Name of Unit	Peripheral Nervous System and Special Sense
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Learning Outcome of Module -04

LO	Learning Outcome (LO)	Course Outcome Code
LO1	To classify the peripheral nervous system.	BP101.4
LO2	To compare the sympathetic and parasympathetic divisions of autonomic nervous system.	BP101.4
LO3	To identify the origin and function of cranial nerves and Spinal Nerves.	BP101.4
LO4	To describe the structural components and structures of eye.	BP101.4
LO5	To describe the physiology of vision	BP101.4
LO6	To study the internal structure, physiology and olfaction and gustation of ear.	BP101.4

Table of Content

PERIPHERAL NERVOUS SYSTEM

INTRODUCTION

The two principle divisions of the nervous system are the central nervous system (CNS) and peripheral nervous system (PNS).The CNS consists of brain and spinal cord, integrates and correlates many different kinds of incoming sensory information. The CNS is also the source of thoughts, emotions and memories. The components of peripheral nervous system (PNS) are subdivided into a somatic nervous system (SNS) and autonomic nervous system (ANS). The SNS is voluntary. The SNS consists of sensory neurons and motor neurons.

✓ **Sensory neurons:** They convey information from somatic receptors in the head, body wall, limbs and from receptors of special senses of vision, hearing, taste and smell to the CNS.

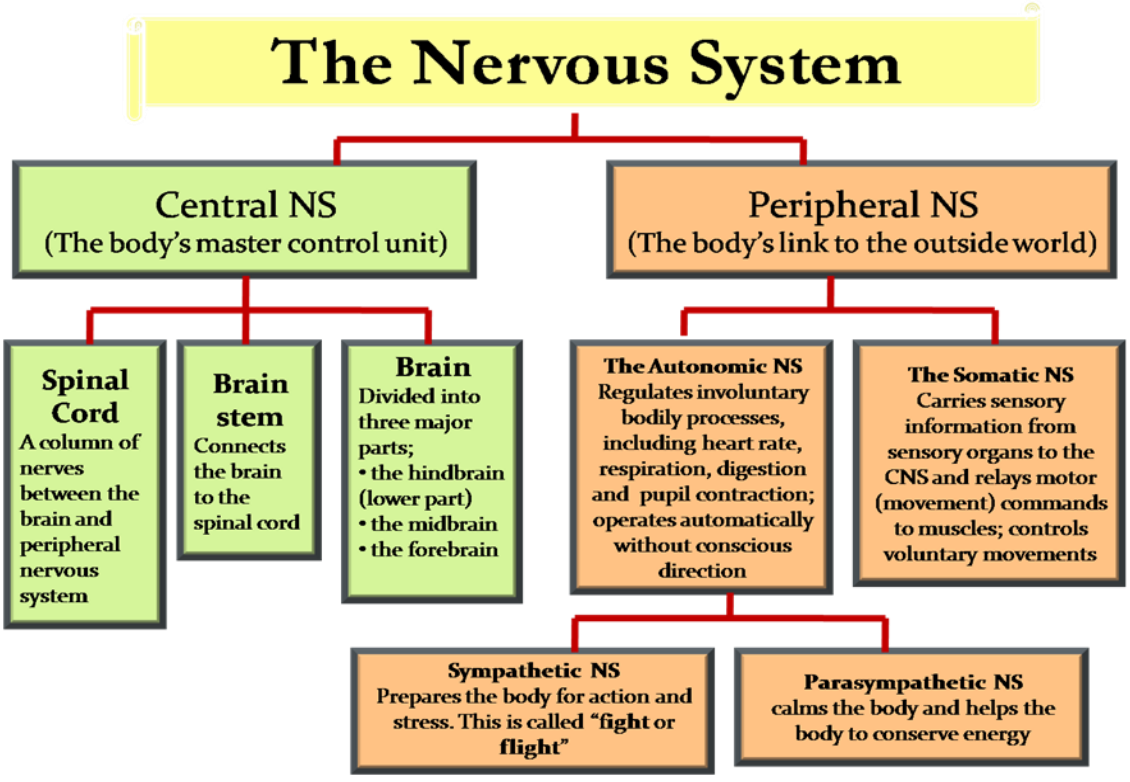
✓ **Motor neurons:** They conduct impulses from the CNS to skeletal muscles.

The ANS is involuntary.

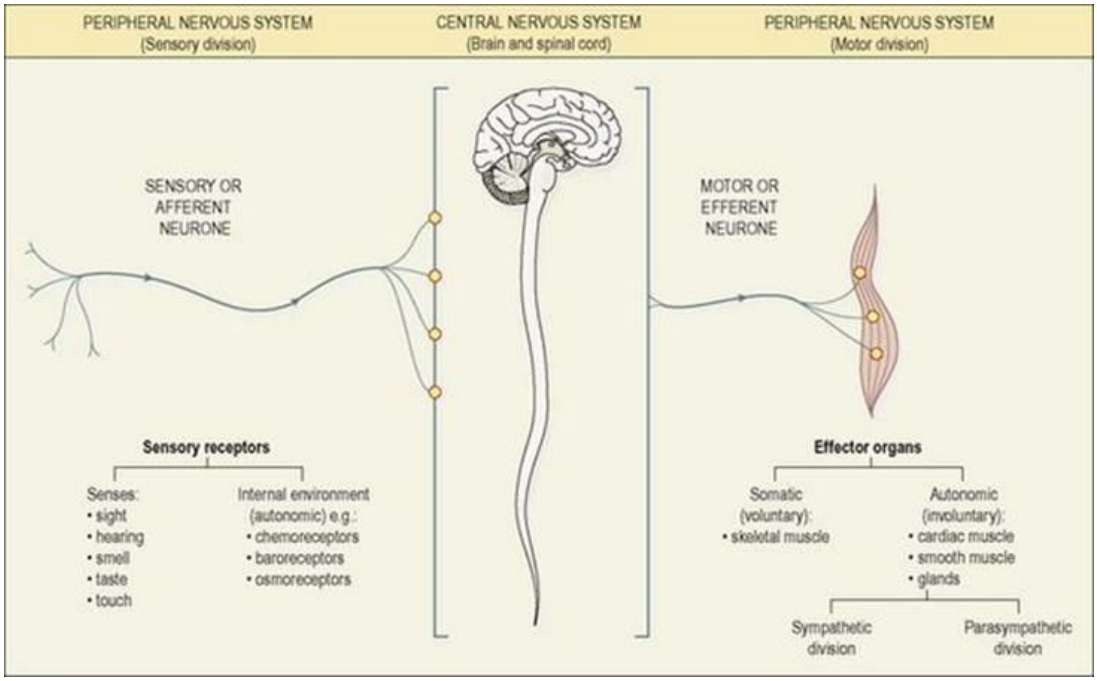
The ANS consists of sympathetic and parasympathetic division.

✓ **Sensory neuron:** They convey information from autonomic sensory receptors, located primarily in visceral organs such as stomach and lungs to the CNS.

Motor neuron: They conduct nerve impulses from the CNS to smooth muscles, cardiac muscles and glands.



Organization of the nervous system



Functional components of nervous system

AUTONOMIC NERVOUS SYSTEM

The peripheral nervous system consists of somatic nervous system (SNS) and autonomic nervous system (ANS). Somatic nervous system consists of sensory neurons and motor neurons. Sensory neurons convey message from periphery to the CNS. These sensations include sensations of pain, temperature, taste, smell, hearing and vision, etc. Motor neurons innervate the skeletal muscles and leads to voluntary movements. The autonomic or involuntary part of the nervous system which controls the autonomic function of the body

It consists of two types of neurons:

✓ Autonomic sensory neuron

✓ Autonomic motor neuron

Autonomic Sensory Neuron (afferent): These neurons are associated with interceptors which are sensory receptors located in blood vessels, visceral organs and muscles. Sensory neurons are responsible for receiving information form sensory receptor to the central nervous system

Autonomic Motor Neuron (efferent): These regulate visceral activities by either increases or decreases in ongoing activities in their effector tissues (cardiac muscle, smooth muscles or glands). E.g. Change in diameter of pupil, dilation or constriction of blood vessels, adjusting the rate and force of heart rate.

Divisions of Autonomic Nervous System:

The autonomic nervous system is separated into two divisions:

✓ Sympathetic (Thoraco lumbar outflow) division

✓ Parasympathetic (Cranio sacral outflow) division

These two divisions have both structural and functional differences. They normally work in opposite manner. Each division has two motor neurons and autonomic ganglia and effector organs.

These are;

Pre-ganglionic neurons: The first motor neurons which lies before the ganglion is called as pre-ganglionic neuron. The myelinated axon is called as pre-ganglionic fiber.

Post-ganglionic neurons: The second motor neuron which lies after the ganglion and terminates in the effector organ is called as post-ganglionic neuron. Its axon is called as post-ganglionic fibers.

The autonomic ganglion is the collection of cell bodies outside the CNS.

Sympathetic Division

It is called as thoracic lumbar division.

It consists of two types of autonomic ganglia.

✓ Sympathetic trunk ganglia

✓Prevertebral ganglia

Sympathetic Trunk Ganglia:

These are the ganglia lie in a vertical row on either side of the vertebral column.

These lies close to the spinal cord and therefore the pre-ganglionic fibers are short.

Prevertebral Ganglia:

These are two types of ganglion:

✓Coeliac ganglion

✓ Superior mesenteric ganglion

✓ Inferior mesenteric ganglionPeripheral Nervous System

These are the ganglion situated close to the abdominal cavity.

Most of the ganglia of sympathetic trunk a term effector organs are arranged on both sides of the spinal cord.

Ganglia are close to the CNS and distant from effector organs.

