21. Neural Control and Coordination

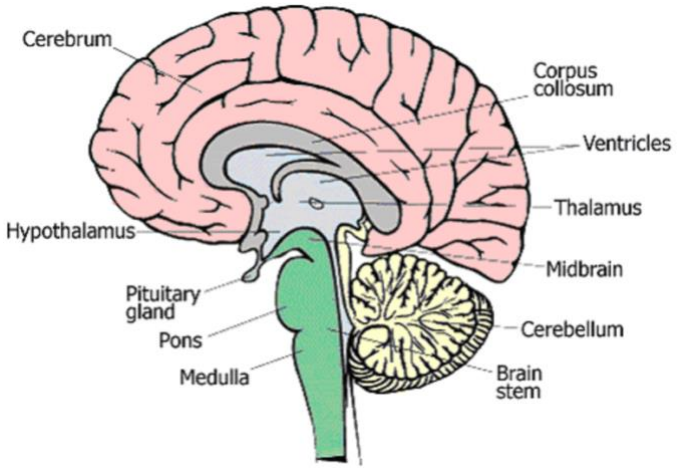
Question 1. Briefly describe the structure of the following:

(a) Brain (b) Eye (c) Ear

Answer: **(A) Brain:**

Brain is the main coordinating centre of the body. It is a part of central nervous system that controls and monitors every organ of the body. It is well protected by cranial meninges that are made up of an outer layer called dura mater, a thin middle layer called arachnoid, and an inner layer called pia mater.

It is divided into three regions − forebrain, midbrain, and hindbrain.



Forebrain: It is the main thinking part of the brain. It consists of cerebrum, thalamus, and hypothalamus.

(a) Cerebrum:

Cerebrum is the largest part of the brain and constitutes about four-fifth of its weight. Cerebrum is divided into two cerebral hemispheres by a deep longitudinal cerebral fissure. These hemispheres are joined by a tract of nerve fibre known as corpus callosum. The cerebral hemispheres are covered by a layer of cells known as cerebral cortex or grey matter. Cerebrum has sensory regions known as association areas that receive sensory impulses from various receptors as well as from motor regions that control the movement of various muscles. The innermost part of cerebrum gives an opaque white appearance to the layer and is known as the white matter.

(b) Thalamus:

Thalamus is the main centre of coordination for sensory and motor signalling. It is wrapped by cerebrum.

(c) Hypothalamus:

It lies at the base of thalamus and contains a number of centres that regulate body temperature and the urge for eating and drinking. Some regions of cerebrum, along with hypothalamus, are involved in the regulation of sexual behaviour and expression of emotional reactions such as excitement, pleasure, fear, etc.

Midbrain:

It is located between the thalamus region of the forebrain and pons region of hindbrain. The dorsal surface of midbrain consists of superior and inferior corpora bigemina and four rounded lobes called corpora quadrigemina. A canal known as cerebral aqueduct passes through the midbrain. Midbrain is concerned with the sense of sight and hearing.

Hindbrain:

It consists of three regions − pons, cerebellum, and medulla oblongata.

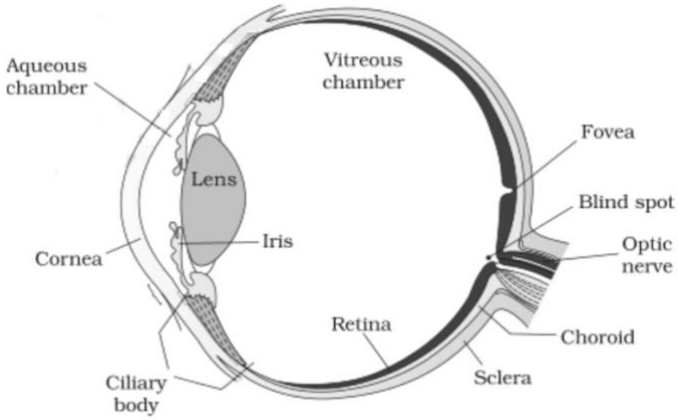
(a) Pons is a band of nerve fibre that lies between medulla oblongata and midbrain. It connects the lateral parts of cerebellar hemisphere together.

