9 Control and Coordination

Can you recall?

1. What is the need for the control and co-ordination in multicellular animals ?
2. How do plants carry out control and coordination ?

Unicellular organisms have a simple organisation of their life processes. However a multicellular organisation of the body organs and organ systems required both, a control over their life processes as well as a coordination between the various systems in order to maintain homeostasis of the organism. Plants and animals both show a control and coordination mechanism. In plants this done by sending chemical signals and brining about various types of movements (e.g. phototropic, chemotactic, thingmotactic, etc). Animals, specially the higher vertebrates show a gradual increase in the complexity of their control and coordination by giving both electrical and chemical singles. In this chapter now you will study about development of nervous system in different animal groups and details of the system in humans.

The porifera (sponges) are the most primitive of the animal phyla.

Can you recall?

1. Do sponges have tissues and organs ?
2. Can sponges coordinate their various functions ?

Even though there are different types of cells in sponges for carrying out different functions, a proper nervous system is lacking. However to bring about efficient working of the body these multicellular animals show division of labour among the cells. This leads to specialization of cells for the various activities like digestion, respiration, excretion and others. Later in the higher animals, phyla the different cells form tissues, organs and systems which must work in coordination with each other for smooth internal functioning of the body. Also the organism must be able to respond and coordinate with respect to various stimuli or changes in the external environment.

In the lower animals like *Hydra* and *Planaria* the nervous system achieves this function, while in higher more complex animals, it is done by two coordinating systems - the **nervous (elctrical) system** and **endocrine (chemical) control system**. These two systems will be studied separately though they work in coordination with each other.

NERVOUS COORDINATION

9.1 Nervous System in *Hydra* :

Hydra, a cnidarian shows the diffused nervous system, which is the most primitive nervous system. The cnidarians are thus the first animal group showing true simple nervous system. It consists of the sensory cells and the nerve cells or neurons along with their fibres. The nerve cells are scattered or distributed throughout the body and inter connected to each other by synapses between their fibres to form the nerve net. There are two nerve nets both in the mesoglea, one connected towards the epidermis and second towards the gastro-dermis. There are sensory cells scattered in the

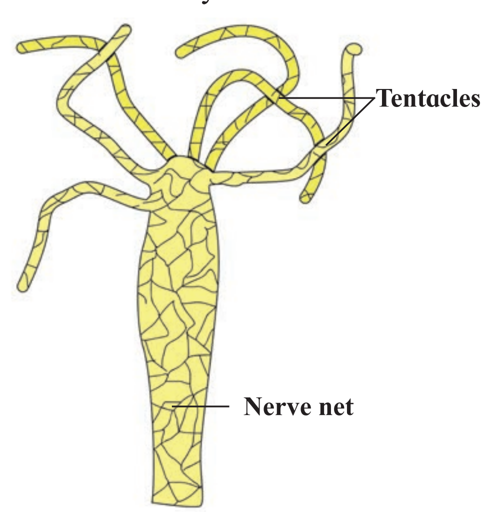


Fig. 9.1 : Nerve net in *Hydra*

body wall and tentacles, but sense organs are lacking. Neurons have fibres but there are no sensory and motor nerves. The nerve impulse shows no polarity or direction. Thus in *Hydra,* activation of sensory cells can happen at any point, and from this point impulse can be carried through out the body in any direction, thus bringing movements of the body or tentacles eg. catching of prey during feeding.

The diffused types of nervous system is the first important landmark in the nervous system. It is seen in the ctenophora as well as in the enteric system or gut wall of higher animals including man.

9.2 Nervous System in *Planaria* (flatworm) :

Planaria is a flatworm belonging to the phylum platyhelminthes. It is the most primitive animal with a central nervous system (CNS) located on the ventral side of body. It consists of a mass of cerebral or cephalic ganglion appearing like an inverted U shaped brain. These lie in the anterior or head region and from each ganglion arise nine branches towards the outer side. Ventrally from below the ganglia arise a pair of Ventral Nerve Cords (VNC) or long nerve cords. These are inter connected to eachother by transfer nerve or commissure in a ladder like manner. The peripheral nerve plexus arising laterally from VNC. The PNS

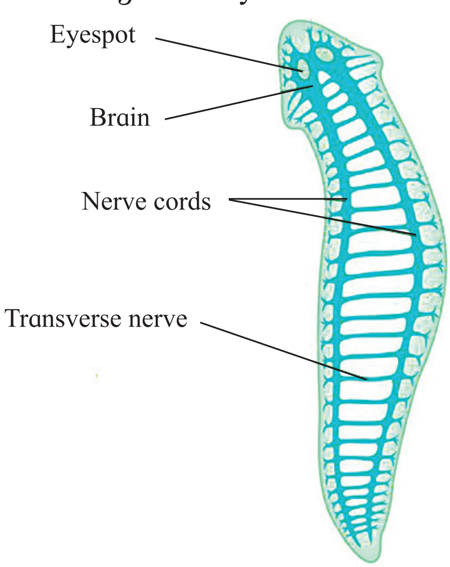


Fig 9.2 Ladder type nervous system in Flatworms e.g. Planaria

include sensory cells arranged in lateral cords in the body. A pair of photosensory structure, the eyes are located on dorsal side of the brain. Also there are single sensory cells scattered in the body.

In the above examples of *Hydra*, *Planaria* and the earlier studied examples of cockroach and humans, we have seen the gradual evolution or changes of the neural system. There is a high level of specialization in the formation of neurons as electrically signalling cells and also in the entire system, gradually from a diffuse neural system to a centralized nervous system. The expansion into a properly organized system involving the brain, its gradual expansion in size and functions. This has lead to centralization of various sense organs assisting in coordinating the internal environment with that of the external environment. Also there evolution of a complex networking system which efficiently transmits signals between one part or organ of the body and another.

Activity :

Note the changes taking place in the internal environment of the body, when a person goes from resting state into a state of physical activity.

9.3 Neural tissue

The neural tissue consists primarily of two types of cells viz the neurons and the neuroglia or glial cells. While a nerve is bundle of axons, the word 'nerve' is used for a bundle of axons outside the CNS while inside the CNS for the same, word 'tract' is used. The nerves may be sensory or motor or mix type i.e. having both the types - sensory and motor fibres.

All these along with nervous organs make up the nervous system of the higher animal and bring about coordination and control of various activities of the body. This is done through the receptors which bring in sensory inputs towards the central nervous system. Processing is carried out in the CNS and then through the

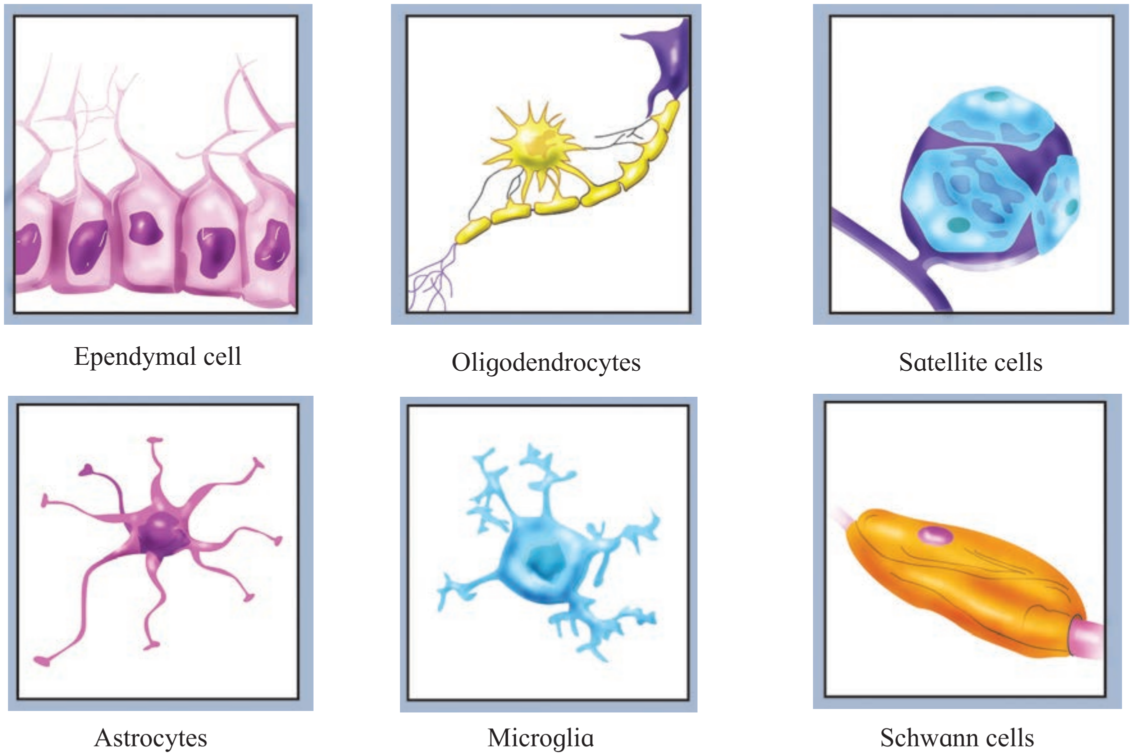


Fig. 9.3 : Types of Neuroglial cells

motor commands, the response is sent out. The nerves arising from the cytons of the CNS, travel throughout the body transmitting the nerves impulses to or from the CNS.

Curiosity Box:

Find out about the nervous system in Earthworm.

Internet my friend

1. How many neurons are present in the human body and specifically in the brain?
2. Normally what percentage of cranial capacity is used by an average human ?
3. What is the ratio between neurons and neuroglia ?

Neurons/Nerve cells : These are the structural and functional units of the nervous system. (You may recall the structure of a neuron studied in earlier classes). Each multipolar neuron has three parts - cyton or cell body, dendron and axon. The **cyton** has a distinct central nucleus with a nucleolus and neuroplasm. A clear film of cytoplasm surrounds the nucleus around which there are nurofibrils, Nissl's granules and other cell organelles Nissl's granules are riboprotein components. They play an important role in the synthesis of the enzyme required for formation of the neurotransmitter. Neurofibrils play an important role in transmission of nerve impulse. **Dendrons** are many small conical processes arising from the cyton. These are highly branched into fine dendrites. Nissl's granules and neurofibrils both can be seen at the base of the dendrons. They transmit message towards the cyton. **Axon** is a single long, usually unbranched process arising from the cyton at the axon hillock. It consists of a bundle of neurofibrils. Nissl's granules are absent. Terminally, the axon gives out branches called telodendrons. The axons carry the messages away from the cytons. The axons may give out lateral branches called collaterals. The terminal branches attach to a muscle, gland, skin or telodendrites of another neuron. The interconnection between two neurons or neuron with motor organ is called **synapse**. It is

Table 9.4 : Types of Neuroglial cells and their functions

Location	Cell type	Functions
CNS (Central Nervous System)	**Oligodendrocytes**	These cells have few branches and mainly form the myelin sheath around the central axons, which form the white matter of CNS. Myelin an isulating sheath is made up of protein and fatty substances. It allows quick transmission of electrical impulses.
	Microglia or brain macrophages	Small sized cells with few branches. These are derived from monocytes and act as macrophages. They go to the site of injury, dead neurons and cell debris in the CNS. They mediate immune response in the CNS.
	Astrocytes	Star shaped cells and the most abundant glial cells of CNS. They have varied roles in the brain, secretion and absorption of neural transmitter and maintence of blood-brain barrier BBB. Regulate the transmission of electrical impulses with the brain.
	Ependymal cells	Form single layer of squamous or columnar, often ciliated epithelial cells lining the ventricles or brain cavities and central canal of spinal cord. Mainly responsible for production and probably also for circulation of CSF in brain ventricles and central canal.
PNS (Peripheral Nervous System)	**Schwann Cells**	These are the most abundant glial cells of PNS. They produce myelin sheath around medullated nerves of PNS.
	Satellite cells	They support the functions of neurons.

usually axo-dendronic or may be axo-axonic, axo-somatic or dendro-dendronic.

The cytons are generally found inside the brain, spinal cord (CNS) and in the ganglia. Small groups of cell bodies inside the white matter of brain are called **basal nuclei**. A bundle of axons called nerve may be covered only by **neurilemma** in the **non-medullated** nerves while in the medullated nerves it is covered both by medullary sheath and on the outside by neurilemma. Conduction of impulse by the medullated nerves is 50 times faster than in the non-medullated nerves. The connective tissue covering around the nerve fascicule is called **endoneurium**. Few nerve fasciculi with endonurium are surrounded by connective tissue, called **perineurium** and a still large bundle of nerves is covered on the outer side by **epineurium**. Blood is supplied to all the nerves to provide oxygen and nutrients.

Neuroglial cells :

The neuroglial cells are far greater in number than the neurons. Most of the supporting cells of the nervous system are derived from the same embryonic tissue layer (ectoderm) that produces neurons. The term neuroglia refers to the supporting cells of the Central Nervous System (CNS) and Peripheral Nervous System (PNS).

9.4 Synapse :

It is a junction between two nerve cells with a minute gap (synaptic cleft) in between them which allows transmission of impulse by a neurotransmitter bridge.

1. Properties of nerve fibres :

a. Excitability/Irritability - The nerve fibres, on account of presence of a polarised membrane, have the ability to perceive stimulus and enter into a state of activity.

b. Conductivity - It is ability to transmit the excitation.

c. Stimulus - It is any detectable, physical, chemical, electrical change in the external or internal environment which brings about excitation in a nerve/muscle/organ/organism. In order to be effective, the stimulus must have a minimum intensity called **threshold stimulus**. **Subliminal** (weak) stimulus will have no effect while **supraliminal** (strong) stimulus will produce the same degree of impulse as the threshold stimulus.

d. Summation effect -A single subliminal stimulus will have no effect but if many such weak stimuli are given in quick succession, they may produce an impulse due to addition or summation of stimuli.

e. All or none law - The nerve will either conduct the impulse along its entire length or will not at all conduct the impulse, as in case of subliminal or weak stimulus.

f. Refractory period - It is the time interval (about millisecond) during which a nerve fails to respond to a second stimulus however strong it is.

g. Synaptic delay - The impulse requires about 0.3 to 0.5 milliseconds to cross a synapse. This time is required for release of neurotransmitter from the axon terminal and excitation in the dendron of the next neuron.

h. Synaptic fatigue - The transmission of nerve impulse across the synapse halts temporarily due to exhaustion of its neurotransmitter.

i. Velocity - The rate of transmission of impulse is higher in long and thick nerves. It is higher in homeotherms than in poikilotherms. The velocity of transmission is higher in voluntary fibres (100 - 120 m/second in man) as opposed to autonomic or involuntary nerves (10-20 m/second). Similarly it is faster in medullated

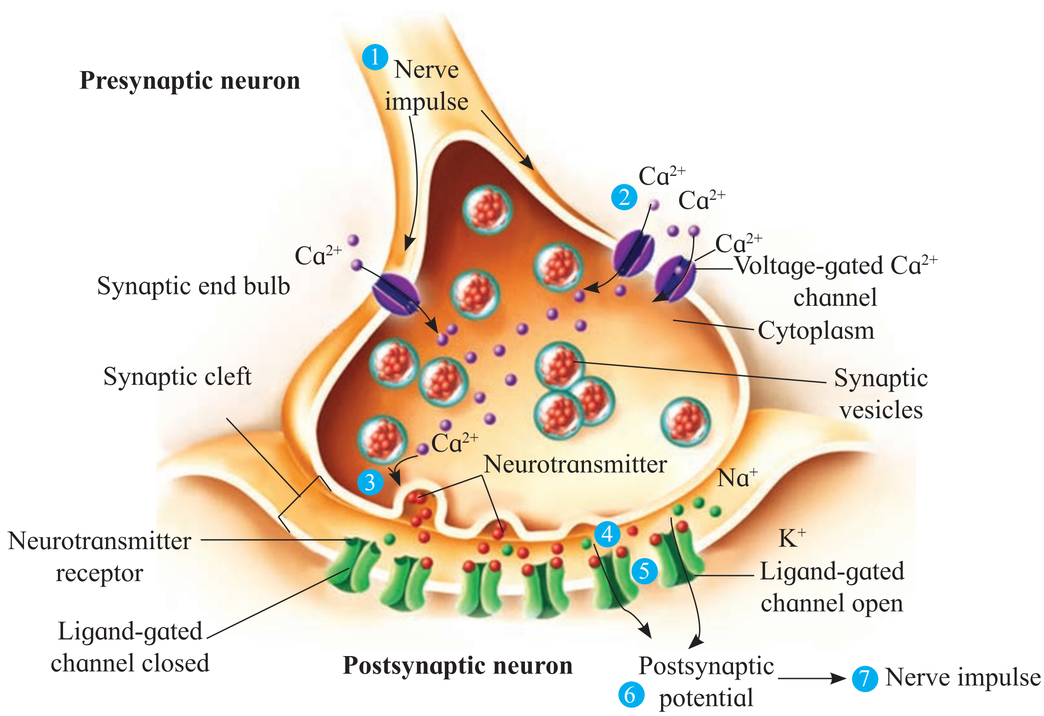


Fig. 9.5 : Synaptic transmission

nerve, as the impulse has to jump from one node of Ranvier to the next. At the synapse where the neurons communicate with one another. The neuron carrying an impulse to the synapse is the pre-synaptic neuron. The neuron receiving input at the synapse is the post synaptic neuron or generator region (gland or muscle). A synaptic cleft or a small intercellular space lies in between two cells having a width about 20-30 nm between them. .

