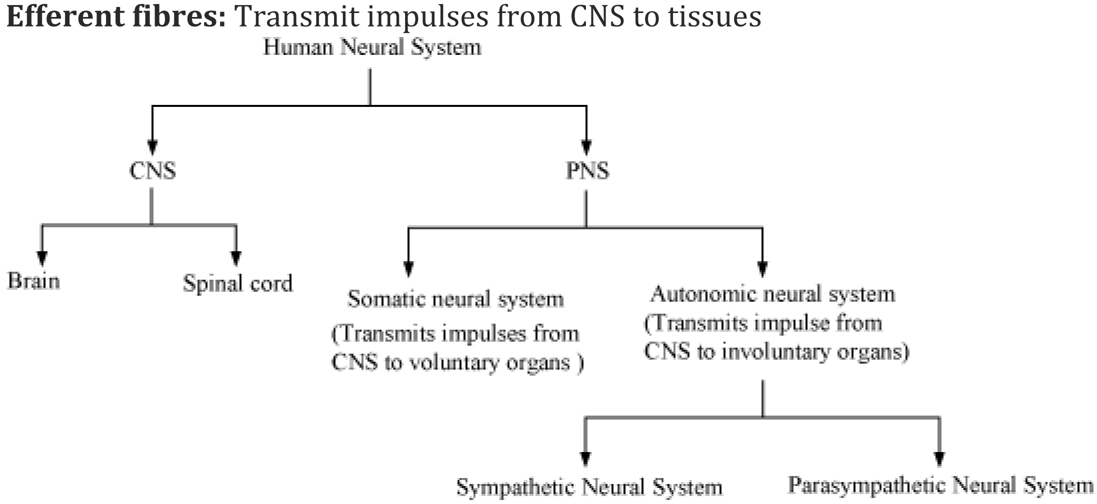
Neural Control and Coordination

Human Neural System: Structure and Function of Neuron

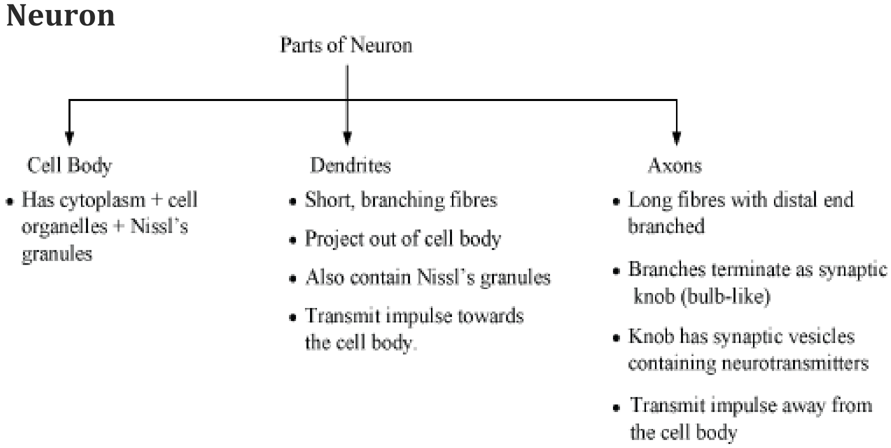
Human Neural System

- Has 2 parts: Central neural system (CNS)
  Peripheral neural system (PNS)
- **CNS:** Brain and Spinal Cord
- **PNS:** Nerves associated with CNS (Afferent fibres and efferent fibres)
- **Afferent fibres:** Transmit impulses from tissues to CNS
- **Efferent fibres:** Transmit impulses from CNS to tissues



- **Structural and functional unit of neural system:** Neuron

Neuron



- Classification of neurons based on the number of axons and dendrites:

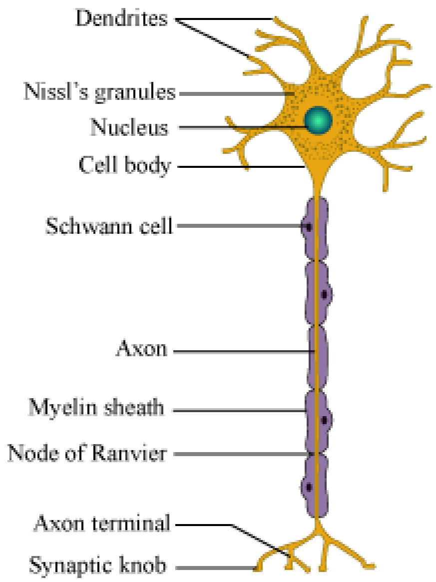
Multipolar neurons	**Bipolar neurons**	**Unipolar neurons**
1 axon and 2 or more dendrites	1 axon and 1 dendrite	1 axon and no dendrite
Found in the cerebral cortex	Found in the retina	During the embryonic stage