(b) Cerebellum is a large and well developed part of hindbrain. It is located below the posterior sides of cerebral hemispheres and above medulla oblongata. It is responsible for maintaining posture and equilibrium of the body.

(c) Medulla oblongata is the posterior and simplest part of the brain. It is located beneath the cerebellum. Its lower end extends in the form of spinal cord and leaves the skull through foramen magnum.

(B) Eye:

Eyes are spherical structures that consist of three layers.



Eye

(a) The outer layer is composed of sclera and cornea.

(i) Sclera is an opaque tissue that is usually known as white of the eye. It is composed of a dense connective tissue.

(ii) Cornea is a transparent anterior portion of eye that lacks blood vessels and is nourished by lymph from the nearby area. It is slightly bulged forward and helps in focusing light rays with the help of lens.

(b) The middle layer of eye is vascular in nature and contains choroid, ciliary body, and iris.

(i) Choroid lies next to the sclera and contains numerous blood vessels that provide nutrients and oxygen to the retina and other tissues.

(ii) Ciliary body: The choroid layer is thin over posterior region and gets thickened in the anterior portion to form ciliary body. It contains blood vessels, ciliary muscles, and ciliary processes.

(iii) Iris: At the junction of sclera and cornea, the ciliary body continues forward to form thin coloured partition called iris. It is the visible coloured portion of eye.

The eye contains a transparent, biconvex, and elastic structure just behind the iris. It is known as lens. The lens is held in position by suspensory ligaments attached to the ciliary body. The lens divides the eye ball into two chambers – an anterior aqueous and posterior vitreous chamber.

(c) The innermost nervous coat of eye contains retina. Retina is the innermost layer. It contains three layers of cells – inner ganglion cells, middle bipolar cells, and outermost photoreceptor cells. The receptor cells present in the retina are of two types – rod cells and cone cells.

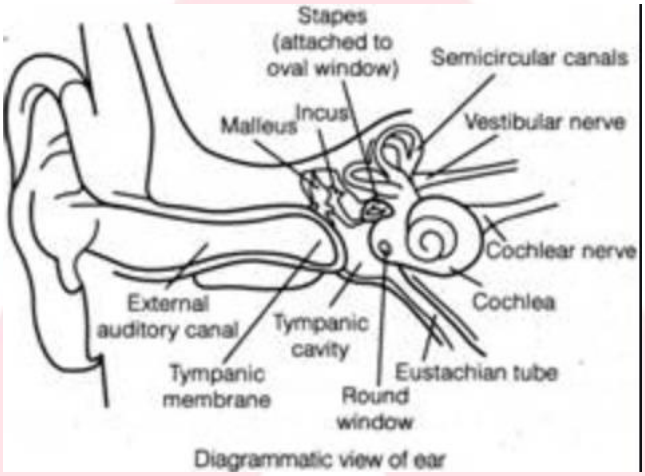
(a) Rod cells –The rods contain the rhodopsin pigment (visual purple) that is highly sensitive to dim light. It is responsible for twilight vision.

(b) Cone cells –The cones contain the iodopsin pigment (visual violet) and are highly sensitive to high intensity light. They are responsible for daylight and colour visions.

The innermost ganglionic cells give rise to optic nerve fibre that forms optic nerve in each eye and is connected with the brain.

(C) Ear:

Ear is the sense organ for hearing and equilibrium. It consists of three portions – external ear, middle ear, and internal ear.



Diagrammatic view of ear

1. External ear:

It consists of pinna, external auditory meatus, and a tympanic membrane.

(a) Pinna is a sensitive structure that collects and directs the vibrations into the ear to produce sound.

(b) External auditory meatus is a tubular passage supported by cartilage in external ear.

(c) Tympanic membrane is a thin membrane that lies close to the auditory canal. It separates the middle ear from external ear.

2. Middle ear:

It is an air-filled tympanic cavity that is connected with pharynx through eustachian tube. Eustachian tube helps to equalize air pressure in both sides of tympanic membrane. The middle ear contains a flexible chain of three middle bones called ear ossicles. The three ear ossicles are malleus, incus, and stapes that are attached to each other.

