Shree H. N. Shukla Institute of Pharmaceutical Education and Research, Rajkot

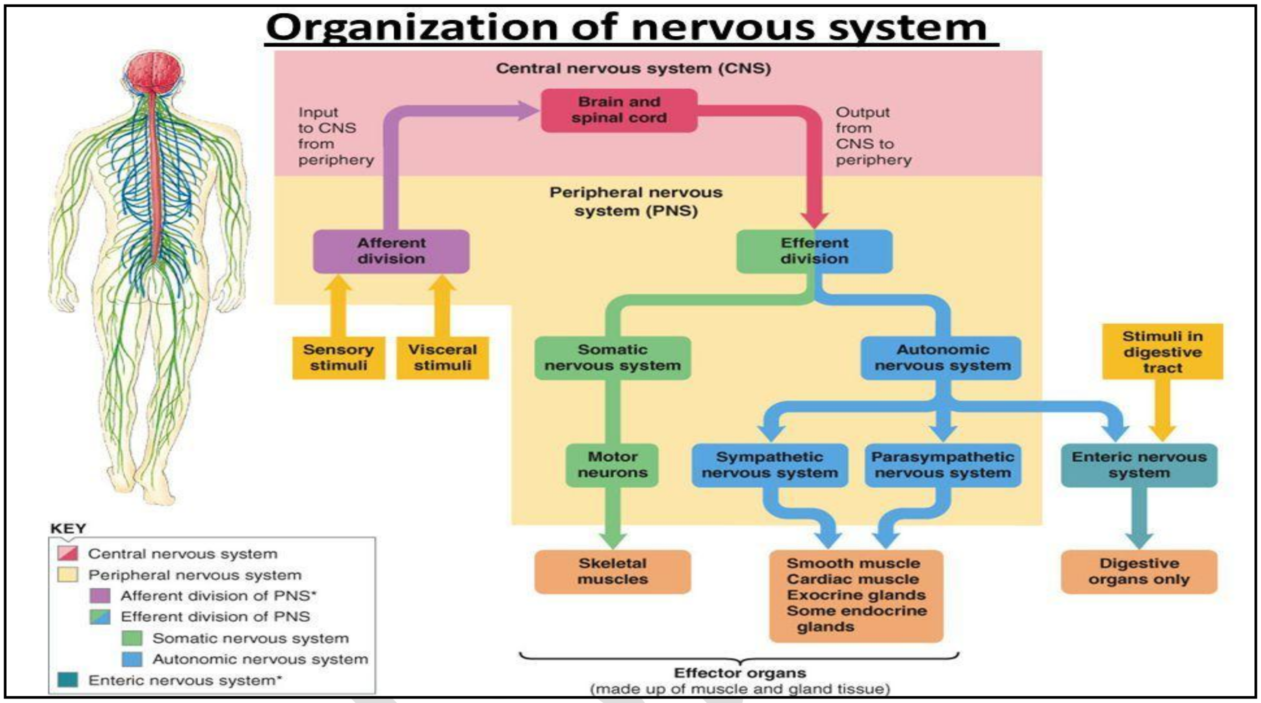
B. Pharm
Semester-I

Subject Name: Human Anatomy & Physiology-I
Subject Code: BP101TP

Chapter-5

PERIPHERAL NERVOUS SYSTEM

The **peripheral nervous system** (**PNS**) is one of the two main parts of the nervous system, the other part is the central nervous system (CNS).



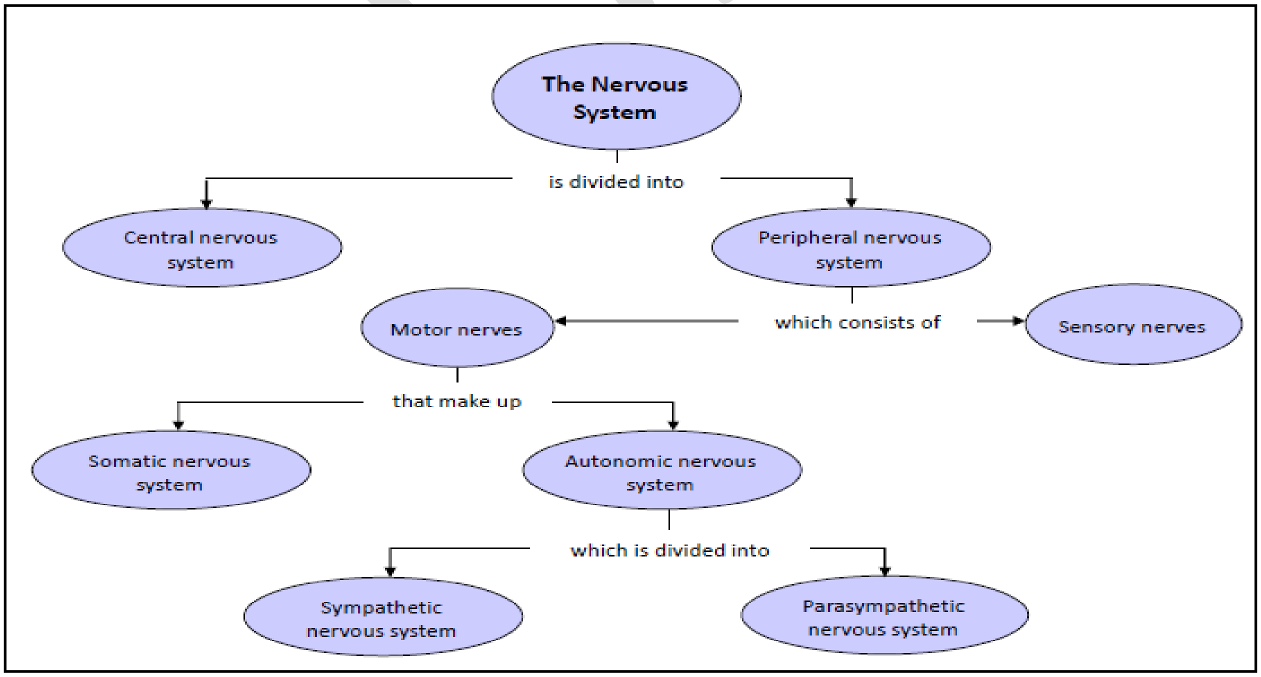
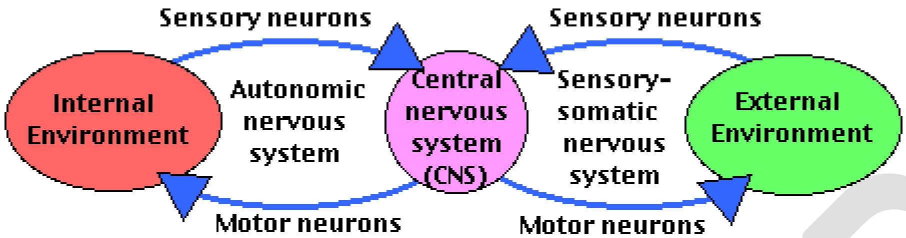


Figure 1: Organization of Nervous system

The PNS consists of the nerves and ganglia outside of the brain and spinal cord. The main function of the PNS is to connect the CNS to the limbs and organs, essentially serving as a relay between the brain and spinal cord and the rest of the body.



Types of Nervous System

The peripheral nervous system is divided into the **somatic nervous system** and the **autonomic nervous system**. In the somatic nervous system, the cranial nerves are part of the PNS.

1. Motor Division – impulses from CNS to muscles or glands

• Two Parts:

– Somatic Nervous System

– Autonomic Nervous System

2. Sensory Division – transmits impulses from sense organs to CNS.

The peripheral nervous system is divided into the somatic nervous system, and the autonomic nervous system. The somatic nervous system is under voluntary control, and transmits signals from the brain to end organs such as muscles. The sensory nervous system is part of the somatic nervous system and transmits signals from senses such as taste and touch (including fine touch and gross touch) to the spinal

cord and brain. The autonomic nervous system is a 'self-regulating' system which influences the function of organs outside of voluntary control, such as the heart rate, or the functions of the digestive system.

PNS → ANS → Efferent Nerves Controls the muscles & glands → viscera Connects CNS to muscles (smooth: blood vessels, eye, Skin hair follicles, stomach; cardiac: heart)

Parasympathetic

- acts to conserve, save energy
- Related to psych relaxation

Rest & Digest

<u>Sympathetic</u>

- stimulates, organizes & mobilizes energy in threat situations
- Related to psych arousal

Flight and Fight

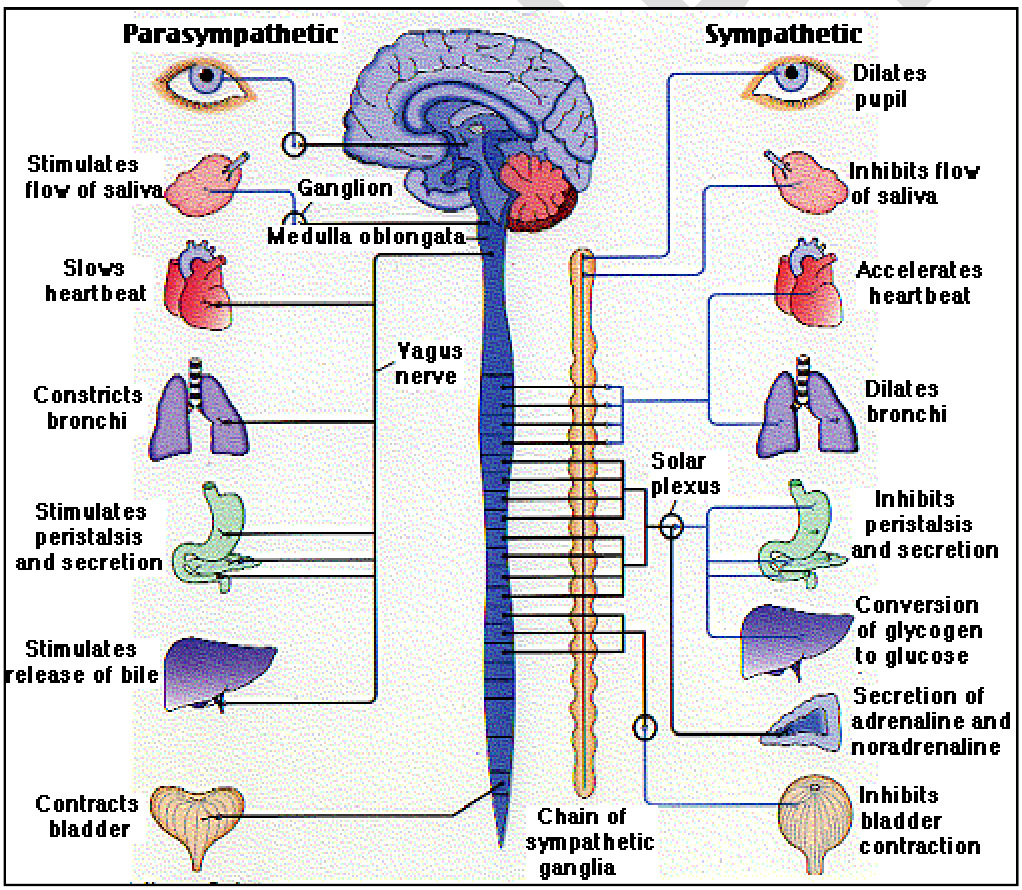


Figure 2. ANS of Human Body

The Sympathetic Nervous System

The **preganglionic** motor neurons of the sympathetic system (shown in black) arise in the spinal cord. They pass into sympathetic ganglia which are organized into two chains that run parallel to and on either side of the spinal cord.

The preganglionic neuron may do one of three things in the sympathetic ganglion:

- synapse with **ostganglionic** neurons (shown in white) which then reenter the spinal nerve and ultimately pass out to the sweat glands and the walls of blood vessels near the surface of the body.
- pass up or down the sympathetic chain and finally synapse with postganglionic neurons in a higher or lower ganglion
- leave the ganglion by way of a cord leading to special ganglia (e.g. the solar plexus) in the viscera. Here it may synapse with postganglionic sympathetic neurons running to the smooth muscular walls of the viscera. However, some of these preganglionic neurons pass right on through this second ganglion and into the **adrenal medulla**. Here they synapse with the highly-modified postganglionic cells that make up the secretory portion of the adrenal medulla.

The neurotransmitter of the preganglionic sympathetic neurons is **acetylcholine** (**ACh**). It stimulates action potentials in the postganglionic neurons.

The neurotransmitter released by the postganglionic neurons is **noradrenaline** (also called n**orepinephrine**).