- Two types of axons:

Myelinated	**Non-Myelinated**
Enveloped with Schwann cells, forming a myelin sheath around the axon	Also enveloped by Schwann cells, but they do not form a myelin sheath around the axon
Nodes of Ranvier present	Nodes of Ranvier absent
Found in the spinal and cranial nerves	Found in the autonomous and somatic neural systems

- **Nodes of** Ranvier: Gaps between two adjacent myelin sheaths

- **Structure of Neuron:**



Generation and Conduction of Nerve Impulse

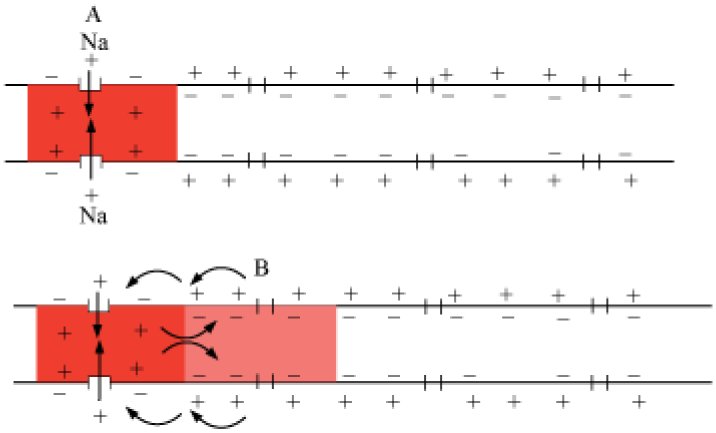
Generation of Nerve Impulse

- Neurons are excitable cells because their membranes are polarised.
- Neural membranes are polarised because **selectively permeable** ion channels are present on them.
- At the resting state of a neuron:
- Axonal membrane is more permeable to K^+ and nearly impermeable to Na^+.
- It is impermeable to negatively charged proteins present inside the axoplasm. Thus, it does not let them go out.
- As a result, the axoplasm has more concentration of K^+ and negatively charged proteins, and less concentration of Na^+. This creates a concentration gradient.
- Gradient is maintained by the **Sodium-Potassium Pump** which pumps 3 Na^+ out and 2 K^+ in.
- Hence, the outer surface of the membrane possesses positive charge and the inner surface possesses negative charge. This potential difference is called **Resting Potential**.
- Membrane is, therefore, polarised.
- When stimulus is applied at a particular site (say site A), that site becomes freely permeable to the influx of Na^+; hence, the polarity at that site is reversed.
- The membrane is now depolarised, and the potential difference across the site is called **Action Potential** (nerve impulse).

Conduction of Nerve Impulse

- At a site (B) that is adjacent to the depolarised site (A), the outer surface of the membrane has positive charge and the inner surface has negative charge.
- Depolarised site (A): Positive (in) and Negative (out)
Adjacent site (B): Positive (out) and Negative (in)
- Current flow on the inner surface: Site A to B
Current flow on the outer surface: Site B to A
- This completes the circuit of current flow. Polarity of site B is reversed and action potential is generated at site B.
- Hence, the impulse travels to site B, and we say that this impulse is conducted. This sequence is repeated along the length of the axon.

- Stimulus-induced permeability to Na^+ is short-lived, and is quickly followed by permeability to K^+. When this happens, the resting potential is restored, and once more, the site can be stimulated.



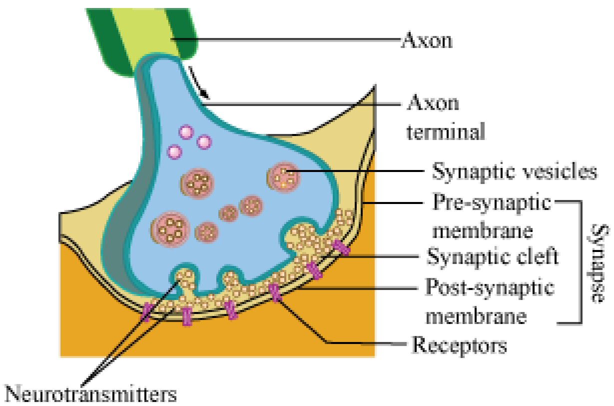
Representation of conduction of impulse at points A and B