The process by which the impulse from the pre-synaptic neuron is conducted to the post-synaptic neuron or cell is called **synaptic transmission**. It is a one way process carried out by neurotransmission.

2. Types of synapses

a. Electrical synapse : In this type of synapse gap between the neighbouring neurons is very narrow. The synapse between such closed neurons is mechanical. The electrical conductive link is formed between the pre and post synaptic neurons. At the gap junction, the two cells are within almost 3.8 nm distance of each other. Transmission across the gap is faster but depends on the connection located at the gap junctions between the two neurons. Electrical synapses are found in those places of the body requiring fastest response as in the defence reflexes. also they are bidirectional, allowing transmission in either direction or may be unidirectional.

b. Chemical synapse : These are specialized junctions through which cells of the neural system send chemical signal to the other neurons and to non-neuronal cells, such as gland and muscle. Synaptic gap is larger than that in electrical synapse and it is 20-40 nm.

A chemical synapse between a motor neuron and a muscle cell is called a neuromuscular junction. There are three components of a typical chemical synapse. 1. The presynaptic terminal (mostly axonic terminal), 2. The synaptic membrane of the post synaptic cell (usually on the dendrite of the next neuron/ gland cell/ muscle) and 3. The post synaptic neuron.

The impulse travels along the axon of the pre-synaptic neuron to the axon terminal. Most presynaptic neurons or axons have several synaptic knobs at their ends or terminals. These knobs have arrays of membranous sacs, called synaptic vesicles, that contain neurotransmitter molecules.

When an impulse reaches a synaptic knob, voltage sensitive Ca^{++} channels open and calcium (Ca^{++}) diffuses inward from the extracellular fluid.

The increased calcium concentration inside the cells, initiates a series of events that fuse the synaptic vesicles with the cell membrane of presynaptic neuron, where they release their neurotransmitters by **exocytosis**. Once the neurotransmitters bind to the receptors of the post-synaptic cell, the action is either excitatory (turning a process on) or inhibitory (turning a process off). This is dependent on the nature of the neurotransmitter involved.

Once the impulse has been transferred across the synapse, the enzyme like **cholinesterase** destroys the neurotransmitter and the synapse is ready to receive a new impulse.

9.5 Transmission of nerve impulse :

The neurons are cells with some specials features. The cells can be excited. The nerve impulse is a wave of bioelectrical or electrochemical disturbances passing along a neuron. The transmission of the nerve impulse along the long nerve fibre/axon tube is a result of electrical charges across the neuronal membrane during conduction of an excitation. Each neuron has a charged cellular membrane with a voltage which is different on the outer and inner side of the membrane. The plasma membrane separates the outer and inner solutions of different chemical compounds but having approximately the same total number of ions. The external tissue fluid has both Na^{+}

and K^+ but there is predominance of Na^+ and Cl^-, while K^+ is predominant within the fibre or in the intracellular fluid. This condition of a resting nerve is also called a polarised state and it is established by maintaining an excess of Na^+ on the outerside. On the inside there is an excess of K^+ along with large negatively charged protein molecules and nucleic acid. Some amount of Na^+ and K^+ is always leaks across the membrane. The Na^+/K^+ pump in the membrane **actively** restores the ions to their appropriate side. Against the concentration and electrochemical gradient, Na^+ is being forced out and K^+ is being forced inside the membrane. This process is called **sodium pump** or **Na-K exchange pump**. This active process requires ATP energy. The difference in distribuiton of Na^+ and K^+ on the two sides of the membrane produces a potential difference of –50 to –100 millivolts (average is –70 millivolts).

This potential difference seen in a resting nerve is thus called resting potential. (–70 millivolts) and it is mainly due to differential permeability of the resting membrane which is much more permeable to K^+ than to Na^+. This results in slightly more K^+ diffusing out than Na^+ moving inside and causing slight difference in polarity. Also ions like negatively charged proteins and nucleic acids inside the cell make the overall charge negative on the inside and positive charge on the outside.

The nerve membrane not only has leakage channels but also has many gated channels for Na^+/K^+. These are also called voltage gated channels. These channels enable the neuron to change it membrane potential to active potential in response to a stimuli. The Na^+/K^+ gated channels are separate so transport of both these ions is separately done. However during resting potential, both these gates are closed and the membrane resting potential is maintained.

Generation of nerve impulse :

1. Depolarization : The origin and maintenance of resting potential depends on the original perfect state. Any change or disturbance to the membrane will cause Na^+ to enter into the membrane and lower the potential difference (lesser than –70 millivolts). This makes the membrane more permeable to Na^+, so there will be rapid influx of Na^+. This property is peculiar to a nerve membrane.

The voltage gated Na^+/K^+ channels are special in 2 ways : They can change the potential difference of the membrane as per the stimulus received and also the gates operate separately and are self closing.

During resting potential, both gates are closed and resting potential is maintained. However during depolarization the Na^+ gates open but not the K^+ gates. This causes Na^+ to rush into the axon and bring about a depolarisation (opposite of polarity). Extra cellular fluid (ECF) becomes electronegative with respect to the inner membrane which becomes electropositive. The value of action potential is +30 millivolts to +60 millivolts. This triggers depolarisation in the next part while it itself starts going to repolarisation.

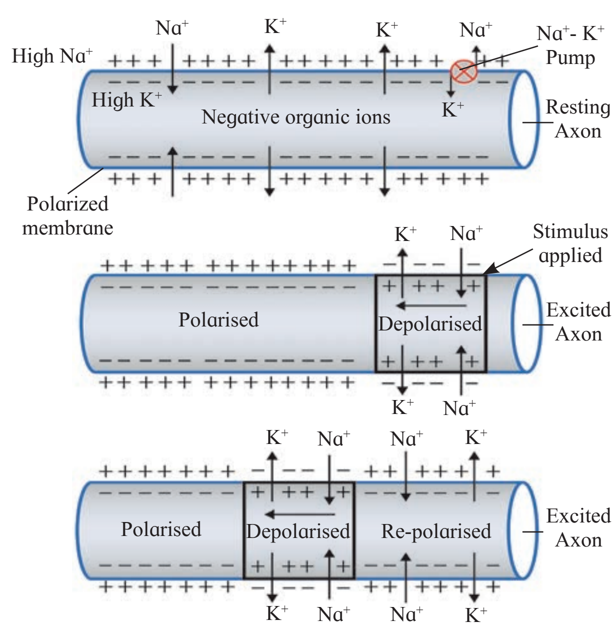


Fig. 9.6 : Polarisation and Depolarisation along a nerve

2. Re-polarization : Change in the polarity from depolarized, back to the original state is done by the process of repolarization. It occurs after a short interval called **refractory period**. The large number of Na^+ on the inside causes a drop in the permeability of membrane to Na^+ and at the same time making it more permeable to K^+ ions by opening the K^+ voltage gates and slowly closing the Na^+ gates. This action is a localized activity. K^+ ions passes out very rapidly as compared to slow entry of Na^+.

In this period, Na^+ gates are closed, K^+ gates are open and Na^+ - K^+ pumps becomes operational. This process of producing a wave of stimulation → causing depolarization → repolarization is repeated continuously upto the end of axon terminal. It is a self propagating process.

In medullated nerves, the insulating fatty myelin sheath prevents flow of ions between the axoplasm and ECF. The transport pump and gated channels can operate only in the region of nodes of Ranvier, where myelin sheath is absent.

The action potential cannot travel as a wave of membrane depolarization it has to jump from node to node. This process called **saltatory conduction**, is at the rate of 120 m/second. It is faster than the continuous conduction in non-medulated fibre (50 :1).

Do you know ?

Na-K pump operates actively and by use of carrier (for every 3 Na^+ pumped out $2K^+$ are pumped in). It is electrogenic.

Always Remember

The resting potential of axon is –70 mV. Na^+- K^+ Pump pumps out 3 Na^+ ions for every 2 K^+ ions they pump into the cell.

Can you tell?

1. Explain how is impulse transmitted through a synapse?
2. Describe the conduction of a nerve impulse in the neuron.

Chart 9.7 : Steps in generation and conduction of nerve impulse

Application of stimulus on a resting nerve

↓

Permeability of membrane changes and it becomes more permeable to Na^+

↓

Na^+ ions diffuse into the neuron from the ECF

↓

Number of positive ions inside axon increases

↓

Membrane potential changes from –70 mV to about +30 mV and this change in the membrane potential is called action potential

↓

Since the polarity has been reversed from negative on outside and positive inside it is also called depolarization (compared to ECF)

↓

Repolarisation : At the peak of action potential (+30 mv), the Na^+ channels close. K^+ gates open. The membrane becomes more permeable to K^+

↓

K^+ ions diffuse out of the axon

↓

The inside of the membrane (becomes less and less positive) becomes negative once again

↓

Axoplasm inside becomes negatively charged and ECF becomes positively charged respectively

9.6 Human Nervous System :

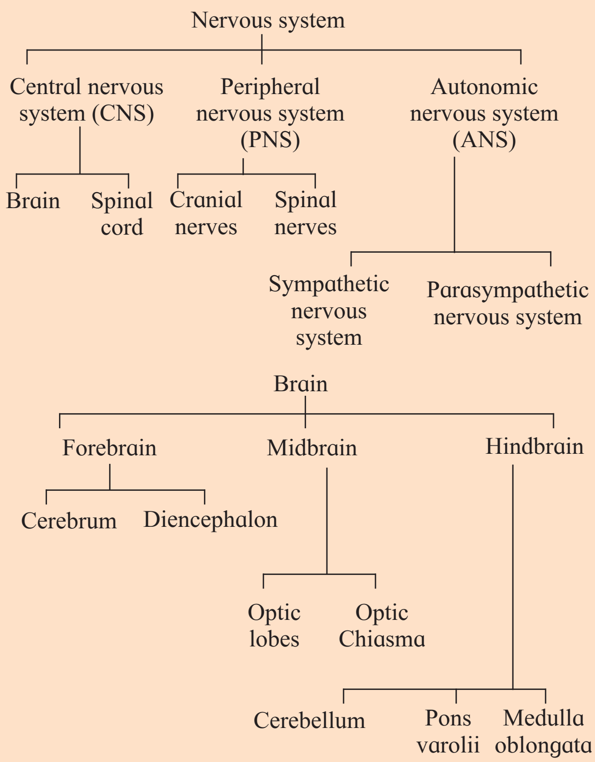
The nervous system in humans is well developed and complex. It is broadly classified into three parts. viz, CNS, PNS and ANS.

1. Central nervous system (CNS) : The brain and spinal cord are the parts of CNS which lie along the mid dorsal axis. Brain is enclosed within the brain box/**cranium** of the skull, whereas the spinal cord occupies the vertebral canal of the **vertebral column**. Inner to these bony coverings, are three protective membranes called **meninges**. That protect the brain and spinal cord.

a. Dura mater : It is the outermost tough, non vascular, thick and fibrous meninx and is attached to the inner side of the cranium. It is separated from the underlying arachnoid mater by the subdural space, filled with a serous fluid.

b. Arachnoid mater : It is the middle, thin and non vascular layer of connective tissue having web like appearance. It is separated from the

Can you recall?



pia mater below by a narrow subarachnoid space filled with cerebro spinal fluid - CSF.

c. Pia mater : It is the innermost delicate, highly vascular membrane lies in close contact with the CNS.

CSF (cerebrospinal fluid) : It is lymph like extra cellular fluid secreted by choroid plexuses of pia mater present inner to subarachnoid space in the ventricles of the brain within the central canal of spinal cord. The CSF is secreted by the pia mater, the choroid plexuses and the ependymal cells lining the ventricles of the brain and central canal of spinal cord. The three openings in the roof of medulla oblogata help in draining out the CSF from brain to the outside. The meninges and CSF act as a shock absorber and protect the brain and spinal cord from mechanical injuries. It also maintains constant pressure inside cranium. It helps in exchange of nutrients and wastes between blood and brain tissue. It helps in the supply of oxygen to the brain. It protects the brain from desiccation.

CSF is slightly alkaline fluid with a specific gravity of 1.005. A total of 100 -120 cc of CSF is present in and around the CNS.

Curiosity Box:

CSF is released by the pia mater. Inside the ventricles/cavities of the brain, there is release of CSF by the choroid plexuses and the ependymal cells.

Does this CSF remain enclosed inside the ventricles ?

What can be the outcome of such a situation ?

Do you know ?

Blood brain barrier (BBB) -
Keeps a check on passage of ions and large molecules from the blood to the brain tissue. Endothelial cells lining the blood capillaries help in this process along with the astrocytes.

Always Remember

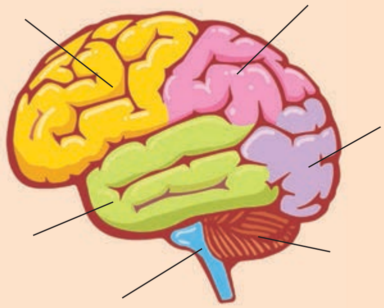
CSF is continuously generated by the ependymal cells lining the ventricles and central canal and simultaneoulsy drained out of the brain into the blood stream. CSF maintains a constant pressure inside the cranium. The nervous tissue is without lympatic vessels.

Think about it

During extraction of a tooth, the dentist gives an injection of Anaesthesia to the patient before extraction. Is the action potential generated ? How does the local anaesthesia work? What is the effect of pain killer on the nervous system.

Can you recall?

Label the various parts of the digram and recall their functions.



