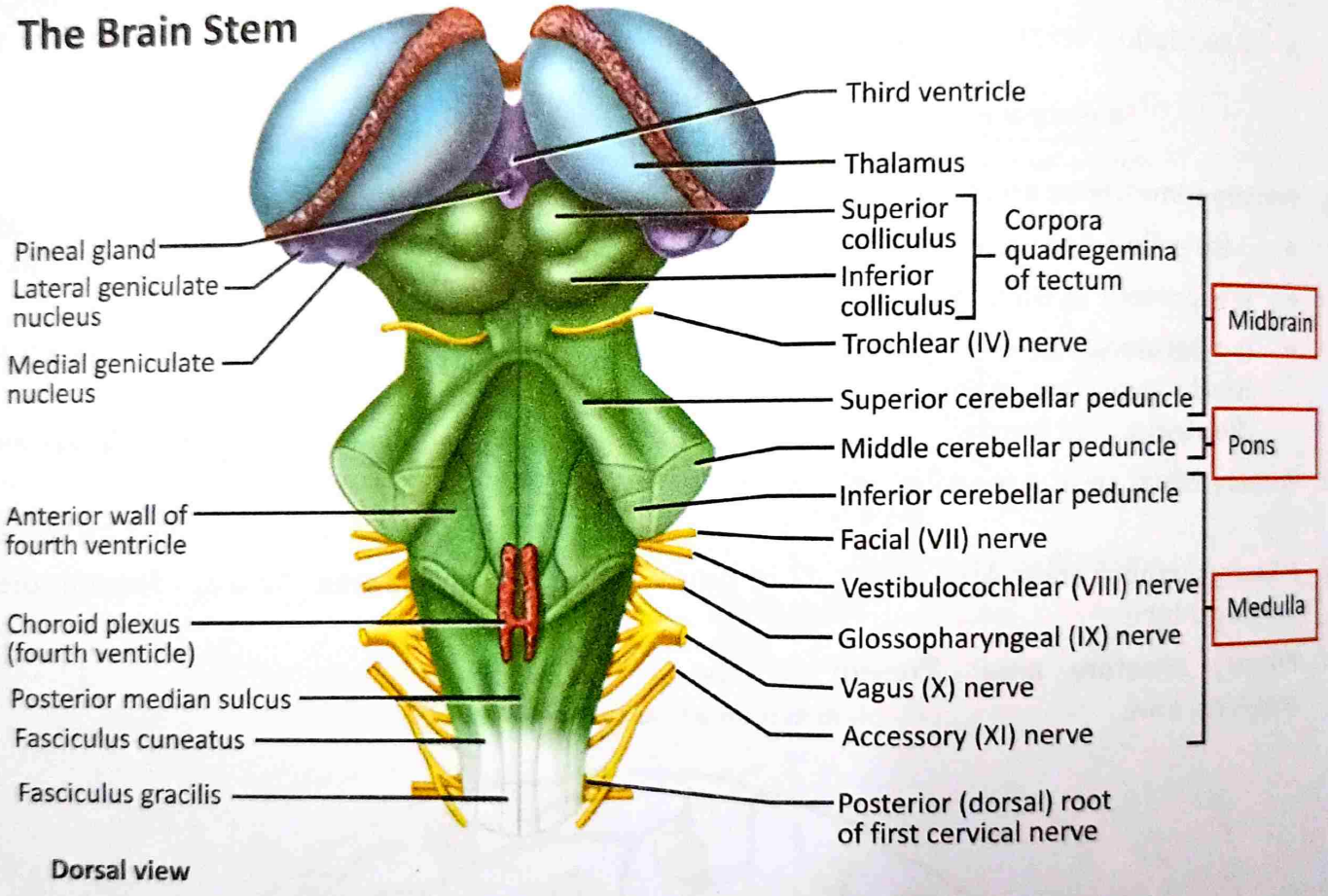


Figure 4.10: The Brain Stem

- It contains a median fissure at the anterior surface.
- On either site of the fissure two swellings called as olive are present.
- Just posterior to the pyramids are elevations called as olive.
- Gracile tubercle and cuneate tubercle corresponding to the nucleus cuneatus and gracilis are present posteriorly in the inferior part of medulla.
- It contains all the sensory and motor tracts which connect spinal cord with brain
- It contains nuclei of five major cranial nerves namely cranial nerve 8-12
  1. Vestibulocochlear nerve
  2. Glossopharyngeal nerve
  3. Vagus nerve
  4. Accessory nerve
  5. Hypoglossal nerve

- It contains medullary rhythmicity area which controls the basic rhythm of breathing.
- Dorsal and ventral group of respiratory neurons are responsible for the maintenance of rhythm of respiration.
- Cardiovascular centre controls rate and force of heart beat and diameter of blood vessels.
- 5. Other centres in medulla coordinate swallowing, vomiting, coughing, sneezing, secretion of saliva and hiccups.

2. Pons

- Pons extends from medulla to midbrain.
- It is about 2.5 cms long.
- Middle cerebellar peduncles present laterally on the pons connect the pons with the cerebellum.
- It's crucial role is associated with respiratory control.
- It has 2 areas pneumotaxic area and apneustic area responsible for maintenance of respiration.
- Pneumotaxic area is situated in upper pons and is responsible for regulation of inspiratory rate by inhibitory effect and apneustic centre is situated in lower pons and it increases the respiratory rate.
- It lodges the nuclei of cranial nerves 5 - 8
  1. Trigeminal nerve
  2. Abducens nerve
  3. Fascial nerve
  4. Vestibulocochlear nerve
- Pons acts as pathway that connects cerebellum with cerebral cortex
- It acts like a pathway for all the pyramidal tracts that pass from the brain

3. Midbrain

- It is present between pons and diencephalon.
- It has 2 areas called superior and inferior colliculus in the posterior part called as tectum.
- Cerebral peduncles are the part of midbrain lying in front of the line passing through the cerebral aqueduct.
- Superior colliculus helps in reflex movements of head, trunk, limbs and movement of eyeball in response to any visual stimuli.
- It is considered as the centre for light reflex.
- Inferior colliculus helps in reflex movements of head and trunk in response to auditory stimuli.
- It is considered as the centre for auditory reflex.
- It has 2 distinct areas called red nuclei which have the cell bodies of cranial nerves 3 and 4 namely the occulomotor nerve and the trochlear nerve.

Cerebellum

- It consists of 2 cerebellar hemispheres which are separated by central body called as vermis.
- It is separated from cerebrum by a deep groove called as transverse fissure and by an extension of cranial duramater called tentorium cerebellum.

Functions

- It compares intended movements with what is actually happening and coordinates complex skilled movements.
- It helps in regulation of muscle tone, posture and balance.
- It is responsible for integration and regulation of muscular activities.
- Prevention of exaggerated muscular movements, coordination of skillful muscular movements that are newly learnt by a person is all due to the activities of cerebellum.
- Cerebellum acts like a conduit or pathway

for many of the tracts or pathways coming from periphery to the centre and from the centre to the periphery.

- It helps in maintenance of equilibrium of the body.

Thalamus

- Thalamus is an oval shaped collection of gray matter.
- It is situated in the region of diencephalon.
- It acts like a relay station for transmission of all sensory impulses from periphery to the cerebral cortex.
- Thalamus forms a part of ascending reticular activating system, (ARAS) which is responsible for keeping a person awake. (Arousal).
- Thalamus is responsible for determining the quality of sensation due to its role in discrimination of sensations.
- It helps in differentiation of different modalities of sensations like heat cold and pain.
- Along with hypothalamus, thalamus too plays a role in maintenance of behaviour and personality.
- Thalamus has centre for a large number of reflexes of head and thorax.
- **Thalamic radiation:** All the thalamocrotical and corticothalamic fibres pass through the thalamus forming thalamic radiation.

Basal Nuclei

- Basal nuclei are **five grey** nuclear masses that are present at the base of cerebral hemispheres.
- They mainly play a role in influencing the motor activities of the body.
- A basal nuclei also regulates cognition, motivation, arousal and social behaviour.
- A basal nuclei controls the muscle tone in the body.
- Reflex activities of the body are also controlled by the basal nuclei.

Components of basal nuclei

1. Caudate nucleus
2. Putamen
3. Globus pallidus
4. Subthalamic body of Luys
5. Sunstantia nigra

Hypothalamus

- Hypothalamus forms a part of diencephalon and is situated below thalamus.
- Hypothalamus plays a regulatory role in functioning of all the homeostatic mechanisms of the body.

Functions

- Hypothalamus controls most of the endocrine glands of the body through the hypothalamo pituitary axis.
- It secretes the controlling hormones of pituitary namely.
  1. Growth hormone releasing hormone (GHRH),
  2. Thyrotropin releasing hormone (TRH),
  3. Corticotrophin releasing hormone (CRH),
  4. Gonadotrophin releasing hormone (Gnrh),
  5. Prolactin inhibiting hormone (PIH).
- **Control of autonomic nervous system:**
  - Sympathetic division of autonomic nervous system is regulated by posterior and lateral nuclei of hypothalamus.
  - The parasympathetic division is controlled by the anterior group of nuclei of hypothalamus.
- Hypothalamus consists of centres for maintenance of heart rate, blood pressure and thermoregulation.
- Feeding centre and satiety centre of

hypothalamus regulates the hunger and food intake of the body.

- Posterior hypothalamus along with hippocampus is responsible for olfaction.
- Regulation of sleep pattern, biological clock is done by hypothalamus there by maintaining the circadian rhythm.
- Hypothalamus is responsible for maintaining the water balance of the body by activating the thirst centre.
- **Role in emotional response and stress management:**
  - Hypothalamus is responsible for the release of catecholamines from medulla.
  - This stimulation of adrenal medulla by hypothalamus plays an important role in emotional responses and management of stressful situations.

Limbic System

- It is the specialised system comprising of organs responsible for the emotions and memory.
- It is one among the primary organs responsible for the mind- body sync.
- It is composed of subcortical structures around the cerebral cortex.
- Hippocampus, dentate gyrus, piriform cortex, olfactory lobe, olfactory tubercle, cingulated gyrus, amygdale, thalamic nuclei, hypothalamic nuclei and reticular formation form the limbic system.

Functions

- Limbic system, mainly the hypothalamus plays a role in regulation of autonomic functions of the body namely:-
  - the thermoregulation,
  - maintenance of water balance,
  - regulation of cardiac and
  - respiratory rate.
- Limbic system is also the primary centre for memory and emotional responses.
- Memory: Hippocampus of the limbic system plays an important role in memory.
- Emotional response: the physical and psychological response of a person to any emotional stimuli is due to the role of hippocampus and the hypothalamus.
- Regulation of endocrine functions through the hypothalamo – pituitary axis is also one of the primary functions of limbic system.

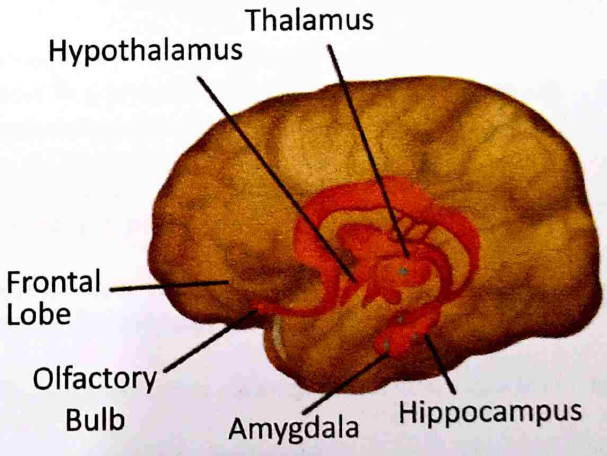
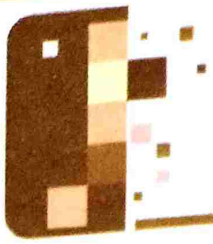


Figure 4.11: Limbic System



Cranial Nerves

Cranial nerves are 12 in number

I	Olfactory	Smell	Sensory
II	Optic	Vision	Sensory
III	Oculomotor	Movement of the eyes, elevation of the eyelids, constriction of pupil in response to light due to the motor innervations of inferior oblique, superior rectus, inferior rectus, medial rectus, constrictor pupillae and cilary muscle. Sensory portion brings proprioceptive information from the above eye muscles.	Both
IV	Trochlear	Inferior and lateral movement of the eyes due to innervations from the superior oblique muscle.(Intorsion, extorsion, depression and elevation of eyeball). The sensory branch brings proprioceptive information from the superior oblique muscle.	Both
V	Trigeminal	Sensory branch brings sensation from the face, mucous and oral cavity. Opening and closing of mouth , control of muscles of mastication and control of the tension in tympanic membrane is through the moyor branch	Both
VI	Abducens	Lateral movement of the eye and sensory portion bring the proprioceptive information from the muscles of eye.	Both
VII	Facial	Control of the muscles involved in facial expression, taste (from anterior 2/3 of tounge), Lacrimation, salivation	Both
VIII	Vestibulocochlear	Hearing , proprioception of head region and balance and equilibrium.	Sensory
IX	Glossopharyngeal	Salivation, taste perceptions (From posterior 1/3 of tongue)and also supplies to the middle ear and Eustachian tube.	
X	Vagus	Control of the muscles involved in swallowing, taste, speech autonomic innervations of various organs. It brings sensory information from the abdomen and the viscera	Both
XI	Accessory	Movement of head and shoulders by innervating the sternocleido mastoid and trapezius muscles.	Motor
XII	Hypoglossal	Control of the muscles of the tongue	Motor

Spinal Cord

- Spinal cord is located within vertebral canal of vertebral column.
- It is protected by bony vertebrae, meninges and cerebrospinal fluid.
- Spinal cord extends from medulla to upper border of 2nd lumbar vertebrae.
- Spinal cord measures about 45 cm in males and 43 cm in females.

