UNIT IV Chapter 10

Neural Control And Coordination

Chapter Outline

Gamma-aminobutyric acid, or GABA, is the brain's major inhibitory neurotransmitter that reduces neuronal excitability.

Learning Objectives:

- *Understands the structure of neuron and neural system of human beings*
- *Learns to differentiate the functions of sensory and motor neuron*
- *Understands the conduction of nerve impulses and learns the importance of myelin sheath- saltatory conduction.*
- *Outlines the role of synapse and neuromuscular junction.*
- *Learns the structure and functions of central neural system*
- *Understands the structure, sensory reception and processing in Photo, Phono, Olfactory, Gustatory and Skin Receptors*

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Did you ever wonder how our body functions? The body maintains a stable condition even when the outside environment changes; Our eyes help to see things around us; Ears help us to hear various sounds; Heart beats continuously and rhythmically; Air goes in and out of lungs; Eyes shed tears when our limbs get hurt. Each cell of the body works in a coordinated manner. Do you know how it is coordinated and controlled?

The neural system of our body coordinates all the other systems to work together effectively and smoothly. Every second, diverse functions in our body are performed by the neural system. Day and night, millions of messages pass as stimuli through the cells of the neural system to stimulate the heart to beat; kidney to excrete waste; and mouth to relish the delicious food. An even more remarkable feature of the neural system is its ability to respond simultaneously to several stimuli, for instance, we can play piano and sing; listen to music and do household chores. In all such coordinated movements, whether skilled performances or routine tasks like cycling or driving, the integrating power of the neural system is involved. In this chapter, you will understand how neural system is organized; how it integrates all organs and what kind of cellular events underlie its functioning.

10.1 Neural System

The neural system comprises of highly specialized cells called **neurons**, which can detect, receive, process and transmit different kinds of stimuli. Simple form of neural system as nerve net is seen in lower invertebrates. The neural system of higher animals are well developed and performs the following basic functions:

- **Sensory functions**- It receives sensory input from internal and external environment.
- **Motor functions**- It transmits motor commands from the brain to the skeletal and muscular system.
- **Autonomic functions**- Reflex actions.

10.2 Human Neural System

The human neural system is divided into two, **the central neural system (CNS)** and **the peripheral neural system (PNS)**. The structural and functional units of the neural system are neurons that transmit nerve impulses. The non-nervous special cells called **neuroglia** form the supporting cells of the nervous tissue.

There are three functional classes of neurons. They are the **afferent neurons** that take sensory impulses to the Central Neural system (CNS) from the sensory organs; the **efferent neurons** that carry motor impulses from the CNS to the effector organs; and **interneurons** that lie entirely within the CNS between the afferent and efferent neurons.

The central neural system lacks connective tissue, so the interneuron space is filled by neuroglia. They perform several functions such as providing nourishment to the surrounding neurons; involving the memory process; repairing the injured tissues due to their dividing and regenerating capacity; and acting as phagocyte cells to engulf the foreign particles at the time of any injury to the brain.

Glial cells do not lose the ability to undergo cell division; so most brain tumours of neural origin consists of glial cells. Neurons themselves do not form tumours because they are unable to divide and multiply.

10.3 Neuron as a Structural and Functional Unit of Neural System

A neuron is a microscopic structure composed of three major parts namely **cell body** (soma), **dendrites** and **axon.** The cell body is the spherical part of the neuron that contains all the cellular organelles as a typical cell (except centriole). The plasma membrane covering the neuron is called **neurilemma** and the axon is **axolemma.** The repeatedly branched short fibres coming out of the cell body are called **dendrites,** which transmit impulses towards the cell body. The cell body and the dendrites contain cytoplasm and granulated endoplasmic reticulum called **Nissl's granules.**

An axon is a long fibre that arises from a cone shaped area of the cell body called the **Axon hillock** and ends at the branched distal end. Axon hillock is the place where the nerve impulse is generated in the motor neurons. The axon of one-neuron branches and forms connections with many other neurons. An axon contains the same organelles found in the dendrites and cell body but lacks Nissl's granules and Golgi apparatus.

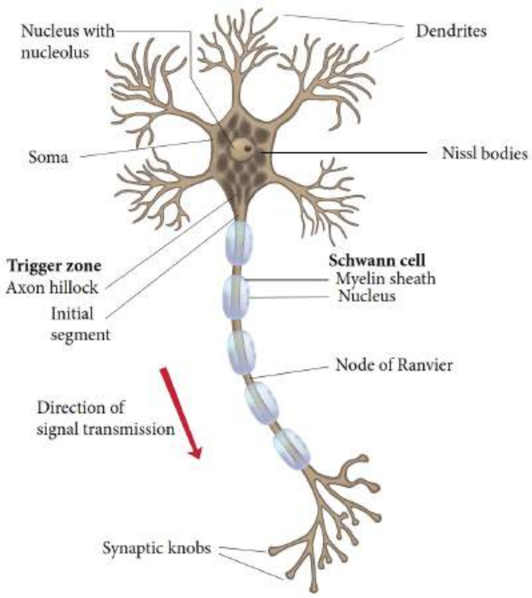


Figure 10.1 Neuron

The axon, particularly of peripheral nerves is surrounded by **Schwann cells** (a type of glial cell) to form myelin sheath, which act as an insulator. **Myelin sheath** is associated only with the axon; dendrites are always non-myelinated. Schwann cells are not continuous along the axon; so there are gaps in the myelin sheath between adjacent Schwann cells. These gaps are called **Nodes of Ranvier**. Large myelinated nerve fibres conduct impulses rapidly, whereas non-myelinated fibres conduct impulses quite slowly (Figure 10.1).

The longest cells in the human body are the **neurons**. The **longest** axons in the **human body**, for example, are those of the sciatic nerve, which run from the base of the spine to the big toe of each foot. These single-cell fibers may extend a meter or even longer. The axons of the inter neurons in the CNS are the shortest.

Each branch at the distal end of the axon terminates into a bulb like structure called **synaptic knob** which possesses **synaptic vesicles** filled with **neurotransmitters**. The axon transmits nerve impulses away from the cell body to an **inter neural space** or to a **neuro-muscular junction.**

The neurons are divided into three types based on number of axon and dendrites they possess (Figure.10.2).

1. Multipolar neurons have many processes with one axon and two or more dendrites. They are mostly interneurons.

2. Bipolar neurons have two processes with one axon and one dendrite. These are found in the retina of the eye, inner ear and the olfactory area of the brain.

3. Unipolar neurons have a single short process and one axon. Unipolar neurons are located in the ganglia of cranial and spinal nerves.

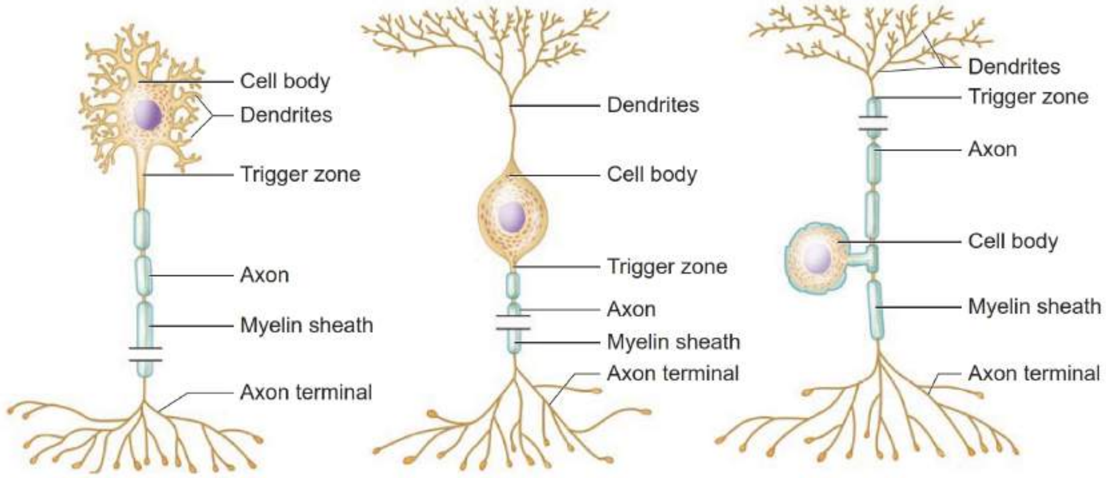


Figure 10.2 Types of Neurons

10.3.1 Generation and Conduction of Nerve Impulses

This section deals with how the nerve impulses are produced and conducted in our body. Sensation felt in the sensory organs are carried by the nerve fibres in the form of electrical impulses. A nerve impulse is a series of electrical impulses, which travel along the nerve fibre. Inner to the axolemma, the cytoplasm contains the **intracellular fluid** (**ICF**) with large amounts of potassium and magnesium phosphate along with negatively charged proteins and other organic molecules.**The extra cellular fluid (ECF)** found outside the axolemma contains large amounts of sodium chloride, bicarbonates, nutrients and oxygen for the cell; and carbon dioxide and metabolic wastes released by the neuronal cells. The ECF and ICF (cytosol) contains negatively charged particles (anions) and positively charged particles (cations). These charged particles are involved in the conduction of impulses.

The neurons maintain an uneven distribution of various inorganic ions across their axolemma for transmission of impulses. This unequal distribution of ions establishes the membrane potential across the axolemma. The axolemma contains a variety of membrane proteins that act as ionic channels and regulates the movement of ions across the axolemma. (Shown in Table 10.1).

10.3.2 Transmission of Impulses

The transmission of impulse involves two main phases; **Resting membrane potential** and **Action membrane potential.**

Resting membrane Potential: The electrical potential difference across the plasma membrane of a resting neuron is called the **resting potential** during which the interior of the cell is negative due to greater efflux of K^+ outside the cell than

Note: The charged particles have potential energy. The potential difference is the measure of potential energy between two points which is measured in volts or millivolts.

