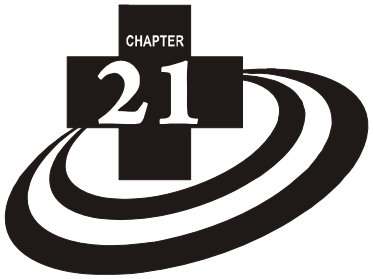


Neural Control and Coordination

INTRODUCTION

Nervous system is a system of highly specialised nerve cells, nerve fibres and organs (called **receptors**), that coordinate and control the activities of different parts of the body. This is done by converting the internal and external stimuli of environmental changes into the form of electrical impulses (a process called **transduction**) and transmit them to other specialised cells called **effectors** (muscles and glands) to react accordingly. Between the receptors and effectors are present the conducting cells of the nervous system, the **neurons**.

Overall function of nervous system is to collect information about the external conditions in relation to the bodyís internal state, to analyze this information, and to initiate appropriate responses to satisfy certain needs (maintain homeostasis). The most important need is survival. The nerves do not form one single system, it forms several systems, which are interrelated. Some of these are physically separate, others are different in function only.

The nervous system is unique in the vast complexity of thought processes and control actions it can perform. It recieves each minute literally millions of bits of information from the different sensory nerves and sensory organs and then integrates all these to determine responses to be made by the body.

Divisions of neural system

Human neural system is divisible into three main parts :

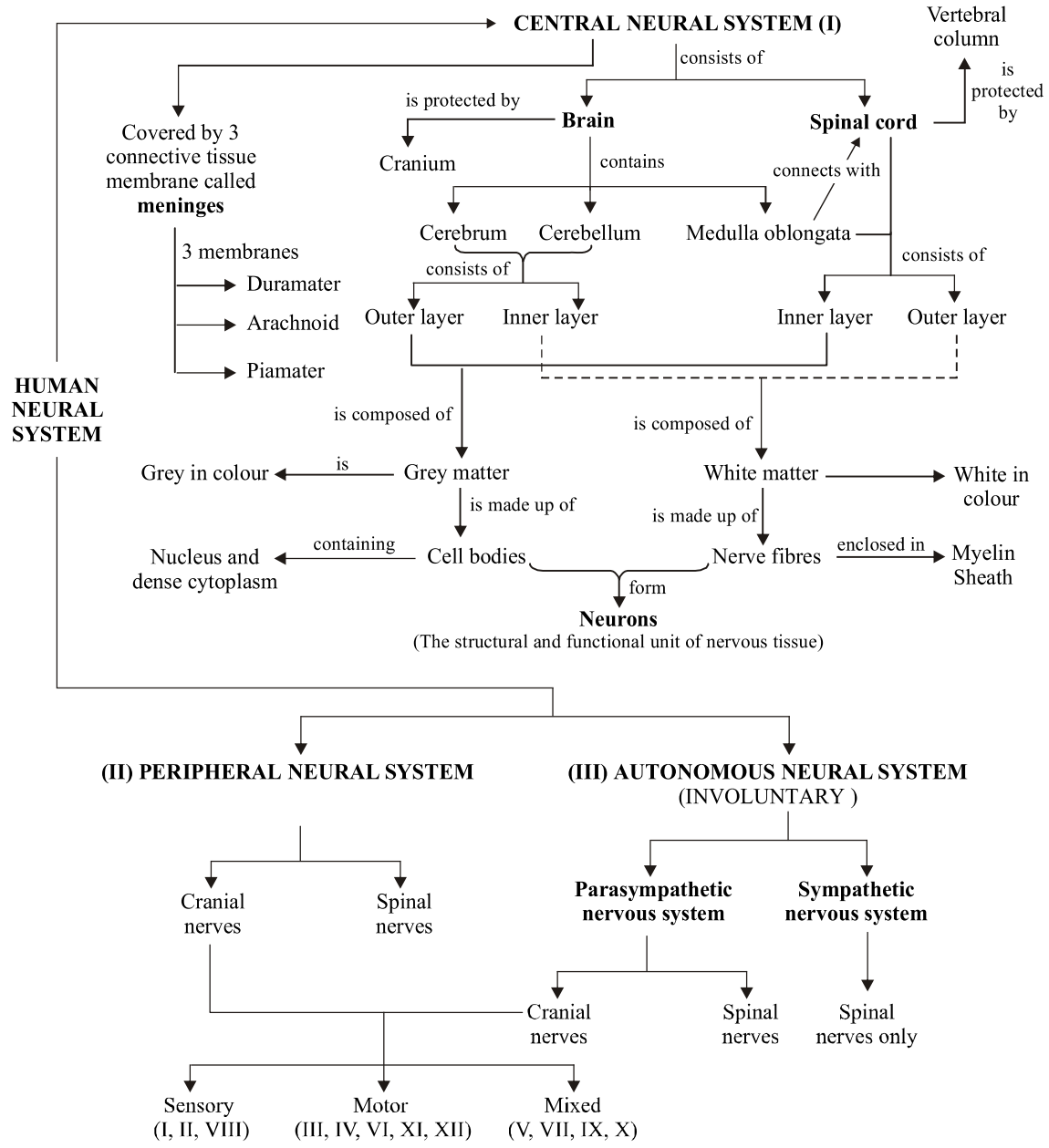
1. **Central neural system (CNS)** ñ It is a hollow, dorsally placed structure lying along the mid-dorsal axis of the body. It consists of **brain** and **spinal cord**. The brain is lodged in the skull while spinal cord is enclosed by the vertebral column. CNS is responsible for the integration of all nervous activities.
2. **Peripheral neural system (PNS) ñ** The nerves arising from the central neural system, constitute the peripheral neural system. It consists of the nerves, which originate from the brain and spinal cord and are known as **cranial** and **spinal nerves** respectively.

Based on their functions, the nerve fibres are divided into two groups, namely **(a) afferent nerve fibre** and **(b) efferent nerve fibres**. The afferent nerve fibres transmit sensory impulses from tissues/organs to the central neural system (CNS) and from the sensory or afferent pathway. The efferent nerve fibres transmit motor impulses from CNS to the concerned tissues/organs and from the motor or efferent pathways.

3. **Autonomic neural system ñ** It controls and coordinates those organs which are under involuntary control. This system is further divided into two ñ

(i) Sympathetic neural system *(*SNS*)*, which has mainly excitatory effects on the body.

(ii) Parasympathetic neural system*,* which acts antagonistically to the SNS and has mainly calming influences.



Flow chart : Various subdivisions of the neural system.

The bundle of nerve fibres within the CNS are called **tracts** while those present in the PNS are called **nerves**.

Neuron (= Nerve cell)

A neuron is a structural and functional unit of the neural tissue and hence the neural systems. Certain neurons may almost equal the length of body itself. Thus neurons with longer processes (projections) are the longest cells in the body. Majority of the neurons occur in the brain. Fully formed neurons never divide and remain in interphase throughout life. Shortly after birth, new neurons do not develop.

A neuron consists of main cell body and cytoplasmic processes arising from it.

(i) Cell body (**= cyton** or **soma**) ñ It varies in size and form. It may be irregular, spherical, oval, rounded, star shaped or pyramidal. Like a typical cell it consists of cytoplasm, nuclues and cell membrane. It has abundant cytoplasm, called **neuroplasm** and a relatively large

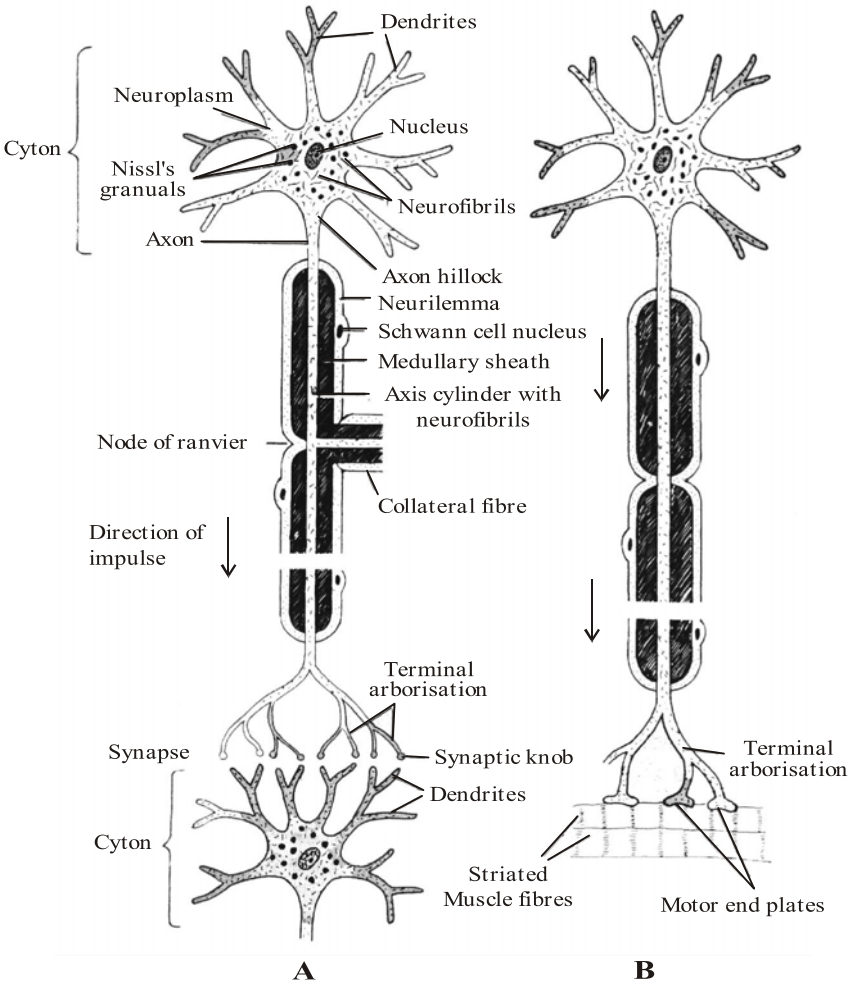


Fig. Neurons and medullated nerve fibres. **A**, showing collateral fibre and synapse. **B,** showing motor neuron and striated muscle fibres.

spherical central nucleus with distinct **nucleolus**. The cytoplasm has mitochondria, Golgi apparatus, rough endoplasmic reticulum ribosomes, lysosomes, fat globules, pigment granules, neurofibrils, neurotubules and Nisslís granules. Presence of neurofibrils and Nisslís granules is characteristic to all neurons. Neurofibrils play a role in the transmission of impulses. Neurotubules are in fact, microtubules which maintain the shape of the neuron. The Nisslís granules (also called Nisslís bodies) are irregular masses of rough endoplamsic reticulum with numerous attached and free ribsosomes and polysomes. The Nisslís granules probably synthesize proteins for the cell. Centrioles, formerly believed to be absent in mature neurons, have been described in nerons and may be associated with the production and maintenance of microtubules. The cytoplasm immediately surrounding the nucleus is loaded with protein-synthetic machinery, and is called **perikaryon**. Previously the name perikaryon was given to the cyton (cell body or soma). Ageing neurons contain a pigment **lipofuscin** (made up of residual bodies derived from lysosomes).

Cyton is concerned with metabolic maintenance and growth.

(ii) Neurites ñ The processes of neurons are called **neurites**. These are of two types : dendrites or dendrons and an axon or axis cylinder or neuraxon.

(a) Dendrites (Dendrons) ñ These are usually shorter, tapering and much branched processes. They may be one to several. The dendrites contain neurofibrils, neurotubules and Nisslís granules. They conduct nerve impulse towards the cell body and are called **afferent process** (= receiving processes).

(b) Axon ñ Axon is a single, usually very long process of uniform thickness. The part of cyton from where the axon arises is called **axon hillock**. Most sensitive part of neuron is axon hillock. The axon contains neurofibrils and neurotubules but does not have Nisslís granules, Golgi complex, ribosomes, pigment granules, fat globulus, etc. In the absence of Nisslís granules, the axon depends on the cell body for the supply of proteins. The cell membrane of the axon is called **axolemma** and its cytoplasm is known as axoplasm. The axons may be covered with a covering of white sheath (the myelin sheath). Such a nerve fiber is called medullated or myelinated nerve fiber. If the sheath is

absent the fiber is called non-medullated or non-myelinated nerve fiber.The axon ends in a group of branches, the **terminal arborizations** (= **axon terminals** or **telodendria**). When terminal arborization of the axon meet the dendrites of another neuron to form a synapse they form **synaptic knobs** (= **end plates**). The synaptic knobs contain mitochondria and secretory vesicles. The part of the sarcolemma (muscle plasma membrane) that lies beneath the axon terminals/ nerve endings, is called **motor end plate**.

Each axon may also possess side branches called **collateral fibres** which are usually much finer than the main axonal process. The axon conducts nerve impulses away from the cell body, therefore, called on **efferent process**.

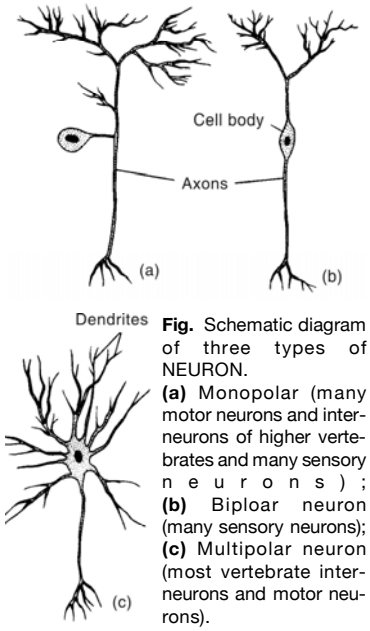


Fig. Schematic diagram of three types of NEURON. **(a)** Monopolar (many motor neurons and interneurons of higher vertebrates and many sensory neurons); **(b)** Biploar neuron (many sensory neurons); **(c)** Multipolar neuron (most vertebrate interneurons and motor neurons).

Types of neurons

- Functionally the nerve fibers are divided into two categories ñ **afferent fibers** (carrying impulses from receptor organ to CNS) and **efferent fibers** (carrying impulses from CNS to effector organs like muscles or glands). In other words, neurons exhibit polarity in conduction of impulses.
- On the basis of structure neurons can be differentiated as ñ

  Unipolar ñ When one axon extends from the cell body. *e.g.,* embryo and then divides into two long branches. *e.g.,* sensory neurons.

  Bipolar neurons ñ When one axon and one dendrite comes out from the soma. *e.g.,* Retina.

  Multipolar neurons ñ When the axon and two or more dendrites extend from the soma. *e.g.,*. Motor neurons and interneurons.

  Pseudounipolar neurons ñ When one axon extends from the cell body and then divides into two. *e.g.,* - dorsal root ganglion.

  Non-polar neurons ñ When all processes of soma are equal and nerve impulse can be conducted in any direction. *e.g.,* neurons of coelenterates.

Illustration 1 : The three classes of neurons in vertebrates and complex invertebrates are ....., which receive information from sensory receptors and transmit it to be the central nervous system, ..., which transmit messages to the effectors (..... and .....) and, ... which transmit message between the other two types of neurons.

Soln.: Sensory neurons; motor neurons; muscles; glands; interneurons.

Illustration 2 : Distinguish between:

(a) Dendrites and axon

(b) Afferent and efferent neurons.

Soln.: (a) Dendrites are usually shorter, tapering and much branched process that project out of the cell body of neuron. These fibres transmit impulses towards the cell body. The axon is long fibre the distal end of which is branched. It transmits nerve impulses away from the cell body to a synapse or to a neuromuscular junction.

(b) The afferent nerve fibres or neurons transmit impulses from tissues or organs to the central neural system and the efferent nerve fibres or neurons transmit regulatory impulses from the central neural system to the concerned peripheral tissues/organs.

CENTRAL NEURAL SYSTEM

Human Brain

As stated earlier it comprises the brain and spinal cord.

Location and protective coverings of the brain. The brain is the anterior most part of the central neural system which is lodged in the cranial cavity (cranium) of the skull. The human brain weighs from 1220

to 1400 grams. The human neural system has about 100 billion neurons, majority of them occur in the brain.

Structure and functions of human brain

The human brain is divisible into three parts.

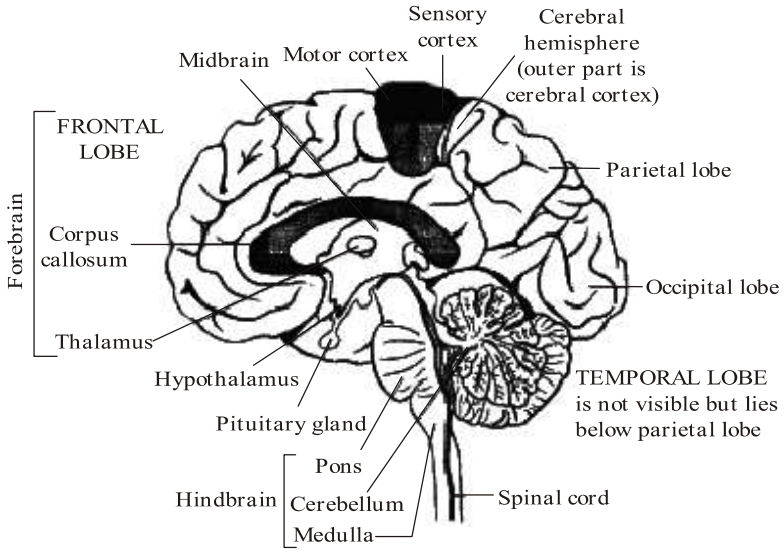


Fig.: Human brain

1. Forebrain or **prosencephalon** includes olfactory lobes, cerebrum and diencephalon.

2. Midbrain or **mesencephalon** comprises corpora quadrigemina and crura cerebri.

3. Hindbrain or **rhombencephalon** consists of cerebellum, pons varolii and medulla oblongata.

1. Forebrain

(i) Olfactory lobes : The anterior part of the brain is formed by a pair of short club-shaped structures, the olfactory lobes. Each lobe consists of two parts, an anterior **olfactory bulb** and a posterior **olfactory tract**. They are fully covered by the cerebral hemispheres and are, therefore, only visible in the ventral view of the brain. A pair of olfactory nerves arises from the olfactory lobes for relaying **sense of smell to temporal lobes.**

(ii) Cerebrum : It is the largest and complex part. It consists of the left and right hemispheres connected by a bundle of myelinated fibres, called corpus callosum. The outer layer of the cerebrum is called the cortex. The surface of the cortex comprises of many folds (usually elevated part) called **gyri** and depression called **sulci**. Gyri increases the surface area of cortex for accomodating far more nerve cells in it.

Cerebrum consists of two partsñ**cerebral cortex** and **cerebral medulla**.

Cerebral cortex is made up of grey matter and contains many layers of nerve cells. The nerve cells of different areas of the cerebral cortex differ in size, shape and functions, for example conical-shaped, pyramidal cells of the motor area of the cortex give rise to different fibres for controlling the skeletal muscle movements. The inner surface is called cerebral medulla which is made up of bundles of myelinated axons (the white matter).

How does right hand knows what the left hand is doing ?

The right and left cerebral hemisphere are connected by a thick band of nerve fibres called the **corpus callosum**. This corpus callosum is the important communicator between the two cerebral hemispheres. If this is cut, the two parts work independently and could not communicate with each other. Thus, corpus callosum tells the right hand what the left hand is doing.

(iii) Diencephalon : It lies between cerebrum and mesencephalon. Its cavity is called third ventricle or diocoel. It contains epithalamus, thalamus and hypothalamus.

- **Epithalamus** is non nervous part which is fused with piamater to form anterior choroid plexus. Just behind this the epithelium forms a short stalk called **pineal stalk** which has rounded body

Table : Important areas present in the four lobes of cerebral hemisphere

Lobes	Area	Function
Frontal lobes	(i) Motor area	Controls voluntary movements of the muscles.
	(ii) Premotor area	The highest centre for involuntary movements of muscles and autonomic nervous system
	(iii) Association area (coordination of sensation and movements)	Involved in memory, learning and reasoning. Basically it interprets and stores the input and initiates a response in light of similar past experience.
	(iv) Brocaís area	Motor speech area
Parietal lobe	(i) Somesthetic area	Perceptions of general sensation like pain, touch temperature and pressure etc.
	(ii) Gustatory area	Sense of taste
	(iii) Left part of parietal lobe	Speech
Temporal lobe	(i) Olfactory area	Sense of smell
	(ii) Auditory area	Hearing
	(iii) Wernickeís area	Understanding speech
Occipital lobe	(i) Visual area	Sensation of light.

called **pineal body.** Pineal body is endocrine in function and secretes a hormone named **melatonin**.

- **Thalamus** directs sensory impulses from the lower parts of the brain and spinal cord to appropriate parts of the cerebrum. It consists of two rounded masses of grey matter bulging into the diocoel. Limited sensory awareness of pain, temperature, touch and pressure is provided by the thalamus.
- **Hypothalamus** Just beneath the thalamus, hypothalamus forms the floor and the part of the lateral walls of the third ventricle.

  It is partially protected by the sella turcica of the sphenoid bone. Its lower middle portion consists of the stalk of pituitary gland and the posterior portion mainly consists of a pair of mammillary bodies, a part of limbic system (that function in the emotional aspect of behaviour) containing nuclei.

  It links nervous system to endocrine system (*via* hypothalamus - hypophyseal axis) and exercises a regulatory control on the functioning of endocrine glands by secreting neurohormones. It synthesises the posterior pituitary hormones and control their release into the blood.

  It contains higher centres of autonomic nervous system controlling hunger, thirst, sleep, fatigue, emotions, satisfaction, anger, pleasure and penance.

  It also controls carbohydrates and fat metabolism, body temperature, blood pressure and water balance.

2. Midbrain

It is very small constricted portion of brain which is covered by the cerebrum. It is represented by a pair of longitudinal bands of nervous tissue, the **cerebral peduncles** or **crura cerebri** on ventral side, dorsally a pair of small swellings called **corpora bigemina** on either side. The four lobes (optic lobe) are collectively called **corpora**

quadrigemina in which superior colliculi are related to optical activity, while the two smaller posterior colliculi are related to the auditory. These two are collectively known as **tectum**. Corpora peduncles relay impulses back and forth between the cerebrum, cerebellum, pons and medulla.

3. Hind brain

Hind brain consists of **cerebellum, medulla oblongata** and **pons varolii**.

(i) Cerebellum : It is the second largest part of brain and is located at the back of the skull. It consists of a pair of **cerebellar hemispheres** and a small median **vermis**. The surface of cerebellum is also highly grooved. The grey matter of cerebellum is called **cerebellar cortex**, while the white matter inside formed a branched tree like structure called **arbor vitae**. Cerebellum is concerned with maintainence of muscle tone and body posture and equilibrium. It coordinate voluntary muscular activities. Alcohol affects the cerebellum. Since, alcohol is a depressant, it interfere with the function of the cerebellum.

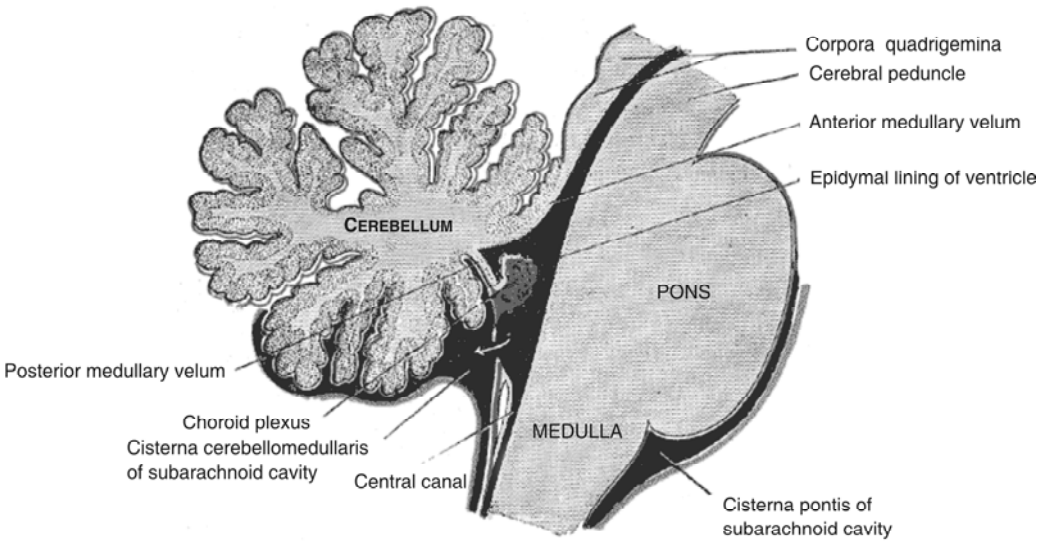


Fig. Parts of Hind brain.

(ii) Medulla oblongata : It is most vital part of the brain. It is a pyramid shaped bulb like structure that follows the cerebellum and is continued into the spinal cord below. Its roof is thin and non-nervous, and constitutes posterior choroid plexus. Below the plexus, the roof has three openings, the two lateral apertures called **foramina of Luschka**, and the median **foramen of Magendie**.

Several medullary centres (reflex centres) are present for controlling the functions of important organs e.g. cardiac centre (heart), respiratory centre, vasomotor centre (for regulating diameter of blood vessels) and reflex centres (for swallowing, vomiting, peristalsis, secretions and activity of alimentary canal, salivation, coughing etc.).

(iii)Pons varolli : It is situated in front of the cerebellum below the mid brain and above the medulla oblongata. It carries impulse from one hemisphere of the cerebellum to another. Functionally, the pons is concerned with maintenance of normal rhythm of respiration. It has got two respiratory centres - the pneumotaxic centre and apneustic

centre. It is also related with the control of facial expression, movement of the eye-ball, micturation etc.