Conus medullaris

After the lumbar enlargement, the spinal cord narrows and moves downward in a cone shaped termination called as conus medullaris.

Filum terminale

It is a non nervous sac extending from conus medularis till the second sacral vertebrae.

Cauda equina

- It is a bundle of spinal nerves that extend from the lumbar enlargement or conus medullaris downwards.
- It is called as cauda equina as it resembles a horse tail.
- Cauda equina contains nerve fibers from 2nd to 5th lumbar vertebrae, 1-5th sacral vertebrae and the coccygeal neve.
- It is divided into spinal segments
  1. Cervical – 8
  2. Thoracic – 12
  3. Lumbar – 5
  4. Sacral – 5
  5. Coccygeal – 1
- After the 2nd lumbar vertebrae an extension of piamater called as filum terminale extends inferiorly till the coccyx.

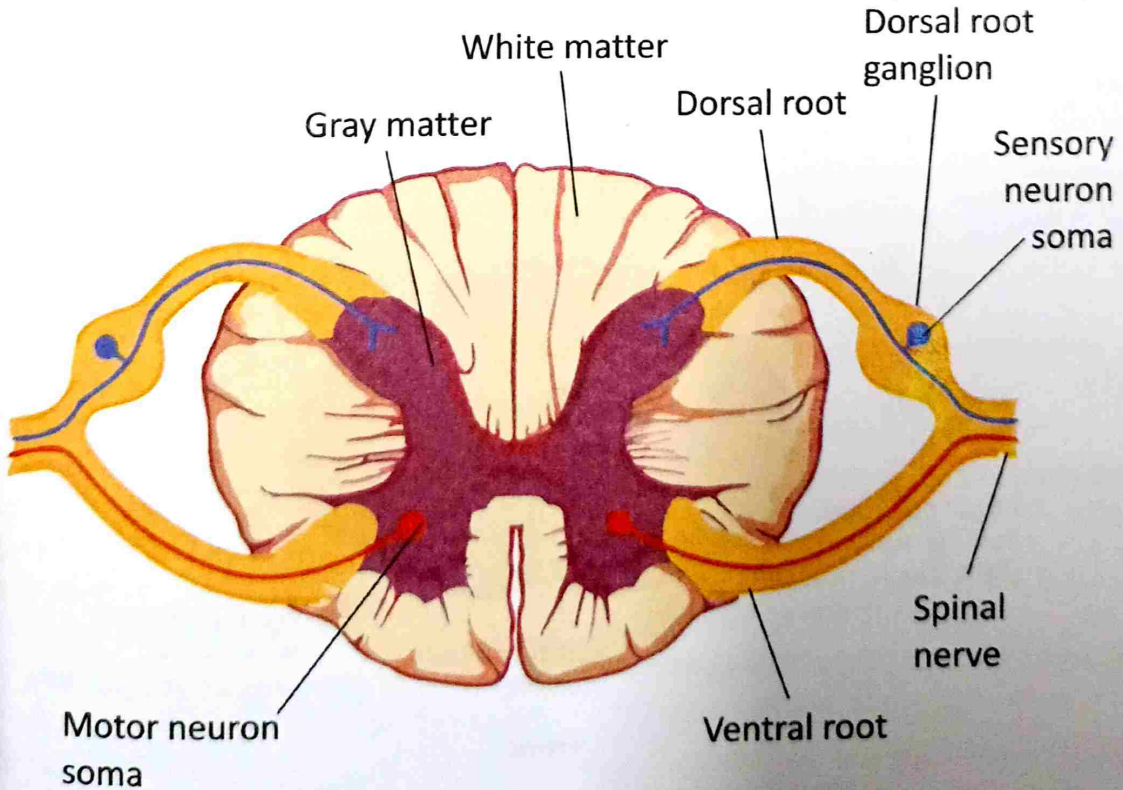


Figure 4.12: Cross Section of Spinal Cord

Structure

- Spinal cord is made up of white matter externally and H shaped grey matter internally
- Two groove/separations divide the spinal cord into right and left grooves.
- The anteromedian fissure and posterior median sulcus.
- **The anteromedian fissureis** a deep wide groove on anterior side and posterior median sulcus is a narrow groove on posterior surface.
- Internally the spinal cord is made up of internal gray matter and external white matter.
- The cross bar of "H" is formed by gray commisure.
- In the centre of gray matter is a small space called central canal.
- This canal extends the entire length of spinal cord.
- Anterior to gray commissure is anterior white commissure which connects white matter of right and left sides of spinal cord.
- The **gray matter on each side of spinal cord** is divided into regions called as horns
  1. Anterior gray horn
  2. Posterior gray horn
  3. Lateral gray horn
- Lateral gray horns are present only in thoracic, upper lumbar and sacral segments of the cord.
- The cell bodies of motor neurons supplying skeletal muscles are located in the anterior gray horn.
- The cell bodies of motor neurons supplying smooth, cardiac muscles and glands through autonomic nervous system are located in the lateral gray horn.
- The **white matter of a spinal cord** is divided into
  1. Anterior white column
  2. Posterior white column
  3. Lateral white column
- These columns contain distinct bundle of nerve axons having common origin and destination and carrying similar information. These bundles are called tracts.

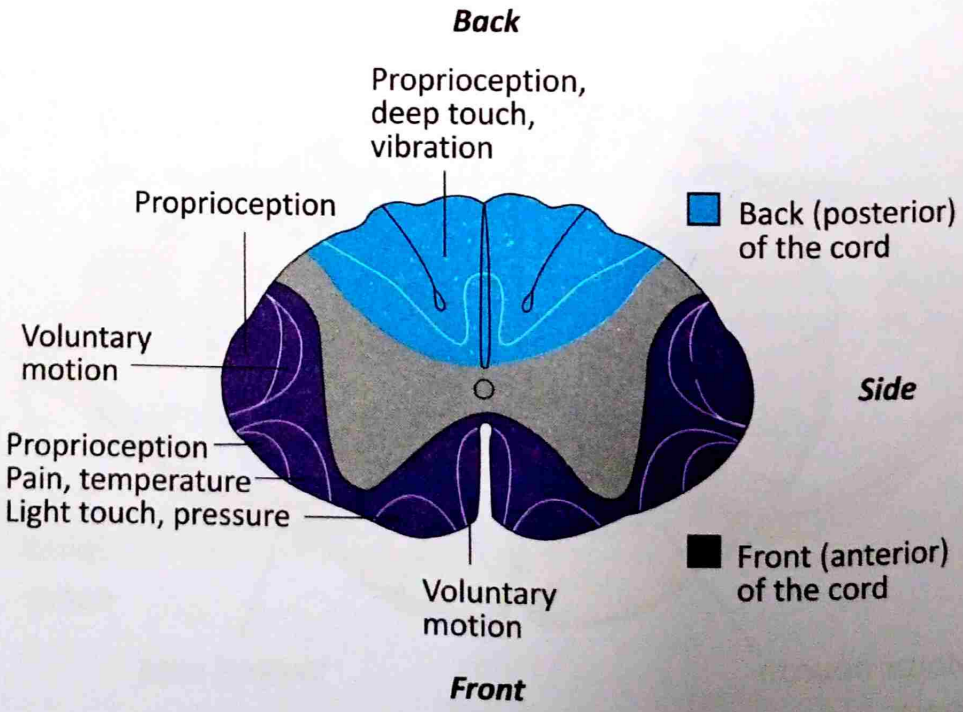


Figure 4.13: Structure of spinal cord

Spinal segment and spinal nerves

- Spinal cord is divided into 31 segments namely:-
  1. 8 cervical,
  2. 12 thoracic,
  3. 5 lumbar,
  4. 5 sacral and
  5. 1 coccygeal segment.
- Spinal nerves are paths of communication between spinal cord and most of the body.
- Each spinal nerve is a mixed nerve formed by the union of a dorsal root (sensory) and a ventral root (motor).
- Spinal nerves are 31 pairs in number and leave the spinal cord at their corresponding vertebrae till L2.
- Later they progress like a horse's tail called as cauda equine.

Ascending and descending tracts of brain

The highways that go in and out of brain

- Ascending tracts (Sensory tracts) contain axons that conduct nerve impulses towards brain.
- And descending tracts (Motor tracts) conduct nerve impulses from brain to the periphery.
- Ascending tracts of spinal cord can be divided into.

Anterior and lateral spinothalamic tracts

- Anterior spino thalamic tract – Carries impulses relating to crude touch. (This tract is explained in detail in the chapter pertaining to the special senses).
- Lateral spino thalamic tract carries impulses relating to the pain and temperature. (This tract is explained in detail in the chapter pertaining to the special senses).
- Ventral and dorsal spino cerebellar tract carries impulses relating to subconscious kinesthetic sensations.
- Spino tectal tract carries sensations relating to spinovisual reflexes.
- Spino reticular tract carries sensations related to consciousness and awareness.
- Spino olivary tracts carry sensations relating to proprioception.
- Spino vestibular tract carries sensations to lateral vestibular nucleus relating to the proprioception.

Posterior column tracts

- Posterior spino thalamic tract carries sensations relating to fine touch and two point discriminations through faciculus gracilis and fasciculus cuneatus.

Descending tracts of spinal cord

- They are the tracts that pass from centre to the periphery.
- The motor tracts of spinal cord are of two types.
  1. Pyramidal tracts
  2. Extra pyramidal tracts

1. Pyramidal tracts

- Pyramidal tracts start from the frontal and parietal lobes of brain.
- They decussate at a region in midbrain called as pyramid.
- They carry sensations pertaining to motor activities of the body.

2. Extra pyramidal tracts

- **Medial longitudinal fasciculus** – Carries sensations pertaining to reflex ocular movements.
- **Anterior and lateral vestibule spinal tract** play a role in adjustment of muscle tone and posture.
- **Reticulospinal tract.**
- **Tectospinal tract** – movement of head in response to the visual stimuli.
- **Rubrospinal tract** play a role in movement of flexor muscles.

- **Olivospinal tract** plays a role in reflex actions.

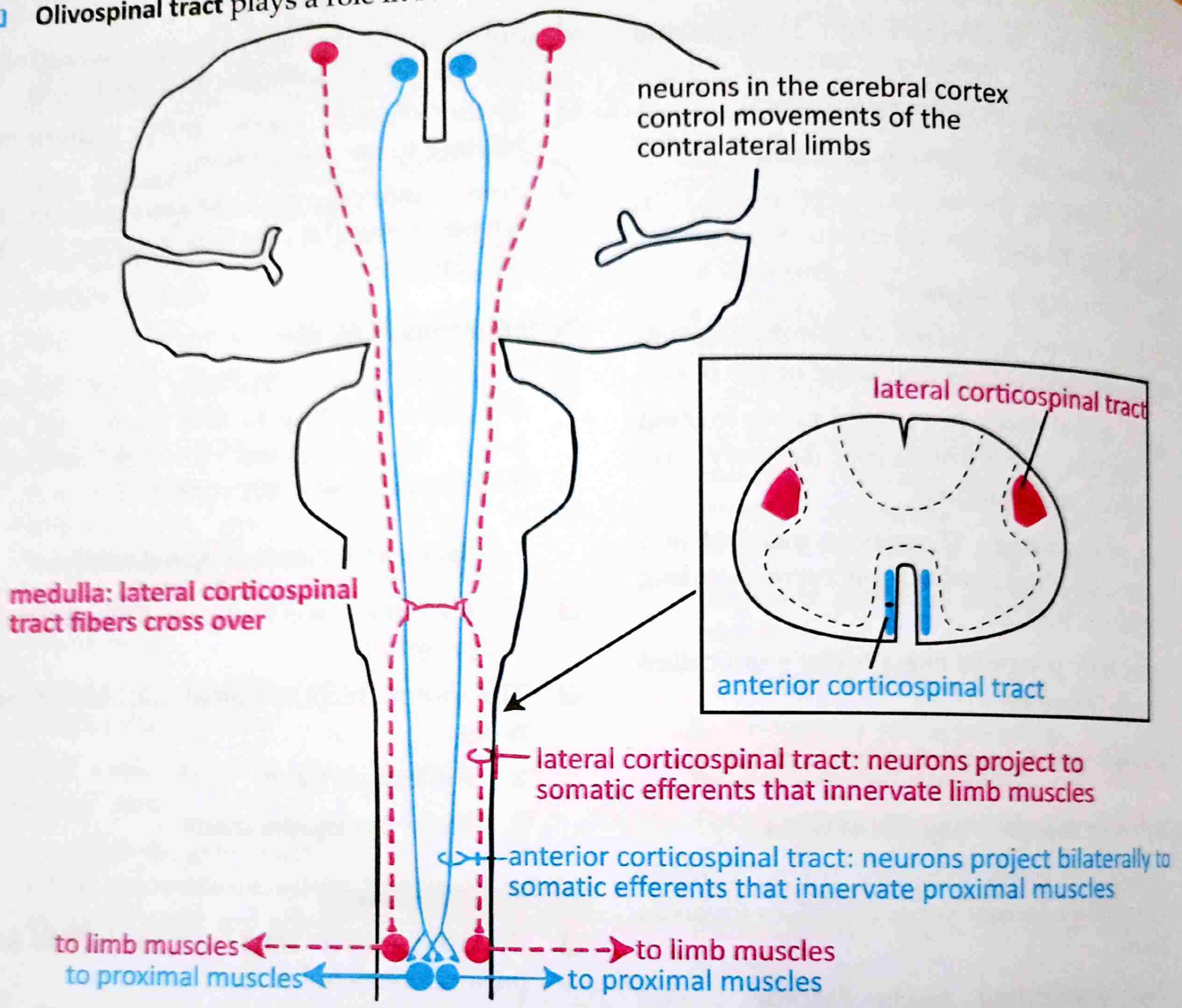


Figure 4.14: Tracts of spinal cord

Reflex

Reflexes are fast, predictable autonomic responses to changes in the environment.