Table 10.1 Ionic Channels in the Axolemma

Leakage Channels are ionic channels that remain open all the time	K^+ leakage channels are more in number than the Na^+ leakage channels. Sarcolemma has greater permeability to K^+ ions than Na^+ ions. These ions keep moving continuosly maintain the potential difference across the axolemma.
Ligand-gated Channels are chemically gated channels which open or close in response to a chemical stimuli.	They are located between the presynaptic membrane of the first axon and post synaptic membrane of the cell body of second neuron [i.e. dendrites and cell bodies]**.** The neurotransmitter acetylcholine opens ligand channels that allow Na^+ and Ca^{++} ions diffuse inward and K^+ ions diffuse outward.
Voltage-gated Channels are mechanically gated channels which open in response to a physical stimulus in the form of vibration such as touch and pressure.	These channels open in response to a change in membrane potential. There are two types of voltage-gated channels. **i. Sodium voltage-gated channel** **ii. Potassium voltage-gated channel**

Na^+ influx into the cell. When the axon is not conducting any impulses i.e. in resting condition, the axon membrane is more permeable to K^+ and less permeable to Na^+ ions, whereas it remains impermeable to negatively charged protein ions.

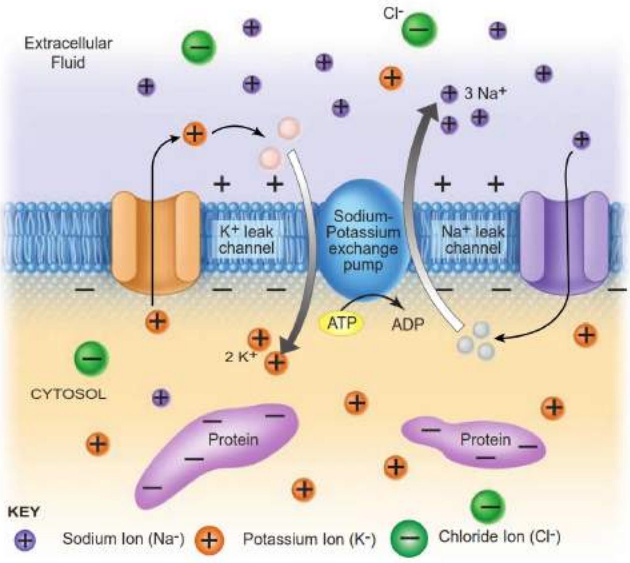


Figure 10.3 Ionic channels

The axoplasm contains high concentration of K^+ and negatively charged proteins and low concentration of Na^+ ions. In contrast, fluid outside the axon (ECF) contains low concentration of K^+ and high concentration of Na^+, and this forms a concentration gradient. This ionic gradient across the resting membrane is maintained by ATP driven **Sodium-Potassium** pump, which exchanges $3Na^+$outwards for $2K^+$ into the cells. In this state, the cell membrane is said to be **polarized**. In neuron, the **resting membrane potential** ranges from **-40mV** to **-90mV**, and its normal value is **-70mV**. The minus sign indicates that the inside of the cell is negative with respect to the outside (Figure 10.4).

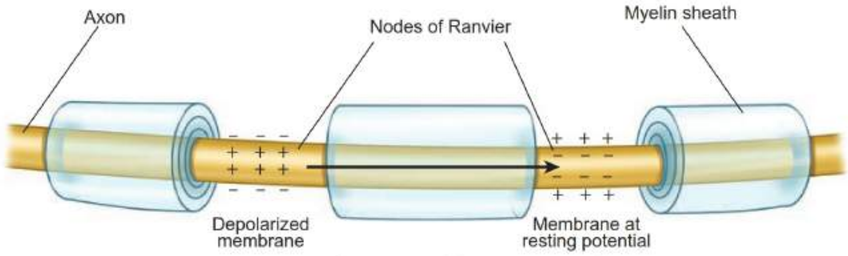


Figure 10.4 Conduction of nerve impulse

Action Membrane Potential

An action potential occurs when a neuron sends information down an axon, away from the cell body. It includes following phases, depolarization, repolarisation and hypo polarization.

Depolarization – Reversal of Polarity

When a nerve fibre is stimulated, **sodium voltage-gate opens** and makes the **axolemma** permeable to Na^+ ions; meanwhile **the potassium voltage gate** closes. As a result, the rate of flow of Na^+ ions into the **axoplasm** exceeds the rate of flow of K^+ ions to the outside fluid [ECF]. Therefore, the axolemma becomes positively charged inside and negatively charged outside. This reversal of electrical charge is called **Depolarization**.

During depolarization, when enough Na^+ ions enter the cell, the action potential reaches a certain level, called **threshold potential** [-55mV]. The particular stimulus which is able to bring the membrane potential to threshold is called **threshold stimulus**.

The action potential occurs in response to a **threshold stimulus** but does not occur at **subthreshold stimuli**. This is called **all or none principle.** Due to the rapid influx of Na^+ ions, the membrane potential shoots rapidly up to +45mV which is called the **Spike potential**.

Repolarisation [Falling Phase]

When the membrane reaches the spike potential, **the sodium voltage-gate closes** and **potassium voltage-gate opens**. It checks influx of Na^+ions and initiates the efflux of K^+ions which lowers the number of positive ions within the cell. Thus, the potential falls back towards the resting potential. The reversal of membrane potential inside the axolemma to negative occurs due to the efflux of K^+ ions. This is called **Repolarisation**.

Hyperpolarization

If repolarization becomes more negative than the resting potential -70 mV to about -90 mV, it is called **Hyperpolarization**.

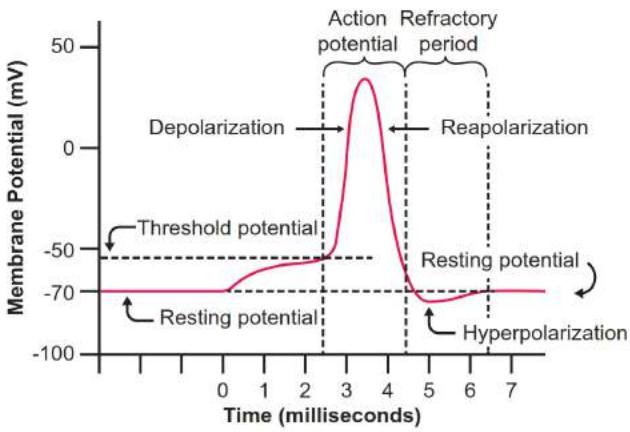


Figure 10.5 Graph showing Action potential in Neuron

During this, K^+ ion gates are more permeable to K^+ even after reaching the threshold level as it closes slowly; hence called **Lazy gates.** The membrane potential returns to its original **resting state** when K^+ ion channels close completely. During hyperpolarization the Na^+ voltage gate remains closed (Figure 10.5).

Conduction Speed of a nerve impulse

The conduction speed of a nerve impulse depends on the diameter of axon. The greater the axon's diameter, the faster is the conduction. The **myelinated axon** conducts the impulse faster than the **non-myelinated axon**. The voltage-gated Na^+ and K^+ channels are concentrated at the **nodes of Ranvier**. As a result, the impulse jumps node to node, rather than travelling the entire length of the nerve fibre. This mechanism of conduction is called **Saltatory Conduction**. Nerve impulses travel at the speed of 1-300 m/s.

10.3.3 Synaptic Transmission

The junction between two neurons is called a **Synapse** through which a nerve impulse is transmitted. The first neuron involved in the synapse forms the **pre-synaptic neuron** and the second neuron is **the post-synaptic neuron**. A small gap between the pre and postsynaptic membranes is called **Synaptic Cleft** that forms a structural gap and a functional bridge between neurons. The axon terminals contain synaptic vesicles filled with **neurotransmitters**. When an impulse [action potential] arrives at the axon terminals, it depolarizes the pre-synaptic membrane, opening the voltage gated calcium channels. Influx of calcium ions stimulates the synaptic vesicles towards the pre-synaptic membrane and fuses with it. In the neurilemma, the vesicles release their neurotransmitters into the synaptic cleft by **exocytosis.** The released neurotransmitters bind to their specific receptors on the post-synaptic membrane, responding to chemical signals. The entry of the ions can generate a new potential in the post-synaptic neuron, which may be either **excitatory** or **inhibitory**. Excitatory post-synaptic potential causes depolarization whereas inhibitory post-synaptic potential causes **hyperpolarization** of post-synaptic membrane (Figure 10.6).

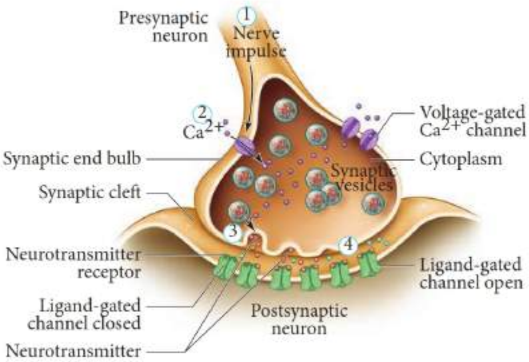


Figure 10.6 Synaptic Transmission

10.4 Central Neural System (CNS)

The CNS includes the brain and the spinal cord, which are protected by the bones of the skull and vertebral column. During its embryonic development, CNS develops from the ectoderm.

> Can you state why some areas of the brain and spinal cord are grey and some are white?

10.4.1 Brain

The brain acts as the command and control system. It is the site of information processing. It is located in the cranial cavity and is covered by three cranial meninges. The outer thick layer is **Duramater** which lines the inner surface of the cranial cavity; the median thin layer is **Arachnoid mater** which is separated from the duramater by a narrow **subdural space.** The innermost layer is **Piamater** which is closely adhered to the brain but separated from the arachnoid mater by the **subarachnoid space**. The brain is divided into three major regions: Forebrain, Midbrain and Hindbrain.