The pre-ganglionic nerve fibres are shorter.

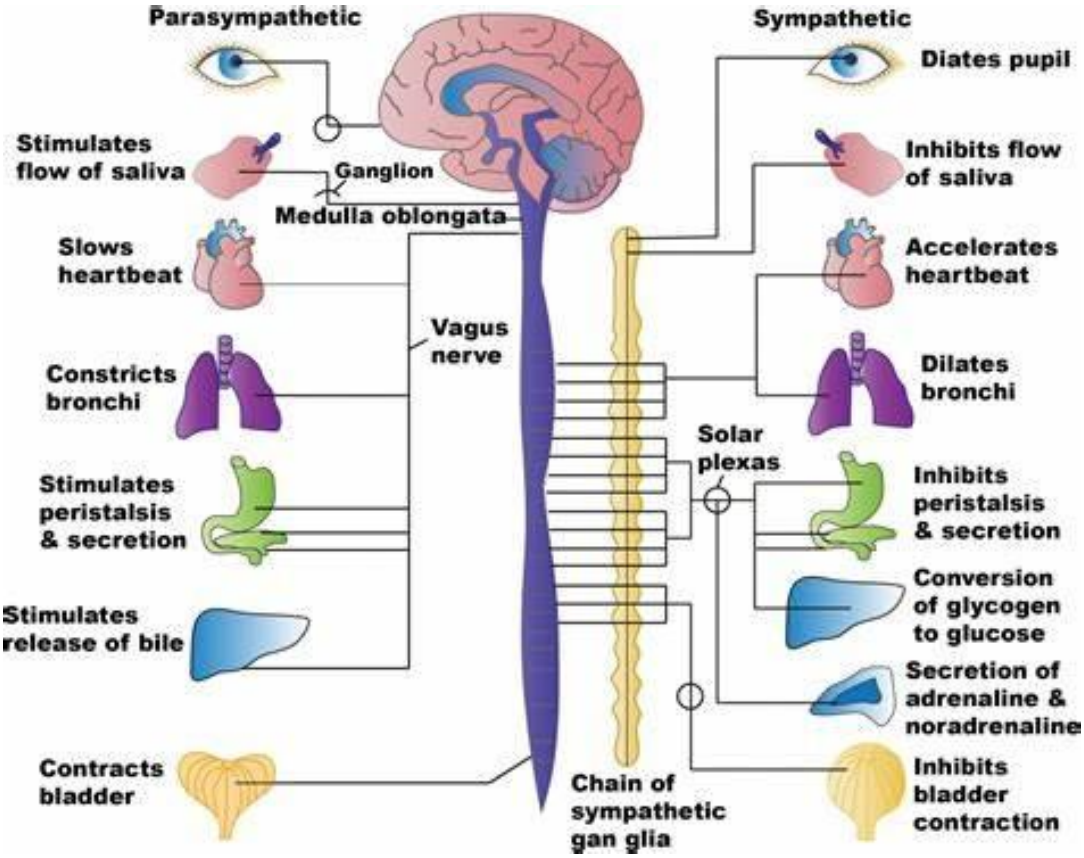
The post-ganglionic nerve fibres are longer.

The pre-ganglionic neurotransmitter is acetylcholine.

Most of the post-ganglionic nerve fibres are adrenergic.

The targeted receptors are mostly adrenergic.

These are distributed throughout the body.



Sympathetic and Parasympathetic Divisions

Parasympathetic Division

It is called as craniosacral division.

It contains parasympathetic ganglia.

The parasympathetic ganglia are dispersed.

The ganglia are near or within the wall of the visceral effectors.

The pre-ganglionic nerve fibres are large.

The post-ganglionic nerve fibres are shorter.

The pre-ganglionic nerve fibres are acetylcholine.

Most of the postganglionic nerve fibres are cholinergic.

The targeted receptors are mostly cholinergic.

The distribution is limited, particularly to heart, viscera of thorax, abdomen and pelvis.

CRANIAL NERVES

There are 12 pairs of cranial nerves originating from the nuclei in the inferior surface of the brain.

Some are sensory, some are motor and some are mixed.

Their names and numbers are as follows:

CRANIAL NERVES

No.	Name	Innervation	Origin	Nature	Function
I	Olfactory	Olfactory Lobe of Brain	Nasal chamber	Sensory	Smell
II	Optic	Diencephalon	Retina of eye	Sensory	Vision
III	Occulomotor	Eye Muscles & Ciliary Body	Cerebral Peduncle	Motor	Movement of eye ball
IV	Trochlear	Superior Oblique eye muscle	Cerebral Peduncle	Motor	Movement of eye ball
V	Trigeminal	Snout, Eye ball, Lacrymal gland, Lower eyelid, Upper lip, Upper jow, Gum, Teeth	Side of Medula	Mixed	Sensation of touch, taste, mestication, movement of lower jaw
VI	Abducent	External rectus muscle of eye ball	Ventral side of Medula	Motor	Eye movement
VII	Facial	Taste Bud, Salivary Gland, Facial & Neck muscle	Side of Medula	Mixed	Taste, Salivation, Tear secretion
VIII	Auditory	Side of Medula	Side of Medula	Sensory	Hearing
IX	Glossopharyngeal	Pharynx, Tounge, Salivary Gland	Side of Medula	Mixed	Taste, Salivation, Swallowing
X	Vagus	Pharynx, Heart,Rrespiratory tract, Pancrease, Blood vessels, Alimentory canal	Side of Medula	Mixed	Gastric & Pancreatic Secretion, GI movement, Cardiac reflex, Visceral reflex, Respiratory reflex
XI	Spinal Assessory	Muscles of Neck & Shoulder	Side of Medula	Motor	Muscles movement & Visceral reflex
XII	Hypoglossal	Tounge muscle	Side of Medula	Motor	Tounge movement

Types of Cranial Nerves

Olfactory Nerves:

It is sensory type of nerve with afferent fiber. It originates in the olfactory lobe i.e. root of nose and terminates in the temporal lobe of cerebrum. It is associated with sense of smell.

Optic Nerves:

It is sensory type of nerve with afferent fibre. It originates in the retina of eyes and terminates in the vision area of occipital lobe of cerebrum. It is related with sense of vision

Oculomotor Nerves:

It is mixed type of nerve with efferent as well as afferent fiber, but primarily it is motor originates in the mid-brain.

✓ ***Efferent (motor) portion:*** It innervates skeletal muscles it moves the eyeball and innervates smooth muscles that constrict pupil and lens shape for far and near vision.

✓ ***Afferent (sensory) portion:*** It is related to movement of eyeball and regulating the size of pupil.

Trochlear Nerves:

It is mixed type of nerve but primarily motor and originates in the midbrain. It is the smallest of the 12 cranial nerves. The motor portion is related to movement of eyeball and sensory vision carries information from muscles of eye to midbrain.

Trigeminal Nerves:

It is a mixed type of nerve fibre. It is the largest among all the cranial nerves. The motor portion originates from pons and innervates the muscles of mastication (skeletal chewing muscles).The sensory portion consists of three branches:

Ophthalmic nerve: It contains axons from skin of eyelids, eyeball, lacrimal glands, nasal cavity, nose, and forehead.

Maxillary nerve: It contains axons from the mucosa of nose, parts of pharynx, upper teeth, upper lip, and lower eyelid.

Mandibular nerve: It contains axon from tongue, lower teeth, skin over mandible, cheek.

Motor function: Chewing.

Sensory function: Conveys impulses for touch, pain and temperature.

Abducens Nerve:

A mixed type of nerve, but 1° motor that originates in the pons. The motor portion innervates the skeletal muscles that move eyeball. The sensory portion transmits information from proprioceptors in muscles. It is related to the movement of eyeball and muscles sense (proprioception).

Motor function: Movement of eyeball

Sensory function: Proprioception

Facial Nerve

It is a mixed type of nerve. The motor fibre originates from pons and innervates skeletal muscle of face, nose, palate, lacrimal and salivary gland. The sensory fibre transmits information from taste buds in the tongue and mouth.

Motor function: Facial expression

Sensory function: Proprioception and taste

Vestibulocochlear Nerve:

It is sensory type of nerve transmits information from receptor in ear. It consists of two nerves:

✓ **Vestibular nerve:** It arises from semicircular canals of the inner ear and conveys impulses to the cerebellum. They are associated with maintenance of posture and balance.

✓ **Cochlear nerve:** It originates in the spiral organ in the inner ear and conveys impulses to the hearing area of cerebral cortex. Cochlear nerve is responsible for hearing.

Glossopharyngeal Nerve:

It is a mixed type of nerve.The motor fibres originate from medulla oblongata and innervate the tongue andpharynx. The sensory fibres originate from salivary glands and terminate in medulla oblongata.

Motor function: Elevates the pharynx during swallowing and speech.

Sensory function: Taste sensations, touch, pain and temperature sensations, monitoring of blood pressure.

Vagus Nerve:

It is a motor type of nerve.The motor fibres originates in the medulla and innervates the smooth muscles of pharynx, larynx, trachea, heart oesophagus, stomach, intestine, pancreas, gall bladder, bile duct, spleen, kidney, ureter, blood vessels in thoracic and abdominal cavities.The sensory fibres convey impulses from same organs to brain.

Motor function: Swallowing, coughing and voice production.

Sensory function: Taste, touch, pain and temperature sensations, monitoring of blood pressure

Accessory Nerve:

It is mixed type of nerve, primarily motor nerve. It originates from medulla oblongata and in the spinal cord. It originates from medulla oblongata and innervates the voluntary muscles of pharynx and skeletal muscle of neck.