A. The Human brain :

The study of all aspects of the brain is called encephalology. The brain can be divided into three main parts - forebrain, midbrain and hindbrain.

a. Forebrain : Forebrain consists of olfactory lobes, cerebrum and diencephalon.

i. Olfactory lobes :

These are highly reduced in human brain and covered by cerebrum from all sides except ventral. Each lobe consists of a olfactory peduncle and olfactory bulb.

ii. Cerebrum :

It is a largest part of the brain, making up about 85 % of total brain. It is divided into right and left cerebral hemisphere by means of a deep median, long fissure. The two hemispheres internally connected to each other by a thick band of nerve fibres called **corpus callosum**.

The outer surface of cerebrum is called **cerebral cortex** while the deep inner part is **cerebral medulla**. The cerebral cortex has outer thin region composed of grey matter and inner medulla composed of white matter.

The surface of each cerebral hemisphere is greatly folded by many convolutions or **gyri** and grooves called **sulci**. These greately increase total surface area for accomodation of the vast number of nerve cells.

Each cerebral hemisphere is further divided into four main lobes by three deep sulci. These are -

Centre sulcus which demarcates frontal lobe from the parietal lobe.

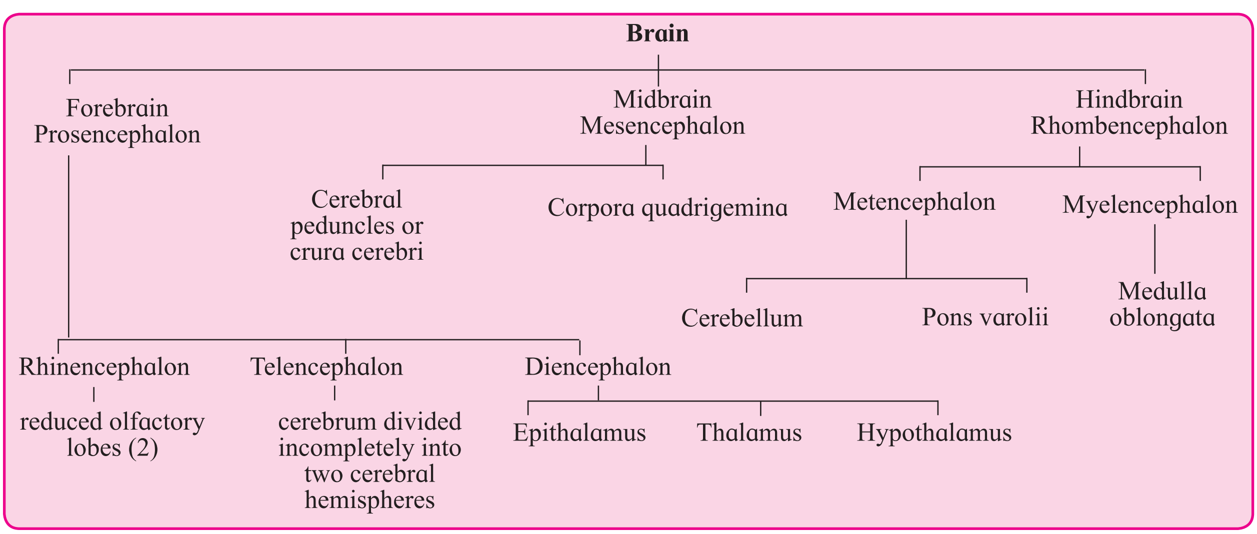
Parieto-occipital sulcus separates the parietal from occipital lobe.

The lateral or **sylvian sulcus** demarcates the temporal lobe from the frontal and parietal lobes

Since these three sulci are not complete, the lobes are not clearly demarcated from each other. A fifth median lobe called **insula** or **insular cortex** is folded deep within the lateral sulcus.

The grey matter of cerebral cortex mainly consists of cell bodies of billions of neurons along with non-medulated fibres and dendrons. The white matter mainly has axons of myelinated nerves.

Chart 9.8 Parts of Brain



> **Do you know ?**
>
> Corpus callosum is typically seen in mammalian brain.
>
> Corpus callosum is the largest commissure of the brain.
>
> It has an anterior and posterior fold called **genu** and **splenium** respectively.
>
> Why an injury to the right cerebrum affects the functioning of the left side of body ?

Functional areas of cerebrum :

1. Frontal lobes : They have motor area which controls voluntary motor activities or movements of muscles. The premotor area is higher centre for involuntary movements and autonomus nervous system. **Association area** is for coordination between sensation and movements. **Broca's area/motor speech area**. It translates the thoughts into speech. Expression of emotions, intelligence, will-power, memory, personality areas are located in the frontal lobe.

2. Parietal lobes : They are mainly for somaesthetic sensation of pain, pressure, temperature, taste (gustatoreceptor).

3. Temporal lobes : It contains centres for smell (olfactory), hearing (auditory), speech and emotions.

4. Occipital lobes : They have visual area mainly for sense of vision.

Area of contact between temporal, parietal and occipital lobes is centre for Wernicke's area or intelligence centre. It helps in the understanding of spoken and written words.

The cerebrum, thus shows all three types of areas sensory, motor and association area.

Basal nuclei or basal ganglia are grey masses present within the white matter or lying on the lateral sides of thalamus. The basal ganglia or nuclei of cerebrum receive neurotransmitters from various parts. They help the cortex in the execution of activities at the subconscious level e.g. writing slow or rapid typing. **Corpus striatum** at the floor of cerebrum is the largest basal nucleus.

> **Curiosity Box:**
> - Find out how different functional areas of the brain can be mapped ?
> - What is EEG ? What information can be obtained from the EEG ?
> - Which are silent areas of the brain?

iii. Diencephalon :

It is the part of the forebrain that contains the epithalamus, thalamus and hypothalamus. It lies below the corpus callosum and above the midbrain. It encloses a single cavity termed **third ventricle/Diocoel** which communicates with the two lateral ventricles of cerebrum through a narrow opening called **foramen of Monro**.

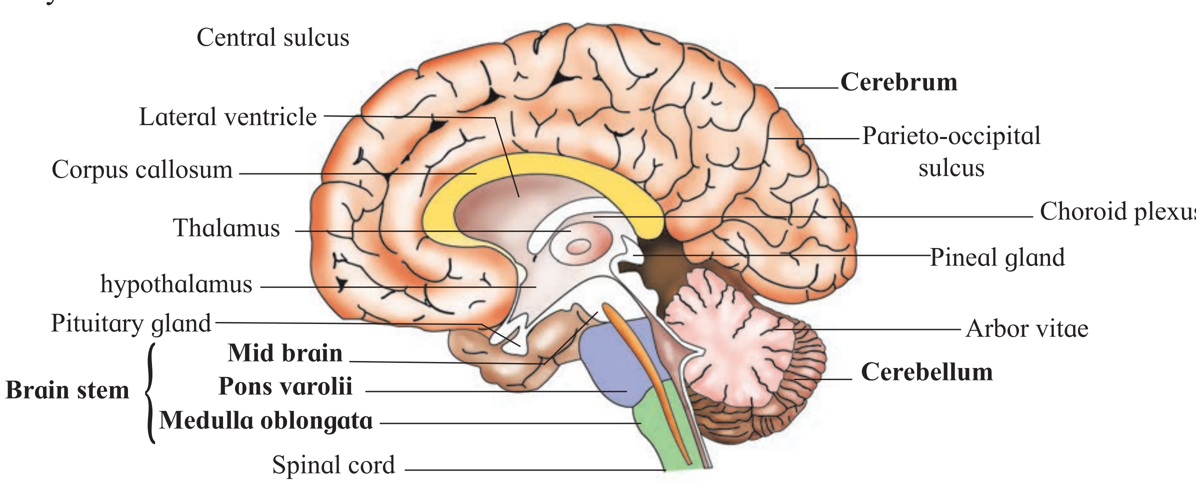


Fig. 9.9 Sagital section of brain

The **epithalamus** is the thin non nervous roof of the diencephalon. Anterioly it is fused with the piamater to form the anterior choroid plexus and from its dorsal wall it is connected to pineal gland through a pineal stalk. (Pineal gland is discussed in detail in chemical co-ordination). Earlier this gland was though to be vestigeal, but later it has been found to produce to hormone melatonin (sleep inducing hormone; also related to reproductive behaviour). The lateral thick walls of diencephalon form the thalami. They mainly contain grey matter. The habenculor commissure connects two thalami. Different parts of the brain are interconnected by the RAS (Reticular Activating System) through the thalami. It is called relay centre as it transmitts all sensory impulses except those of olfactory (smell) to the cerebrum (gatekeeper of cerebrum connecting the anterior lateral ventricle to the **iter** posteriorly. The narrow cavity of diencephalon is called **IIIrd** ventricle or **diocoel**. It connects anteriorly to the two lateral ventricles by a single opening called Foramen of Monroe and posteriorly to the **IVth ventricle or metacoel** through a narrow **duct of Sylvius** or **iter**.

Hypothalamus : It forms a floor of the **diencephalon**. It is richly supplied with blood vessels (Hypothalamo-hypophyseal portal vein) helps in feed back mechanism for hormonal control). It maintains homeostasis, internal equilibrium of the body and involuntary behaviour control. Like in the cerebrum, the hypothalamus also contains hypothalamic nuclei in its white matter (refer fig. 9.33 pituitary gland) with neuro-secretory cells involved in the production of hormones oxytocin and vasopressin.

The hypothalamus is a link between the nervous and the endocrine system. It has higher centres for endocrine system. It regulates heart rate, respiration, blood pressure (B.P.), body temperature, water and electrolyte balance. It has centres for hunger, thirst, sleep, fatique, satiety centre, secretion of glands of stomach and intestine. It also produces neurohormones that stimulate the pituitary gland. A complex neuronal circuit called the **limbic system** is formed by the hypothalamus amygdala, parts of epithalamus and thalamus, hippocampus and other areas. It appears to be responsible for emotional reactions, motivational drives and memory. The floor of the hypothalamus continues as a downward projection called hypopyseal stalk or infundibulum which connects it to the hypophysis (pituitary gland) both physically and functionally by secretion of neurotransmitters (details in chemical coordination). The inferior surface of hypothalamus also bears the optic chiasma (crossing of the two optic nerves) and a pair of mammillary bodies (unique to mammmalian brain and responsible for recollective memory).

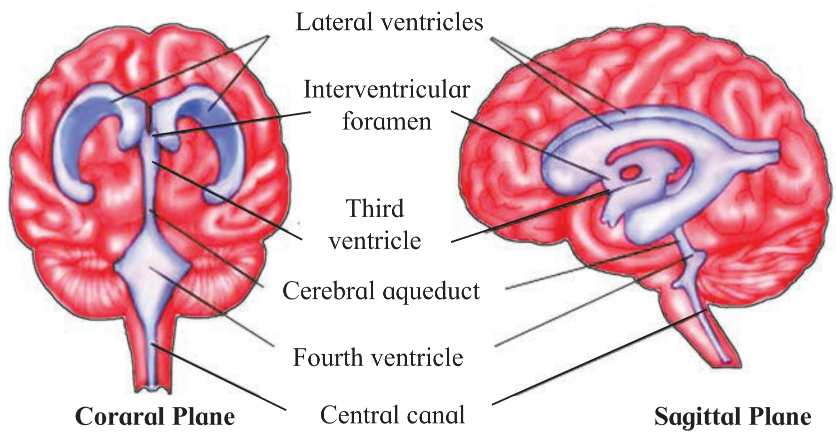


Fig. 9.10 : Ventricles of brain

b. Mid brain :

It is located between diencephalon and the pons varolli. It contains the cerebral aqueduct or iter that connects the third and fourth ventricles. The **corpora quadrigemina** are four rounded elevations on the dorsal surface of the mid brain. The two superior colliculi are involved in visual reflexes and the two inferior colliculi are relay centres for auditory reflexes that operate when it is necessary to move the head to hear sounds more distinctly.

The mid brain also contains on its inferior surface two thick fibrous tracks called cerebral peduncles or **crura cerebri.** These tracts of ascending and descending nerve fibres from RAS and connect the cerebrum mid brain. Near the centre of the mid brain is a mass of grey matter scattered within the white matter. It is called the **red nucleus**. It plays an important role in controlling posture and muscle tone, modifying some motor activities and motor co-ordination.

Always Remember

Wernicke's area : It is the sensory speech area responsible for understanding and formulating written and spoken language.

Broca's area : It is the motor speech area and translates thoughts into speech and controls movement of tongue, lips and vocal cords.

c. Hind brain :

The posterior region of the brain is called **hind brain**. It consists of pons varolli, cerebellum and medulla oblongata. The **pons varolli** appears as a rounded bulge on the underside of the brain stem (brain stem consist of mid brain, pons and medulla and continues upto spinal cord), and contains a cross band of nerve fibres connecting cerebrum, cerebellar lobes, medulla oblongata and spinal cord. It also contains several nuclei. The **cerebellum** is the second largest part of the brain and consists of two lateral hemispheres and a central vermis. It is composed of white matter with a thin layer of grey matter, the cortex. The white matter intermixes with the grey matter and shows a tree-like pattern called **arbor vitae**.

Can you tell?

Explain - "Cerebullum is well developed in humans".

The surface of cerebellum shows convolutions (gyri and sulci) a number of nuclei lie deep within each lateral or cerebellar hemisphere. Over 30 million neurons lie in the cortex. Three pairs of myelinated nerve bundles called cerebullar penduncles connect cerebellum to the other parts of CNS. It is an important centre which maintains equilibrium of body, posture, balancing orientation, moderation of voluntary movements, maintainance of muscle tone. It is a regulatory centre for neuromuscular activities and controls the rapid activities like walking, running, speaking etc. All activitie of cerebellum are involuntanry (though may involve learning in early stages). The **medulla oblongata** is the posterior conical part of the brain and continues as the spinal cord. It has inner grey matter and outer white matter. It controls involuntary vital functions like heart beat, respiration, vasomotor activities and peristalsis. It also controls non-vital reflex activities like coughing, sneezing, swallowing, vomitting, yawning etc. The cavity of medulla is called IV^{th} ventricle or metacoel. It's roof has the posterior choroid plexes for secretion of CSF. The posterior choroid plexes also shows 3 openings - a pair of lateral foramen of Luschka and a median foramen of Magendie.

Internet my friend

- Find out the role of the foramina mentioned above.
- What is ataxia ?

Can you tell?

1. The functions of fore brain
2. Injury to the medulla oblongata causes sudden death - Explain.
3. Distinguish between cerebrum and cerebellum.
4. About the mid brain.

B. Spinal Cord :

Spinal cord is the part of central nervous system and forms the lower extension of the medulla oblongata of the brain. Like the brain, it is covered and protected by bony covering and membranes. It lies within the neural canal of the vertebral column and is surrounded by three meninges - dura mater, arachnoid mater and pia mater. The Cerebro Spinal Fluid (CSF) secreted by pia mater, forms a fluid cushion around the spinal cord and within it inside the central canal.

Externally, the spinal cord appears as long cylindrical rod, 42 to 45 cm long and 2.0 to 2.5 cm broad. The spinal cord is broadest at its anterior end gradually tapers into **conus medullaris** (L1 to L2) and continues as a thread like **filum terminale** end posteriorly. Spinal cord shows two swellings along its length called cervical and lumbar swelling.

31 pairs of spinal nerves arise from lateral sides of the spinal cord. These nerves are concentrated in the region of cervical and lumbar swelling and around the conus medullaris. The bunch of nerves in the hind part of the spinal cord, along with the filum terminale, appear like a horse's tail, so called **cauda equina**.