Fore Brain

It comprises the following regions: **Cerebrum** and **Diencephalon**. Cerebrum is the 'seat of intelligence' and forms the major part of the brain. The cerebrum consists of an outer cortex, inner medulla and **basal nuclei.** The superficial region of the cerebrum is called **cerebral cortex**, which looks grey due to the presence of unmyelinated nerve cells. Cerebral cortex consists of neuronal cell body, dendrites, associated glial and blood vessels. The surface of the cerebrum shows many convolutions (folds) and grooves. The folds are called **gyri** (singular gyrus); the shallow grooves between the gyri are called **sulci** (singular sulcus) and deep grooves are called fissures. These sulci and gyri increase the surface area of the cerebral cortex. Several sulci divide the cerebrum into eight lobes: a pair of **frontals, parietals, temporals and occipital lobes** (Figure10.7 & Table 10.2).

A median longitudinal fissure divides the cerebrum longitudinally into two cerebral hemispheres (Figure 10.7). A transverse fissure separates the cerebral hemispheres from the cerebellum. The hemispheres are connected by a tract of nerve fibres called **corpus callosum**. Cerebral cortex has three functional areas namely **sensory areas** occur in the parietal, temporal and occipital lobes of the cortex. They receive and interpret the sensory impulses. **Motor area** of the cortex which controls voluntary muscular movements lies in the posterior part of the frontal lobes. The areas other than sensory and motor areas are called **Association areas** that deal with integrative functions such as memory, communications, learning and reasoning. Inner to the cortex is **medulla** which is white in colour and acts as a nerve tract between the cortex and the diencephalon.

Table 10.2 Functions of brain lobes

Structure	Functions
Frontal	Behaviour, Intelligence, Memory, Movement
Parietal	Language, Reading, Sensation
Temporal	Speech, Hearing, Memory
Occipital	Visual processing

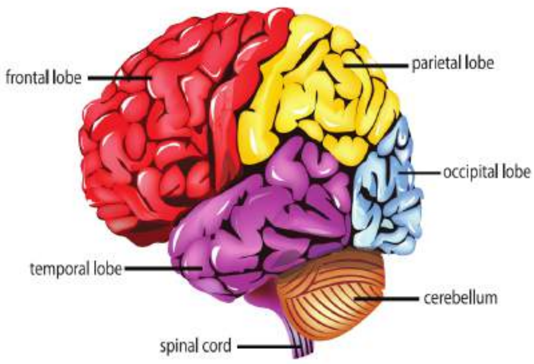


Figure 10.7 Lobes of Cerebral hemisphere

Diencephalon consists largely of following three paired structures.

Epithalamus forms the roof of the diencephalon and it is a non-nervous tissue. The anterior part of epithalamus is vascular and folded to form the anterior **choroid**

plexus. Just behind the choroid plexus, the epithalamus forms a short stalk which ends in a rounded body called **pineal body** which secretes the hormone, **melatonin** which regulates sleep and wake cycle.

Thalamus is composed of grey mater which serves as a relay centre for impulses between the spinal cord, brain stem and cerebrum. Within the thalamus, information is sorted and edited and plays a key role inlearning and memory. It is a major coordinating centre for sensory and motor signalling.

Human brain is formed of a large number of parts like cerebrum, thalamus, hypothalamus, pons, cerebellum and medulla oblongata. Each part performs some specialized function and all the parts are essential for the survival of a person. Discuss the following statements :

a) Thalami are called relay centres of the brain.
b) Damage to medulla may cause the death of organism.

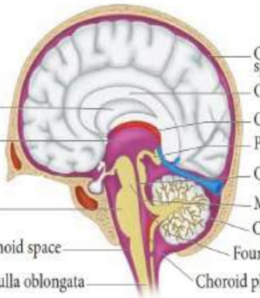


Figure 10.8 Mid sagittal section of brain

Hypothalamus forms the floor of the diencephalon. The downward extension of the hypothalamus, the **infundibulum** connects the hypothalamus with the pituitary gland. The hypothalamus contains a pair of small rounded body called **mammillary bodies** that are involved in olfactory reflexes and emotional responses to odour. Hypothalamus maintains homeostasis and has many centres which control the body temperature, urge for eating and drinking. It also contains a group of neurosecretory cells which secrete the hypothalamic hormones. Hypothalamus also acts as the **satiety centre.**

Depression is a functional deficiency of **seratonin** or **norepinephrine** or both. This disorder is characterized by a pervasive negative mood, loss of interest, an inability to experience pleasure and suicidal tendencies. Antidepressant drugs increase the available concentration of these neurotransmitters in the CNS. Hence depression is treatable.

Limbic System

The inner part of the cerebral hemisphere constitutes the limbic system. The main components of limbic system are **olfactory bulbs, cingulate gyrus, mammillary body, amygdala, hippocampus and hypothalamus.** The limbic system is called 'emotional brain' because it plays a primary role in the regulation of pleasure, pain, anger, fear, sexual feeling and affection. The hippocampus and amygdala also play a role in memory (Figure 10.9).

Brain stem is the part of the brain between the spinal cord and the diencephalon. It consists of mid brain, pons varolii and medulla oblongata (Figure 10.10).

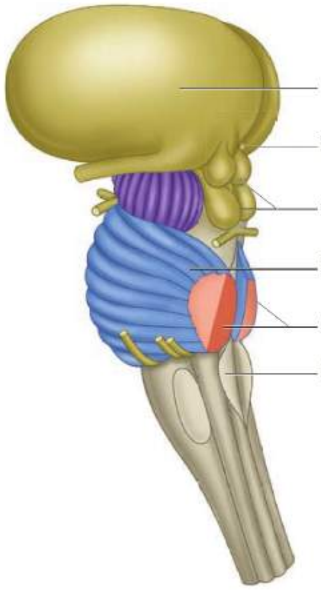


Figure 10.10 Brain stem

Mid brain

The mid brain is located between the diencephalon and the pons. The lower portion of the midbrain consists of a pair of longitudinal bands of nervous tissue called **cerebral peduncles** which relay impulses back and forth between cerebrum, cerebellum, pons and medulla. The dorsal portion of the midbrain consists of four rounded bodies called **corpora quadrigemina** which acts as a reflex centre for vision and hearing.

Hind brain

Rhombencephalon forms the hind brain. It comprises of cerebellum, pons varolii and medulla oblongata. **Cerebellum** is the second largest part of the brain. It consists of two **cerebellar hemispheres** and central worm shaped part, **the vermis.** The cerebellum controls and coordinates muscular movements and body equilibrium. Any damage to cerebellum often results in uncoordinated voluntary muscle movements.

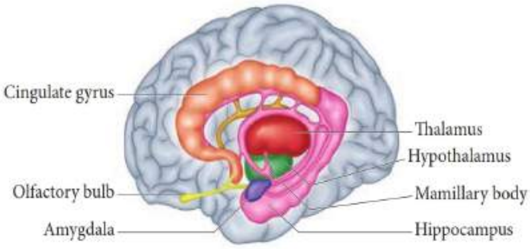


Figure 10.9 Limbic system

Pons varoli lies infront of the cerebellum between the midbrain and the medulla oblongata. The nerve fibres in the pons varolii form a bridge between the two cerebellar hemispheres and connect the medulla oblongata with the other region of the brain. The respiratory nuclei found in the pons cooperate with the medulla to control respiration.

Medulla oblongata forms the posterior most part of the brain. It connects the spinal cord with various parts of the brain. It receives and integrates signals from spinal cord and sends it to the cerebellum and thalamus. Medulla contains vital centres that control cardio vascular reflexes, respiration and gastric secretions.

Ventricles of the Brain

The brain has four hollow, fluid filled spaces. The C- shaped space found inside each cerebral hemisphere forms the lateral **ventricles I and II** which are separated from each other by a thin membrane called the **septum pellucidum.** Each lateral ventricle communicates with the narrow III ventricle in the diencephalon through an opening called **interventricular foramen (foramen of Monro).** The ventricle III is continuous with the ventricle IV in the hind brain through a canal called **aqueduct of Sylvius (cerebral aqueduct).** Choroid plexus is a network of blood capillaries found in the roof of the ventricles and forms **cerebro spinal fluid (CSF)** from the blood. CSF provides buoyancy to the CNS structures; CSF acts as a shock absorber for the brain and spinal cord; it nourishes the brain cells by transporting constant supply of food and oxygen; it carries harmful metabolic wastes from the brain to the blood; and maintains a constant pressure inside the cranial vessels.

10.4.2 Spinal Cord

The spinal cord is a long, slender, cylindrical nervous tissue. It is protected by the vertebral column and surrounded by the three membranes as in the brain. The spinal cord that extends from the brain stem into the vertebral canal of the vertebral column up to the level of 1^{st} or 2^{nd} lumbar vertebra. So the nerve roots of the remaining nerves are greatly elongated to exit the vertebral column at their appropriate space. The thick bundle of elongated nerve roots within the lower vertebral canal is called the **cauda equina** (horse's tail) because of its appearance.