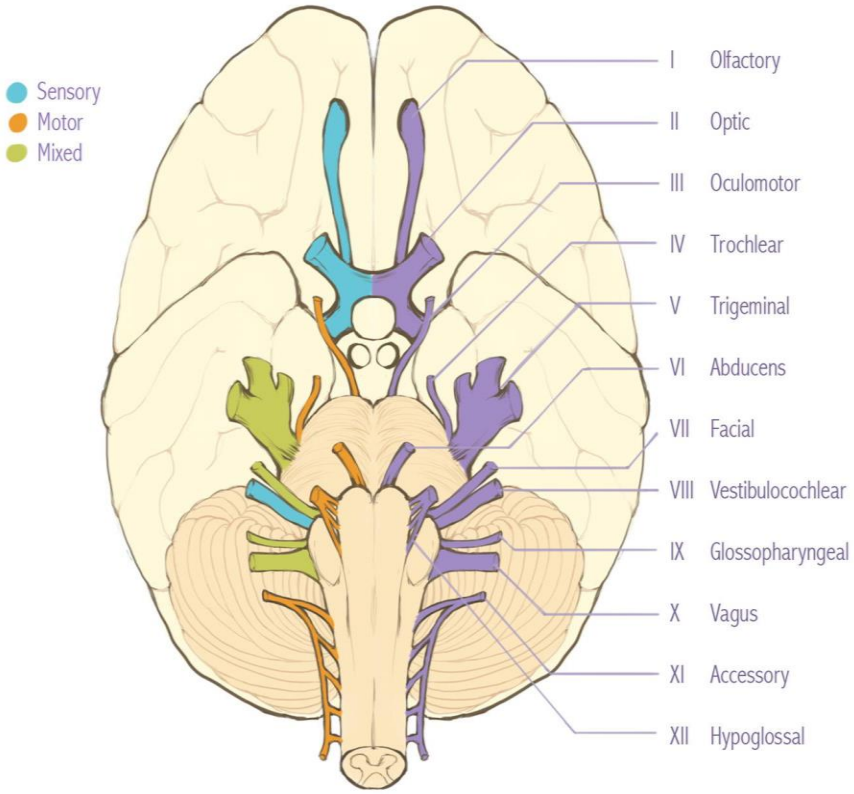
Motor function: Neck controls swallowing movements and movement of head and shoulders.

Hypoglossal Nerve:

It is mixed type of nerve but primarily motor nerve. It originates in the medulla and supplies to the muscle of tongue. The sensory function is gives sensation to tongue.

Sensory function: Proprioception

Motor function: Movement of tongue during speech and swallowing



Origin of Cranial nerves

SPINAL NERVES

There are 31 pairs of spinal nerves that leave the vertebral canal by passing through the intervertebral foramina formed by adjacent vertebrae. They are named and grouped according to the vertebrae with which they are associated.

✓ 8 Cervical

✓12 Thoracic

✓ 5 Lumbar

5 Sacral

1 Coccygeal

Even though there are only seven cervical vertebrae, eight cervical nerves are present because the first pair leaves the vertebral canal between the occipital bone and the atlas and the eighth pair leaves beneath the last cervical vertebra. The lumbar, sacral and coccygeal nerves leave the spinal cord near its termination at the level of first lumbar vertebra, and extend downwards inside the vertebral canal in the subarachnoid space, forming horse's tail like structure called as Cauda equina. A typical spinal nerve has two connections to the cord: Posterior root and anterior root.

Anterior Nerve Root:

It consists of motor nerve fibres which are the axons of the nerve cells in the anterior column of grey matter in the spinal cord and, in the thoracic and lumbar regions, sympathetic nerve fibres which are the axons of cells in the lateral columns of grey matter.

Posterior Nerve Root:

It consists of sensory nerve fibres. Just outside the spinal cord there is a spinal ganglion (posterior root ganglion), consisting of a little cluster of cell bodies. Sensory nerve fibres pass through these ganglia before entering the spinal cord. The posterior and anterior roots unite to form a spinal nerve at the intervertebral foramen. Because the posterior root contains sensory axons and the anterior root contains motor axons, as spinal nerve is classified as a mixed nerve.

The posterior root contains a posterior root ganglion in which cell bodies of sensory neurons are located. After leaving the spinal cord the nerve roots have a covering of dura and arachnoid matters. These terminate before the two roots join to form the mixed spinal nerve. The nerve roots do not have the pia matter covering. After emerging from the intervertebral foramen each spinal nerve divides into a ramus communicans, a posterior ramus and an anterior ramus. The rami communicans are part of preganglionic sympathetic neurons of the autonomic nervous system. The posterior rami pass backwards and divide into medial and lateral branches to supply skin and muscles of relatively small areas of the posterior aspect of the head, neck and trunk. The anterior rami supply the anterior and lateral aspects of the neck, trunk and the upper and lower limbs. In the cervical, lumbar and sacral regions the anterior rami unite near their origins to form plexuses (large masses of nerves), where nerve fibres are regrouped and rearranged before proceeding to supply skin, bones, muscles and joints of a particular area. There are five large plexuses of mixed nerves formed on each side of vertebral column.

They are as follows;

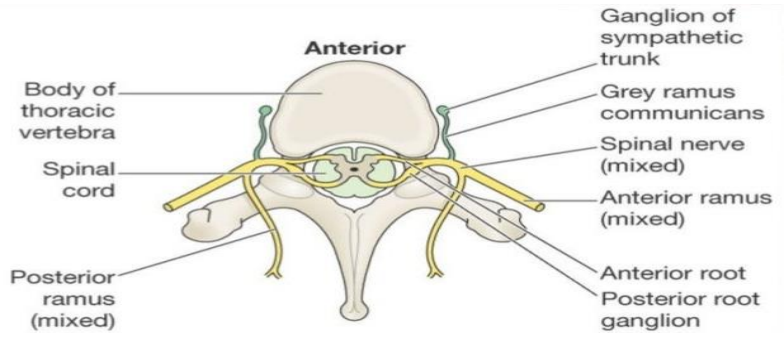
Cervical plexuses: It is formed by the anterior rami of the first four cervical nerves.

Brachial plexuses: The anterior rami of the lower four cervical nerves and a large part of the first thoracic nerve form the brachial plexus.

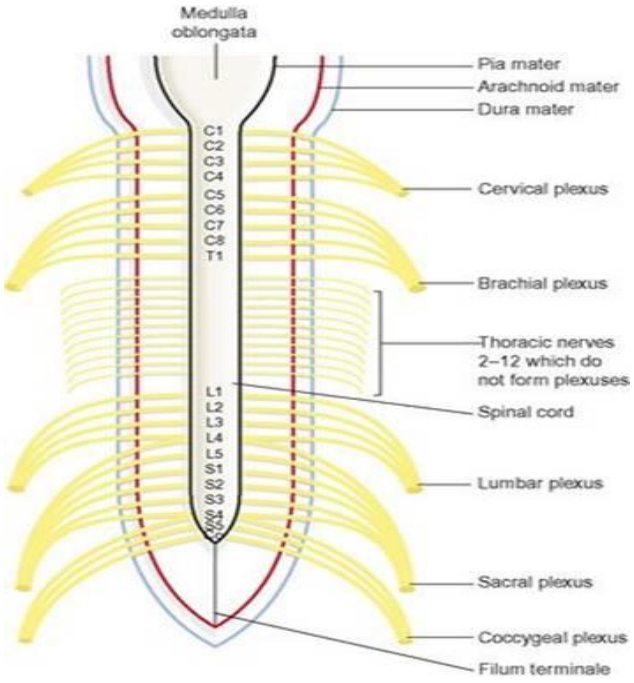
Lumbar plexuses: It is formed by the anterior rami of the first three and part of the fourth lumbar nerves.

Sacral plexuses: It is formed by the anterior rami of the lumbosacral trunk and the first, second and third sacral nerves.

Coccygeal plexuses: The coccygeal plexus is a very small plexus formed by part of the fourth and fifth sacral and the coccygeal nerves.



Relationship between sympathetic and mixed spinal nerves



Covering of Spinal Cord, Spinal Nerves and Plexuses

SPECIAL SENSE

INTRODUCTION

The body has an innate ability to sense change in its internal and external environment, which enables it to maintain a state of homeostasis and continued survival. Special sense organs are characterised by large and complex organs, each with a unique function. Sensory organs have special receptors that allow us to smell, taste, see, hear and maintain equilibrium or balance. Information conveyed from these receptors to the central nervous system is used to help to maintain homeostasis.

Ophthalmology: It is the branch of science that deals with the study of eyes and their disorders.

Otorhinolaryngology: It is the branch of science that deals with the study and treatment of diseases of the ear, nose and throat.

EYE

Vision is extremely important for human survival. More than half of the sensory receptors are located in the eyes. The eye is situated in the orbital cavity and is supplied by optic nerves. It is spherical in shape and about 2.5 cm in diameter. The eye is located in bony socket called as orbit. The space between the eye and the orbital cavity is occupied by adipose tissue. The bony walls of the orbit help to protect the eye from injury.