Reflex arc

- Reflex arc includes **five basic** components.

1. **Receptors:** they are of many types like pacinian corpuscles for touch, nociceptors for pain, photoreceptors for light etc.
2. **Sensory neuron:** The fibres carrying sensory information.
3. **Integrating centre:** brain or the spinal cord
4. **Motor neuron:** The fibres carrying motor commands.
5. **Effector:** The functional units of the muscle or gland that respond to the sensory stimulus.

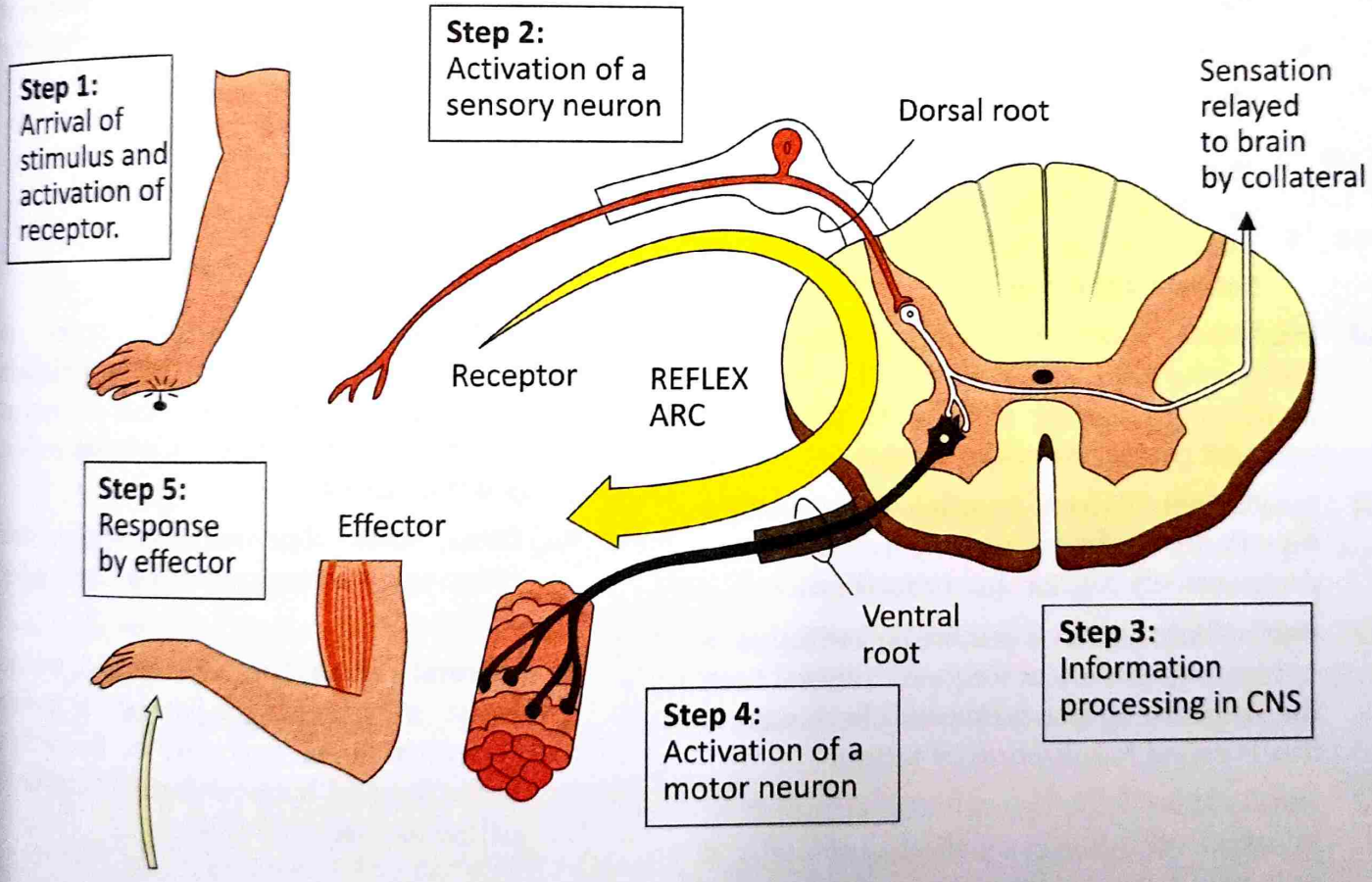


Figure 4.15: Reflex Arc

Classification of reflexes :

- **Monosynaptic:** Only one synapse will be present in between afferent and efferent neuron.
- **Polysynaptic reflexes:** This is a type of reflex that contains more than one inter neuron between the afferent and efferent neuron.

Basic properties of reflexes

- **Adequate stimulus:** Every reflex requires adequate stimulus for eliciting a reflex. Subadequate stimulus will fail to elicit the reflex.

- **Delay :** Every reflex is associated with a time interval between the application of stimulus and generation of a response.
- **One way conduction:** In a reflex arc, the impulses are transmitted only in one direction. The impulses started from the receptor to the centre and from centre to the effector.
- **Summation**
  - Upon application of repeated stimuli at frequent intervals then the next stimulus will get a add on from the previous postsynaptic potential and will lead to a wider response. This type of summation is called **Temporal summation.**
  - In the case where a post synaptic neuron receives impulses from a large number of presynaptic terminals at the same time then there will be a adding up effect eliciting a greater response. This type of summation is called as **Spatial summation.**
- **Irradiation:** When the stimulus applied is too strong then the reflex will spread to many neighbouring neurons in the centre and will produce a wider response.
- **Facilitation:** When areflex iselicited repeatedly its response becomes progressively higher due to facilitation.
- **Habituation:** When a particular stimulus is applied repeatedly at frequent interval then the response of the reflex will be lessened this is called habituation or fatigue.
- **Sensitization:** When an adverse stimulus or injurious stimulus is applied repeatedly it will result in aamplification of the reflex response.

Spinal cord reflexes are of three types.

1. **Muscle reflex**

   Stretch reflex and golgi tendon reflex.

   - **Stretch reflex:**

     It results in reflex contraction of the muscle that is being stretched.

   - **Golgi tendon reflex:**

     It is also called as inverse stretch reflex. It is a protective reflex seen in receptors called as golgi tendon organs.

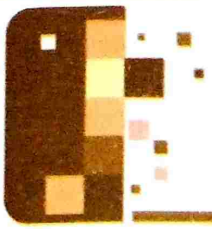
2. **Cutaneous reflex:**

   Withdrawal reflex

   This sort of a reflex occurs in response to a painful stimuli and results in removal or withdrawal of the body part from the painful stimiuli.

3. **Clinical reflexes of 3 types namely**
   1. Superficial reflex
   2. Deep reflex
   3. Visceral reflex

   - **Superficial reflex:** These types of reflexes are seen upon the stimulation of receptors present on skin or mucus membrane. Example : Corneal reflex, plantar reflex.
   - **Deep reflex:** The reflexes originated from stimulating a tendon are deep reflexes.
   - **Visceral reflex:** The reflexes originated from a visceral organand a reflex where at least one part of the reflex arc is formed by an autonomic nerve is called as visceral reflex.



Autonomic Nervous System

- Autonomic nervous system is a subdivision of peripheral nervous system which is concerned with the regulation of visceral and involuntary functions of the body.
- It is subdivided into sympathetic nervous system and parasympathetic nervous system.
- Autonomic nervous system is independent of the conscious will of the person. Hence it is called as autonomous or independent.
- Sympathetic nervous system is the cranio sacral outflow and parasympathetic nervous system is the thoraco-lumbar outflow.

Sympathetic division of Autonomic nervous system

- Sympathetic outflow occurs through the 12 thoracic and 1st and 2nd lumbar spinal nerves.
- The nerve fibres arising from these segments terminate in post ganglionic neurons of sympathetic ganglia.
- There are three types of neurons in sympathetic ganglia
  1. **Paravertebral ganglia**
     They are situated in either side of spinal cord in segmental fashion along the anterolateral surface of vertebral column.
  2. **Prevertebral ganglia**
     Situated in thorax abdomen and pelvis.
  3. **Terminal ganglia**
     Situated near to the structures innervated by them namely heart, pancreas, urinary bladder etc.

Parasympathetic division

- Parasympathetic nervous system has its fibres ousting through the 3, 7, 9 and 10th cranial nerves and 2nd, 3rd and 4th sacral nerve.
- The cranial out flow of parasympathetic system innervates head, neck, thorax and abdomen.
- They arise from the region of brain stem.
- The sacral outflow of the parasympathetic system arises from the 2nd, 3rd, 4th sacral segments of spinal cord.
- They innervate abdominal and lower abdominal structures like large intestine, liver spleen,external genitalia etc.

Structural differences	
Sympathetic nervous system	**Parasympathetic nervous system**
It is the thoraco lumbar division of spinal cord	It is the craniosacral division of spinal cord
Postganglionic neuron is located closer to the centre	Post ganglionic neuron is closer to the periphery
Preganglionic fibres are short	Preganglionic neurons are long
Post ganglionic fibres are long	Post ganglionic fibres are short
Preganglionic neurotransmitter is Acetylcholine	Preganglionic neurotransmitter is Acetylcholine
Postganglionic neurotransmitter is noradrenaline	Post ganglionic neurotransmitter is Acetylcholine

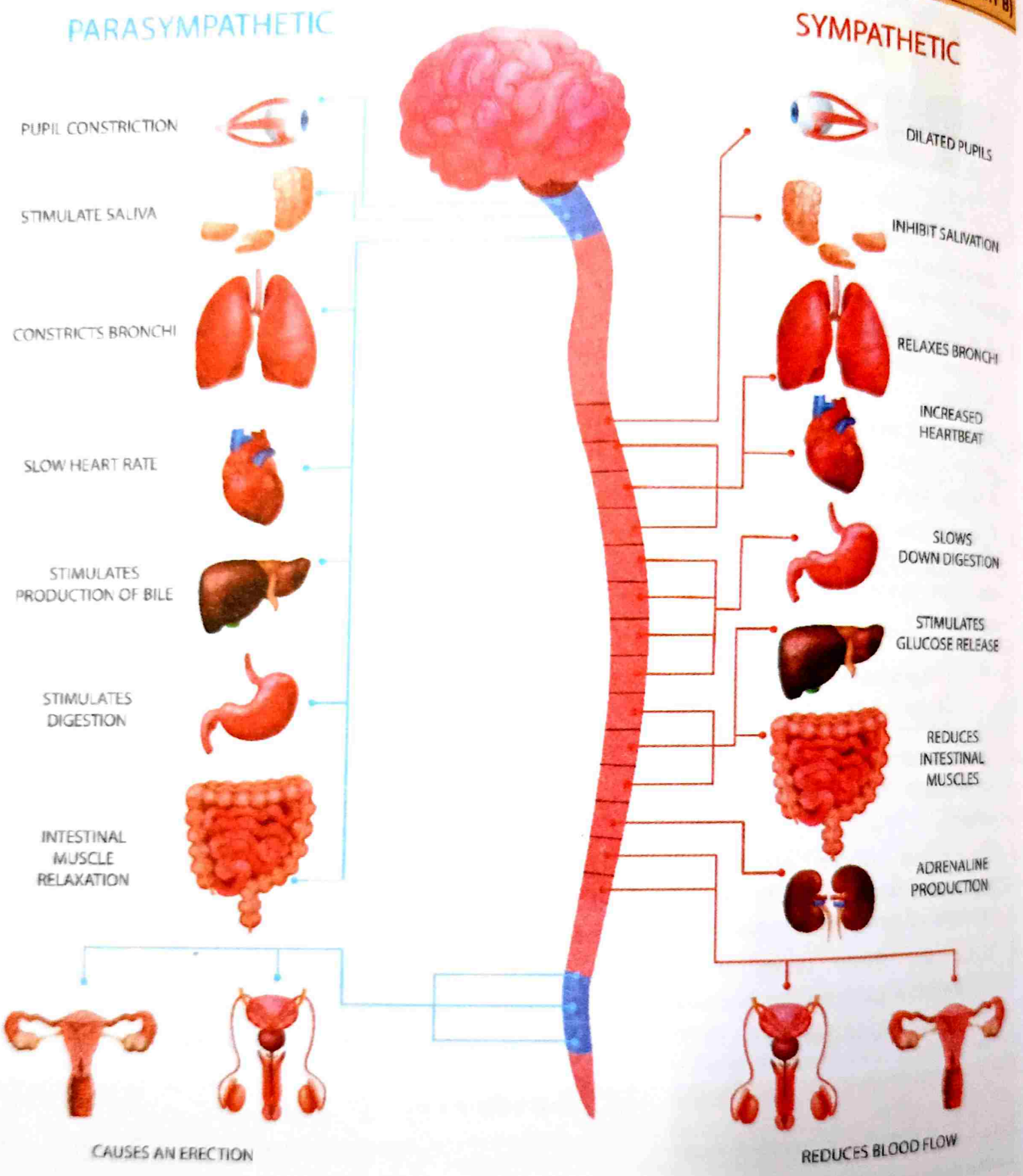


Figure 4.16: Human Nervous System

Functional differences		
Organ	**Sympathetic nervous system**	**Parasympathetic nervous system**
Eyes	Dilation of pupils	Constriction of pupils
GI tract	Inhibition of secretory functions	Stimulation of body secretions