In the cross section of spinal cord (Figure 10.11), there are two indentations: the posterior median sulcus and the anterior median fissure. Although there might be slight variations, the cross section of spinal cord is generally the same throughout its length. In contrast to the brain, the grey matter in the spinal cord forms an inner butterfly shaped region surrounded by the outer white matter. The grey matter consists of neuronal cell bodies and their dendrites, interneurons and glial cells. White matter consists of bundles of nerve fibres. In the center of the grey matter there is a central canal which is filled with CSF. Each half of the grey matter is divided into **a dorsal horn, a ventral horn** and **a lateral horn.**

The dorsal horn contains cell bodies of interneurons on which afferent neurons terminate. The ventral horn contains cell bodies of the efferent motor neurons supplying the skeletal muscle. Autonomic nerve fibres, supplying cardiac and smooth muscles and exocrine glands, originate from the cell bodies found in the lateral horn. In the white matter, the bundles of nerve fibres form two types of

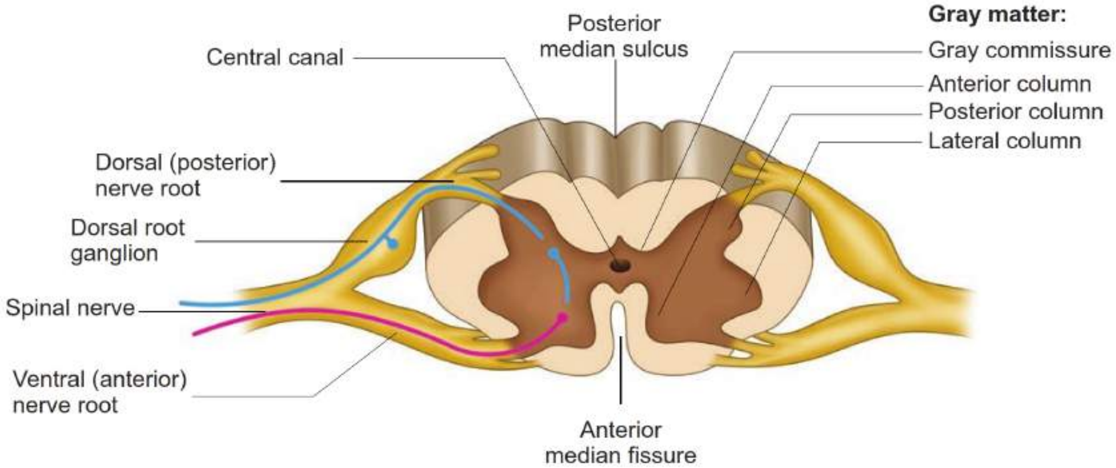


Figure 10.11 C.S. of Spinal cord

tracts namely **ascending tracts** which carry sensory impulses to the brain and descending **tracts** which carry motor impulses from the brain to the spinal nerves at various levels of the spinal cord. The spinal cord shows two enlargements, one in the cervical region and another one in the lumbosacral region. The **cervical enlargement** serves the upper limb and **lumbar enlargement** serves the lower limbs.

10.5 Reflex Action and Reflex Arc

When dust falls in our eyes, the eyelids close immediately not waiting for our willingness; on touching a hot pan, the hand is withdrawn rapidly. Do you know how this happens?

The spinal cord remains as a connecting functional nervous structure in between the brain and effector organs. But sometimes when a very quick response is needed, the spinal cord can effect motor initiation as the brain and brings about an effect. This rapid action by spinal cord is called reflex action. It is a fast, involuntary, unplanned sequence of actions that occurs in response to a particular stimulus. The nervous elements involved in carrying out the reflex action constitute a reflex arc or in other words the pathway followed by a nerve impulse to produce a reflex action is called a reflex arc (Figure 10.12).

Functional Components of a Reflex Arc

Sensory Receptor - It is a sensory structure that responds to a specific stimulus.

Sensory Neuron - This neuron takes the sensory impulse to the grey (afferent) matter of the spinal cord through the dorsal root of the spinal cord.

Interneurons - One or two interneurons may serve to transmit the impulses from the sensory neuron to the motor neuron.

Motor Neuron - it transmits impulse from CNS to the effector organ.

Effector Organs - It may be a muscle or gland which responds to the impulse received.

There are two types of reflexes. They are

1) **Unconditional reflex** is an inborn reflex for an unconditioned stimulus. It does not need any past experience, knowledge or training to occur; Ex: blinking of an eye when a dust particle about to fall into it, sneezing and coughing due to foreign particle entering the nose or larynx.

2) **Conditioned reflex** is a respone to a stimulus that has been acquired by learning. This does not naturally exists in animals. Only an experience makes it a part of the behaviour. Example: excitement of salivary gland on seeing and smelling a food. The conditioned reflex was first demonstrated by the Russian physiologist **Pavlov** in his classical conditioning experiment in a dog. The cerebral cortex controls the conditioned reflex.

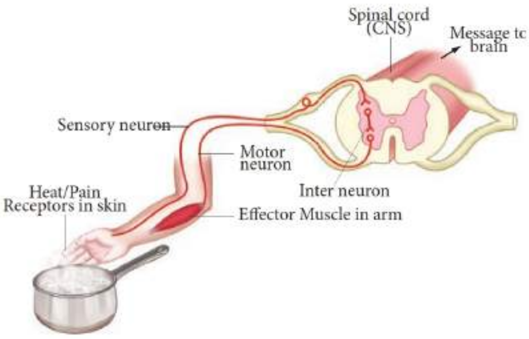


Figure 10.12 Reflex arc

Peripheral Neural System (PNS)

PNS consists of all nervous tissue outside the CNS. Components of PNS include nerves, ganglia, enteric plexuses and sensory receptors. A nerve is a chord like structure that encloses several neurons inside. Ganglia (singular-ganglion) are small masses of nervous tissue, consisting primarily of neuron cell bodies and are located outside the brain and spinal cord. Enteric plexuses are extensive networks of neurons located in the walls of organs of the gastrointestinal tract. The neurons of these plexuses help in regulating the digestive system. The specialized structure that helps to respond to changes in the environment i.e. stimuli are called **sensory receptor** which triggers nerve impulses along the afferent fibres to CNS. PNS comprises of cranial nerves arising from the brain and spinal nerves arising from the spinal cord.

(A) Cranial Nerves: There are 12 pairs of cranial nerves, of which the first two pairs arise from the fore brain and the remaining 10 pairs from the mid brain. Other than the Vagus nerve, which extends into the abdomen, all cranial nerves serve the head and face.

(B) Spinal Nerves: 31 pairs of spinal nerves emerge out from the spinal cord through spaces called the **intervertebral foramina** found between the adjacent vertebrae. The spinal nerves are named according to the region of vertebral column from which they originate

i. Cervical nerves (8 pairs)
ii. Thoracic nerves (12 pairs)
iii. Lumbar nerves (5 pairs)
iv. Sacral nerves (5 pairs)
v. Coccygeal nerves (1 pair)

Each spinal nerve is a mixed nerve containing both afferent (sensory) and efferent (motor) fibres. It originates as two roots:1) a posterior dorsal root with a ganglion outside the spinal cord and 2) an anterior ventral root with no external ganglion.

Somatic Neural System (SNS)

The **somatic neural system** (SNS or voluntary neural system) is the part of the peripheral neural system associated with the voluntary control of body movements via skeletal muscles. The sensory and motor nerves that innervate striated muscles form the somatic neural system. Major functions of the somatic neural system include voluntary movement of the muscles and organs, and reflex movements.

> In adult, the total CSF volume is about 150 ml and is replaced every 8 hours. About 500 ml of CSF is formed daily. The choroid plexus helps cleanse the CSF by removing waste products.

Autonomic Neural System

The autonomic neural system is auto functioning and self governed. It is a part of peripheral neural system that innervates smooth muscles, glands and cardiac muscle. This system controls and coordinates the involuntary activities of various organs. ANS controlling centre is in the hypothalamus.

Autonomic neural system comprises the following components:

Preganglionic neuron whose cell body is in the brain or spinal cord; its myelinated axon exits the CNS as part of cranial or spinal nerve and ends in an autonomic ganglion.

Autonomic ganglion consists of axon of preganglionic neuron and cell bodies of postganglionic neuron.

Postganglionic neuron conveys nerve impulses from autonomic ganglia to visceral effector organs.

The autonomic neural system consists of **Sympathetic neural system** and **Parasympathetic neural system.**

Your friend is returning home after his visit to USA. All at home are waiting for his arrival. How would you feel? State the division of ANS that predominates and mention few changes that take place in your body.

10. 6 Sensory Reception and Processing

Our senses make us aware of changes that occur in our surroundings and also within our body. **Sensation** [awareness of the stimulus] and **perception** [interpretation of the meaning of the stimulus] occur in the brain.

Receptors are classified based on their location: **1. Exteroceptors** are located at or near the surface of the body. These are sensitive to external stimuli and receive sensory inputs for hearing, vision, touch, taste and smell. **2. Interoceptors** are located in the visceral organs and blood vessels. They are sensitive to internal stimuli. **Proprioceptors** are also a kind of interoceptors. They provide information about position and movements of the body. These are located in the skeletal muscles, tendons, joints, ligaments and in connective tissue coverings of bones and muscles. Receptors based on the type of stimulus are shown in Table 10.3.

10.6.1 Photoreceptor - Eye

Eye is the organ of vision; located in the orbit of the skull and held in its position with the help of six extrinsic muscles. They are **superior, inferior, lateral, median rectus muscles, superior oblique and inferior oblique** muscles. These muscles aid in the movement of the eyes and they receive their nerve innervation from III, IV and VI cranial nerves. Eyelids, eye lashes and eye brows are the accessory structures useful in protecting the eyes. The eye lids protect the eyes from excessive light and foreign objects and spread lubricating secretions over the eyeballs.

Eyelashes and the eyebrows help to protect the eyeballs from foreign objects, perspiration and also from the direct rays of sunlight. **Sebaceous glands** at the base of the eyelashes are called **ciliary glands** which secrete a lubricating fluid into the hair follicles. **Lacrymal glands,** located in the upper lateral region of each orbit, secrete tears. Tears are secreted at the rate of 1mL/day and it contains salts, mucus and **lysozyme** enzyme to destroy bacteria.

Table 10.3 Types of receptors

Receptors	Stimulus	Effector organs
Mechano receptors	Pressure and vibration	Mechano receptors are present in the cochlea of the inner ear and the semi circular canal and utriculus
Chemoreceptors	Chemicals	Taste buds in the tongue and nasal epithelium
Thermoreceptors	Temperature	Skin
Photoreceptors	Light	Rod and cone cells of the retina in the eye

The conjunctiva is a thin, protective mucous membrane found lining the outer surface of the eyeball (Figure 10.13).