Accessory Structures of the Eye:

Accessory structure of eye includes:

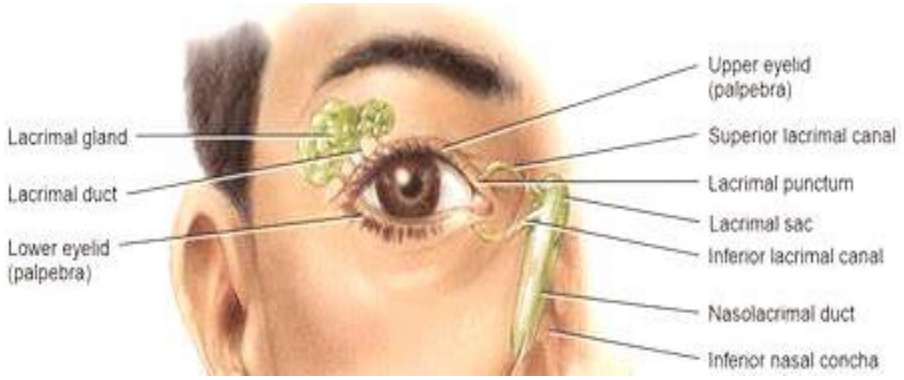
✓ Eyelids

✓ Eyelashes

✓ Eyebrows

✓ Lacrimal apparatus

✓ Extrinsic eye muscles



Accessory structures of the eye

Eyelids:

The eyelids are two movable folds of tissue situated above and below the front of each eye.

On their free edges there are short, curved hairs called as eyelashes. Various layers of tissue forming the eyelids are:

✓ A thin covering of skin

✓ A thin sheet of subcutaneous connective tissue (loose areolar tissue)

✓ Two muscles: The orbicularis oculi and the levator palpebrae superioris

✓ A thin sheet of dense connective tissue - Tarsal plate

✓ Lining of conjunctiva

Functions:

The eyelids and eyelashes protect the eye from injury. The eyelids protect the front surface of eyes from excessive wind, small particles in the air and from minor mechanical injury. Blinking at about 3-7 seconds intervals spreads tears and oily secretions over the cornea, preventing injury to eye."

Conjunctiva:

It is a thin transparent membrane that lines the eyelids and the front of the eyeball. The corneal conjunctiva consists of avascular stratified epithelium i.e. epithelium without blood vessels. When the eyelids are closed, the conjunctiva becomes a closed sac. It protects the delicate cornea and the front of eye.

Eyebrows:

Numerous hairs (eyebrows) projects obliquely from the surface of the skin. They protect the eyeball from sweat, dust and other foreign bodies.

Lacrimal Apparatus:

It consists of:

✓ 1 Lacrimal gland and its ducts

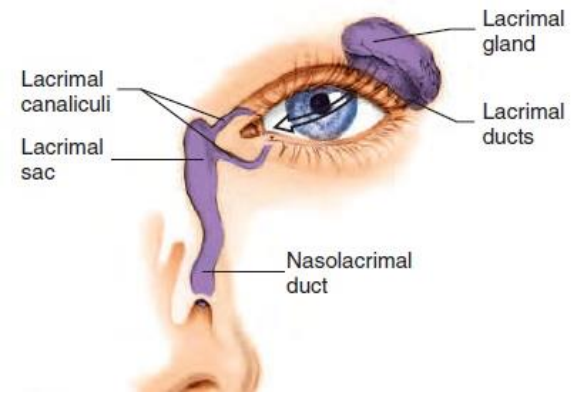
✓ 2 Lacrimal canaliculi

✓ 1 Lacrimal sac

✓ 1 Nasolacrimal duct

The lacrimal apparatus is a structure that produces and drains lacrimal fluid (tears). It has size and shape of an almond.It secrets lacrimal fluid which drains into 6-12 excretory lacrimal ducts that empty tears onto the surface of conjunctiva of the upper lid. From the upper lid, tear passes to surface of the eyeball to enter two small openings called as lacrimal puncta. Tears then pass

into two ducts, the lacrimal canals which lead into the lacrimal sac and then into the nasolacrimal ducts. This duct carries the secretion into the nasal cavity. The lacrimal fluid produced by the gland is a watery solution containing salts, mucous and lysozyme - a protective bactericidal enzyme. The fluid protects, clean, lubricates and moistens the eyeball.



Lacrimal Apparatus

Extrinsic eye muscles:

Six extrinsic muscles move the eye together.

✓ Superior rectus

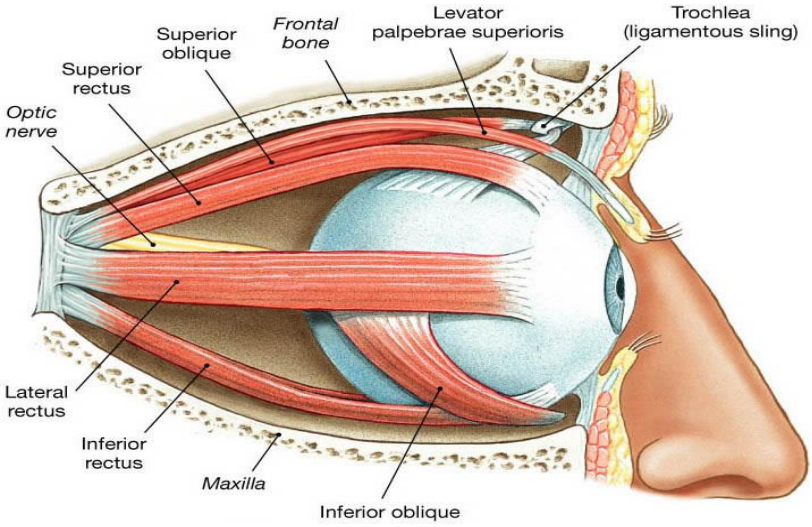
✓ Inferior rectus

✓Lateral rectus

✓ Medial rectus

✓ Superior oblique

Inferior oblique



Extrinsic eye muscles

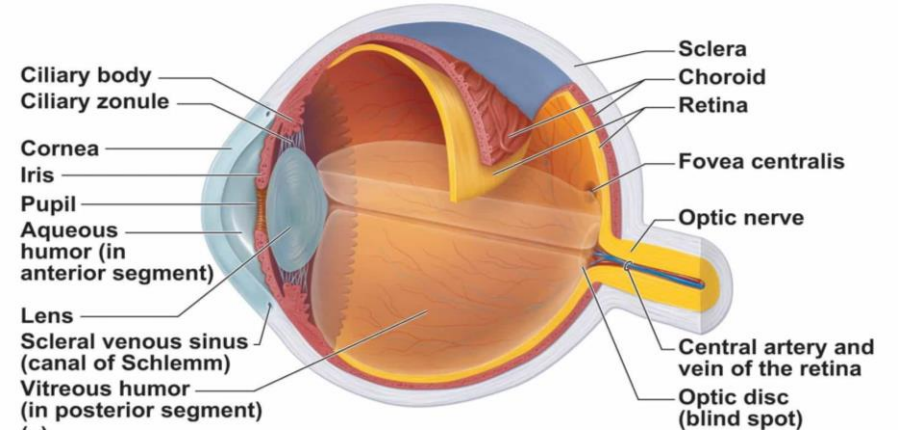
Anatomy of the Eyeball:

The adult eyeball measures about 2.5 cm in diameter. Only the anterior 1/6th is exposed, the rest is protected in bony socket of the orbit. The wall of eyeball consists of three layers.

✓ Fibrous tunic

✓ Vascular tunic

✓ Retina



Internal structure of the eyeball

Fibrous Tunic:

It is the superior layer of eyeball. It consists of anterior cornea and posterior sclera. The cornea is transparent coat that covered the coloured iris. Because it is curved, the cornea helps to focus the light onto the retina. The cornea is about 0.5 to 1 mm thick and consists mainly of the following structure:

✓ Corneal epithelium

✓ Substantia propia

✓ Corneal endothelium

The sclera: The white of the eye is a layer of dense connective tissue made up of collagen fibres and fibroblasts The sclera covers the entire eyeball except the cornea. It gives shapes to the eyeball, makes it more rigid and protects its inner parts. At the junction of sclera and cornea is an opening known as canal of schlemm. A fluid called aqueous humour drains into the sinus.

Vascular Tunic:

The vascular tunic/uvea is the middle layer of eyeball.

It is composed of three parts.

✓ Choroid

✓ Ciliary body

✓ Iris

Highly vascularized choroid is the posterior portion of the vascular tunic lines most of the internal surface of the sclera. Its numerous blood vessels provide nutrients to the posterior surface of retina. The choroid also contains melanocytes that produce the pigment melanin which appear dark brown in colour. In the anterior portion of the vascular tunic, the choroid becomes the ciliary body. Like the choroid the ciliary body appears dark brown in colour because it contains melanin producing melanocytes. In addition ciliary body contains ciliary body processes and ciliary muscles. The coloured portion of eyeball has a flattened donut shape.

It is suspended between the cornea and lens and is attached to its outer margin to the ciliary processes. It consists of melanocytes, circular and radial smooth muscle fibres.

The amount of melanin in the iris determines the eye colour.

✓ High concentration: Brown/Black eye colour

✓ Moderate concentration: Green eye colour

✓ Low concentration: Blur eye colour

The principal function of the iris is to regulate the amount of light entering the eyeball through the pupil, the hole in the centre of the iris. When bright light stimulates the eye, parasympathetic fibres of oculomotor nerves (III) stimulates the circular muscles (sphincter papillae) of the iris to contract causing decrease in the size of the pupil (Constriction). In dim light, sympathetic neurones stimulates the radial muscles (dilator papillae) of the iris to contract causing increase in the size of the pupil (Dilation).

Retina:

The third and inner coat of the eyeball is the retina. It is extremely thin and transparent.

The optic disc is the site where the optic (II) nerve exits the eyeball.

It consists of:

✓ Central retinal artery

✓ Central retinal vein

The retina consists of a pigmented layer and neural layer. The pigmented layer is a sheet of melanin-containing epithelial cells. The melanin in the pigmented layer of retina also helps to absorb stray light rays. The neural layer is a multi-layered outgrowth of the brain.