Functional differences		
Organ	**Sympathetic nervous system**	**Parasympathetic nervous system**
Heart	Cardio acceleratory in function	Cardio inhibitory in function
Lungs	Increase of respiratory rate Bronchodilator in action	Decrease of respiratory rate Causes bronchoconst-riction
Intestines	Decreases intestinal motility and decreases peristalsis	Promotes motility of digestive tract and increases peristalsis
Hormonal secretion	Increase in secretion of cortisol, thyroid hormones and adrenalin	Decrease in secretion of cortisol, thyroid hormones and adrenalin
Blood vessels	Vasoconstriction	Vasodilation
Bladder	Inhibits micturition	Stimulates Micturition
Large intestine, rectum	Inhibits defecation	Stimulates Defecation
Reproductive system	Stimulates ejaculation in reproductive system	Stimulates erection in reproductive system
Type of action	Mainly plays a role in "fight and flight"	Mainly plays role in "rest and digest"
Sweat glands	Causes localised sweating (Adrenergic sweating)	Causes generalised sweating (Cholinergic sweating)
Gall bladder	Causes relaxation of gall bladder	Causes contraction of gall bladder
Hairs	Causes erection of hair due to contraction of erector pili	No
Liver	Increases breakdown of glycogen and formation of glucose of energy production	Promotes formation of glycogen from glucose

Physiology of Learning and Memory

Learning

- "The process of acquiring new information by experience is called as learning".
- It results in alteration or adaptation of a person's response to particular stimuli.
- It is classified into
  1. Associative learning
  2. Non Associative learning

Non associative learning

It is divided into two types

1. Habituation
2. Sensitization

1. Habituation

- This is a process in which a person gets accustomed to particular stimuli in such a way that repeated application of that stimuli will elicit less and less response.
- **Example:** When a person is exposed to cold breeze he feels the bite in his skin, but on regular exposure he will not notice the change due to habituation.

2. Sensitization

- This is a process in which a person becomes more and more responsive to particular stimuli due to repeated exposure.
- **Example:** If a person's fingers are exposed to a burn/pain due to fire while doing some work, he will be sensitized to that stimulus of fire.

  He will learn to be very alert to that stimuli.

  And if the person is exposed to any work associated with fire again his fingers will be extra sensitive to heat.

Associative learning

Classical conditioning

- Here an unconditioned stimulus (which usually elicits a reflex) is paired with a neutral stimulus repeatedly.
- This will result in the eliciting of both the unconditioned stimulus and the neutral stimulus.

Example for classical conditioning:

- When a dog is always given food after the ring of a bell as in pavlov'sexperiments. (In the beginning the sight of food will cause salivation in the dog.
- But due to repeated pairing of the ring of the bell and food even a mere ring of bell will cause salivation in the dog.)

Operant conditioning

- This involves applying a reward or punishment after a behaviour.
- Operant conditioning involves making of a relationship between a voluntary behaviour and the consequence.

Examples for operant conditioning:

1. **Training a dog to fetch the ball**
   - When a dog is rewarded with a bone whenever it fetches the ball, the reward will reinforce the fetching of ball in much better way.
   - This is because the dog develops a relationship between he bone and the fetching of the ball.
2. **Child getting scolded for biting nails**
   - When a child is getting scolded every time it bites its nails.
   - This punishment of scolding will deter the child from biting the nails again.

Memory

- Memory is defined as retention of learned information and experiences.
- Memory is a process by which information is acquired, stored and retrieved.

Stages of memory

- The memory process is completed through three stages, namely.
  1. **Encoding:** Receiving and processing information.
  2. **Storage:** Creation of permanent synaptic connections.
  3. **Retrieval:** Recall of information in response to any stimuli.
- Any event, experience or fact is at first coded through development of new codes or new sensory connections.
- This is followed by development of newer synapses and connection of newer synapses which leads to storage of memory.
- This stored information is retrieved upon exposure to certain trigger or stimuli which usually happens to be any of the sensory perception associated with that experience or fact.

Classification of memory

Based on duration memory

1. Sensory memory
2. Short term memory
3. Long term memory

1. Sensory memory

- This type of memory is very short lived.
- It involves the different things we see, different sounds we hear in our daily life without really noticing them

2. Short term memory

- Memory pertaining to recent events.
- This is the memory pertaining to events that we are currently aware of or thinking about.
- This type of memory can be recalled till few hours.
- It is also called as working memory.
- Consolidation of this memory will make it a long term memory otherwise short term memory will usually fade away.

3. Long term memory

- Memory pertaining to older events.
- This is the well consolidated memory which can be retrieved even after a very long time of many years.

Based on quality of memory

1. Implicit memory
2. Explicit memory

1. Explicit memory

- It is the memory that involves conscious recollection of events that have been experienced by the person. It is also called as declarative memory.
- It is of two types
  1. **Episodic memory:** Episodic memory includes memories of specific events in episodes.

     How was the taste of today's meal – the answer good /bad/ not so good may vary based on the experience of the person.
  2. **Semantic memory:** This type of memory involves recollection of facts, names, and events.

     Eg: Which is the largest gland of the body? – The answer is liver for each and everybody.

2. Implicit memory

- It is the memory that involves recollection of memory pertaining to a skill or work experienced by the person.
- This type of memory does not involve conscious recollection of events.
- It will be usually related to acquisition of a skill or art.

  Eg: swimming, dancing etc.

Areas of memory

- Memory is formed due to the formation of newer synapses in brain with respect to memory and storage of information.
- Multiple cortical and subcortical structures are involved with the storage and recall.
- Most importantly the Hippocampus, Amygdala, hypothalamus, cingulated gyrus, rticula formation are the main areas of the memory.

Physiology of speech and articulation

- Speech is the vocalized form of human communication.
- Speech is one of the most advanced traits of a living organism.
- Speech helps a man to communicate and interact verbally with his surroundings.
- Speech involves the activity of brain and the lungs, larynx and the vocal tract for the production of sound and giving proper meaning to that sound.

Speech centres in brain

- Brocas area present inferior to frontal gyrus of cerebral cortex is concerned with motor aspects of speech.
- It is called as motor speech area (Area 44, 45).
- Wernickes area present in posterior part of superior temporal gyrus and angular gyrus (Area 39) plays a very important role as associative areas in production of speech.
- Exners writing area located in the posterior part of frontal lobe helps in visual perception of written words.

Stages of speech production

1. Respiration
2. Phonation
3. Resonance
4. Articulation

1. Respiration

- This is the first stage of speech production where the inspiration and expiration processes involved in respiration will be responsible for movement of air in and out of larynx.
- There can be no speech without respiration.

2. Phonation

- This is the stage of sound production by vibration of vocal cords.
- Sound is produced by modulating the air flowing out of lungs.

3. Resonance

- The proper texture and amplification given to the sound produced with the help of mouth, nose, teeth and oral structures is called as resonance.

4. Articulation

- The sounds produced by phonation will be given specific meaning by the process of articulation.
- This is brought about by the movements of palate, teeth, lips and mouth.

Classification of sounds

Sounds have been classified into multiple types based on the way of articulation as: -

- Labial,
- Labiodental,
- Labiopalatal,
- Linguodental,
- Linguopalatal,
- Palatal,
- Nasal,
- Vowels.

Thermoregulation

- Based on ability to regulate body temperature living organisms are broadly classified into two categories.
  1. **Homeothermic animals** are animals that are capable of regulating their internal body temperature and
  2. **Poikilothermic animals** are cold blooded animals that are not capable of regulating their internal body temperature.
- The human body temperature has to be maintained constant in this ever changing climate and environment.
- Moreover the different physiological processes taking place in the body also produce heat which has to be regulated by the body.
- **Heat gain centre**
  - Heat gain centre is situated in posterior hypothalamus.
  - Stimulation of this centre stimulates shivering and secretion of thyrotrophin releasing hormone which increases the BMR and temperature.
- **Heat loss centre**
  - Heat loss centre is situated in the preoptic nucleus of anterior hypothalamus.
  - Stimulation of this centre produces cutaneous vasodilation and sweating.
- The normal temperature is about 98.6° F or 37°C.
- It may range from 35.8°C – 37.3°C or 97-99° F.
- But the climatic temperature on earth varies from -50°C to 52°C in extreme climatic conditions.
- Human body has to maintain its temperature in this particular range irrespective of the atmospheric temperature.
- Therefore human body faces this task of regulating the body temperature constantly through the process of homeostasis.

Up-regulation of temperature

Following are some of the physiological changes undertaken by the body in order to cause Up-regulation of temperature

1. **Vasoconstriction**: In order to prevent heat loss.
2. **Increase of metabolic activities:** To promote heat production.
3. **Shivering:** To promote heat promotion due to the muscle activity.
4. **Muscle contraction:** For heat generation.
5. Increased appetite.
6. **Reduction in surface area of the body (crouching):** In order to reduce the exposed surface area and prevent loss of heat.

Down regulation of temperature

The physiological changes initiated by the body to cause down regulation of temperature are as follows.

1. **Promotion of sweat secretion and increase of peripheral circulation:** to promote heat loss.
2. **Inhibiting** heat promoting metabolic activities.
3. **Increase** in respiration and circulation also promotes heat loss from the body.
4. **Vaso dilation:** In order to promote and facilitate heat loss.

5. **Reduction** in muscle activity and reduced appetite to prevent heat production.
6. **Increase of body surface area (stretching):** To increase the area available for heat loss.

Mechanisms of temperature regulation

When temperature increases in the body, the heat loss from the body happens through following mechanisms namely:

1. **Conduction:**
   - Heat is lost by contact of body to surrounding surfaces.
   - Every object that comes into contact with the body can conduct heat into the body or out of the body.

     Eg: Loss of heat to a chair while being seated.
2. **Radiation:**
   - Transfer of body heat to surrounding objects in form of radiation of infrared rays.
3. **Convection:**
   - This is a process in which heat is carried away from the body by air or water which comes into contact with the body.

     Eg: Heat can be convected by blowing wind or air from a fan.
4. **Evaporation:**
   - Heat is lost from the body through evaporation (Through conversion of water into gas or water vapour) from lungs and sweat.

     Eg: Through perspiration.

Physiology of Pain

Definition

Pain is an unpleasant sensation induced by a noxious stimulus and received and transmitted by free nerve endings.

Types

1. **Fast pain:**

It is sharp, precisely localised and very fast.

2. **Slow pain:**

It is dull, slow and may not be precisely located or may also be diffused.

Other types of pain

- **Referred pain:**

- Referred pain in the pain that is perceived at a site adjacent or away from the site of origin of pain.
- Referred pain occurs due to the dermatomal rule, where pain occurs in the same structures that are embryological origin.

  Eg: Cardiac pain is felt at the inner part of left arm and left shoulder.

Pain Pathway

Pain from the skin and deeper structures is felt through the lateral spino thalamic tract.

Lateral spinothalamic tract

The receptors will be located in the free nerve endings which are distributed throughout the body.