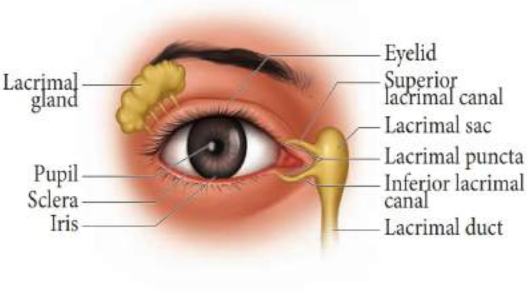


Figure.10.13 The human eye

The eye has two compartments, the **anterior** and **posterior compartments**. The anterior compartment has two chambers, first one lies between the cornea and iris and the second one lies between the iris and lens. These two chambers are filled with watery fluid called **aqueous humor**. The posterior compartment lies between the lens and retina and it is filled with a jelly like fluid called **vitreous humor** that helps to retain the spherical nature of the eye. **Eye lens** is transparent and biconvex, made up of long columnar epithelial cells called **lens fibres**. These cells are accumulated with the proteins called **crystalline**.

The Eye Ball

The eye ball is spherical in nature. The anterior one- sixth of the eyeball is exposed; the remaining region is fitted well into the orbit. The wall of the eye ball consists of three layers: fibrous **Sclera**, vascular **Choroid** and sensory **Retina** (Figure 10.14).

The outer coat is composed of dense non-vascular connective tissue. It has two regions: the anterior **cornea** and the posterior **sclera**. Cornea is a non-vascular transparent coat formed of stratified squamous epithelium which helps the cornea to renew continuously as it is very vulnerable to damage from dust. Sclera forms the white of the eye and protects the eyeball. Posteriorly the sclera is innervated by the optic nerve. At the junction of the sclera and the cornea, is a channel called **'canal of schlemm'** which continuously drains out the excess of aqueous humor.

Dilation and congestion of the blood vessels of the conjunctiva due to local irritation or infection are the cause of bloodshot eye (conjunctivitis - commonly called Madras eye). Infection of ciliary glands by bacteria causes a painful, pus filled swelling called a Sty.

The cornea is the only tissue in the body that can be transplanted from one person to another with little or no possibility of rejection. This is because cornea does not have blood vessels.

Choroid is highly vascularized pigmented layer that nourishes all the eye layers and its pigments absorb light to prevent internal reflection.
Anteriorly the choroid thickens to form the ciliary body and iris. Iris is the coloured portion of the eye lying between the cornea and lens. The aperture at the centre of the iris is the **pupil** through which the light enters the inner chamber. Iris is made of two types of muscles the **dilator papillae** (the radial muscle) and the **sphincter papillae** (the circular muscle).In the bright light, the circular muscle in the iris contract; so that the size of pupil decreases and less light enters the eye. In dim light, the radial muscle

in the iris contract; so that the pupil size increases and more light enters the eye. Smooth muscle present in the ciliary body is called the **ciliary muscle** which alters the convexity of the lens for near and far vision. The ability of the eyes to focus objects at varying distances is called **accommodation** which is achieved by **suspensory ligament, ciliary muscle** and **ciliary body**. The suspensory ligament extends from the ciliary body and helps to hold the lens in its upright position. The ciliary body is provided with blood capillaries that secrete a watery fluid called **aqueous humor** that fills the anterior chamber.

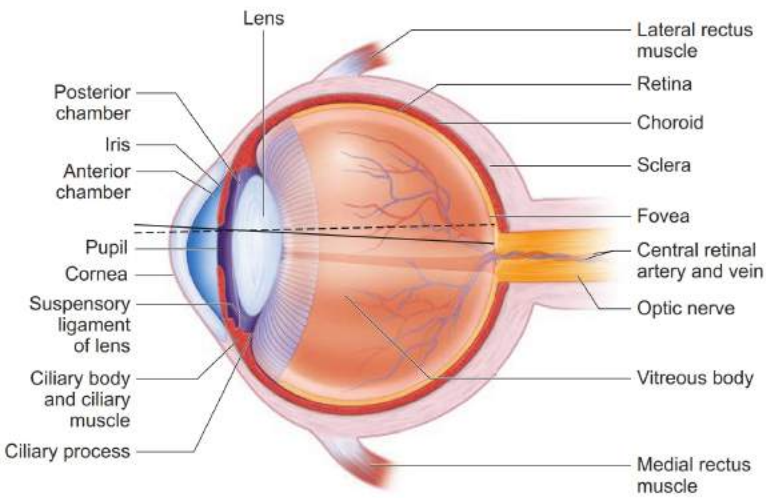


Figure 10.14 L.S. of the eye

Figure 10.15 Rod and Cone cells

Retina forms the inner most layer of the eye and it contains two regions: A sheet of **pigmented epithelium** (non visual part) and **neural visual regions.** The neural retina layer contains three types of cells: photoreceptor cells – **cones and rods** (Figure 10.15 and Table 10.4), **bipolar cells and ganglion cells.** The yellow flat spot at the centre of the posterior region of the retina is called **macula lutea** which is responsible for sharp detailed vision. A small depression present in the centre of the yellow spot is called **fovea centralis** which contains only cones. The optic nerves and the retinal blood vessels enter the eye slightly

Table 10.4 Differences between rod and cone cells

Rod cells	Cone cells
Rods are responsible for vision in dim light	The cones are responsible for colour vision and works best in the bright light.
The pigment present in the rods is rhodopsin, formed of a protein scotopsin and retinal (an aldehyde of vitamin A)	The pigment present in the cones is photopsin, formed of opsin protein and retinal.
There are about 120 millions rod cells	There may be 6-7 millions cone cells
Rods are predominant in the extra fovea region	Cones are concentrated in the fovea region

below the posterior pole, which is devoid of photo receptors; hence this region is called **blind spot.**

Mechanism of Vision

When light enters the eyes, it gets refracted by the **cornea, aqueous humor and lens and it is focused** on the retina and excites the rod and cone cells. The photo pigment consists of **Opsin**, the protein part and **Retinal**, a derivative of vitamin A. Light induces dissociation of retinal from opsin and causes the structural changes in opsin. This generates an action potential in the photoreceptor cells and is transmitted by the optic nerves to the visual cortex of the brain, via bipolar cells, ganglia and optic nerves, for the perception of vision.

Refractive errors of eye

Myopia (near sightedness): The affected person can see the nearby objects but not the distant objects. This condition may result due to an elongated eyeball or thickened lens; so that the image of distant object is formed in front of the yellow spot. This error can be corrected using concave lens that diverge the entering light rays and focuses it on the retina.

Hypermetropia (long sightedness): the affected person can see only the distant objects clearly but not the objects nearby. This condition results due to a shortened eyeball and thin lens; so the image of closest object is converged behind the retina. This defect can be overcome by using convex lens that converge the entering light rays on the retina.

Presbyopia: Due to aging, the lens loses elasticity and the power of accommodation. Convex lenses are used to correct this defect.

Astigmatism is due to the rough (irregular) curvature of cornea or lens. Cylindrical glasses are used to correct this error (Figure 10.16).

Cataract: Due to the changes in nature of protein, the lens becomes opaque. It can be corrected by surgical procedures.

> Visual pigments for colour vision are i) the red cones having the visual pigment, Erythropsin is sensitive to long wavelength close to 560 nm. ii) The green cones having the pigment, chloropsin is sensitive to medium wavelength of 530 nm iii) the blue cones having the pigment, cyanopsin is sensitive to short wavelength of 420 nm.

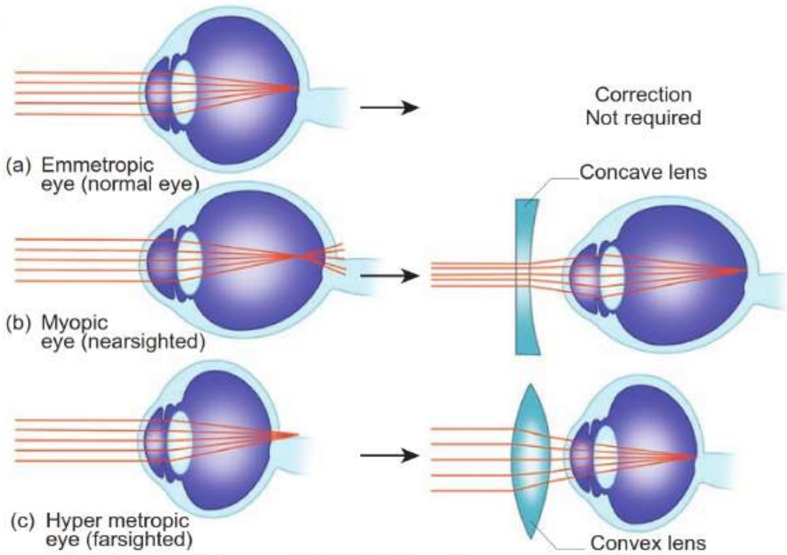


Figure 10.16 Refractive errors of the eye

Aqueous humour supplies nutrients and oxygen to the lens, cornea and some retinal cells. The aqueous humor is produced and drained at the same rate, maintaining a constant intra ocular pressure of about 16 mmHg. Any block in the canal of schlemm increases the intra-ocular pressure of aqueous humor and leads to 'Glaucoma' where the optic nerve and the retina are compressed due to pressure.

10.6.2 Phonoreceptor

The ear is the site of reception of two senses namely hearing and equilibrium. Anatomically, the ear is divided into three regions: the external ear, the middle ear and internal ear.

The external ear consists of **pinna, external auditory meatus** and **ear drum**. The pinna is flap of elastic cartilage covered by skin. It collects the sound waves. The external auditory meatus is a curved tube that extends up to the tympanic membrane [the ear drum]. The tympanic membrane is composed of connective tissues covered with skin outside and with mucus membrane inside.

There are very fine hairs and wax producing sebaceous glands called **ceruminous glands** in the external auditory meatus. The combination of hair and the **ear wax** [cerumen] helps in preventing dust and foreign particles from entering the ear.

The middle ear is a small air-filled cavity in the temporal bone. It is separated from the external ear by the eardrum and from the internal ear by a thin bony partition; the bony partition contains two small membrane covered openings called the oval window and the round window.