The medulla oblongata, pons varolii, and mid brain are collectively called **brain stem** which maintains life support systems. It connects the brain to the spinal cord. The brain stem not only coordinates and integrates all incoming information, it also serves as the place of entry or exit for ten of the twelve cranial nerve.

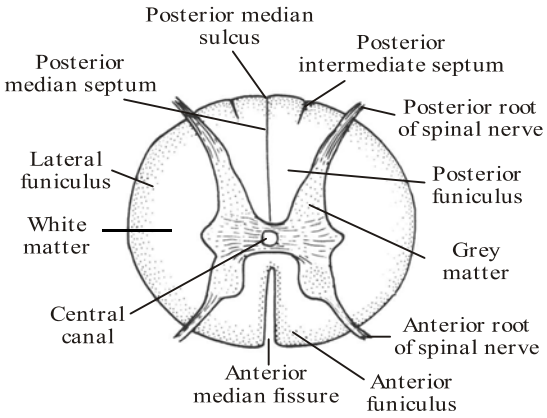


Fig. T.S. of human spinal cord

SPINAL CORD

• Spinal cord is 42-45 cm long cord-like nearly tubular or cylindrical structure of about 2.5 cm diameter. It is the lower part of CNS (extension of the medulla oblongata) which lies inside the neural canal of vertebral column. That is, the spinal cord originates in the brain at the inferior end of the medulla oblongata exiting the skull *via* the foramen magnum. It is wrapped in the three layers of membranes, called meninges.

• It begins in the atlas and tapers to a point, **conus medullaris**, in the first or second lumbar vertebra.

Conus medullaris is connected to coccygeal end of vertebral column by fibrous connective tissue derived from piamater and is called **filum terminale**.

- The spinal cord is slightly flattened anteroposteriorly (dorsoventrally) and has 2 **enlargements:** upper **cervical** and lower **lumbar**. These swellings have more nerve cell bodies than elsewhere and send nerves to the arms and legs respectively. The **cervical enlargement** extends from the fourth cervical to the first thoracic vertebrae; it is the region from which nerves supplying the arms arise *via* brachial plexus.
- Spinal nerves often run for some distance to come out of their specific places. As a result a number of parallel spinal nerves are observed in the hinder part of spinal cord. This grouping is called **cauda equina**.
- All along its length, the spinal cord has a deep **anterior median fissure**, a pair of shallow **posterolateral sulci**, and a shallow **posterior median sulcus**.
- A cross section through the spinal cord reveals that there is a central canal (= **neurocoel**), a narrow longitudinal cavity carrying CSF and surrounded by grey matter on the inside and this is surrounded by white matter. This is opposite to the brainís cerebral cortex.
- Central canal is lined by a simple ciliated columnar epithelium called **ependyma**.
- The central canal opens above into the fourth ventricle of the brain, but is closed below. It is filled with the cerebrospinal fluid.
- The inner butterfly-shaped area is the **grey matter** of the spinal cord. Grey matter is composed of nerve cell bodies, dendrites and synapses formed by interneurons which are meant for changing, integrating and routing signals. Grey matter is so named because it lacks myelin and therefore, appears grey in an unstained preparation. Surrounding the grey matter are bundles of myelinated nerve fibres, called fasciculi or white columns, which together form the **white matter** of the spinal cord. It is divided into six funiculi.

- In each segment of the spinal cord a spinal nerve arises from each side of the cord.
- Each spinal nerve connects with the cord through two nerve roots: **dorsal** and **ventral**. The **dorsal nerve root** consists of a bundle of sensory axons (carrying incoming signals) whose cell bodies are located in the **dorsal root ganglion**. These axons extend into the **posterior horn** of the grey matter, where they often form synapses with other neurons, some of which are called **interneurons.** Interneurons, short neurons confined to the grey matter of the cord, form synapses with other interneurons and with the motor neurons whose cell bodies are located in the **anterior horn** of the grey matter.

  Aggregations of motor axons (carrying outgoing signals) from these cell bodies form the **ventral nerve roots**.
- The **lateral horns** lies between the anterior and posterior horns. The hollow **central canal** contains cerebrospinal fluid.
- Along the white matter of the spinal cord there are two kinds of fasciculi, or bundles of axons, the **ascending tracts,** and the **descending tracts.**
- Damage to the spinal cord, called myelopathy, can result in paraplegia or quadriplegia, depending on the level within the spinal cord of the damage. **Paraplegia** is a condition where the lower half of a patientís body is paralyzed and cannot move. It is usually the result of spinal cord injury or a congenital condition such as spina bifida. **Quadriplegia** is caused by damage to the spinal cord at a high level (e.g. cervical spine) or the brain. The injury causes the victim to lose use of the arms and legs. The condition is also termed tetraplegia; both terms mean ìparalysis of four limbsî.
- Spinal cord **performs the following functions**:
  (i) The stimuli are passed from and to the brain through the spinal cord.
  (ii) It is the centre of spinal reflex action.
  (iii) Provides nervous connection to a large number of parts of body.

Nourishment of the brain

Although the brain is only 2% of the bodyís weight, it uses 20% of the oxygen supply and gets 20% of the blood flow. Blood vessels (arteries, capillaries, and veins) supply the brain with oxygen and nourishment, and take away wastes. If brain cells do not get oxygen for 4 to 5 minutes, they begin to die.

Importance of glucose for brain

The organ most affected by the lack of oxygen and glucose is brain. Glucose is the form of sugar that travels in the blood streams to fuel the mitochondrial furnaces responsible for brain power. Glucose is the only fuel normally used by brain cells. Because neurons cannot store glucose, they depend on the blood streams to deliver a constant supply of this precious fuel to maintain energy metabolism and avoid injury or death.

Mammalian characters in human brain

(i) Olfactory lobes are small and solid.
(ii) Cerebral hemispheres are quite large in size and divided into lobes.
(iii) Corpus callosum is also found.
(iv) Optic lobes are solid and further divided into corpora quadri-gemina.
(v) Pons varolii is present.
(vi) Cerebellum is very much folded and solid.

Limbic system

The limbic system (or the limbic areas) is a group of structures that includes the amygdala, the hippocampus, mammillary bodies and cingulate gyrus. These area are important for controlling the emotional response to a given situation. The hippocampus is also important for memory.

Ventricles of the brain

The ventricles consist of hollow, fluid filled spaces inside the brain. Different types of ventricle systems of the brain are described in the following table.

Table : Ventricle systems of the brain

Structure	Description	Significance
Ventricle, **lateral**	paired spaces within cerebral hemispheres	they drain cerebrospinal fluid to the third ventricle *via* the interventricular foramina (of Monro)
Ventricle, **third**	midline space within the diencephalon between the paired dorsal thalami and the hypothalamus	communicates rostrolaterally with paired lateral ventricles *via* interventricular foramina, communicates posteroinferiorly with fourth ventricle *via* cerebral aqueduct
Ventricle, **fourth**	midline space between cerebellum posteriorly and pons and upper medulla anteriorly	communicates anterosuperiorly with third ventricle *via* cerebral aqueduct; drains CSF *via* median aperature and lateral aperatures
Choroid plexus	vascular membranes that occur within the ventricles	production of cerebrospinal fluid
Interventricular foramen	communication between the lateral ventricle and the third ventricle; paired, one on each side	also known as **foramina of Monro**
Cerebral aqueduct	canal connecting third and fourth ventricles, passing through mid brain	also known as **aqueduct of Sylvius** (iter)
Median aperture	midline, irregular foramen draining fourth ventricle posteroinferiorly into cerebellomedullary cisternae	also known as **foramen of Magendie**
Lateral aperture	paired foramina draining fourth ventricle laterally into cerebello-medullary cisternae	also known as **foramina of Luschka**
Central canal of spinal cord	small opening in the center of the spinal cord	continuous with the central canal of the medulla and, through it, with the fourth ventricle of the brain

Meninges

These are connective tissue membranes which protect the central nervous/neural system and projections of its structure.

1. **Piamater** ñ It is the inner one and thinnest of all meninges. It is vascular and pigmented sheath that lies in contact with brain.
2. **Arachnoid** ñ It is thin, webby and slightly vascular middle sheath.

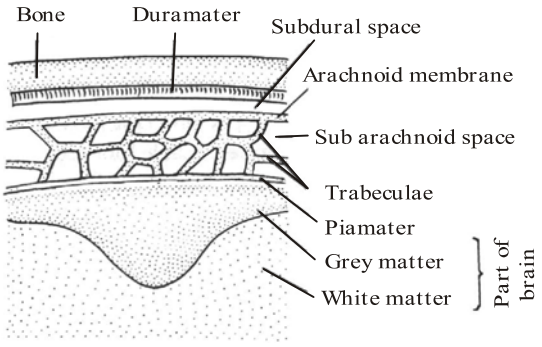


Fig : Diagram showing meninges, grey matter and white matter of brain.

3. **Duramater** ñ It is the outermost double layered thick and tough non-vascular meninx. It lines the cranial cavity.

Cerebrospinal fluid (CSF)

The cerebrospinal fluid is secreted by anterior choroid plexus and posterior choroid plexus and is found inside the ventricles of the brain, the central canal of the spinal cord and in the subarachnoid space

	around the brain and spinal cord. The cerebrospinal fluid performs the following functions : (i) Protection of the brain and spinal cord (ii) Buoyancy of the brain (iii) Excretion (iv) Endocrine medium for the brain
Blood brain barrier	The blood-brain barrier (BBB) explains why certain substances circulating in the blood are able to get into the brain and others do not. The blood-brain barrier (BBB) is the specialized system of capillary endothelial cells that protects the brain from harmful substances in the blood stream, while supplying the brain with the required nutrients for proper function. Unlike peripheral capillaries that allow relatively free exchange of substance across/between cells, the BBB strictly limits transport into the brain through both physical (tight junctions) and metabolic (enzymes) barriers. Thus the BBB is often the rate-limiting factor in determining permeation of therapeutic drugs into the brain.

Illustration 3 : Give an account of hindbrain of human brain.

Soln.: Hindbrain is the part of the brain comprising the cerebellum, pons and medulla oblongata. The pons and medulla contain the nuclei of many of the cranial nerves, which issue from their surfaces, and the reticular formation. The fluid-filled cavity in the mid-line is the fourth ventricle.

Illustration 4 : Mention where the following are located in the human brain, and give one function of each:

(i) Cerebellum (ii) Pons (iii) Medulla oblongata

Soln.: (i) Cerebellum : It lies at the base of posterior part of the brain.

It helps in the maintenance of balance.

(ii) Pons : The pons lies in the front of the cerebellum and above the medulla.

It coordinates the movements of two sides of body.

(iii) Medulla oblongata : It lies between the pons and the spinal cord.

It controls the activities of internal organs such as heart, lung and digestive tract, vasomotor centre.

Illustration 5 : Why glucose is needed by brain cells?

Soln.: The brain thrives on glucose, so enhanced mental performance requires a steady stream. The brain uses glucose both to power neurons and produce acetylcholine, a neurotransmitter important to memory.

Glucose is the only fuel normally used by brain cells. Glucose is the form of sugar that travels in the bloodstreams to fuel the mitochondrial furnaces responsible for brain power. Because neurons cannot store glucose, they depend on the blood stream to deliver a constant supply of this precious fuel to maintain energy metabolism and avoid injury or death.

Illustration 6 : What is brain death ? How it can be determined?

Soln.: Brain death is defined as the irreversible loss of all functions of the brain. It can be determined in several ways. First no electrical activity in the brain, this is determined by an EEG. Second - no blood flow to the brain, this is determined by blood flow studies. Third -absence of function of all parts of the brain - as determined by clinical assessment (no movement, no response to stimulation, no breathing, no brain reflexes).

There are several ways in which a person can become brain dead, these include ≠

(i) Anoxia ñ Caused by drowning, respiratory diseases, or drug overdose.

(ii) Ischemia ñ Blockage of an artery leading to the brain or in the brain, heart attack (stoppage of the heart for a period of time), bleeding in the brain.

(iii) Intracranial hematoma caused by a head injury (a blow to the head) or a ruptured aneurism.

(iv) A gunshot wound to the head causing destruction of brain tissue and swelling of the brain.

(v) Intracranial aneurysm, the balloning of a blood vessel supplying the brain-can cut off blood supply or rupture.

(vi) Brain tumors can destroy brain tissue and increase pressure within the brain.

When any of the above occurs, it causes swelling of the brain. Because the brain is enclosed in the skull, it does not have room to swell, thus pressure within the skull increases (this is ëintracranial

pressureí). This can stop blood flow to the brain, killing brain cells and causes herniation of the brain (pushing the brain outside to its normal space). When brain cells die, they do not grow back, thus any damage caused is permanent and irreversible.

Illustration 7 : Write the differences between cerebrum and cerebellum.

Soln.:

S.N.	Cerebrum	Cerebellum
i.	Largest part of the fore brain.	Largest part of the hind brain.
ii.	Present at the top of the brain stem.	Present at the posterior side of the brain stem.
iii.	Oval in shape.	Orbicular in shape.
iv.	Corpus callosum joins two cerebral hemispheres.	Vermis joins two cerebellar hemisphere.
v.	Site of intelligence.	Regulates body posture and equilibrium.

Illustration 8 : The vertebrate central nervous system is protected by three layers of connective tissue called ..... . The outer layer is the ....., the middle layer is the ..... membrane, and the inner layer is the ..... .

Soln.: Meninges; dura mater; arachnoid; pia mater.

Illustration 9 : While in the human cerebrum the outer layer, or ....., is ..... matter and the interior is ..... matter, in the spinal cord the relationship is reversed.

Soln.: Cortex; grey; white

Illustration 10 : The three main divisions of all vertebrate brains are: hindbrain, or .....; midbrain, or .....; and forebrain, or ..... . The brain stem includes all parts of the mid-brain and hindbrain except the ..... .

Soln.: Rhombencephalon; mesencephalon; prosencephalon; cerebellum.

PERIPHERAL NEURAL SYSTEM

It is constituted by the nerves which arises from the brain and spinal cord. They are respectively called **cranial** (= cerebral) and **spinal nerves**.

Cranial Nerves

There are twelve pairs of cranial nerves in man. Their origin, supply and nature are given in the following table :

Spinal nerves

Arising from the spinal cord, spinal nerves make their exits through the intervertebral foramen. In human body there are 31 pairs of spinal nerves which are formed by the union of dorsal and ventral roots shortly after they leave the spinal cord. All these nerves are mixed. *i.e.* sensory (afferent) as well as motor (efferent). They are classified into 5 groups.
(i) 8 pairs of cervical nerves
(ii) 12 pairs of thoracic nerves
(iii) 5 pairs of lumbar nerves
(iv) 5 pairs of sacral nerves, and
(v) one pair of coccygeal.

Table : Summary of the cranial nerves

	Name	Origin	Distribution	Functions
1.	**Olfactory** (sensory)	Olfactory lobe or bulb	Olfactory epithelium in nasal cavity	Smell
	Olfactory is the only nerve that projects directly to the fore brain.			
2.	**Optic** (sensory)	Optic lobe on midbrain	Retina of eye	Sight (Retina of eye)
3.	**Oculomotor** (motor)	Floor of mid brain	Eye, 4 muscles of eyeball	Movements of eye-ball, iris, lens, eyelid and constriction of pupil
4.	**Trochlear** (Pathetic) (motor)	Floor of mid brain	Eye, superior oblique muscles of eyeball	Rotation of eyeball

	*Trochlear is the thinnest and **smallest** cranial nerve.*			
5.	**Trigeminal** (mixed) divided into three : - **Opthalamic** - **Maxillary** - **Mandibular**	Ventral surface of pons varolii	- Lacrimal glands, conjunctiva of eye, skin of fore head, eyelids etc. - Cheeks, upper gums, upper teeth & lower eyelids - Teeth and gums of lower jaw, pinna of the ear, lower lip and tongue	Movement of tongue, jaw muscles for chewing.
	*Trigeminal (mandibular) is the **largest** cranial nerve as it has to end at the ventral surface of the brain.*			
6.	**Abducens** (motor)	Ventral side of medulla	External rectus muscle of eyeball	Rotation of eyeball
7.	**Facial** (mixed) (bearing geniculate ganglion)	Lateral side of pons varolii	Anterior 2/3 tongue (taste buds), muscle of face, neck and chewing (salivary gland)	Taste Facial expression, chewing, movement of neck.
8.	**Auditory** (sensory) (also called vestibuloco-chlear)	Lateral side of medulla oblongata	Organ of Corti in cochlea, semicircular canals	Hearing and equilibrium
9.	**Glossop-haryngeal** (mixed)	Lateral side of medulla oblongata	Posterior 1/3 tongue, mucous membrane and muscles of pharynx	Taste and touch, movements (swallowing) of pharynx
10.	**Vagus** (pneumo-gastric) (mixed)	Lateral side and floor of medulla oblongata	Muscles of pharynx, vocal cords, lungs, heart, oesophagus, stomach intestine	Vocal cords (sound production), lungs, respiratory reflexes, peristaltic movements, speech, swallowing, secretion of gastric glands, inhibition of heart beat.
	*Vagus is the **longest** cranial nerve. It has maximum branches and is also called **wandering nerve** as it reaches almost all over the body.*			
11.	**Spinal - Accessary nerves** (motor)	Floor of medulla (lateral side of medulla oblongata)	Muscles of palate, larynx, vocal cords, neck, shoulder	Motor muscles of pharynx, larynx, neck, shoulder movements.
12.	**Hypoglossal** (motor)	Floor of medulla (ventral side of medulla oblongata)	Muscles of tongue, neck	Motor movements of tongue.

Some important functions of spinal nerves

(i) All afferent (posterior) nerve root fibres consists of both somatic and autonomic (visceral) nerve fibre. Thus they carry sensory impulse from the different parts of the body to the central nervous system.

(ii) Some of the efferent (anterior) nerve root fibres carry motor impulse to somatic muscle fibres and thus regulate muscle tone, posture and equilibrium of the body.

(iii) Some of the efferent (anterior) nerve root fibres originate from thoracic and lumbar, and also from sacral segments of the spinal cord to serve as sympathetic and parasympathetic nerves respectively.

AUTONOMIC (OR VISCERAL) NEURAL SYSTEM

The autonomic neural system (ANS) is primarily associated with the ëautomaticí control of many organs, as both homeostatic and acute regulator in response to changing physiological, environmental and emotional stimuli.

The ANS can be subdivided into two principal anatomical components (1) the sympathetic and (2) the parasympathetic systems.
The ANS is both directly and indirectly involved in the aetiology of many disease processes including asthma, cardiovascular disease and diabetes. Nerve fibres of the autonomic neural system connects to the various internal organs such as heart, lungs, intestines and glands. Control by ANS is involuntary, although certain parts of the system such as anal and bladder sphincter muscles, can be put under voluntary control.

Sympathetic neural system

It is represented by a chain of 21 sympathetic ganglia on either side of the spinal cord. It receives preganglionic sympathetic fibres from the spinal cord which make their exit along with thoracic and lumbar nerves and constitute **thoraco-lumbar outflow**.

Parasympathetic neural system

It consists of preganglionic parasympathetic fibres, parasympathetic ganglia and postganglionic parasympathetic fibres.
Preganglionic parasympathetic fibres make their exit along with the 3rd, 7th, 9th and 10th cranial nerves, and 2nd, 3rd, 4th sacral nerves. They together form **cranio- sacral outflow**.

Table : Differences between sympathetic and parasympathetic neural systems

	Sympathetic Neural System	Parasympathetic Neural System
1.	Have their final synapse in a remote ganglion.	Have their final synapse near effector organ
2.	Heart beats and stroke volume increase when sympathetic nervous system is stimulated.	Decrease in heart beats and stroke volume
3.	Coronary blood vessels dilated.	Constricted
4.	Pupil dilated	Constricted
5.	Gut motility reduced	Increased
6.	Digestive juice secretion decreased	Increased
7.	Secrete adrenaline (epinephrine) or nor-adrenaline (norepinephrine) as neurotransmitter	Secrete acetylcholine at nerve endings as neurotransmitter.
8.	Dominant during danger, stress activity and controls reaction to stress.	Dominant during rest and controls routine body activities.
9.	Have excitatory homoestatic effect	Have inhibitory homoestatic effect

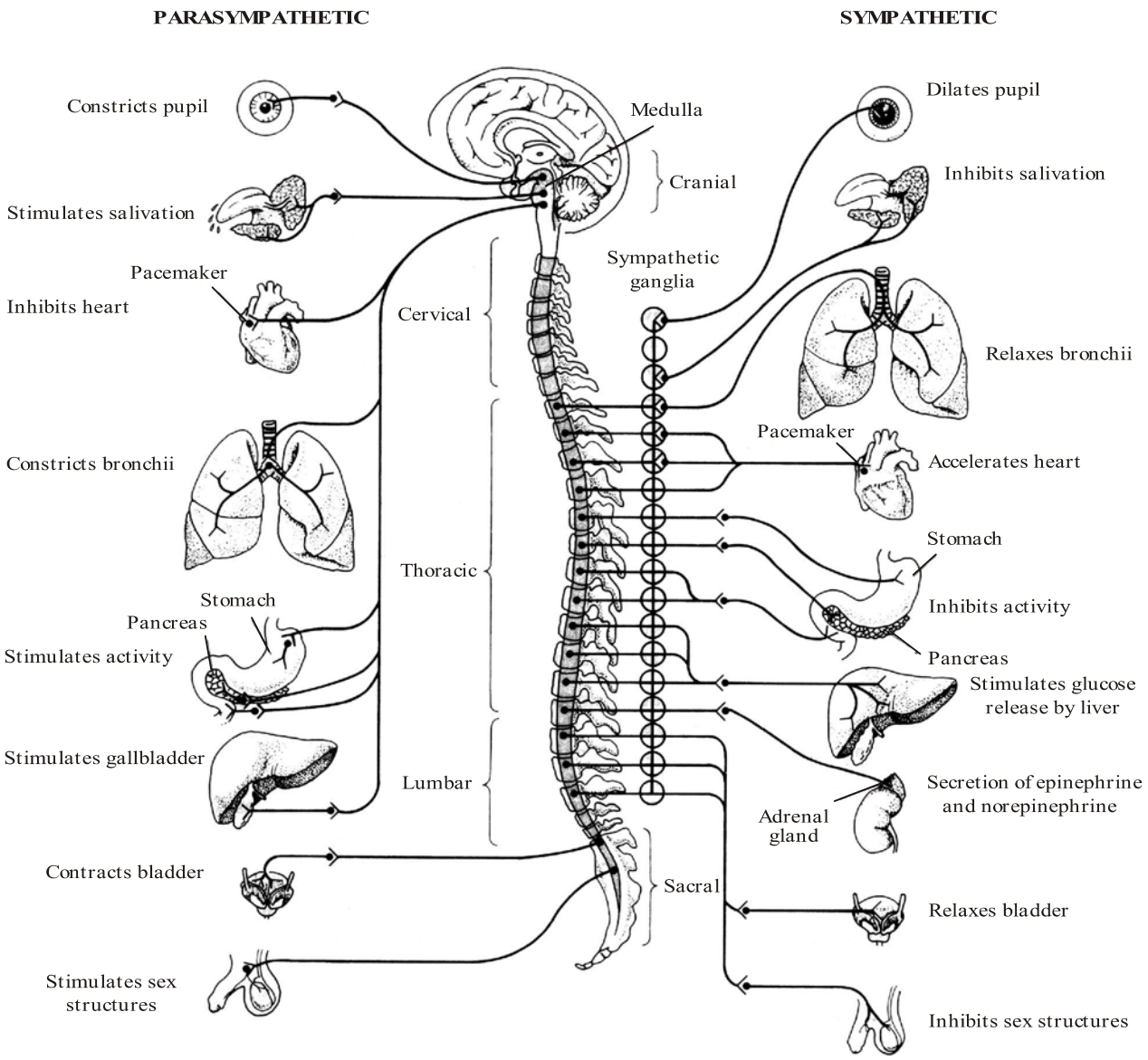


Fig : The parasympathetic and sympathetic divisions of the autonomic neural system. The parasympathetic neurons that exit the central neural system is cranial and sacral nerves, while the sympathetic neurons exit in thoracic and lumbar nerves. These nerves exit in pairs, one member of each pair on either side of the central nervous system, but only one nerve of each pair is shown. The sympathetic preganglionic neuron synapse with a postganglionic neuron in the sympathetic ganglia near and on both sides of the spinal cord, while a parasympathetic neuron synapses near the innervated organ.

Illustration 11 : The five groups of human spinal nerves, from head anterior end to downward along the spine are :
..... pairs of ..... nerves; ..... pairs of ..... nerves; ..... pairs of ..... nerves; ..... pairs of ..... nerves; and ..... pair of ..... nerves.
Soln.: 8; cervical; 12; thoracic; 5; lumbar; 5; sacral; 1; coccygeal.

Illustration 12 : In vertebrate evolution, a dorsal, tubular ..... became expanded and was modified into a spinal cord and brain. The central canal of the spinal cord extends into the brain, where it expands into the ..... that are filled with ..... .
Soln.: Nerve cord; ventricles; cerebrospinal fluid.

Illustration 13 : In the vertebrate autonomic nervous system, most ganglia of the ..... system are in a chain of ganglia near the spinal cord, while ganglia in the ..... system are close to the innervated organs.
Soln.: Sympathetic; parasympathetic

TRANSMISSION OF NERVE IMPULSE

Nerve impulse is a wave of bioelectric/electrochemical disturbance that passes along a neuron during conduction of an excitation. Nature of nerve impulse or conduction of nerve impulse is an electro-chemical process. It has been found that impulse conduction depends upon permeability of axon membrane (axolemma) and osmotic equilibrium and electrical equivalence between the axoplasm and extracellular fluid (ECF) present outside the axon.