The action of noradrenaline on a particular gland or muscle is excitatory is some cases, inhibitory in others. (At excitatory terminals, ATP may be released along with noradrenaline.)

The **release of noradrenaline**

- stimulates heartbeat
- raises blood pressure
- dilates the pupils
- dilates the trachea and bronchi
- stimulates glycogenolysis — the conversion of liver glycogen into glucose
- shunts blood away from the skin and viscera to the skeletal muscles, brain, and heart
- inhibits peristalsis in the gastrointestinal (GI) tract
- inhibits contraction of the bladder and rectum

- and, at least in rats and mice, increases the number of AMPA receptors in the hippocampus and thus increases long-term potentiation (LTP).

In short, stimulation of the sympathetic branch of the autonomic nervous system prepares the body for emergencies: for "**fight or flight**" (and, perhaps, enhances the memory of the event that triggered the response).

Activation of the sympathetic system is quite general because

- a single preganglionic neuron usually synapses with many postganglionic neurons;
- the release of **adrenaline** from the adrenal medulla into the blood ensures that all the cells of the body will be exposed to sympathetic stimulation even if no postganglionic neurons reach them directly.

The Parasympathetic Nervous System

- The main nerves of the parasympathetic system are the tenth (X) cranial nerves, the **vagus nerves**. They originate in the **medulla oblongata**. Parasympathetic neurons also extend from three other cranial nerves (III, VII, and IX). Recent work (in mice) indicates that there are no pre-ganglionic parasympathetic nerves extending from the tip of the spinal cord. If this is true for humans, then the bottom-left part of the above figure is incorrect.
- Each preganglionic parasympathetic neuron synapses with just a few postganglionic neurons, which are located near — or in — the effector organ, a muscle or gland. **Acetylcholine** (**ACh**) is the neurotransmitter at all the pre- and many of the postganglionic neurons of the parasympathetic system. However, some postganglionic neurons release nitric oxide (NO) as their neurotransmitter, and some release noradrenaline.

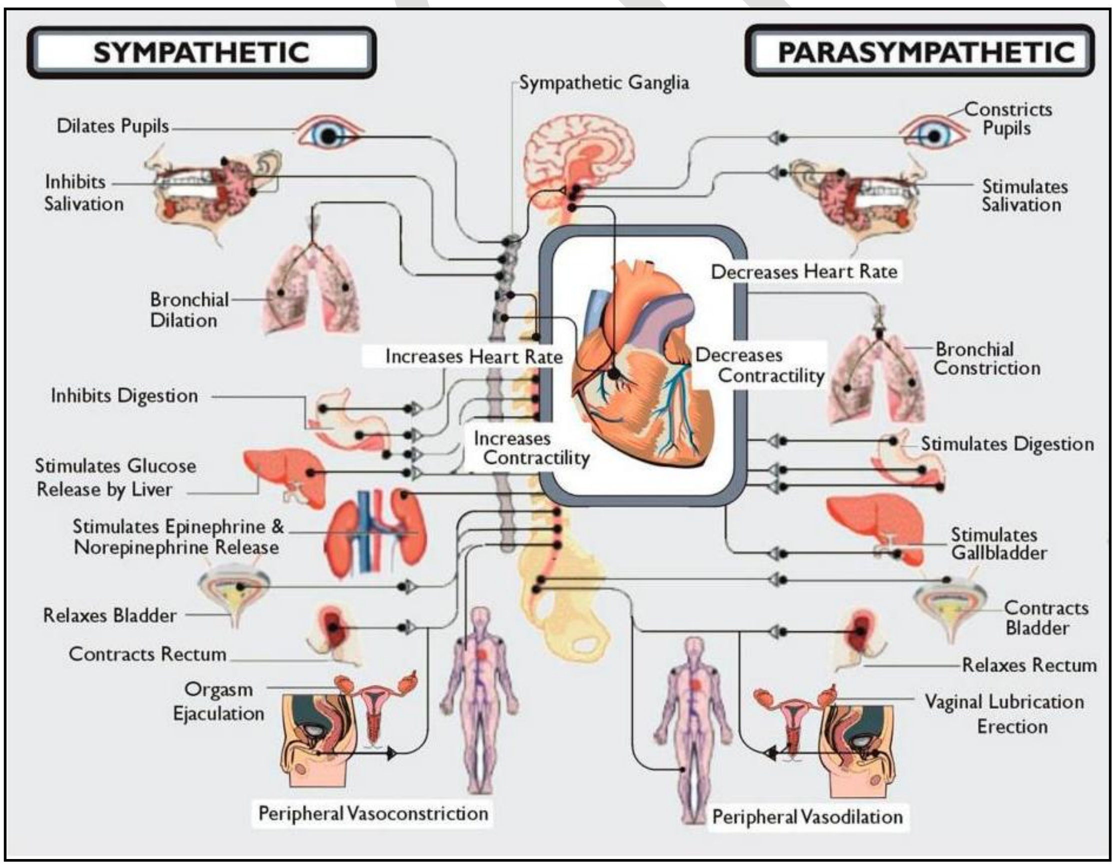
Parasympathetic stimulation causes

- slowing down of the heartbeat (as Loewi demonstrated)
- lowering of blood pressure
- constriction of the pupils
- increased blood flow to the skin and viscera
- peristalsis of the GI tract

In short, the parasympathetic system returns the body functions to normal after they have been altered by sympathetic stimulation. In times of danger, the sympathetic system prepares the body for violent activity. The parasympathetic system reverses these changes when the danger is over.

Functions of ANS

Sympathetic	Parasympathetic
Heart	Heart
↑ heart rate	↓ heart rate
↑ force of contraction	↓force of contraction
Blood vessels	Blood vessels
Constriction	No effect
Lungs	Lungs
Bronchodilation	Bronchoconstriction
GIT	GIT
↓ motility	↑ motility
Sphincter contraction	Sphincter relaxation
Decreased secretions	Increased secretions



Functions of the Sympathetic & Parasympathetic

	(Noradrenergic Receptors)	(Cholinergic)
Organ	Sympathetic Effect	Parasympathetic Effect
Salivary Gland	decreases secretion	increases secretion
Heart	increases heart rate	decreases heart rate
Blood Vessels	constricts blood vessels	dilates blood vessels
Iris radial muscle	dilates pupils	no effect
Iris sphincter muscle	no effect	constricts pupils
Tear Gland	no effect	stimulates secretion
Sweat Gland	stimulates secretion	no effect
Stomach & Intestine	no effect	stimulates secretion
Lungs	dilates bronchioles	constricts bronhioles
Arrector Pili muscle	piloerection	no effect
Penis	ejaculation	erection

Spinal nerves in which Peripheral Nervous System consists of:

• i) 31 pairs of Spinal Nerves

• Ii) 12 pairs of Cranial Nerves.

• There are 31 pairs of spinal nerves that leaves the vertebral canal (formed by 33 vertebrae) by passing through the intervertebral foramina. They are named and grouped according to the vertebrae with which they are associated:

- 8 cervical
- 12 thoracic
- 5 lumbar
- 5 sacral
- 1 coccygeal

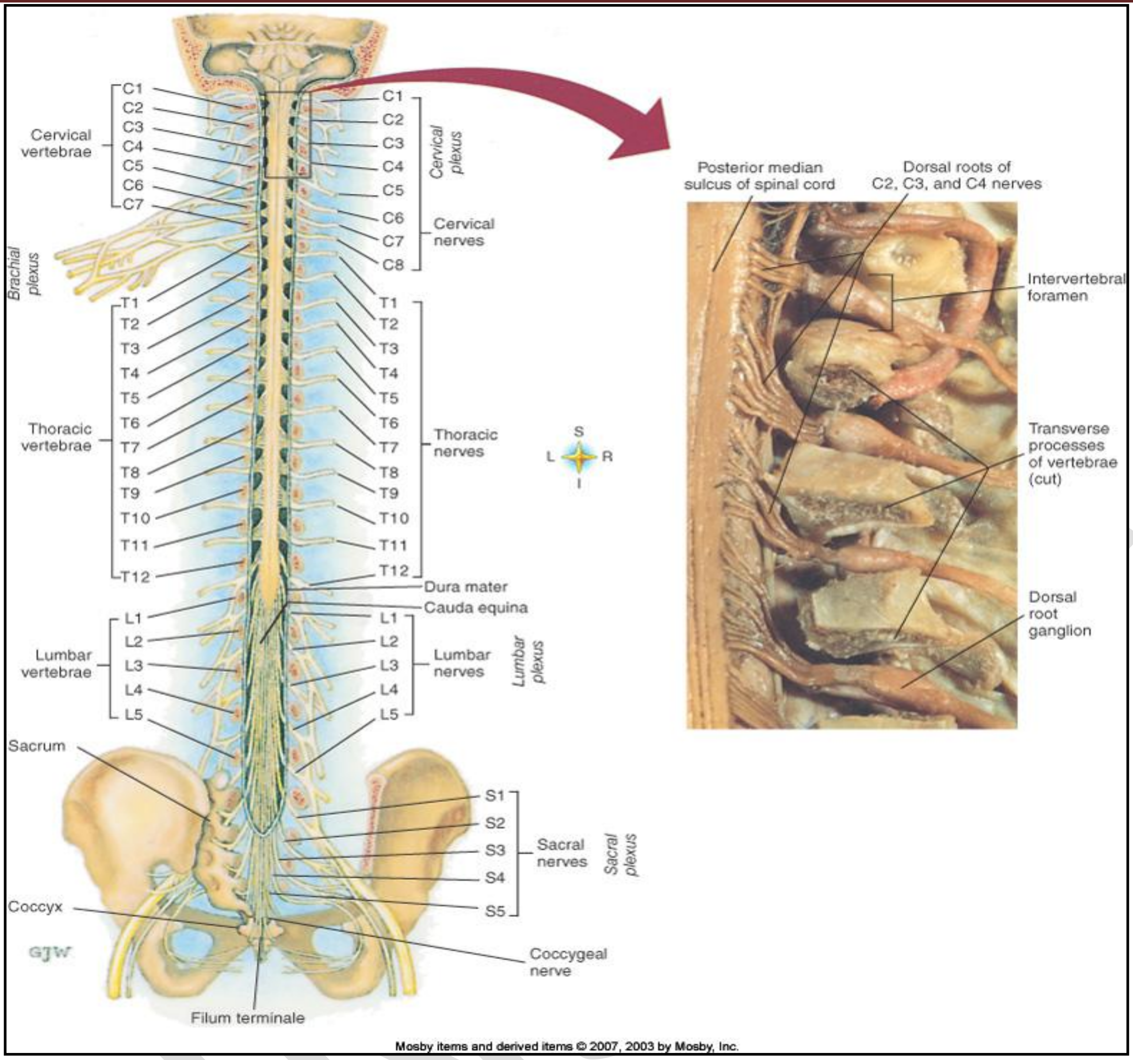


Figure 3: Spiral nerves

Neuron

• Neurons are made up of the following parts:

– The **nucleus** (which contains the genetic organelles)

– The **soma** (or cell body)

– **Dendrites** (branch-like structures which receive information from other neurons)

– **Axons** (long tubular pathways which send information to other parts of the brain)

– An (axonal) **presynaptic terminal.** The presynaptic terminal connects to other neurons via **synapses**. Many axons are surrounded by **myelin**, essentially sheaths which help axons quickly send signals over long distances.

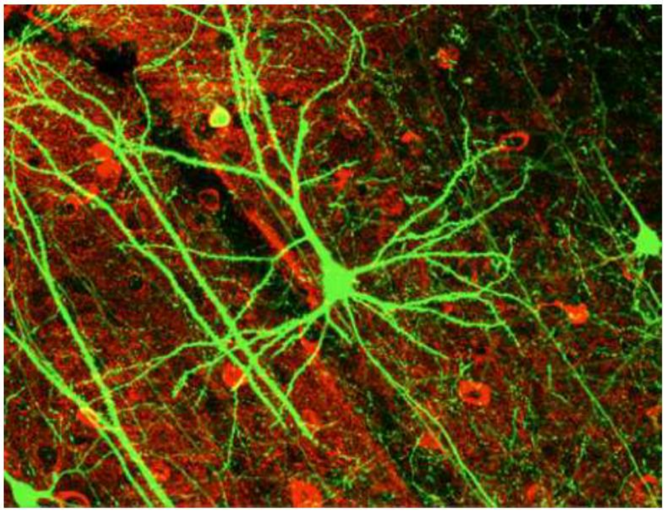


Figure 6: Electron microphotograph of neuron

Covering of a neuron: Each nerve consists of bundles of nerve fibers each of which is covered with fine connective tissues, which is;

1. Endoneurium: is a layer of delicate connective tissue around the myelin sheath of each myelinated nerve fiber.

2. Perineurium: Nerve fibers are bundled together into groups known as fascicles, each surrounded by a protective sheath known as the perineurium.