The middle ear contains three ossicles: **malleus** [hammer bone], **incus** [anvil bone] and **stapes** [stirrup bone] which are attached to one another. The malleus is attached to the tympanic membrane and its head articulates with the incus which is the intermediate bone lying between the malleus and stapes. The stapes is attached to the oval window in the inner ear. The ear ossicles transmit sound waves to the inner ear. A tube called Eustachian tube connects the middle ear cavity with the pharynx. This tube helps in equalizing the pressure of air on either sides of the ear drum.

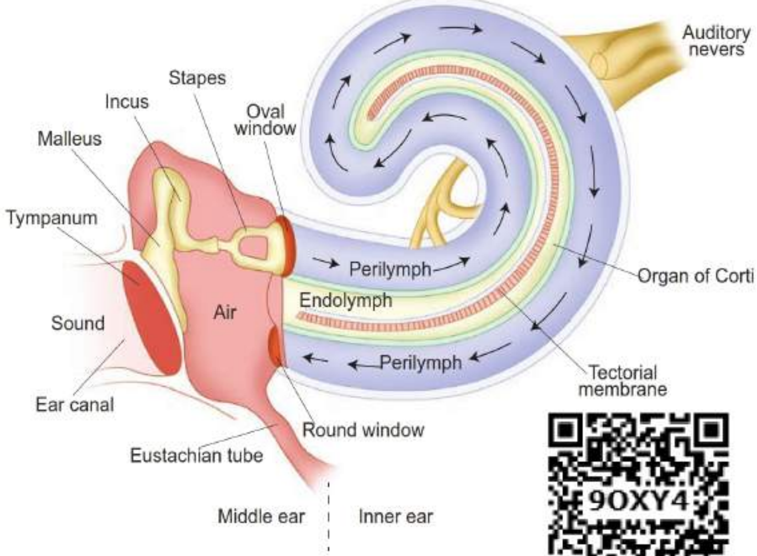


Figure 10.17 Path of Sound wave

Inner ear is the fluid filled cavity consisting of two parts, the bony labyrinth and the membranous labyrinths. The bony labyrinth consists of three areas: **cochlea, ve**stibule and semicircular canals. The cochlea is a coiled portion consisting of 3 chambers namely: scala vestibuli and scala tympani- these two are filled with perilymph; and the scala media is filled with endolymph. At the base of the cochlea, the scala vestibule ends at the 'oval window' whereas the scala tympani ends at the 'round window' of the middle ear. The chambers scala vestibuli and scala media are separated by a membrane called Reisner's membrane whereas the scala media and scala tympani are separated by a membrane called Basilar membrane (Figure 10.17)

Organ of Corti

The **organ of Corti** (Figure.10.18) is a sensory ridge located on the top of **the Basilar membrane** and it contains numerous hair cells that are arranged in four rows along the length of the basilar membrane. Protruding from the apical part of each hair cell is hair like structures known as **stereocilia.** During the conduction of sound wave, stereocilia makes a contact with the stiff gel membrane called **tectorial membrane,** a roof like structure overhanging the organ of corti throughout its length.

Mechanism of hearing

Sound waves entering the external auditory meatus fall on the tympanic membrane. This causes the ear drum to vibrate, and these vibrations are transmitted to the oval window through the three auditory ossicles. Since the tympanic membrane is 17-20 times larger than the oval window, the pressure exerted on the oval window is about 20 times more than that on the tympanic membrane. This increased pressure generates pressure waves in the fluid of perilymph. This pressure causes the round window to alternately bulge outward and inward meanwhile the basilar membrane along with the organ of Corti move up and down. These movements of the hair alternately open and close the mechanically gated ion channels in the base of hair cells and the action potential is propagated to the brain as sound sensation through cochlear nerve.

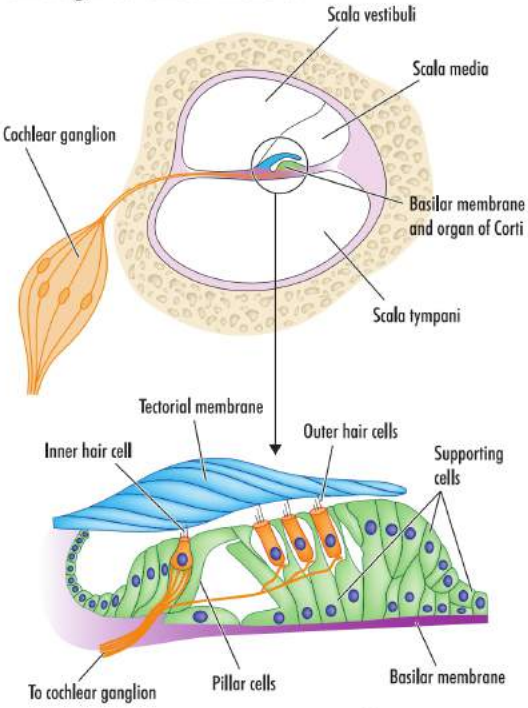


Figure 10.18 Organ of Corti

Defects of Ear

Deafness may be temporary or permanent. It can be further classified into **conductive deafness** and **sensory-neural deafness**. Possible causes for conductive deafness may be due to

i. the blockage of ear canal with earwax,
ii. Rupture of eardrum
iii. Middle ear infection with fluid accumulation
iv. Restriction of ossicular movement.In **sensory-neural deafness**, the defect may be in the organ of Corti or the auditory nerve or in the ascending auditory pathways or auditory cortex.

Organ of Equilibrium

Balance is part of a sense called proprioception, which is the ability to sense the position, orientation and movement of the body. The organ of balance is known as the **vestibular system** which is located in the inner ear next to the cochlea. The vestibular system is composed of a series of fluid filled sacs and tubules.These sacs and tubules contain endolymph and are kept in the surrounding perilymph (Figure 10.19). These two fluids, perilymph and endolymph, respond to the mechanical forces, during changes occurring in body position and acceleration.

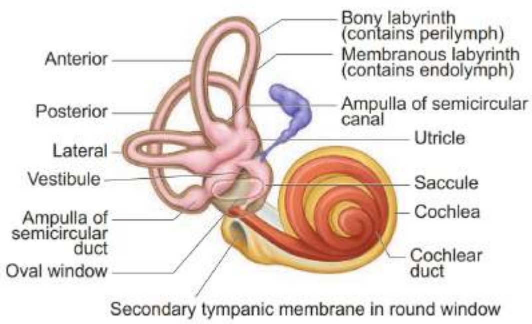


Figure 10.19 Organ of Equilibrium

Name the parts of the organ of equilibrium involved in the following functions.

a) Linear movement of the body
b) Changes in the body position
c) Rotational movement of the head.

The utricle and saccule are two membranous sacs, found nearest the cochlea and contain equilibrium receptor regions called **maculae** that are involved in detecting the linear movement of the head. The maculae contain the hair cells that act as mechanorecptors. These hair cells are embeded in a gelatinous otolithic membrane that contains small calcareous particles called **otoliths**. This membrane adds weight to the top of the hair cells and increase the inertia.

The canals that lie posterior and lateral to the vestibule are semicircular canals; they are **anterior, posterior and lateral canals** oriented at right angles to each other. At one end of each semicircular canal, at its lower end has a swollen area called **ampulla**. Each ampulla has a sensory area known as **crista ampullaris** which is formed of sensory hair cells and supporting cells. The function of these canals is to detect rotational movement of the head.

The intensity of sound is measured in decibels (dB). 0 dB is the threshold of hearing for normal ear. Severe hearing loss occurs with frequent or prolonged exposure to sound with intensities greater than 90dB. For meaningful conversations the intensity should be in the 50 dB range.

10.6.3 Olfactory Receptors

The receptors for taste and smell are the chemoreceptors. The smell receptors are excited by air borne chemicals that dissolve in fluids. The yellow coloured patches of olfactory epithelium form the olfactory organs that are located on the roof of the nasal cavity. The olfactory epithelium is covered by a thin coat of mucus layer below and olfactory glands bounded connective tissues, above. It contains three types of cells: **supporting cells, Basal cells** and millions of pin shaped **olfactory receptor cells** (which are unusual bipolar cells). The olfactory glands and the supporting cells secrete the mucus. The unmyelinated axons of the olfactory receptor cells are gathered to form the filaments of olfactory nerve [cranial nerve I] which synapse with cells of olfactory bulb. The impulse, through the olfactory nerves, is transmitted to the frontal

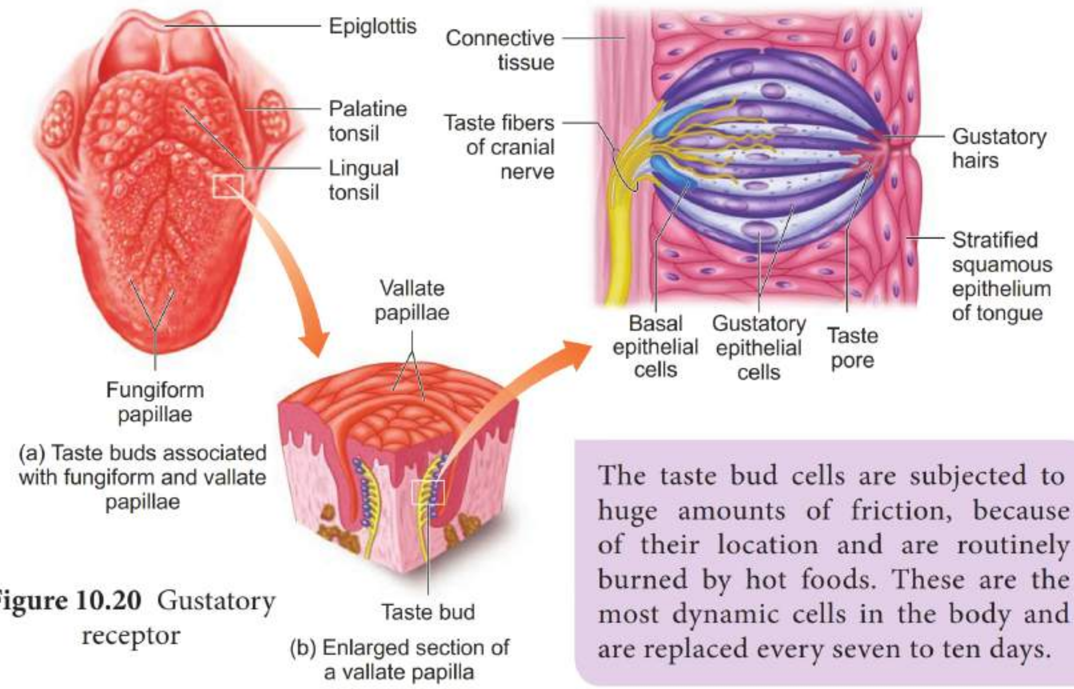


Figure 10.20 Gustatory receptor

The taste bud cells are subjected to huge amounts of friction, because of their location and are routinely burned by hot foods. These are the most dynamic cells in the body and are replaced every seven to ten days.

lobe of the brain for identification of smell and the limbic system for the emotional responses to odour.