1. **First order neurons**
   - Fast pain sensations are carried by fibres called as Aδ fibers.
   - Slow pain is carried by C type fibres.
2. **Second order neurons**
   - Marginal nucleus and substantia gelatinosa of Rolando form the second order neurons.
   - The fibres from these neurons cross the over and ascend along the lateral spinothalamic tract.
3. **Third order neurons**
   - These neurons mainly arise from thalamic nucleus, reticular formation, tectum and the gray matter around the aqueduct of Sylvius.
   - Axons from these neurons terminate in the parietal lobe of cerebral cortex.
   - The centre for pain sensation lies in the post central gyrus of cerebral cortex.

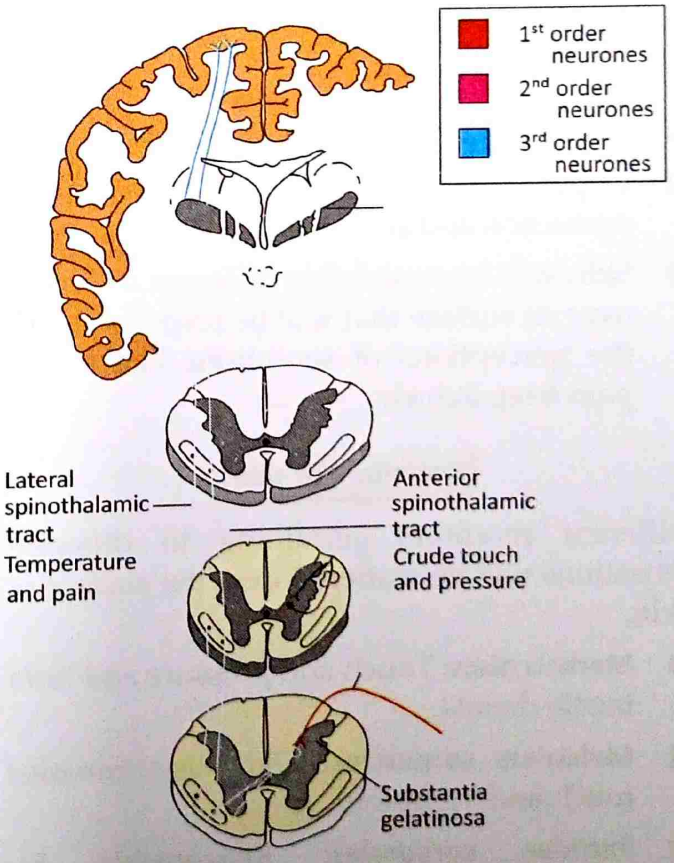


Figure 4.17: Pain Pathways

Tactile Sensations and Skin

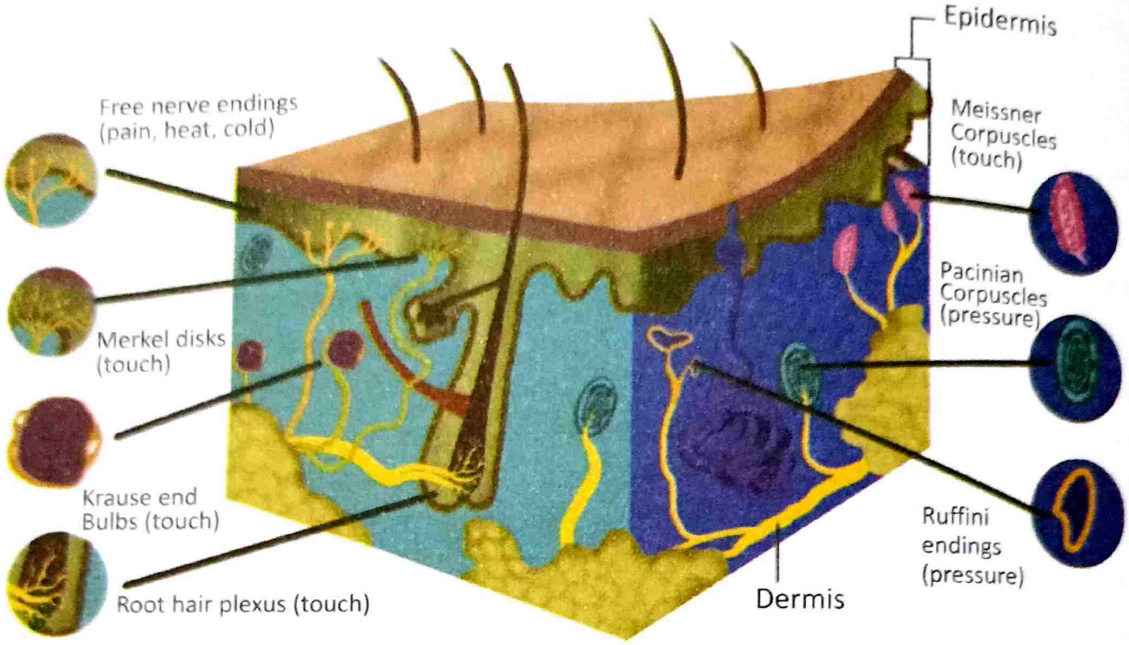


Figure 4.18: Tactile Sensations and Skin

- Skin is the largest organ of the body.
- It performs the important functions of protection and sensation.
- Skin will be containing different receptors over its surface that will be responsible for the perceptions of sensations like touch, pain heat, itch etc.

Receptors of skin

Different receptors pertaining to different sensations will be scattered over the surface of skin.

- **Merkels discs:** Touch and pressure and finer tactile details.
- **Meissners corpuscles:** Fine discriminative touch and vibration.
- **Pacinian corpuscles:** Responsible for sensations of vibrations and pressure.
- **Ruffinis end organs :** Crude touch and heat.
- **Free nerve endings :** Pain.
- **Krauses end bulb :** touch and pressure.

Fine Touch pathway

- The pathway for fine touch is called as **dorsal column medial lemniscus pathway.**
- Here the **first order neurons** that reside in dorsal root ganglion bring somatosensory sensations from the periphery to the dorsal grey horn.
- It will ascend through fasciculus cuneatus and fasiculus gracili and terminate in nuclei cuneatus and nuclei gracilis present in medulla oblongata.
- Here the **nerve fibers will decussate** (cross over) and will ascend upwards in the contralateral side to end in the Ventral Posterolateral nuclei of thalamus.
- The **third order neurons** from VPL nucleus of thalamus will ascend upwards and terminate in primary somatosenory area of parietal lobe of cerebral cortex.

Receptors
↓
Dorsal root ganglion
↓
Dorsal grey horn
↓
Fasciculus cuneatus and fasciculus graciclis
↓
Nuclei cuneatus and gracilis in medulla
↓
Thalamus (VPL nucleus)
↓
Somatosensory area of cerebral cortex

Crude touch

- The pathway for crude touch is called as **anterior spinothalamic tract.**
- Here the first order neurons from Dorsal root ganglion will terminate in the dorsal horn of spinal cord.
- Here they will decussate and will ascend contra laterally to the VPL Nucleus of thalamus.
- The third order neurons from thalamus will end in somatosensory area of cerebral cortex.

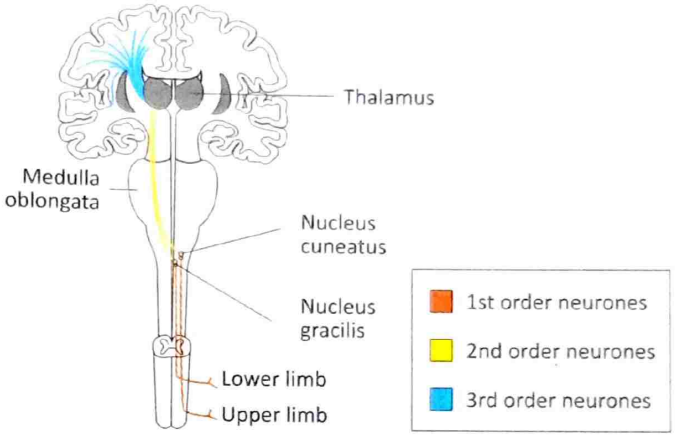


Figure 4.19: Crude touch

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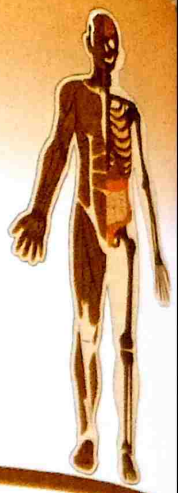
CHAPTER 5

Endocrinology



Learning objectives

A student at the end of the chapter a student should be able to

- ⇨ Understand what is a gland and write the classification of glands,
- ⇨ Understand what is a hormone and write its classifications
- ⇨ Explain in detail about structure, function and applied physiology of each of the endocrine gland.

Hormones

Definition

- Hormones are chemical messengers that are produced by endocrine glands in response to a specific stimuli and act like messenger molecules by exerting their effects on the target cells.
- Hormones influence the functioning of one or more physiological entities of the body by acting at a cellular level.
- Hormone is derived from greek word "horman" meaning to excite.
- Secretin was the first hormone to be discovered in the year 1902.

Mode of action of hormones

- Hormones act on their target cells by binding with the specific receptors located on their target cell.
- The receptor mediated actions of the hormones are executed in different ways like:

1. **By altering the permeability of cell membrane:** Certain hormones like adrenaline undertake their actions by altering the opening and closing of ions channels on the cell membrane.
2. **By activating intracellular enzymes:** In certain cells, the binding of the receptor and the hormone will generate intercellular enzymes or second messengers within the cell. These second messengers will bring about the desired action in the cell.
3. Through gene activation.
4. Through tyrosine kinase activation.

Types of hormones

Based on their structure hormones are classified into three types.

1. **Peptide hormones:** Hormones like insulin, growth hormone, secretin etc.
2. **Steroid hormones:** Glucocorticoids, mineralocorticoids, estrogen.
3. **Hormones derived from aminoacid tyrosine:** They are thyroxine, epinephrine dopamine etc.

Classification of Hormones

1. **Classical hormones:** They are liberated from endocrine glands and are carried by blood or lymph.
2. **Neuro hormones:** They are secreted from axon terminals and are released into circulation.

3. **Paracrine hormones:** These are the hormones that have their effect on their adjacent cells.
4. **Autocrine hormones:** They are the hormones secreted by the cell into the fluid surrounding it and act on the same cell to regulate its functions.

Types of glands

1. **Endocrine glands:** The glands without duct are endocrine glands these are the glands that secrete their hormones directly into the blood circulation.

   Eg: Thyroid gland, pituitary gland.

2. **Exocrine glands:** These are the glands with ducts; they secrete their secretions through their ducts into the site of action.

   Eg: Parotid glands, oxyntic glands.

They are again divided into 3 types based on nature and mode of secretion.

1. **Holocrine glands:** The cell membrane of a cell ruptures off during secretion of the chemical messengers by these types of glands. This results in destruction of the secreting cell.

   Eg: Sebaceous glands.

2. **Mesocrine glands:** They are the glands where the cells secrete their substances by exocytosis into an duct.

   Eg: Salivary glands.

3. **Apocrine glands:** The portion of cell membrane that contains the secretion or hormone buds off during the secretion of hormone,.

   Eg: Apocrine sweat glands.

Endocrine glands

- The endocrine glands in the body are many in number.
- Some are exclusively endocrine where as some of the organs function as both endocrine glands and also as organs or other important systems.

  Eg: Kidneys and heart also have endocrine secretions but they serve more important functions in renal and circulatory systems respectively.

Pituitary Gland

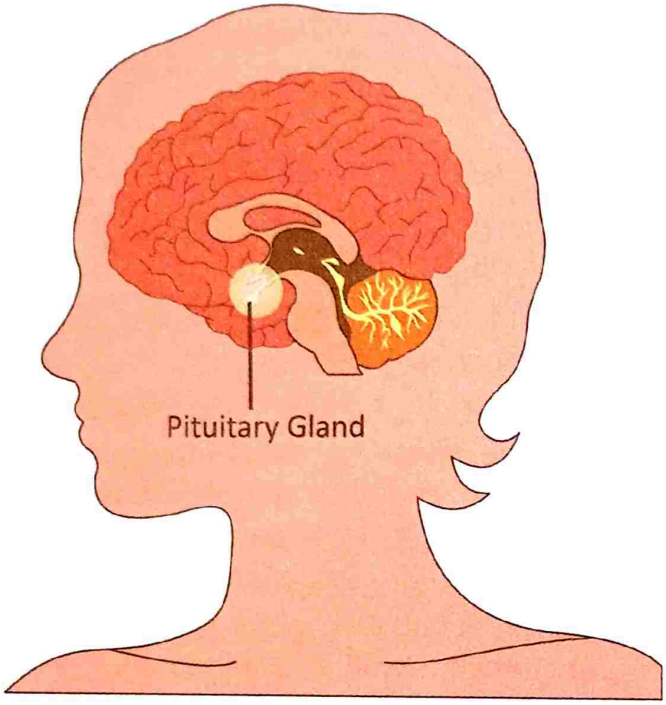


Figure 5.1: Pituitary Gland

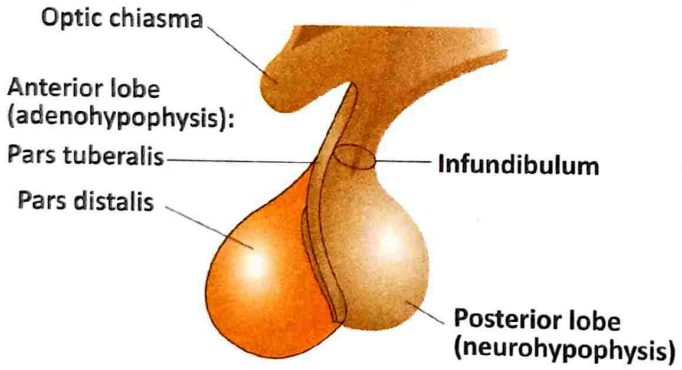


Figure 5.2: Endocrine System

- Pituitary gland is also called as hypophysis.
- **Functional anatomy:** It is a small pea sized structure weighing 0.5 -1 gram.
- **Location:** Sella turcica of sphenoid bone at the base of skull.
- It is made out of 3 lobes
  1. Anterior pituitary (Adenohypophysis).
  2. Posterior pituitary (Neurohypophysis).
  3. Intermediate pituitary (Pars intermedia).