3. Epineurium: is the outermost layer of dense irregular connective tissue surrounding a peripheral nerve.

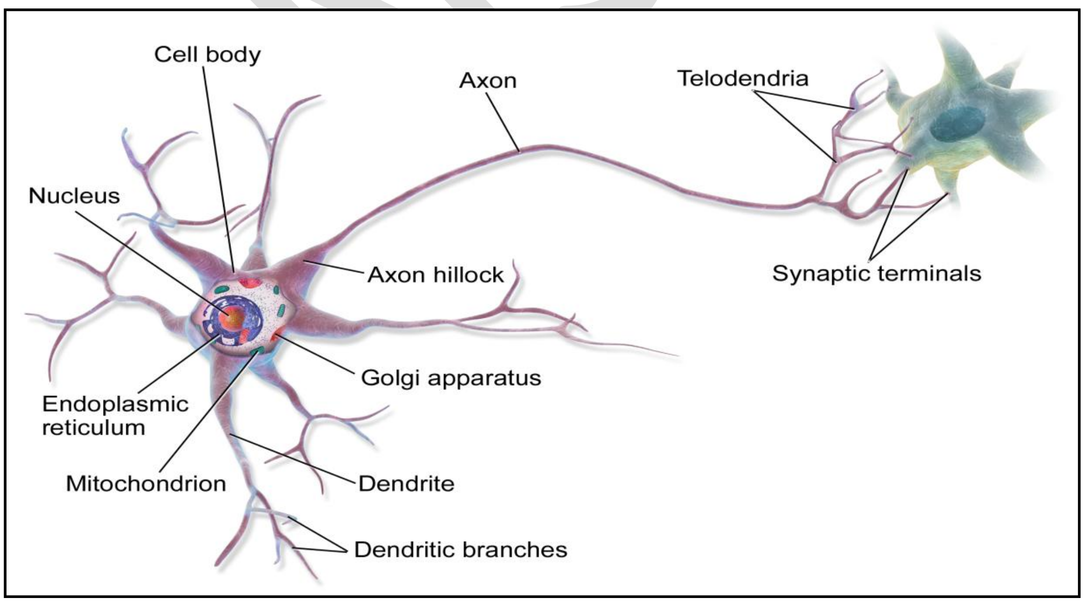


Figure 5: Structure of Neuron

Basic types of neurons

Neurons are divided on the basis of structures and size.

There are 3 different types of neurons:

- Multipolar neurons: one axon, many dendrites
- Bipolar neurons: one axon, one dendrite
- Pseudounipolar neurons: One process that branches in two.

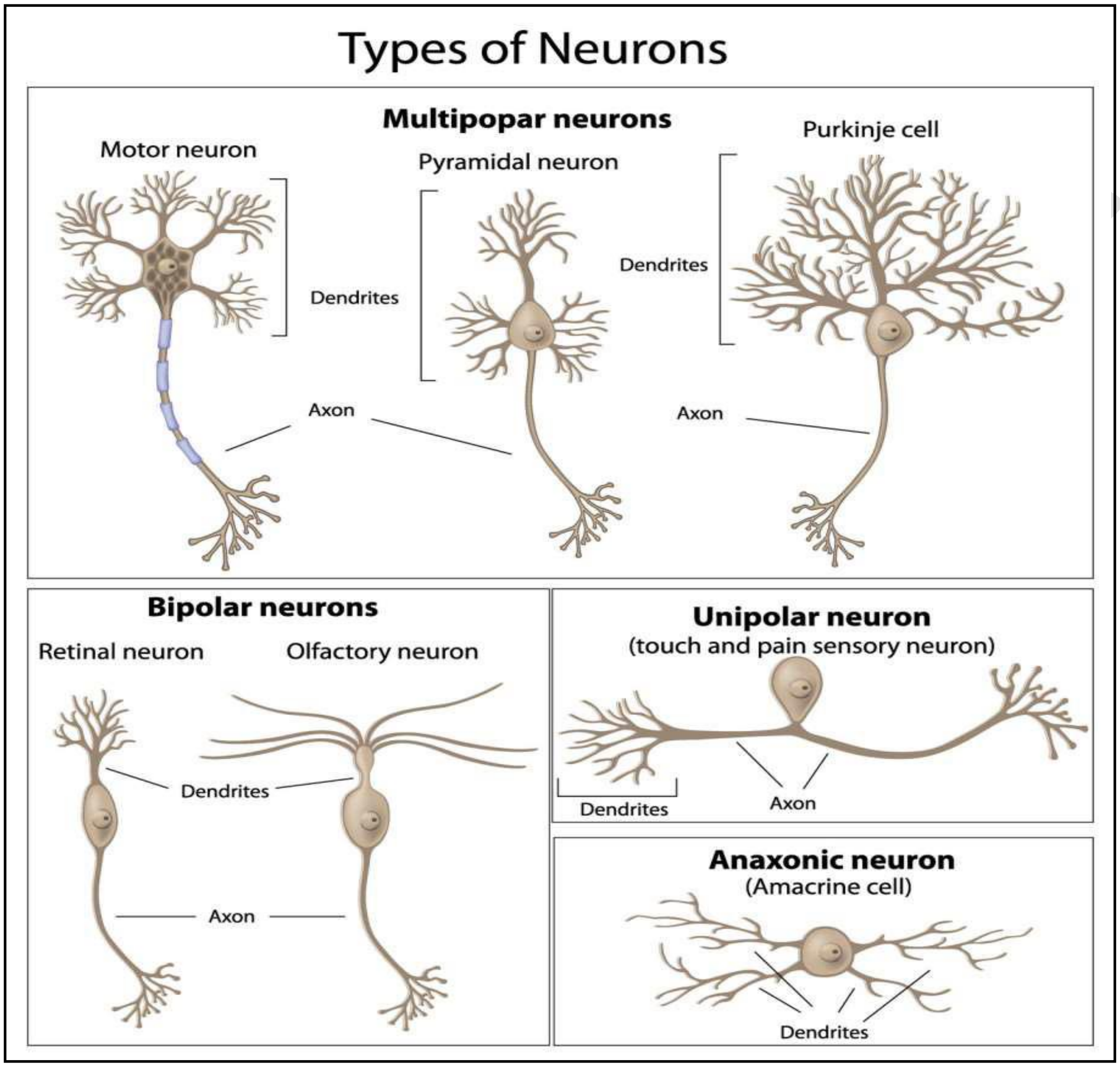
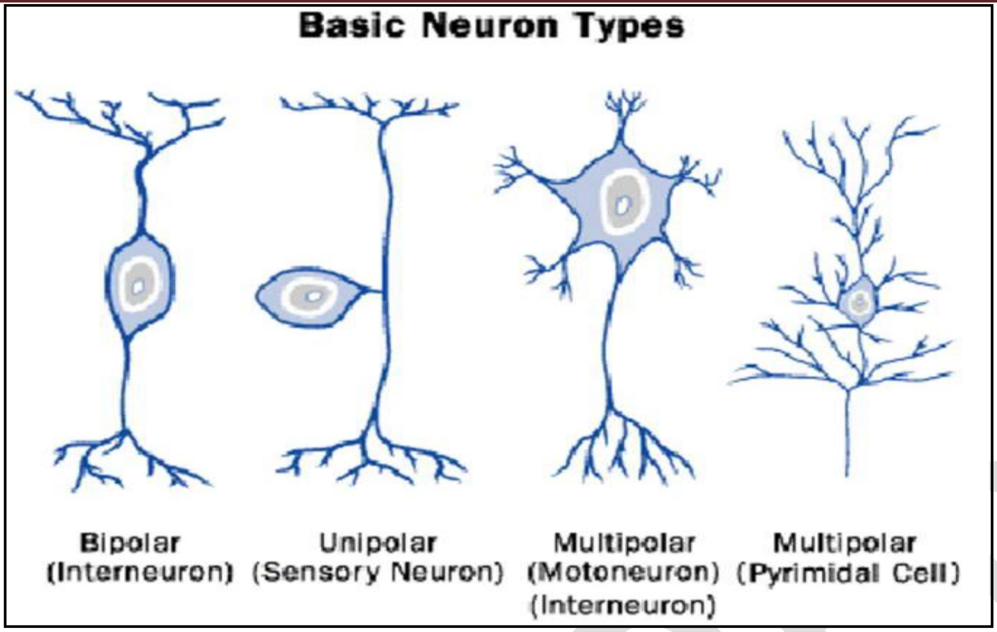


Figure 6: Types of Neuron

These nerves extend from the central nervous system to the outermost areas of the body.

- The nervous system is divided into the
  - Peripheral nervous system (PNS)
  - Central nervous system (CNS)



MULTIPOLAR NEURONS.

• These neurons contain a number of dendrites and one axon. They are the most common type of neurons and they can be found more or less anywhere in the nervous system. For example:

• **Pyramidal neurons** in the cerebral cortex

• **Purkinje neurons** in the cerebellum

• **Motor neurons** in the anterior horn of the spinal cord

2. BIPOLAR NEURONS

• Bipolar neurons have only two process that connect to the cell body: one dendrite and one axon. (This is easy to remember as, generally speaking, the prefix "bi" refers to the number two, such as in bilingual – two languages)

• Bipolar neurons are only found in specific areas of the nervous system:

• In the retina

• In the nose (receptors of the olfactory epithelium)

3. PSEUDOUNIPOLAR NEURONS

• There is only one process (this gives us the "unipolar part") that branches into two (which is why we add "pseudo" at the beginning. It doesn't look unipolar). This process is structurally similar to that of an axon, but it can receive information as well.

• Pseudounipolar neurons can be found in the spinal ganglions.

MINIMUM POINTS TO REMEMBER:

Neurons are the type of cells. They are made of:

• A cell body-called the soma

• Dendrites that receive information

• An axon that transmits information to another cell.

• Neurons are polarized in that the information can only travel in one direction: dendrite to axon.

Synapsis:

There are 3 types of synaptic connections between 2 neurons:

a) Axodendritic

b) Axosomatic

c) Axoaxonic

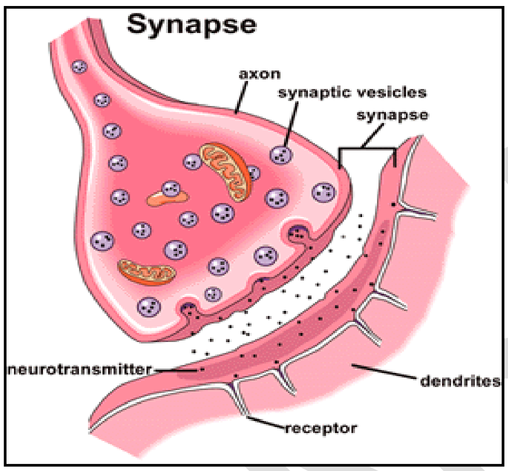


Figure 7: Synapase

Function

• The primary role of nerve is to transmit information reliably from the anterior horn cells to muscles for motor system (Efferent Pathway)m& from the sensory receptors to the spinal cord or CNS for the sensory system (Afferent Pathway)

• Although functionally nerves may seem similar to electrical wires, there are vast differences between them.

• At the molecular level, a complex set of chemical and electrical events allows nerve to propagate an electrical signal.