Gustatory receptor: The sense of taste is considered to be the most pleasurable of all senses. The tongue is provided with many small projections called **papillae** which give the tongue an abrasive feel. Taste buds are located mainly on the papillae which are scattered over the entire tongue surface. Most taste buds are seen on the tongue (Figure 10.20) few are scattered on the soft palate, inner surface of the cheeks, pharynx and epiglottis of the larynx. Taste buds are flask-shaped and consist of 50 – 100 epithelial cells of two major types.

Gustatory epithelial cells (taste cells) and **Basal epithelial cells** (Repairing cells) Long microvilli called **gustatory hairs** project from the tip of the gustatory cells and extends through a taste pore to the surface of the epithelium where they are bathed by saliva. Gustatory hairs are the sensitive portion of the gustatory cells and they have sensory dendrites which send the signal to the brain. The basal cells that act as stem cells, divide and differentiate into new gustatory cells (Figure 10.20).

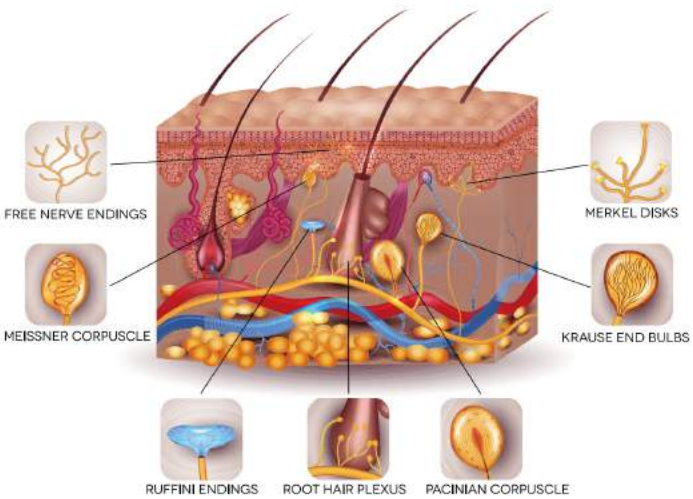


Figure 10.21 Skin receptors

Skin-Sense of touch

Skin is the sensory organ of touch and is also the largest sense organ. This sensation comes from millions of microscopic sensory receptors located all over the skin and associated with the general sensations of contact, pressure, heat, cold and pain. Some parts of the body, such as the finger tips have a large number of these receptors, making them more sensitive. Some of the sensory receptors present in the skin (Figure 10.21) are:

- **Tactile merkel disc** is light touch receptor lying in the deeper layer of epidermis.
- **Hair follicle receptors** are light touch receptors lying around the hair follicles.
- **Meissner's corpuscles** are small light pressure receptors found just beneath the epidermis in the dermal papillae. They are numerous in hairless skin areas such as finger tips and soles of the feet.
- **Pacinian corpuscles** are the large egg shaped receptors found scattered deep in the dermis and monitoring vibration due to pressure. It allows to detect different textures, temperature, hardness and pain
- **Ruffini endings** which lie in the dermis responds to continuous pressure.
- **Krause end bulbs** are thermoreceptors that sense temperature.

Melanocytes are the cells responsible for producing the skin pigment, melanin, which gives skin its colour and protects it from the sun's UV rays. Vitiligo (Leucoderma) is a condition in which the melanin pigment is lost from areas of the skin, causing white patches, often with no clear cause. Vitiligo is not contagious. It can affect people of any age, gender, or ethnic group. The patches appear when melanocytes fails to synthesis melanin pigment.

Summary

Neural system coordinates and integrates the functions of all organs and responds to changes in the internal and external environments.

Neural system includes two types of cells neurons and neuroglia. Neuron forms the structural and functional unit of the neural system.

CNS includes brain and spinal cord. The major parts of the brain are the cerebrum, diencephalon, cerebellum and the brain stem. The brain is protected by the cranium and meninges. CSF provides mechanical protection and nutrients to the CNS.

The spinal cord is the continuation of the medulla oblongata and ends at the second lumbar vertebra as conus medullaris. The components involved in reflex action are called reflex arc.

There are 12 pairs of cranial nerves which arise from the brain and 31 pairs of spinal nerves from the spinal cord make the PNS. The PNS is further divided into Somatic Neural system and Autonomic Neural system. The SNS operates under conscious control. The ANS usually operates unconsciously.

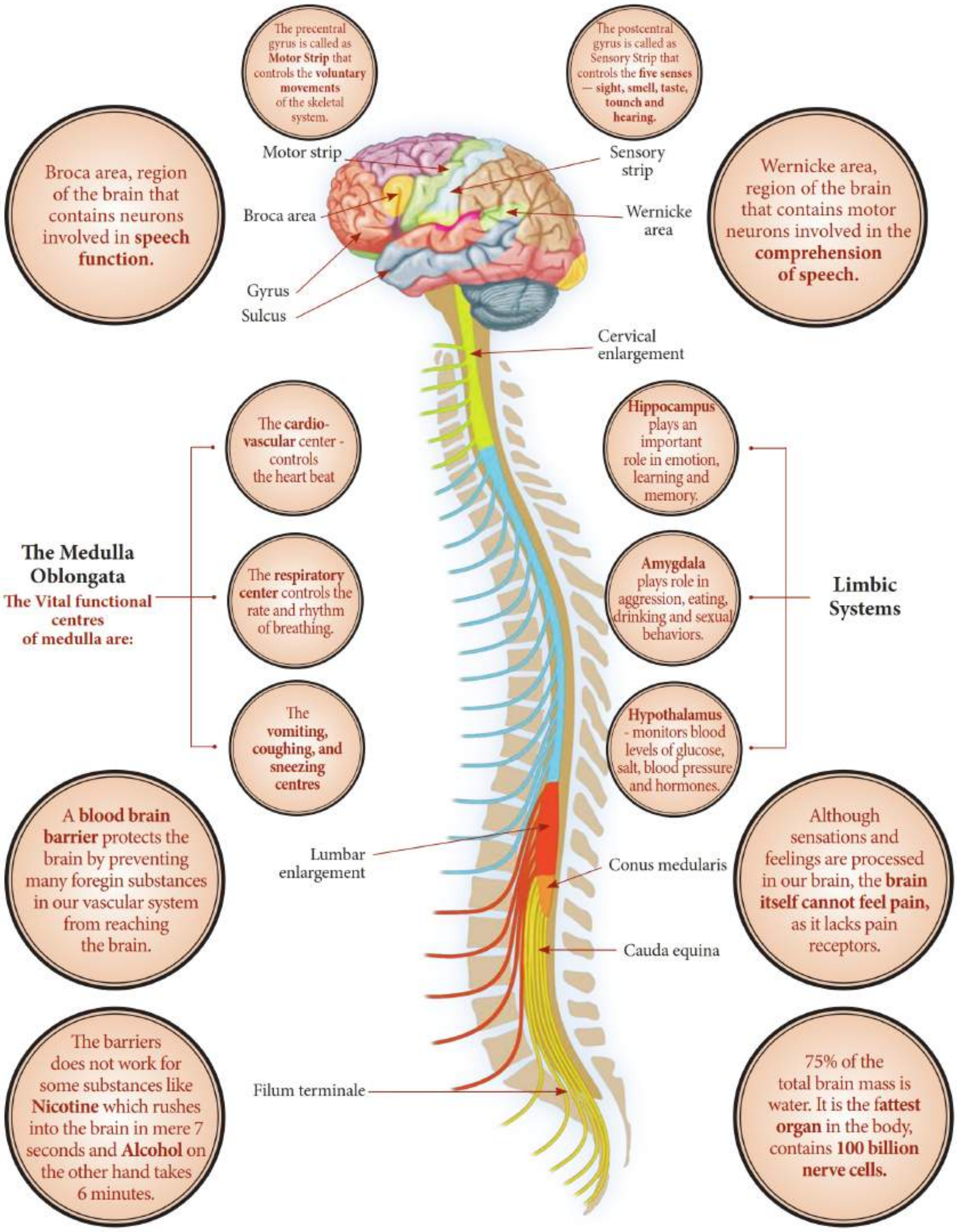
The motor portion of ANS has two major divisions: sympathetic and parasympathetic.

Sensation is the conscious or subconscious awareness of changes in the external or internal environment. Four events namely stimulation, transduction, generation of impulses and integration occurs typically for a sensation to take place.

Simple receptors are associated with the general senses such as somatic senses (skin); complex receptors are associated with the special senses such as smell, taste, vision, hearing and equilibrium.

Nervous System

The Nervous system is a complex collection of specialized nerve cells known as neurons that transmit signals between different parts of the body.