Transmission of Impulse

- Transmission of nerve impulse is through synapses.
- Synapses are junctions formed by membranes of pre- and post-synaptic neurons.
- Synaptic cleft: Gaps separating pre- and post-synaptic neurons. It may or may not be present.
- Two types of synapses: electrical and chemical synapses

Type of synapses	**Electrical**	**Chemical**
Mode of action	Membranes of neurons are in close proximity. Hence, electrical current flows directly from one neuron to another.	Membranes of neurons are separated by fluid-filled spaces called synaptic cleft. Axon terminals have vesicles filled with chemicals (neurotransmitters). Impulse stimulates the movement of synaptic vesicles towards the membrane. Here, they fuse with the plasma membrane, and release their neurotransmitters at the synaptic cleft where they bind with their specific receptors. This binding opens the ion channels, allowing entry of ions which can generate a new impulse.

Speed	Fast	Slow
More information	These are rare.	New potential that they develop may be excitatory or inhibitory.



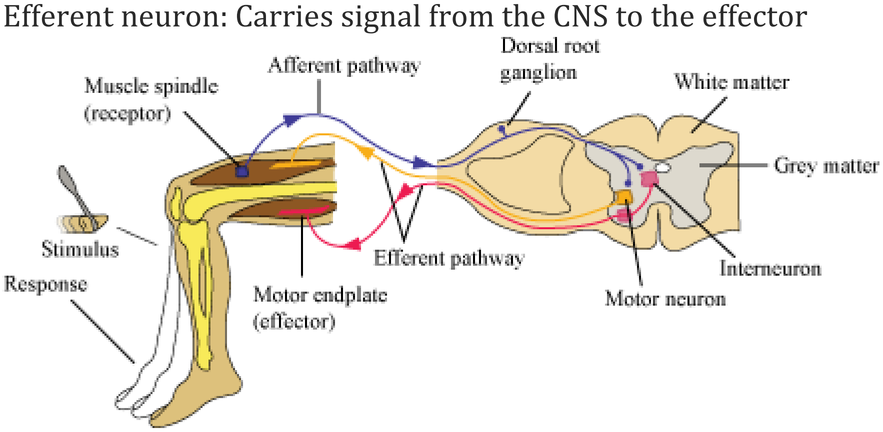
Synapse

Reflex Action and Reflex Arc

Reflex Action and Reflex Arc

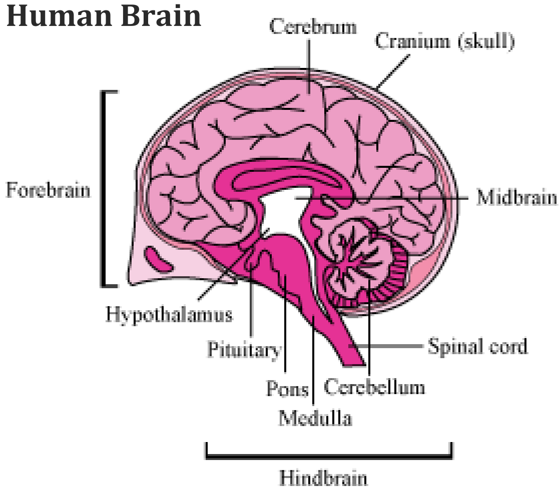
- Involves all sudden responses (involuntary)
- Consists of at least one afferent neuron (receptor) and one efferent neuron (effector)
- Receptor and effector are arranged in series
- Afferent neuron: Receives signal from the sense organ and transmits it to the CNS (spinal cord level)

- Efferent neuron: Carries signal from the CNS to the effector

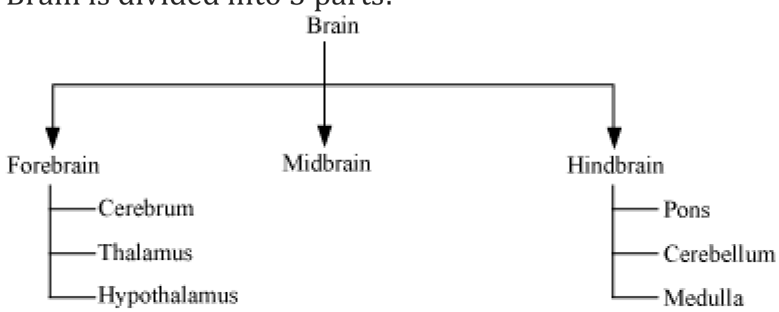


Central Nervous System

Human Brain



- Protected by the skull
- Protective covering: Cranial meninges
- Cranial meninges (Three-layered): Dura mater (outer), Arachnoid (middle), pia mater (inner)
- Brain is divided into 3 parts:



Forebrain: Has the cerebrum, thalamus and hypothalamus

- **Cerebrum** (major part of the brain) is divided by a deep cleft into the left and right cerebral hemispheres.
- Corpus callosum: A tract of nerve fibres that connect the two hemispheres
- Cerebral Cortex: Layer of cells covering the cerebral hemispheres. It is also called ‘grey matter” due to its greyish appearance, imparted by the high concentration of neuron cell bodies.

- Cerebral cortex consists of 3 areas:
  Motor areas, Sensory areas, Association areas (not clearly distinguishable into motor or sensory)

- Association areas: Responsible for complex functions like inter-sensory association, memory and communication

- Fibres of tracts present in the inner parts of the hemispheres are called “white matter” due to the opaque white appearance, imparted by the myelin sheath covering.

- **Thalamus**: Coordinates sensory and motor signalling

- **Hypothalamus**: Controls body temperature, hunger and thirst; contains neurosecretory cells which secrete hormones

- Limbic System = Inner parts of the cerebral hemispheres + Amygdale + Hippocampus

- Limbic System + Hypothalamus = Involved in the regulation of emotions, sexual behaviour and motivation

Midbrain

- Location: Between the thalamus/hypothalamus of the forebrain and the pons of the hindbrain

- Cerebral aqueduct: Canal passing through the midbrain

- Corpora quadrigemina: 4 round swellings (lobes) on the dorsal portion of the midbrain.

Hindbrain: Pons + Cerebellum + Medulla

- Hindbrain and midbrain form the brain stem.

- **Pons**: Fibre tracts that connect various portions of the brain

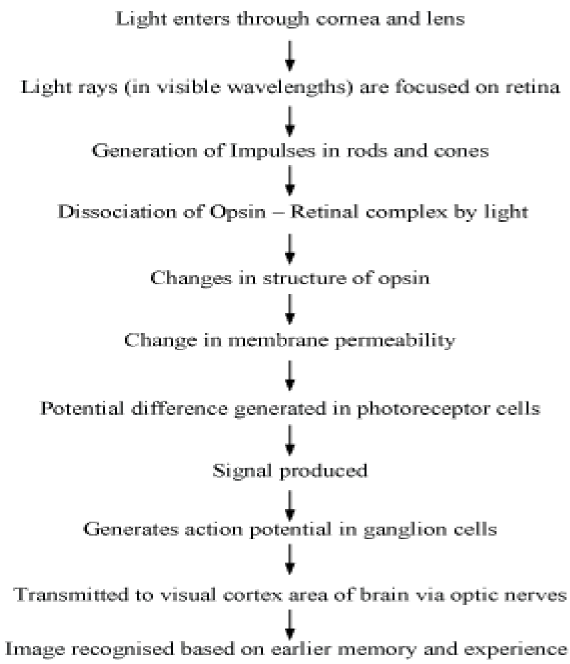
- **Cerebellum** has a convoluted surface to provide space for more neurons.

- **Medulla**connects to the spinal cord, and controls respiration, cardiovascular reflexes and gastric secretions.

Mechanism of Vision

Mechanism of Vision

Photopigments in the eye consist of opsin (a protein) and retinal (an aldehyde of vitamin A).



Accommodation

Accommodation is the adjustment of the eye for a clear vision of objects at varying distances.

Accommodation is brought about by changing the curvature of the elastic lens and making it more convex or concave with the help of suspensory ligaments and ciliary body.

When eye is at rest or is focused on distant objects, the suspensory ligaments are under great pressure. Therefore, the lens becomes flat and has maximum focal length. On the contrary, when we want to see the nearby objects, the ciliary muscles contract and pressure on the ligaments is released. The lens therefore bulges and becomes more round and convex.

Binocular Vision

Whenever we want to perceive depth or the relative distance of the objects, both our eyes focus simultaneously on the object.

Two separate images are formed, which the brain correlates and interprets as a single image. This results in a three-dimensional vision. It is also called stereoscopic vision.

Continuous Movement

The impression of an image remains on our brain for one-tenth of a second. If some other image is superimposed on the previous one, then the previous one is wiped off and we get an illusion of continuous movement.