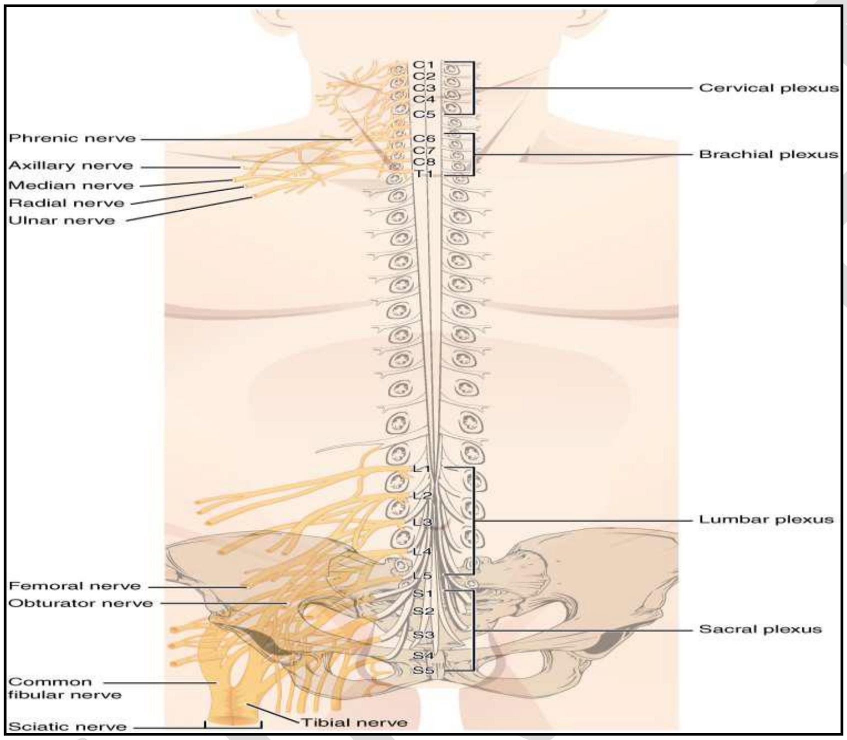
Branches:

• Immediately after emerging from the intervertebral foramina spinal nerves divide into branches, or rami: posterior ramus and anterior ramus.

• Posterior ramus supply skin and muscles of back and anterior ramus forms the plexus.

• There are five large plexuses of mixed nerves formed on each side of the vertebral column":

1. Cervical
2. Brachial
3. Lumbar
4. Sacral
5. Coccygeal



The definition of the peripheral nervous system generally includes the peripheral nerves, their primary motor and sensory neurons, neuromuscular junctions (NMJs), and muscles. In addition, cranial nerves **II** to **XII** usually are included in the peripheral nervous system, being essentially the same as peripheral nerves except that their primary motor neurons are located in the brainstem rather than the spinal cord. The primary motor neurons, the *anterior horn cells,* are located in the ventral gray matter of the spinal cord. The axons of these cells ultimately become the motor fibers in peripheral nerves. Their projections first run through the white matter of the anterior spinal cord before exiting ventrally as the *motor roots* In contrast to the anterior horn cell, however, the primary sensory neuron, the *dorsal root ganglion* (DRG), is not found within the substance of the spinal cord itself but lies outside, near the intervertebral foramen. The dorsal root ganglia are bipolar cells with two separate axonal projections. Their central projections form the *sensory nerve roots.*

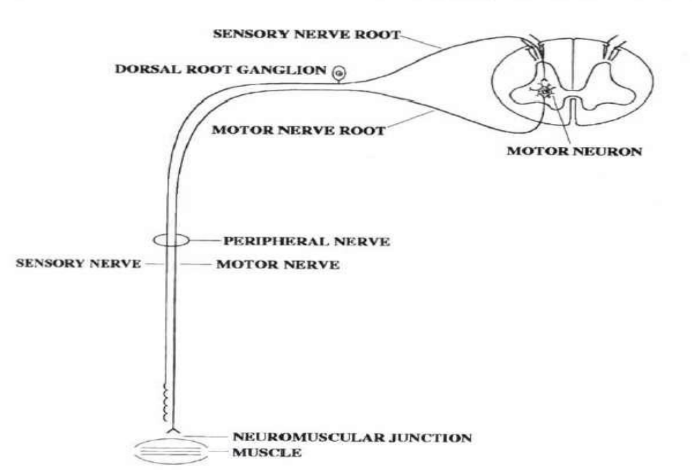


FIGURE 1–1
Elements of the peripheral nervous system. *Note that the primary motor neuron resides within the spinal cord, whereas the primary sensory neuron, the dorsal root ganglion, lies outside the spinal cord. The dorsal root ganglion is a bipolar cell. Its proximal process forms the sensory nerve root; the distal process becomes the peripheral sensory nerve.*

Motor and sensory roots at each spinal level unite distal to tile DRG to become a mixed *spinal nerve.* There are 31 pairs of spinal nerves (8 cervical, 12 thoracic, 5 lumbar, 5 sacral, I coccygeal. Each spinal nerve divides into a *dorsal* and *ventral ramus*.

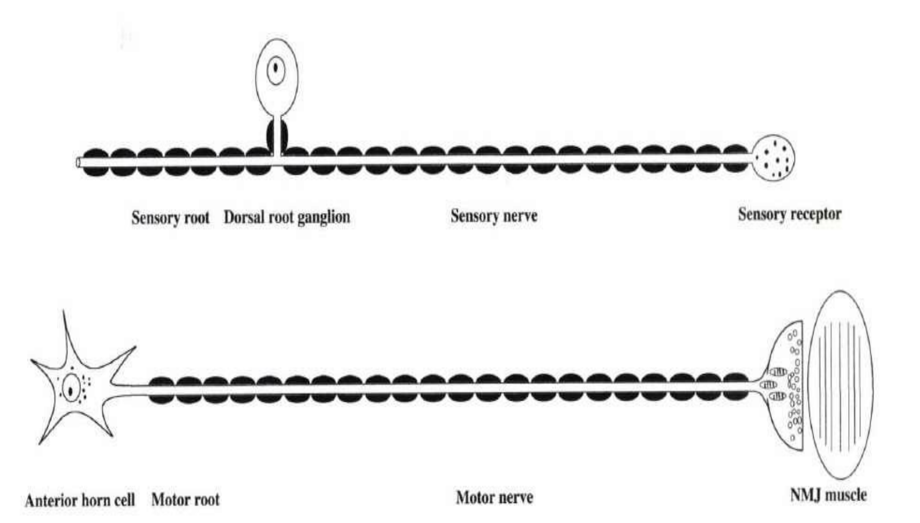
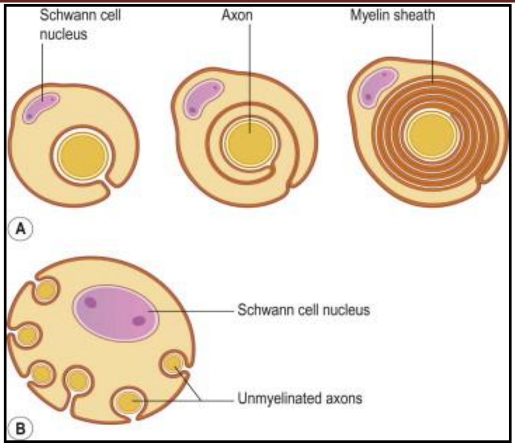


FIGURE 2–1
Elements of the peripheral nervous system. *The peripheral nervous system includes the peripheral motor and sensory nerves; their primary neurons, the anterior horn cells, and dorsal root ganglia; the neuromuscular junctions; and muscle. The dorsal root ganglion, a bipolar cell located distal to the sensory root, is anatomically different from the anterior horn cell. Consequently, lesions of the nerve roots result in abnormalities of motor nerve conduction studies but spare the sensory conduction studies, as the dorsal root ganglion and its peripheral nerve remain intact.*



The sensory roots enter the spinal cord on the dorsal side to either ascend in the posterior columns or synapse with sensory neurons in the dorsal homo The peripheral projections of the DRGs ultimately become the sensory fibers in peripheral nerves. These anatomic differences between the anterior horn cells and dorsal root ganglia result in a different pattern of motor and sensory nerve conduction abnormalities, depending on whether the lesion is in the peripheral nerve or proximal to the DRG at the root level.

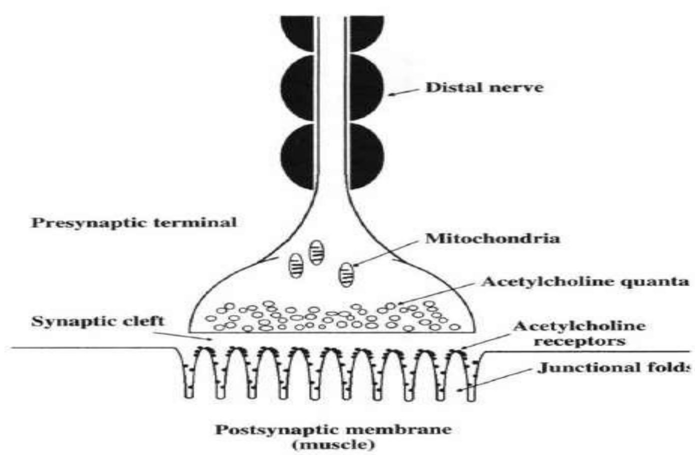
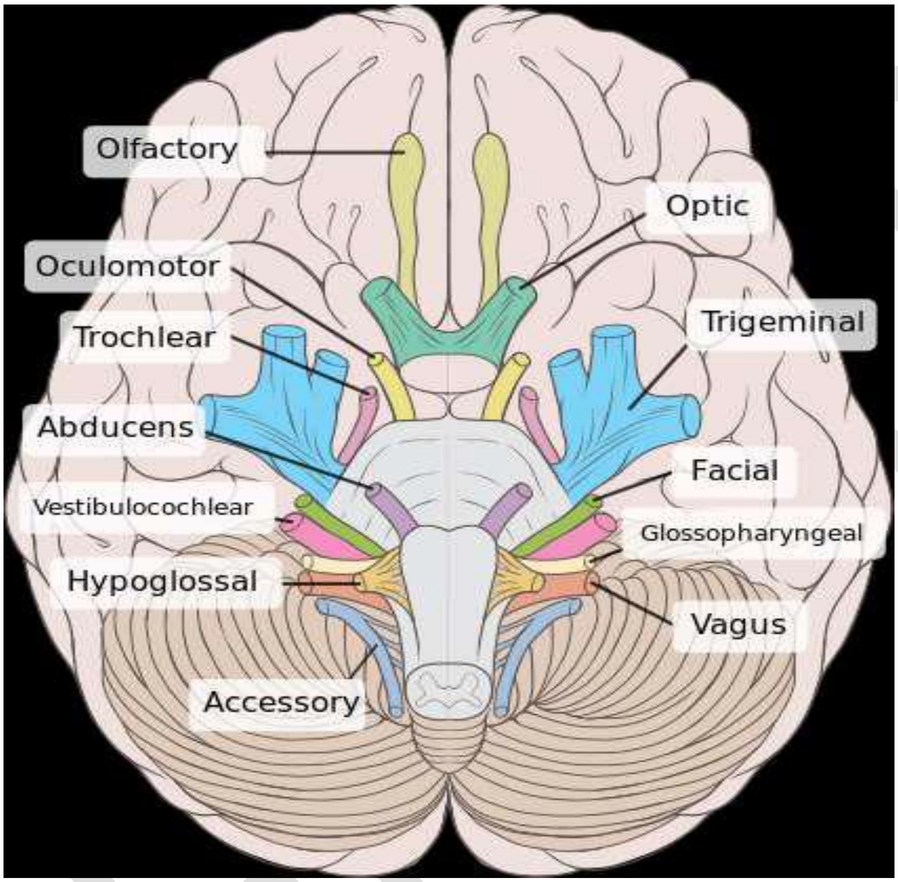


FIGURE 2–15
Neuromuscular junction. *The neuromuscular junction is a specialized junction between the terminal axon and muscle fiber. When the nerve action potential invades the presynaptic terminal, acetylcholine is released and diffuses across the synaptic cleft to bind to acetylcholine receptors on the muscle membrane. This binding results in a muscle endplate potential, which, once threshold is reached, causes the generation of a muscle fiber action potential.*

Cranial nerves:

• **Cranial nerves** are the nerves that emerge directly from the brain (including the brainstem), in contrast to spinal nerves (which emerge from segments of the spinal cord). 10 of 12 of the cranial nerves originate in the brainstem. Cranial nerves relay information between the brain and parts of the body, primarily to and from regions of the head and neck.

• The terminal nerves, olfactory nerves (I) and optic nerves (II) emerge from the cerebrum or forebrain, and the remaining ten pairs arise from the brainstem, which is the lower part of the brain.