Evaluation

1 Which structure in the ear converts pressure waves to action potentials?

a. Tympanic membrane
b. Organ of Corti
c. Oval window
d. Semicircular canal

2. Which of the following pairings is correct?

a. Sensory nerve – afferent
b. Motor nerve - afferent
c. Sensory nerve – ventral
d. Motor nerve – dorsal

3. During synaptic transmission of nerve impulse, neurotransmitter (P) is released from synaptic vesicles by the action of ions (Q). Choose the correct P and Q.

a. P = Acetylcholine, Q = Ca++
b. P = Acetylcholine, Q = Na+
c. P = GABA, Q=Na+
d. P = Cholinesterase, Q = Ca++

4. Examine the diagram of the two cell types A and B given below and select the correct option.

a. Cell-A is the rod cell found evenly all over retina
b. Cell-A is the cone cell more concentrated in the fovea centralis
c. Cell-B is concerned with colour vision in bright light
d. Cell-A is sensitive to bright light intensities

5. Assertion: The imbalance in concentration of Na^+, K^+ and proteins generates action potential.

Reason: To maintain the unequal distribution of Na^+ and K^+, the neurons use electrical energy.

a. Both Assertion and Reason are true and Reason is the correct explanation of the Assertion.
b. Both Assertion and Reason are true but the Reason is not the correct explanations of Assertion.
c. Assertion is true, but Reason is false.
d. Both Assertion and Reason are false.

6. Which part of the human brain is concerned with the regulation of body temperature?

a. Cerebellum
b. Cerebrum
c. Medulla oblongata
d. Hypothalamus

7. The respiratory centre is present in the

a. Medulla oblongata
b. Hypothalamus
c. Cerebellum
d. Thalamus

8. Match the following human spinal nerves in column I with their respective number in column II and choose the correct option

column I	column II
P. Cervical nerves	i. 5 pairs
Q. Thoracic nerve	ii. 1 pair
R. Lumbar nerve	iii. 12 pair
S. Coccygeal nerve	iv. 8 pair

a. (P-iv),(Q-iii),(R-i),(S-ii)
b. (P-iii), (Q-i), (R-ii), (S-iv)
c. (P-iv),(Q-i),(R-ii),(S-iii)
d. (P-ii), (Q-iv), (R-i), (S-iii)

9. The abundant intracellular cation is

a. H^+ b. K^+ c. Na^+ d. Ca^{++}

10. Which of the following statements is wrong regarding conduction of nerve impulse?

a. In a resting neuron, the axonal membrane is more permeable to K^+ ions and nearly impermeable to Na^+ ions.

b. Fluid outside the axon has a high concentration of Na^+ ions and low concentration of K^+, in a resting neuron.

c. Ionic gradient s are maintained by Na^+ K^+ pumps across the resting membrane, which transport 3Na ions outwards for $2K^+$ into the cell.

d. A neuron is polarized only when the outer surface of the axonal membrane possess a negative a charge and its inner surface is positively charged.

11. All of the following are associated with the myeline sheath except

a. Faster conduction of nerve impulses

b. Nodes of Ranvier forming gaps along the axon

c. Increased energy output for nerve impulse conduction

d. Saltatory conduction of action potential

12. Several statements are given here in reference to cone cells which of the following option indicates all correct statements for cone cells ?

Statements

(i) Cone cells are less sensitive in bright light than Rod cells

(ii) They are responsible for colour vision

(iii) Erythropsin is a photo pigment which is sensitive to red colour light

(iv) They are present in fovea of retina

a. (iii), (ii) and (i)

b. (ii) , (iii) and (iv)

c. (i), (iii) and (iv)

d. (i), (ii) and (iv)

13. Which of the following statement concerning the somatic division of the peripheral neural system is incorrect?

a. Its pathways innervate skeletal muscles

b. Its pathways are usually voluntary

c. Some of its pathways are referred to as reflex arcs

d. Its pathways always involve four neurons

14. When the potential across the axon membrane is more negative than the normal resting potential, the neuron is said to be in a state of

a. Depolarization

b. Hyperpolarization

c. Repolarization

d. Hypopolarization

15. Why is the blind spot called so?

16. Sam's optometrist tells him that his intraocular pressure is high. What is this condition called and which fluid does it involve?

17. The action potential occurs in response to a threshold stimulus; but not at sub threshold stimuli. What is the name of the principle involved?

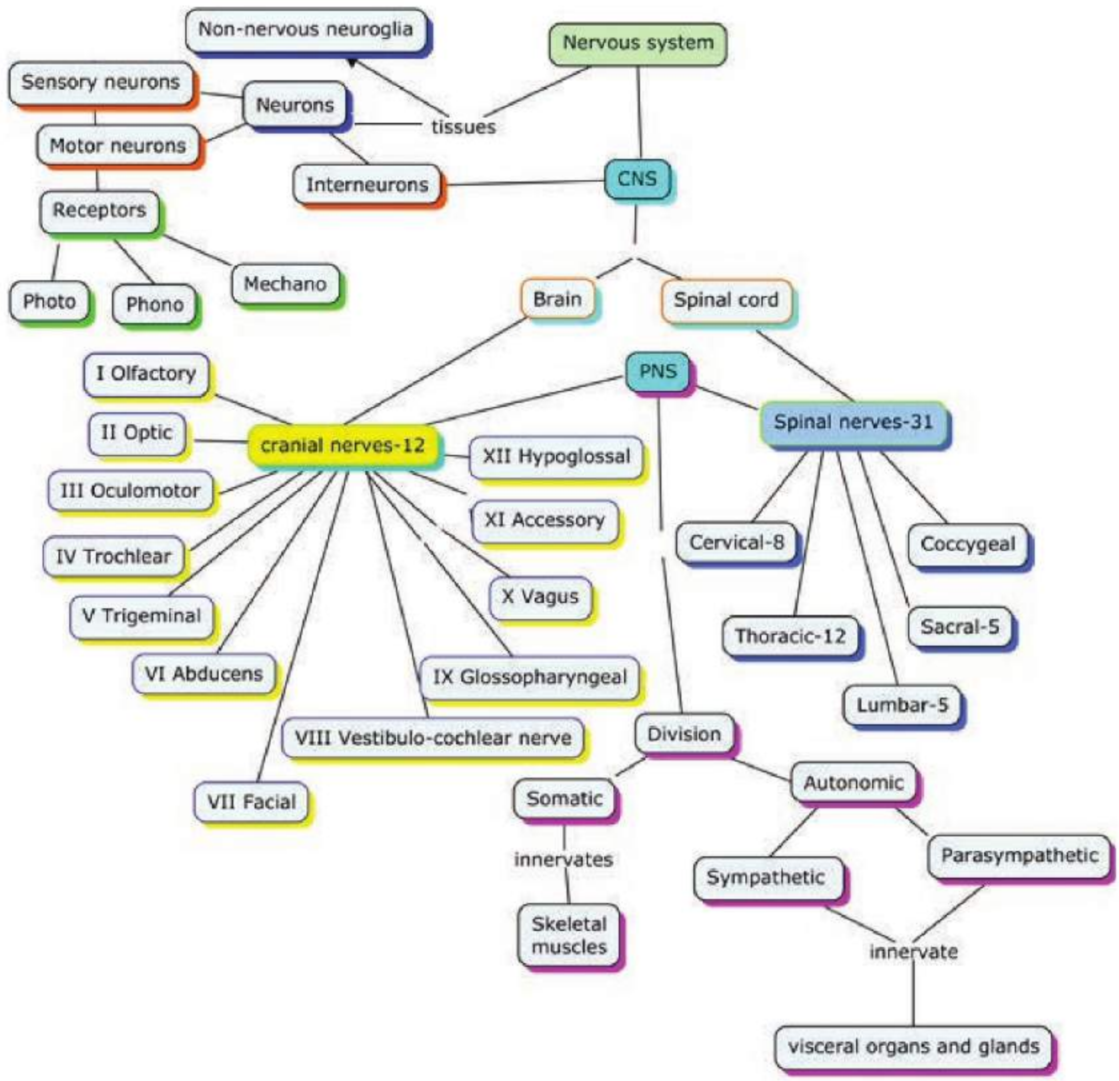
18. Pleasant smell of food urged Ravi to rush into the kitchen. Name the parts of the brain involved in the identification of food and emotional responses to odour.

19. Cornea transplant in humans is almost never rejected. State the reason.

20. At the end of repolarization, the nerve membrane gets hyperpolarized. Why?
21. The choroid plexus secretes cerebrospinal fluid. List the function of it.
22. What is ANS? Explain the components of ANS.
23. Why the limbic system is called the emotional brain? Name the parts of it.
24. Classify receptors based on type of stimuli.
25. Differentiate between rod and cone cells.
26. The sense of taste is considered to be the most pleasurable of all senses.

    Describe the structure of the receptor involved with a diagram.
27. Describe the sensory receptors present in the skin.

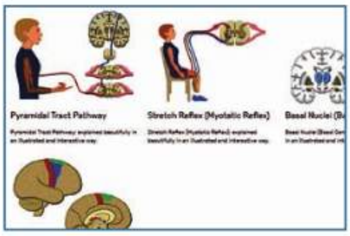
Concept Map



ICT Corner

The Transmitters

Let's explore the structure and various functions of the **Nervous System**.



Step – 1

Use the URL to reach the 'Nervous system' page. Select 'Nervous System organization' from grid and explore the autonomic and somatic organizations of nervous system.

Step – 2

Then reach the 'Nervous system' page by clicking back button on the top of the window or use the 'Backspace' key. Select 'Nerve cells' from the grid and explore.

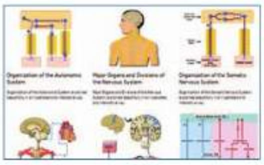
Step – 3

Follow the above steps and explore each and every parts and their functions of nervous system.

Step – 4

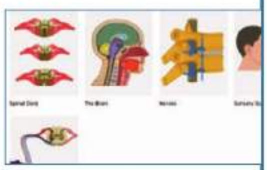
Use the reference given below to acquire additional details about nervous system.

Step 1



Step 2

Step 3



Step 4

Nervous System's URL:

https://www.getbodysmart.com/nervous-system

3D-Brain:
http://www.brainfacts.org/3d-brain#intro=false&focus=Brain&zoom=false

3D-Ear:
https://www.amplifon.com/web/uk/interactive-ear/index.html

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* Pictures are indicative only