T. S. of spinal cord

The spinal cord is dorsoventrally flattened due to the presence of deep, narrow posterior fissure and shallow, broad anterior fissure. A central canal can be seen in the centre. The fissures divide the spinal cord incompletely into a right and left side. The grey matter is somewhat H-shaped or butterfly shaped and is on the inner side, while the white matter is on the outer side. The fissures divide the grey matter into six horns, namely dorsal, lateral and ventral horns, while the white matter is divisible into 6 columns or funiculi, namely dorsal, lateral and ventral funiculi. The dorsal and ventral horns extend out of the spinal cord as dorsal root and ventral root of spinal cord respectively. Of these, the dorsal root is connected to the dorsal root ganglion. (It lies just outside and lateral to the spinal cord). It has an aggregation/collection of unipolar sensory neurons.

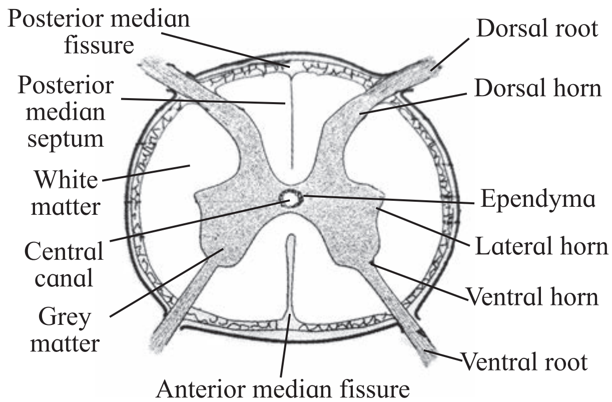


Fig. 9.11 : T. S. of spinal cord

The association or inter-neurons lie inside the grey matter. The receive signal from the sensory nerve, integrate it and direct the response towards motor neurons lying towards the ventral horn. The lateral horns have neurons of autonomic nervous system (ANS). The nerves arising from these neurons, emerge out from the ventral root of spinal nerve.

The white matter consists mainly of bundles of myelinated nerve fibre called ascending and descending tracts. The ascending tracts conduct sensory impulses from spinal cord to the brain and these lie in the dorsal column/funiculi. The descending tracts conduct motor impulses from brain to the lateral and ventral funiculi of spinal cord.

Functions : The spinal cord is the main centre for the most reflex actions. It provides pathway for conduction of sensory and motor impulses to and from the brain. It provides nervous connection to many parts of the body.

2. Peripheral Nervous System (PNS) : The peripheral nervous system connects the central nervous system to the different parts of the body having receptors and effectors. Depending on the connection to the CNS, the peripheral nerves are classified into two main types -

Cranial nerves - connected to the brain.

Spinal nerves - connected to the spinal cord.

Table 9.12 Cranial nerves - nature and functions

No.	Name	Type	Origin	Organs Innervated	Functions
I.	Olfactory	Sensory	Olfactory bulb	Epithelium of Nose	Smell
II.	Optic	Sensory	Side of diencephalon	Retina of Eye	Vision
III.	Occulomotor	Motor	Floor of mid brain	Eye muscles (4 of 6 eye muscles)	Movement of eye ball
IV.	Pathetic	Motor	Floor of mid brain	Eye muscles (1 of 6 eye muscles, forehead scalp)	Rotation and movement of eye ball
V.	Trigeminal (Dentist's nerve)	Mixed	Ventral side of pons	-	Sensation of skin touch, taste, jaw movement.
	a. Ophthalmic	Sensory	-	Nasal cavity, Upper eyelids, forehead, scalp, conjunctiva, lacrimal gland, scalp	
	b. Maxillary	Sensory	-	Mucosa of nose, palate, upper teeth, upper lip, lower eye lid parts of pharynx	
	c. Mandibular (largest)	Mixed	-	Lower teeth, skin over mandible cheek, side of head in front ear, muscles of mastication	
VI.	Abducens	Motor	Pons	Muscles of eye ball, lateral rectus muscle	Movement of eye
VII.	Facial (bearing geniculate ganglion)	Mixed	Pons	facial, scalp and neck muscles, lacrimal, sublingual, submandibula, nasal and palatine glands	Facial expression, movement of neck, secretion of tears, taste, salivary secretion.
VIII.	Auditory (vestibulo-cochlear)	Sensory	Pons	Internal Ear	Hearing and equilibrium
	i. Vestibular		-		
	ii. Cochlear		-		
IX.	Glossopharyngeal	Mixed	Side of medulla oblongata	Pharynx, tongue, salivary glands	Taste, salivation and swallowing

X.	Vagus (Pneumogastric)	Mixed	Side of medulla oblongata	Larynx, trachea, pharynx, alimentary canal, heart, lungs, pancreas, blood vessels,	Visceral sensations and visceral movements like breathing cardiac, slowing, gastric and pancreatic secretion, gastrointestinal movements
XI.	Spinal accessory	Motor	Side of medulla oblongata	Neck and shoulder muscles, reflexes of thoracic and abdominal vicera larynx, pharynx	Movements of larynx, pharynx, neck and shoulder
XII.	Hypoglossal	Motor	Side of medulla oblongata	Tongue muscles	Movement of tongue

Cranial Nerves : These nerves develop from the brain, in all amniotes (reptiles, birds and mammals). There are 12 pairs of cranial nerves. Roman numbering I to XII is used to denote them. These nerves originate from or terminate into the brain.

According to their function, these are classified as **sensory** (I, II, VIII), **motor** (III, IV, VI, XI, XII) and **mixed** (V, VII, IX, X) nerves.

The details of cranial nerves present in the human body is presented in Table 9.15.

Spinal Nerves : Thirty one pairs of spinal nerves originate from the spinal cord. They are mixed nerves and they provide two way communication between the spinal cord and part of the upper and lower limbs, neck and trunk.

Table 9.13 : Number and types of spinal Nerves

Group	No. of pairs	Region of origin from vertebral column
Cervical	8 (C1-C8)	Neck
Thoracis	12 (T1-T12)	Thorax
Lumbar	5 (L1-L5)	Abdomen
Sacral	5 (S1-S5)	Pelvis
Coccygeal	1 (Co1)	Coccyx

Do you know ?

1. Of the 12 pairs of cranial nerves, only the X (vagus) passes into the body and innervates internal organs.
2. Vagus has the maximum number of branches and longest distribution.
3. V/trigeminal/Dentist's nerve is the largest cranial nerve
4. VI/abducens is the smallest cranial neve.

Formation of a typical spinal nerve : All spinal nerves are of the mixed type i.e. they have some nerve fibre as sensory and some motor. Each spinal nerve is formed inside the neural canal of verterbral column by two roots - the posterior or dorsal sensory root and anterior or ventral root. Anterior root receives the sensory nerve from the dorsal root ganglion (cell bodies of sensory neurons are located in the ganglion), while the anterior/ventral root gives out the motor nerve. The dorsal sensory and the ventral motor nerves together form the mixed spinal nerve. It emerges out from both sides of the spinal cord through the intervertebral foramen. As soon as it emerges out of vertebral column, it shows three branches viz.

- **Ramus dorsalis :** from skin and to muscles of dorsal side
- **Ramus ventralis :** the largest of the three supplies the organs and muscles on lateral and anterior side
- **Ramus communicans :** the smallest of the three and given out from 1st thoracic upto 3rd lumbar (L3) spinal nerve. It joins the sympathetic ganglia.

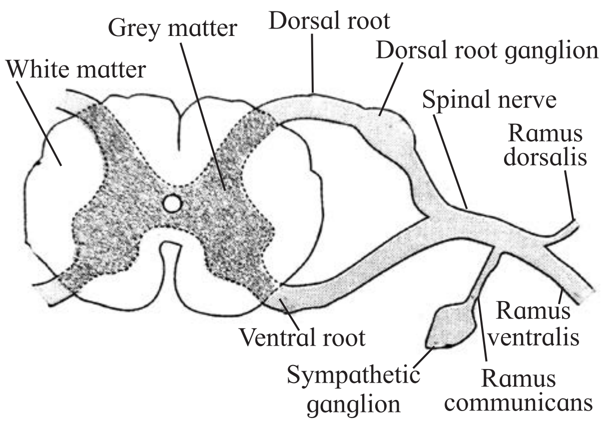


Fig. 9.14 Formation of Spinal Nerve

Reflex Action : It is a sudden, spontaneous automatic, involuntary response to stimulus. The response to stimulus is said to be involuntary as it is carried out without any conscious effort by the brain. The path along which the action is carried out is called **reflex arc**.

[Note : In your earlier classes you have studied about the reflex actions.]

Human nervous system is divided into CNS, PNS, ANS. PNS consist of network of nerves arising from or going to the CNS. Accordingly peripheral nerves are classified as

a. Afferent nerves

b. Efferent nerves

Afferent nerve fibres transmit sensory impulse from tissue or organ to the CNS and the efferent nerve fibres transmit regulatory or motor impulses from the CNS to the various peripheral tissues and organ.

Chart 9.15 Types of Reflex actions

1. On the basis of control over the actions.

Reflex actions

Cranial reflexes
- carried out by brain
- slow action response
- eg. watering of mouth on sight or smell of good food

Spinal reflexes
- carried out through spinal cord
- urgency for response is required so these are quick acting
- eg. withdrawal of leg while stepping on something hot or pointed

2. Based on previous experiences

Reflex actions

Unconditional reflexes
- These do not require any previous experience
- eg. sneezing, coughing, yawning, hiccuping.

Conditional reflexes
- These actions are based on previous experience. eg. swimming, dancing, cycling etc.
- Initially these actions are voluntary when learning is being done, later after perfection they become involuntary. These were first studied by E. Pavlov on salivation in dog (at the sight and sound of bell)

3. According to number of synapses involved

Reflex actions

Simple monosynaptic
- It involves only sensory and motor neurons eg. knee jerk reflex

Complex polysynaptic refexes
- It involves sensory internervous and motor or neurons eg. cycling, swimming, etc.

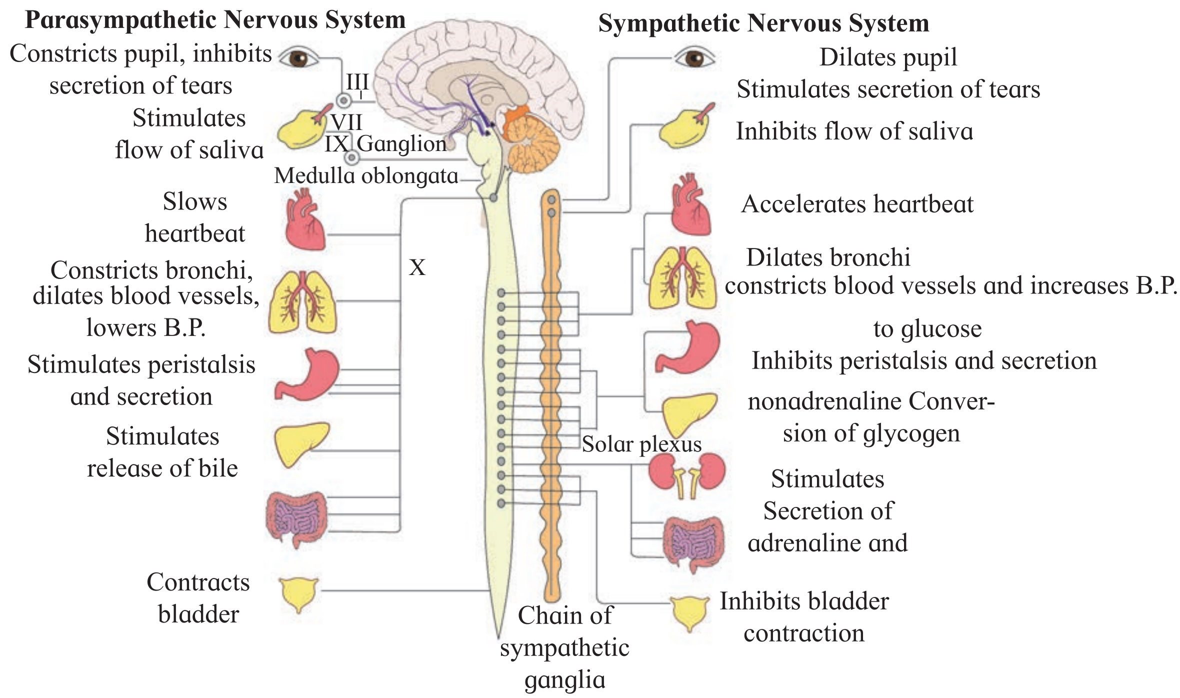


Fig. 9.16 Autonomic Nervous System

However according to recent studies, the extent of PNS has been broadened to incorporate the ANS.

According to this view, the PNS is divided into

i. somatic nervous system and

ii. autonomic nervous system

The somatic nerous system relays impulses from CNS to the skeletal or voluntary muscles of the body.

3. Autonomic Nervous System (ANS) :

Autonomic nervous system transmits impulses from CNS to the involuntary organs and smooth muscles of the body.

ANS consists of a special set of peripheral nerves that regulate the activities of involuntary organs like cardiac muscles, smooth muscles, glands etc. In this, impulses are conducted from the Central Nervous system by an axon that synapses with an autonomous ganglion. It is preganglionic neuron. The second neuron in this ganglionic pathway has an axon that extends from the autonomic ganglion to an effector organ and is known as postganglionic neuron.

Autonomic nervous system consists of sympathetic and parasympathetic nervous system.

Use your brain power

Mr. Sharma suffered from a stroke and the right side of his body was paralysed. However his response was normal for knee jerk reflex with either leg. Explain how and why ?

a. Sympathetic Nervous System (SNS):

It is also called thoraco-lumbar outflow. It originates in the thoracic and lumbar region of spinal cord (T1 to L3) and consists of 22 pairs of sympathetic ganglia which lie on a pair of sympathetic cords on lateral sides of the spinal cord.

The pre-ganglionic nerve fibres are short and post ganglionic nerve fibres are long. Adrenaline and Noradrenaline is produced at the terminal ends of postganglionic nerve fibres at the effector organ, hence it is also called **Adrenergic fibres**. Sympathetic nervous system controls body activities during emergencies (fight or flight response). It has excitatory and stimulating effect on most organs of the body except in the digestive and the excretory organ.

Table 9.17 : Comparison between sympathetic and Parasympathetic Nervous System

Organ/Region	Sympathetic effect	Parasympathetic effect
Heart beat	Increases	Decreases
Blood vessels	Constricts	Dilates
Arterial B.P.	Increases	Decreases
Pupil of Eye	Dilates	Constricts
Gastrointestinal movements (stomach and intestine)	Retards peristalsis	Accelerates peristalsis
Urinary bladder	Relaxes the bladder	Contracts the bladder

b. Parasympathetic Nervous System :

It is also called cranio-sacral outflow. It consists of the branches from the cranial (III, VII, IX, X) nerves, sacral (II, III) and spinal (IV) nerves. It consists of ganglia which are very close or within the wall of the effector organs. The pre-ganglionic nerves are long and post-ganglionic nerves are short. Acetyl-choline is produced at the terminal end of post-ganglionic nerve at the effector organ, hence these are also called **cholinergic fibres**.

Parasympathetic nervous system is antagonistic to sympathetic nervous system. It brings back to normal, all activities which are stimulated by the sympathetic system. Hence it is also called housekeeping system. It has an inhibitory effect on most organs. However, the activities like those associated with digestion, peristalsis and micturition, which are inhibited by sympathetic system are thus accelerated by the parasympathetic system.