It consists of three layers:

✓ The photoreceptor layer

✓ Bipolar cell layer

✓ Ganglion cell layer

Lens

The lens is present behind the pupil and iris within the cavity of the eyeball. A crystalline protein, arranged like the layers of an onion, make up the lenses transparent and lacks blood vessels. The lens helps to focus images on the retina to facilitate clear vision.

Inferior of the Eyeball:

The lens divides the interior of the eyeball into two cavities:

✓ The anterior cavity

✓ The vitreous chamber

The anterior cavity consists of two chambers:

✔***Anterior chamber:*** It lies between the iris and in front of the lens.

✓ ***Posterior chamber:*** It lies behind the iris and in front of the lens.

Both the chambers of the anterior cavity are filled with aqueous humour - a watery fluidthat nourishes the lens and cornea. Normally, aqueous humour is completely replaced about every 90 minutes. The second and larger cavity of the eyeball is the vitreous chamber which lies between the lens and the retina. It is never replace throughout the life. This substance contributes the intraocular pressure and helps in preventing eyeball from collapsing. The pressure in the eye, called intraocular pressure, is produced mainly by the aqueous humour and partly by the vitreous body It is normally about 16 mm Hg. The intraocular pressure maintains the shape of the eyeball and prevents it from collapsing.

Physiology of Vision

The rods and cones are two types of photoreceptors that helps in transducing light rays into the receptor potential. The retina of each eye contains about 6 millions of cones and 120 millions of rods.

Rods: These help in viewing grey shades in dim light and are responsible for absorbing shapes and movements.

Cones: They provide colour vision in bright light. The cones cannot functions in dim light.

The rods and cones are named because of their shapes. The rods and cones are differentiated into two parts:

✓ Outer segment

✓ Inner segment

The outer segments of cones are cone shaped whereas those of rods are rod shaped. The outer segment of rods as well as cones contains invaginated membranes called as discs. The first step in visual transduction in absorption of light by a photo pigments. These pigments are coloured protein that undergoes structural changes when they absorb light, in the outer segment of photoreceptor.

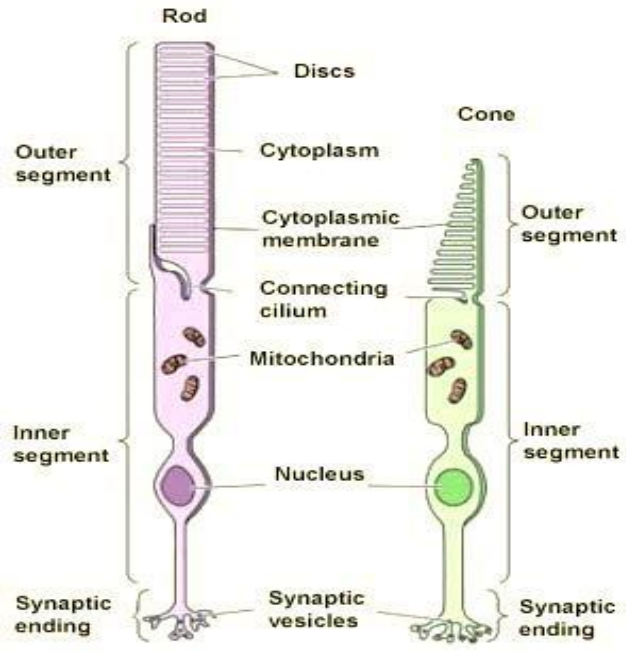
The pigment present in the rods is rhodopsin and the cones is iodopsin. Both rhodopsin as well as iodopsin contains retinal (derivatives of vitamin-A).

All photo pigments associated with vision contains two parts:

✓ A glycoprotein known as opsin.

✓ Derivative of vitamin - A known as retinal.

Good vision depends on adequate dietary intake of carotene-rich vegetables such as carrots, spinach, broccoli and yellow squash or foods that contains vitamin-A such as liver. Retinal is light absorbing part of all visual photo pigments. In human retina there are four different opsins, three in the cones and one in the rods (rhodopsin).



Rod cell and Cone cell

Activation of Photo-pigments:

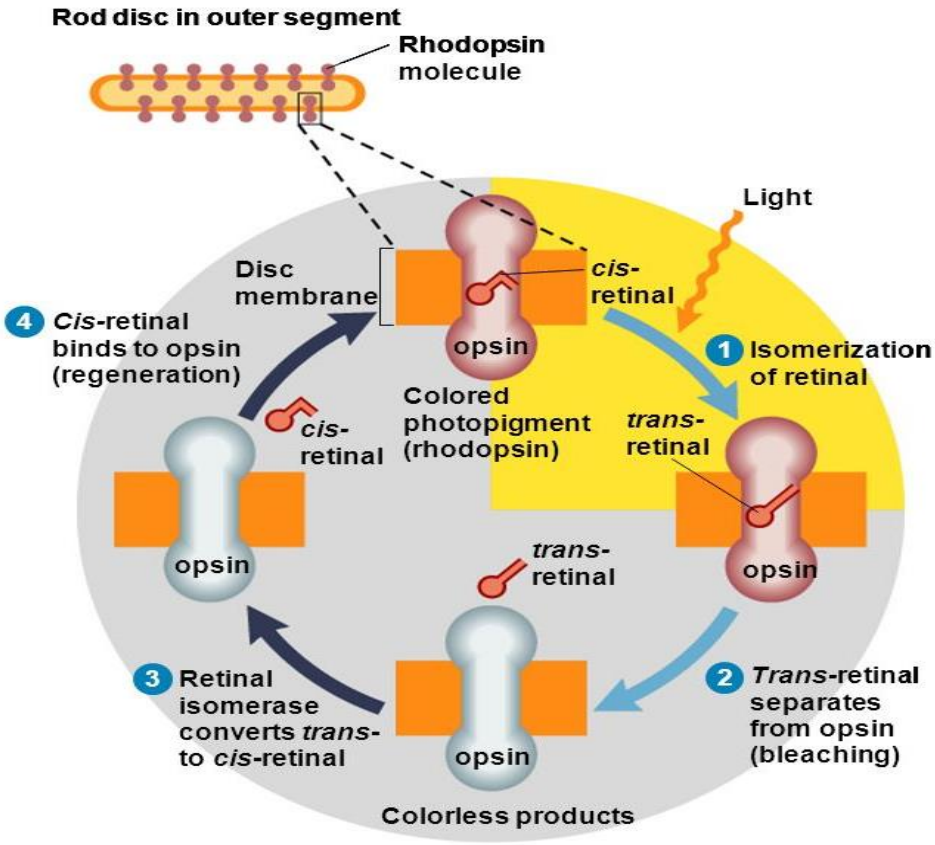
Photo-pigments respond to light in the following process:

(1) In darkness, retinal has a bent shape, called cis-retinal, which fits tightly into the opsin portion of the photopigment when cis-retinal absorbs a photon of light; it straightens out to a shape called trans-retinal.

(2) This cis-to-trans conversion called as isomerisation and is the first step in visual transduction.

(3) An enzyme called as retinal isomerase converts trans-retinal back to cis-retinal.

(4) The cis-retinal then binds to opsin, reforming a functional photopigment. This process of resynthesis of photopigment called as regeneration. The inner segment of rods and cones contains mitochondria, which provides energy. The discs of the rods are constantly regenerated whereas this does not occur in cones.



Activation of photo-pigments

Light and Dark Adaptation:

When the person emerges from dark surroundings (a tunnel) into the sunshine, light adaptation occurs. Our visual system adjusts in seconds to the brighter environment by decreasing its sensitivity. When the person enters a darkened room such as a theatre, visual system undergoes dark adaptation by increasing sensitivity. As the light level increases more and more photo

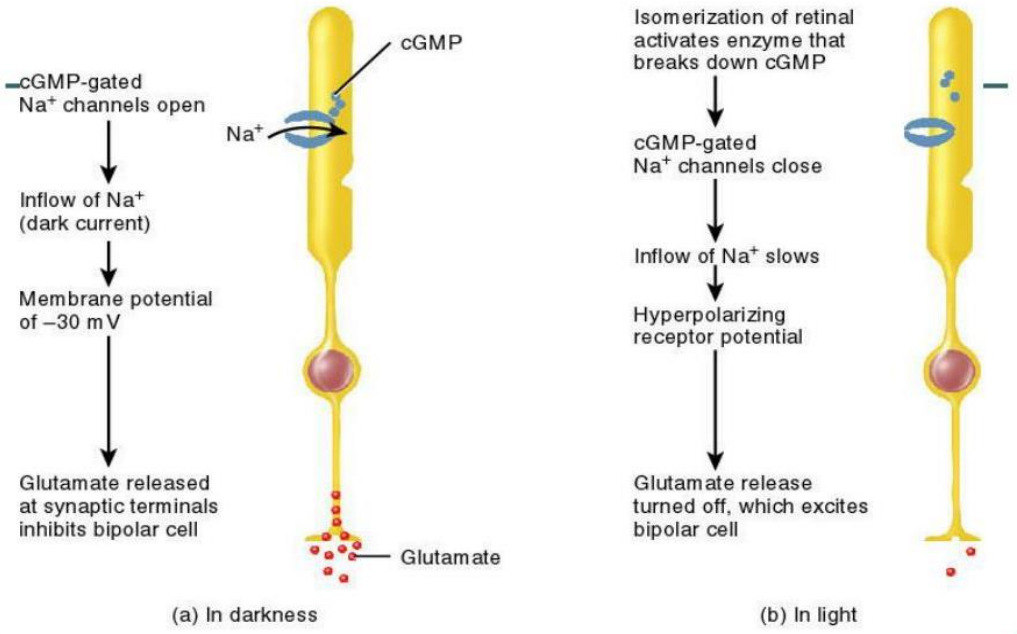
pigment is bleached. While light is bleaching, more photopigment molecules however, others are being regenerated.