Function:

• Smell (I)

• Vision (II)

• Eye movement (III, IV, VI)

• Trigeminal nerve (sensation to the skin of the face) (V)

• Facial expression (VII)

• Hearing and balance (VIII)

• Oral sensation, taste, and salivation (IX)

• Vagus nerve (blood pressure and heart rate) (X)

• Shoulder elevation and head-turning (XI)

• Tongue movement (XII)

The Cranial Nerves			
Nerve Number and Name		Composition	Some Functions
I	Olfactory	Sensory only	Olfaction (smell)
II	Optic	Sensory only	Vision
III	Oculomotor	Motor and sensory	Serves muscles of the eye
IV	Trochlear	Motor and sensory	Serves the superior oblique eye muscle
V	Trigeminal	Motor and sensory	Sensory from face and mouth; motor to muscles of mastication (chewing)
VI	Abducens	Motor and sensory	Serves the lateral rectus eye muscle
VII	Facial	Motor and sensory	Serves the muscles of facial expression, lacrimal glands,andsalivaryglands
VIII	Vestibulocochlear	Sensory only	Equilibrium and hearing
IX	Glossopharyngeal	Motor and sensory	Serves the pharynx (throat) for swallowing, posterior third of tongue, parotid salivary gland
X	Vagus	Motor and sensory	Sensations from visceral (internal) organs, and parasympathetic motor regulation of visceral organs
XI	Accessory	Motor and sensory	Serves muscles that move head, neck, and shoulders
XII	Hypoglossal	Motor and sensory	Serves muscles of the tongue

The special senses of hearing, sight, smell and taste all have specialised sensory receptors that collect and transmit information to specific areas of the brain.

•Incoming nerve impulses from sensory receptors in the ears, eyes, nose and mouth are integrated and coordinated within the brain allowing perception of this sensory information.

Anatomy of Ear

The ear is the organ of hearing and is also involved in balance.

•It is supplied by the 8th cranial nerve= *vestibulocochlear nerve*, which is stimulated by vibrations caused by sound waves.

Structure

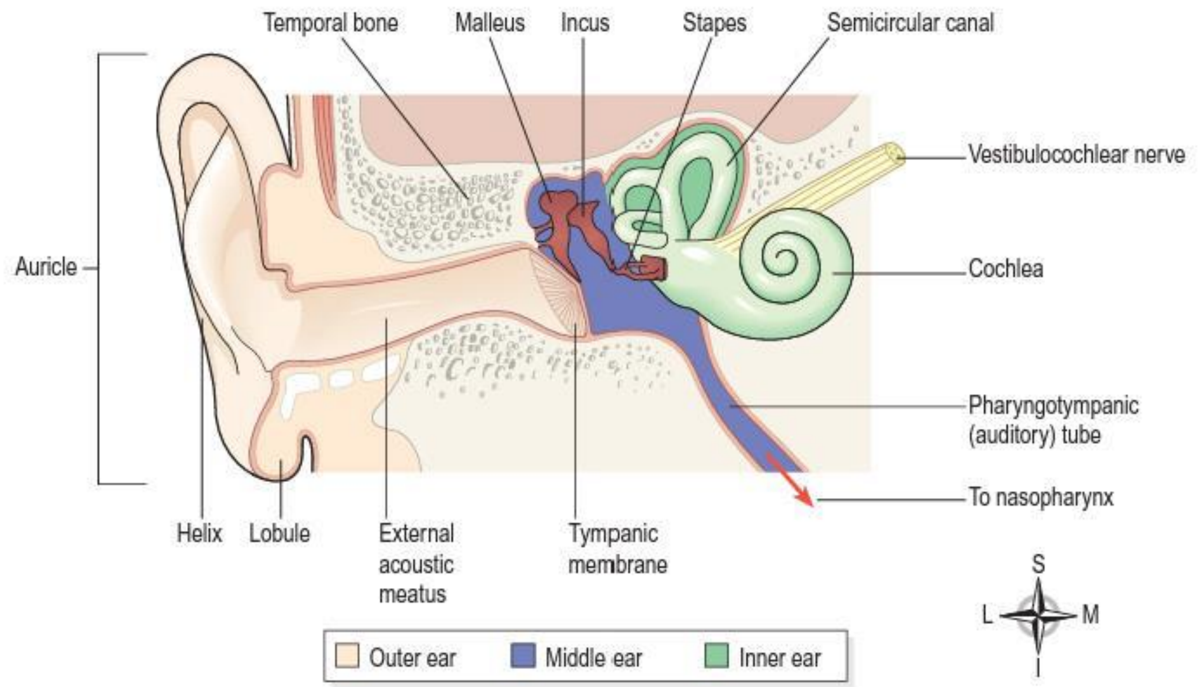
The ear is divided into three distinct parts

1)outer ear

2)middle ear (tympanic cavity)

3)inner ear.

•The outer ear collects the sound waves and directs them to the middle ear, which in turn transfers them to the inner ear, where they are converted into nerve impulses and transmitted to the hearing area in the cerebral cortex.

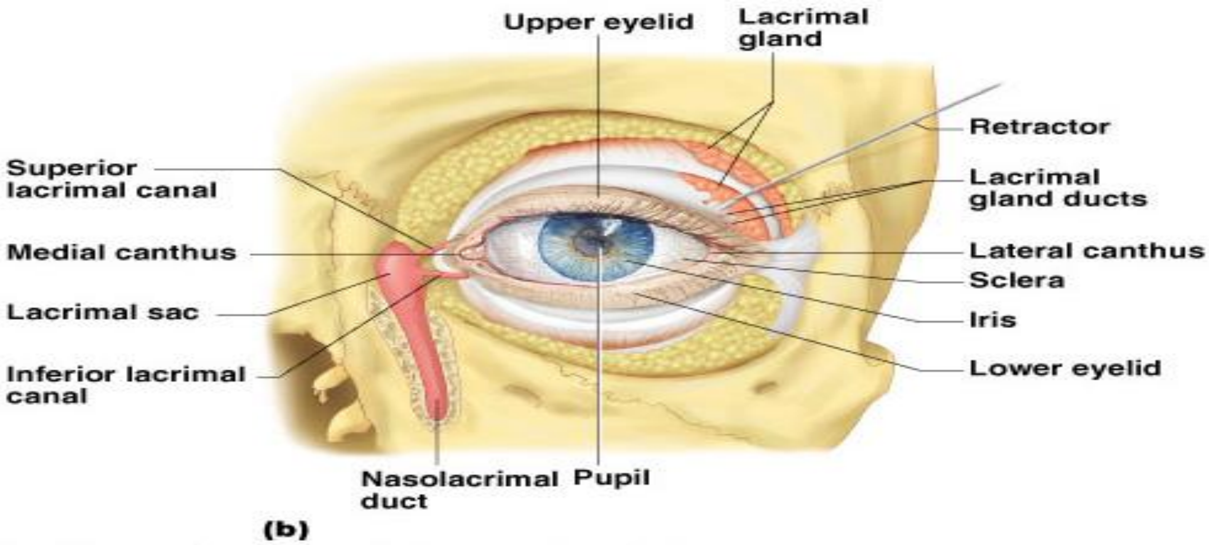


parts of the ear.

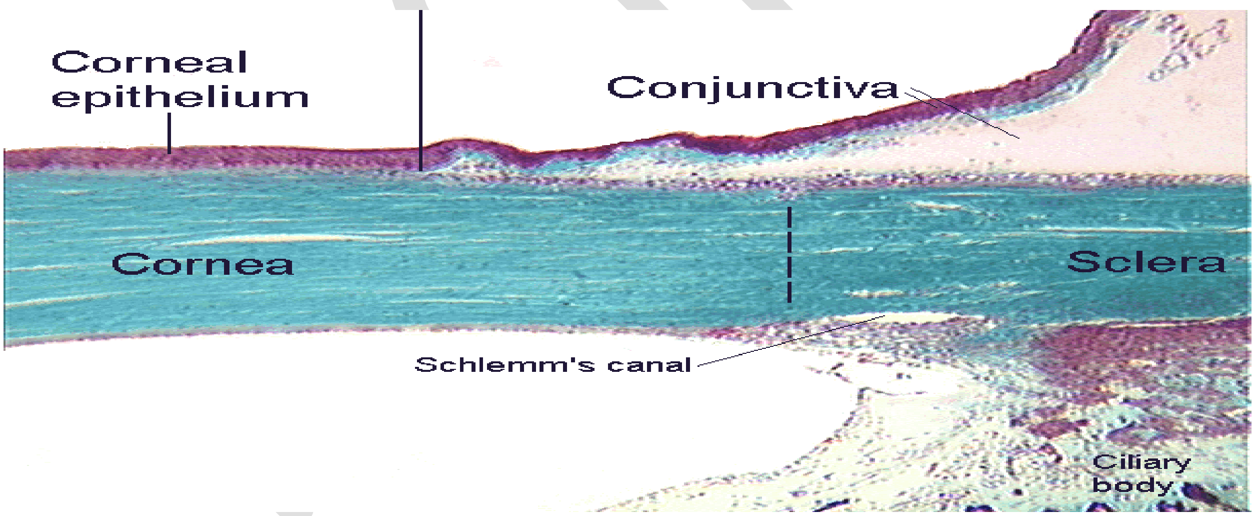
The Eye and Vision

- 70 percent of all sensory receptors are in the eyes
- Each eye has over a million nerve fibers
- Protection for the eye
    - Most of the eye is enclosed in a bony orbit made up of the lacrimal (medial), ethmoid (posterior), sphenoid (lateral), frontal (superior), and zygomatic and maxilla (inferior)
    - A cushion of fat surrounds most of the eye
- Eyelids- brush particles out of eye or cover eye

- Eyelashes- trap particles and keep them out of the eye



- **Conjunctiva**
  - Membrane that lines the eyelids
  - Connects to the surface of the eye- forms a seal
  - Secretes mucus to lubricate the eye

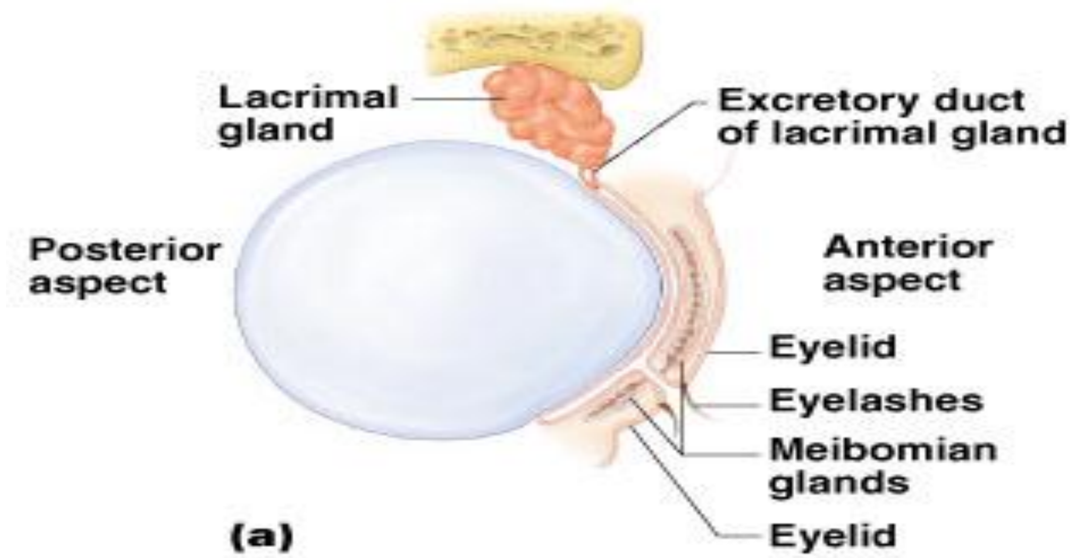


- Inflammation of the conjunctiva
- Caused by bacterial or viral infection
- Highly contagious

ACCESSORY STRUCTURES OF THE EYE

- **Lacrimal apparatus**

- Lacrimal gland – produces lacrimal fluid
- Lacrimal canals – drains lacrimal fluid from eyes

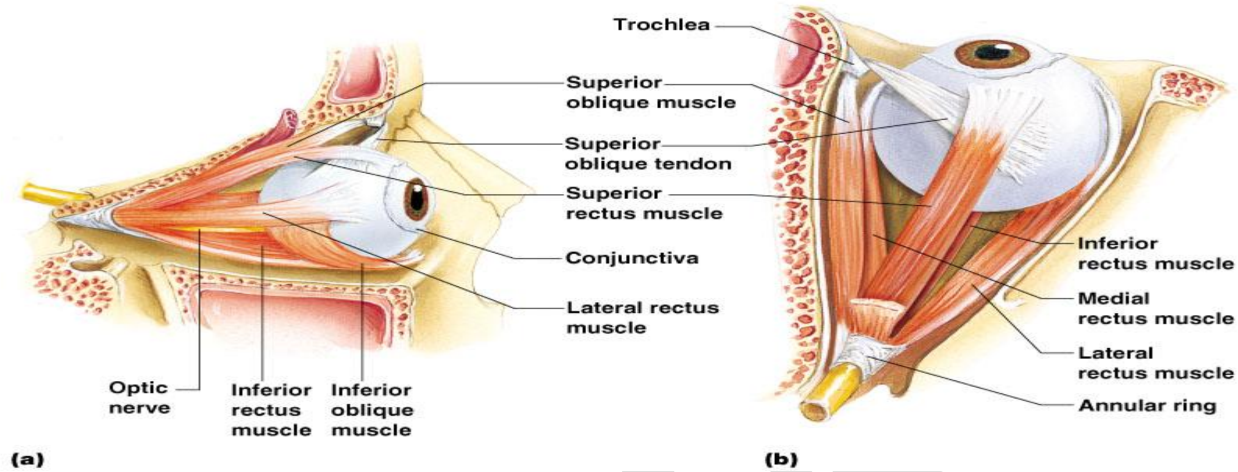


- Lacrimal sac – provides passage of lacrimal fluid towards nasal cavity
- Nasolacrimal duct – empties lacrimal fluid into the nasal cavity