Resting membrane potential

A neural membrane, like the plasma membrane of any cell, is selectively permeable; certain atoms and molecules are kept inside the cell, others enter and leave freely, and still others are allowed to move in only one direction. Because many of these particles are ions, this selective permeability produces a forced separation of charges between the inside and outside of the membrane. A membrane potential is a measure (in millivolts) of the charge inside the membrane relative to the charge outside. **The resting membrane potential of the axon** of a neuron is this potential difference between inside and outside when the axon is ìresting,î *i.e*., not actively conducting impulses. In this state, if one of the two electrodes connected to a voltmeter is inserted in the axonís cytoplasm while the other is placed nearby on the external surface of the membrane, the voltmeter will typically show a potential of ñ 70 millivolts (mV). This means that the interior of the axon is 70mV more negative than the exterior.

Three types of ions play significant roles in determining resting potentials; **sodium (Na^+), potassium (K^+), and large negatively charged organic molecules (amino acid and proteins).** The inside of the resting axon contains approximately 30 times more potassium ions and about 10 times fewer sodium ions than the external fluids. All of the large negatively charged organic molecules are located inside the axon. The different concentrations of these three types of ions are maintained by an interplay of several factors; diffusion; electrical attractions and repulsions; active transport across the cell membrane; and selective permeability of the axon membrane to these three ions.

Channels in the axon membrane permit some movement of these ions through the membrane. The sodium ions move through a specific channel with a gate that is sensitive to the electrical state of the membrane. At the resting membrane potential, these voltage-sensitive gates are essentially closed, although some sodium ions leak inward down their concentration gradients. The potassium ions move through two types of channelsñone that is permanently open and another, comparable to the sodium cannel, that has voltage-sensitive gate. In the resting stage, the voltage-sensitive gate is closed, but the potassium ions can still move freely out of the cell along the permanently open channels. The negatively charged organic molecules, the third type of ion, are too large to fit through the membrane channels and always remain inside the axon.

The potassium ions tends to diffuse out of the axon slowly and continuously, but their movement is opposed by both attraction to the negatively charged organic molecules and their repulsion by the positively charged sodium ions outside the membrane. Nevertheless, potassium diffusion outward is more rapid than sodium diffusion inward. If there were no other mechanism operating during the resting phase, the interior of the axon would not be at a constant ñ 70 mV but would instead become increasingly negative. However, an active-transport mechanism called the sodium-potassium pump is continuously moving sodium out of the cell and returning potassium to the interior. This pump, a protein molecule within the

membrane, operates from energy stored in ATP molecules; it moves three sodium ions out for every two potassium ions that moves to the interior.

Action potential

An action potential is a very rapid change in the axon membrane potential from the negative resting potential (ñ 70 mV) to a positive peak (typically, + 40 mV) and then back to the resting potential. This change, if it occurs at all, always occurs in exactly the same pattern, which is why it is called an all-or-none event.

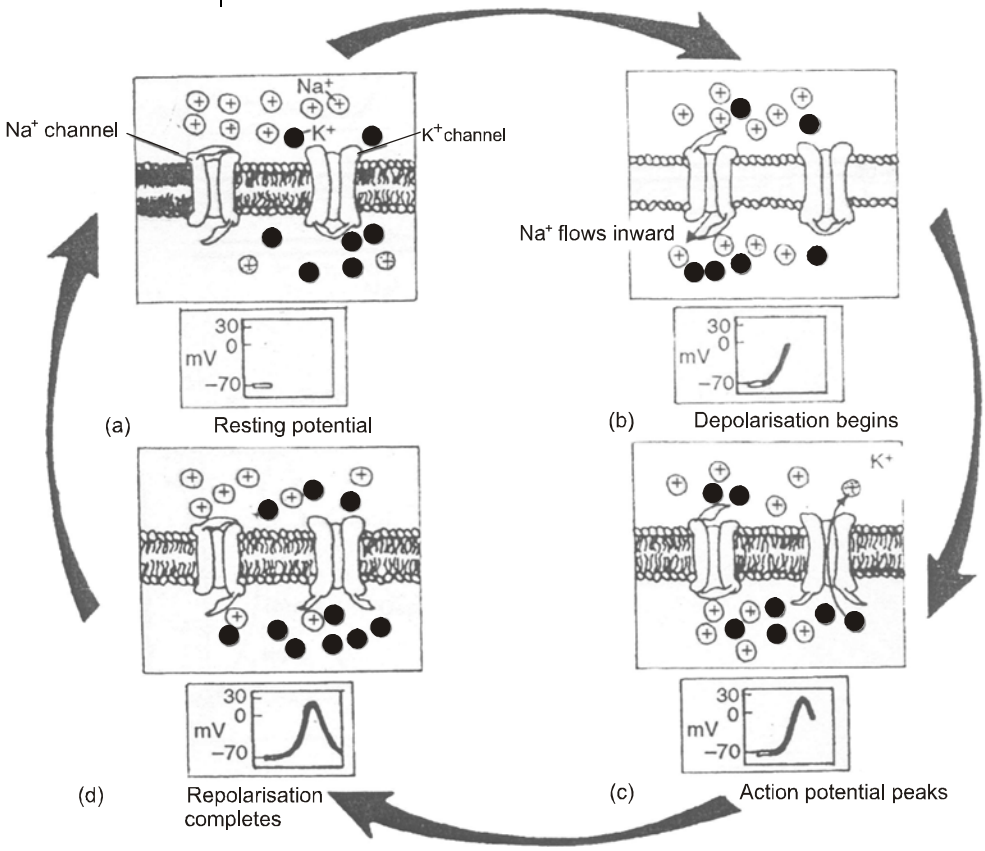


Fig.: Stages in axon membrane potential during resting, depolarisation, action potential and repolarisation.

The action potential is always preceeded by a gradual decrease in the axonís negativity towards a threshold of excitation (or **threshold potential**) of roughly ñ 60 mV. This slow decrease is due to summation of excitatory inputs from other neurons. At threshold, some voltage-sensitive sodium gates open, allowing an increase in the inward diffusion of sodium ions. This ì**depolarization**î of the membrane triggers more sodium gates to open, until the membrane potential reaches roughly + 40 mV. At this point, the sodium gates close (inactivate) and the voltage-sensitive potassium gates open. So much potassium now flows out that the cell is briefly ìhyperpolarizedî (the membrane potential is more negative than ñ 70 mV). During this phase, the membrane is said to be in a **refractory period** because it cannot respond to another stimulus. The voltage-sensitive potassium gates then close, and the sodium-potassium pump restores the resting potential.

Synapse

The junction between two neurons is known as a **synapse**. It comprises of a **synaptic cleft** between the end of one nerve fibre and the beginning of the next. The presynaptic neuron forms terminal swellings called **synaptic knobs**, on the post synaptic neuron. The synaptic knob contains numerous **synaptic vesicles**, which contain the neurotransmitter acetylcholine. This is formed in the cell body and then transported down the axon to the presynaptic terminals. The formation of acetylcholine is helped by a special enzyme, **choline acetylase**.

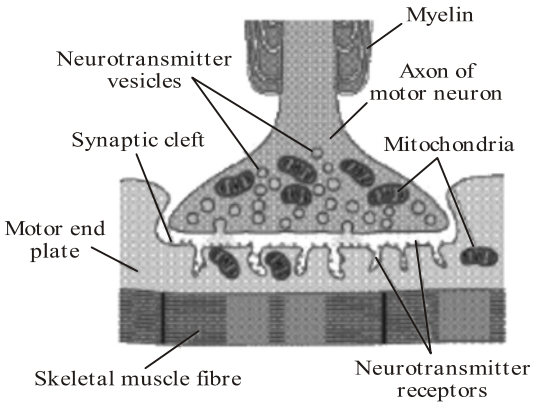


Fig. Structure of synapse

The arrival of an impulse at the synaptic knob causes acetylcholine to be discharged into the synaptic cleft. Accumulation of acetylcholine in the synaptic cleft reduces the polarization of dendrites, or cell body of the next neuron. If depolarization is sufficient the threshold of the next neurons will be reached and a nerve impulse generated in it. Hence acetylcholine serves as a chemical transmitter of the nerve impulse.

With each passing nerve impulse, the concentration of acetylcholine becomes highly concentrated in the synaptic cleft and diffuses in all directions. An enzyme, acetylcholinesterase is present here which break down the acetylcholine, preventing continued depolarization of the next fibre or the inordinate (exceeding normal limits) spreading of the nerve impulse to other nerve fibres.

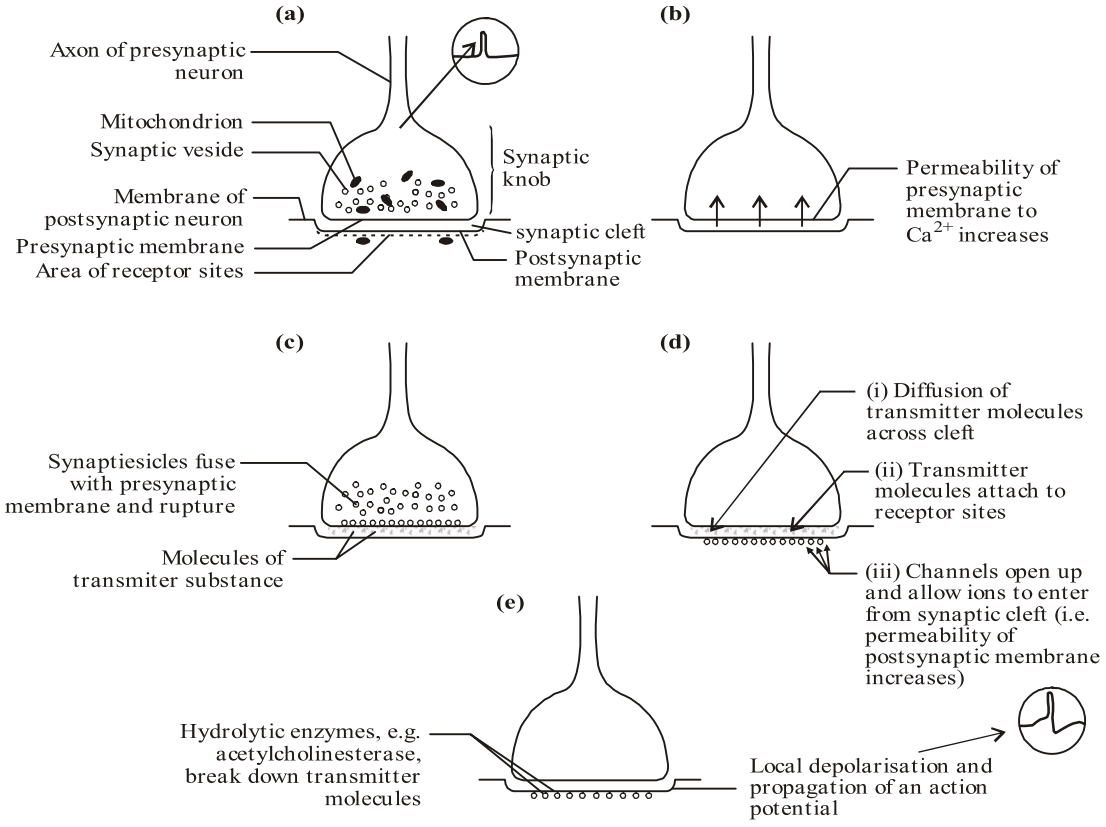


Fig. Summary of diagrams showing the mechanisms involved in chemical transmission at a synapse, (a) to (e) time sequence.

In a synapse the propagation is strictly one way proceeding from axon of one neuron to the soma, or dendron of another neuron. Since dendrites do not release any chemical neurotransmitter so, any nerve impulse passing along a single neuron from axon to dendrites would fade out at the synapse. Hence the synapse acts as a valve permitting only one way traffic of nerve impulse.

Saltatory conduction of nerve impulse

The properties of impulse conduction described so far apply to unmyelinated neurons. However, the myelin sheath of many axons in the body insulates those axons except at the nodes of Ranvier. When an impulse travels along a myelinated neuron, depolarization occurs only at the nodes. It leaps over the myelin sheath from one node to the next. This process, the **saltatory conduction**, gets its name from the root word saltere, which means to leap. Saltatory conduction accounts for the greater speed of an impulse travelling along a myelinated neuron than along a nonmyelinated one. Less energy is required for saltatory conduction than for conduction along a nonmyelinated neuron because smaller amounts of ATP are used to operate the sodium pump. It is upto 50 times faster than the nonmyelinated nerve fibre.

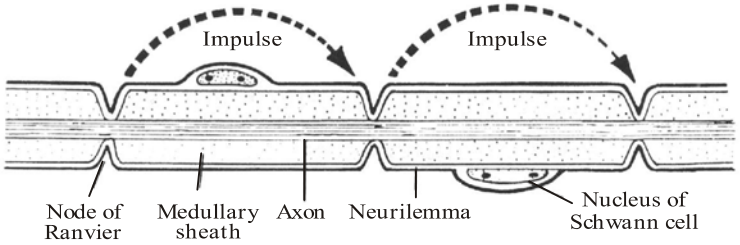


Fig. Saltatory conduction of nerve impulse in a medullated nerve fibre.

Neuromuscular Junction

The neuromuscular junction is a specialised form of synapse which is found between a motor neuron and skeletal muscle fibre. Each muscle fibre has a specialised region called motor end plate which contains vesicles and mitochondria. When the motor impulse from the nerve is received on the motor end plates, a local depolarization occurs thereby resulting in the excitation of the muscle fibre. They always use the neubyrotransmitter acetylcholine and are always excitatory.

Summation

As stated above, a subthreshold stimulus is unable to generate a nerve impulse. A series of subthreshold stimuli applied to a nerve fibre may succeed in initiating an impulse. This additive effect of several subthreshold stimuli is called summation.

All-or-none Principle

It states that a neuron either conducts or does not conduct an impulse. If it conducts an impulse it is always of maximum size. Therefore, according to the all-or-none principle, a neuron can be thought of as being either ìonî or ìoffî.

Illustration 14 : Describe transmission of nerve impulse across a synapse.

Soln.: Transmission of nerve impulse across a synapse : Synapse is the close proximity of terminal branch of the axon of one neuron with dendrites of the next neuron in a chain without actual contact. It results in depolarization of dendrite membrane initiating a new impulse (action potential) that passes along the next neuron. To check continued stimulation of dendrite membrane an enzyme acetylcholinesterase inactivates the acetylcholine.

Some sympathetic fibres secrete norepinephrine as neurotransmitter. It is inactivated by enzyme monoamino oxidase to prevent continued stimulation of muscle.

It involves two processes; neurosecretion by axon endings and chemoreception by dendrites and get into state of excitation.

Illustration 15 : When an action potential reaches a vertebrate chemical synapse, it opens ..... gates in the plasma membrane of the synaptic knob, permitting this ion to diffuse into the knob. This in turn causes ..... containing neurotransmitters to fuse with the ..... and release the neurotransmitters into the ..... . The neurotransmitters then diffuse over to the ....., where they interact with ..... proteins; this interaction produces either an ..... or an .....

Soln.: Ca^{2+}; synaptic vesicles; presynaptic membrane; synaptic cleft; postsynaptic membrane; receptor; EPSP (excitatory postsynaptic potential); IPSP (inhibitory postsynaptic potential)

Illustration 16 : In the resting state, the axon membrane is ....., with more ..... charged ions outside than inside. This unequal distribution of ions is due to: (1) the selective permeability of the membrane, which forms an almost impenetrable barrier to ....., and (2) the action of the ....., which pumps ..... Na^+ out of the neuron for every ..... K^+ brought in.

Soln.: Polarized; positively; Na^+; sodium-potassium pump; three; two.

Illustration 17 : An action potential is initiated each time the membrane potential is raised to ..... potential. Because action potentials never occur below this potential and upon occurring are always of the same ....., action potentials are called ..... events.

Soln.: Threshold; size; all-or-none.

Illustration 18 : The positive phase of an action potential is initiated when a stimulus ..... the membrane to ..... potential and the voltage-sensitive ..... gates open. The membrane potential returns to negative, *i.e.*, is ....., when the ..... gates ..... and the voltage-sensitive .....gates open.

Soln.: Depolarizes; threshold; Na^+; repolarized; Na^+; inactivate; K^+.

NEUROTRANSMITTERS

These are low molecular mass substances released in minute amounts at interneural, neuromuscular and neuroglandular synapses. It may be **excitatory** (depolarizing postsynaptic membrane) or **inhibitory** (hyperpolarizing postsynaptic membrane). **Neuromodulators** are additional neurotransmitters, that are released and modify the transmission of an impulse at a synapse, either prolonging or inhibiting it and are responsible for **mood** and **emotion** in the brain. Addictive drugs, such as cocaine, often act as neuromodulators. The brain adjusts its synapses to accommodate such drugs, and the result is physiological dependence, or addiction.

Examples of neurotransmitters are acetylcholine (excitatory), norepinephrine (excitatory), GABA (Gamma amino butyric acid) and glycine (inhibitory).

Other neurotransmitters areñserotonin, dopamine, histamine, glutamate, 5 hydroxy tryptamine etc.

REFLEX ACTION

Reflex action (Marshal Hall, 1833) is an immediate involuntary action of any organ or part of the body in response to a particular stimulus.

The nervous pathway taken by nerve impulses in a reflex action is called **reflex arc**. The components that mediate a reflex, usually includes a receptor, afferent pathway, integrating centre, efferent pathway, and effector. Hence the entire impulse circuit of a reflex response is -

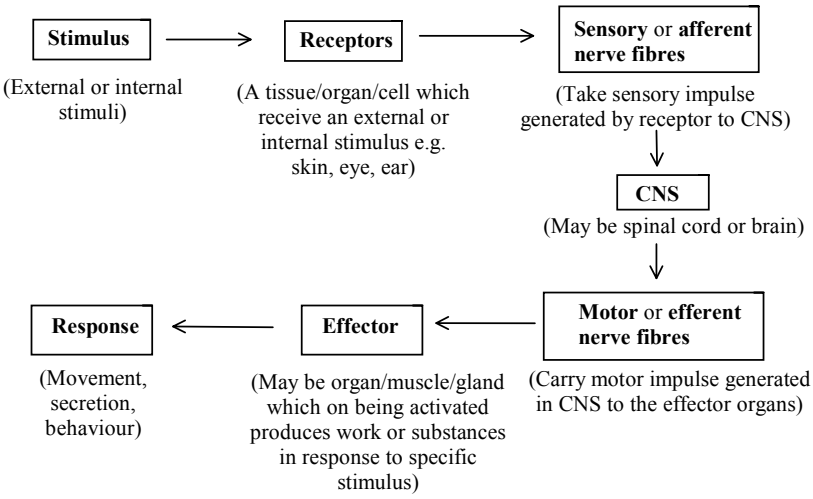


Fig.: Reflex arc

Examples of reflex action

1. Blinking of an eyelid when a moving object approaches the face.
2. Sneezing is a reflex response to a stimulus in nose.
3. Salivation occurs at the sight or smell of food.
4. An immediate removal of hand when it is touched with a hot thing.

Reflex actions are of two types - **conditioned** and **unconditioned**.

Simple or unconditioned reflex

A simple reflex is inborn, unlearned response to a stimulus or any change in the environment. Most reflex actions are protective in nature. The anatomical basis of the simple reflex is the reflex arc described earlier.

In a simple reflex, the nerve impulse is initiated when the sensory nerve endings in the receptor organ are stimulated. The impulse travels along the afferent or sensory neuron until it reaches the terminal branches of the axon forming a synapse with the dendrites of the connector neuron. In the spinal cord, the impulse proceeds along the length of this connector neuron to its axon endings which form another synapse with the dendrites of the motor neuron. At this synapse an impulse is initiated in the efferent or motor neuron. The terminal axon branches of the motor neuron end in the effector organ. The reflex or response made by the effector organ as a result of the arriving nerve impulse is either muscular contraction or glandular secretion, depending on the effector involved.

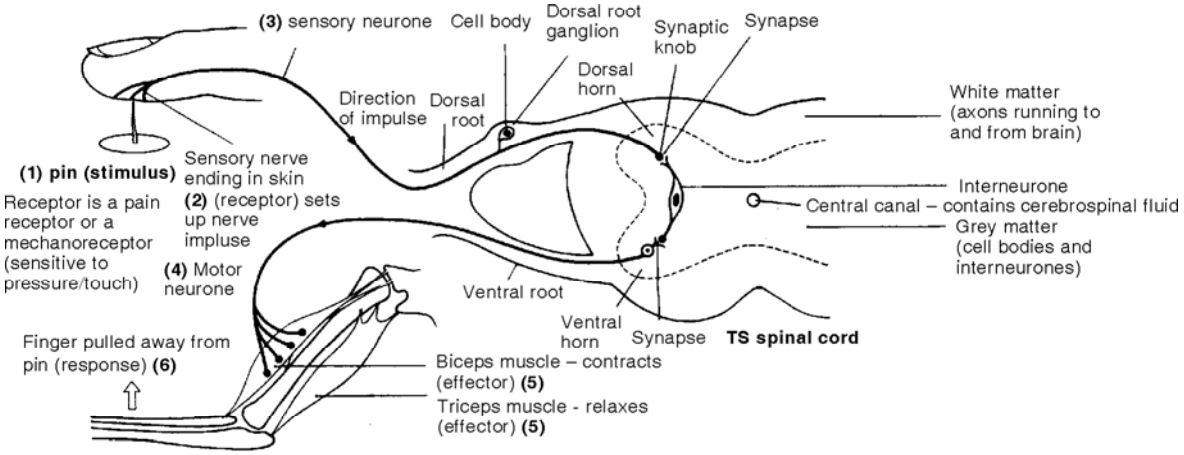


Fig.: A simplified example of reflex action and a reflex arc. The numbers in brackets refer to the basic structures in any reflex arc. Note the sequence : 1, Stimulus, 2. Receptor, 3, Sensory neuron, 4. Motor neuron, 5. Effector, 6. Response

Inhibition of Reflex Action

In the infant the act of micturition and defaecation are carried out by reflex action and there is no voluntary control over these processes. As the child grows, the sensory nerve tracts of the spinal cord become fully developed, the impulses from the bladder and rectum reach the brain and can be controlled. Hence now the **act of micturition and defaecation become a conscious voluntary act in the adult**.

Conditioned reflex

Conditioned reflexes are not inborn but are acquired during the life time of an individual. It was first demonstrated by **I.P. Pavlov**. He presented a hungry dog with food, which elicited a reflex of salivation by the stimulation of the taste buds in the mouth. He then rang a bell each time the dog was given the food to associate the unconditioned response (salivation) with an additional stimulus (bell). After a few trials, he was able to demonstrate that the dog salivated at the sound of the bell without the sight or smell of food. This is thus known as conditioned reflexes.

Conditioned reflexes are very important for studying the process of learning and behaviour in animals.

DISEASES OR DISORDERS OF THE BRAIN

Some of the most common diseases or disorders of the brain are as follows:

- **Brain fever**

It is a disease caused by the Japanese encephalitis virus (JEV).

- **Paralysis**

It is a disease of the nervous system characterized by the loss of ability of the body or its parts to respond to stimuli.

It is often caused due to any of the following factors:

(a) Inadequate supply of blood to the brain.
(b) Bleeding in the brain.
(c) Habitual drinking of alcoholic drinks.
(d) Habitual use of tobacco.

- **Cerebral haemorrhage**

It is a disorder of the brain characterized by discharge of blood i.e., internal bleeding in the brain tissue due to rupture of blood vessels.

- **Cerebral thrombosis**

The formation of an internal blood clot within any one of the major arteries supplying blood to the brain is called **cerebral thrombosis.**

- **Epilepsy**

A chronic functional disease of the nervous system, manifested by recurring attacks of sudden insensibility or impairment of consciousness commonly accompanied by convulsive seizures.

- **Meningitis**

Meningitis refers to infection or inflammation of meninges resulting in severe headache, vomiting and pain, and stiffness of the neck. Cause of meningitis is the infection of bacteria *viz*. *Streptococcus pneumoniae, Neisseria meningitidis* and *Haemophilus influenzae*.

- **Stroke**

A condition due to the lack of oxygen to the brain which may lead to reversible or irreversible damage. The damage to a group of nerve cells in the brain is often due to interrupted blood flow, caused by blood clots or blood vessel bursting. Depending on the area of the brain that is damaged, a stroke can cause coma, paralysis, speech problems and dementia.

- **Cerebral palsy**

A developmental defect that happens to the brain during birth. It causes spastic paralysis, in-coordination, speech impairment. People having cerebral palsy can have a normal IQ or higher.

- **Multiple sclerosis**

It affects the CNS or the central nervous system. It hardens the connective tissues. Axons in the nerve cells lose their myelin sheaths, so nerve cells cannot conduct the impulse. The results of multiple sclerosis are general weakness, bad muscular coordination, and blurring vision. It may result in death.

- **Headaches**

The most common illness that happens to the brain. It is not due to brain hurting as brain cells are insensitive to pain. Swollen blood vessels, spasm of scalp muscles, or stretching or irritation of meninges may be the cause of headache.

- **Parkinsonís disease**

It is caused by the destruction of the neurons of basal ganglia that produce the neurotransmitter dopamine. Thus dopamine is reduced in the brain. Symptoms include tremors and shakes in the limbs, a slowing of voluntary movements and feeling of depression. It is treated by dopamine. The drug Exelon, prescribed to restore memory in Alzheimerís patients, may also offer some help for people who develop dementia from Parkinsonís disease. One of the examples of this disease is the great boxer Mohammed Ali.

- **Wilsonís disease**

Along with all symptoms of Parkinsonís disease, there is degeneration of liver tissues also. The degeneration changes in liver and brain are due to disturbed copper metabolism. Wilsonís disease is due to damage of the lenticular nucleus (a part of basal ganglia).