The answers to all these questions are the presence of a sensory system in our body. It consists of simple to complex structures called sensory receptors.

9.7 Sensory Receptors :

Sensory Receptors are some specialised structures in the body to receive the various stimuli from the external or internal environment. The nature of the receptor is defined by a type of stimuli that it can respond to eg. a photoreceptor responds to light, what exactly is the meaning of the receptor. It implies that when a specific type of stimulus reaches the sensory neuron (receptor) it causes the production of an action potential in it and this action potential is carried in the form of an impulse. These impulses are conducted to the different functional areas of the brain for processing and interpretation.

Curiosity Box:

1. Ever wondered as to how we are able to understand the smell of the first showers of rain, or the sudden changes in the climate ?
2. How are we able to hear the chirping of the birds and recognize the sound of the bird ?
3. How can we see and enjoy the beautiful colours of the nature after the sunrise ?

Internet my friend

Find out the fifth category of taste called Umami apart from the four recognized ones - salty, sour, sweet, bitter.

Classification of receptors :

Receptors are classified on the basis of their location, function and their sensitivity to specific stimuli. Their classification is given in the following chart.

Chart 9.18. Types of receptors

No.	Name/Type of receptor	Location	Function
I. Exteroceptors : Receive external stimuli			
	a. Phonoreceptors	Internal Ear - organ of corti	Sound reception
	b. Statoreceptors	Internal Ear-semicircular canals	Receptors for maintaining balance and equilibrium
	c. Photoreceptors	Retina of Eye	Receives sensory stimuli for vision
	d. Thermoreceptors	Skin	Receives sensory stimuli for heat (caloriceptors) and cold (trigidocetptors)
	e. Mechanoreceptors	Skin	Sensitive to mechanical stimuli like touch, pain, pressure, deep pressure, etc.
	f. Chemoreceptors • Gustatoreceptors • Olfactory receptors	Taste buds of tongue Olfactory Epithelium of Nose	Sensitive to taste of sweet, salt, sour, bitter and umami. Sensitive to about 10,000 different smells
II. Interoceptors : Receive stimuli coming from within the body			
	a. Enteroceptors	from internal body organs	Sensitive to stimuli coming from internal organs like hunger, thirst, pain, osmotic change
	b. Proprioceptors	Joints, muscles and tendons	Detect changes in the movements of joints, tendons and muscles; pain, tension and sensitive to vibrations
	c. Baroreceptors (*These are also considered as mechanoreceptors, receiving signals from internal organ)	Present in walls of atria, venae cavae, aortic arch, carotid sinus	Sense changes in B.P. so as to restore homeostasis through vasodilation or vasoconstriction

Eye :

The eyes are a pair of sensory organs of vision. These are located in the orbit of skull with a cushion of fat around them. Each eye is spherical/rounded and called eyeball. The eyes are protected bones, eyebrows, upper and lower eyelids with eyelashes and the lacrimal/ tear glands. Movement of the eyeball within the orbit is controlled by 6 sets of muscles.

Wall of the eyeball is made up of 3 layers (1) sclera, (2) choroid and (3) retina

1. Sclera/scelrotic : It is the outermost layer made of dense fibroelastic connetive tissue with collagen fibres. It provides attachment to the eyeball muscles. The anterior thick, transparent part of sclera is cornea. It is slightly bulged out for focussing light on the retina. The sclera is provided with blood vessels, however the cornea is devoid of them. Cornea is nourished by aqueous humour and also by lacrimal secretion. The exposed part of sclera and the entire Cornea are covered by a transparent membranous covering called **conjuctiva**. It provides protection and lubrication to the cornea.

2. Choroid /Uvea : It is the middle, vascular and pigmented layer. It is not a complete layer and can be divided into 3 regions - a. Choroid proper b. Ciliary body c. Iris

a. The choroid proper : It lines the sclera. Due to its pigmented nature it prevents internal reflection. The blood vessels of choroid provide nutrition and oxygen to the retina.

b. Ciliary body : It is a thick, muscular, ring like structure at the junction of choroid and iris. Its epithelium secretes aqueous humor. Attached to the ciliary body are suspensory ligaments which hold the lens. The ligaments and muscles of the ciliary body help in the adjustment of the size of lens.

c. Iris : At the junction of the sclera and cornea, the vascular part of choroid sharply bends into the cavity of eyeball, forming a thin and coloured partition called iris. It is perforated in the middle by an aperture called pupil. Smooth muscles of the iris help in regulating the size of pupil depending on the intensity of light entering the eyeball. The pigment in the iris determines the colour of the eye.

Lens : It is a transparent, elastic, biconvex structure. It is suspended in the eyeball by the suspensory ligaments. The lens and suspensory ligaments divide the cavity of the eyeball into a small anterior aqueous chamber, filled with a clear watery fluid aqueous humor and a posterior large vitreous chamber, filled with a jelly like vitreous humor. It maintains shape of the eyeball and maintain pressure for keeping the lens in position.

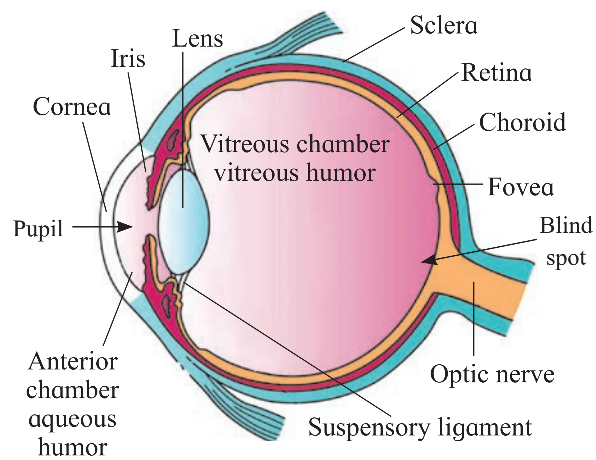


Fig. 9.19 : Eye

3. Retina : It is the innermost, delicate, non vascular light sensitive layer. It has 2 regions (a) single layer of pigmented non sensory part lining the iris and ciliary body (b) sensory part lining the choroid. It has an outer pigmented part and an inner nervous part. The inner nervous part is transparent and made of 3 layers (1) outer photosensitive layer made of rod and cone cells. (2) middle layer of bipolar nerve cells (3) inner layer of ganglion cells. The nerve fibres from the basal end of the ganglion cells collectively form the optic nerve.

Do you know ?

Why do eyes of cats and dogs glow in the night ? The glowing of eyes in some animals is due to presence of a reflecting layer behind the retina, called tapetum lucidum.

The blind spot is an area diagonally opposite to the lens. It is the area of retina from where the optic nerve and blood vessels leave the eyeball. There are no rod and cone cells in this region. An area, lateral to the and above the blind spot is called yellow area or macula lutea. At its centre is a depression called lovea centralis. It has maximum density of cone cells and is the place of formation of sharpest vision.

The rod and cone cells lie deep in the retina, so that light has to pass through the ganglion and bipolar cells before reaching them.

Photo receptor cells : These are of two types (a) Rod cells (b) cone cells.

They contain light sensitive proteins termed as photopigments. The cones are responsible for daylight (photopic) vision and colour vision. While the rods function in dim light (Scotopic) vision. The purple red protein called rhodopsin is present in the rods which is vitamin A derivative. The cones are of three types, which contain their own characteristic photo-pigments that respond to red, green and blue lights. Various combinations of these cones and their photopigments produce sensation of different colours. The sensation of white light is produced due to the simultaneous equal stimulation of these three types of cones.

The Optic nerve consists of the fibres arising from the base of ganglion cells. It leaves the eye ball from the posterior side and carries visual impulses from the retina to the brain.

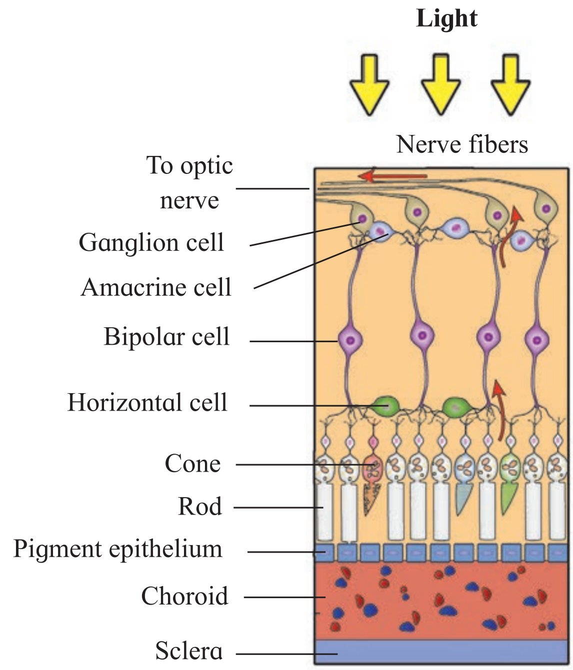


Fig. 9.20 : Structure of retina

Generation of image :

The light rays from the object pass through the conjunctiva, cornea through the pupil upon the lens and is focused on the retina to form an image. In the visual area of cerebrum, the nerve impulses are analysed and the image formed is recognized.

Always Remember

Accomodation : The lens makes fine adjustments to bring a sharp focus on retina. The ability of the lens by which the light ray from far and near objects is focused on the retina is called accomodation power of the lens.

Internet my friend

- Find out information about those who can donate eyes ?
- Is there any age limit for donating eyes ?
- Who cannot donate eyes ?
- Facts about eye donation.

Activity :

Collect information about causes and corrections for myopia, hypermetropia, astigmatism, presbyopia, cataract, night blindness.

Changes in retina when light rays fall on it

↓

Light falls on rod and cone cells in Retina

↓

Breaking up of light sensitive pigments by specific wavelength of light

↓

Stimulation of rod and cone cells and generation of nerve impulse

↓

Nerve impulse transmitted to bipolar nerve cells

↓

Nerve impulse transmitted to ganglion cells

↓

Nerve impulse in the axons of ganglion cells converge and leave via the optic nerve

↓

Nerve impulse is transmitted by optic nerve to brain

↓

Perception of image by the brain cells (in the visual area of cerebrum)

Ear :

The human ear is called stato-acoustic organ and it has two functions - hearing and body equilibrium. Anatomically the ear is made up of three parts : the external ear, middle ear and inner ear.

The **external ear** consists of ear pinna, auditory canal and tympanic membrane. In humans, the ear **pinna** is an immovable part, supported by elastic cartilage structure. It leads into an auditory canal. The pinna collects and sends the sound waves into the auditory canal. The **auditory canal** ends at the ear drum. It transfers the sound waves to the ear drum. There are very fine hair and wax secreting sebaceous glands in the skin of pinna and auditory canal. The **tympanic membrane** is a delicate, membranous structure which transmits the sound waves to the middle ear. It is formed of connective tissues covered with skin on the outside and mucous membrane on the inside.

The **middle ear** consists of chain of three ear ossicles called **Malleus** (hammer), **Incus** (anvil) and **Stapes** (stirrup-the smallest bone). On receiving the vibrations from the tympanic membrane, the ear ossicles amplify the vibrations and transfer these to the **cochlea**. A short **eustachian tube** connects the middle ear to the pharynx. It equalises air pressure on both sides of the ear drum.

The **internal ear** consists of the labyrinth and vestibular apparatus. The labyrinth consists of bony labyrinth and membranous labyrinth. These are filled with perilymph and endolymph respectively. The coiled portion of the labyrinth is **cochlea**.

The cochlea contains fluid filled three chambers separated by Reissner's membrane and basilar membrane. The upper chamber towards vestibul is called scala vestibuli and the bottom chamber scala tympani are filled with perilymph. The middle chamber is the scala media. It is filled with endolymph while scala vestibuli and scala tymphnith are filled with perilymph. The **organ of Corti** is a pea sized structure located on basilar membrane (floor of scala media).

The organ of corti has a sensory epithelium over the basilar membrane. The sensory epithelium is in contact with a gelatinous tectorial membrane. The sensory cells have sensory hair on their free end so also called hair cell. In between the rows of hair cells are present supporting cells.

Hair cells have long stiff microvilli called **stereocillia** on their apical surfaces. Above these stereocellia, is a jelly like membrane

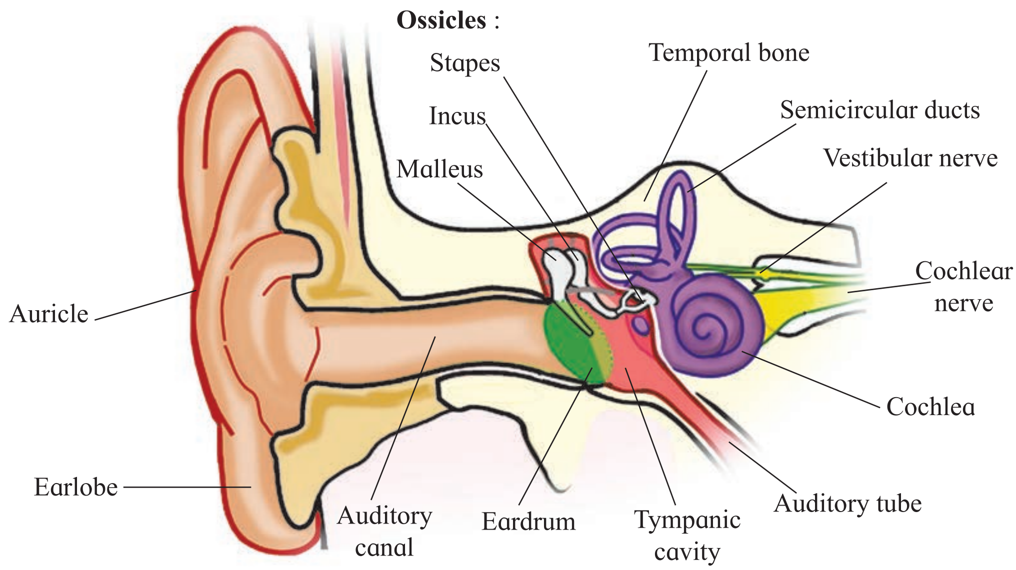


Fig. 9.21 : Structure of human ear

called **tectorial membrane**. This organ acts as a transducer, converting sound vibrations into nerve impulses.

