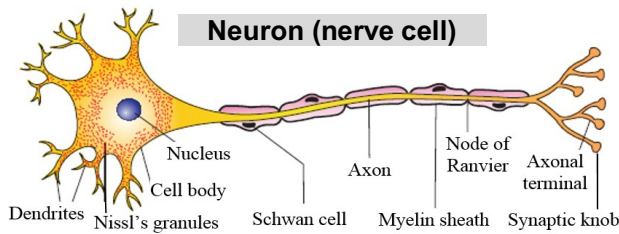


# NEURAL CONTROL AND CO-ORDINATION

- Neural (Nervous) system is a system that controls and coordinates the body activities, conducts and integrates the information and responds to stimuli.
- It includes **brain, spinal cord** and **nerves**.
- It is made up of specialized cells known as **neurons**.



Neuron is the **structural and functional unit** of neural system. It is composed of

- **Cell body (cyton):** Contains cytoplasm, cell organelles and **Nissl's granules** (granular bodies).
- **Dendron:** Short fibres projecting from the cyton. Their sub branches (**dendrites**) transmit impulses towards the cyton.

- **Axon:** A long fibre which transmit impulses away from the cell body. The branching of axon is called **axonite**. Each axonite ends as a bulb-like structure called **synaptic knob**.

## Types of Neurons

- **Unipolar:** One axon. No Dendron. Found in embryo.
- **Bipolar:** One axon and one dendron. Found in the retina.
- **Multipolar:** One axon and 2 or more dendrons. Most common type. Found in the CNS & PNS.

## Types of axon

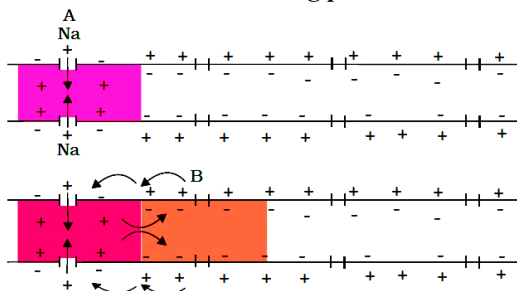
- **Myelinated axon:** It is enveloped with **Schwann cells** that form a **myelin sheath** around the axon. Found in **spinal & cranial nerves**. The white coloured area, formed of myelinated nerve fibres is called **white matter**. Gaps b/w 2 adjacent myelin sheaths are called **nodes of Ranvier**.
- **Non-myelinated axon:** Schwann cells present but no myelin sheath. The gray coloured area without myelin sheath is called **gray matter**. Found in **autonomous & somatic neural systems**.

## GENERATION & CONDUCTION OF NERVE IMPULSES

Impulse transmission is **electrochemical**. It has 3 steps:

### 1. Maintenance of resting membrane potential

- Neural membrane contains various selectively permeable ion channels.
- In a resting neuron (neuron not conducting impulse), the axonal membrane is more permeable to  $K^+$  ions and nearly impermeable to  $Na^+$  ions. Also, the membrane is impermeable to negatively charged proteins in axoplasm.
- Therefore, concentration of  $K^+$  and  $-vely$  charged proteins in axoplasm is high and concentration of  $Na^+$  is low.
- The fluid outside the axon contains low concentration of  $K^+$  and high concentration of  $Na^+$ . This forms an ionic or concentration gradient across resting membrane.
- The ionic gradients are maintained by the active transport of ions by the **Na-K pump**. It transports **3  $Na^+$**  outwards for **2  $K^+$**  into the cell. As a result, the outer surface becomes positively charged and inner surface becomes negatively charged (i.e, polarized).
- The electrical potential difference across the resting plasma membrane is called as the **resting potential**.



### 2. Action Potential

- When a stimulus is applied, the membrane at the site A becomes permeable to  $Na^+$ . This causes rapid influx of  $Na^+$  and reversal of the polarity at that site (outer negative and inner positive). It is called **depolarization**.

- The electrical potential difference during depolarization across the plasma membrane is called **action potential** (a **nerve impulse**).