Structure of Human Eye

Sense Organs: Organs that helps us to be aware of our surroundings are known as sense organs. Some of the major sense organs of our body include eyes, ears, nose, tongue and skin.

Receptors: Any cell or tissue sensitive to a selective stimuli is known as receptor. Some common receptors are:

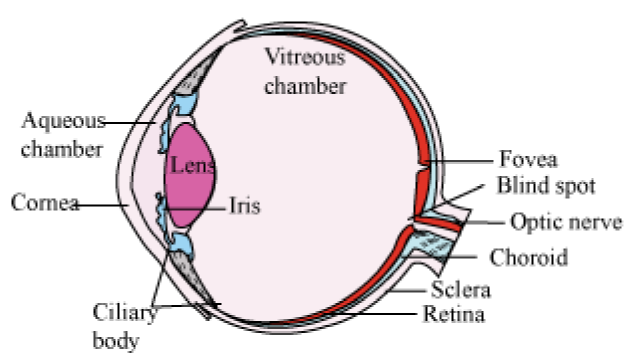
- Mechanoreceptors: Receptors for touch or pressure; found in skin
- Thermoreceptors: Receptors fro temperature; found in skin
- Chemoreceptors: Receptors of taste (in tongue) and of smell (in nose)
- Photoreceptors: Receptors of light; found in eyes (rod and cone cells)

Eye

Eye is one of the most sensitive sense organs in the human body. Our eye enables us to see this beautiful world. It consists of a lens, which is made up of living tissues. **How does our eye work? What are the nature, position and relative sizes of the images formed by the lens in the eye?**

In this section, we will learn about the structure and functioning of human eye.

Structure of human eye



The human eye is roughly spherical in shape with diameter of about 2.3 cm. It is situated in the front side of the skull in bony sockets. It is covered by the eyelids that have eye lashes which prevent dust and other substances from entering into the eye. It consists of a convex lens made up of living tissues. Hence, human lenses are living organs contrary to the simple optical lenses. The inner region of the upper eye lid contains **Lacrymal glands,** that produces secretion known as **tears,** which keep eye surface moist and wash out dirt and other substances. Tears contain some salts and act as an antiseptic because of the presence of the enzyme **lysozyme** which kills the germs**.**

Structure of Human Eye:

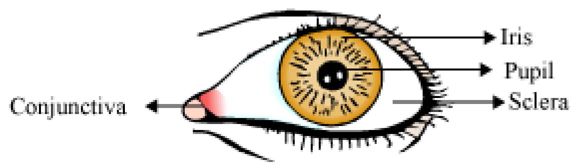
The wall of the eye consists of three layers namely sclera, choroid and retina.

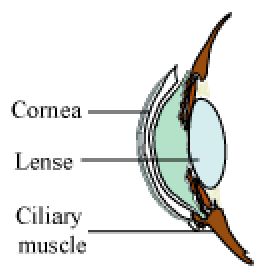
The following table lists the main parts of the human eye and their respective functions.

S. No.	**Human eye part**	**Function**
1.	Pupil	Opens and closes in order to regulate and control the amount of light
2.	Iris	Controls light level similar to the aperture of a camera
3.	Sclera	Protective outer coat
4.	Cornea	Thin membrane which provides 67% of the eye's focusing power
5.	Crystalline lens	Helps to focus light into the retina
6.	Conjunctiva	Covers the outer surface (visible part) of the eye
7.	Aqueous humour	Provides power to the cornea
8.	Vitreous humour	Provides the eye its form and shape
9.	Retina	Captures the light rays focussed by the lens and sends impulses to the brain via optic nerve
10.	Optic nerve	Transmits electrical signals to the brain
11.	Ciliary muscles	Contracts and extends in order to change the lens shape for focusing.

The **white of the eye** is known as the **sclera.** It is the tough, opaque tissue that protects the outer layer of the eye. The bulged, transparent front portion of the sclera is called **cornea**. It is protected by thin, transparent tissue known as the **conjunctiva**.

The middle layer called choroid is supplied with nerves and blood vessels. It consists of the coloured layer of tissue called **iris.** It is responsible for the colour of the eye. **Pupil** is the black, circular hole that is located at the centre of the iris.





The lens consists of layers of tissues enclosed in a tough capsule. The focus of the lens is adjusted by the ciliary muscles that suspend and hold it. The lens focuses the light rays on **retina** where inverted image of the object is formed.

Retina contains two types of cells **rods** and **cones**. Rods are sensitive to dim light and cannot differentiate between various colours while as cones are sensitive to bright light and can distinguish various colours.