Release of Neurotransmitter by Photoreceptors:

Operation of Rod Photoreceptor in Darkness:

In darkness, the cyclic GMP levels of photoreceptors are high. This level of GMP opens the ligand gated sodium ions channels. Inflow of Nations through the channel in the photoreceptor takes place called as dark current which partially depolarizes the photoreceptor.

As a result, in darkness the membrane potential of a photoreceptor is -30 mV which is much closer to -70 mV. This partial depolarization during darkness triggers release of neurotransmitter at the synaptic terminals. The neurotransmitter is the amino acid glutamate or glutamic acid, This glutamate inhibits the bipolar cells that synapse with rods.



Operation of photoreceptor in darkness and light

Operation of Rod Photoreceptor in Light:

When light strikes on retina the cis-retinal undergoes isomerisation to trans-retinal, enzyme transduction get activated which activates phosphodiesterase which breaks down cyclic GMP and leads to decrease in cyclic GMP levels which in turn is responsible for closing of sodium channels. So, inflows of Na_+ ions in photoreceptor get decreases. The membrane potential becomes more negative -70 mV (hyperpolarizing receptor potential). This sequence of events produces a hyperpolarizing receptor potential that decreases the release of neurotransmitter

glutamate. Thus, light excites bipolar cells that synapse with rods by turning off the release of inhibition of neurotransmitter.

The excited bipolar cells subsequently stimulate the ganglion cells to form action potentials in their axons.

EAR

It is the organ of hearing. It is supplied by 8th cranial nerve i.e. the cochlear part of the vestibulocochlear nerve which is stimulated by vibrations caused by sound waves.

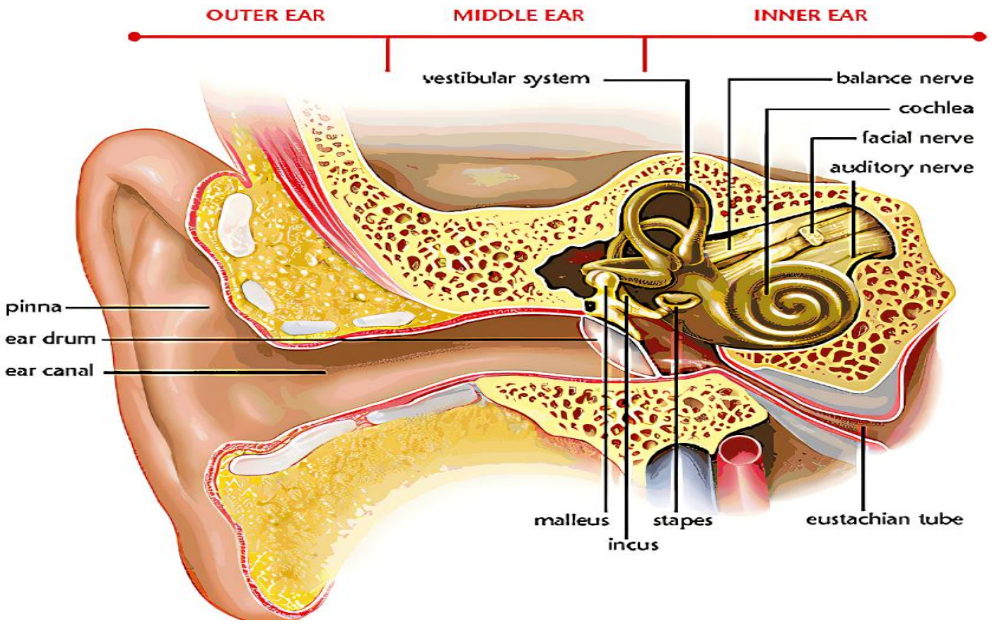
Anatomy of Ear:

Parts of ear:

External ear

Middle ear

Internal ear



Internal structure of ear

External Ear:

The external ear collects sound waves and channels them inwards. External ear consists of three basic parts:

✓ Auricle (Pinna)

✓ External auditory canal

Auricle is a sheet of elastic cartilage covered with skin. The rim of auricle is the helix and the inferior portion is called as lobule. Muscles and ligaments attach the auricle to the 2.5 cm long.

Pinna opens into the external auditory canal. The external auditory canal extends from pinna to eardrum.

External auditory canals contain many specialized sebaceous glands which secrete wax called as ceremonious glands. Hairs are present in this canal and along with earwax; they prevent the entry of dust and foreign particles inside the ear. The external auditory canal ends at the tympanic membrane which is called as eardrum. The eardrum or tympanic membrane is a thin, semi-transparent partition between the external auditory canal and middle ear.

It is covered by epidermis and is lined by simple cuboidal epithelium.

Middle Ear:

It coveys sound vibrations to the oval window. The middle ear is also called as tympanic cavity.

The middle ear is a small, air-filled cavity in the temporal bone that is line by epithelium. It is separated from the external ear by a thin bony partition that contains two small membrane covered openings.

✓ Oval window

✓ Round Window

Three tiny ligaments attached bones are present in the middle ear.

These bones are called as auditory ossicles.

These are named according to their shapes.

✓ The malleus or the hammer

✓The incus or the anvil

✓ The stapes or the stirrup

The Malleus:

The handle of malleus attaches to the internal surface of the eardrum. The head of the malleus articulates with the body of the incus.

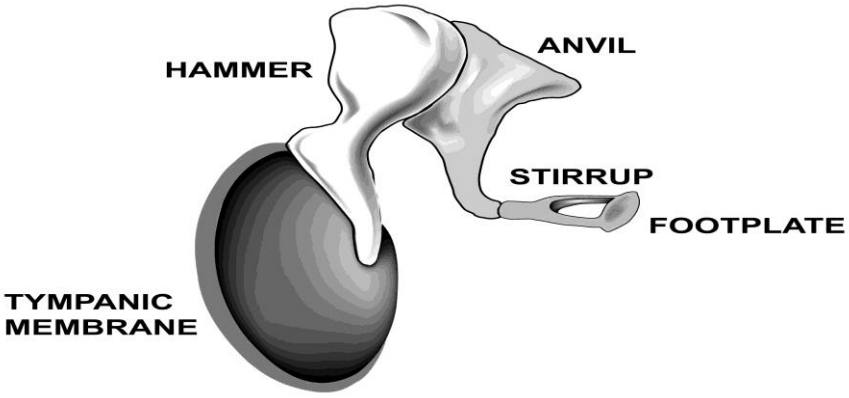
The Incus:

The middle bone in the series articulates with the head of the stapes.

The Stapes:

The base or footplate of the stapes fit into the oval window. Directly below the oval window is another opening the round window which is enclosed by a membrane called as secondary tympanic membrane. The middle ear also filled with air.The middle ear is connected to pharynx

through a tube called as eustachian tube. It helps maintain equal air pressure on the two sides of the eardrum.



Auditory ossicles

Internal Ear:

The internal ear is also called as labyrinth. Structurally, it consists of two parts.

✓ ***Bony labyrinth:*** Outer part of labyrinth

Membranous labyrinth: Inner part of labyrinth

It is divided into three parts:

✓ The semi-circular canals

✓The vestibule

✓The cochlea

The receptors for equilibrium are located in the semi-circular canals. The receptors for hearing are located in cochlea.The fluid present in bony labyrinth called as perilymph. The fluid present in membranous labyrinth called as endolymph.The central portion of bony labyrinth is the vestibule.The vestibule is connected with the three semi-circular canals in the posterior side whereas anteriorly it is connected with cochlea.

✓ Anterior semi-circular canal

✓ Posterior semi-circular canal

✓Lateral semi-circular canal

The vestibule consists of two sacs are:

✓ Utricle

✓ Saccule

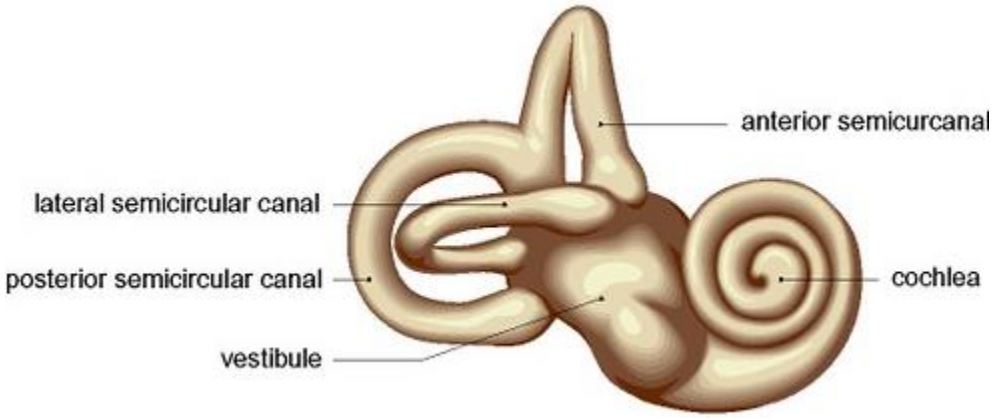
Each semi-circular canal lies at approximately right angles to the other two. At one end of each canal is a swollen enlargement called as ampulla.

Anterior to the vestibule is the cochlea, a bony spiral canal that resembles a snails shell and makes almost three turns around a central bony core called the modiolus. The receptor cells are located in the cochlea. The cochlea is divided into cochlear duct and cochlear spiral. One side of the cochlear duct is made up of basilar membrane and the organ of corti is attached to it. The sensitive receptors of ear are present in the organ of corti.These cells are called as hair cells are responsible for converting the pressure waves into receptor potential.