3. Internal ear:

It is also known as labyrinth. Labyrinth is divided into bony labyrinth and a membranous labyrinth. Bony labyrinth is filled with perilymph while membranous labyrinth is filled with endolymph. Membranous labyrinth is divided into 2 parts.

(a) Vestibular apparatus

Vestibular apparatus is a central sac-like part that is divided into utriculus and sacculus. A special group of sensory cells called macula are present in sacculus and utriculus.

Vestibular apparatus also contains three semi-circular canals. The lower end of each semi-circular canal contains a projecting ridge called crista ampularis. Each ampulla has a group of sensory cells called crista. Crista and macula are responsible for maintaining the balance of body and posture.

(b) Cochlea:

Cochlea is a long and coiled outgrowth of sacculus. It is the main hearing organ. Cochlea consists of three membranes. The organ of corti, a hearing organ, is located on the basilar membrane that has hair cells.

Question 2. Compare the following:

(a) Central neural system (CNS) and Peripheral neural system (PNS)

(b) Resting potential and action potential

(c) Choroid and retina

Answer:
(a) Central nervous system (CNS) and peripheral nervous system (PNS)

CNS	PNS
Central neural system is the main coordinating centre of the body	Peripheral neural system is not the main coordinating centre of the body.
It includes brain and spinal cord.	It includes cranial and spinal nerves that connect central nervous system to different parts of the body.

(b) Resting potential and action potential

Resting potential	Action potential
Resting potential is the potential difference across the nerve fibre when there is no conduction of nerve impulse.	Action potential is the potential difference across nerve fibre when there is conduction of nerve impulse.
The membrane is more permeable to K+ ions than to Na+ ions.	The membrane is more permeable to Na+ ions than to K+ ions.

(c) Choroid and Retina

Choroid	Retina
Choroid is the middle vascular layer of eye.	Retina is the innermost nervous coat of eye.
It contains numerous blood vessels that provide nutrients and oxygen to retina and other tissues.	It contains photoreceptor cells, rods and cones that are associated with twilight and colour vision respectively.

Question 3. Explain the following processes:

(a) Polarisation of the membrane of a nerve fibre

(b) Depolarisation of the membrane of a nerve fibre

(c) Conduction of a nerve impulse along a nerve fibre

(d) Transmission of a nerve impulse across a chemical synapse

Answer:

(i) Polarisation of the membrane of a nerve fibre: When a neuron is not conducting an impulse, i.e., resting, the axonal membrane is more permeable to K+ and nearly impermeable to Na+ . Similarly, the membrane is impermeable to negatively charged proteins present in the axoplasm. Consequently, the axoplasm contains high concentration of K+ and negatively charged proteins and low concentration of Na+ . In contrast, the fluid outside contains a low concentration of K+ , a high concentration of Na and thus forms a concentration gradient. These ionic gradients across the resting membrane are maintained

by the sodium-potassium pump. As a result, the outer surface of the axonal membrane possesses a positive charge while its inner surface becomes negatively charged and therefore is polarised.

(ii) Depolarization of the membrane of a nerve fibre:

(a) Stimulation of an axon immediately enhances manifold its membrane permeability to Na+. As a result, Na+ ions diffuse across the membrane from the extracellular fluid (ECF) where their concentration is higher, to the interior of the fibre where the concentration is much lower. But the membrane permeability to K+ starts rising somewhat later only, so there is simultaneous rise in the outward diffusion of K+ from the cell interior having a higher K+ concentration.

(b) These effects lower the overall cation concentration outside and enhance its concentration inside the membrane.

(c) The membrane is, thus deposited, with its interior becoming electropositive to the exterior.

(d) The depolarization spreads a local current. It induces nearby passive Na+ channels to open and so as to depolarize the nearby site.

(e) Hence the initial depolarization passes outward over the membrane and spreads out in all directions from the site of stimulation.

(iii) Conduction of nerve impulse along a nerve fibre:

(a) It is a property of nerve fibre to become excited by a stimulus and then conduct that stimulus for the required and appropriate response.