### 3. Propagation of action potential

- At sites ahead (site B), outer surface is positive and inner surface is negative. As a result, a current flows on the inner surface from site A to site B.
- On the outer surface, current flows from site B to site A to complete the circuit. Hence, the polarity is reversed and action potential is generated at site B. i.e., action potential at site A arrives at site B.
- The sequence is repeated along the axon and the impulse is conducted.
- The rise in permeability to  $Na^+$  is extremely short lived. It is quickly followed by a rise in permeability to  $K^+$ .
- Immediately,  $K^+$  diffuses outside the membrane and restores the resting membrane. Thus the fibre becomes ready for further stimulation.

### Synaptic transmission of impulses

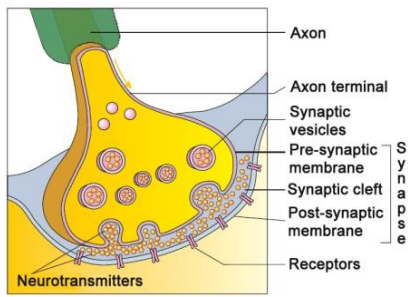
- Synapse is a functional junction between two neurons.
- It is 2 types: **Electrical & Chemical**.

#### 1. Electrical synapses

- In this, the membranes of pre- and post-synaptic neurons are in close proximity. So impulse transmission is similar to the transmission along an axon.
- Impulse transmission is faster than in chemical synapse.
- Electrical synapses are very rare in human system.

#### 2. Chemical synapses

- In this, there is a fluid filled space (**synaptic cleft**) between the presynaptic neuron and postsynaptic neuron.
- The presynaptic regions have swellings called **Synaptic knob (buttons)**. They contain **synaptic vesicles** filled with **neurotransmitters (acetylcholine or adrenaline)**.



### Impulse transmission through chemical synapse:

*Impulse reaches at axon terminal → synaptic vesicles bind on plasma membrane → release of neurotransmitter → It diffuses across synaptic cleft → combine with receptors on the post synaptic membrane → opening of ion channels allowing entry of ions → generates action potential.*

- This action potential may be excitatory or inhibitory.

## HUMAN NERVOUS (NEURAL) SYSTEM

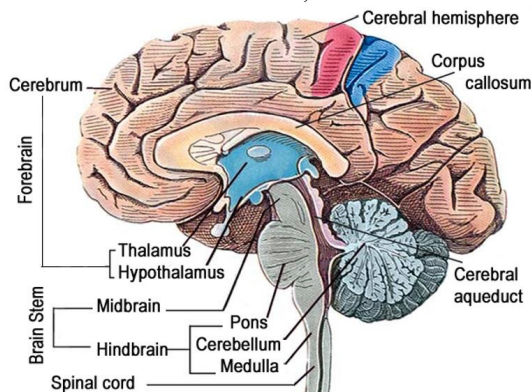
It has 2 parts:

- **Central neural system (CNS):** Brain & spinal cord.
- **Peripheral nervous system (PNS):** All nerves.

### CENTRAL NEURAL SYSTEM (CNS)

#### A. BRAIN

- It is protected in **cranial cavity**.
- It has 3-layered connective tissue membranes called **cranial meninges**.
- Meninges consist of outer **dura mater**, middle **arachnoid mater** and inner **pia mater**.
- The **subarachnoid space** (space between pia mater and arachnoid mater) is filled with **cerebrospinal fluid (CSF)**. The **ventricles** of brain are also filled with CSF.
- Brain has 3 divisions: Forebrain, Midbrain & Hindbrain.



#### a. Forebrain (Prosencephalon)

It is the anterior part. Consists of **cerebrum & diencephalon**.

##### Cerebrum

- Largest part. It has 2 **cerebral hemispheres** held together by a tract of nerve fibres (**Corpus callosum**).
- Outer part of cerebrum is called **cerebral cortex**. It has convulsions & depressions and is formed of **gray matter**. Gray colour is due to the presence of neuron cell bodies.
- Inner part of cerebrum is formed of **white matter**.
- Cerebral cortex consists of
  - **Motor area:** Controls voluntary movements of muscles.
  - **Sensory (Somaesthetic) area:** Controls the functioning of sense organs.
  - **Association area:** It is neither clearly sensory nor motor in function. Responsible for intersensory associations, memory and communication.