- **Function of the Lacrimal Apparatus**
- Properties of lacrimal fluid
  - Dilute salt solution (tears)
  - Contains antibodies (fight antigens- foreign substance) and lysozyme (enzyme that destroys bacteria)
- Protects, moistens, and lubricates the eye Empties into the nasal cavity

Extrinsic Eye Muscles

- Muscles attach to the outer surface of the eye
- Produce eye movements



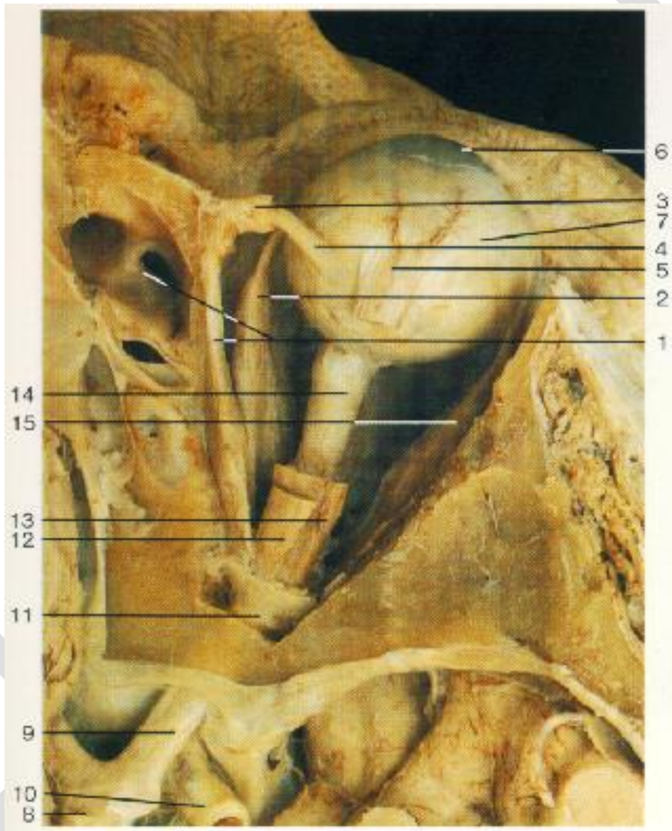
WHEN EXTRINSIC EYE MUSCLES CONTRACT

- Superior oblique- eyes look out and down
- Superior rectus- eyes looks up
- Lateral rectus- eyes look outward
- Medial rectus- eyes look inward
- Inferior rectus- eyes looks down
- Inferior oblique- eyes look in and up

The Fibrous Tunic

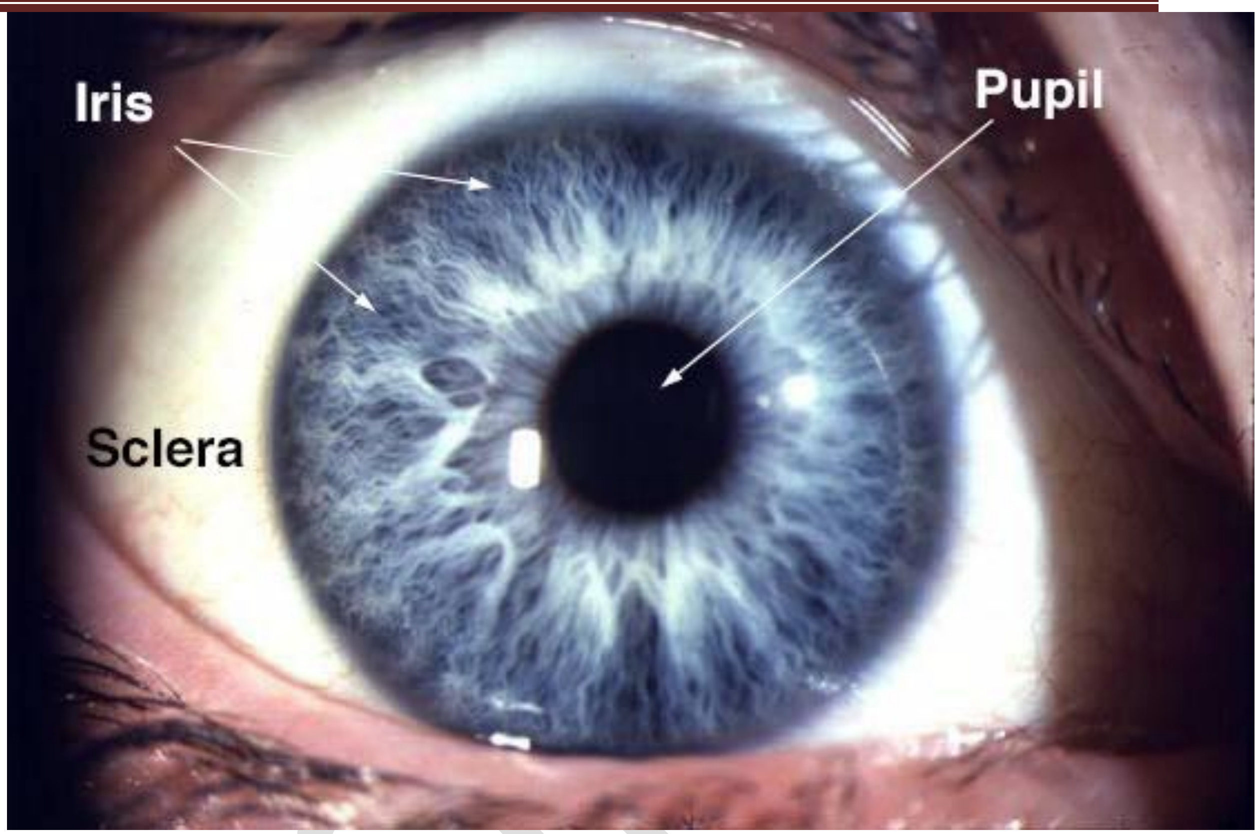
- Sclera
  - White connective tissue layer
  - Seen anteriorly as the "white of the eye"
  - Semi-transparent
- Cornea
  - Transparent, central anterior portion

- Allows for light to pass through (refracts, or bends, light slightly)
- Repairs itself easily
- The only human tissue that can be transplanted without fear of rejection



1 Superior oblique muscle and ethmoid air cells
2 Medial rectus
3 Trochlea
4 Tendon of superior oblique
5 Superior rectus
6 Cornea
7 Eyeball
8 Optic chiasma
9 Optic nerve (intracranial part)
10 Internal carotid artery
11 Anular tendon
12 Levator palpebrae superioris
13 Superior rectus
14 Optic nerve (extracranial part)
15 Lateral rectus

Right orbit with eyeball and extraocular muscles. From above. (The roof of the orbit has been removed, the superior rectus and the levator palpebrae superioris have been severed.)



Choroid Layer

- Modified interiorly into two structures
- Cilliary body – smooth muscle (contracts to adjust the shape of the lens)
- Iris- pigmented layer that gives eye color (contracts to adjust the size of the pupil- regulates entry of light into the eye)
- Pupil – rounded opening in the iris

How do we see colors?

- To see any color, the brain must compare the input from different kinds of cone cells—and then make many other comparisons as well.
- The lightning-fast work of judging a color begins in the retina, which has three layers of cells. Signals from the red and green cones in the first layer are compared by specialized red-green "opponent" cells in the second layer. These opponent cells compute the balance between red and green light coming from a particular part of the visual field. Other

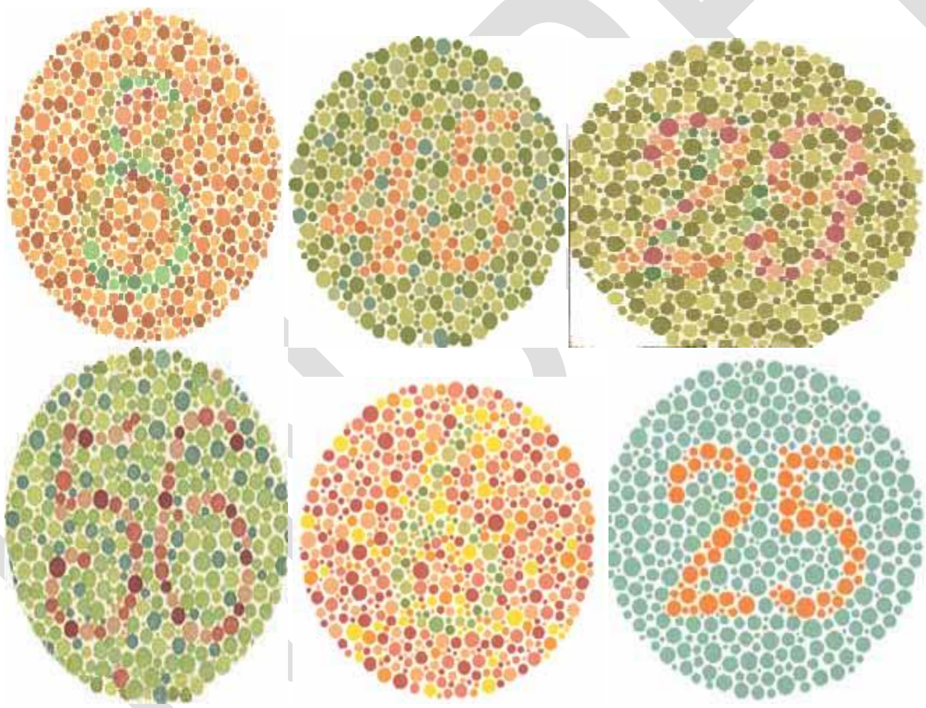
opponent cells then compare signals from blue cones with the combined signals from red and green cones.

COLORBLINDNESS

- An inherited trait that is transferred on the sex chromosomes (23^{rd} pair)- sex-linked trait
- Occurs more often in males
- Can not be cured or corrected
- Comes from a lack of one or more types of color receptors.
- Most are green or red or both and that is due to a lack of red receptors.

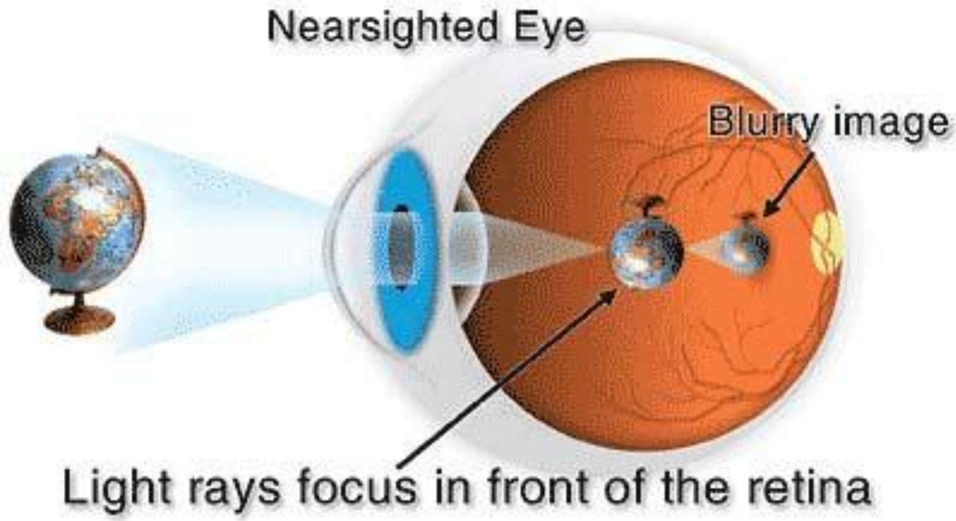
Another possibility is to have the color receptors missing entirely, which would result in black and white vision.