(b) In conducting a stimulus, the nerve axon has to pass through resting phase to active phase and then the recovery phase.

(iv) Transmission of a Nerve impulse across a chemical Synapse:

(a) The physiological junction between two neurons across which nerve impulses can be transmitted is known as synapse.

(b) Synapse occur between the knob like axon endings of one neuron and the dendrites of cell body of another.

(c) At the junction of two neurons a narrow fluid filled space called synaptic cleft is present.

(d) Knob like endings of one neuron form many membrane bound vesicles called synaptic vesicles.

(e) Since they help in the transmission of nerve impulse, they are also called as neurotransmitters.

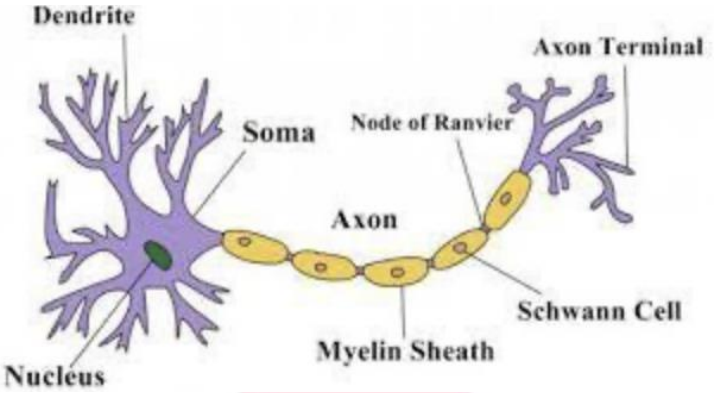
(f) When a nerve impulse reaches the axon terminal the synaptic vesicles get stimulated and release their stored chemicals in the synaptic cleft. These chemicals then diffuse through these clefts to reach the membrane of the next neurons and stimulate the next neurons.

Question 4. Draw labelled diagrams of the following:

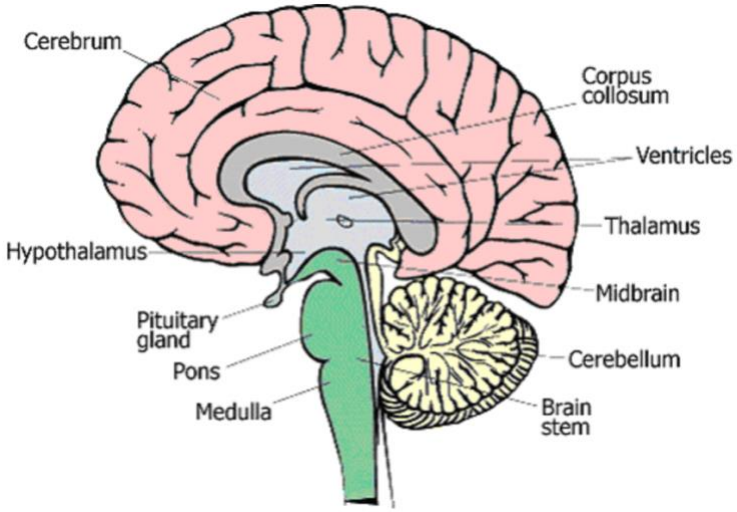
(a) Neuron (b) Brain (c) Eye (d) Ear

Answer:

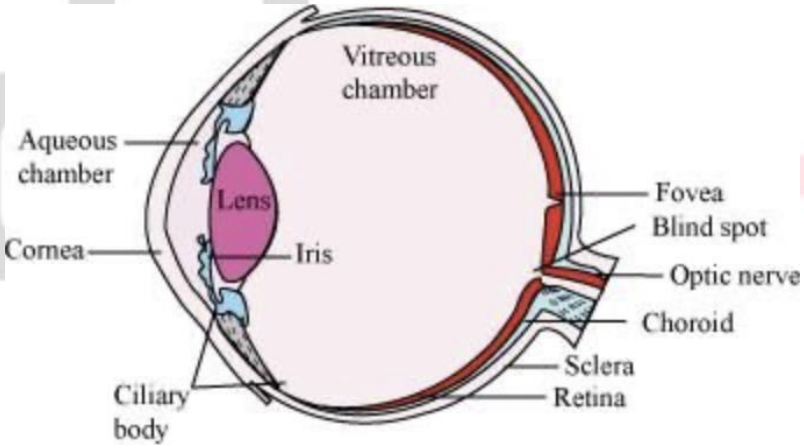
(a) Neuron



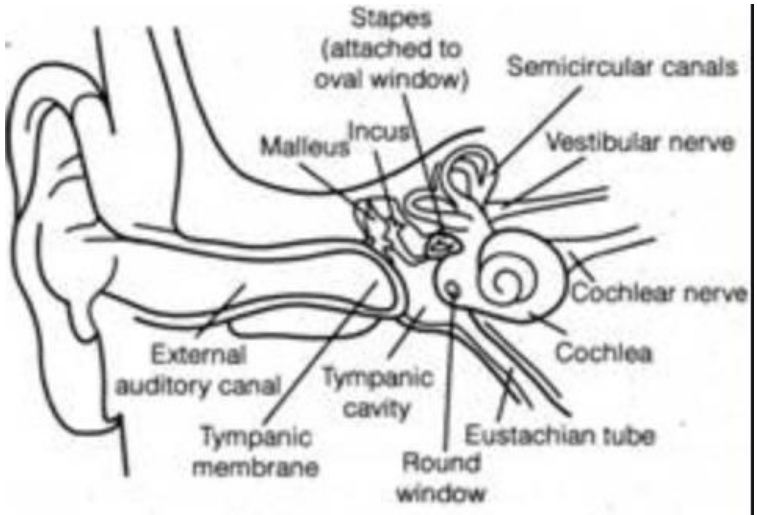
(b) Brain



(c) Eye



(d) Ear



Diagrammatic view of ear

Question 5. Write short notes on the following:

(a) Neural coordination

(b) Forebrain

(c) Midbrain

(d) Hindbrain

(e) Retina

(f) Ear ossicles

(g) Cochlea

(h) Organ of Corti

(i) Synapse

Answer:

(a) Neural coordination : When higher animals respond to various stimuli, each response to a specific stimulus generally involves many organs (parts) of their bodies. Therefore, it is necessary that all the concerned organs (parts) of the body should work in a systematic manner to produce the response. The working together of various organs (parts) of the body of multicelullar organism in a proper manner to complement the functions of each other is called coordination. This is achieved by three overlapping processes of nervous system-sensory input, integration and motor output.

(b) Forebrain: It consists of: Olfactory lobes, the paired structures concerned with the sense of smell. Cerebrum which is the largest and most complex of all the parts of the human brain. It is divided by a cleft into left and right cerebral hemispheres which are connected by a large bundle of myelinated fibres the. corpus callosum. The outer cover of cerebral hemisphere is called cerebral cortex. It consists of sensory and motor areas. Hypothalamus region of forebrain contains centres which control body temperature, hunger and also contains group of neurosecretory cells.

(c) Midbrain: The midbrain is located between the thalamus/hypothalamus of the forebrain and pons of the hindbrain. A canal called the cerebral aqueduct passess through the midbrain. The dorsal portion of the midbrain consists mainly of four round swellings (lobes) called corpora quadrigemina. Midbrain and hindbrain form the brain stem.

(d) Hindbrain: The hindbrain comprises pons, cerebellum and medulla. Pons consists of fibre tracts that interconnect different regions of the brain. Cerebellum has very convoluted surface in order to provide the additional space of many more neurons. The medulla of the brain is connected to the spinal cord. The medulla contains centres which control respiration, cardiovascular reflexes and gastric secretions.

(e) Retina: Retina is the inner layer of an eye and it contains three layers of cells-from inside to outside – ganglion cells, bipolar cells and photoreceptor cells. There are two types of photoreceptor cells, namely, rods and cones. These cells contain the light-sensitive proteins called the photopigments. The daylight (photopic) vision and colour vision are functions of cones and the twilight (scotopic) vision is the function of the rods. The rods contain a purplish-red protein called the rhodopsin or visual purple, which contains a derivative of Vitamin A. In the human eye, there are three types of cones which possess their own characteristic photopigments that respond to red, green and blue lights. The sensations of different colours are produced by various combinations of these cones and their photopigments. When these cones are stimulated equally, a sensation of white light is produced.