On the sides of cochlear duct are present the following fluid filled compartments:

✓***Scala vestibule:*** It is located on sides of cochlear duct and ends at the oval window.

✓***Scala tympani:*** It is present below the cochlear duct and ends at round window.



Internal ear

Physiology of Hearing:

The following events occur in hearing:

1. The auricle directs sound waves into the external auditory canal.

2. When sound waves strike the tympanic membrane, the alternating high and low pressure of the air causes the tympanic membrane to vibrate back and forth. The distance it moves, which is very small, depends on the intensity and frequency of the sound waves. The eardrum vibrates slowly in response to low-frequency (low-pitched) sounds and rapidly in response to high-frequency (high-pitched) sounds.

3. The central area of the eardrum connects to the malleus, which also starts to vibrate.

The vibration is transmitted from the malleus to the incus and then to the stapes.

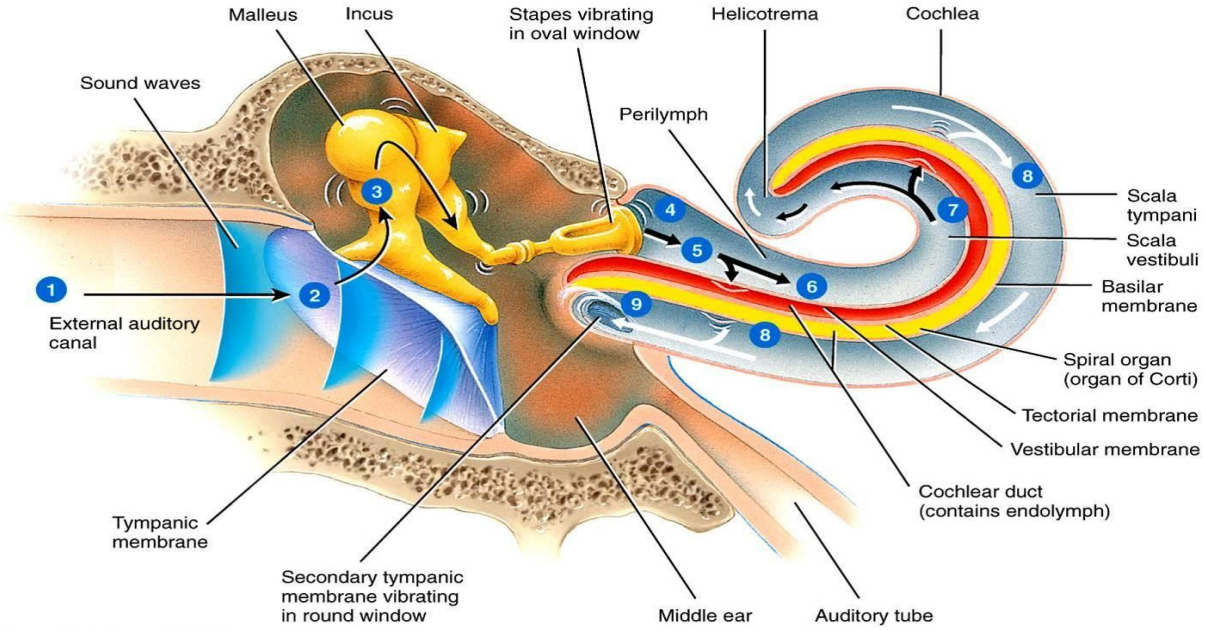
4. As the stapes moves back and forth, it pushes the membrane of the oval window in and out.

5. The movement of the oval window sets up fluid pressure waves in the perilymph of the cochlea. As the oval window bulges inward, it pushes on the perilymph of the scala vestibuli.

6. Pressure waves are transmitted from the scala vestibuli to the scala tympani and eventually to the round window, causing it to bulge outward into the middle ear.

7. As the pressure waves deform the walls of the scala vestibuli and scala tympani, they also push the vestibular membrane back and forth, creating pressure waves in the endolymph inside the cochlear duct.

8. The pressure waves in the endolymph cause the basilar membrane to vibrate, which moves the hair cells of the spiral organ against the tectorial membrane. This leads to bending of the hair cell stereocilia, which produces receptor potentials that ultimately lead to the generation of nerve impulses.



Physiology of hearing

OLFACTION: SENSE OF SMELL

Both smell and taste are chemical senses, because the sensations arise from the interaction of molecules with smell or taste receptors.

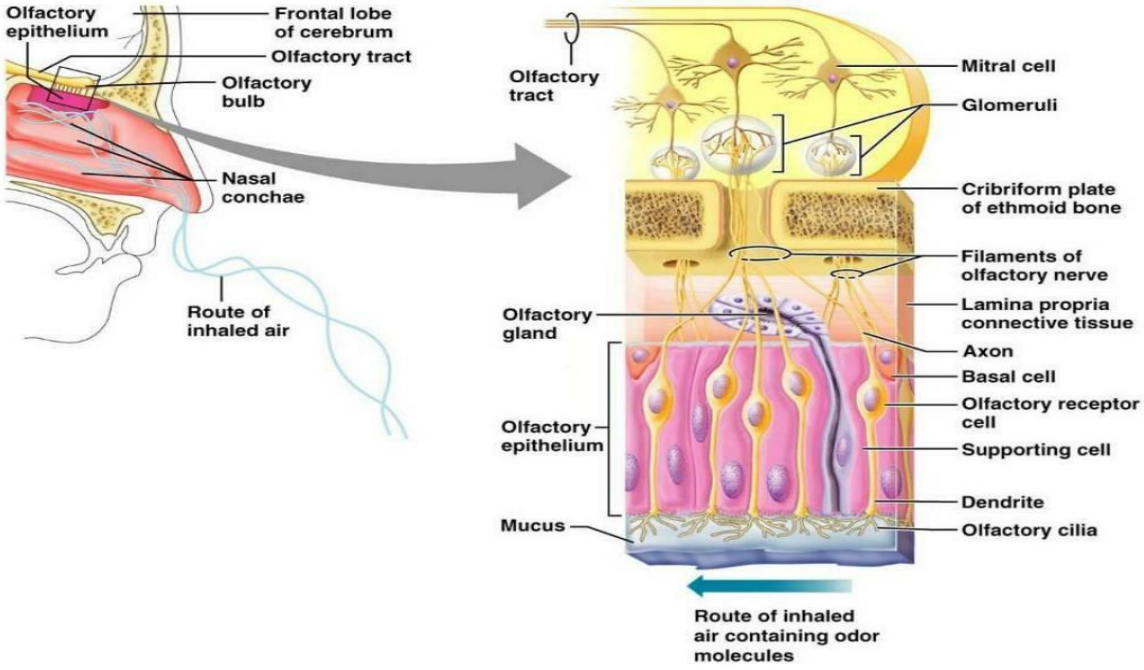
Anatomy of Olfactory Receptors:

The nose contains 10-100 million receptors for the sense of smell or olfaction which are contained within an area called the olfactory epithelium. The olfactory epithelium consists of three kinds of cells:

Olfactory receptors

Supporting cells

Basal Cells



Olfactory receptors

Olfactory receptors:

These are the first-order neurons of the olfactory pathway. Each olfactory receptor is a bipolar neuron with an exposed knob-shaped dendrite and an axon projecting through the cribriform plate and ending in the olfactory bulb. The parts of the olfactory receptors that respond to inhaled chemicals are the olfactory hair, cilia that project from the dendrite. Chemicals that have an odour and can stimulate the olfactory hairs are called as odorants. Olfactory receptors respond to the chemical stimulation of an odorant molecule by producing a generator potential, thus initiating the olfactory response.

Supporting cells:

These are columnar epithelial cells of the mucous membrane lining the nose. They provide physical support, nourishment, and electrical insulation for the olfactory receptors, and they help detoxify chemicals that come in contact with the olfactory epithelium.

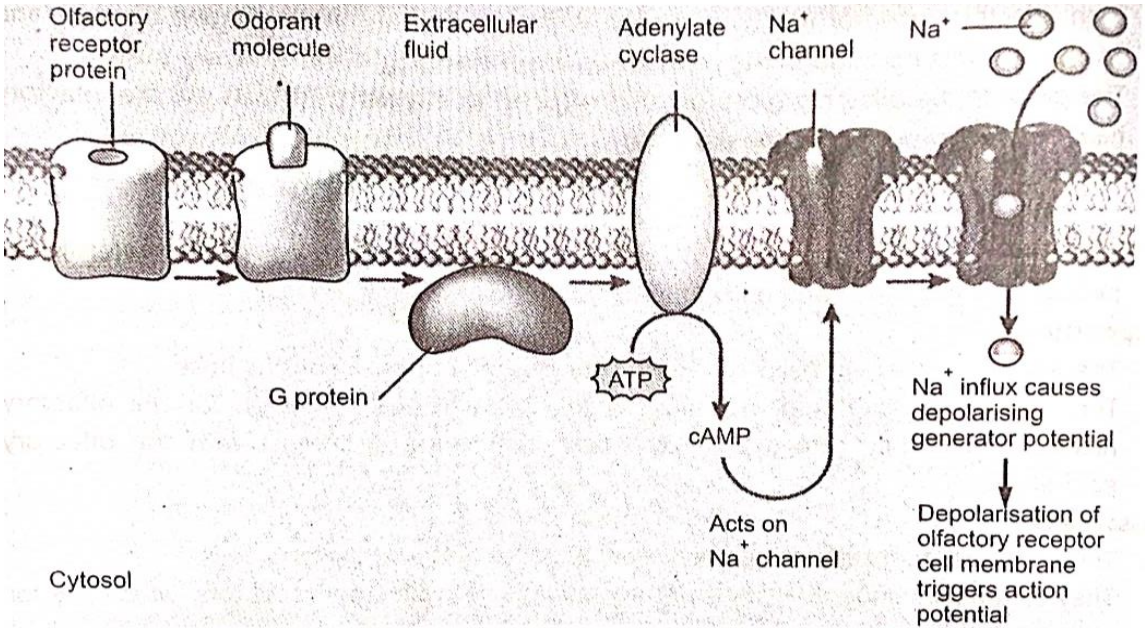
Basal cells:

These are the stem cells located between the bases of the supporting cells. They continually undergo cell division to produce new olfactory receptors, which live for only a month. Olfactory epithelium produces mucous that is carried to the surface of the epithelium by ducts.