Integrated activities of different centres of cerebral cortex control intelligence, memory, judgment, learning, thinking and articulate speech.

#### Diencephalon (Thalamus & Hypothalamus)

- **Thalamus:** It is the structure around which the cerebrum wraps. It is a coordinating centre (relay station) for sensory and motor impulses.
- **Hypothalamus:** Seen below the thalamus. It
  - Regulates temperature, thirst, hunger and emotions.
  - Secretes hypothalamic hormones.
  - Controls pituitary gland.
  - Controls sleep, wakefulness, blood pressure, heart rate.
- The inner parts of cerebral hemispheres and a group of associated deep structures like **amygdala, hippocampus, hypothalamus**, etc. together constitute **Limbic system (Limbic lobe)**. It regulates sexual behavior, motivations, emotions (excitement, pleasure, rage, fear etc).

#### b. Midbrain (Mesencephalon)

- It is located between **thalamus/hypothalamus** and **Pons**.
- A canal (**cerebral aqueduct**) passes through the mid brain.
- Mid brain consists of 4 round lobes called **Corpora quadrigemina**. Their anterior pair is the centre of **visual reflexes** and the posterior pair is a centre of **auditory reflex**.

#### c. Hindbrain (Rhombencephalon)

It consists of **cerebellum, Pons & Medulla oblongata**.

Midbrain & hindbrain form the **Brain stem**.

- **Cerebellum ("little cerebrum"):** It has very convoluted surface to accommodate more neurons. It co-ordinates muscular activities and body equilibrium.
- **Pons varoli:** It consists of fibre tracts that interconnect different regions of the brain. It co-ordinates the activities of eye and ear and regulates respiration.
- **Medulla oblongata:** It is connected to spinal cord. It controls respiration, cardiovascular reflexes, gastric secretions, peristalsis etc. It also controls salivation, vomiting, sneezing & coughing.

## B. SPINAL CORD

- It is enclosed within the spinal canal of vertebral column.
- It is also protected by meninges.
- Spinal cord has a central canal containing CSF.
- Outer white matter and inner gray matter.

**Functions:**

- Conduction of impulses to and from the brain.
- Centre of spinal reflexes.

### PERIPHERAL NEURAL SYSTEM (PNS)

It includes **cranial nerves** and **spinal nerves**.

Nerve fibres of PNS are 2 types:

- **Afferent (sensory) fibres:** Carry impulses from sense organs to CNS.
  - **Efferent (motor) fibres:** Carry impulses from CNS to muscles and glands.
- PNS has 2 divisions. They are
- **Somatic neural system:** Relays impulses from the CNS to skeletal muscles.
  - **Autonomic neural system (ANS):** Transmits impulses from CNS to involuntary organs & smooth muscles. It includes *sympathetic* & *parasympathetic* nerves. Sympathetic system prepares body to cope with emergencies, stresses & dangers. It increases heartbeat, breathing rate, constricts arteries and elevates BP. Parasympathetic system returns the body to a resting state after stressful situations and slows down heartbeat, dilates arteries, lowers BP etc.

**Visceral nervous system** is the part of PNS. It includes **nerves, fibres, ganglia & plexus** by which impulses travel from CNS to the viscera and from viscera to CNS.

## REFLEX ACTION

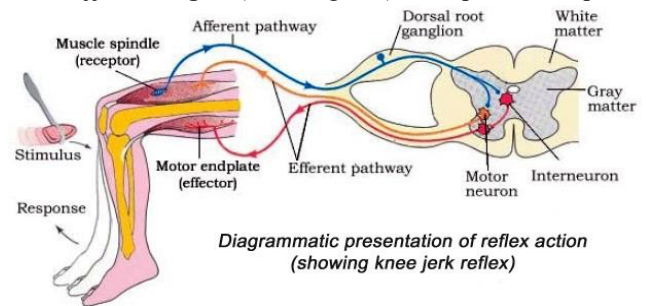
It is the **rapid, involuntary** and **unconscious actions** of body in response to a stimulus. E.g.