- **Alzheimerís disease (AD)**

It is caused due to destruction of vast number of neurons in the hippocampus (a part of brain). Evidence suggests that it is due to combination of genetic factors, environmental or lifestyle factors and the ageing process. There is loss of neurotransmitter acetylcholine. Individuals with AD initially have trouble remembering recent events. In the later stages, the patients may fail to recognise their spouse or children. The disease is due to dementia (progressive loss of memory). Drugs that inhibits acetylcholinesterase (AChE), the enzyme that inactivates acetylcholine (ACh), improves alertness. Former USA President Ronald Reagan was suffering from Alzeheimerís disease.

SENSE ORGANS

Sense organ is any organ that an animal uses to gain information about its surroundings. All sense organs have specialized receptors (such as light receptors in the eye) and some means of translating their response into a nerve impulse that travels to the brain. The **main human sense organs** are the **eye**, which detects light and colour (different wavelengths of light); the **ear**, which detects sound (vibrations of the air) and gravity;

the **nose,** which detects some of the chemical molecules in the air and the **tongue**, which detects some of the chemicals in food, giving a sense of taste. There are also many small sense organs in the skin, including pain, temperature, and pressure sensors, contributing to our sense of touch. Receptor of special sense tend to be more complex than those of general senses in term of their overall anatomic structure.

The principle function of the special sensory receptors is to detect environmental stimuli and transduce their energy into electrical impulses. These are then conveyed along sensory neurons to the central nervous system, where they are integrated and processed, and a response is produced.

Classification of receptors according to the type of stimuli they receive

1. **Mechanoreceptors** - respond to mechanical forces such as touch, pressure, vibration and itch by generating nerve impulses. Includes the receptors such as free dendric nerve endings of sensory neurons, Merkelís discs, hair follicle endings, Pacinian corpuscles, muscle spindles, and Golgi tendon organs.
2. **Thermoreceptors** - respond to temperature changes. Include free nerve endings and Krauseís end bulbs.
3. **Chemoreceptors** - respond to chemical molecules. Include olfactory cells in the nasal mucosa.
4. **Nociceptors** - respond to painful stimuli which may be damaging to tissues. Include free nerve endings.
5. **Photoreceptors** - respond to light energy. Include cones and rods in the retina.

EYE (ORGAN OF SIGHT)

The organ of vision consists of a pair of eyes located in the eye orbits of the skull. The exposed part of the eye is protected by a upper and a lower eyelid which are provided with eye lashes. Each eye is represented in the form of a spherical eye ball which is moved in the eye orbit with the help of six eye muscles (extraocular muscles) namely **superior oblique, inferior oblique, superior rectus, inferior rectus, external rectus and internal rectus**. These six muscles are governed by the cranial nerves III (oculomotor), IV (trochlear) and VI (abducens).

Table : Action of external ocular muscles

Muscle	Movement produced	Cranial nerve
Superior rectus	Up	Oculomotor (III)
Inferior rectus	Down	Oculomotor (III)
Medial rectus	Toward nose	Oculomotor (III)
Lateral rectus	Away from nose	Abducens (VI)
Superior oblique	Down and in	Trochlear (IV)
Inferior oblique	Up and out	Oculomotor (III)

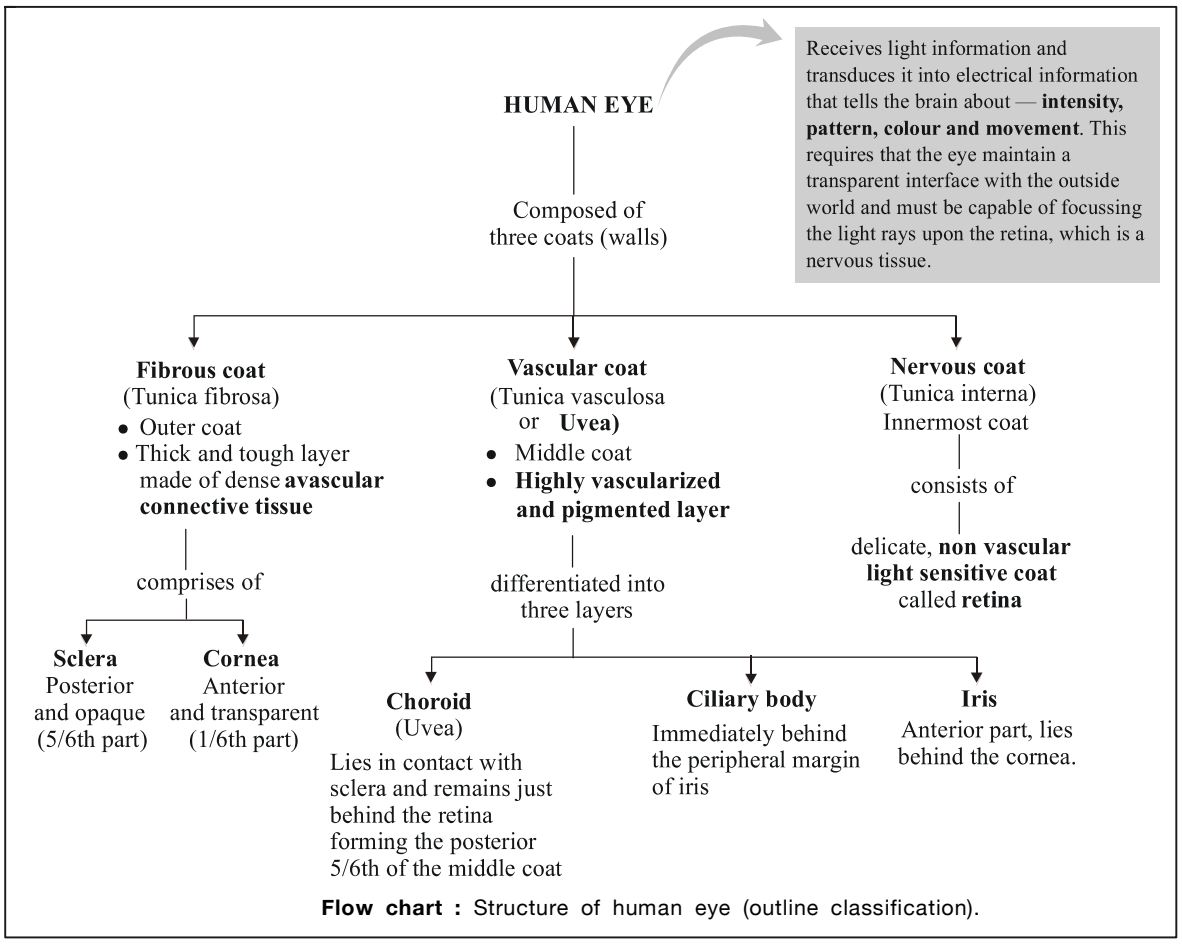
Structure of the eye

Human eyes are spherical structures present in the bony sockets of the skull. Each eye is about 2.5 cm in diameter and consists of tissues present in three concentric layers

(i) Outer most layer consists of **sclera** and **cornea**.

(ii) Middle vascular layer consists of **choroid, ciliary body** and **iris** (**also called uvea**).

(iii) Inner most layer consists of **retina.**



Flow chart : Structure of human eye (outline classification).

Fibrous Coat

1. Sclera

- It is an opaque, fibro-elastic collagen capsule that forms the outermost covering. It is opaque bluish white in appearance except at the front where it forms the transparent cornea. It maintains the shape of the eyeball and protects all the inner layers of the eye.

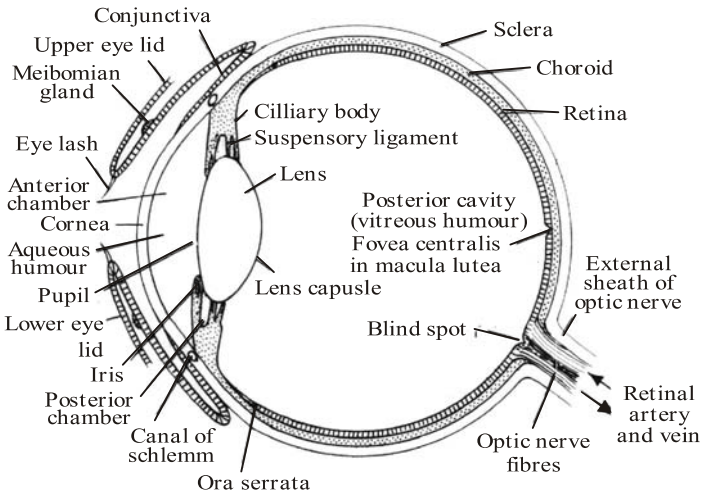


Fig. V. S. Human eye

2. Cornea

- It is a thin transparent, front part of sclera. It forms a slight bulge (called conjunctiva) at the front and covers about 1/6th part of the sclera. It lacks blood vessels but is rich in nerve endings, chiefly of pain type. Stimulation of nerve endings reflexly causes blinking and tear flow.

The cornea is kept moist by tears and mucous from conjunctival glands. As cornea is

avascular so its living materials like epithelium, corneal corpuscles and endothelium get nutrition from aqueous humour and from super marginal plexus of blood vessles. Therefore corneal transplant is easiest over 90% success.

- It allows the light to pass into the eye. Due to its curvature, it helps in focusing a real inverted image of the object on retina. The cornea also serves as a filter, screening out some of the most damaging ultraviolet (UV) rays in sunlight. Without this protection, the lens and the retina would be highly susceptible to injury from UV radiation.

Conjunctiva

- It is a thin transparent layer present over the cornea and is continuous with the skin over the eye. It is composed of a stratified epithelium and is continuous with the epidermis that lines the eyelids. In sore or ìpinkî eyes, the conjunctiva gets inflammed, causing **conjunctivitis**. It protects the cornea and also secretes oils and mucous that moisten and lubricate the eye.

Vascular Coat

1. Choroid

- It is a **pigmented layer** present beneath the sclera. It is composed of connective tissue and is of dark brown colour. It is homologous to the pia-arachnoid of the brain. It contains numerous blood vessels and nourishes the retina. The pigmentation prevents reflection within the eye.
- It **provides nutrition to retina**.

2. Ciliary body

- It is attached to the choroid and is present at the junction of sclera and the cornea. This part of the eye is less vascular, thick and less pigmented. Its inner surface is, folded to form **ciliary processes**. The latter **secretes aqueous humour**. It contains ciliary muscles and is also supplied with blood vessels.

Ciliary muscles

- These are complex set of smooth muscles present in a circular form in the ciliary body. These are controlled by autonomous nervous system. The ciliary muscles are of two types: **circular** and **meridional**. The inner ends of the meridional muscles are attached to the choroid and their outer ends are inserted in the outer coat at the junction of the sclera and the cornea.
- They alter the shape of lens. The contraction of ciliary muscles results in spherical shape of the lens and the relaxation in the flattened shape (*i.e*. **accomodation**).

Suspensory ligament

- They are thread like ligaments that attach the ciliary body to the lens. They hold the lens in position, stretching and relaxation of this changes the focal length of the lens for accommodation, which increases the convexity of lens and the level of refraction of light passing through it.

3. Iris

- It is the most anterior part of uvea. It forms a pigmented circle of muscular diaphragm attached to the ciliary body in front of the lens.
- Its pigment **gives eyes its colour** (depending upon the amount of pigment present) like a black, blue or green.
- The movement of iris controls the size of pupil. The iris contains two sets of smooth muscles: **sphincters** and **dilators** of ectodermal

origin. These muscles regulate the amount of light entering the eye ball by varying the size of the pupil.

Pupil

- It refers to the opening in the iris. The parasympathetic fibres constrict the pupil and the sympathetic fibres dilate it. In bright light, the pupil becomes smaller and in the dim light it becomes larger.
- Light enters the eye through the pupil. Pupil in woman is **larger than** that in man. If the two pupils are unequal then the condition is described as **anisocoria**. Anisocoria is harmless but should not be considered as normal. Unilateral or bilateral lesions may produce anisocoria.

Nervous Coat (Retina)

- Retina is the innermost light sensitive layer. It allows the light to pass into the eye and forms an inverted image of the object at the retina. It is delicate, inner, nonvascular, light sensitive coat of the eye ball which is differentiated into three partsñoptic, ciliary and iridial. Ciliary and iridial parts are nonsensory and formed of a single layer of pigmented cells that line the ciliary body and iris respectively.
- The irregular interior margin of the pars optica of the retina, lying internal to the junction of choroid and ciliary body is called **ora serrata retinae. Optic part** is thick and composed of four layers of cells. Beginning from the choroid side, it has a layer of **pigmented cells**, a layer of **receptor cells**, a layer of **bipolar nerve cells** and a layer of ganglion cells.
- The pigmented layer is composed of dark brown pigment granules containing cuboidal cells which has pigmented processes. It is continuous beyond ora serrata**.** The pigmented cells have phagocytic properties and ion transport properties. This layer functions in regeneration of bleached cells. This layer is the storage site for vitamin A. The receptor cells synapse with the bipolar cells, which in turn synapse with the ganglion cells. The axons of the ganglion cells form the optic nerve.
- A thin limiting membrane covers the inner surface of the retina.
- The receptor cells are called **photoreceptors** or **visual cells**. They are of two types: **rod cells** and **cone cells**, named after their shapes. Both have light-sensitive pigments. Specific wavelengths of light breakdown the light-sensitive pigments and this stimulates the receptor cells to set up nerve impulses.

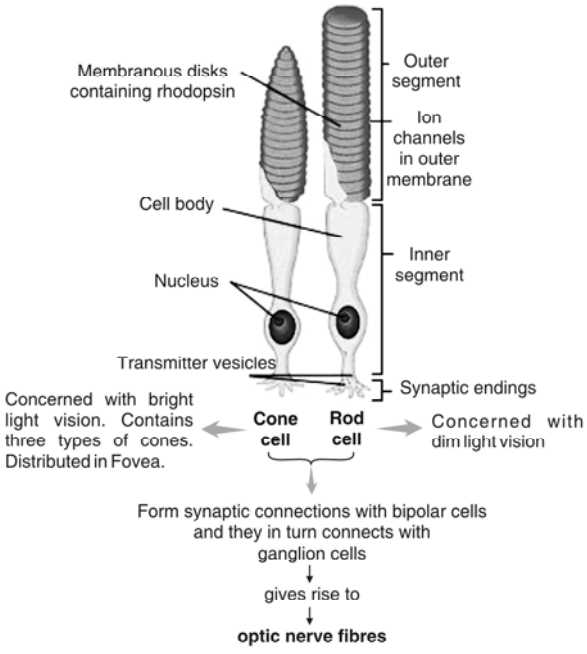


Fig. Structure of rods and cones.

Major cell types of the retina

- **Rod photoreceptor cells** are specialized for reception in dim light.
- **Cone photoreceptor cells** are specialized for sensing bright light and for **color vision**. There are different cone cell types (each with a different photo-pigment) for each of the three primary colors.
- **Horizontal cells** interconnect groups of photoreceptor cells. **Bipolar cells** (at least 4 types, one for the rod cells and one for each type of cone cell) interconnect photoreceptor cells with ganglion cells. **Amacrine cells** interconnect groups of ganglion cells and bipolar cells. They are unusual neurons because they have no true axon. **Ganglion cells** possess long axons that extend through the nerve fibre layer of the retina and then come together to form the optic nerve. They are the

only cell type in the retina possessing long axons (which bundle together to form the nerve fibre layer) and **exhibiting self-propagated action potentials. Muller cells** are large glial-like cells that extend from the internal limiting membrane (basement membrane) to the external limiting membrane (a region of junction between the muller cells and the photoreceptor cells). The glial cells are very rich in glycogen.

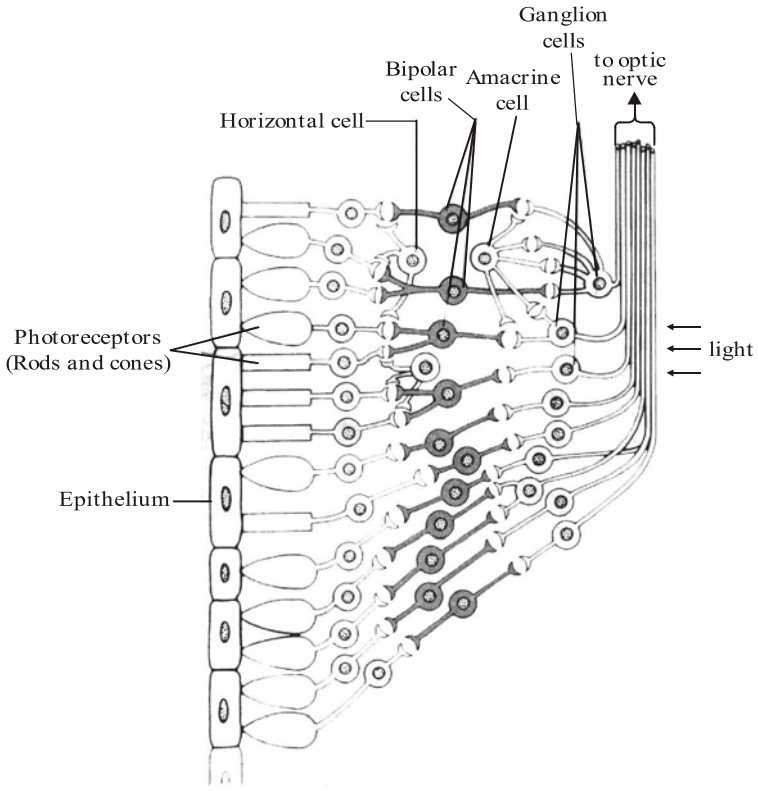


Fig. The retina of a vertebrate eye

Bleaching and regeneration of rhodopsin

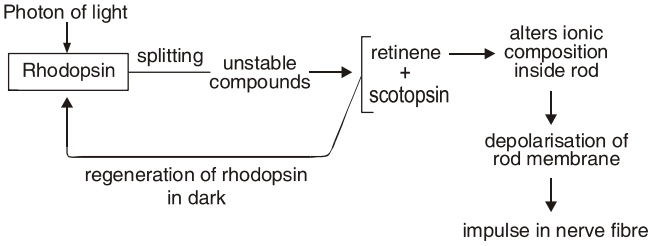
Light splits rhodopsin (visual purple) into a pigment retinene (= retinal) an aldehyde derivative of vitamin A and a protein scotopsin (opsin). The process of splitting is called **bleaching**.

In light :

Rhodopsin $\xrightarrow{\text{bleaching}}$ Retinene + Scotopsin + Energy + Nerve impulse

In darkness : Retinene + Scotopsin + Energy from ATP $\rightarrow$ Rhodopsin

Resynthesis of rhodopsin takes some time, so when we go suddenly from bright light into darkness or semidarkness we can see things only after a few minutes. It is due to reappearence of rhodopsin. Similarly, when we go from darkness into bright light we remain blind for a few minutes till rhodopsin is depleted to enable cones to become active visual cells.



Flow chart : Bleaching and regeneration of rhodopsin

- **Cone vision**

  The three types of cones provide us the basis of color vision. Cones are "tuned" to different portions of the visible spectrum.
  - ñ red absorbing cones **(erythrolabe)** ; those that absorb best at the relatively long wavelengths peaking at 565 nm
  - ñ green absorbing cones **(chlorabe)** with a peak absorption at 535 nm
  - ñ blue absorbing cones **(cyanolabe)** with a peak absorption at 440 nm.

Table : Differences between rods and cones.

	Rods	Cones
1.	Longer, slender and filamentous	Shorter and thicker
2.	More numerous and uniformily distributed in the retina	Less numerous, dispersed and tightly packed together at fovea to give a sharp image
3.	Sensitive to dim light but have less resolution	Sensitive to bright light hence helps in differentiating colours and give high resolution.
4.	Contain photosensitive pigment, rhodopsin or visual purple (Rhodopsin consists of the protein scotopsin and retinene, a derivative of vitamin A which is required for proper vision)	Contain photosensitive pigment, called iodopsin
5.	Specialised for light vision	Specialised for colour vision.
6.	Only one type, so only mono-chromatic vision	3 types (red, green & blue), so are responsible for colour vision

The portion of retina exactly opposite to the pupil is called **yellow spot** or **macula lutea** or **area centralis**. In the centre of yellow spot is present shallow depression called **fovea centralis**. It is the place of most distinct vision due to predominance of cone cells and they are smaller and more closely packed than elsewhere on the retina. Peripheral portion of retina is most suitable for detecting motion *i.e*. moving objects.

All the nerve impulses generated in the retina travel back to the brain by way of the axons in the optic nerve. At the point on the retina where the approximately 1 million axons converge on the optic nerve, there are no rods or cones. This spot, called the **blind spot**, is thus insensitive to light.

The interior of the eye is divided into three chambers or compartments referred to as the anterior (front) chamber, posterior (back) chamber and **vitreous chamber**. The **anterior chamber** is located between the cornea and the iris and contains aqueous humor (a clear fluid produced by the ciliary body). The posterior chamber is located between the iris and lens and also contains aqueous humor. The vitreous chamber is behind the lens and in front of the retina. It is occupied by vitreous, a gel-like substance that helps to maintain the round shape of the eye. Aqueous humour maintains the shape of the cornea and supply nutrition to both lens and cornea while vitreous humour maintains the shape of the eyeball and contribute to intraocular pressure and also to the focussing of light on the retina.

Other important structures of the eye

- The **orbit** is the bony cavity that contains and protects the eyeball.
- The **eyelids** are extensions of the skin of the face, and they are designed to protect the eye. The outer surface of the eyelid is covered with skin and contains the eyelashes. The inside is lined with a pink-white colored conjunctival membrane.

- The nictitans or **third eyelid** arises from the inside corner of the eye and contains a strong cartilage support and a tear gland. It is also designed as an extra protective mechanism for the eye.
- The **conjunctiva** is a thin, nearly transparent, vascularized (containing blood vessels) tissue that covers the white of the eye and lines the eyelids.
- The **lens** is a soft, transparent, spherical structure that is suspended within the eye by suspensory ligaments just behind the pupil. The lens is responsible for focussing light coming in through the pupil onto the retina in the back of the eye.
- The **lacrimal system**, which includes the lacrimal (major tear) gland and the gland of the third eyelid, is responsible for tear production and drainage of tears away from the eye.

Changes in retina when light rays fall on it → Light falls at the receptor cells (rods and cones) in retina → Breaking up of light sensitive pigments present in rods and cones by specific wavelengths of light → Stimulation of rods and cones and generation of nerve impulse → Nerve impulse transmitted to bipolar nerve cells → Nerve impulse transmitted to ganglion cells → Nerve impulse in the axons of ganglion cells which converge and form the optic nerve → Nerve impulse transmitted to brain → **Perception of light by brain cells** (in the visual area of cerebral cortex)

Diseases of the eye

The common diseases of the eye include injury and trauma, conjunctivitis (inflammation of the conjunctiva or "pink eye"), corneal ulcers, corneal inflammation (keratitis), inflammation of the uveal layer of the eye (uveitis), glaucoma (high pressure within the eye), and certain diseases of the retina and orbit. A variety of tumors can also affect the eyelids, internal structures of the eye, and the orbit.

- **Farsightedness**

If the eyeball is too short or the lens too flat or inflexible, the light rays entering the eye - particularly those from nearby objects - will not be brought to a focus by the time they strike the retina. Eyeglasses with convex lenses can correct the problem. Farsightedness is called **hypermetropia** or **hyperopia**.

- **Nearsightedness**

If the eyeball is too long or the lens too spherical, the image of distant objects is brought to a focus in front of the retina and is out of focus again before the light strikes the retina. Nearby objects can be seen more easily. Eyeglasses with concave lenses correct this problem by diverging the light rays before they enter the eye. Nearsightedness is called **myopia**.

- **Presbyopia**

It is inability to focus on nearby objects due to loss of elasticity of crystalline lens.

- **Cataract**

One or both lenses often become cloudy as one ages. When a cataract seriously interferes with seeing, the cloudy lens is easily removed and a plastic one substituted. The entire process can be done in a few minutes as an outpatient under local anesthesia.

- **Trachoma**

It is a chronic contagious conjunctivitis caused by infection of a bacterium *Chlamydia trachomatis.*

- **Astigmatism**

It is a condition in which irregular lens or cornea produce a blurred image.

- **Squint**

It results in diplopia or two image and occur due to weakness in ocular muscle or due to defect in the position of two eyes.

Illustration 19 : Match the following structures of the vertebrate eye with their respective functions.

(a) Cornea	(1)	Provides opening for light to enter
(b) Fovea	(2)	Transduces blue, green, and red light
(c) Iris	(3)	Transduces all waves of light
(d) Lens	(4)	Controls the amount of light that enters
(e) Optic nerve	(5)	Alters the shape of the lens
(f) Pupil	(6)	Transmits information to the CNS
(g) Periphery of retina	(7)	Focuses light directly on retina
(h) Ciliary muscle	(8)	Bends light and protects inner eye

Soln.: (1) f; (2) b; (3) g; (4) c; (5) h; (6) e; (7) d; (8) a

Illustration 20 : How is light focused on the retina of a vertebrate eye?

Soln.: Light reaches the eye in rays that range from an almost parallel to a diverging alignment. The image is focused when the light rays are bent to converge precisely on the retina. The cornea and lens are two accessory structures of the vertebrate eye that bend incoming light.
The curved shape of the cornea bends light so the rays converge towards the retina. The shape of the cornea, however, is not adjustable; it cannot accommodate for the distance of an object from the eye.
The lens is a convex, elastic structure that changes shape in accordance with how far the object is being viewed from the eye. In all vertebrates except fishes and amphibians, the lens is connected via suspensory ligaments to ciliary muscles that contract to flatten the lens and relax to make the lens more convex. The farther the object is from the eye, the more parallel the light rays coming from it, and the less bending required to focus the image on the retina. Thus, the ciliary muscles contract more to give the lens a flatter shape. Conversely, the closer the object, the more divergent are its light rays and the more they need to be bent. Thus, the ciliary muscles relax and the lens returns by its own elastic recoil, to its more natural convex shape.

Illustration 21 : Match the following retinal cells with their respective functions.