COLORBLINDNESS TEST PLATES

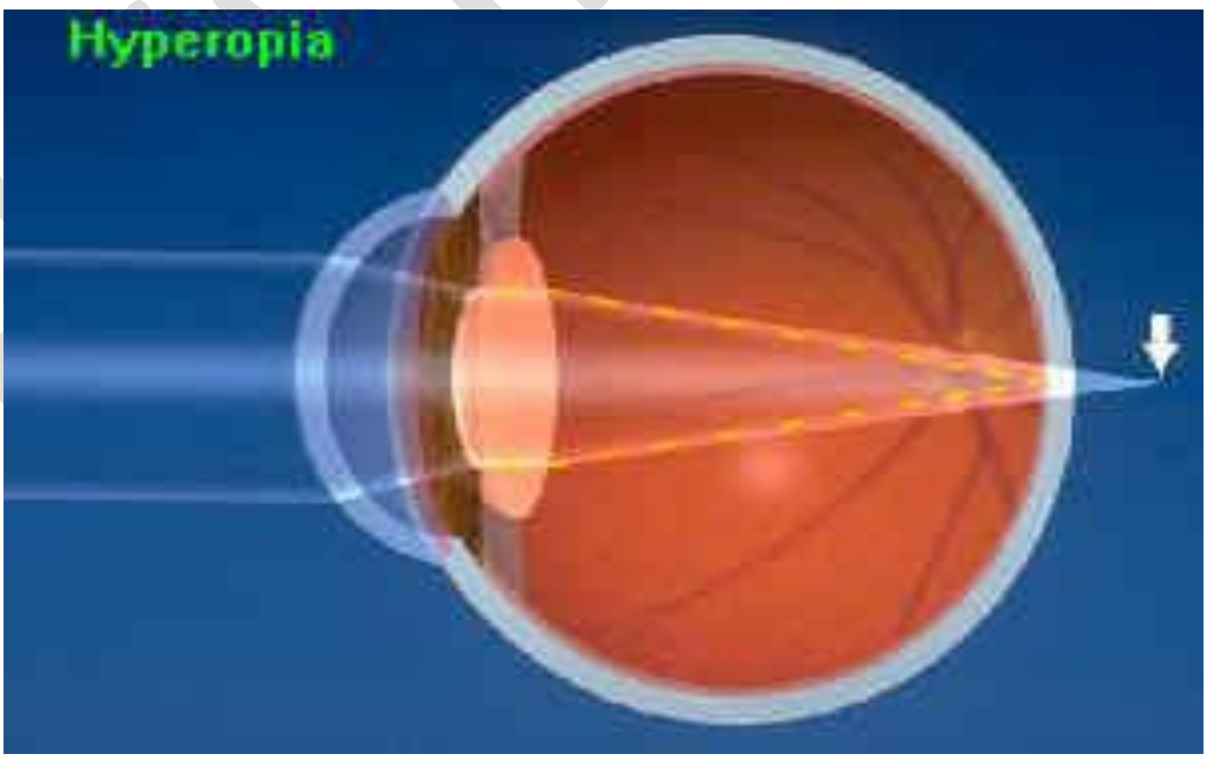


MYOPIA

- Nearsightedness, or myopia is the difficulty of seeing objects at a distance
- Myopia occurs when the eyeball is slightly longer than usual from front to back. This causes light rays to focus at a point in front of the retina, rather than directly on its surface.
- Concave lenses are used to correct the problem.

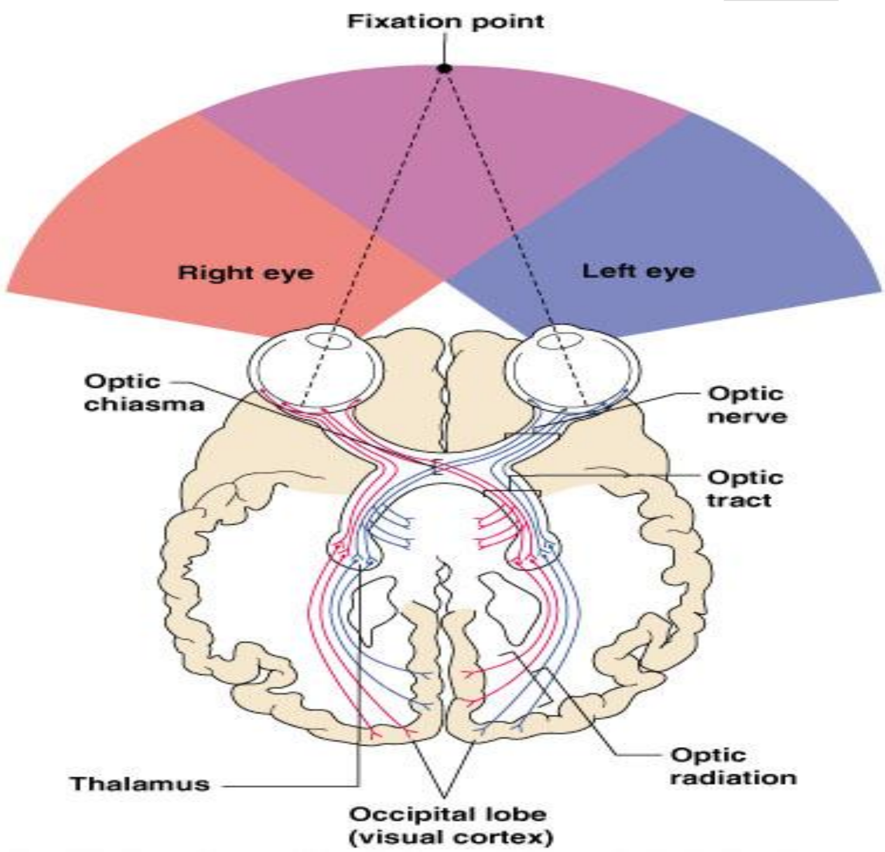


HYPEROPIA

- Hyperopia, or farsightedness, is when light entering the eye focuses behind the retina.
- Hyperoptic eyes are shorter than normal.
- Hyperopia is treated using a convex lens.
- 

Visual Pathway

- **Photoreceptors of the retina**
- **Optic nerve**
- **Optic nerve crosses at the optic chiasma**



EYE REFLEXES

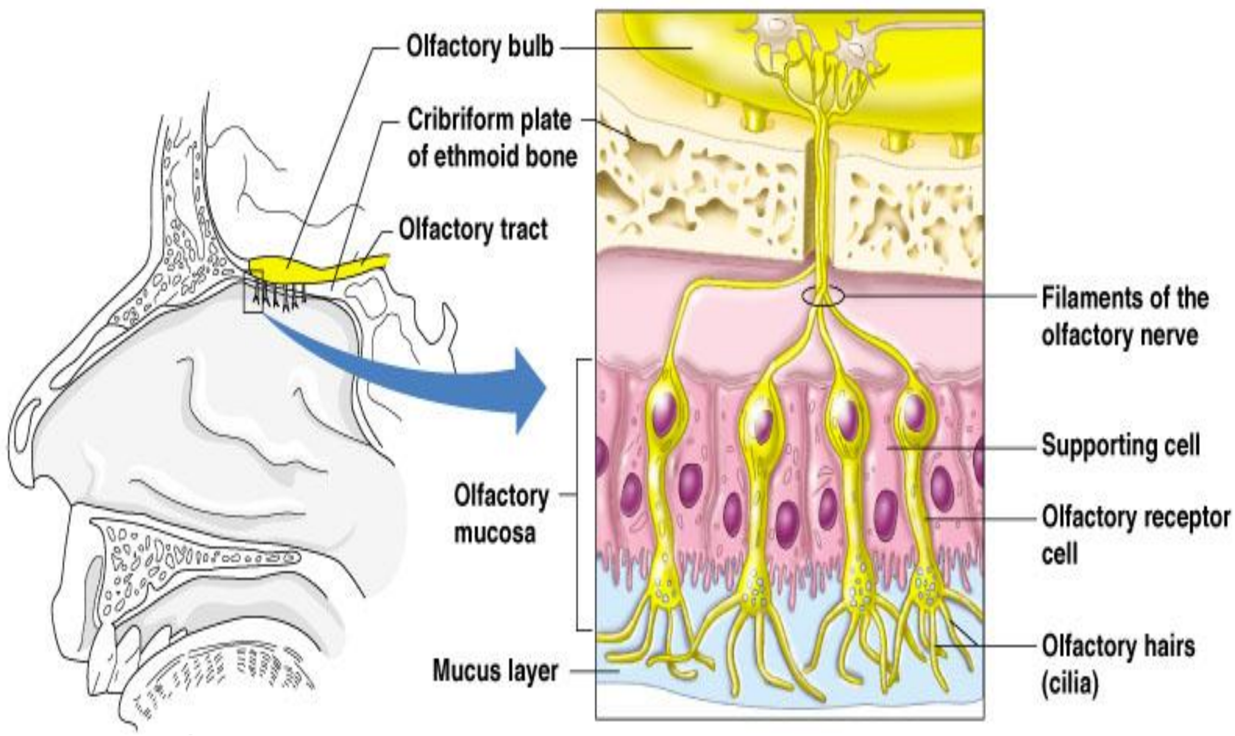
- Internal muscles are controlled by the autonomic nervous system
- Bright light causes pupils to constrict through action of radial (iris) and ciliary muscles
- Viewing close objects causes accommodation
- External muscles control eye movement to follow objects- voluntary, controlled at the frontal eye field
- Viewing close objects causes convergence (eyes moving medially)

Chemical Senses – Taste and Smell

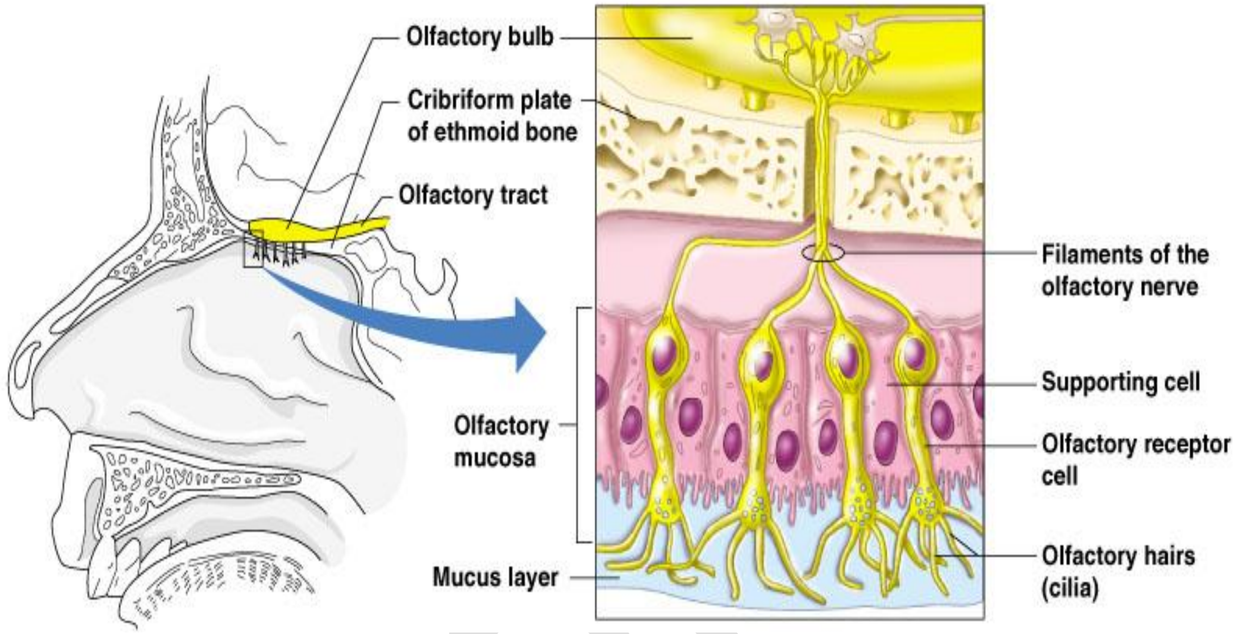
- Both senses use chemoreceptors
- Stimulated by chemicals in solution
- Taste has four types of receptors
- Smell can differentiate a large range of chemicals
- Both senses complement each other and respond to many of the same stimuli