Inner Ear and the mechanism of balance :

Besides the cochlea, the inner ear also has the vestibular apparatus which is composed of three semi-circular canals and the utriculo saccular region with the otolith organ. All three **semi-circular canals** lie in different planes at right angle to each other. These canals are filled with endolymph. The base of each of the canal has an ampulla in which there is a sensory spot called **crista**. The cristae help in maintaining equilibrium. The vestibule has two sensory spots-macula of saccule and utricle the macula consist of hair cells and supporting cells. Tips of the hair and cilium project into a thick gelataneous sheath otolithic membrane. Within this membrane minute particle otoliths or otoconia are secreted. These are made of $CaCO_3$ and protein. The macula and crista are the receptors sensitive to the position of the head with respect to gravity. The three semicircular canals are arranged such away that the movement in any plane can be detected by these cells and the balance and posture of the body is maintained. Receptors for dynamic balance lie in the cristae of ampullae while for

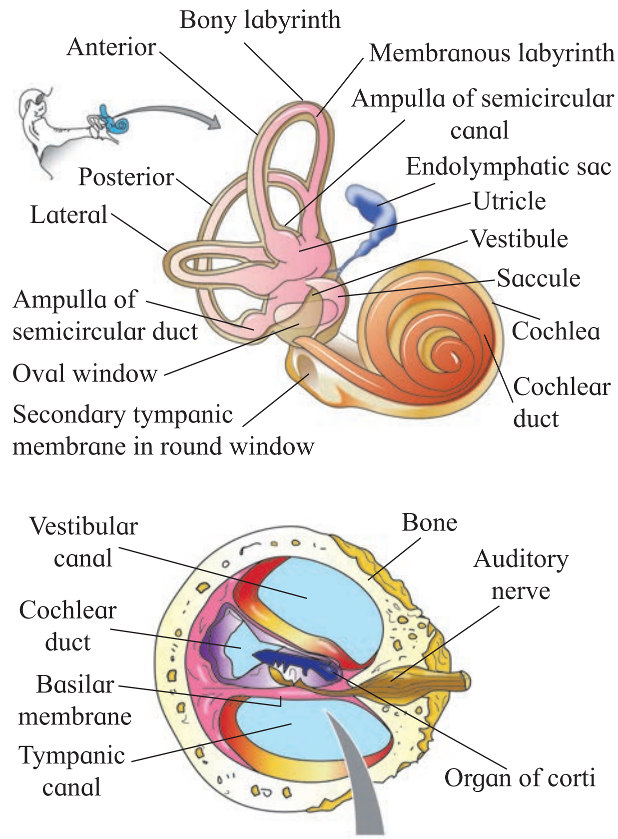


Fig. 9.22 : Human Internal Ear

Activity :

The auditory centre of the brain analyses the impulses received and the sound is perceived.

Draw flow chart of mechanism of hearing.

static/linear balance these are in the maculae of utriculus and sacculus.

Mechanism of Hearing :

Pinna of the ear receives the sound waves and directs them to eardrum. Eardrum vibrates and these vibrations are amplified and transmitted through the ear ossicles to the endolymph inside cochlea. This generates, wave in the endolymph. These waves induce ripples in the basilar membrane. These movements in the basilar membrane cause the hair cells to press against tectorial membrane. This generates nerve impulse in the afferent neurons. Impulse is sent to the brain via the auditory nerve. Auditory cortex of the brain decodes the sound.

Use your brain power

1. What is the function of tympanic membrane?
2. Enlist the various receptors found at various location in the body.

9.8 Disorders of nervous system :

Psychological disorders :

Commonly called mental disorders, are a wide range of conditions that affect the mood, thinking or behaviour. These affect multiple areas of life and create distress for the person suffering from it. Some of the major categories of psychological disorders are - Intellectual disability (formerly known as mental retardation), Autism spectrum disorder, bipolar disorder, depression, anxiety disorder, ADHD (Attention Deficit Hyperactivity Disorder), and stress related disorders.

Parkinson's disease :

Degeneration of dopamine-producing neurons in the CNS causes Parkinson's disease. **Symptoms** develop gradually over the years. Symptoms are tremors, stiffness, difficulty in walking, balance and co-ordination.

Alzheimer's disease :

It is the most common form of dementia. Its incidence increases with the age, showing the loss of cognitive functioning -thinking, remembering, reasoning and behavioral abilities to such an extent that it interferes with the persons daily life and activities. It occurs due to loss of cholinergic and other neurons in the CNS, accumulation of amyloid proteins. There is no cure for Alzheimer's, but treatment slows down the progression of the disease and may improve the quality of life.

CHEMICAL COORDINATION

The cells and organisams communicate with each other through chemical signals. Also they are broadly of four types as follows :

Autocrines : Cells release secretion to stimulate itself.

Paracrines : Cells release secretion to stimulate neighbouring cells.

Endocrines : Cells release secretion to stimulate distant cells.

Pheromones : Organs release secretions to stimulate other organism.

Higher animals have complex body organization. Due to this, in addition to the nervous coordination, there is need of chemical coordination. Chemical coordination is carried out by secretions of ductless glands. This chemical coordination system is also called the endocrine system.

9.9 Endocrine system :

The endocrine system controls body activities by means of chemical messengers called hormones. Hormones are released directly into the blood. The hormone is carried all over the body via blood. However the message is relayed only to the target organs which are stimulated to carry out specific process which include activities like growth and development.

Chemical nature of hormones

I. Amines : These are simple amines. Catecholamines secreted by adrenal medulla, epinephrine and non-epinephrine and melatonin from pineal gland. Some are modified from the amino acids. e.g., Thyroxine.

II. Peptide hormones : These hormones consist of long or short chains of amino acids. e.g. Hormones of hypothalamus oxytocin, ADH, GnRH.

III. Protein hormone : Insulin, glucagon TSH, FSH, LTH, GH, relaxin.

IV. Fatty acid derivatives :- Prostaglandin

V. Steroid hormones : These hormones are lipid soluble and derived from cholesterol and other steroids. e.g. estrogen testosterone, aldosterone. Action of these hormones is concerned with long lasting responses.

VI. Gas : NO (Nitric Oxide)

Properties of Hormones :

They act as chemical messengers and are effective in very low concentration. Hormones can function as regulators that inhibit or stimulate or modify specific processess. Some hormones interact with receptors present on plasma membrane of target cells where as some enter the necluses to interact with genes. Hypersecretion or Hyposecretion of hormons leads to various disorders.

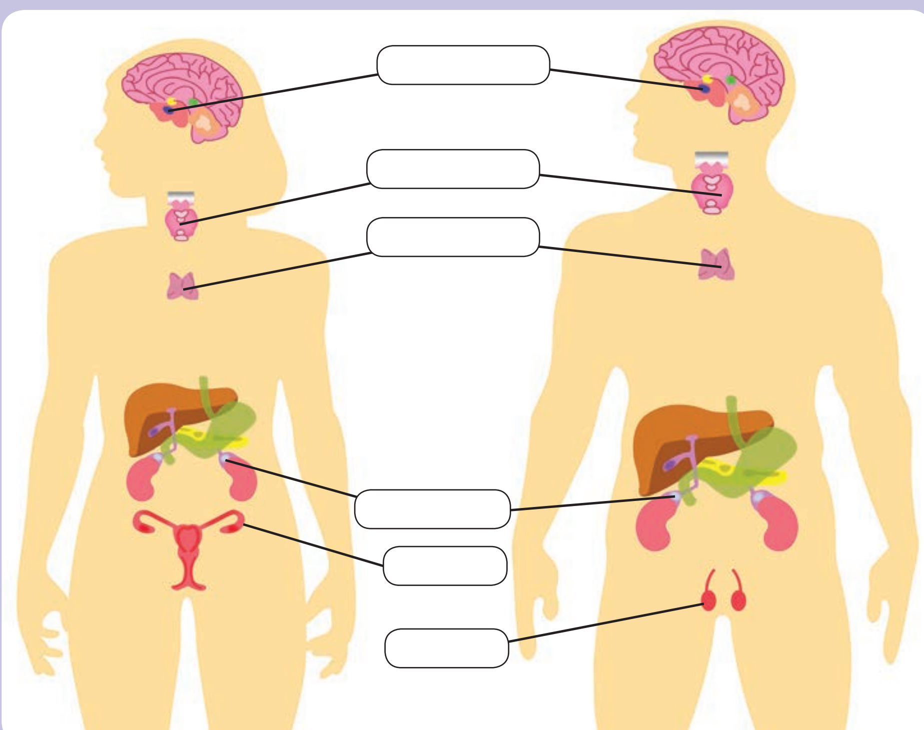
These are metabolised after their function. Thus cannot be reused. Hormone secretion is regulated by positive or negative feedback mechanism.

Mechanism of hormone action :

Hormones are released in a very small quantity. They produce their effect on the target organs cells by binding to hormone receptors. The hormone receptors may be on the cell membrane or may be intracellular. A hormone

Activity :

Identify the glands and state their functions.



hormone receptor complex is formed and this leads to biochemical change in the target tissue.

A. Mode of hormone action through membrane receptors :

Hormones like catecholamines, peptide and polypeptide hormones are not lipid soluble. Therefore they cannot enter their target cells through plasma membrane.

These non steroid water soluble hormones interact with surface receptor, which initiate metabolic activity. Molecules of amino acid derivatives, peptide hormones bind to specific receptor molecules located on the plasma membrane. The hormone receptor complex causes the release of an enzyme adenylate cyclase from the receptor site. This enzyme forms cyclic AMP from ATP of the cell. cAMP activates enzymatic actions. The hormone acts as the first messenger and cAMP is the second messenger. Other kind of second messengers are Ca^{++}, cGMP and IP_3 (Inositol triphosphate).

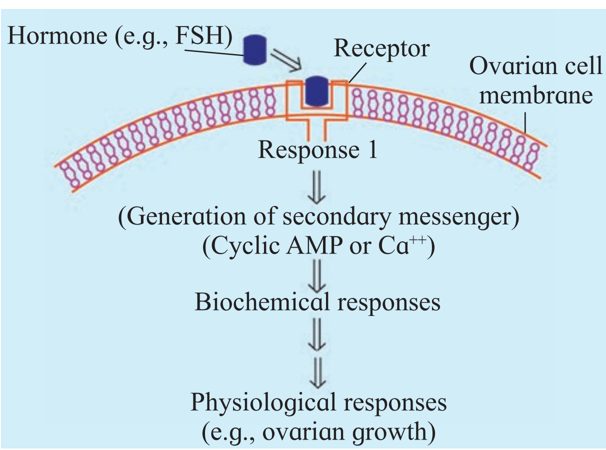


Fig. 9.23 : Mechanism of hormone action through membrane receptor

Internet my friend

What is negative and positive feedback of hormone action ?

B. Mode of action through intracellular receptors :

Steroid and thyroid hormones are lipid soluble and easily pass through plasma membrane of target cell into the cytoplasm. In the cytoplasm, they bind to specific intra cellular receptor proteins forming a hormone-receptor complex that enters the nucleus. In the nucleus, the hormone receptor complex binds to a specific regulatory site of DNA. The activated genes transcribes mRNA which directs protein synthesis and enzymes in the cytoplasm. Action of lipid soluble hormones is slower but long lasting.

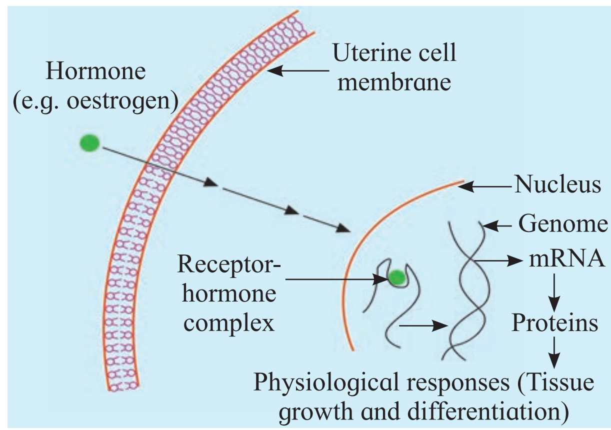


Fig. 9.24 : Mechanism of hormone action through intracellular receptor

9.13 Major endocrine glands :

A. Hypothalamus :

It is ectodermal in origin. It is located at the floor of diencephalon. Major function of hypothalamus is to maintain homeostasis. It controls the secretory activity of pituitary gland by the release and inhibiting hormones. All hormones of hypothalamus are peptide hormones. They are secreted by the neurosecretory cells so they are called neurohormones. The hormones secreted by hypothalamus are : ADH, Oxytocin.

1. **Adrenocorticotropin Releasing Hormone :** It stimulates the release of ACTH by the anterior pituitary gland.
2. **Thyrotropin Releasing Hormone :** It stimulates the release of TSH by anterior pituitary gland.
3. **Gonadotropin Releasing Hormone (GnRH) :** It stimulates pituitary to secrete gonadotropins.
4. **Prolactin Inhibiting Hormone (Prolactostatin) :** It inhibits prolactin release by anterior piturary gland.
5. **Somatostatin :** It inhibits the release of growth hormone.
6. **Somatotropin** stimulates release of growth hormone.
7. **Gastrin Releasing Peptide (GRP) and**
8. **Gastric Inhibitory Polypeptide (GIP)**

B. Pituitary gland or hypophysis gland :

The pituitary gland is the smallest gland. Pituitary gland is a pea sized reddish-grey coloured gland. It controls almost all other endocrine glands, hence earlier it was called the master endocrine gland. It is located just below the hypothalamus and is attached to it by a stalk called **infundibulum** or hypophyseal stalk. Pituitary gland remains lodged in a bony depression called **sella turcica** of the sphenoid bone. Pituitary gland consists of two lobes called **anterior lobe (Adenohypophysis)** and **posterior lobe (Neurohypophysis)**. Both the lobes develop from different parts of embryo. Hence it has of dual origin.

Adenohypophysis is an outgrowth from the roof of buccal cavity. This outgrowth is called Rathke's pouch. It grows upward towards the brain. The neurohypophysis grows as a downward extension of hypothalamus. The two outgrowths together form the pituitary gland. The connection of Rathke's pouch with pituitray gland is lost in embryo. Intermediate lobe (Pars intermedia) is a small reduced part lying in the cleft between the anterior and posterior lob.

Neurohypophysis is connected directly to the hypothalamus by axon fibres. Adenohypophysis and intermediate lobes are connected to the hypothalamus through **hypophyseal portal system**.

Hypophyseal portal system :

Various hormones secreted by hypothalamus reach the pituitary gland through the hypophyseal portal system. The portal vein collects blood from various parts of hypothalamus and opens into anterior lobe of pituitary. From pituitary, the vein finally carries the blood into the superior vena cava.

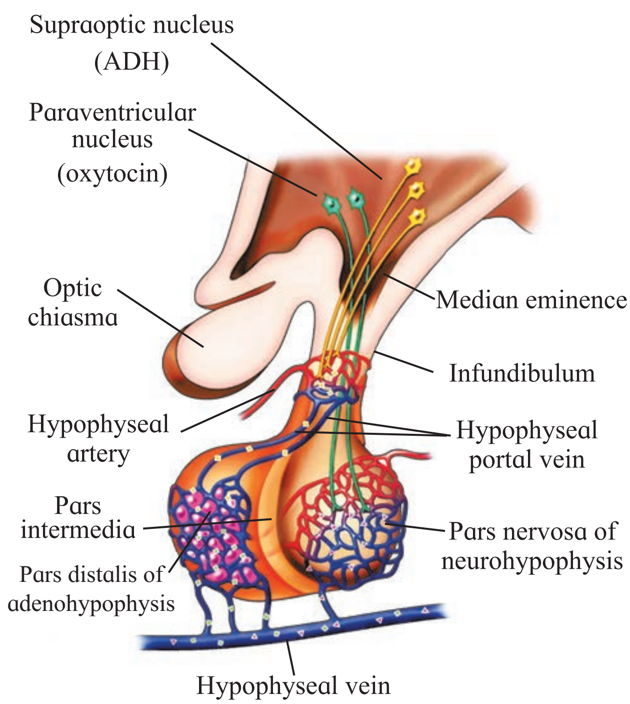


Fig. 9.25 : Pituitary gland

Adenohypophysis: It is the larger lobe of pituitary gland. It is a highly cellular and vascular part of pituitary gland. It contains various types of epitheloid secretory cells, acidophils, basophils, chromatophores. It is differentiated into three parts – pars distalis, pars intermedia and pars tuberalis. .