Functioning of the human eye

Light rays enter the eye through the cornea. The rays are bent, refracted, and focused by the cornea, lens, and the vitreous humour. The main function of the lens is to focus the light rays sharply on the retina. It is the outer surface of the cornea where most of the refraction of light occurs.

Iris controls the size of the pupil and the amount of light respectively. Since the eye lens is convex in nature, the resulting image is real, small, and inverted. This image is formed on the retina. The retina converts these light rays into electrical signals with the help of light sensitive cells. These signals are sent to the brain via translated and perceived objects in an erect or upright position.

The head of the optic nerve is devoid of photosensitive cells (rods and cones). Hence, no image is formed at that point called the **blind spot** of the eye.

Lateral to the blind spot, a **yellow spot (fovea)** is present that contains large number of cone cells. At this portion of retina a most clear and sharp image is formed.

Power of Accommodation
This is a special capacity of human eye to adjust its focus depending upon the object they are seeing. This happens because of the presence of flexible ciliary muscles around the eyes that helps in adjusting the focus of the eye lens.
For distant vision the lens flattens whereas for near vision it becomes more convex.

Stereoscopic Vision
Humans and monkeys/apes have a special ability to perceive depth and relative distance as they can simultaneously focus on an object with both eyes. This results in the generation of a three dimensional image in our brain. This ability is known as stereoscopic vision.

On sunny days, when you enter a dimly lit room, you are unable to see clearly for a moment. Why does this happen?

In bright light, the iris expands, thereby contracting the pupil. This happens so that only a small quantity of light enters the eye. As a result, the retina is protected from exposure to excessive light.

On entering a dimly lit room after having been in the sun for some time, the iris contracts slowly to expand the pupil. Gradually, more light is able to enter the eye. Hence, it takes a few seconds before we are able to see the objects present in the dimly lit room.

Structure of Human Ear

Functions of the Ears

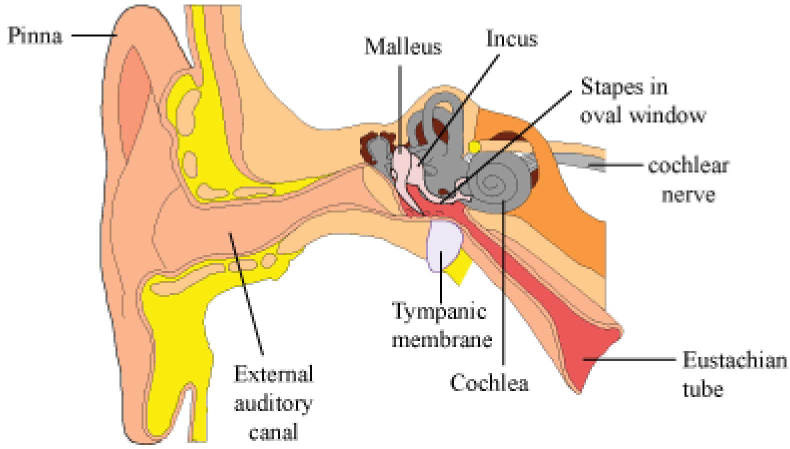
- Hearing
- Maintenance of body balance

Anatomy of the Ear

- Divided into three major sections:

- Outer ear
- Middle ear

- Inner ear



- Outer ear **=** Pinna + External auditory meatus (Canal)

- Pinna – collects the vibrations that produce sound
- Canal – leads inwards and extends up to the tympanic membrane (Ear drum)
- Wax-secreting sebaceous glands are present in the skin of the pinna and the canal.

- Middle ear: Has 3 ossicles (Malleus, Incus, Stapes)

- Malleus is attached to the ear drum and stapes is attached to the oval window of the cochlea. Middle ear communicates to the inner ear through the oval window.
- Ossicles increase efficiency of transmission of sound waves to the inner ear.
- Eustachian tube – connects the middle ear cavity with the pharynx; equalises the pressure on either sides of the ear drum

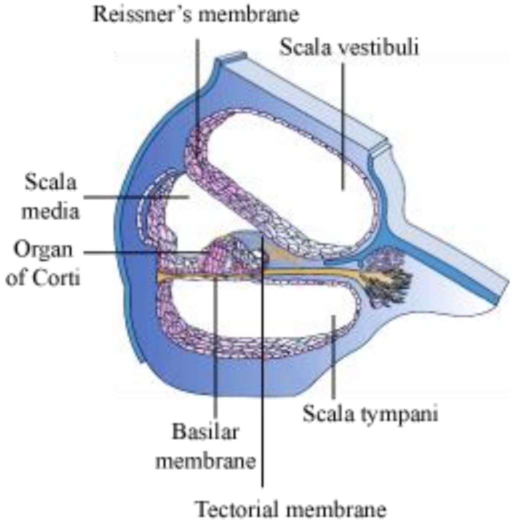
- Inner ear (labyrinth): Has 2 parts (Bony Labyrinth and Membranous Labyrinth)