(f) Ear ossicles : There is a small flexible chain of three small bones called as ear ossicles – the malleus (hammer shaped), the incus (anvil shaped) and the stapes (stirrup shaped) in the middle ear. Malleus is attached to the tympanic membrane on one side and incus on the other side. Incus in turn is connected with the stapes. Malleus is the largest ossicle, however stapes is the smallest ossicle.

(g) Cochlea : It is the main hearing organ which is connected with saccule. It is a spirally coiled tube that resembles a snail shell in appearance. It tapers from a broad base to an almost pointed apex.
(h) Organ of Corti: It is a structure located on the basilar membrane which contains hair cells that act as auditory receptors. The hair cells are present in rows on the internal side of the organ of Corti.

(i) Synapse : It is the junction between the axon of one neuron and the dendrite or cyton of another neuron for transmission of nerve impulse.

Question 6. Give a brief account of:

(a) Mechanism of synaptic transmission

(b) Mechanism of vision

(c) Mechanism of hearing

Answer:

(a) Synapse is a junction between two neurons. It is present between the axon terminal of one neuron and the dendrite of next neuron separated by a cleft.

There are two ways of synaptic transmission.

(1) Chemical transmission

(2) Electrical transmission

1. Chemical transmission: When a nerve impulse reaches the end plate of the axon, it releases a neurotransmitter (acetylcholine) across the synaptic cleft. This chemical is synthesized in the cell body of the neuron and is transported to the axon terminal. The acetylcholine diffuses across the cleft and binds to the receptors present on the membrane of next neuron. This causes depolarization of membrane and initiates an action potential.

2. Electrical transmission: In this type of transmission, an electric current is formed in the neuron. This electric current generates an action potential and leads to transmission of a nerve impulse across the nerve fibre. This represents a faster method of nerve conduction than the chemical method of transmission.

(b) Mechanism of vision

Retina is the innermost layer of the eye. It contains three layers of cells – inner ganglion cells, middle bipolar cells, and outermost photoreceptor cells. A photoreceptor cell is composed of a protein called as opsin and an aldehyde of vitamin A called as retinal. When light rays are focused on the retina through the cornea, it leads to the dissociation of retinal from opsin protein. This changes the structure of opsin. As the structure of opsin changes, the permeability of membrane changes, generating a potential difference in the cells. This generates an action potential in the ganglionic cells and is transmitted to the visual cortex of the brain via optic nerves. In the cortex region of the brain, the impulses are analysed and the image is formed on the retina.

(c) Mechanism of hearing

The pinna of the external region collects the sound waves and directs it towards ear drum or external auditory canal. These waves strike the tympanic membrane and vibrations are created. Then, these vibrations are transmitted to the oval window, fenestra ovalis, through three ear ossicles, named as malleus, incus, and stapes. These ear ossicles act as a lever and transmit the sound waves to internal ear. These vibrations from fenestra ovalis are transmitted into the cochlear fluid. This generates sound waves in the lymph. The formation of waves generates a ripple in the basilar membrane. This

movement bends the sensory hair cells present on the organ of Corti against tectorial membrane. As a result of this, sound waves are converted into nerve impulses. These impulses are then carried to the auditory cortex of brain via auditory nerves. In cerebral cortex of the brain, the impulses are analysed and the sound is recognized.

Question 7. Answer briefly:

(a) How do you perceive the colour of an object?

(b) Which part of our body helps us in maintaining the body balance?

(c) How does the eye regulate the amount of light that falls on the retina?

Answer:
(a) Photoreceptors are cells that are sensitive to light . They are of two types - rods and cones. These are present in the retina . Cones help in distinguishing colours. There are three types of cone cells - those responding to green light , those responding to blue light , and those responding to red light .