The hormones of adenohypophysis are as follows :

1. **Somatotropin /Somatotropic Hormone / STH / Growth hormone / GH :**

This hormone stimulates growth and development of all tissues by accelerating protein synthesis and cell division. Highest secretion the GH is seen till puberty and then its secretion of becomes low. However, it is continuously secreted through out life for repair and replacement of body tissue or cells.

Improper secretion of growth hormone produces various disorders. Hyposecretion of growth hormone since childhood results in stunted physical growth and condition is called **pituitary dwarfism**.

Hypersecretion of growth hormone in childhood causes **Gigantism**, a condition of overgrowth. The individual attains abnormal height. When the pituitary gland produces excess growth hormone in middle aged adults, it results in disproportionate growth causing disfigurement and enlargement of bones of nose, lower jaw, hands, fingers and feet. The condition is called **Acromegaly**.

2. **Thyrotropin / Thyroid stimulating Hormone / TSH :** Its primary action is to stimulate the thyroid gland secretion of the hormone thyroxine.
3. **Adreno corticotropic hormone / ACTH / Adrenocorticotropin :** It stimulates adrenal cortex to produce and secrete its hormones. It maintains functioning of adrenal cortex.
4. **Prolactin / Luteotropin / Mammotropin:** Prolactin is unique among pituitary hormones as it is under predominant inhibitory control from hypothalamus. Prolactin activates growth of breasts during pregnancy (mammotropin) and stimulates the milk production and secretion of milk (lactogenic) by mammary gland after child birth.

Internet my friend

Collect the information about Simmond's disease and Gorilla rib.

5. **Gonadotropin :**

a. Follicle stimulating hormone/ FSH :

It stimulates growth of ovarian follicles in the females, while in males, it is concerned with the development of seminiferous tubules.

b. Leutinizing Hormone/ LH :

In female, the leutinizing hormone helps in ovulation (discharge of ovum from graafian follicle). FSH and LH are responsible for stimulation of ovaries to produce oestrogen while LH induces the ruptured follicles to develop into corpus luteum and for production of progesterone.

c. Interstitial cell stimulating hormone / ICSH :

In males, it stimulates the testes to produce the androgen called testosterone. Testosterone is responsible for development of secondary sexual characters.

Neurohypophysis: It is differentiated into three parts, 1. Pars nervosa/ neural lobe 2. Infundibulum 3. Median eminence.

The pars nervosa acts as storage area for the secretions of hypothalamus. It stores and releases oxytocin and vasopressin.

1. Oxytocin : It stimulates contraction of uterus during parturition. It also stimulates the contraction of mammary glands to initiate ejection or release of milk. So is called birth hormone or milk ejecting hormone.

2. Antiduretic Hormone (ADH)/ Vasopressin: It stimulates the re-absorption of water in distal convoluted tubule and collecting ducts of uriniferous tubules of the kidneys. It decreases loss of water by reducing the urine quantity. It increases blood pressure by causing vaso constriction.

Deficiency of ADH reduces water re-absorption and increases urine output. This condition is called **diabetes insipidus** No glucose is lost in the urine. Excessive micturition causes excessive thirst. This condition is called polydipsia.

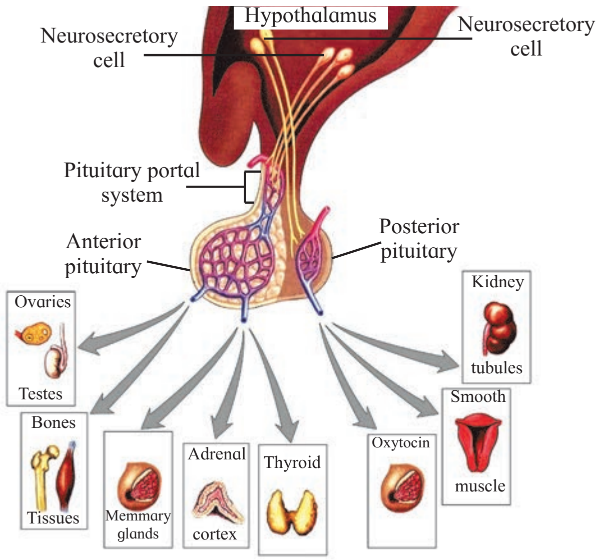


Fig. 9.26: Hypothalamus, Adenohypophysis and Neurohypophysis

Pars intermedia : It is poorly developed in human beings. It secretes Melanocyte Stimulating Hormone (MSH) in some lower vertebrates.

MSH stimulates the dispersion of melanin granules in melanocytes and is responsible for skin pigmentation.

Can you tell?

1. State properties of hormones ?
2. Explain the mode of action of steroid hormones ?
3. Describe neurohormonal regulation of pituitary and thyroid gland ?
4. Give names and functions of hormones secreated by adenohypophysis ?

C. Pineal gland :

The pineal gland is given off from the roof of diencephalon and is located between the two cerebral hemispheres. The pineal gland is sensitive to the biochemical signals of light. It secretes a hormone called **melatonin** also known as sleep hormone. Melatonin is derived from tryptophan and plays a very important role in the regulation of Biological Clock (e.g. 24 hour diurnal rhythm) of our body. It helps in maintaining the normal rhythm of sleep-wake cycle and also influences body temperature, metabolism and reproductive cycles.

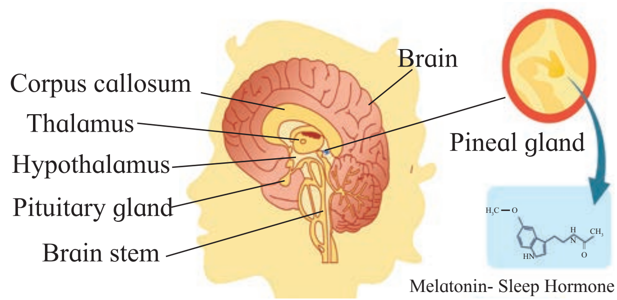
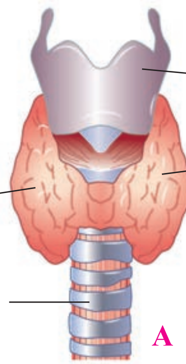


Fig. 9.27 : Pineal gland

D. Thyroid gland :

It is the largest endocrine gland. This bilobed gland is situated in front of the trachea just below the larynx. It is richly supplied with blood vessels. The two lobes of thyroid gland are connected a non-secretory band called **isthmus**. The thyroid lobes are composed of rounded follicles held together by interfollicular connective tissue called **stroma**. The stroma contains blood capillaries and small group of **parafollicular cell** or 'C' cells (**clear cells**). Thyroid **follicles** are composed of cuboidal epithelium resting on a basement membrane and is filled with a gelatinous **colloid**.



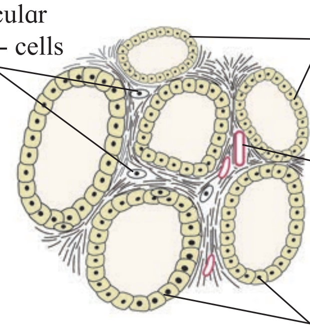


Fig. 9.28 Thyroid gland

Thyroid gland is stimulated to secrete its hormones by thyroid stimulating hormone (TSH). The two hormones secreted by the follicular cells are Thyroxine/tetra iodothyronine/ T_4 (four atoms of iodine) and Triiodothyronine or T_3 (three atoms of iodine). Thyroxine is synthesized by attaching iodine to amino acid tyrosine by enzymatic action. The amino acid tyrosine molecule binds to iodine to produce Monoiodotyronine (T_1) or 2 atoms of iodine to produce Diiodothyronine (T_2). T_1 and T_2 molecules bind end to end to make colloidal mass inside the follicle. They are further metabolised to prepare T_3 and T_4. Triidothyronine or T_3 is also secreted in small quantity. It is physiologically more active. Thyroid gland is the only gland that stores its hormones. T_3 and T_4 hormones are stored before secretion and are regulated by thyrotropin of pituitary gland by negative feed back mechanism.

Think about it

1. Patient suffering from hypothyroidism shows increased level of TSH. Why ?
2. Why do we use iodized salt?
3. In which part thyroid gland stores its hormones?

Thyroxine regulates the basal metabolic rate of body. It also regulates metabolism by stimulating protein synthesis and promotes growth of body tissues. It helps in thermoregulation by increasing heat production. It increases action of neuro transmitters- adrenaline and nor adrenaline. It also supports the process of RBC production and maintenance of water and electrolyte balance. It also regulates reproductive cycles in females.

Parafollicular cells or 'C' cells produce calcitonin hormone, which regulates calcium metabolism.

Disorders related to thyroid gland:

a. Hyperthyroidism :

It is caused by increase in the levels of thyroid hormones. This increases metabolic rate, sensitivity, sweating, flushing, rapid respiration, bulging of eye balls, and affects various physiological activities.

Fig. 9.29 Bulging eyeballs

Grave's disease (Exopthalmic goitre) **:** Hyperthyrodism in adults, is characterised by protruding eyeballs, increased BMR and weight loss. Increased BMR produces a range of effect like increased heart beat, increased BP, higher body temperature, nervousness, irritability, tremor of fingers and bulging eyeballs.

b. Hypothyroidism : It is caused by deficiency of thyroid hormones or removal of thyroid gland (Thyroidectomy).

Cretinism : Hyposecretion in infants leads to cretinism. A cretin has reduced BMR and low oxidation. They are short statured because the skeleton fails to grow. They are mentally retarded. They show dry skin, thick tongue, prolonged neonatal jaundice, lethargy and constipation. This can be treated by early administration of thyroid hormones. The cretin shows stunted physical growth delayed puberity and mental retardation.

Myxoedema : It is the deficiency of thyroid hormones in adults. It is characterised by a peculiar thickening and puffiness of skin and subcutaneous tissue particularly of the face and extremities. Patient lacks alertness, intelligence. The patient suffers from slow heart rate, low B.P., always feeling cold, low body temperature and retarded sexual development.

Do you know ?

During pregnancy, hypothyroidism causes defective development and maturation of growing baby.

Simple goitre : (Iodine deficiency goitre) Iodine is needed for synthesis of thyroid hormone. If there is deficiency of iodine in the diet, it causes enlargement of thyroid gland leading to simple goitre. This disease is common in hilly areas. Addition of iodine to table salt prevents this disease. Size of the thyroid gland is increased but total output of thyroxine is decreased.

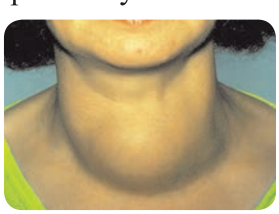


Fig. 9.30 Simple goitre

Find out

Why are African pygmies diminutive. Is it due to lack of GH, thyroxine or absence of thyroxine receptors on their cell surface?

Calcitonin : It is secreted by the 'C' cells. It regulates the concentration of calcium and phosphorus in the blood. It is under feedback control of plasma calcium concentration in plasma. It is secreted when concentration of calcium rises in the blood. It lowers concentration of calcium and phosphorus in the plasma by decreasing their release from the bones and accelerating the uptake of calcium and phosphorous by the bones.

E. Parathyroid gland :

Parathyroid gland is situated on the posterior surface of the lobes of thyroid gland. Parathyroids are four in number and named as superior and inferior parathyroid glands. The cells of parathyroid glands are arranged in a compact mass.

The parathyroids secrete a peptide hormone called **parathormone (PTH)**. It is also called **Collip's hormone**. It regulates calcium and phosphate balance between blood and other tissues. Release of parathormone increases blood calcium level. It draws calcium from bones increases calcium absorption in the digestive tract and reduces loss of calcium in the urine. Secretion of parathormone is under feedback control of blood calcium level.

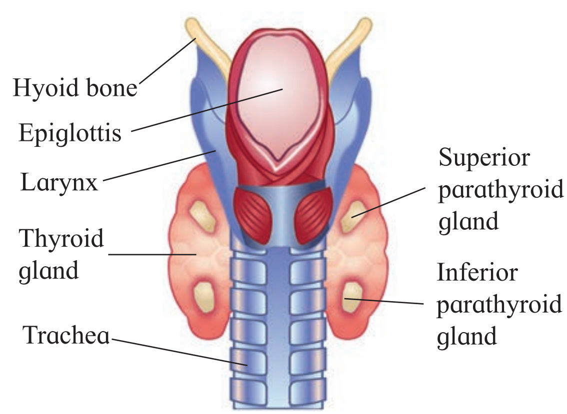


Fig. 9.31 Parathyroid gland

Concentration of calcium and phosphate is maintained by parathormone and calcitonin. These two hormones form an antagonistic pair like insulin and glucagon.

Hyposecretion of parathormone lowers concentration of calcium in the blood. This increases excitability of nerves and muscles causing muscle twitch and spasm. This is called **parathyroid tetany** or **hypocalcaemic tetany**. Hypersecretion of parathormone is responsible for more absorption of calcium from bones i.e., demineralization of bones resulting in softening, bending and fracture of bone. This is called osteoporosis. It is common in women who have reached menopause.

Can you tell?

1. With the help of a suitable diagram describe the structure of thyroid gland.
2. How does fall and rise in blood calcium stimulate secretion of parathyroids?

F. Thymus gland :

Thymus gland is located in the upper part of thorax on the dorsal side of the heart. It is soft, pinkish, bilobed mass of lymphoid tissue. It is a prominent gland at birth but gets gradually atrophied in the adult, so it is called temporary gland.

It secretes the hormone **thymosin**. It has an important role in the development of immune system by maturation of T-lymphocytes.

It also promotes production of antibodies by providing humoral immunity.

G. Adrenal gland/Suprarenal gland :

Adrenal glands have dual origin from mesoderm and ectoderm. They are located on the upper border of each kidney. Adrenal glands are small, conical yellowish glands and show two distinct regions, outer cortex and inner medulla.

1. Adrenal cortex :

Adrenal cortex is derived from embryonic mesoderm. Adrenal cortex secretes many hormones together called corticoids. It is differentiated into three concentric regions.

a. Outer thin **zona glomerulosa** : It secretes ***Mineralocorticods.*** They are released for regulating sodium and potassium ion concentration. They regulate salt-water balance, blood volume and blood pressure. **Aldosterone** (salt retaining hormone) is the main mineralocorticoid. It balances Na-K levels.