(a) Amacrine cell	(1)	Absorbs all wavelengths of light not captured by photoreceptors
(b) Bipolar cell	(2)	Carries signals from one photoreceptor to another and to several bipolar cells
(c) Cone	(3)	Carries signals from one bipolar cell to another and to several ganglion cells
(d) Ganglion cell	(4)	Controls frequency of action potentials in the optic nerve
(e) Horizontal cell	(5)	Modifies output from the photoreceptors
(f) Pigmented epithelial cell	(6)	Transduces blue, green or red light
(g) Rod	(7)	Transduces almost all wavelengths of light

Soln.: (1) f; (2) e; (3) a; (4) d; (5) b; (6) c; (7) g

EAR (ORGAN OF HEARING)

The ear is the organ of hearing and equilibrium. It contains both receptors that respond to movements of the head and, receptors that convert sound waves into nerve impulses. Impulses from both types of receptors are transmitted via the vestibulocochlear (VIII) cranial nerve to the brain for interpretation.

The ear of a human adult consists of three structural and functional divisions: the external ear, the middle ear, and the internal ear.

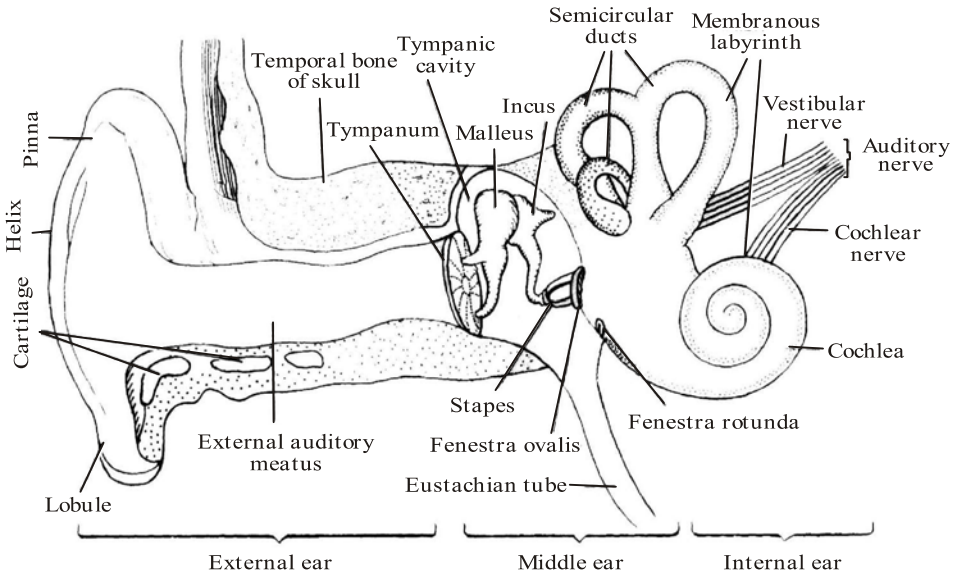


Fig. The parts of ear

External Ear

The external ear consists of the **pinna** (or auricle) and the **external auditory meatus**.

- **Pinna**

The pinna serves to direct sound waves to the auditory meatus. It is attached by ligaments and muscles to the skull. Its blood supply is from the posterior auricular artery which is a branch from the external carotid artery and the occipital artery, which is a branch of the superficial temporal artery.

- **External auditory meatus**

The external auditory meatus is a short (1") canal extending from the pinna to the ear drum (tympanic membrane or tympanum). It is lined with skin containing hairs and sebaceous glands near its entrance. Deeper within the meatus are ceruminous glands (wax-secreting glands). Cerumen (ear wax) keeps the tympanum soft and waterproof and together with the hairs prevent foreign objects from reaching the ear drum.

Functions of external ear

The exact effect of the pinna and auditory meatus on sounds arriving at the tympanum is not completely understood, but some filtering effect is probable.

Middle Ear

It includes the following :

- **Tympanic membrane**

The tympanum (tympanic membrane) or ear drum is a thin, double-layered, epithelial partition between the external auditory meatus and the middle ear. It is approximately 1 cm in diameter and is composed of an outer concave layer of stratified squamous epithelium and an inner convex layer of low columnar epithelium.

- **Tympanic cavity**

The tympanic cavity is a narrow air-filled cavity located in the temporal bones of the skull. It is separated from the external auditory meatus of the outer ear by the tympanic membrane. It is separated from the inner ear by a bony partition which contains two windows - the oval window (fenestra vestibuli) and the round window (fenestra cochlea).

The **eustachian tube** (auditory tube) connects the tympanic cavity anteriorly with the nasopharynx and equalizes air pressure on both sides of the tympanic membrane.

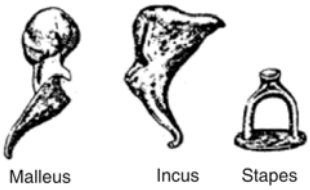


Fig. Ossicles of the middle ear.

- **The ossicles**

Connected at one end by ligaments to the tympanic membrane and in contact at the other end with the oval window (fenestra vestibuli) is a series of three auditory ossicles -the malleus **(hammer shaped)**, the incus **(anvil shaped)** and the stapes **(stirrup shaped)**. The latter is the smallest bone in the human body being roughly the size of a grain of rice.

The function of the middle ear

The ossicles is to transmit and amplify sound waves across the tympanic cavity from the tympanic membrane to the oval window. The ossicles are connected in such a way as to act as a lever system to increase the force of the vibration from the ear drum. In addition the force of vibration is intensified as it is transmitted from the relatively large surface of the ear drum to the smaller surface area of the oval window. The combined effect increases the force of vibrations roughly twenty times.

Internal Ear

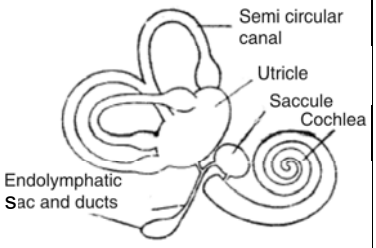


Fig. Membranous labyrinth.

The internal ear (the labyrinth) contains the organs of both hearing and of equilibrium. It consists of two parts: the **outer osseous (bony) labyrinth** and a **membranous labyrinth** contained within the osseous labyrinth and made up of interconnected sacs and tubes. The space between the two is filled with the perilymph, a fluid secreted by the cells lining the bony canals. The tubular chambers of the membranous labyrinth are filled with a second fluid, known as the endolymph. These fluids provide the media for vibrations involved in hearing and maintenance of equilibrium.

The osseous or bony labyrinth consists of three structural and functional divisions: **vestibule**, **semicircular canals** and **cochlea**.

- **Vestibule**

The vestibule is the central part of the bony labyrinth. Its lateral wall contains the oval window shown as the bean shaped white blotch between the utricle and saccule. The membranous labyrinth within the vestibule consists of two interconnected sacs called the **utricle** and the **saccule**. The utricle is the larger of the two. Both contain receptors which are sensitive to gravity and linear movements of the head. On the inside walls of both the utricle and saccule is a bed of several thousand hair cells covered by small flat piles of calcium carbonate crystals embedded in a gel like substance. The crystals are called **otolith** meaning ear stones. Hence utricle and saccule are often called **otolith organ**.

The utricle like the rest of the membranous labyrinth is filled with endolymph. It consists of connective tissue and epithelium. It has five openings for the semicircular canals and the duct connecting it to the saccule. The sense organ of the utricle is called the **macula utriculi** which is an oval thickened area in which fibres of the vestibular branch of the acoustic nerve terminate. It is covered with hair cells which respond to movement of the endolymph. The saccule has openings into the endolymphatic duct and the cochlear duct. Its sense organ in the **macula sacculi.**

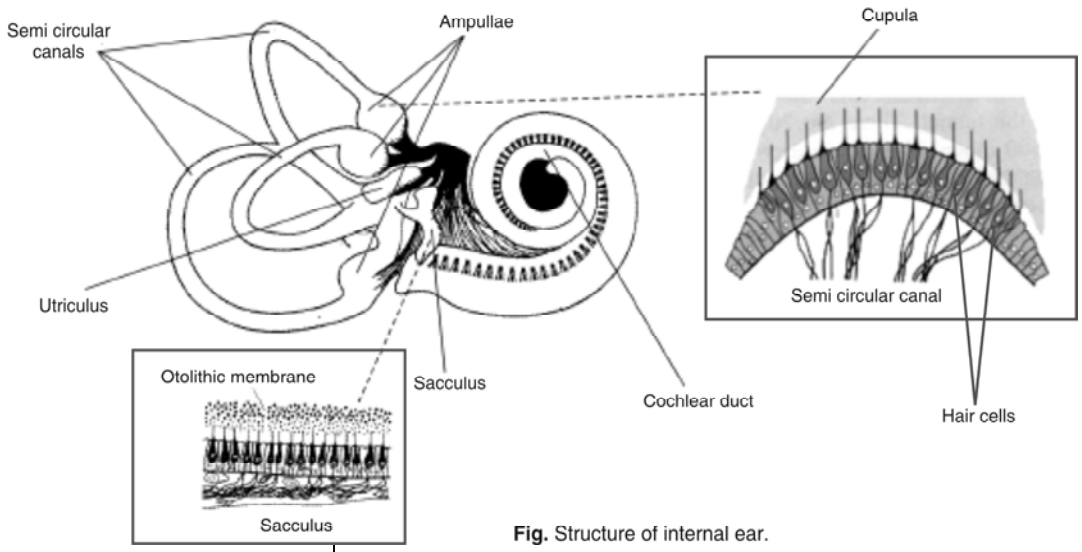


Fig. Structure of internal ear.

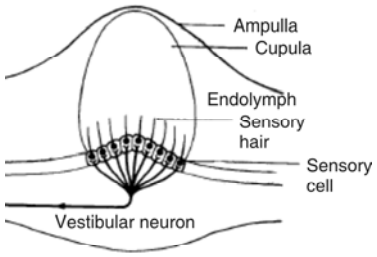


Fig. T.S. of semicircular canal through ampulla.

- **Semicircular canal**

  The three bony semicircular canals are oriented at right angles to each other and are positioned posteriorly (dorsally) to the vestibule. They are named the superior, posterior, and lateral semicircular canals. Each has an **ampulla** (dilation) which connects to the vestibule. Within the semicircular canals are present the semicircular ducts which are part of the membranous labyrinth. Receptors inside the semicircular ducts are sensitive to angular acceleration and deceleration of the head as in rotational movement. These receptors are located in the ampullae and are called **cristae ampullaris** which has gelatinous substance called **cupula** lacking ear stones or otoliths or otoconic.

- **Cochlea**

  The cochlea is shaped like a snail shell. It winds two and three quarters turns around a central bony axis, the modiolus. Projecting outward from the modiolus is a thin bony plate, the **spiral lamina** which partially divides the cochlear canal into an upper passageway called the **scala vestibuli** which originates at the oval window and is continuous with the vestibule and a lower one called the **scala tympani** which terminates at the round window. Both of these are filled with perilymph and are separate except at the very narrow apex of the cochlea, an area called the helicotrema. In between these canals there is the triangular passageway called the **cochlear duct**. The roof of the cochlear duct bears the **vestibular membrane** while its floor is called the **basilar membrane**. The cochlear duct is filled with endolymph and terminates at the helicotrema. It contains the organ of Corti.

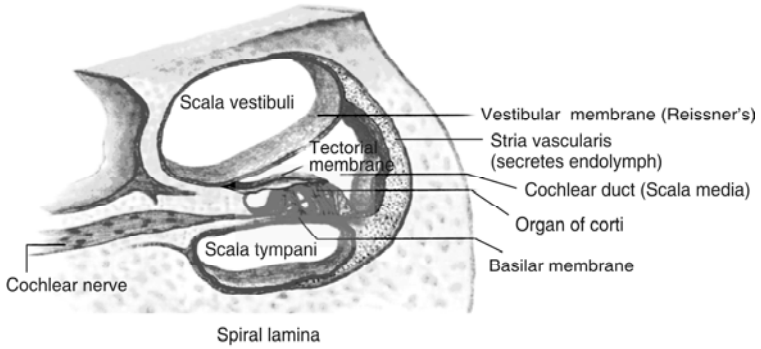


Fig. T. S. of cochlea showing organ of Corti and three chambers.

- **Organ of Corti**

The organ of Corti contains the sound receptors that transduce mechanical vibrations into nerve impulses. It is the functional unit of hearing. The epithelium of the organ of Corti consists of supporting cells and hair cells. The bases of the latter are anchored in the basilar membrane while their tips are embedded in tectorial membrane. Cochlea is the main hearing organ.

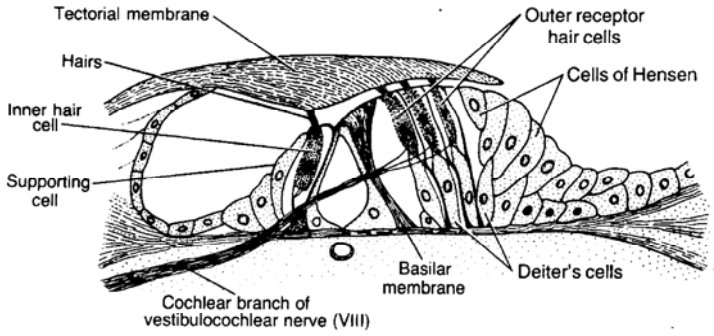


Fig. Detailed structure of organ of Corti (vertical section)

Physiology of hearing

Sound is produced by the vibration of particles within a medium. It travels as waves consisting of alternating regions of high and low pressure and will pass through liquids, solids and gases. Hearing is controlled by auditory area of temporal lobe of cerebral cortex. Human ear is sensitive to sound frequency of ranging between **20 - 20000 cycles/sec**. The measuring unit of sound intensity is **decibel**. Ear is divided into two parts ñ conductive apparatus and perceptive apparatus.

- **Conductive apparatus**

(i) Though pinna has little function in sound conduction in human being, it collects sound waves to some extent. Vibrating sound waves vibrate the tympanic membrane which come through the external canal. The sound waves vibrate three ossicles which rotate about an axis through the anterior ligament of malleus and short process of the incus. The stapes moves in a rocking rather than piston motion which sets the perilymphatic fluid in vibrating motion.

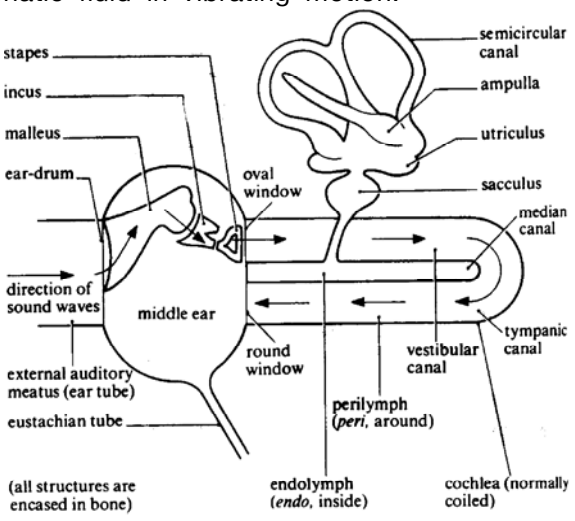


Fig. Sound conduction

Some sound is transmitted through skull bone into the inner ear fluid and basilar membrane.

(ii) Inner ear converts mechanical sound energy to electrical energy.

(a) Movement of stapes footplate produce vibration in perilymph in the form of wave and reaches scala tympani through helicotrema. This sound vibrates at the basal end of cochlea and reaches point of maximum displacement at a point.

(b) Shearing movement of tectorial membrane and hair cells results in the development of cochlear microphonic potential due to electrical potential difference in perilymph, endolymph and organ of Corti which helps acoustic impulse to be transmitted as neural impulse. This impulse is carried to auditory cortex through the cochlear nerve.

Sound wave → Auditory meatus → Tympanic membrane → Ossicles of middle ear → Oval window → Perilymph → Cochlea → Organ of Corti → Hair cells → Auditory nerve → Auditory centre of brain → Hearing

- **Balance**

  The semicircular canals, utricle and saccule of membranous labyrinth are the structures of equilibrium (balancing). Whenever the animal gets tilted or displaced the hair cells of the cristae and maculae are stimulated by the movement of the endolymph and otolith. The stimulus is carried to the brain through the auditory nerve and the change of the position is detected by the medulla oblongata of the brain. After that, the brain sends impulses (messages) to the muscles to regain the normal conditions.

Disorders of ear

- **Balance disorder**

  A disturbance that causes an individual to feel unsteady, giddy, woozy or have a sensation of movement, spinning, or floating. An organ in our inner ear, the labyrinth, is an important part of our vestibular (balance) system.

- **Menieréís disease**

  An inner ear fluid balance disorder that causes episodes of vertigo, fluctuating hearing loss, tinnitus (a raging or roaring in the ears), and sensation of fullness in the ear.

- **Otitis media**

  An infection or inflammation of the middle ear. This inflammation often begins when infections that causes sore throats, colds, or other respiratory or breathing problems spread to the middle ear.

- **Presbyacusis**

  Hearing loss occurring with age. It occurs due to decreased blood supply to the inner ear possibly due to heart disease, high blood pressure or arteriosclerosis or hereditary factors.

- **Tinnitus**

  A ringing sensation in the ears caused by irritative stimulation of either the inner ear or the vestibulocochlear nerve. In this the person hears when there is no real sound. It is usually accompanied by hearing loss.

Illustration 22 : Sound reaches mechanoreceptors of the inner ear when pressure waves in the ..... of the ..... causes vibration of the ..... membrane. This vibrating membrane rubs the mechanoreceptors, which are ..... cells, against the stationary ..... membrane to cause distortions of the plasma membranes of the mechanoreceptors. Sodium gates in the plasma membranes open, and a ..... potential is produced.

Soln.: Fluid; cochlea; basilar; hair; tectorial; receptor.

COMPETITION WINDOW

- **Neural system** is a system of neurons, nerves and nervous organs that coordinate and control the activities of different parts of animal body by sending and receiving nerve impulses.
- Study of morphology, physiology and pathology of nervous system is called **neurology**.
- The **neural system** is the **bodyís information, gatherer, storage centre** and **control system**.
- In humans the cells called **neurons** make up the nervous system.
- Neurons allow messages to be carried from one cell to another so that communication among all body parts is smooth and efficient.
- The neural system is divided into **three major divisions :** the **central neural system** the **peripheral neural system** and the **autonomic neural system**.
- **Central neural system** consists of **brain** and **spinal cord** whereas the **peripheral nervous system** consists of neurons not included in the brain and spinal cord.
- The **autonomic neural system** is the **involuntary part** which seems to be concerned with striking a balance or maintanining homeostasis in the functioning of many organs of the body.
- **Brain** (also called **encephalon**) is the widest and uppermost part of CNS which **lies protected** (against mechanical injury and shock) **inside the cranial cavity of skull** and **controls all activities** of **nervous system**.
- The brain is primarily made up of two types of **cells: glia** and **neurons**.
- **Glia** function primarily to support and protect the neurons. The **neurons** carry information in the form of electrical impulses known as **action potentials.**
- They communicate with other neurons in the brain and throughout the body by sending various chemicals called **neurotransmitters** across gaps known as **synapses.**
- Brain is made of **three main parts : fore brain** (also called prosencephalon); **mid brain** (also called mesencephalon); **hind brain** (also called rhombencephalon) which continues into spinal cord.
- **Fore brain** occupies **anterior two third** of brain and is formed of the following three parts : **olfactory lobes** (rhinencephalon), **cerebral hemisphere** (telencephalon) and **diencephalon**.
- Olfactory lobes **control the smell**. These are **small sized** in man.
- **80%** of the weight of brain is formed of **cerebral hemisphere**.
- Two cerebral hemisphere are collectively called **cerebrum** but are demarcated by **cerebral fissure**.
- The ridges and depressions in the roof of cerebral hemisphere is called **gyri** and **sulci** respectively.
- The gyri **increases the surface area of the cortex**.
- The increased surface area permits the large numbers of neurons to fit easily within the confines of the skull.
- The whitish nervous band by which two cerebral hemispheres are interconnected is called **corpus callosum**.
- Corpus callosum **participates in the formation of 5th ventricle or pseudocoel.**
- The grey matter of cerebral hemisphere is called **cerebral cortex** and deeper white matter is called **cerebral medulla**.
- **Centre of highest sensation and activities** is **cerebral cortex**.
- Each cerebral hemisphere is divided into four regions called **lobes.** These are **frontal** at the front, **parietal** towards the top of the head, **temporal** on the side and **occipital** at the rear.
- **Diencephalon** contains **epithalamus, thalamus** and **hypothalamus**.
- Diencephalon lies between cerebrum and mesencephalon. Its cavity is called **third ventricle or diocoel**.
- **Epithalamus** is **non-nervous part** which is fused with piamater to form anterior choroid plexus.
- The **thalamus and hypothalamus** are found in the part of the brain between the brain stem and

cerebrum.

- Immediately below the thalamus is the **hypothalamus**, which is the **control centre for hunger, thirst, fatigue, anger and body temperature.**
- Parts of the diencephalon and the cerebrum are included in an important group of connected brain centres called the **limbic system**.
- The limbic system plays an **important role in emotions, memory, and motivation, among other things**.
- Midbrain is formed of **optic lobes** and **cerebral peduncles**.
- Midbrain **controls muscle tone and some motor activities**.
- **Cerebellum, medulla oblongata** and **pons varolii** are the three parts of **hind brain**.
- The **cerebellum** is similar to the cerebrum in that it has two hemispheres and has a highly folded surface or cortex. Cerebellum is **associated with regulation and coordination of movement, posture, and balance**.
- **Medulla oblongata** (myelencephalon) is the **posterior most** part of the brain.
- Medulla oblongata controls **involuntary functions** like, heart beat, rate of respiration, secretion of glands, vomiting, coughing etc.
- In medulla oblongata and pons varolii, **grey matter** is **internal** and **white matter** is **external** while the arrangement is reverse in other parts of brain.
- **Pons varolii** is situated in front of the cerebellum below the mid brain and above the medulla oblongata.
- It **carries impulse from one hemisphere of the cerebellum to another**.
- Functionally, the pons is **concerned with maintenance of normal rhythm of respiration**. It **has got two respiratory centres** - the **pneumotaxic centre** and **apneustic centre**. It is also related with the control of facial expression, movement of the eye-ball, micturation etc.
- The **brain stem** connects the brain to the spinal cord.
- The brain stem, which **maintains life support system**, consist of the diencephalon, medulla oblongata, pons varolii and the midbrain.
- The brain stem not only coordinates and integrates all incoming information; it also serves as the **place of entry or exit for ten of the twelve cranial nerves**.
- Spinal cord **provides the link between the brain and rest of the body.**
- In spinal cord, **white matter** is found outside the **grey matter** (reverse in brain).
- Spinal cord **coordinate and control those reflex responses which occur without brain**.
- Spinal cord is **present in neural canal of vertebrates**.
- Spinal cord in rabbit **extends upto 4th lumbar vertebra.**
- Grey matter surrounding central canal is **H-shaped** or **butterfly-shaped.**
- Spinal cord **conduct impulses** to and from the brain and **controls most of the reflex activities and provides a means of communication between spinal nerves and the brain**.
- All nerves connecting the central neural system with receptors and effectors (muscles and glands) constitute the **peripheral neural system** (PNS).
- **Cranial nerves** and **spinal nerves** are the **main constituents of PNS**.
- **12 pairs** of cranial nerves are present in amniotes and **10 pairs** in anamniotes.
- **Autonomic neural system (ANS)** is a system of peripheral nerves and ganglion which innervates various organs & glands to stimulate, accelerate, slow down or inhibit their function without directly consulting the will.
- Autonomic neural system is **regulated by centres in brain like - cerebral cortex**, **hypothalamus** and **medulla oblongata**.
- ANS is concerned with **heart rate, breathing rate, blood pressure, body temperature** and other visceral activities that work together to maintain homeostasis.
- ANS, also called **visceral efferent neural system**, is made of two opposing divisionsñ**sympathetic** and **parasympathetic**.
- **Sympathetic neural system** is also called **thoracico-lumbar outflow**.
- It is **active** in stress condition, pain, fear and anger.
- The post-ganglionic sympathetic fibres are **mostly adrenergic** *i.e.*, they release neurotransmitter **noradrenaline** at their terminations. However, pre-ganglionic sympathetic fibres are **cholinergic**

i.e., liberate **acetylcholine** at their endings.