- Bony Labyrinth – series of channels in which the membranous labyrinth lies
- Membranous Labyrinth – surrounded by a fluid called perilymph and filled with a fluid called endolymph

- Cochlea – coiled portion of the labyrinth

- 2 membranes surround cochlea, the reissner's membrane and the basilar membrane.
- These membranes divide the bony labyrinth into 3 parts -upper scala vestibuli, middle scala media and lower scala tympani.
- Scala media – filled with endolymph
- Scala vestibuli – ends at the oval window
  Scala tympani – ends at the round window that opens to the middle ear
- Organ of Corti – located on the basilar membrane and contains auditory receptors called hair cells (close contact with afferent nerve fibres)

- Tectorial membrane – elastic membrane present above the rows of hair cells



- Vestibular apparatus: Complex system located above the cochlea
- Composition – 3 semi-circular canals and otolith organ (has saccule and utricle)
- Base of the canals is swollen to form ampulla, which contains a projecting ridge called the crista ampullaris; it has hair cells
- Saccule and utricle – contain macula, which along with crista is responsible for maintaining the balance of the body and posture

Mechanism of Hearing

Mechanism of Hearing

External ear receives sound waves
↓
Send them to the ear drums
↓
Ear drum vibrates
↓
Vibrations transmit through the ear ossicles to the oval window
↓
Transmit onto the fluid in the cochlea
↓
Generate waves in the lymph
↓
Generate ripples in the basilar membrane
↓
Bend the hair cells and press them against the tectorial membrane
↓
Nerve impulses are generated in the associated afferent neurons
↓
Auditory nerves transmit them to the auditory cortex of the brain
↓
Brain recognises the sound

Role of Ear in Body Balancing

The fluid inside the semicircular canals moves when we turn our head. This moving fluid pushes against the sensory hair cells. This results in transmission of nerve impulse to brain through auditory nerve.The cells present in the semicircular canals are highly sensitive to dynamic equilibrium. Hence, they help us in maintaining balance of our bodies.

Senses of Smell, Touch and Taste

Sense Organs, in humans and other animals, are the faculties by which outside information is received for evaluation and response. This is accomplished by the effect of a particular stimulus on a specialized organ, which then transmits impulses to the brain via a nerve or nerves.

There are five type of senses which can be sensed by our sense organs - touch, vision, hearing, smell and taste.

These five type of senses can be categorised as general and special senses.

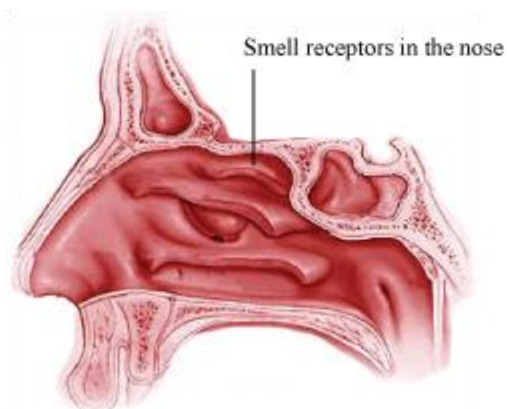
- General senses -
- contain general sensory receptors
- mostly modified dendritic ends of sensory neurons
- present throughout the body
- monitor most of the types of general sensory information such as tactile sensation, heat, cold, pain and muscle sense
- Special senses -
- contain special sensory receptors
- confined to the head region, sensory organs like eyes and ears and tissues of the taste buds and olfactory epithelium

We are very much familiar with eye and ear. So let’s learn the details of other three sense organs.