- ♦ Withdrawal of the hand when it touches a hot object.
- ♦ Touching lips of a nursing baby evokes sucking reflex.

- ♦ Closing of the eyelids when light falls on them.
- ♦ Knee jerk phenomenon.
- ♦ If a child sees or smells a food unknown to him, he does not salivate. But if he sees or smells that food every time before tasting it, he salivates (**conditioned reflex**).

The pathway of impulses in a reflex action is called **Reflex arc**. It consists of

- A **receptor organ:** It receives the stimulus.
- **Sensory (afferent) neuron:** It transmits impulses from sense organ to CNS.
- **Intermediate (connector) neuron:** It connects sensory and motor neurons.
- **Motor (efferent/effector/excitor) neuron:** It conducts impulse from the CNS to effector organ.
- An **effector organ** (muscle/gland): It responds to impulse.

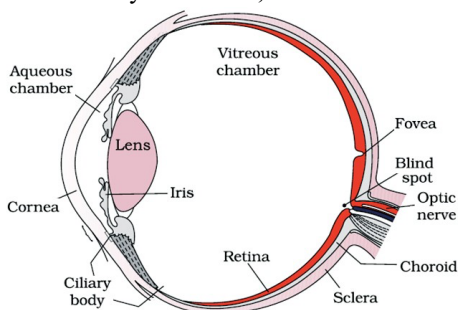


## SENSORY RECEPTION & PROCESSING (SENSE ORGANS)

- These are the organs that detect the changes in the environment and convey the information to the CNS.
- It includes **eye, ear, nose, tongue & skin**.

### EYE

- Two eyes are located in sockets of the skull called **orbits**.
- The adult human eyeball is nearly spherical.
- Eyeball has three layers: **Sclera, Choroid & Retina**.



#### a. Sclera

- The external layer formed of a dense connective tissue.
- Anterior transparent portion of sclera is called **cornea**.

#### b. Choroid

- Bluish middle layer. Contains many blood vessels.
- Choroid is thin over posterior two-thirds of the eyeball, but it is thick in the anterior part to form **ciliary body**.
- Ciliary body continues forward to form a visible pigmented and opaque portion of the eye called the **iris**.
- Iris has a central opening called **pupil**. The diameter of the pupil is regulated by the muscle fibres of iris. This helps to regulate the amount of light entering the eye.
- The eyeball contains a transparent crystalline **lens**. It is held in place by **ligaments** attached to the ciliary body.

#### c. Retina

- Inner layer. It contains 3 layers of cells – from inner to outer – **ganglion cells, bipolar cells & photoreceptor cells**.
- Photoreceptor cells are 2 types: **rods** and **cones**. They contain **photosensitive proteins (photopigments)**.
- Photopigments are formed of **opsin** (a protein) and **retinal** (an aldehyde of vitamin A).

#### Cone cells:

- **Function: Daylight (photopic) vision & colour vision.**
- There are 3 types of cones containing photopigments (**photopsin**) that respond to red, green and blue lights.
- The sensations of different colours are produced by combinations of these cones and their photopigments.
- When the cones are stimulated equally, a sensation of white light is produced.

#### Rod cells:

- **Function: Twilight (scotopic) vision.**
- They contain a purplish-red protein called **rhodopsin** (visual purple). It contains a derivative of **Vitamin A**.
- At the region, slightly above the posterior pole of the eyeball, **optic nerves** leave the eye and retinal blood vessels enter it. Here, photoreceptor cells are absent. It is called **blind spot**.
- Lateral to the blind spot, there is a yellowish pigmented spot called **macula lutea** with a central pit (**fovea**).
- The fovea is a thinned-out portion of the retina where only the cones are densely packed. It is the point of greatest visual acuity (resolution).
- The space between the cornea and lens is called **aqueous chamber**. It contains **aqueous humor** (thin watery fluid).