- **Parasympathetic neural system** consists of preganglionic para-sympathetic fibres, para-sympathetic ganglia and postganglionic parasympathetic fibres.
- Parasympathetic ANS is also called **cranio- sacral outflow**.
- Preganglionic nerve fibre of sympathetic ANS is **small sized** whereas that of parasympathetic ANS is **larger**.
- Action of sympathetic and para sympathetic ANS is **antagonistic** to each other but **neither exclusively excitatory nor inhibitory**.
- **Nerve impulse** is a wave of bioelectric disturbance that passes along a neuron during conduction of an excitation.
- The **mineral necessary for nervous conduction is sodium** and **potassium**.
- **Nature of nerve impulse** or conduction of nerve impulse is an **electro-chemical process**.
- Impulse conduction **depends upon permeability of axon membrane (axolemma)** and **osmotic equilibrium** and **electrical equivalence between the axoplasm and extracellular fluid (ECF)** present outside the axon.
- The **resting membrane potential** is about **ñ40 mV to ñ90 mV** with an **average of ñ70 mV** (1 mV or milli volt = 1/1000 volt).
- **Threshold** or **firing level** is the minimum strength to initiate action potential.
- The time for restoration of nerve fibres is called **refractory period**. It is about **0.001 sec**.
- **Transmission of nerve impulse occurs in three** stages ñ **polarised state**, **depolarised stage** and **repolarised stage**.
- Speed of nerve impulse in **more** (about 20 times faster) **in myelinated nerve than in unmyelinated fibre**.
- In myelinated nerve fibres the exchange of ions take place only at the **node of Ranvier**. This jumping conduction of action potential from node to node is called **saltatory conduction**.
- **Saltatory propagation** increases the speed of nerve impulse.
- **Velocity of nerve impulse** depends on myelination as well as diameter of the fibre. It is **slower in thinner fibre than in thicker fibre**.
- A **synapse** is in the close proximity of end knob of one neuron and dendron or cell body of next neuron.
- Nerve impulse through synapse is **unidirectional**.
- The synaptic knob **contains numerous synaptic vesicles**, which contain the neurotransmitter acetylcholine.
- **Neuromuscular junction** is a **specialised form of synapse** which is **found between a motor neuron and skeletal muscle fibre**. Each muscle fibre has a specialised region called **motor end plate** which contains vesicles and mitochondria. When the motor impulse from the nerve is received on the motor end plates, a local depolarization occurs thereby resulting in the excitation of the muscle fibre. They **always use the neurotransmitter acetylcholine and are always excitatory**.
- Neurotransmitter may be **excitatory** (depolarizing post-synaptic membrane) or **inhibitory** (hyperpolarizing post-synaptic membrane).
- Neurotransmitters are **stored in the nerve cellís bulbous end (axon)**.
- Neurotransmitters transmit information within the brain and from the brain to all the parts of the body. **Acetylcholine**, for example, sends messages to the skeletal muscles, sweat glands, and heart; serotonin release underlies the process of learning and consciousness.
- Abnormalities in the production or functioning of certain neurotransmitters have been implicated in a number of diseases including **Parkinsonís disease, amyotrophic lateral sclerosis, and clinical depression**.
- **Synaptic fatigue** is due to exhaustion of neurotransmitter.
- **Reflex action** (**Marshal Hall**, 1833) is the spontaneous, automatic mechanical response produced by stimulating specific receptors.
- **Examples of simple reflex** are ñ
  - ñ **Knee jerk** (stress reflex) ñ tendon of patella tapped.
  - ñ **Corneal reflex** (Blinking reflex) ñ closing of eyelids.
  - ñ Rapid withdrawal of hand while burned or pricked.
  - ñ Quick recovery of balance while falling.
  - ñ **Scratch reflex** of frog ñ in pithed frog with acetic acid.
  - ñ Coughing, sneezing and yawning ñ

- The **main human sense organs** are ñ
  - ñ The **eye** which detects light and colour (different wavelengths of light)
  - ñ The **ear** which detects sound (vibrations of the air) and gravity
  - ñ The **nose** which detects some of the chemical molecules in the air
  - ñ The **tongue** which detects some of the chemicals in food, giving a sense of taste.
- Pupil becomes **smallest in bright light** and in **dim light it becomes larger**.
- **Accomodation** is an **adjustment for distant and close vision** during which contraction of ciliary muscles releases tension in the suspensory ligaments and allows the lens to elastically recoil and bulge out on both of its sides. This **increases the convexity of the lens and increases the level of refraction of light passing through it**.
- The lens is **responsible for focussing light coming in through the pupil onto the retina in the back of the eye**.
- The **ciliary muscles of the ciliary body** contract or relax which varies the shape of the lens so that light can be focused on the inner layer ñ the retina.
- The **lens and the sensory ligament divide** the interior of the **eyeball into two chambers** ñ **aqueous** and **vitreous chamber**.
- **Retina** is delicate, inner, non-vascular light sensitive coat of the eyeball.
- It is differentiated into **three parts** ñ **optic**, **ciliary** and **iridial**.
- The retina **acts like the film in a camera and transmits electrical images through the optic nerves to the brain**.
- The **retina contains the light receptors** - the **rods** and **cones** (and thus serves as the ìfilmî of the eye).
- **Path taken by light rays in the eye ball is** ñ
  conjunctiva → cornea → aqueous humour → lens (through pupil) → vitreous humour → retina.
- The retina **converts light energy into electrical signals and sends them to the brain** *via* **the optic nerve**. In the brain the electrical signals are translated into an image that is perceived in an upright position.
- Ears are **statoacoustic organs** meant for both balancing & hearing.
- Ear **contains** both **receptors that respond to movements of the head** and **receptors that convert sound waves into nerve impulses**. Impulses from both types of receptors are transmitted *via* the vestibulocochlear (VIII) cranial nerve to the brain for interpretation.
- **Stapes** bone and its muscle **ëstapediusí** are the **smallest in the human body**.
- The auditory ossicles **transmit sound induced vibrations of the ear drum to the fluid called endolymph**, **filling the internal ear**.
- The internal ear or inner ear is called labyrinth consisting of two parts-**bony labyrinth and membranous labyrinth.**
- Bony labyrinth is filled with a fluid called **perilymph**.
- Membranous labyrinth contains a fluid called **endolymph**.
- Membranous labyrinth is divided into **three parts** ñ **vestibule, semicircular canal** & **cochlear duct**.
- **Vestibule** is a central sac having larger upper **utriculus** & a smaller lower **sacculus** sac containing granules of calcium carbonate called **otolith** (ear stones).
- Both utricle and saccule **contain receptors which are sensitive to gravity and linear movements of the head**.
- Utriculus and sacculus, connected by a small narrow **sacculo-utricular duct**, are often called **otolith organ**.
- **Macula**, a group of sensory cells are found in both sacs.
- Macula **takes part in maintaining static equilibrium**.
- **Semicircular canals** are three semicircular ducts borne over the utriculus at right angles to one another.
- Three semicircular canals are ñ **anterior vertical**, **posterior vertical** and **lateral horizontal**.
- The lower end of each semicircular canal has a swelling called **ampulla** containing a group of sensory hair cells called **cristae**.

- **Cristae**, covered by a mass of gelatinous material (**cupula**) **has longer sensory hairs** & **lacks otolith** (particle of calcium carbonate).
- Cristae **maintains dynamic equilibrium of the body**.
- The **receptor organs for equilibrium** are the **sacculus**, **utriculus** and **semicircular canals**. All of these are known as **vestibular apparatus**.
- Vestibular apparatus is a type of **proprioceptor**.
- Utriculus and sacculus are considered to be sense organs of **static equilibrium**. The three semicircular canals maintain **dynamic equilibrium**.
- **Cochlea** (auditory region of internal ear) is a long coiled tubular and blind outgrowth of sacculus.
- Cochlea is **divided into 3 chambers** ñ **scala vestibuli**, **scala media** & **scala tympani**.
- **Scala media** is also known as **cochlear duct**.
- Scala media **contains endolymph** while the other two chambers contain **perilymph**.
- Two partitions in cochlea are dorsal vestibular membrane, also called **Reissnerís membrane**, between scala media and scala vestibuli & ventral **basilar membrane** between scala media and scala vestibuli.
- Scala media **has receptor organ for hearing** called **organ of Corti** containing **receptor hair cells**, **Deiterís cell** & **cells of Hensen** etc.
- **Organ of Corti** (also called **spiral organ**) rests on the basilar membrane.
- The organ of Corti is stimulated by sound waves or nerve impulse of hearing starts from organ of Corti.
- Organ of Corti is **associated with hearing**.
- The perception of sound by a mammal involves the stimulation of mechanoreceptors located on organ of corti.
- The **measuring unit of sound** is **decibel**.
- Ear is most sensitive to frequency **1000-3000 cycles/sec**.

EXERCISE

Multiple Choice Questions

1. Conditioned reflexes are different from unconditioned reflexes in that
(a) conditioned reflexes are limited to brain
(b) unconditioned reflexes are limited to brain
(c) both (a) & (b)
(d) none of the above.

2. By which nervous system and of what type, the blood is supplied into visceral organs?
(a) Both SNS and PNS, involuntary
(b) Para-sympathetic nervous system, involuntary
(c) Sympathetic nervous system, involuntary
(d) Sympathetic nervous system, voluntary.

3. A frog has its brain crushed. But when pinched on the leg, the leg draws away. It is an example of –
(a) a neurotransmitter induced response
(b) simple reflex
(c) conditioned reflex
(d) automated motor response.

4. Depolarization of axolemma during nerve conduction takes place because of
(a) equal amount of Na^+ and K^+ move out across axolemma
(b) Na^+ move inside and K^+ move more outside.
(c) more Na^+ outside
(d) none of the above.

5. Which of the following statements is correct for node of Ranvier of nerve?
(a) Neurilemma is discontinuous
(b) Myelin sheath is discontinuous
(c) Both neurilemma and myelin sheath are discontinuous
(d) Covered by myelin sheath.

6. In which animal nerve cell is present but brain is absent?
(a) Sponge (b) Earthworm
(c) Cockroach (d) *Hydra.*

7. Name the cranial nerves of humans being *viz.*, II, VII, VIII, IX
(a) optic, auditory, facial, hypoglossal
(b) oculomotor, auditory, abducens, hypoglossal
(c) optic, facial, auditory, glossopharyngeal
(d) optic, facial, abducens, glossopharyngeal

8. The outermost covering of brain is
(a) duramater (b) arachnoid
(c) piamater (d) choroid layer

9. Nissl's granules are located in
(a) dendrites (b) myelin sheath
(c) cyton (d) axon

10. What is the cause of one way transmission of nerve impulse ?
(a) Dendron do not secrete neurotransmitters
(b) Neurotransmitters are specific
(c) Repetition of impulse cause synaptic fatigue
(d) Axons are connected to dendron

11. Band of nerve fibres connecting two cerebral hemispheres is known as
(a) corpus callosum (b) corpus luteum
(c) corpora allata (d) corpus spongiosum

12. Centre for thermoregulation is
(a) cerebral cortex
(b) hypothalamus
(c) medulla oblongata
(d) cerebellum

13. Which of the following causes transmission of impulse across the synapse?
(a) Na^+ (b) K^+
(c) Ca^{2+} (d) Mg^{2+}

14. Preganglionic sympathetic fibres are
(a) adrenergic (b) cholinergic
(c) synergic (d) hypergonic.

15. Iter is the structure which is present between
(a) third and fourth ventricle
(b) lateral and third ventricle
(c) second and lateral ventricle
(d) none of these.

16. The cranial nerves which control the movement of eyeball are
(a) 5,8 and 9 (b) 2,3 and 5
(c) 3,4 and 6 (d) 4,6 and 7

17. Broca's area is connected with
(a) learning and reasoning
(b) speech function
(c) receiving the impulse from eye
(d) sensation of smell.

18. In the nerve cells, the reversal of the resting potential is known as depolarization. This occurs due to
(a) influx of Na^+ (b) influx of K^+
(c) influx of Ca^{2+} and Cl^-
(d) efflux of Na^+

19. One of the examples of the action of the autonomous nervous system is
(a) swallowing of food
(b) pupillary reflex
(c) peristalsis of the intestines
(d) knee-jerk response.

20. Common neurotransmitter in PNS is
(a) epinephrine (b) colchicine
(c) acetylcholine (d) both (a) and (c).

21. Centre of thirst and hunger is
(a) medulla oblongata
(b) cerebellum
(c) cerebrum (d) hypothalamus

22. Which of the following is a motor nerve?
(a) Auditory (b) Optic nerve
(c) Abducens (d) Trigeminal nerve

23. A 'drunk person' has the earliest effect on which part of the brain?
(a) Cerebrum (b) Pons varolii
(c) Cerebellum (d) Medulla oblongata

24. Mammalian brain differs from an amphibian brain in possessing
(a) cerebellum (b) hypothalamus
(c) olfactory lobes (d) corpus callosum

25. Which of the following has non-myelinated nerve fibres?
(a) Optic nerves (b) Spinal nerves
(c) Cranial nerves (d) Autonomic nerves.

26. Saltatory conduction occurs in
(a) liver cells
(b) non-myelinated nerve fibres
(c) myelinated nerve fibres
(d) none of the above.

27. Which of the following cranial nerve of man is both sensory and motor ?
(a) Olfactory (b) Optic
(c) Trigeminal (d) Vagus.

28. Sympathetic nerves in mammals arise from
(a) sacral-region
(b) cervical region
(c) thoraco-lumbar region
(d) 3^{rd}, 7^{th}, 9^{th} and 10^{th} cranial nerves.

29. A person is suffering from impaired nervous system and madness after prolonged consumption of polluted water. Which metal is responsible?
(a) Hg (b) Ca
(c) Mn (d) Pb.

30. A part of brain of frog is removed which helps it to respire and locomote. The removed part of brain is
(a) medulla oblongata
(b) diencephalon
(c) cerebellum
(d) cerebral hemisphere.

31. A person having parkinson's disease shows defective action of which neutrotransmitter in brain ?
(a) Dopamine (b) Seratonin
(c) Noradrenaline (d) Eukalphia.

32. Pneumotaxis and inhibitory centres are associated with
(a) breathing (b) respiration
(c) digestion (d) sleeping.

33. Excessive stimulation of vagus nerve in humans may lead to
(a) hoarse voice
(b) peptic ulcers
(c) efficient digestion of proteins
(d) irregular contractions of diaphragm.

34. Most of the neurons of our body are
(a) multipolar (b) unipolar
(c) pseudounipolar (d) bipolar.

35. Which cranial nerve supplies the heart muscles?
(a) Vagus (b) Facial
(b) Auditory (d) Trochlear.

36. CSF is principally secreted by
(a) choroid plexus
(b) arachnoid granulation
(c) floor of fourth ventricle
(d) periaqueductal grey.

37. Body temperature is regulated by
(a) hypothalamus
(b) cerebrum and hypothalamus
(c) cerebellum
(d) medulla oblongata.

38. Spinal cord passes through
(a) foramen magnum
(b) foramen of Monro
(c) iter (d) none of these.

39. Relation between nerve thickness and conduction velocity is
(a) linear (b) parabolic
(c) hyperbolic (d) no relation.

40. Four healthy people in their twenties got involved in injuries resulting in damage and death of few cells of the following. Which of the cells are least likely to be replaced by new cells?
(a) Liver cells (b) Neurons
(c) Malpighian layer of the skin
(d) Osteocytes.

41. Cerebellum is the centre for reflex co-ordination and muscular tone; if it is injured
(a) movements become jerky walk controlled
(b) movements are shaky and speech defective
(c) movements are unbalanced
(d) no effect at all

42. Which part of human brain is associated with integration of sympathetic and parasympathetic activities ?
(a) Hypothalamus
(b) Cerebrum
(c) Medulla oblongata
(d) Neopallium.

43. The synaptic channels on the end-plate of skeletal muscle are
(a) highly selective for Na^+
(b) opened when the cell membrane depolarizes
(c) activated by acetylcholine (ACh)
(d) inhibited by atropine

44. In fore brain the centre which maintains homeostasis & controls emotional responses is called
(a) limbic system
(b) basal ganglia
(c) superior colliculi
(d) thalamus

45. The cranial nerve with the longest intracranial course is
(a) optic (b) abducens
(c) trigeminal (d) oculomotor

46. Wrist drop is seen with injury to.....nerve
(a) median (b) radial
(c) ulnar (c) axillary

47. The smallest cranial nerve is the
(a) olfactory (b) oculomotor
(c) trochlear (d) accessory

48. Unmyelinated axons in spinal cord are present in
(a) white matter (b) grey matter
(c) both (a) and (b) (d) none of these.

49. Fourth ventricle of human brain is present in
(a) diencephalon (b) medulla
(c) cerebral hemisphere
(d) none of these.

50. Which of the following works as central nervous system stimulant ?
(a) Opium (b) Heroin
(c) Amphetamine (d) Pethedine.

51. Cells found in the choroid plexus that secrete cerebrospinal fluid are
(a) astrocytes (b) microglia
(c) ependymal cells (d) oligodendrocytes

52. Grey matter contains primarily
(a) neuron cell bodies
(b) Schwann cells
(c) both (a) and (b) (d) none of these

53. In a man, abducens nerve is injured. Which one of the following functions will be affected?
(a) Movement of the eyeball
(b) Movement of the tongue
(c) Swallowing
(d) Movement of the neck.

54. Retina of eye is analogous to which part of camera?
(a) Film (b) Lens
(c) Shutter (d) Glass.

55. Pain is experienced by
(a) algesireceptor (b) caloreceptor
(c) hygroreceptor (d) proprioreceptor

56. Cochlea is divided into three chambers or spaces
1. scala vestibuli 2. scala media
3. scala tympani

Basilar membrane and Reissner's membrane are respectively found between
(a) 1 and 3 and 1 and 2
(b) 1 and 2 and 2 and 3
(c) 2 and 3 and 1 and 3
(d) 2 and 3 and 1 and 2

57. Meissner's corpuscles are responsible for
(a) heat and present in skin
(b) cold and present in skin
(c) pressure and present in skin
(d) pain and present in skin

58. Middle ear is located in ..... lobe
(a) frontal (b) parietal
(c) temporal (d) occipital

59. An area of retina which does not have rods and cones is
(a) yellow spot (b) red spot
(c) blind spot (d) blue spot

60. Myopia is corrected by using
(a) biconcave lens (b) biconvex lens
(c) cylindrical lens (d) plain glass

61. The pigment rhodopsin is present in
(a) choroids (b) retina
(c) sclera (d) cornea.

62. The arrangement of ear ossicles in mammalian ear is
(a) stapes, malleus, incus
(b) malleus, incus, stapes
(c) incus, malleus, stapes
(d) columella, malleus, incus.

63. The size of the pupil decreases
(a) when radial iris muscles contract and circular iris muscles relax
(b) when radial iris muscles relax and circular iris muscles contract
(c) when both radial and circular iris muscles contract
(d) when both radial and circular iris muscles relax

64. Night blindness is caused due to
(a) deficiency of vitamin A
(b) deficiency of vitamin D
(c) deficiency of vitamin C
(d) none of these

65. Vestibular apparatus acts as
(a) receptor organs of equilibrium
(b) olfactory organs
(c) organs for vision
(d) none of these

66. Path taken by sound waves in the ear is
(a) tympanic membrane → sound waves .....→ auditory area of brain
(b) sound waves → auditory areas of brain .....→ reissner's membrane
(c) sound waves → tympanic membrane ..... → auditory area of brain
(d) sound waves .....→ auditory area of brain → round window

67. Sinusitis is an infection
(a) of the sinuses near the nose
(b) of sinus venosus
(c) of middle ear
(d) none of these

68. Which of the following disorder of eye is only associated with old age?
(a) Myopia (b) Hypermetropia
(c) Cataract (d) Presbyopia

69. The functioning of the pigment rhodopsin is related with
(a) bleaching and regeneration
(b) breaking and joining
(c) addition and deletion
(d) regeneration and deletion

70. Each eye moves in the eye orbit with the help of
(a) six eye muscles (b) two eye muscles
(c) one eye muscles (d) none of these

71. Astigmatism is corrected by
(a) convex glasses (b) contact lenses
(c) concave glasses (d) cylindrical glasses

72. Organ of Corti is found in
(a) heart (b) inner ear
(c) kidneys (d) nasal chamber

73. The shape of eye lens is changed by
(a) pupil (b) iris
(c) optic nerve (d) ciliary muscle.

74. Which food should be eaten in deficiency of rhodopsin in eyes
(a) carrot and ripe papayas
(b) guava, banana
(c) mango and potato
(d) none of the above

75. Which nerve is associated with retina of eye?
(a) Optic nerve (b) Olfactory
(c) Hypoglossal (d) Vagus.

76. The balancing organ of ear is
(a) lagena and sacculus
(b) semicircular canal and utriculus
(c) semicircular canal and otolith
(d) otolith and lagena

77. The 'end organs of Ruffini' are receptors of
(a) pressure (b) cold
(c) heat (d) touch

78. The receptors for touch present in the skin are called
(a) Meissner's corpuscles
(b) Krause's end bulbs
(c) pacinian corpuscles
(d) stratum lucidium

79. Pacinian corpuscles occur in the skin of certain parts of body in mammals. These are
(a) type of glands
(b) pain receptors
(c) naked tactile receptors
(d) encapsulated pressure receptors

80. Glaucoma is caused due to
(a) opacity of lens
(b) increase the size of eye ball
(c) abnormally high pressure in the eye
(d) viterous humour becomes dry

81. Schneiderian membrane is found in
(a) loop of henle
(b) trachea
(c) Bowman's capsule
(d) nasal mucosa.

82. Blue vision is caused by
(a) digoxin (b) rifampicin
(c) ethambutol (d) chloroquine

83. Ora serrata is
(a) gland present in oral cavity of frog
(b) a part of third wall of retina of eye
(c) present in utriculus of ear
(d) oral cavity of protochordates

84. Otoconium is found in
(a) synovial fluid
(b) perilymph
(c) otolithic membrane
(d) haemolymph.

85. The black pigment in the eye, which reduces the internal reflection is located in
(a) retina (b) iris
(c) sclerotic (d) cornea.

86. Cells of deiter occur in
(a) utriculus (b) retina of eyes
(c) organ of Corti (d) sebaceous glands.

87. Retina is most sensitive at
(a) macula lutea (b) optic disc
(c) fovea centralis (d) periphery.

88. Colour blindness is related with a defect in
(a) eye muscle (b) rods
(c) cones (d) all of these.

89. Now-a-days cornea transplantation has been done on large scale because
(a) it does not link up with blood vessels
(b) it has a transparent portion
(c) it is easily available
(d) none of these

90. If a person wears a special kind of a spectacle that produce an upright image on the retina then he will
(a) see everything upside down
(b) see everything upright
(c) initially see everything upside down but regain normal upright vision after a few days
(d) initially see everything upright but after a few days see everything upsided down.

91. Which of the following refractive problems most closely resembles presbyopia ?
(a) Hyperopia (b) Myopia
(c) Astigmatism (d) Cataract

92. Which of the following statements correctly describes the role played by transducin during the response of rods and cones to light ?
(a) Transducin reduces membrane conductance by closing Na^+ channels
(b) Transducin stimulates synaptic transmitter release by opening Ca^{2+} channels
(c) Transducin initiates the photoreceptor response by converting 11-cis retinal to all trans retinal
(d) Transducin reduces the concentration of cyclic guanosine monophosphate (cGMP) by activating a phosphodiesterase enzyme.

93. If the refractive power of the unaccommodated eye of an emmetropic woman is 60 diopters (D), the axial length of her eye is closest to
(a) 14.5 mm
(b) 15.5 mm
(c) 16.5 mm
(d) 17.5 mm

94. Which one of the following is more descriptive of rods than of cones ?
(a) Not located within the fovea
(b) Provide information about the color of an object
(c) Recover their sensitivity more rapidly after exposure to bright light
(d) Responsible for the high visual acuity of the visual system

95. A sound stimulus of 20 decibels (dB) is
(a) 10 times threshold
(b) 20 time threshold
(c) 50 times threshold
(d) 100 times threshold

96. Cochlea has
(a) one compartment
(b) two compartments
(c) three compartments
(d) four compartments

97. Colour blindness results from the
(a) absence of a gene
(b) presence of gene
(c) doubling of a gene
(d) none of these

98. Red colour blindness is called
(a) deuteranopia
(b) protanopia
(c) protanomaly
(d) deuteranomaly

99. The optical power of the eye is
(a) 25 diopters (b) 50 diopters
(c) 60 diopters (d) 75 diopters.

Assertion and Reason AIIMS

In each of the following questions, a statement of Assertion (A) is given followed by a corresponding statement of Reason (R) just below it. Of the statements, mark the correct answer -

(a) *If both assertion and reason are true and reason is the correct explanation of assertion*
(b) *If both assertion and reason are true but reason is not the correct explanation of assertion*
(c) *If assertion is true but resason is false*
(d) *If both assertion and reason are false*

1. **Assertion :** Dogs have an acute olfactory sense.
Reason : Olfactory epithelium is very extensive in dogs.

2. **Assertion :** Vitamin A deficiency produces night blindness.
Reason : Photosensitive pigment rhodopsin is synthesized from vitamin A.

3. **Assertion :** The auditory ossicles help in hearing.
Reason : Auditory ossicles maintain the balance of air pressure between two sides of the eardrum.

4. **Assertion :** All of the cranial nerves are said to be mixed nerves.
Reason : All cranial nerves carry both sensory and motor nerve fibres simultaneously.

5. **Assertion :** Motor neuron terminates on a motor end plate at the neuromuscular junction.
Reason : Motor end plate acts as receptor for detecting changes in the muscle fibres.

6. **Assertion :** The chemicals stored in the synaptic vesicles are termed as neurotransmitters.
Reason : Synaptic vesicles release these chemicals in the synaptic cleft.

7. **Assertion :** Nerve impluse can never be transmitted from dendrite or cell body of one neuron to the axon of the next neuron, across a synapse.
Reason : This happens because of the synaptic delay at each synapse.

8. **Assertion :** Brain and spinal cord has a common covering.
Reason : Both the brain and spinal cord possess meninges.

9. **Assertion :** Nerve impulse is originated from threshold stimulus.
Reason : Threshold stimulus is the minimum strength of stimulus which is applied to the nerve fibre to stimulate it effectively.

10. **Assertion :** Corpus callosum is present in the space between the pia and arachnoid maters.

Reason : It serves to maintain a constant pressure inside the cranium.

11. **Assertion :** Myopia or short sightedness can be corrected by using spectacles with biconcave lenses.
Reason : Biconcave lenses diverge the parallel rays before their entry into the eye.

12. **Assertion :** Image focussed on the fovea is seen most accurately.
Reason : Fovea of retina contains numerous photoreceptor rod cells.

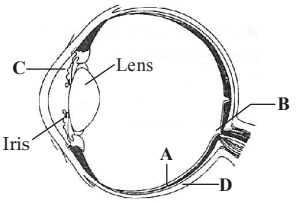
13. **Assertion :** Some areas of the brain and spinal cord look white.
Reason : This is because cell bodies of neurons are situated in those areas.

14. **Assertion :** All motor neurons are efferent neurons.
Reason : Motor neurons conduct nerve impulses from the spinal cord to the brain.