(b) Vestibular apparatus is located in the internal ear , above the cochlea and helps in maintaining body balance.
Crista and macuta are the sensory spots of the vestibular apparatus controlling dynamic equilibrium .

(c) Pupil is the small aperture in the iris that regulates the amount of light entering the eye . Cornea , aqueous humour , lens and vitreous humour act together and refract light rays , focussing them onto the photoreceptor cells of the retina.

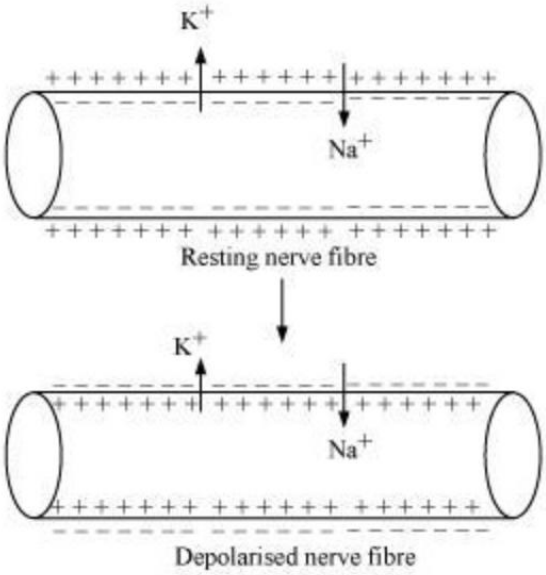
Question 8. Explain the following:

(a) Role of Na+ in the generation of action potential.

(b) Mechanism of generation of light-induced impulse in the retina.

(c) Mechanism through which a sound produces a nerve impulse in the inner ear.

Answer:
(a) Sodium ions play an important role in the generation of action potential. When a nerve fibre is stimulated, the membrane potential decreases. The membrane becomes more permeable to Na^+ ions than to K^+ ions. As a result, Na^+ diffuses from the outside to the inside of the membrane. This causes the inside of the membrane to become positively-charged, while the outer membrane gains a negatively charge. This reversal of polarity across the membrane is known as depolarisation. The rapid inflow of Na^+ ions causes the membrane potential to increase, thereby generating an action potential.



(b) Retina is the innermost layer of the eye. It contains three layers of cells – inner ganglion cells, middle bipolar cells, and outermost photoreceptor cells. Photoreceptor cells are composed of a protein called opsin and an aldehyde of vitamin A called retinal. When light rays are focused on the retina through the cornea, retinal gets dissociated from opsin. As a result, the structure of opsin gets changed. This in turn causes the permeability of the membrane to change, thereby generating a potential difference in the cells. Consequently, an action potential is generated in the ganglion cells and is transmitted to the visual cortex of the brain via the optic nerves. In the cortex region of the brain, the impulses are analysed and the image is formed on the retina.

(c) The pinna of the external ear collects the sound waves and directs them to the tympanic membrane (ear drum) via the external auditory canal. The ear drum then vibrates the sound waves and conducts them to the internal ear through the ear ossicles. The ear ossicles increase the intensity of the sound waves. These vibrating sound waves are conducted through the oval window to the fluid in the cochlea. Consequently, a movement is created in the lymph. This movement produces vibrations in the basilar membrane, which in turn stimulate the auditory hair cells. These cells generate a nerve impulse, conducting it to the auditory cortex of the brain via afferent fibres. The auditory cortex region interprets the nerve impulse and sound is recognised.

Question 9. Differentiate between:

(a) Myelinated and non-myelinated axons

(b) Dendrites and axons

(c) Rods and cones

(d) Thalamus and Hypothalamus

(e) Cerebrum and Cerebellum

Answer:

(a) Myelinated and non-myelinated axons

Myelinated axons	Non-myelinated axons
Myelin sheath is present around them.	Myelin sheath is absent.
Nodes of Ranvier are present at intervals.	Nodes of Ranvier are absent.
They appear white in fresh state.	They appear grey in fresh state.
Conduction is fast.	Conduction is low.