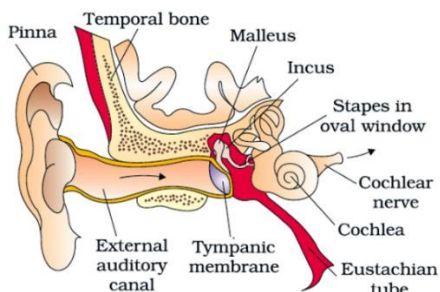
- The space between the lens and retina is called **vitreous chamber**. It contains **vitreous humor** (a transparent gel).

### Mechanism of vision

Light reflected from an object → enters the eye through cornea & lens → focus on retina → dissociation of **retinal** from **opsin** → changes in **membrane permeability** → generates potential differences (impulse) in photoreceptor cells → generates action potentials in ganglion cells through bipolar cells → impulses are transmitted by **optic nerves** to brain (**visual cortex**) → impulses are analyzed and the image is recognized based on memory and experience → vision.

## EAR (STATO-ACOUSTIC ORGAN)

- It is the organ for hearing & balancing.
- It has 3 divisions: **External ear, middle ear & inner ear.**



### External ear

- Consists of **pinna (ear lobe)** & **auditory meatus (ear canal)**.
- At the opening of ear canal, hairs are seen.
- Ear canal and skin of pinna contains **ceruminous glands** (modified sweat glands). They secrete **wax (cerumen)**.
- Wax and hairs protects ears from foreign objects.
- Ear canal ends in **tympanic membrane (Tympanum or ear drum)**. It is a semi-transparent membrane covered by a thin layer of skin on its outer surface and by mucous membrane on the inside.

### Middle ear

- Consists of **tympanic cavity** and **ear ossicles**.
- Tympanic cavity is an air filled space that separates the external and inner ear portions.
- An **auditory tube (Eustachian canal)** connects middle ear to the pharynx. It maintains an equal pressure on either side of the eardrum.
- **Ear ossicles** include 3 small bones namely **Malleus, Incus** and **stapes**. Malleus is attached to tympanum.
- **Stapes** is the **smallest bone** of the body. It is attached to membrane of **oval window (fenestra ovalis)** of inner ear.

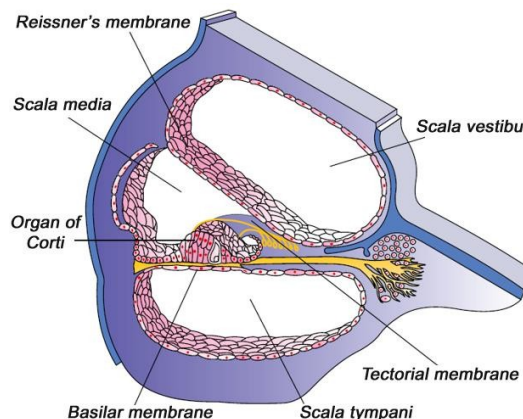
### Inner ear

- It consists of **bony labyrinth & membranous labyrinth**.
- Bony labyrinth is a cavity filled with **perilymph**.
- The membranous labyrinth consists of **cochlea** and **Vestibular apparatus**.

### Cochlea (organ of hearing):

- It is a coiled structure having 3 canals - upper **scala vestibula**, middle **scala media** and lower **scala tympani**.
- Scala vestibula & scala media are separated by **Reissner's membrane**.

- Scala media and scala tympani are separated by **basilar membrane**.
- S. vestibula & S. tympani are filled with **perilymph** and scala media is filled with **endolymph**.
- Resting on the basilar membrane and projecting into scala media is complex receptor organ called **Organ of Corti**. It consists of row of **sensory hair cells**. The hairs (stereocilia) of these cells project upwards and lie in contact with **tectorial membrane**, which projects above them.



### Vestibular apparatus:

- It consists of 3 **semicircular canals** and **otolith organ**.
- 2 semicircular canals are vertical and one is horizontal. One end of each canal has a bulging called **ampulla**. Inside it is a lump called **crista ampullaris**. Long cilia of cells of crista are grouped together in a bundle (**cupula**).
- **Otolith organ** consists of **utricle** and **sacculle**.
- Utricle & Sacculle have a projecting ridge called **macula**.
- **Crista** and **Macula** are specific receptors in vestibular apparatus. They contain **sensory hair cells**. They are responsible **equilibrium & posture** of body.