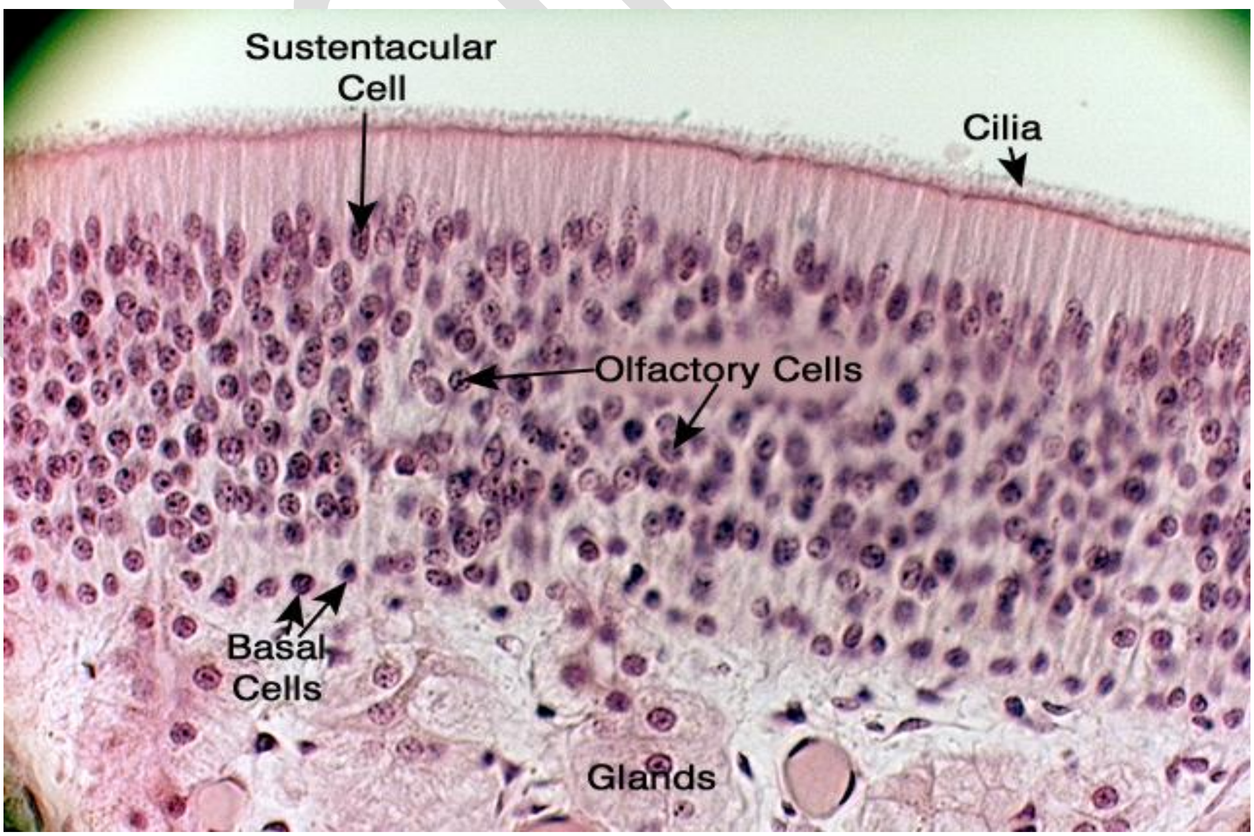
Olfaction – The Sense of Smell

- Olfactory receptors are in the roof of the nasal cavity
- Neurons with long cilia
- Chemicals must be dissolved in mucus for detection



- Olfactory receptors are in the roof of the nasal cavity
- Neurons with long cilia
- Chemicals must be dissolved in mucus for detection
- Impulses are transmitted via the olfactory nerve
- Interpretation of smells is made in the cortex **(olfactory area of temporal lobe)**

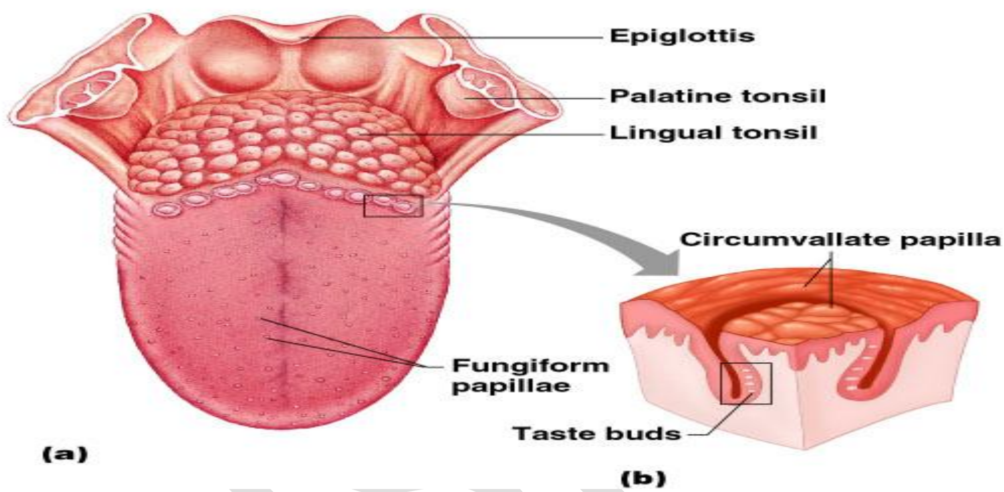

Olfactory bulb
Cribriform plate of ethmoid bone
Olfactory tract
Filaments of the olfactory nerve
Supporting cell
Olfactory receptor cell
Olfactory mucosa
Olfactory hairs (cilia)
Mucus layer


Sustentacular Cell
Cilia
Olfactory Cells
Basal Cells
Glands

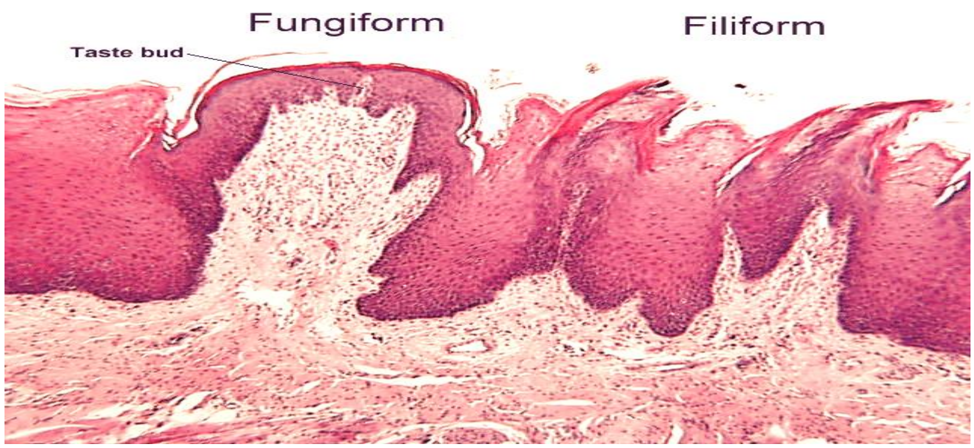
The Sense of Taste

- **Taste buds house the receptor organs**
- **Location of taste buds**
  - **Most are on the tongue**
  - **Soft palate**

Cheeks

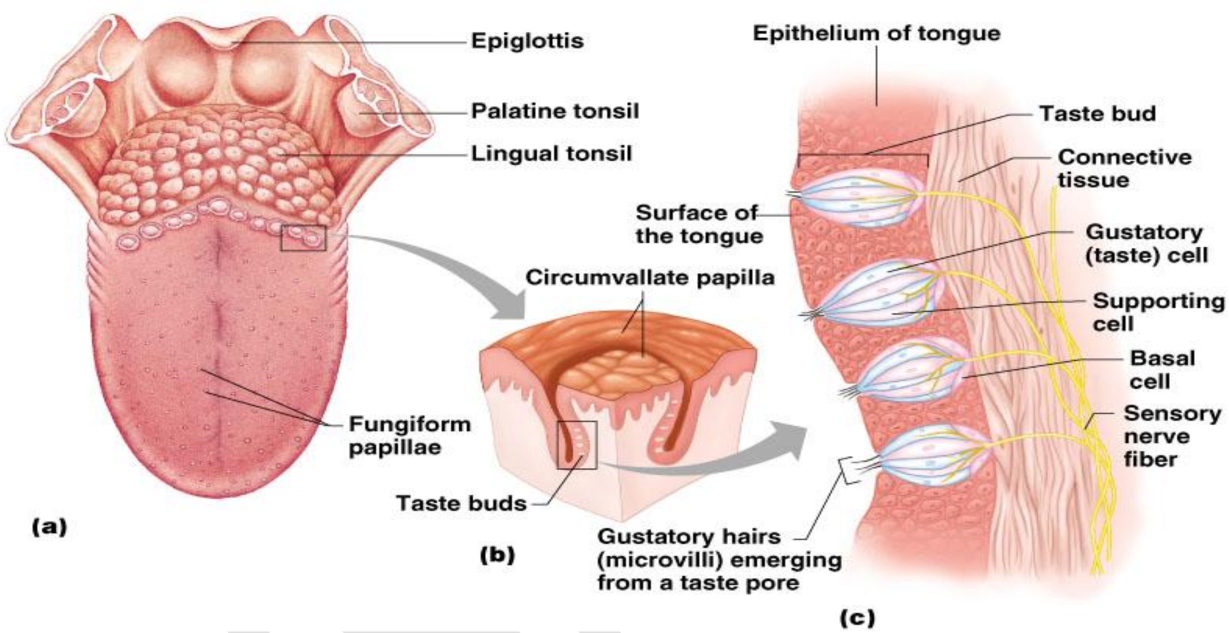


- **The tongue is covered with projections called papillae**
  - **Filiform papillae – sharp with no taste buds**
  - **Fungifiorm papillae – rounded with taste buds**
  - **Circumvallate papillae – large papillae with taste buds**
- **Taste buds are found on the sides of papillae**



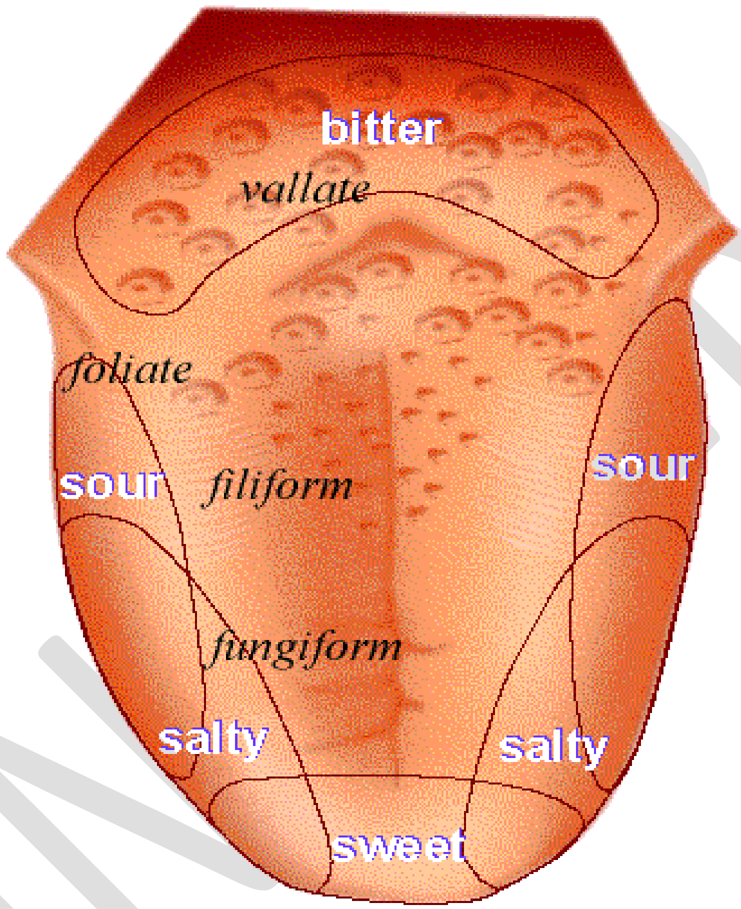
Structure of Taste Buds

- Gustatory cells are the receptors
- Have gustatory hairs (long microvilli)
- Hairs are stimulated by chemicals dissolved in saliva



Taste Sensations

- Sweet receptors
- Sugars
- Saccharine
- Some amino acids
- Sour receptors
- Acids
- Bitter receptors
- Alkaloids
- Salty receptors
- Metal ions



Developmental Aspects of the Special Senses

- **Formed early in embryonic development**
- **Eyes are outgrowths of the brain**
- **All special senses are functional at birth**