Adenohypophysis (Anterior pituitary)

- **Functional anatomy:** It is made up of three lobes.
  1. Pars distalis
  2. Pars tuberalis
  3. Pars intermedia
- Anterior pituitary is made out of 2 types of cells.
  1. **Chromophobe cells**
     - They are structural cells and are not secretory.
     - Chromophobe cells are about 25% whereas chromophil cells are remaining 75% and are secretory in nature.
  2. **Chromophil cells**
     - Secretory in nature.
     - Chromophil cells are of 5 types
       1. **Somatotrophs:** They secrete Growth hormone.
       2. **Thyrotrophs:** They secrete thyroid stimulating hormone.
       3. **Corticotrophs:** They secrete adrenocorticotrophic hormone (ACTH).
       4. **Gonadotrophs:** They secrete luteinising hormone and follicle stimulating hormone.
       5. **Lactotrophs:** They secrete prolactin.
- Hypothalamus executes a control over pituitary gland by means of its hormones which have a stimulating and an inhibitory effect over the pituitary.

- Hypothalamus releases these hormones into pituitary through the hypothalamo - hypophyseal axis.

Hormones of Hypothalamus

- **GHRH (Growth hormone releasing hormone):** Stimulates the release of growth hormone.
- **Growth hormone releasing hormone (GHIH):** Inhibits the release of growth hormone.
- **Thyrotropic releasing hormone:** Stimulates the release of thyroid stimulating hormone.
- **Corticotrophin releasing hormone (CRH):** Stimulates the release of adrenocorticotrophin.
- **Gonadotrophin releasing hormone (GnRH):** Stimulates the release of LH and FSH.
- **Prolactin inhibitory hormone (PIH):** It inhibits the secretion of prolactin.

Growth hormone

- It is secreted from somatotrophs and is under the control of hypothalamus through growth . hormone releasing hormone (GHRH) and growth hormone inhibiting hormone (GHIH.)
- **Effect on growth:** Growth hormone promotes the growth and repair of tissues in the body by stimulating chondrocytes present in epiphyseal end of long bones in cartilages.
- **Effect on bones:** It promotes bone growth by promoting osteoblastic activity.
- **Effect on muscles:** Growth hormone promotes the growth of skeletal muscle by increasing protein synthesis.
- **Effect on proteins:** It promotes synthesis of proteins for tissue growth and repair.
- **Effect on carbohydrates:** It increases hepatic release of glucose by promoting gluconogenesis.
- **Effect on lipid metabolism:** It causes mobilization of fats from adipose tissues by splitting them into fatty acids.
- **Effect on cell:** Growth hormone increases the entry of acids into the cells and tissues and promotes synthesis of DNA and RNA in the cell.
- **Effect on electrolytes:** Increases plasma calcium, causes sodium retention and increases ECF volume.

Thyroid stimulating hormone

- It is secreted from the thyrotrophs.
- It controls the growth and functioning of thyroid gland.
- It increases iodide uptake and iodide trapping in the thyroid.
- It cause growth and hypertrophy of thyroid gland and increases blood circulation of thyroid gland.
- It stimulates thyroid gland to produce and release its hormones.
- It increases blood flow to thyroid gland and causes growth of thyroid gland.

Adrenocorticotrophic hormone

- It controls the functioning of adrenal cortex.
- It stimulates adrenal cortex to secrete cortisol and other hormones.
- It controls the growth of adrenal cortex and stimulates the synthesis of cortisol and plays a crucial role in stress physiology.
- ACTH Increases MSH (Melanocyte stimulating hormone) activity causing hyper pigmentation of skin.
- ACTH controls the immune system by controlling the secretion of cytokines from lymphocytes.

Follicle stimulating hormone

- It is secreted from the gonaotrophs of anterior pituitary.
- It is under the control of hypothalamus through GnRH (Gonadotroph releasing hormone).
- It helps in proliferation of primordial

ovarian follicles into mature Graafian follicles.

- It also stimulates the theca cells of Graafian follicle to secrete estrogen.
- In males it helps in the process of stimulation of spermatogenesis.

Leutinising hormone

- It is secreted from the gonadotrophs of anterior pituitary.
- It is under the control of hypothalamus through Gnrh (Gonadotroph releasing hormone).
- In females it is the main hormone responsible for ovulation.
- The secretion of LH (Luteinizing Hormone) suddenly surges on 13th or 14th day of the menstrual cycle.
- The LH (Luteinizing Hormone) surge is responsible for the rupture of Graafian follicle and release of ovum. Thereby helping in fertilization.
- The secretion of LH (Luteinizing Hormone) reduces again after ovulation due to the negative feedback mechanism.
- In males it is also called as ICSH (Interstitial Cell Stimulating Hormone) as it stimulates interstitial cells of leydig to secrete testosterone.

Prolactin

- It is secreted from lactotrophic cells
- It is under the control of hypothalamus through the prolactin inhibiting hormone (PIH) and prolactin releasing hormone (PRH).
- Pregnancy and breast feeding further promotes synthesis of prolactin.
- It helps in development of alveolar system and duct system in the mammary glands and causes hyperplasia of breast tissue.
- Prolactin stimulates synthesis of milk and secretion of milk.
- It acts on alveolar epithelium and promotes lactogenic activity.
- Increased levels of prolactin inhibit the secretions of FSH and LH and thereby cause lactational amenorrhoea.
- This is caused due to negative feedback of prolatin on the GnRH secretion from hypothalamus.

Melanocyte stimulating hormone

- It is a hormone secreted from intermediate lobe of pituitary and also through corticotrophs.
- (Intermediate lobe is prominent in lower animals and is rudimentary in humans).
- MSH causes dispersion of melanin granules and darkening of the skin.
- Pigmentation of skin has a protective effect on skin.

Posterior pituitary

- It is made up of neural cells called as pituicytes and unmyelinated nerve fibers.
- Posterior pituitary does not produce the hormones by itself but it stores and later releases the hormones produced from hypothalamus.

Oxytocin

- Oxytocin is a peptide hormone synthesised from the hypothalamus and released from the posterior pituitary.
- It primarily acts on the breasts and the uterus.
- Control and regulation of secretion.
- Oxytocin secretion increases in response to suckling reflex during breast feeding.
- Cervical dilatation during parturition also stimulates secretion of oxytocin.
- Emotional stimulus and stimulation of cervix during coitus also stimulates the oxytocin.

Actions on breast

- It helps in ejection of milk from the breast.

- Oxytocin causes contraction of myoepithelial cells of mammary gland which will be responsible for ejection of milk.

Action on uterus

- Oxytocin causes contraction of the smooth muscles of uterus in pregnant women thereby causing uterine contractions which are responsible for parturition (Parturition: expulsion of fetus or labour).

Effect on reproductive system

- **Sperm transport:** oxytocin facilitates the transport of sperm in female genital tract.
- Oxytocin secretion is also known to be increased in males during orgasm and has a supportive role to play in ejaculation.

Anti diuretic hormone

- Anti - against; diuresis - (Expulsion of water in the form of urine).
- It is also called as vasopressin (Vaso- vessels; Pressin- contracting).

Effect on water balance

- Anti diuretic hormone helps in reabsorption of water in the distal convoluted tubules of the nephron there by preventing excess excretion of water from the body.
- It increases the permeability of water in DCT and collecting ducts through channels called as aquaporins.
- It is responsible for maintenance of water balance in the body by its antidiuretic action.

Effect on blood vessels

- ADH is a vasoconstrictor and is also called as vasopressin.
- Secretion of ADH leads to increase of blood pressure due to the vasoconstrictor effect and due to increase of peripheral resistance.

Effect on metabolism

- ADH is also known to cause glycogenolytic actions in the liver by causing breakdown of glycogen.

Effect on smooth muscles

- It causes the constriction of smooth muscles of spermatic chord.

Applied physiology

Growth hormone

1. **Hyper secretion of growth hormone**
   - It is caused due to tumours in acidophilic cells or somatotrophic cells.
   - It causes gigantism when seen in children and Acromegaly when seen in adults.
   - Gigantism is characterised by excessive growth of long bones at the epiphyseal ends leading to abnormal height and may be associated to osteo arthritic conditions.

Acromegaly:

It is characterised by

- Acromegalic face: thick nose, lips, face.
- Prognathism : Protrusion of lower jaw.
- kyphosis due to bending of vertebra and abnormally large palms and feet.

2. **Hyposecretion of growth hormone**
   - It causes dwarfism when in seen in children and tetany in adults.
   - Tetany is characterised by growth retardation and impotency.
   - Dwarfism is characterised by reduced growth, reduced muscle mass and reduced development of gonads and secondary sexual characters.

Adrenocorticotrophic hormone:

1. **Hyper secretion**
   - It leads to Cushing's disease, characterised by increased secretion of cortisol

- Improper secretions of luteinising hormone and follicle stimulating hormone will cause disorders of sterility and menstrual irregularities.

2. **Hypo secretion**
   - Hypo secretion of Antidiuretic hormone causes diabetes insipidus characterised by excretion of large amount of dilute urine.
   - It is characterised by polyurea and polydipsia.

Prolocatin:

- Increased prolactin secretion in males reduces spermatogenesis.

Thyroid stimulating hormone (TSH):

- Reduced secretion of thyroid stimulating hormone leads to secondary hypo thyroidism and atrophy of thyroid gland.
- Increased secretion of thyroid stimulating hormone results in hypertrophy of thyroid gland.

Adrenal Gland

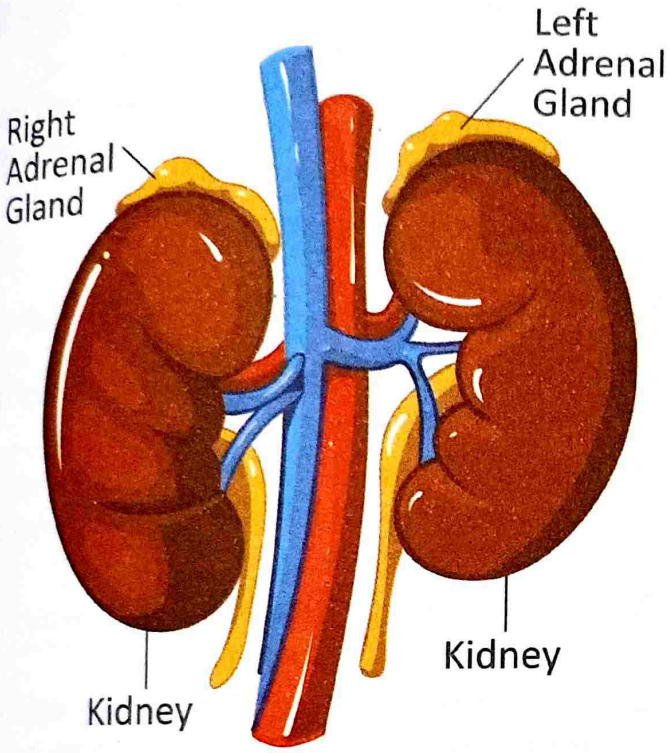


Figure 5.3: Kidney

- Adrenal glands are a pair of glands situated on the upper pole of the kidneys.

Functional anatomy

- It is made up of two divisions.
  1. Outer part of adrenal gland is called as **Adrenal Cortex** and.
  2. Inner part is called as **Adrenal Medulla.**

Adrenal cortex

- It is divided into 3 layers which secrete three groups of hormones
  1. **Zona glomerulosa:** It secretes mineralocrticoids.
  2. **Zona fasciculata:** It secretes glucocorticoids.
  3. **Zona reticularis:** It secretes sex steroids.