### Mechanism of hearing

**Pinna** collects sound waves → waves reach the **tympanic membrane** via ear canal → tympanic membrane vibrates → vibrations transmit to **ear ossicles & oval window** → **perilymph** in the **vestibular canal** vibrates → vibrations reach the **scala tympani** and force the **basilar membrane** to vibrate → hair endings of **sensory hair cells** press against **tectorial membrane** → sensory hair cells are excited → **auditory nerve** carries impulses to **auditory centre** of the brain → hearing.

## NOSE

- Organ of **smell (olfaction)**.
- It contains mucus-coated receptors (**olfactory receptors**) made up of **olfactory epithelium**. They receive sense of smell. It contains 3 kinds of cells.
- The neurons of olfactory epithelium extend from the outside environment directly into a pair of broad bean-sized organs, called **olfactory bulb**. These are extensions of the brain's limbic system.

## TONGUE

- Organ of **taste (gustation)**.
- 4 primary tastes are **sweet, salt, sour** and **bitter**.

- **Taste buds (Gustatoreceptors + supporting cells)** are seen around the bases of **taste papillae**.

taste buds and a complex flavour is perceived.

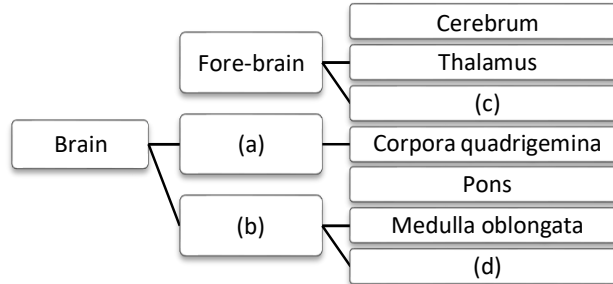
Nose & tongue are **chemoreceptors** (detect dissolved chemicals). Senses of taste & smell are functionally similar and interrelated. The brain integrates different input from

**SKIN (Cutaneous receptors)**

- Largest sense organ.
- It contains receptors for **heat, cold, touch, pain & pressure**.

**MODEL QUESTIONS**

1. Analyze the concept map given below and fill the gaps appropriately.



2. Note the relationship between first two words and fill up the fourth place

- a) Cone cells: Iodopsin      Rod cells: .....
- b) Unipolar: No Dendron      Bipolar: .....

3. Odd man out. Justify your answer.

- a) Tympanic membrane, Basilar membrane, Arachnoid membrane, Reissner’s membrane
- b) Amygdala, Crista, Ampulla, Vestibular apparatus

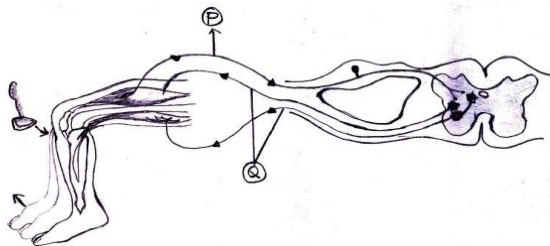
4. Arrange the following processes in nerve impulse conduction in a sequential order.

- a) Bursting of synaptic vesicle      b) Development of action potential
- c) Na<sup>+</sup> - K<sup>+</sup> pump starts functioning      d) Stimulus received and influx of Na<sup>+</sup> ions
- e) Maintenance of resting potential      f) Binding of neurotransmitter with post synaptic membrane

5. Match the following

A	B	C
Yellow spot	Macula	CSF
Otolith organ	Neurotransmitter	Keenest vision
Synaptic knob	Subarachnoid space	Acetyl choline
Meninges	Cone cells	Equilibrium

6. Observe the following figure.



- a) Identify the diagrammatic representation.
- b) Name P & Q.
- c) Mention the function of P & Q.

7. Prepare a flow chart showing the steps of hearing processes.