MCQs ▶ NEET / AIPMT AIIMS

Multiple Choice Questions

1. Parts A, B, C and D of the human eye are shown in the diagram. Select the option which gives correct identification along with its functions/ characteristics.



(a) C-Aqueous chamber-Reflects the light which does not pass through the lens.
(b) D - Choroid - Its anterior part forms ciliary body.
(c) A - Retina - Contains photoreceptors *i.e.*, rods and cones.
(d) B - Blind spot-Has only a few rods and cones.

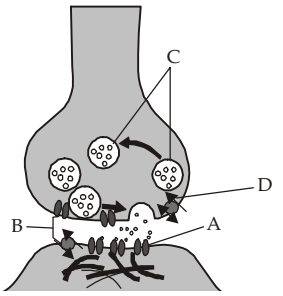
(NEET 2013)

2. The most abundant intracellular cation is

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

(NEET 2013)

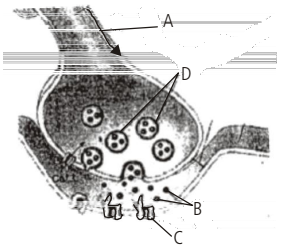
3. A diagram showing axon terminal and synapse is given. Identify correctly at least two of A - D.



(a) A - Neurotransmitter, B - Synaptic cleft
(b) C - Neurotransmitter, D - Ca^{++}
(c) A - Receptor, C - Synaptic vesicles
(d) B - Synaptic connection, D - K^+

(NEET 2013)

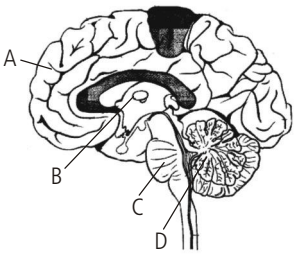
4. The figure shows an axon terminal and synapse. Select the option giving correct identification of labels A-D.



(a) A-Action potential, C-Neurotransmitter
(b) B-Neurotransmitter, D- Receptor capsules
(c) C-Receptor, D-Synaptic vesicles
(d) A-Axon terminal, B- Serotonin complex

(NEET Karnataka 2013)

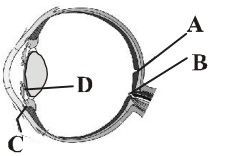
5. A sagittal section of human brain is shown here. Identify at least two labels from A-D.



(a) C-Mid brain, D-Cerebellum
(b) A-Cerebrum, C-Pons
(c) B-Corpus callosum, D-Medulla
(d) A-Cerebral hemispheres, B-Cerebellum

(NEET Karnataka 2013)

6. Which of the following is true for the function of labelled parts in the diagram below?



(a) A - Blind spot – Image is formed here
(b) B - Fovea – No visual activity is present
(c) C - Cornea – Helps to hold lens in place
(d) D - Iris – Visible coloured portion of eye

(AIIMS 2013)

7. Injury localized to the hypothalamus would most likely disrupt

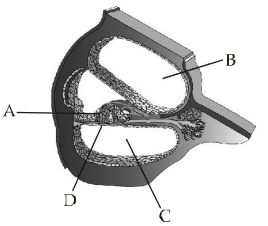
(a) short - term memory
(b) co-ordination during locomotion
(c) executive functions, such as decision making
(d) regulation of body temperature.

(AIPMT 2014)

8. Which one of the following statements is not correct?
(a) Retinal is the light absorbing portion of visual photo pigments.
(b) In retina the rods have the photopigment rhodopsin while cones have three different photopigments.
(c) Retinal is a derivative of vitamin C.
(d) Rhodopsin is the purplish red protein present in rods only.

(AIPMT 2014)

9. Given is the diagrammatic representation of the sectional view of cochlea. Select the correct option regarding it.



(a) A - Organ of corti - responsible for maintenance of balance of the body and posture.
(b) B - Scala vestibuli-filled with perilymph that ends at the oval window.
(c) C - Scala tympani - terminates at the round window which opens to the middle ear.
(d) D - Basilar membrane - nerve impulses are generated against it.

(AIIMS 2014)

10. A gymnast is able to balance his body upside down even in the total darkness because of
(a) tectorial membrane
(b) organ of corti
(c) cochlea
(d) vestibular apparatus.

(AIPMT 2015, Cancelled)

11. Which of the following regions of the brain is incorrectly paired with its function?
(a) Corpus callosum - communication between the left and right cerebral cortices
(b) Cerebrum - calculation and contemplation
(c) Medulla oblongata - homeostatic control
(d) Cerebellum - language comprehension

(AIPMT 2015, Cancelled)

12. Destruction of the anterior horn cells of the spinal cord would result in loss of
(a) commissural impulses
(b) integrating impulses
(c) sensory impulses
(d) voluntary motor impulses.

(AIPMT 2015)

13. In mammalian eye, the 'fovea' is the center of the visual field, where
(a) only rods are present
(b) more rods than cones are found
(c) high density of cones occur, but has no rods
(d) the optic nerve leaves the eye.

(AIPMT 2015)

14. Photosensitive compound in human eye is made up of
(a) opsin and retinol
(b) transducin and retinene
(c) guanosine and retinol
(d) opsin and retinal.

(NEET-I 2016)

15. Choose the correct statement.
(a) Nociceptors respond to changes in pressure.
(b) Meissner's corpuscles are thermoreceptors.
(c) Photoreceptors in the human eye are depolarised during darkness and become hyperpolarised in response to the light stimulus.
(d) Receptors do not produce graded potentials.

(NEET-II 2016)

16. Myelin sheath is produced by
(a) astrocytes and Schwann cells
(b) oligodendrocytes and osteoclasts
(c) osteoclasts and astrocytes
(d) Schwann cells and oligodendrocytes.

(NEET 2017)

17. Receptor sites for neurotransmitters are present on
(a) pre-synaptic membrane
(b) tips of axons
(c) post-synaptic membrane
(d) membranes of synaptic vesicles.

(NEET 2017)

18. Good vision depends on adequate intake of carotene rich food.
Select the best option from the following statements.
(1) Vitamin A derivatives are formed from carotene.

(2) The photopigments are embedded in the membrane discs of the inner segment.
(3) Retinal is a derivative of vitamin A.
(4) Retinal is a light absorbing part of all the visual photopigments.
(a) (1), (3) and (4) (b) (1) and (3)
(c) (2), (3) and (4) (d) (1) and (2)

(NEET 2017)

Assertion and Reason

Directions : *In the following questions, a statement of assertion (A) is followed by a statement of reason (R). Mark the correct choice as :*

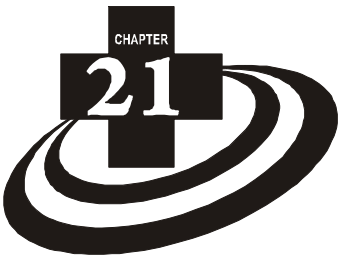
(a) *If both assertion and reason are true and reason is the correct explanation of assertion*
(b) *If both assertion and reason are true but reason is not the correct explanation of assertion*
(c) *If assertion is true but reason is false*
(d) *If both assertion and reason are false.*

19. Assertion : The optic nerves leave the eye at the point called blind spot.
Reason : Only cone are densely packed at the blind spot, hence is the name.

(AIIMS 2014)

20. Assertion : All motor neurons are efferent neurons.
Reason : Motor neurons conduct nerve impulses from the spinal cord to the brain.

(AIIMS 2016)



Neural Control and Coordination

Multiple Choice Questions

1. **(a) :** Conditioned reflexes, also called acquired reflexes are not inborn but developed by training and learning, hence are related to brain. Conditioned reflex is a type of reflex action (an immediate involuntary action of any organ or part of the body in response to a particular stimulus). Whereas unconditioned reflexes are genetic and inherited, hence, present at birth.

2. **(a) :** The blood is supplied into visceral organs by both SNS and PNS, involuntarily. In all individuals, blood pressure and blood flow through blood vessels are maintained by a special portion of the nervous system called 'autonomic" since usually it is not under conscious control. The autonomic nervous system consists of two antagonistic components - sympathetic and parasympathetic. Thus, SNS (sympathetic nervous system), PNS (parasympathetic nervous system) involuntarily controls the blood flow.

3. **(b) :** A simple reflex action is a nerve mediated spontaneous automatic and involuntary response to a stimulus acting on a specific receptor without consulting the will of the animal. Conditioned reflexes are those reflex action that are not present at birth but develop later in life through learning, habit, experience etc.

4. **(b) :** When an axon receives stimulus, a wave of depolarization passes through it. It reverses the membrane potential with the inner surface becoming positive and outer surface electronegative.

5. **(b) :** At the level of node of Ranvier the myelin sheath is discontinuous but not the neurilemmal lining.

Actually myelin sheath is an integral part of Schwann's cell – which form a continuous neurilemmal covering. Each Schwann's cell wrap-around the neurite to form concentric layers of plasma membrane. Investment of sphingolipid material in between leads to appearance of myelin sheath. But at the level of junction between two Schwann's cells myelin can not be formed and thus a gap appears.

6. **(d) :** *Hydra* is a member of phylum coelenterata in which nerve cells first appear. Coelenterata is a diploblastic, tissue grade animal with nonpolar neurons. Such neurons are with neurites which can act both as an axon as well as dendron. All such neurites from a network in the body of *Hydra* but there is no so called central processing unit or brain.

Sponges are also diploblastic but with cellular grade organisation and there is no nerve cell in the body.

Earthworm (annelida) and cockroach (arthropoda) are both triploblastic, organograde animals with brain.

7. **(c) :** Cranial nerves are peripheral nerves emerging from the vertebrate brains. There are 12 pairs of cranial nerves in human beings. I (Olfactory), II (Optic), III (Oculomotor), IV (Trochlear), V (Trigeminal), VI (Abducens), VII (Facial), VIII (Auditory), IX (Glossopharyngeal), X (Vagus), XI (Accessory spinal) & XII (Hypoglossal).

8. **(a) :** Brain is covered by three meninges piamater (thin, innermost vascular and pigmented sheath), arachnoid (thin, webby & slightly vascular middle sheath) and duramater (outer thick nonvascular membranes).

9. **(c) :** Nissl's granules are irregular masses of rough endoplasmic reticulum with numerous attached and free ribosomes and polysomes. Nissl's granules are present in cell body *i.e.* cyton. Presence of neurofibres and Nissl's granules is characteristic to all neurons.

10. **(a) :** Nerve impulse can only pass from an axon to another axon, cell body or dendron of the next neuron. This is so because only the axon terminals release the neurotransmitters that are required for the conduction of the nerve impulses across the synapse.

11. (a) : The corpus callosum is a very thick bundle of nerve fibers containing both myelinated and unmyelinated axons and allowing communication between the right and left sides of the brain.Corpus luteum literally means 'Yellow Body'. The structure formed in the ruptured follicle after ovulation, which produces progesterone. If the ovum (egg cell) is fertilised, the corpus luteum continues to produce hormones to support the early pregnancy. If fertilisation does not occur, the corpus luteum degenerates within 12-16 days.Corpora allata are paired or fused ganglion-like bodies in the head of insects. The bodies secrete hormones important in the regulation of metamorphosis and the development of some adult tissues. Corpus spongiosum is the mass of spongy tissue surrounding the male urethra within the penis.

12. (b) : Cerebral cortex contains many control centres. Cerebellum controls equilibrium of body, moderation of voluntary movements and maintenance of muscle tone. Medulla has vasomotor centre, respiratory centre, cardiac centre and reflex centres for swallowing, vomiting etc.

13. (c) : Synapse usually has an axon terminal or presynaptic knob, a narrow fluid filled gap or synaptic cleft and postsynaptic membrane of a dendrite of next neuron. As soon as an impulse generate the synaptic vesicles discharge neurotransmitter into synaptic cleft. Calcium is required for the release of neurotransmitter whereas magnesium inhibits it.

14. (b): Preganglionic sympathetic nerve fibres are cholinergic *i.e.* the nerve fibres release acetylcholine neurotransimitter.

15. (a) : The midbrain contains a narrow canal or iter that connects third and fourth ventricle. It is also called aqueduct of Sylvius.

16. (c) : The movement of eyeball is controlled by oculomotor (III), Trochlear or pathetic nerves (IV) and abducens (VI). IIIrd and IVth nerve innervate the inferior oblique and superior oblique muscles of eyeball while VI abducens innervate the posterior rectus muscles of the eyes.

17. (b) : Broca's area is known as sensory speech area or motor speech area. It translates thought into speech and is located in the frontal lobe towards left side. It is associated with language area and also interpretes translation of written words into speech.

18. (a) : When an axon receives stimulus a wave of depolarization passes through it reversing the membrane potential with the inner surface becoming positive and outer surface electronegative due to

(i) membrane becoming 10 times more permeable to Na^+ than K^+ and hence flow of Na^+ from extracellular fluid to the neuron interior.

(ii) Stoppage of $Na^+ - K^+$ pump.

19. (c) : Option (a), (b) and (d) are reflex action. Autonomic nervous system is involved in the peristalsis of intestine which is effected through mesentric plexus.

20. (d) : PNS (Peripheral nervous system) generally uses three neurotransmitters–epinephrine, acetylcholine, norepinephrine (or noradrenaline).

Acetylcholine is the most common neurotransmitter of many internal, neuromuscular and other cholinergic effector synapses. The nerve fibres which release acetylcholine neurotransmitter are called cholinergic, formed in mitochondria, it relays electrical signal at the post synaptic membranes.

Colchicine, an antimitotic drug, is produced by many species of the family liliaceae. It binds to one tubulin molecule and preventing its polymerisation. As a result of this binding the microtubules break down and cell mitosis is blocked at metaphase due to absence of mitotic spindle.

Adrenaline hormone, derivative of aminoacid, tyrosine, (hence catecholamines) is secreted by chromaffin cells of adrenal gland and to a lesser extent by sympathetic nerve endings.

21. (d) : Cerebrum contains the premotor areas for involuntary movements and autonomous nervous system; association area for coordination of sensation and movements among other centres. Cerebellum controls equilibrium of body, moderation of voluntary movements and maintenance of muscle tone. Medulla oblongata has the respiratory centre, cardiac centre and reflex centres for swallowing, peristalsis etc.

22. (c) : Abducens is a purly motor nerve originated from lateral side of medulla. It is distributed to the external rectus muscle of eyeball. This nerve helps in rotation of eyeball.

23. (a) : Alcohol is a central nervous system depressant. In small amounts most people experience sensations of relaxation as the alcohol "depresses" brain activity. The cerebrum controls higher functions, such as vision, emotions, reasoning and recognition. When alcohol depresses the cerebrum inhibitions are lowered, judgement is impacted, and impairments occur in vision, movement and speech. These effects have resulted in the reference to alcohol as a "social lubricant." This occurs at blood alcohol levels of 0.01% – 0.30%.

The cerebellum coordinates movement, thus, when depressed by alcohol the effect is impaired coordination, slowed reflexes and impaired balance. There are some of the effects that may be evaluated when an individual is asked to walk in a straight line, to balance on one foot, etc. These impairment occur at blood alcohol levels of 0.15% – 0.35%.

24. (d) : The whitish nervous band by which two cerebral hemispheres are interconnected is called corpus callosum. Corpus callosum participates in the formation of 5th ventricle or pseudocoel.

25. (d) : In nonmyelinated nerve fibres, the axis cylinder has a single sheath neurilemma. It is found in autonomic nerves. Mostly the axons of the postganglionic neurons of the autonomic nervous system have non-myelinated nerve fibres. It automatically regulates the activites of involuntary smooth muscles, cardiac muscles and glands. Without consulting the will. It is also called visceral nervous system because the autonomic nervous system innervates viscera.

26. (c) : Saltatory conduction is a means by which action potentials are transmitted along myelinated nerve fibers.

Because the salty cytoplasm of the axon is electrically conductive, and because the myelin inhibits charge leakage through the membrane, depolarization at one node of Ranvier is sufficient to elevate the voltage at a neighboring node to the threshold for action potential initiation. Thus in myelinated axons, action potentials do not propagate as waves, but recur at successive nodes and in effect hop along the axon, by which process they travel faster than they would otherwise.

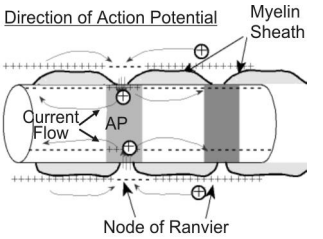


Fig. Saltatory Conduction.

27. (c) : Trigeminal nerve (cranial nerve V) is one of the pairs of nerves that arise from the anterior end of the vertebrate hindbrain to supply impulses to the mouth and the jaws. It carries sensory nerve fibres from the head surface and mouth cavity and motor nerve fibres serving the jaw muscles.

28. (c) : Sympathetic nerves in mammals arise from thoraco-lumber region. Nerves of the sympathetic system originate within the spinal cord of the thoracic and lumbar segments, but beyond the vertebrae each departs from the cord and turns ventrally in a short, white ramus to enter a sympathetic ganglion.

29. (d) : Studies on the effects of lead in human especially in children have demonstrated a relationship between exposure to lead and a variety of adverse health effects. These effects include impaired mental and physical development, decreased heme biosynthesis, elevated hearing threshold and decreased serum levels of Vit D. The neurotoxicity of lead is of particular concern.

30. (a) : A part of brain of frog which helps to respire and locomote is called medulla oblongata. It is a part of hind brain. Diencephalon helps in metabolism of carbohydrate, fat and proteins. The temperature and reproductive activity of the body are also controlled by it. Cerebellum helps in maintaining equilibrium. Cerebral hemispheres help in controlling intelligence, memory, thought etc.

31. (a) : Parkinson's disease is a progressive neuro-degenerative disorder which affects movement or control of movements. The causes of Parkinson's is not completely understood but a known cause is the degeneration of a group of nerves in the centre of the brain. These nerves

produce a chemical messenger called dopamine. When 80% of dopamine is lost, the symptoms of the disease is produced.

32. (a) : Pneumotaxis and inhibitory centres are associated with breathing. Pneumotaxis centre is pons. Stimulation inhibits inspiratory centre activity thereby control rate and depth of ventilation. This area is important for regulating the amount of air one takes in with each breath.

33. (b) : Excessive stimulation of vagus nerve in humans may lead to peptic ulcer. Vagal stimulation increases peristalsis which in excess, secretes more HCl and pepsin from stomach. These cause erosion through protective barrier of mucus and muscularis mucosa into the submucosa which leads to peptic ulcer.

34. (a) : Most of the neurons present in our body are multipolar. Multipolar neurons have many processes that extend from the cell body. However, each neuron has only one axon (example, spinal motor neurons, pyramidal neurons, purkinje cells etc.).

35. (a) : The Xth cranial nerve vagus supplies to the heart muscle. Its function is to inhibit the heart beat. The origin of vagus is lateral side and floor of medulla oblongata. It is the longest cranial nerve and has maximum branches and also called **wandering nerve.** Its distribution is in muscles of pharynx, vocal cords, lungs, heart, oesophagus, stomach, intestine. Function of vagus is sound production (vocal cords), respiratory reflexes, peristaltic movements, speech, swallowing sceretion of gastric gland, inhibition of heart beat etc.

36. (a) : Cerebrospinal fluid (CSF) is clear, low in protein, and has few lymphocytes. CSF is formed at the choroid plexus. Choroid plexus occur in the lateral ventricles, third ventricle and on the 4th ventricle roof. CSF is produced by ultrafilteration. It flows through ventricles and enters subarachnoid space, where it returns to the venous system. Arachnoid granulations help in return of CSF to venous system.

37. (a) : Body temperature is regulated by hypothalamus. Hypothalamus contains reflex centres linked to the autonomic nervous system. They include thermoregulation centre for temperature regulation. Temperature is also regulated by parietal lobe of cerebral hemisphere.

38. (a) : Foramen magnum is the large hole in the occipital bone at the base of the skull. Spinal cord is an elongated cylindrical structure which is continued with the medulla oblongata through foramen magnum of skull.

39. (a) : The speed of propagation depends on the type of fibre. Conduction velocity is faster in myelinated fibre as compared to non-myelinated fibres. But, the relation between nerve thickness and conduction velocity remains linear in both the cases. In myelinated fibres, the conduction velocity is 6 times the fibre diameter. It varies between 6-120 m/sec. In non-myelinated fibres, the speed of propagation is proportional to the square root of the diameter and is approximately 1 m/sec.

40. (b) : Neurons have least regeneration power therefore neurons are least likely to be replaced by new cells.

41. (b) : Damage to cerebellum will produce two types of defects; defects of posture and defects of voluntary movements mainly causing atonia (less tone); asthenia (weakness of movements) and ataxia (unco-ordinated movement).

42. (a) : Hypothalamus integrates the autonomic nervous system, with centres for sympathetic and parasympathetic control.

43. (c) : Acetylcholine (ACh) is released from the alpha motor neuron nerve terminal and activates the synaptic channels on the skeletal muscle end plate. These channels, unlike the channels that produce the action potential, are not affected by changes in the membrane potential. The ACh receptor is inhibited by curare; atropine blocks ACh receptors activated by postganglionic parasympathetic neurons. The channel opened by the ACh receptor is equally permeable to Na^+ and K^+.

44. (a) : The term limbic system is applied to the part of the brain that consists of a rim of cortical tissue around the hilus of cerebral hemisphere and a group of associated deep structures. The basal ganglia are involved in the planning and programming of movement. Thalamus is a part of telencephalon of the brain and is organized into nuclei relaying sensory information from spinal cord, brain stem and cerebellum to cerebral cortex.

45. (b) : The cranial nerve with the longest intracranial course is abducens. The longest cranial nerve is vagus (X).

46. (b) : Wrist drop in which there is an inability to extend the wrist occurs due to injury to radial nerve. Fracture of humeral condyles or radius are common causes of such an injury. Carpal tunnel syndrome results from compression of median nerve. Injury to axillary nerve leads to paralysis of deltoid muscle. This leads to loss of round contour of the shoulder and inability to abduct raise arm.

47. (c) : Trochlear, the IVth cranial nerve, is the thinnest and smallest of all cranial nerves. It supplies the superior oblique muscle which is one of the extraocular muscles controlling eyeball movement. Paralysis of trochlear nerve leads to limitation in inferolateral eyeball movement, producing diplopia (double vision).

48. (b) : The grey matter consists of unmyelinated axons arranged in an H-shaped area *i.e.*, the centre of the spinal cord. The neurons communicating with the brain have myelinated axons which are located in the white matter surrounding the grey matter.

49. (b) : The cavities of human brain are the first and second lateral ventricles which lie in cerebral hemispheres, the third ventricle is present in diencephalon and the fourth ventricle is in medulla.

50. (c) : Amphetamines cause augmentation in central nervous system activities and generate a feeling of euphoria.

51. (c) : Ependymal cells are the epithelial cells which line the neural tube and the ventricles of the brain. In certain regions of the brain they possess cilia (which is best seen in younger brains)., whose beating helps to move the cerebrospinal fluid. Modified ependymal cells form the epithelium of the choroid plexus found in the walls of the lateral, third and fourth ventricles of the brain.

52. (a) : Grey matter is a category of nervous tissue with many nerve cell bodies and few myelinated axons. Grey matter look reddish grey on a freshly removed brain.

It forms the superficial parts of the brain and the deep parts of the spinal cord.

It is composed of the bodies of the nerve cells (neuron) and the initial parts of its processes (axons and dendrites) just emerging from the neurons.

Grey matter is the major part of the nervous system in which the nerve impulses for all kinds of mental functions are produced and then sent away to be carried to their target organs by white matter.

The cerebrum and the subcortical nuclei, such as the putamen and the caudate, are composed of grey matter.

Generally, **grey matter** can be understood as the parts of the brain responsible for information processing; whereas, **white matter** is responsible for information transmission.

53. (a) : Abducens innervates the external rectus muscles of the eyeball. Movement of the tongue is controlled by the hypoglossal nerve. Neck movement is controlled by the facial nerve. Swallowing is by glossopharyngeal.

54. (a) : Retina of eye is analogous to the film or light sensitive plate of camera. Retina encodes the image into nerve impulses and transmits them to the brain.

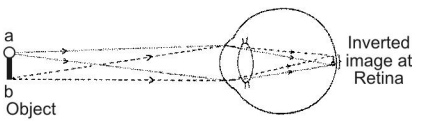


Fig. Image formation in eye

55. (a) : Algesireceptor are pain receptors which include branched and naked terminals scattered to the epidermis and dermis of skin. Besides pain, these are also sensitive to itching and burning. Caloreceptor, a type of thermoreceptor is sensitive to heat/warmth. Eg. end organs of Ruffini, which occur in the deeper layer of dermis. Proprioreceptor are sensitive to internal stimuli like heavy touch, pressure, joint rotation (eg. Golgi Mazzoni Organs), tension tissue vibration and pressure (eg. Pacinian corpuscles). Hygroreceptor is sensitive to water.

56. (d) : The cochlea has three longitudinal chambers. The middle chamber is called the scala media. It is filled with endolymph. The floor of the scala media is called the basilar membrane, and its roof, the Reissner's membrane. The upper and lower chambers of the cochlea are termed as the scala vestibuli and scala tympani respectively. They contain perilymph and both communicate with each other at the distal end of the cochlea by a narrow passage, called the helicotrema.

57. (c) : Messiner's corpuscles are tactile or touch corpuscles. Number of these corpuscles decreases with increasing age. These corpuscle present in skin are responsible for pressure.

58. (c) : Middle ear has a air filled chamber called tympanic cavity lined by mucous membrane which communicates with pharynx by a eustachian tube. It is enclosed in a flask shaped bone, tympanic bulla, which is a part of temporal bone of skull.

59. (c) : Blind spot is a region of retina where optic nerve and blood vessels enter and leave the eye ball as it does not possess visual cells, rods and cones. It, therefore does not take part in photoreception and is called blind spot.