Nose

The nose is the organ for smelling. The receptors for smell called olfactory receptors are present in the nose to perceive the smell. Impulses are sent to the brain by these receptors and we are able to smell things

- The receptors for smell are located in small patches is the upper portion of the nasal cavity. The mucosa of upper nasal chamber is called olfactory epithelium.
- Three types of cells present in olfactory epithelium- olfactory receptor cells, columnar supportive cells and short basal cells.
- Olfactory receptors are unusual bipolar sensory neurons.
- Thin dendrites of neurons bear clusters of 20 modified cilia which function as receptor sites.
- Cilia extend from the olfactory epithelium into the thin coat of nasal mucous secreted by the supportive cells and olfactory glands.
- Mucus present in nose acts as a solvent.
- The olfactory nerve carries the stimuli from these cells to the brain.
- The smell receptors in the nose are sensitive to chemicals and they send impulses to the brain via the olfactory nerve to the cerebrum.

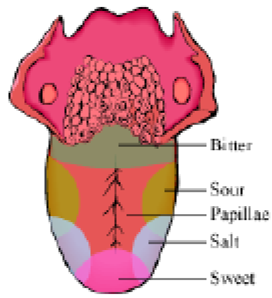


Tongue

The tongue is the sense organ responsible for taste. It has patches of sensory receptors known as taste buds. Different portions of the tongue are responsible for comprehending the different tastes.

- Nerves arise from the ends of the sensory taste buds and they together constitute the taste nerve.
- The nerve carries the signals to the brain where it is interpreted.
- The tongue has taste buds for the four basic tastes – sweet, sour, bitter and salty.

- The tip of the tongue is sensitive to sweet and salty tastes.
- The sides are sensitive to sour taste.
- The posterior portion is sensitive to bitter taste.



- **Mechanism of tasting -**
- dissolved chemicals contacting the microvilli bind to specific receptor proteins on it
- this depolarizes the cell
- dendrites of the associated sensory neurons coil intimately around the receptor cells and synapse with them
- a neurotransmitter is released when a receptor cell is stimulated and depolarized
- this leads to the generation of an action potential in the associated sensory neuron
- each dendrite receives signals from several receptor cells within the taste bud
- nerve fibers emerging from the taste buds pass to the brain stem
- from here the nerve impulse is relayed to the taste centre in the cerebral cortex of the brain that perceives the taste sensation

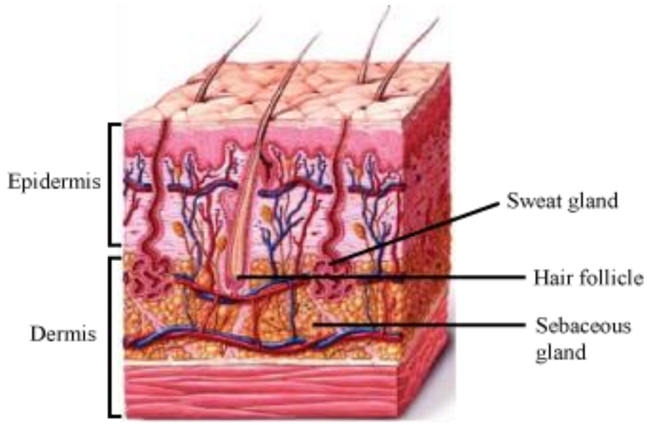
Skin

The skin is the sense organ for touch and feel. It also protects the body. It makes us aware of temperature, pressure, pain, etc

- Skin has two layers -
- The epidermis – It is the outer layer, made up of epithelial tissue and contains a brown pigment called melanin.

- Dermis – It is the inner layer and is made up of connective tissue and contains sweat glands and oil glands which give off moisture and oil which keeps the skin soft.

- It also contains hair follicles from which hair grows the skin also has nerve endings which act as touch receptors.



- Some of the receptors present in the skin are

Receptor	Response
Paciniam corpuscles	Strong pressure and vibrations
Meissner's corpuscles	Touch
Ruffini corpuscles	Heat
Root hair plexus	Touch
Krause's corpuscles	cold

Lets study some of these receptors in detail -

- Free or bare dendritic nerve endings - present throughout the epidermis taking an extensive branching or "zigzag" form. Respond chiefly to pain and temperature but some respond to pressure as well.
- Meissner's corpuscles - small receptors in which a few spiraling dendrites are surrounded by specialized capsule (Schawann) cells. Found just beneath the skin epidermis in dermal papillae and especially abundant in finger tips and soles of the feet.
- Pacinian corpuscles - large egg shaped bodies. Single dendrite surrounded by multilayers of capsule cells. Scattered deep in the dermis and in the subcutaneous tissue of the skin.

Mechanism of touch -

- an impulse or action potential is generated whenever one or more of these sensory receptors are stimulated (by heat, cold, vibrations, pressure or pain)

- impulse is then taken to the spinal cord and from there to the brain

- brain analyses the stimulus and then generates an appropriate response