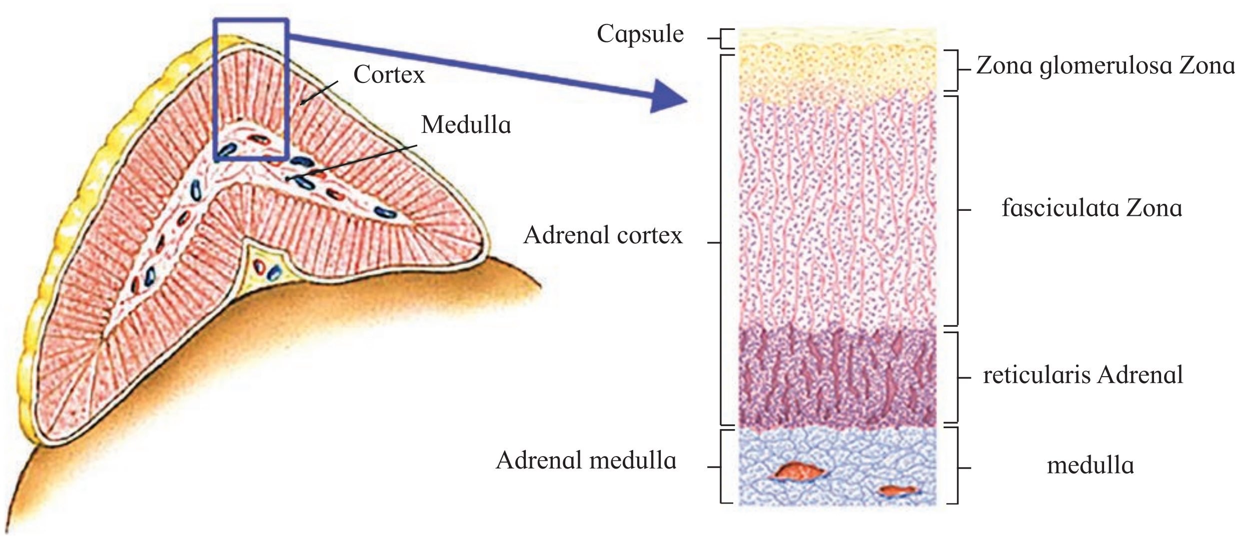


Fig. 9.32 Histology of Adrenal gland

b. Middle thick **zona fasciculata** : It is responsible for secretion of ***Glucocorticoids*** like cortisol. It regulates metabolism of carbohydrates, proteins and lipids. Cortisol is an important glucocorticoid. It is responsible for increase in blood glucose level. It is also immuno suppressive. It suppresses synthesis of antibodies. So it is used in treatment of allergy. It prepares animals to face emergencies in nature.

c. Inner thin **zona reticularis :** It is responsible for production of sex corticoids **(***Gonadocorticoids*). In males, they have a role in development and maintenance of external sex characters. Excess sex corticoids in female causes adrenal virilism and hirsutism (excess hair on face) while in males it causes gynaecomastia i.e. enlarged breast. Androgens and estradiols are the produced by the adrenal cortex.

Disorders related to Adrenal cortex :

a. Hyposecretion of mineralocorticoids and glucocorticoids is responsible for **Addison's disease**. Characteristic features of this disease are low blood sugar, low Na^+ and high K^+ concentration in plasma, increased loss of Na^+ and water in urine. It leads to weight loss, weakness, nausea, vomiting and diarrhoea.

b. Hyper secretion of glucocorticoids produces **Cushing's disease**. It leads to high blood sugar level, excretion of glucose in urine, rise Na^+ in blood volume, high blood pressure, obesity and wasting of limb muscles.

Adrenal medulla : It develops from ectoderm. It secretes two hormones adrenaline (epinephrine) and noradrenaline (norepinephrine). **Adrenaline** is also known as emergency hormone, also called 3F hormone – (fight, flight and fright). **Noradrenaline** regulates the blood pressure under normal condition. It also acts as vasoconstrictor.

H. Pancreas :

It develops from endoderm. It is both exocrine (studied in Digestive System) and endocrine gland. Endocrine cells of pancreas form groups of cells called **Islets of Langehans**. There are four kinds of cells in islets of Langerhans which secrete hormones.

I. Alpha (α) cells (20%) secrete **glucagon**. It stimulates liver for glucogenolysis to increase blood glucose level.

II. Beta (β) cells (70%) secrete **insulin**. It stimulates liver and muscles for glycogenesis. This lowers blood glucose level.

III. Delta (δ) cell (5%) secrete **somatostatin** which inhibits the secretion of glucagon and insulin. It also decreases the gastric secretions, motility and absorption in digestive tract.

IV. PP cells or F cells (5%) secrete pancreatic polypeptide (PP). It inhibits the release of pancreatic juice.

Disorder related to pancreas :

Diabetes mellitus (Hyperglycemia)

This is the most common metabolic endocrine disorder of pancreas. It leads to increase in blood glucose level. This is due to under activity of Beta cells, which results in reduced secretion of insulin. In children, such a condition is called **insulin dependent diabetes mellitus**/ Type I (IDDM) The other form of diabetes is **Non insulin dependent diabetes mellitus**/ Type II (NIDDM). It is caused due to failure of insulin to facilitate the movement of glucose into cells. Reduced sensitivity to insulin is called **insulin resistance**.

Can you tell?

1. Distinguish between glucocorticoids and mineralcorticoids.
2. Name the hormones secreted by the adrenal cortex and state their role.
3. Write a note on Islets of Langerhans.
4. Pancreas is both exocrine as well as endocrine gland. Give reason.

In both disorders, blood glucose level increases. Some of the glucose is excreted in urine. It also causes excessive urination and dehydration of body tissues. Degradation of fats increases formation of ketone bodies (ketosis). Administration of insulin lowers blood glucose level.

I. Gonads :

Gonads are sex organs (the testes and the ovaries).

i. Ovaries : They produce

1. **Estrogen :** These are secreted by developing follicle. Estradiol is the main oestrogen. It is responsible for secondary sexual characters in female.
2. **Progesterone :** It is secreted by corpus luteum of the ovary after ovulation. This hormone is essential for thickening of uterine endometrium, thus preparing the uterus for implantation of fertilized ovum. It is responsible for development of mammary glands during pregnancy. It inhibits uterine contractions during pregnancy.
3. **Relaxin :** It is secreted by the corpus luteum of the ovary at the end of gestation period. It relaxes the cervix of the pregnant female and ligaments of pelvic girdle for easy birth of young one.
4. **Inhibin :** It is secreted by the corpus luteum. Inhibin inhibits the FSH and GnRH production.

ii. Testes :

Testes secrete male sex hormones called androgens such as testosterone.

Testosterone : It is secreted from interstitial cells or Leydig cells by the influence of luteinising hormone (LH). Rise in testosterone level in blood above normal inhibits LH secretion.

It is also responsible for appearance of secondary sexual characters such as facial and pubic hair, deepening of voice, broadening of shoulders, male aggressiveness, etc. It also helps in maintenance of testes.

J. Diffuse endocrine glands

Placenta :

It is the intimate connection between foetus and uterine wall of the mother for physiological exchange of the material. Placenta is a temporary endocrine gland.

During pregnancy, placenta secretes hormones such as estrogen, progesterone, hCG (Human Chorionic Gonadotropin) and human placental progesterone. These hormones check the contraction of uterine muscles and also maintain the thickness of uterine endometrium thus they help to maintain pregnancy.

Gastro intestinal tract :

Do you know ?

Presence of HCG in urine sample indicates pregnancy.

In the gastrointestinal mucosa, certain cells are endocrine in function. These cells produce hormones which play vital role in digestive processes and flow of digestive juices.

1. **Gastrin :** It stimulates gastric glands to produce gastric juice.
2. **Secretin :** It is responsible for secretion of pancreatic juice and bile from presence and liver.
3. **Cholecystokinin CCK/ Pancreozymin PZ :** This hormone stimulates the pancreas to

release its enzymes and also stimulates gall bladder to release bile.

4. **Entero-gastrone / Gastric inhibitory peptide (GIP) :** It slows gastric contractions and inhibits the secretion of gastric juice.

Kidney : It produces **renin**, **erythropoietin** and **calcitriol** (calcitriol is the active form of vitamin cholecalciferol (D_3)).

Heart : Atrial natriuretic hormone /ANF. Increases sodium excretion by kidneys and reduces blood pressure.

Hormone therapy/ HT : Hormone therapy is the use of hormones in medical treatment. HT is applied in Pregnancy, Menopause, Osteoprosis, Growth hormone deficiency, Insulin Resistance, Cancer, etc.

Can you tell?

1. Give significance of relaxin and inhibin.
2. Enlist hormones secreted by GI tract and state their role.
3. Mention the role of heart and kidney in hormone secretion.

Do you know ?

Chemicals that operate between members of the same species are social hormones or pheromones. These are commonly also called sex attractants or external hormones.

A pheromone is a volatile substance produced and discharged by an organism, which induces a physiological response in other organism of the same species. Pheromones are produced by many species of insects. Some pheromones enhance the chance of mating between the sexes. These are called signaling pheromones used to induce a behavioral response. Social insects such as ants make use of signaling pheromones to locate food sources and warn of danger.

Worker bees are females maintained in a sterile state by the pheromone called anti– queen factor produced by queen. The factor spreads among the workers preventing maturation of the ovaries of workers as long as the queen is present in the bee hive. Increase in colony size results in dilution of pheromones and second queen may develop.

Activity :

1. **Categorise given activities into appropriate type of reflex action.**

Swimming	
Dancing	
Cycling	
Salivation	
Blinking of eyes	
Sneezing	

2. **Prepare concept map of mechanism of hearing.**

Exercise

Q. 1 Multiple choice questions.

1. The nervous system of mammals uses both electrical and chemical means to send signals via neurons. Which part of the neuron receives impulse?
   a. Axon b. Dendron
   c. Nodes of Ranvier d. Neurilemma

2. ___________ is a neurotransmitter.
   a. ADH b. Acetyl CoA
   c. Acetyl choline d. Inositol

3. The supporting cells that produce myelin sheath in the PNS are _________.
   a. Oligodendrocytes
   b. Satellite cells
   c. Astrocytes
   d. Schwann cells

4. A collection of neuron cell bodies located outside the CNS is called _________.
   a. Tract b. Nucleus
   c. Nerve d. Ganglionl

5. Receptors for protein hormones are located
   a. in cytoplasm b. on cell surface
   c. in nucleus d. on Golgi complex

6. If parathyroid gland of man are removed, the specific result will be
   a. onset of aging
   b. disturbance of Ca^{++}
   c. onset of myxoedema
   d. elevation of blood pressure

7. Hormone thyroxine, adrenaline and non-adrenaline are formed from ----------
   a. Glycine b. Arginine
   c. Ornithine d. Tyrosine

8. Pheromones are chemical messengers produced by animals and released outside the body. The odour of these substance affects
   a. skin colour b. excretion
   c. digestion d. behaviour

9. Which one of the following is a set of discrete endocrine gland
   a. Salivary, thyroid, adrenal, ovary
   b. Adrenal, testis, ovary, liver
   c. Pituitary, thyroid, adrenal, thymus
   d. pituitary, pancreas, adrenal, thymus

10. After ovulation, Graafian follicle changes into
    a. Corpus luteum
    b. Corpus albicans
    c. Corpus spongiosum
    d. Corpus callosum

11. Which one of the following pair correctly matches a hormone with a disease resulting from its deficiency?
    a. Parathyroid hormone - Diabetes insipidus
    b. Leutinising hormone - Diabetes mellitus
    c. Insulin - Hyperglycemia
    d. Thyroxine - Tetany

12. ___________ is in direct contact of brain in human
    a. Cranium b. Duramater
    c. Arachnoid d. Piamater

Q. 2 Very very short answer questions.

1. What is the function of red nucleus?
2. What is the importance of Corpora quadrigemina?
3. What does the cerebellum of brain control?
4. Name the three ossicles of the middle ear.
5. Name the hormone which is anti abortion hormone
6. Name an organ which acts as temporary

endocrine gland.

7. Name the type of hormones binding to DNA and alter gene expression.
8. What is the cause of abnormal elongation of long bones of arms and legs and of lower jaw.
9. Name the hormone secreted by the pineal gland.
10. Which endocrine gland plays important, role in improving immunity?

Q. 3 Match the organism with the type of nervous system found in them.

1. Neurons	a. Earthworm
2. Ladder type	b. Hydra
3. Ganglion	c. Flatworm
4. Nerve net	d. Human

Q. 4 Very short answer questions.

1. Describe the endocrine role of islets of Langerhans.
2. Mention the function of testosterone?
3. Give symptoms of the disease caused by hyposecretion of ADH.

Q. 5 Short answer questions

1. Rakesh got hurt on his head when he fell down from his motorbike. Which inner membranes must have protected his brain? What other roles do they have to play?
2. Give reason - Injury to medulla oblongata may prove fatal.
3. Distinguish between the sympathetic and parasympathetic nervous system on the basis of the effect they have on:
   a. Heart beat b. Urinary Bladder
4. While holding a tea cup Mr. Kothari's hands rattle. Which disorder he may be suffering from and what is the reason for this?
5. List the properties of the nerve fibres.
6. How does tongue detect the sensation of taste?
7. State the site of production and function of Secretin, Gastrin and Cholecystokinin.
8. An adult patient surffers from low heart rate, low metabolic rate and low body temperature. He also lacks alertness, intelligence and initiative. What can be this disease? What can be its cause and care?
9. Where is the pituitary gland located? Enlist the hormones secreted by anterior pituitary.
10. Explain how the adrenal medulla and sympathetic nervous system function as a closely integrated system.
11. Name the secretion of alpha, beta and delta cells of islets of langerhans. Explain their role.
12. Which are the 2 types of goitre? What are their causes?
13. Name the ovarian hormone and give their functions.

Q. 6 Answer the following.

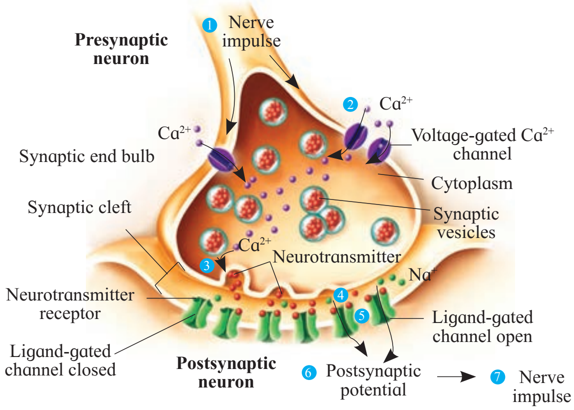
1. Complete the table.

Location	Cell Type	Function
PNS	....	Produce myelin sheath
PNS	Satellite cells	....
....	Oligodendrocytes	Form myelin sheath around central axon
CNS	....	Phagocytose pathogens
CNS	....	Form the epithelial lining of brain cavities and central canal.

Q. 7 Long answer questions.

1. Explain the process of conduction of nerve impulses upto development of action potential
2. Draw the neat labelled diagrams of.
   a. Human ear
   b. Sectional view of human eye
   c. L. S. of human brain
   d. Multipolar Neuron

3. Answer the questions after observing the diagram given below.



   a. What do the synaptic vesicles contain?
   b. What process is used to release the neurotransmitter?
   c. What should be the reason for the next impulse to be conducted?
   d. Will the impulse be carried by post-synaptic membrane carried even if one pre-synaptic neuron is there?
   e. Can you name the channel responsible for their transmission?

4. Explain the Reflex Pathway with the help of a neat labelled diagram.
5. Krishna was going to school and on the way he saw a major bus accident. His heart beat increased and hands and feet become cold. Name the part of the nervous system that had a role to play in this reaction.
6. What will be the effect of thyroid gland atrophy on the human body?
7. Write the names of hormones and the glands secreting them for the regulation of following functions.
   a. Growth of thyroid and secretion of thyroxine.
   b. Helps in relaxing pubic ligaments to facilitate easy birth of young ones.
   c. Stimulate intestinal glands to secrete interstitial juice.
   d. Controls calcium level in the blood
   e. Controls tubular absorption of water in kidneys.
   f. Urinary elimination of water.
   g. Sodium and potassium ion metabolism.
   h. Basal Metabolic rate.
   i. Uterine contraction.
   j. Heart beat and blood pressure.
   k. Secretion of growth hormone.
   l. Maturation of Graafian follicle.
8. Explain the role of hypothalamus and pituitary as a coordinated unit in maintaining homeostasis?
9. What is adenohypophysis? Name the homones secreted by it?
10. Describe in brief, an account of disorders of adrenal gland.
11. Explain action of steroid hormones and proteinous hormones.
12. Describe in brief an account of disorders of the thyroid.

Project : Prepare animated powerpoint presentataion to explain mechanisms of hormonal action.