60. (a) : Myopia is short or near sightedness. It is common in young persons due to either higher convexity of lens or longer eye ball which results in image of distant objects being formed in front of retina. It is corrected by wearing concave or convergent glasses.

61. (b) : The rod cells of the retina contain the pigment rhodopsin or visual purple pigment and enables the animal to see in darkness.
Sclera covers most of the eyeball and protects and maintains shape of eyeball. Cornea is the transparent portion that admits and helps to focus light waves as they enter the eye.

62. (b) : The three ear ossicles – malleus (hammer shaped), incus (anvil shaped), and stapes (stirrup shaped) connect the tympanum with the internal ear. The malleus is attached to the tympanic membrane on one end and to the incus on the other end. Incus is connected with the stapes which is attached to the oval window of inner ear.

63. (b) : Iris and ciliary muscles are of two types - radial muscles and circular muscle. When radial muscles contract or circular muscles relax, the pupil size increases, and when radial muscles relax and circular muscles contract, the pupil size decreases.

64. (a) : Night blindness is caused due to the deficiency of vitamin A. Vitamin A is necessary for the formation of a visual pigment called rhodopsin that helps to see in dim light.

65. (a) : Receptor organs of equilibrium are semicircular canal, sacculus and utriculus which are collectively known as vestibular apparatus. Static equilibrium refers to orientation of the body (mainly head) relative to gravity. It is regulated by sacculus and utriculus. Dynamic position is a response to sudden movement. It is regulated by cristae (ampulla of semicircular canal).

66. (c) : Path taken by sound waves in the ear is like this-

Path taken by sound waves in the ear

Soundwaves → Auditory canal → Tympanic membrane
↓
Three ear ossicles
↓
Oval window (fenestra ovalis)
↓
Perilymph in vestibular canal
↓
Endolymph in scala media ← Reissner's membrane
↓
Basilar membrane → Perilymph in tympanic canal → Round window → Sound waves dissipated through the middle ear
↓
Generation of neural impulse in inner ear → Transmitted *via* auditory nerve (8th nerve) to **auditory area of brain**.

67. (a) : Sinusitis is an infection of the sinuses (cavities, or air-filled pockets) near the nose. These infections usually occur after a cold or after an allergic inflammation. Sometimes, a sinus infection happens after an upper respiratory infection (URI) or common cold.

68. (d) : Presbyopia is a common defect in old age people due to the loss of elasticity of lens and reduced power of accomodation. The disorder can be compensated with reading glasses, bifocal, trifocals or contact lenses.

69. (a) : The functioning of the pigment rhodopsin is as follows :
Light splits rhodopsin (visual purple) into a pigment retinene (= retinal) an aldehyde derivative of vitamin A and a protein scotopsin (opsin). The process of splitting is called **bleaching**. This depolarizes the rod cells to release a neurotransmitter, transmitting the nerve impulse to the bipolar cells, ganglion cells and then to the optic nerves.
In light Rhodopsin $\xrightarrow{\text{bleaching}}$ Retinene + Scotopsin + Energy + Nerve impulse
In darkness Retinene + Scotopsin + Energy from ATP → Rhodopsin

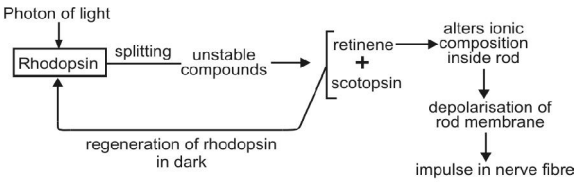


Fig. Bleaching and regeneration of rhodopsin

70. (a) : Each eye is moved in the eye orbit with the help of six muscles. These six muscles are governed by the cranial nerves.

Muscles	Movement produced	Cranial nerve
Superior rectus	Up	Oculomotor (III)
Inferior rectus	Down	Oculomotor (III)
Medial rectus	Toward nose	Oculomotor (III)
Lateral rectus	Away from nose	Abducens (VI)
Superior oblique	Down and in	Trochlear (IV)
Inferior oblique	Up and out	Oculomotor (III)

71. (d) : Astigmatism is the disorder due to rough curvature of cornea or lens which can be corrected by the use of cylindrical glasses. During this, instead of the rays of light converging on the retina as points they converge as lines which results in blurry images.

72. (b) : Organ of Corti is found in cochlea of inner ear. It is present on the basilar membrane as a sensory ridge and formed of receptor cells, Deiter's cells and supporting cells.

73. (d) : Present within the ciliary body of eye are ciliary muscles. These ciliary muscles are circular sheet of smooth muscle fibres that form bundles of circular and radial muscles which alter the shape of the lens during accomodation.

74. (a) : Deficiency of vitamin A causes deficiency of rhodopsin in eye. To overcome its deficiency food should be full of vitamin A.

75. (a) : The optic nerve is the structure which takes the information from the retina as electrical signals and delivers it to the brain where this information is interpreted as a visual image. The optic nerve consists of a bundle of about one million nerve fibres.

76. (b) : The balancing organs of ear is semicircular canal and utriculus. Receptor organs of equilibrium are semicircular canal, sacculus and utriculus which are collectively known as vestibular apparatus. Both static and dynamic equilibrium are maintained by this vestibular apparatus.

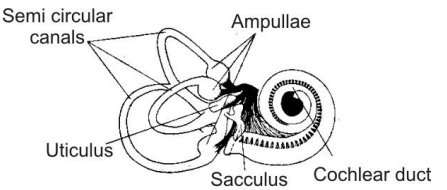


Fig. Major structure involved in hearing and balance

77. (c) : The 'end organs of Ruffini' is elongated and somewhat spindle-shaped having two or more interwinding and encapsulated dendrites of sensory neurons occur in the deeper layer of dermis. This is thermoreceptor organ, *i.e*, sensitive to heat (low temperature).

78. (a) : The receptors for touch present in the skin are called Meissner's corpuscle. This is rapidly adapted touch receptors.

79. (d) : Pacinian corpuscles are sensitive to deep or heavy pressure; found in subcutaneous tissue and many other parts of the body.

80. (c) : Glaucoma is an disease in which the pressure of the fluid inside the eye is too high, resulting in a loss of peripheral vision. If the condition is not diagnosed and treated, the increased pressure can damage the optic nerve and eventually lead to total blindness. Vision lost as a result of such damage cannot be restored. A person who has glaucoma may not realize it at first, because the disease often progresses with no symptoms or warning signs.

81. (d) : Schneiderian membrane is found in nasal mucosa. The olfactory organs of vertebrates have a lining of olfactory mucous membrane or schneiderian membrane. It is made up of basal cells, supporting cells and elongated neurosensory cells.

82. (c) : Loss of visual acquity, loss of colour vision field defects blue vision is caused by ethambutol which are its most important side effects. With early recognition and stoppage of therapy, visual toxicity is largely reversible. It is used in treatment of tuberculosis. Digoxin and chloroquine are also known to cause vision problems.

83. (b) : Ora serrata is a part of third wall of retina of eye. It is composed of neural tissue containing the receptor cells. The posterior part of the retina which ends at the ciliary body along an irregular line is termed as ora serrata.

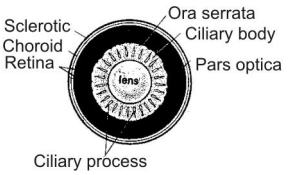


Fig. Anterior half of the eye seen from behind.

84. (c) : Otoconium are minute particles, composed chiefly of calcium carbonate. They are found in otolithic membrane on surface of maculae of inner ear.

85. (a) : The black pigment in the eye, which reduces the internal reflection is known as retina. It is the innermost coat of the eyeball and it is a thin, light sensitive nervous layer. The external coat of the eyeball is known as sclerotic but in front of the sclerotic, there is a transparent connective tissue called cornea. Iris is the pigmented part present in front of choroid.

86. (c) : Cells of deiter occur in organ of Corti. These are the supporting cells present in three rows in organ of corti. It also appears to contribute lesser amount of collagen to the tectorial membrane. Deiter cells present towards the cochlea forms the rods of Corti. Its main function is to hold the organ of corti together.

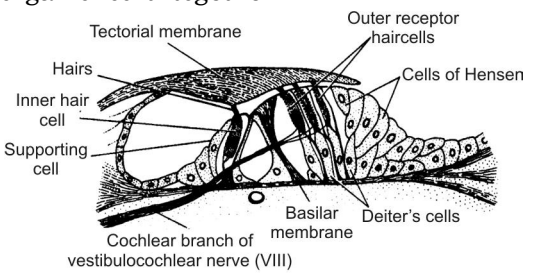


Fig. Organ of Corti

87. (c) : Macula lutea is part of retina. It is an oval area of greater resolution with fovea centralis, a shallow depression with greatest resolution. The most sensitive part of the retina is fovea centralis. This region has exclusively cones and they are smaller and more closely packed than else where on the retina.

88. (c) : The photoreceptor or visual cells in eye are of two types: rods and cones. Rods have visual purple pigment called rhodopsin and are sensitive to dim light so these help in twilight vision during night. Deficiency of rhodopsin in rods causes night blindness. Rods have no role in colour vision. Cones have visual violet pigment iodopsin, cones help in colour vision. Colour blindness is believed to be due to failure of one or more of the three classes of primary colour cones.

89. (a)

90. (a) : In normal vision the image on retina is always inverted which is formed by lens. When sensory impulses of this image are carried to the brain by fibres of optic nerve, the nerve centre of sight, located in animal becomes aware of the normal erect pattern of the object. If a person wears a special kind of spectacle that produced an upright image on the retina he will see everything upside down.

91. (a) : Presbyopia is the loss of accommodative power that occurs as a person ages. Because accommodation cannot occur, the near point moves away from the eye and images must be held at some distance from the eye to be clearly seen. This is similar to the situation in hyperopia where the converging power is too weak for the axial length of the eye. Hyperopes must accommodate to see distant objects clearly and thus have less accommodation avialable for near vision. Thus hyperopes, like presbyopes, must hold objects at a distance to see them clearly (hence the term "farsighted").

92. (d) : Transducin is a G protein that, when activated by the photoisomerization of 11-*cis* retinal to all-*trans* retinal, activates a cyclic guanosine monophosphte (cGMP) phosphodiesterase. The hydrolysis of cGMP by the phosophodiesterase leads to the closing of Na^+ channels, the hyperpolarization of the membrane, and a reduction in the release of synaptic transmitter. Formation of 11-*cis* retinal from vitamin A requires two steps,the vitamin A must be isomerized to its 11-*cis* isomer by an isomerase enzyme and then the 11-*cis* retinol must be oxidized to the aldehyde, 11-*cis* retinal.

93. (c) : The focal point of an optical system (in meters) is the reciprocal of the refractive power of the system. Therefore, the focal point is 1/60 diopter (D), or 16.7 mm. An emmetropic eye forms a focused image of a distant object on the retina without accommodation. If the axial length is 16.5 mm, the image will be focused on the retina.

94. (a) : Rods are not located within the fovea, only cones are present. The three types of cones (red, green, blue) make color vision possible. Because cones are smaller than rods, have a greater

sensitivity to light, and are organized into smaller center-surround receptor fields, they are capable of high visual acuity. After being exposed to bright light, cones recover their sensitivity about five times faster than rods.

95. (a) : A decible (dB) is a unit of sound intensity based on the formula:

$$dB = 20 \times \log \frac{I}{I_0}, \text{ where}$$

I = stimulus intensity

I_0 = threshold stimulus

This formula can be used to calculate the decibels above threshold for any sound for which the amplitude is known. According to this formula, a sound intensity of 20 dB is 10 times threshold :

$$20 = 20 \times \log \frac{10 \times I_0}{I_0}.$$

96. (c) : The cochlea is a spiral tube which in humans has two and one-half turns. Two membranes divide the cochlea into three compartments. Reissner's membrane separates the scala vestibuli from the scala media. The basilar membrane separates the scala tympani from the scala media.

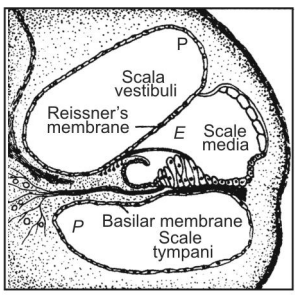


Fig. The components of the cochlea shown in croos-section. *P* = perilymph; *E* = endolymph.

97. (a) : Colour blindness results from absence of the gene that codes for either the red, blue or green opsin. Red-green colour blindness results from the inability to synthesize either red or green pigment. The genes for these pigments are on X chromosome. Approximately 9% of the male population has some sort of red or green colour deficit. Red colour blindness is called protanopia. Blue colour blindness occurs due to defects in genes on chromosome 7 and is very rare.

98. (b) : *Refer to answer 97.*

99. (c) : In a normal eye, an image of a distant object is focussed on the retina by the cornea and lens. The converging power of the unaccomodated lens (approximately 20 D) and the cornea (approximately 40 D) are combined into a single optical refractive power of approximately 60 D.

Assertion and Reason

1. (a) : Smell or olfaction is evoked by specific chemical substances stimulating the receptors concerned. The nose is the sense organ for olfaction. Receptors for smell occur in a modified form of pseudostratified epithelium covering a part of the nasal mucosa. This epithelium is called olfactory epithelium. It lines the surface of only a small area in the roof of the nasal cavity near the nasal septum in man. But it is far more extensive in animals like dogs. This is the reason why dogs possess such an acute olfactory sense. Many thousand types of odours are discernible to dogs. Dogs can track people because they can distinguish between the odours of different persons.

2. (a) : Our eyes are the sense organs for vision. The light sensitive inner layer of eyeball called retina contain photoreceptors viz. rod and cone cells which convert the energy of specific wavelengths of light into action potentials of nerve fibres. Rods are sensitive even to dim light and consequently enable to see in dim light and at night. They contain a purple - coloured photosensitive pigment, called rhodopsin. Rhodopsin consists of the protein scotopsin and retinene, a derivative of vitamin A which is required for proper vision and is required for the regeneration of rhodopsin after it has been exposed to light. Therefore, the deficiency of vitamin A causes night blindness in man because rods cannot function if rhodopsin is not synthesised from vitamin A.

3. (c) : Auditory ossicles are the three small bones present in the cavity of the middle ear. These are hammer - like malleus, anvil - like incus and stirrup - like stapes. Malleus is attached on one hand, to the ear-drum and articulates, on the other hand, with the incus. Incus articulates, in turn with the stapes, the foot plate of which is attached to the membrane over an oval window between the middle and the internal ears. Sound waves reach the ear - drum through the external auditory canal and vibrates the ear - drum. The vibrations of the latter are transmitted by the auditory ossicles to the fluid endolymph which fills the internal ear. The auditory ossicles also increase the force of vibrations by approximately ten times.

The cavity of middle ear communicates with that of the pharynx through an air - filled tube, called eustachian tube. The latter maintains the balance in air pressure between two sides of the eardrum and thus allows it to vibrate freely when sound waves impinge on it.

4. **(d) :** The nerves arising from different parts of the brain are called cranial nerves. Man possesses twelve pairs of cranial nerves. A nerve which carries only sensory nerve fibres is called a sensory nerve and a nerve carrying only motor nerve fibres is called a motor nerve. Those nerves which carry simultaneously both sensory and motor nerve fibres are called mixed nerves. Out of twelve pairs of cranial nerves, only four pairs are mixed nerves. Table below gives the names, nature and major functions of the cranial nerves.

No.	Name	Fibres	Functions
Ist	Olfactory	Sensory	Smell
2nd	Optic	Sensory	Vision
3rd	Oculomotor	Motor	Eyeball movements
4th	Trochlear	Motor	Eyeball movement
5th	Trigeminal	Mixed	Cutaneous sensation, muscle movements
6th	Abducens	Motor	Eyeball movement
7th	Facial	Mixed	Taste salivation, muscles movements, tear secretion
8th	Auditory	Sensory	Hearing, equilibrium sense
9th	Glosso-pharyngeal	Mixed	Taste, salivation, swallowing
10th	Vagus	Mixed	Gastric and pancreatic secretion, cardiac slowing gastrointestinal movements, respiratory reflexes, vasomotor reflexes,visceral reflexes
11th	Spinal	Motor	Muscle movements, visceral reflexes accessory
12th	Hypoglossal	Motor	Tongue movements

5. **(c) :** The axon of a motor neuron terminates on either a muscle fibre or a gland cell in the peripheral region of the body. When it terminates on a muscle fibre, a specialised structure is formed called as neuromotor junction or motor - end plate at the neuromuscular junction. At the motor end plate each axon loses its myelin sheath and ends in an expanded foot - like structure. Here, there is no actual continuity between the neuron and the muscle fibre. Both are separated from each other by a very narrow cleft like fluid - filled space. Nerve impulses are transmitted across this junction from the axon terminal to the muscle fibre. On the contrary, the dendrite of a sensory neuron, terminates in the peripheral tissue on a structure specialised for receiving information about specific changes near it. This structure at the sensory nerve terminal is called a receptor.

6. **(b) :** The axon terminal of the neuron contains many membrane bound vesicles called synaptic vesicles, in its cytoplasm. Within these vesicles, chemical substances such as adrenaline and acetylcholine remain stored. These chemicals are called neurotransmitters, because they help to transmit nerve impulses across the synapses. When a nerve impulse passes the axon terminal, its synaptic vesicles release their stored chemicals in the synaptic cleft.These diffuses through the cleft to reach the membrane of the next neuron, stimulating the latter. This causes the nerve impulse to be transmitted along the next neuron.

7. **(d) :** Normal pattern of conduction is transfer of depolarising wave from axon to dendrite but other forms of transmission like axo-axonic, dendro-axonic are also found and synaptic delay has nothing to do with it.

8. **(a) :** Both the brain and spinal cord are the main structures of central nervous system which are completely covered by three connective tissue membranes. These are called pia mater, arachnoid mater and duramater, respectively from within outward. Together they are known as meninges.

9. **(b) :** A minimum strength of stimulus, the threshold stimulus is applied to the nerve fibre. When the nerve fibre is effectively stimulated, its resting membrane potential undergoes a change - the inner side of the membrane now becomes electropositive to its outside. This potential change is called action potential, and is propagated along the nerve fibre as the nerve impulse.

10. **(d) :** It is not corpus callosum but cerebrospinal fluid which is present in the subarachnoid spaces between the pia and arachnoid maters.

Pia and arachnoid along with the dura mater are called meninges. These are connective tissue membranes which cover both the brain and spinal cord. Cerebrospinal fluid affords protection to the central nervous system (CNS) against mechanical injury and shock. The exchange of materials between it and the neurons help in their nutrition and excretion. The cerebrospinal fluid serves to maintain a constant pressure inside the cranium in spite of fluctuations in the volume and pressure of blood in the cranial vessels. It also occupies the lumens of several inter-communicating cavities, called cerebral ventricles inside the brain and the spinal canal running along the centre of the spinal cord.

Corpus callosum is a thick and curved band of nerve fibres which joins the two cerebral hemispheres of the cerebrum.

11. (a) : Our eye possesses a biconvex transparent lens which is an elastic structure made up mainly of non nucleated, transparent and elongated cells. Lens focuses the rays of light passing through it on the light sensitive layer retina. Lens helps in accomodation for near and distant objects by increasing or decreasing its curvature. Myopia or short - sightedness results from either an abnormally long eyeball or an abnormally high curvature of the lens. It results in the focussing of parallel rays from distant objects in front of the retina instead of on the retina. Myopia can be corrected by spectacles with biconcave lenses, because biconcave lenses diverge the parallel rays before their entry into the eye; this brings the rays to a sharp focus on the retina.

12. (c) : Retina is the light sensitive layer constituting the inner layer of the posterior two - thirds of the eyeball. The retina contains two types of photoreceptors *viz*. rod and cone cells which contain light sensitive pigments. A posterior depressed part of the retina contains only cones and no rods. This area is called fovea or fovea centralis or yellow spot. Ability for vision is highest in the fovea. When eyes are fixed on an object, its image is focused on the fovea and is consequently seen most accurately.

13. (c) : The brain and the spinal cord constitute the central nervous system. The areas of the CNS where the cell bodies of the neurons are situated, look grey and constitute the grey matter. Other areas look white and constitute the white matter of the CNS. The white matter contains only nerve fibres cruising from or to the nerve cells in the grey matter. It looks white due to the presence of myelin around the myelinated fibres. In most parts of the brain, the grey matter containing the nerve cells is situated on the surface while the white matter made of fibres is located deep inside the brain; but in the spinal cord, the grey matter is internal and white matter occurs outside.

14. (c) : The neurons and nerve fibres which conduct nerve impulses from the central nervous system (CNS) to the peripheral organs and tissues are called efferent neurons and efferent nerve fibres respectively. Some of the neurons and nerve fibres conduct nerve impulses to the muscles and glands to stimulate or inhibit their activities. Many of these nerve fibres cause movements of muscles. So, such neurons and nerve fibres are known as motor neurons and motor nerve fibres, respectively. The motor nerve fibres are the axons of motor neurons. All motor neurons are efferent neurons, because they conduct impulses from the CNS system to the peripheral tissues *viz*. muscles and glands. The nerve fibres which reach nerve impulses to the eye muscles to control their movements are motor fibres; so also are the fibres carrying impulses to the salivary glands and controlling their secretion.

The nerve impulses are conducted from the spinal cord to the brain by ascending nerve tracts which are the bundles of nerve fibres ascending along the white matter of the spinal cord.

MCQs – NEET / AIPMT, AIIMS

1. (c) : In the given figure, A is retina which is the innermost layer, containing photoreceptors rods and cones. B is blind spot. Optic nerves pierce through retina at blind spot. It has no visual cells. C is aqueous humor. It nourishes cornea and lens both of which are avascular. D is sclera. It is the outermost covering and maintains shape of eyeball. It also protects inner layers of the eye.

2. (b) : K^+ ions predominate in the intracellular fluid whereas Na^+ ions predominate in extracellular fluid.

3. (c)

4. (c) : A - Action potential
B - Neurotransmitter
C - Receptor
D - Synaptic vesicles.

5. **(b) :** A - Cerebral hemisphere
B - Thalamus
C - Pons varolii
D - Cerebellum.

6. **(d) :** A - Fovea centralis : Sharpest vision occurs here.
B - Blindspot : No image is formed here.
C - Ciliary body: It helps to hold the lens in position.
D - Iris : Visible coloured portion of eye.

7. **(d) :** Hypothalamus lies at the base of the thalamus. It provides anatomical connection between the nervous and endocrine systems by its relationship to the pituitary gland. Hypothalamus is thermoregulatory centre. Hence, it is called "thermostat" of the body. It keeps body temperature at roughly 37°C by means of a complex thermostat system. Any localised injury to hypothalamus will, hence, disrupt regulation of body temperature.

8. **(c) :** Retinal pigment is an aldehyde of vitamin A.

9. **(c)**

10. **(d) :** Vestibular apparatus is a part of inner ear which is located above the choclea. It consists of three semicircular canals, which detect movements of the head, and the utriculus and sacculus which detect the position of head. It does not play any role in hearing, but is responsible for maintaining the balance of the body and posture.

11. **(d) :** Language comprehension is a function of cerebrum. Cerebellum coordinates and controls rapid muscular activities such as running, typing etc. Although it does not initiate such voluntary movements, but it is an important centre for coordinating movements and for controlling posture and balance. Cerebellum's function is almost exclusively motor; but it is also implicated in some forms of learning.

12. **(d) :** The anterior horns of spinal cord contains cells with fibres that form the anterior (motor) root end and are essential for the voluntary and reflex activity of muscles they innervate. If the anterior horn motor cells are destroyed, the nerves cannot regenerate and muscles are never useful again.

13. **(c) :** A small oval, yellowish area of the retina lying exactly opposite the centre of the cornea is named the macula lutea or yellow spot which has at its middle a shallow depression, the fovea centralis. The fovea centralis has cone cells only. It is devoid of rods and blood vessels. The fovea centralis is the place of most distinct vision.

14. **(d) :** The rods contain a photosensitive pigment called the rhodopsin. Rhodopsin is composed of opsin and retinene. The opsin is a protein and is called scotopsin in rhodopsin. The retinene is an aldehyde of vitamin A and is called retinal.

15. **(c) :** Photoreceptors in human eye are unique because they are only type of sensory cells that are relatively depolarised (about –35mV) when it is at rest (*i.e.,* in the dark), and hyperpolarised (to about –70mV) in response to adequate light stimulus. Nociceptors respond to potentially damaging stimuli that result in pain. Meissner's corpuscles are a type of mechanoreceptor, responsible for touch sensitivity. Receptors generally produce graded potentials called receptor potentials.

16. **(d) :** Schwann cells and oligodendrocytes form myelin sheath around the axon. Myelin sheath serves as an insulating layer, preventing loss of energy of the nerve impulse during its passage along the fibre.

17. **(c) :** Neurotransmitter is a chemical substance responsible for transmission of nerve impulse across synapse. It is released by synaptic vesicle into the synaptic cleft. Neurotransmitter binds with protein receptor molecule present on post synaptic membrane causing its depolarisation and generation of action potential.

18. **(b)**

19. **(c) :** The nerve fibres from all parts of the retina converge to leave through a point called blindspot. It is the place in the visual field that corresponds to the lack of light detecting photo receptor cells on the optic disc of the retina. It is devoid of rods and blood vessels. The fovea centralis is the place of most distinct vision. Here the nerve fibres from the light sensitive cells leave the eye ball to form the optic nerve.

20. **(c) :** The neurons and nerve fibres which conduct nerve impulses from the Central Nervous System (CNS) to the peripheral organs and tissues are called efferent neurons and efferent nerve fibres respectively. Some of the neurons and nerve fibres conduct nerve impulses to the muscles and glands to stimulate or inhibit their activities. Many of these nerve fibres cause movements of muscles. So, such neurons and nerve fibres are known as motor neurons and motor nerve fibres, respectively. All motor neurons are efferent neurons, because they conduct impulses from the CNS system to the peripheral tissues *viz.* muscles and glands.