Mineralocorticoids

- Aldosterone and Deoxycorticosterone is the most important mineralocorticoids.
- It acts on the P cells of DCT (Distal Convoluted Tubules) and CT (Collecting Tubules) thereby helping in reabsorption of Na^+ ions and water in exchange for potassium ions.
- It decreases the excretion of Na^+ in the sweat and increases the excretion of K^+ and HCO_3^-.
- This helps in maintaining the electrolyte balance in the body.
- It helps in regulation of blood pressure through the influence of rennin-angiotensin mechanism.
- **H+ excretion:** Aldosterone helps in excretion of H^+ in exchange for reabsorption of K^+ ions in collecting duct.
- **Regulation of aldosterone secretion:** The secretion of aldosterone is regulated by the secretion of Angiotensin 2 in the renin angiotensin mechanism.

Glucocorticoids

- Cortisol is the most important glucocorticoid.
- Corticosterone and cortisone are the other important glucocorticoids.
- Cortisol has a hyperglycaemic effect over the body.
- It decreases peripheral utilisation of glucose through its anti insulin effect.
- Cortisol makes the glucose available for the tissues by promoting gluconeogenesis (glucose production by breakdown of proteins and fatty acids).

- Cortisol increases synthesis of glycogen and its deposition in liver.
- Cortisol causes redistribution of fats by causing lipolysis at first followed by deposition of lipids.
- Cortisol increases appetite and food intake.
- Helps in excretion of water thereby maintaining the water balance.
- Increases GFR by increasing glomerular blood flow and causes excretion of water.
- Glucocorticoids have anti-inflammatory and anti-allergic effects over the body.
- Cortisol has anti allergic effects by preventing the histamine release and preventing the growth of mast cells.
- Cortisol is known to increase the secretions from parietal cells of stomach of pepsin and HCL.

Action over CVS

- Cortisol is responsible for maintenance of vascular reactivity.
- It increases responsiveness of arterioles to catecholamines and angiotensin 2 and decreases release of vasodilators like prostaglandins.
- Cortisol promotes bone resorption and might cause reduced bone mass in its hyper secretion.

Action over GI tract

Cortisol promotes HCl secretion from stomach and increases calcium absorption from intestines.

Role of cortisol in stress

- Cortisol plays a protective role in conditions of stress. Stress causes secretion of CRH (corticotrophin releasing hormone) from hypothalamus and ACTH (Adrenocorticotrophic hormone) from anterior pituitary.
- Cortisol causes ready availability of glucose through its hyper glycemic effect.
- Cortisol makes ready availability of Free fatty acids as a source of energy production. Cortisol maintains vascular reactivity in stress and hence prevents shock in cases of stress.
- Cortisol prevents the release of histamine and formation of mast cells in stress full situations.
- This reduces allergic reactions and aids the body physiology in channelizing itself to counter the stressful situation.

Sex steroids

- Adrenal cortex produces androgens mainly dehydroepiandrosterone and androstnedione that helps in reproductive functions in males.
- These hormone increase protein synthesis, facilitate growth and cause a masculinising effect in males.
- In both males and females, it helps in muscle growth and repair.
- Small amounts of estrogen and progesterone are also produced in the adrenal cortex.
- In fetal life too adrenals act as a main precursor for production of estrogen by placenta.

Applied physiology

- Hypersecretion of glucocorticoids will lead to a condition called as Cushing's syndrome.
- It is characterized by centripetal obesity, moon facies, skin thinning with striae, excess sodium retention and potassium excretion, hirsutism, menstrual irregularity, osteoporosis, delayed wound healing and reproductive dysfunction.
- Hyposecretion of glucocorticoids will lead to a condition called as Addison's disease.
- Addison's disease is characterized by muscle weakness, confusion, hyper pigmentation of skin, decreased blood pressure and decreased blood sugar levels, increased count of eosinophils and loss of

adaptability to stress.

- Hypersecretion of aldosterone leads to Conn's syndrome, it is characterized by Hypernatraemia, Hypertension, muscle weakness.
- Hypersecretion of adrenal sex steroids leads to Adrenogenital syndrome characterized by masculinisation features in females and Precocious Pseudopuberty in young males.

Adrenal medulla

- It is the inner core of adrenal gland it is composed of cells called as pheochrome cells or chromaffin cells .
- It is functionally a part of sympathetic nervous system.
- These cells secrete hormones upon sympathetic stimulation.
- They secrete catecholamines derived out of amino acid tyrosine, namely adrenaline, nor adrenaline and dopamine.

Functions

- These hormones are cardioaccelerator, they also increase the basal metabolic rate, respiratory rate, and blood pressure and blood sugar levels.
- Catecholamine's cause glycogenolysis, stimulate gluconeogenesis and cause thermo genesis in the body.
- Catecholamine's cause inhibition of motility and secretions of GIT.
- They cause dilatation of pupil and increases vision during alertness.
- Catecholamine's cause vasodilatation, increases physical and mental alertness and initiates fight and flight response.

Applied physiology

- Hyper secretion of adrenaline and noradrenaline occurs in tumour of adrenal medulla called as pheochromocytoma.
- It is characterised hypertension, increased blood sugar levels anxiety and muscular weakness.

Thyroid Gland

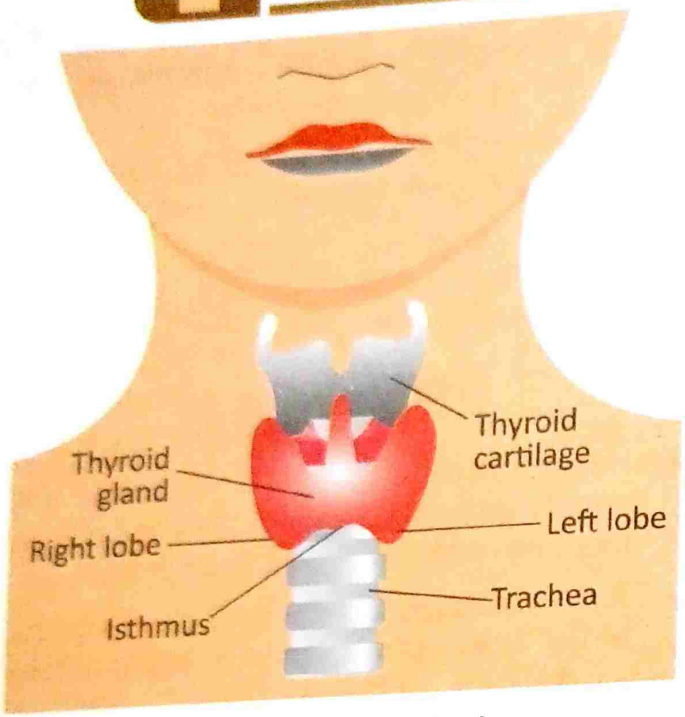


Figure 5.4: Thyroid Gland

- It is an endocrine gland that is situated at the root of neck anterior to and on either side of trachea.
- It is located between the cricoid cartilage and the suprasternal notch.
- It has two lobes which are connected to each other by isthumus.
- Each lobe of thyroid gland is made up of several follicles each being made up of follicular cells.
- The follicular cells are present around a matrix called as thyroglobulin. Such a unit is called as a follicle.
- Thyroid gland is composed of thousands such units called as follicles.
- Scattered cells called as parafollicular cells are found around the follicular cells.
- Parafollicular cells are responsible for secretion of calcitonin.
- The main thyroid hormones are T_3 and T_4. (Tri iodothyronine and tetra iodothyronine) and calcitonin.

Synthesis of thyroid hormone

Synthesis of thyroid hormone takes place in following stages

1. **Thyroglobulin synthesis:** Follicular cells in thyroid gland synthesise a large glycoprotein called as thyroglobulin which plays a main role in thyroxine formation.
2. **Iodide trapping:** The iodide is taken up by the thyroglobulin of thyroid gland by Na^+-I- symport mechanism.
3. **Oxidation of iodide to iodine:** Iodide is actively transported into the thyroglobulin and iodide is oxidised into iodine in order to facilitate the combination with tyrosine to form the thyroid hormones.
4. **Iodination of tyrosine:**
   - The iodine is transported into the follicular cavity and bound with thyroglobulin.
   - Here iodination of tyrosine takes place into MIT and DIT (Mono iodo tyrosine and Di iodo tyrosine).
5. **Coupling reactions**
   - Coupling reactions take place between DIT and MIT to form the thyroid hormones namely Tri iodotyrosine (T_3) and Tetra iodo tyrosine (T_4).
   - Two molecules of DIT undergo oxidative condensation to form Tetra iodo tyrosine (T_4) and one MIT and one DIT combine to form one tri iodo tyrosine (T_3).

Effects of Thyroxine

Thyroxine has following effect on the body physiology

Action over BMR

- Increase of Basal metabolic rate by increasing the basal oxygen consumption in cells.

Action over cells

- It increases cellular metabolism by increasing the Na K ATPase activity in cells.

Actions over growth

- It stimulates growth and skeletal maturation.
- Thyroid hormones are necessary for the growth, development and sustenance of musculoskeletal system.

Action over brain and cognition

- Thyroid hormones sustain memory learning and intellectual abilities in the brain.
- Thyroid hormones are necessary for growth in central nervous system during infancy and pregnancy.

Action over carbohydrates, proteins and fats

- Thyroid hormones cause increase absorption of glucose from intestine and promotes gluconeogenesis.
- Thyroid hormones promote proteolysis and promote release of aminoacids.
- Thyroid hormones have lipolytic effect thereby causing break down of fat.

Action on GIT

- Thyroid hormones enhance the motility of gastrointestinal tract.

Action over respiratory system

- Secretion of thyroid hormones is responsible for increase of respiratory rate and cardiac output.

Thermogenic action

- Thyroid hormones increase of body temperature and perspiration and help in maintaining the thermoregulation.

Effect over CVS and blood pressure

- Secretion of thyroid hormone has a cardio acceleratory effect and increases the systolic blood pressure and marginally decreases diastolic pressure.

Effect over hemopoiesis

- Thyroid hormones stimulate erythropoietic activity.

Applied physiology

Hyper Thyroidism

- It is caused due to different causes like graves disease, or toxic nodular goitre or hyper secretion of thyroid stimulating hormones due to pituitary tumours.
- Hyper secretion of thyroid hormones or hyperthyroidism will be characterised by increased pulse rate, increased respiratory rate, increased blood pressure, increased body temperature, increased frequency of defecation, increased hunger, increased stimulation of nervous system, tremors and loss of sleep.
- Hyper thyroidism in long run can cause protrusion of eyeball with retracted lid (exophthalmous), swelling of thyroid gland, loss of libido and gynaecomastia in males.

Hypo thyroidism

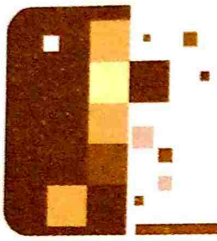
- Hypo thyroidism or reduced secretion of thyroid hormones will cause decreased pulse rate, decreased respiratory rate, decreased blood pressure, and decreased body temperature, decreased frequency of defecation, loss of appetite, decreased stimulation of nervous system, excessive sleep and cold intolerance.
- Hypothyroidism in adults over a longer period of time can cause a condition called as myxedema characterised by puffy or swollen eyelids, coarse, dry skin, brady

cardia, decreased time in tendon reflexes, cool extremities, menorrhagia, lethargy, tirednessconfusion, hoarseness of voice and weakness of muscles.

- Severe thyroid deficiency in fetal life may cause cretinism characterised by mental retardation.

Calcitonin

- Calcitonin is a hormone secreted from the parafollicular cells of thyroid gland.
- Calcitonin helps in regulation of calcium levels in the body.
- It decreases the plasma calcium levels by promoting deposition of calcium in bones, it also inhibits bone resorption by inhibiting the osteoclastic activity in bones and reduces the absorption of calcium and phosphate in kidneys.
- It is antagonist to parathormone in its actions.



Parathyroid Gland

- Parathyroid glands are two pairs of glands situated on the upper and lower poles of the thyroid gland.
- Parathyroid gland is composed of cells called as chief cells and oxyphill cells.
- Chief cells are secretory in nature and secrete hormone called as parathormone.
  1. Parathormone helps in regulation of calcium levels in the body.
  2. It promotes the process of demineralization or resorption of calcium from the bone when the calcium levels in the body decrease.
  3. Parathormone also increases the reabsorption of calcium from the intestine and nephrons.
  4. It also increases the formation of 25-hydroxycholecalciferol from Vit D3. (25-hydroxycholecalciferol further increases the absorption of calcium from the intestines there by helping in increase of calcium levels.)
  5. Parathormone increases the resorption of phosphate from the bones and increases the absorption of phosphate from the gut.
  6. It also increases the urinary excretion of phosphate.
  7. Parathormone also promotes the bone synthesis by increasing the osteoblastic activity in the bones.

Hypoparathyroidism

Hypoparathyroidism will be characterised by reduced plasma calcium levels due to decreased reabsorption of calcium in nephron and gut, reduction of Vitamin D and reduced bone resorption leading to hypocalcemia.