(b) Dendrites and axons

Dendrites	Axons
These are the extensions of the cyton present at the anterior position.	These are the extensions of the cyton present at the posterior position.
These are numerous in number.	These are only one in a neuron.

(c) Rods and cones

Rods	Cones
They are about 120 million in human eye.	They are about 7 millions in human eye.
Outer segment is cylindrical and contains rhodopsin.	Outer segment is conical and contains iodopsin.
Inner end bears a knob.	Inner end is branched.
All the rod cells are alike and take no part in colour vision.	Cone cells provide colour vision.
These cells are sensitive to low light intensity and function in dim light.	Cone cells are sensitive to high light intensity i.e., function in bright light.

(d) Thalamus and hypothalamus

Thalamus	Hypothalamus
The side of the diencephalon is called thalamus.	The floor of the diencephalon is called hypothalamus.
It is a major coordinating centre for sensory and motor signalling.	It has centres that control body temperature, eating and drinking.
It secretes no hormones.	It secretes hormones.

(e) Cerebrum and Cerebellum

Cerebrum	Cerebellum
Brain is majorly covered by the cerebrum	Second largest part of the brain after cerebrum
It is a part of forebrain.	It is a part of hindbrain.
The two sides are connected by corpus callosum.	The two sides are joined by pons varolli.
The cavities are called lateral ventricles.	It contains a narrow cerebellar ventricle.

Question 10. Answer the following:

(a) Which part of the ear determines the pitch of a sound?

(b) Which part of the human brain is the most developed?

(c) Which part of our central neural system acts as a master clock?

Answer:
(a) Cochlea determines the pitch of a sound.

(b) Forebrain is largest and the most developed part of the human brain.

(c) Hypothalamus acts as a master clock in the human body.

Question 11. The region of the vertebrate eye, where the optic nerve passes out of the retina, is called the

(a) fovea

(b) iris

(c) blind spot

(d) optic chaisma

Answer: Blind spot is the part where the optic nerve passes out of the retina. Photoreceptors are absent in this region. Blind spot is a small portion of the visual field of each eye that corresponds to the position of the optic disc (also known as the optic nerve head) within the retina. There are no photoreceptors (i.e., rods or cones) in the optic disc, and, therefore, there is no image detection in this area. So, the correct answer is option C.

Question 12. Distinguish between:

(a) afferent neurons and efferent neurons

(b) impulse conduction in a myelinated nerve fibre and unmyelinated nerve fibre

(c) aqueous humor and vitreous humor

(d) blind spot and yellow spot

(e) cranial nerves and spinal nerves.

Answer:
(a) Afferent neurons and efferent neurons

Afferent neurons	Efferent neurons
Afferent neuron conducts nerve impulses toward the brain or the spinal cord.	Efferent neuron conducts nerve impulses from the brain or spinal cord to the effector organs such as muscles or glands.

(b) Impulse conduction in a myelinated nerve fibre and an unmyelinated nerve fibre

Impulse conduction in a myelinated nerve fibre	Impulse conduction in an unmyelinated nerve fibre
In a myelinated nerve fibre, the action potential is conducted from one node to another.	In an unmyelinated nerve fibre, the action potential is not conducted from node to node. It is carried along the whole length of the nerve fibre.
The conduction of impulses is faster.	The conduction of impulses is slower.

(c) Aqueous humour and vitreous humour

Aqueous humour	Vitreous humour
It is a thin, watery fluid present between the cornea and the lens.	It is a transparent gel present between the lens and the retina.

(d) Blind spot and yellow spot

Blind spot	Yellow spot
Blind spot is a spot on the retina present at the point of origin of the optic nerve.	Yellow spot is a small area on the retina present at the posterior pole of the eye, lateral to the blind spot.
Photoreceptor cells are absent from this region.	Only cones are present in this region.
They are insensitive to light as both rods and cones are absent.	They are sensitive to bright light as cones are present.

(e) Cranial nerves and spinal nerves

Cranial nerves	Spinal nerves
Cranial nerves arise from the brain.	Spinal nerves arise from the spinal cord.
There are 12 pairs of cranial nerves.	There are 31 pairs of spinal nerves.