The secretion moistens the surface of the olfactory epithelium and dissolves odorants so that transduction can occur.

Physiology of olfaction's

Human being ability to recognize about 10,000 different odours probably depends on patterns of activity in the brain that arise from activation of many different combinations of olfactory receptors. Olfactory receptors react to odorant molecules in the same way that most sensory receptors react to their specific stimuli: A generator potential (depolarization) develops and triggers one or more nerve impulses. In some cases, an odorant binds to an olfactory receptor protein in the plasma membrane of an olfactory hair. The olfactory receptor protein is coupled to a membrane protein called a G protein, which in turn activates the enzyme adenylate cyclase. The result is the following chain of events: production of cyclic adenosine monophosphate (CAMP): opening of sodium ion (Na) channels →inflow of Na* depolarizing generator potential →generation of nerve impulse and propagation along axon of olfactory receptor.



Physiology of olfaction

GUSTATION: SENSE OF SMELL

Taste or gustation is a chemical sense.

It consists of five primary tastes:

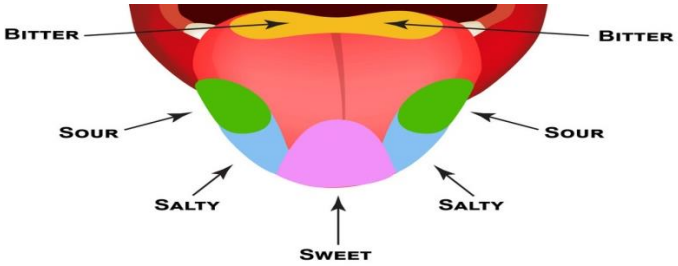
✓ Sour

✓ Sweet

✓ Bitter

✓ Salty

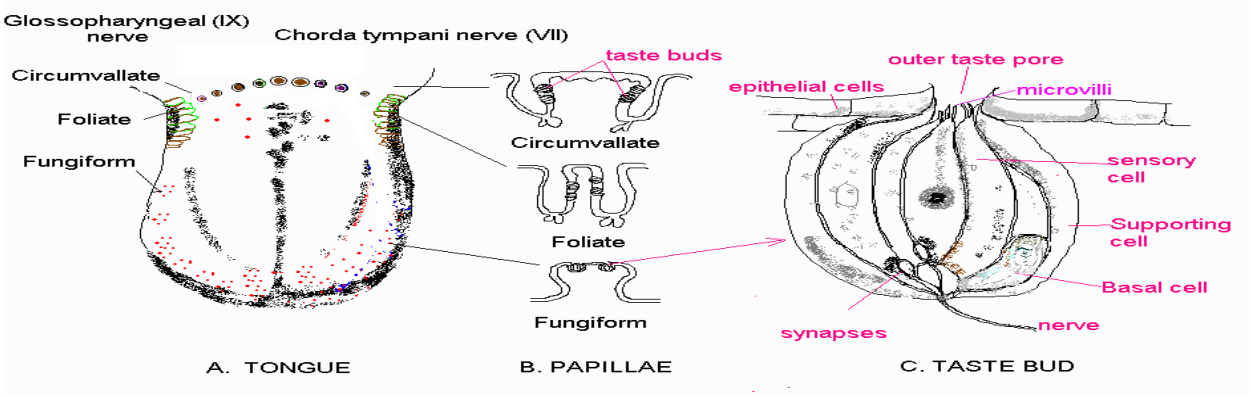
✓ Umami



The umami taste recently reported and is described as meaty taste. Odours from food can pass upward from the mouth into the nasal cavity, where they stimulate olfactory receptors. Because olfaction is much more sensitive than taste, a given concentration of a food substance may stimulate the olfactory system thousands of times more strongly than it stimulates the gustatory system.

Anatomy of Taste Buds and Papillae:

The receptors for sensations of taste are located in the taste buds. Nearly 10,000 taste buds are present on the tongue of a young adult, but some are found on the soft palate, pharynx and epiglottis. The number of taste buds declines with age.



Taste Buds and Papillae

Each taste bud is an oval body consisting of three kinds of epithelial cells:

(a) Supporting cells: The supporting cells surround about 50 gustatory receptor cells in each taste bud.

(b) Gustatory receptor cells: A single, long microvillus, called a gustatory hair, projects from each gustatory receptor cell to the external surface through the taste pore (opening in the taste bud).

(c) Basal cells: Basal cells, stem cells found at the periphery of the taste bud near the connective tissue layer, produce supporting cells, which then develop into gustatory receptor cells.

Each gustatory receptor cell has a life span of about 10 days.

At their base, the gustatory receptor cells synapse with dendrites of the first-order neurons that form the first part of the gustatory pathway.

Taste buds are found in elevations on the tangue called papillae which provide a rough texture to the upper surface of the tongue.

Four types of papillae contain taste buds.

(a) Circumvallate papillae: It form an inverted V-shaped row at the back of the tongue.

Each of these papillae houses 100-300 taste buds.

(b) Fungiform papillae: These are mushroom-shaped elevations scattered over the entire surface of the tongue that contain about 5 taste buds each.

(c) Foliate papillae: These are located in small trenches on the lateral margins of the tongue, but most of these taste buds degenerate in early childhood.

(d) Filiform papillae: In addition, the entire surface of the tongue has filiform papillae.

These pointed, threadlike structures contain tactile receptors but no taste buds. They increase friction between the tongue and food, making it easier for the tongue to move food in the oral cavity.

Physiology of Gustation:

Chemicals that stimulate gustatory receptor cells are known as tastants. Once a tastant is dissolved in saliva, it can make contact with the plasma membrane of the gustatory hairs, which are the sites of taste transduction. The result is a receptor potential that stimulates exocytosis of synaptic vesicles from the gustatory receptor cell.

The liberated neurotransmitter molecules trigger nerve impulses in the first-order sensory neurons that synapse with gustatory receptor cells. The receptor potential arises differently for different tastants. The sodium ions (Na) in a salty food enter gustatory receptor cells via Na* channels in the plasma membranes. The accumulation of Nat inside causes depolarization that leads to release of a neurotransmitter. The hydrogen ions (H*) in sour tastants may flow into gustatory receptor cells via H* channels. They also influence opening and closing of other types of ion channels. Again, the result is depolarization and the liberation of the neurotransmitter.

Other tastants, responsible for stimulating sweet, bitter, and umami tastes, do not themselves enter gustatory receptor cells. Rather, they bind to receptors on the plasma membrane that are linked to G proteins. The G proteins then activate several different chemicals known as second messengers inside the gustatory receptor cell. Different second messengers cause depolarizationin in different ways to release the neurotransmitter.

DISORDERS OF SENSE ORGANS

Cataract:

A common cause of blindness is a loss of transparency of the lens known as a cataract. The lens becomes cloudy (less transparent) due to changes in the structure of the lens proteins. Cataracts often occurs with aging but may also be caused by injury, excessive exposure to ultraviolet rays, certain medications (such as long-term use of steroids), or complications of other diseases (for example, diabetes).

Glaucoma:

Glaucoma is an abnormally high intraocular pressure due to a build-up of aqueous humor within the anterior cavity. The fluid compresses the lens into the vitreous body and puts pressure on the neurons of the retina. Persistent pressure results in a progression from mild visual impairment to irreversible destruction of neurons of the retina, damage to the optic nerve, and blindness

Deafness:

Deafness is significant or total hearing loss. Sensorineural deafness is caused by either impairment of hair cells in the cochlea or damage of the cochlear branch of the vestibulocochlear (VIII) nerve.

This type of deafness may be caused by atherosclerosis, which reduces blood supply to the ears; by repeated exposure to loud noise, which destroys hair cells of the spiral organ; and/or by certain drugs such as aspirin and streptomycin.

Meniere's Disease:

Meniere's disease results from an increased amount of endolymph that enlarges the membranous labyrinth. The symptoms are fluctuating hearing loss (caused by distortion of the basilar membrane of the cochlea) and roaring tinnitus (ringing).

Otitis Media:

Otitis media is an acute infection of the middle ear caused mainly by bacteria and associated with infections of the nose and throat. Symptoms include pain, malaise, fever, and a reddening and outward bulging of the eardrum.

Long Answer Questions:

1. Describe the sympathetic and parasympathetic nervous system.
2. Explain the anatomy of eyeball.
3. Give the anatomy of ear.
4. Discuss the physiology of hearing.
5. Discuss the physiology of vision.

Short Answer Questions:

1. Describe the origin and function of cranial nerves.
2. Write a note on spinal nerves.
3. Give the difference between sympathetic and parasympathetic nervous system
4. Note on interior of eye ball.
5. Draw the diagram of internal structure of eye ball.
6. Explain physiology of hearing.
7. Note on physiology of sight.
8. List and describes the accessory structures of the eyes.
9. Describe components of external, middle and internal ear.
10. Explain structure and function of ear.
11. Write note on eye.
12. Explain the physiology of gustation