Pancreas

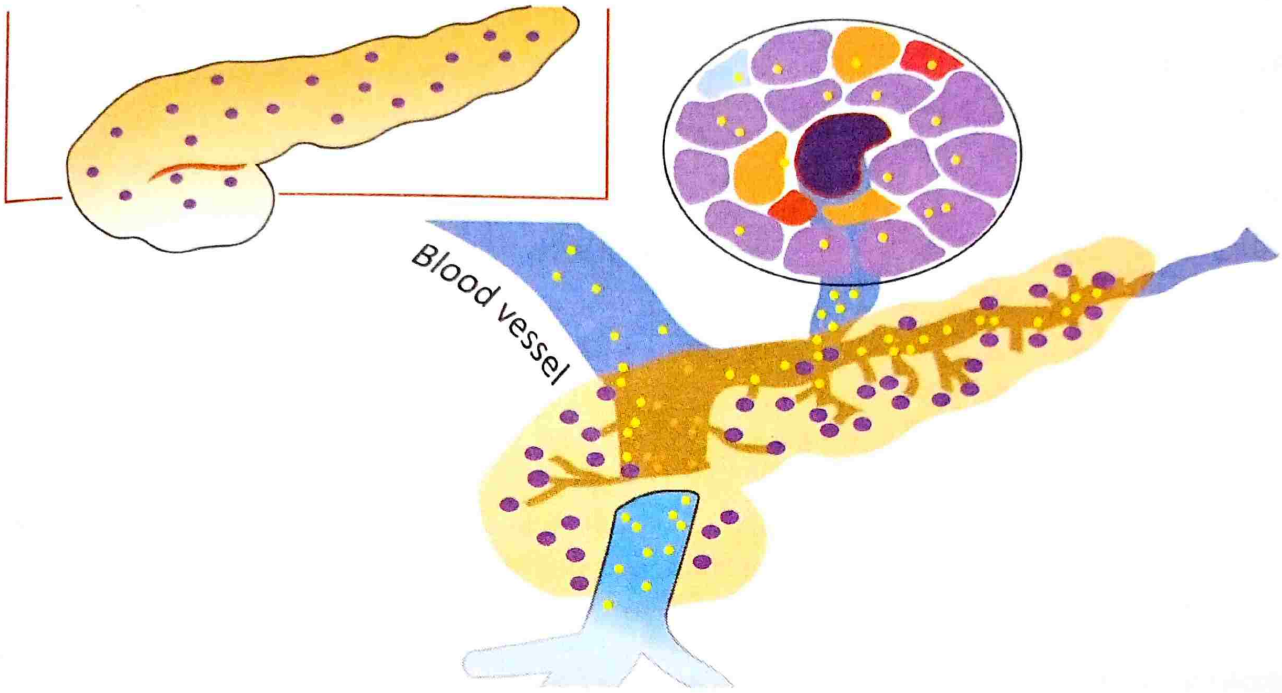


Figure 5.5: Pancreas

- Pancreas is an organ that is both endocrine and exocrine in nature.
- Exocrine part of pancreas secretes pancreatic juice whereas endocrine part secretes hormones.

Functional anatomy

- Pancreas is a J shaped organ that is divided into head, neck body and tail.
- It is made up of acinus which constitutes the exocrine part of pancreas.
- The endocrine part of pancreas is made up of islet of langerhans.
- The islet of langerhans have got 4 types of cells

1. **α cells** –They constitute about 20% of cell and secrete glucagon
2. **β cells** – They constitute 70% of the cells and secrete insulin
3. **δ cells** – They constitute about 9% of cells and secrete somatostatin
4. **F cells** – The constitute about 1% of cells and they secrete pancreatic polypeptide

Insulin

Insulin is very important hormone that acts on metabolism of carbohydrates, proteins and lipids and plays an important role in growth and repair of body tissues.

1. Action on carbohydrates

- Insulin enhances uptake and glucose by cells by increasing the permeability of cells to the glucose.
- It acts on insulin receptors in various cells and activates GLUTs or glucose transporters.
- It promotes the peripheral utilization of

glucose.

- It promotes the storage of glucose in the form of glycogen.
- Insulin inhibits gluconeogenesis. (i.e production of glucose from proteins and fatty acids).

2. Action on proteins

- It promotes the synthesis and storage of proteins and inhibits cellular utilization of proteins.

3. Action on lipids

- It enhances conversion of excess glucose into fatty acids and triglycerides and storage of lipids in adipose tissue.
- Insulin reduces ketogenesis in the body.

4. Action on Ions

- It reduces plasma K^+ levels by promoting entry of K^+ into the cells.

5. Growth and repair

- It helps in the growth and repair of body tissues by aiding the transport of amino acids into the cells.

Regulation of insulin secretion

- The level of blood glucose helps in regulation of insulin by feedback mechanisms.
- Insulin secretion is accelerated in response to the elevated levels of blood glucose.
- Hormones like gastrin, secretin, CCK, stimulate insulin secretion.
- Epinephrine and somatostatin inhibit the secretion of insulin secretions.

Glucagon

- Glucagon is a hormone that is antagonist to insulin and helps in maintenance of homeostasis of the body.
- Most of its functions are opposite to the functions of insulin in the body.
- It increases blood glucose levels by its calorigenic action.
- It causes increased glycogenolysis and gluconeogenesis there by promoting increase in blood glucose levels.
- It has lipolytic action on fats.

Somatostatin

- It inhibits the secretion of both insulin and glucagon.
- It reduces the motility of stomach and intestines.
- It inhibits HCL and pepsin secretions in stomach.
- It inhibits secretion of gastrin and secretin in GIT.

Pancreatic polypeptide

It acts in inhibiting the exocrine secretion of pancreas.

Applied physiology

Diabetes mellitus

- Reduced secretion of insulin leads to improper uptake and utilisation of glucose by the cells. This leads to increased blood sugar levels and is called as type 1 diabetes mellitus.
- Reduced response of insulin receptors to the insulin will also cause increased blood sugar levels because of lack of insulin inside the cells.
- This is called as Type 2 diabetes mellitus.
- Diabetes caused by faulty glucose uptake and utilisation is Diabetes mellitus.
- It is characterised by.
  - **Glycosuria:** Presence of glucose in urine.
  - **Polyuria:** increased frequency of urination.
  - **Cellular dehydration:** High glucose concentration increases osmotic pressure of ECF there by driving water out of the cells into the ECF.

- **Polydipsia:** Increased frequency of water intake.
- **Polyphagia:** Increased frequency of food intake.
- **Asthenia:** Loss of strength.
- **Ketogeneisis** may be caused in cases where the body is not able to utilise glucose for energy production. Ketone bodies are produced when the body utilises the fats for its energy needs.

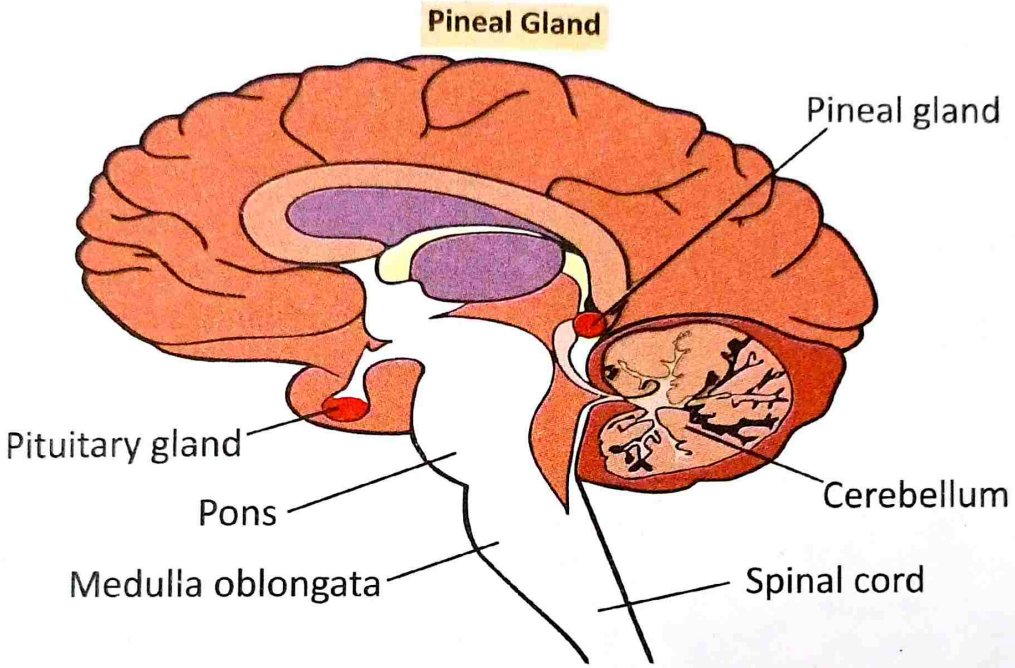


Figure 5.6: Pineal Gland

- Pineal gland is a small gland located in the diencephalic area of brain above the hypothalamus.
- It is a very small gland weighing about 150 mg.
- It is a cone shaped structure consisting of two types of cells parenchymal cells and neuroglial cells.
- It is pine cone shaped in appearance and is also called as epiphysis.

Secretion

- Pineal gland secretes a hormone called as melatonin.
- It helps in maintenance of sleep – wake cycle and circadian rhythm in humans.
- It helps in maintenance of biological rhythms of the body.
- It is known to regulate the sexual behaviour in some of the lower animals due to its antigonadotropic action.
- Secretion of melatonin exhibits diurnal variations. The secretion is more during phases of night and in dark hours of the day.

Thymus Gland

- Thymus gland is a lymphoid organ situated in front of trachea below the thyroid gland in the superior mediastinum.
- It is located between the sternum and the aorta.
- Thymus gland enlarges during puberty and gradually decreases in size with age and will be rudimentary in adults.
- Thymus gland plays a key role in processing T lymphocytes.
- Immature T cells migrate from the red bone marrow to the cortex of thymus gland where they proliferate and mature.
- Most of this proliferation activity in the thymus gland is undertaken few weeks before the birth of the baby and a few

weeks after the birth.

- **Secretion:** Thymosin.
- **Thymosin:** It suppresses release of acetylcholine and suppresses excessive neuromuscular activity.
- Thymus gland is the site for processing of T lymphocytes and there by promoting the cellular immunity in the body.

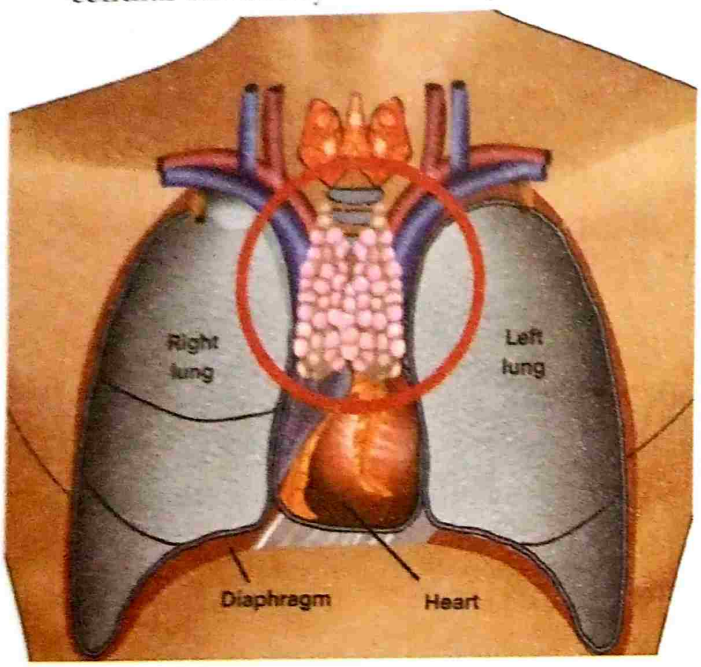


Figure 5.7: Lymphatic System

Endocrine functions of Heart

Atrial natriuretic peptide

- ANP is produced by the atrial cells of the heart.
- It is secreted whenever there is a stretch seen in the atrial walls due to increased blood volume and increased blood pressure.
- It causes natriuresis and diuresis. ANP acts on the mesangial cells of the glomeruli and increases the glomerular filtration rate.
- ANP also causes reduced reabsorption of sodium in the renal tubules.
- ANP reduces the blood volume and blood pressure due to its natriuretic effect.

Local hormones

- Local hormones are the hormones that are produced in the different tissues of the body and exert their action locally.
- **Serotonin:** Serotonin is produced from aminoacid tryptophan. It is produced by enterochromaffin cells, platelets, lungs and in brain.
- **Actions:** Serotonin acts as a vasoconstrictor.
- It is a cardiac stimulant and increases blood pressure.
- It has specific actions on mood, behaviour, sleep and analgesia.

Prostaglandins

- Prostaglandins are synthesised from the arachidonic acid. They can be synthesised in most of the tissues of the body.
- Actions: Prostaglandins have vasodilator effect.
- They are bronchodilators
- They decrease progesterone secretion and delay blood coagulation.

Histamine

- It is a local hormone produced from aminoacid histidine.
- Histamine is found in mast cells, basophils, gastric mucosal cells and brain cells.
- It is responsible for allergic reactions like anaphylactic shock and bronchoconstriction.
- It increases gastric motility and gastric secretion.
- It is responsible for initiation of mechanisms for pain and itching.

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