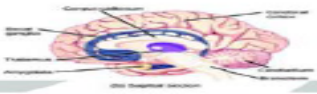


Chapter- 9

Control And Coordination

Unicellular organisms have a simple organisation of their life processes. However, a multicellular organisms body organs and organ systems requires a control over their life processes as well as a co-ordination between the various systems to maintain homeostasis of the organism.

Plants and animals both show a control and coordination mechanism.

In plants, control and co-ordination by sending chemical signals and brining about various types of movements takes place. (e.g. phototropic, chemotactic, thingmotactic (response to stimulus of touch or contact), etc.

In Animals, specially the higher vertebrates show a gradual increase in the complexity of their control and coordination by giving both electrical and chemical signals.

The porifera (sponges) are the most primitive of the animal phyla. Even though there are different types of cells in sponges for carrying out different functions, a proper nervous system is absent.

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.

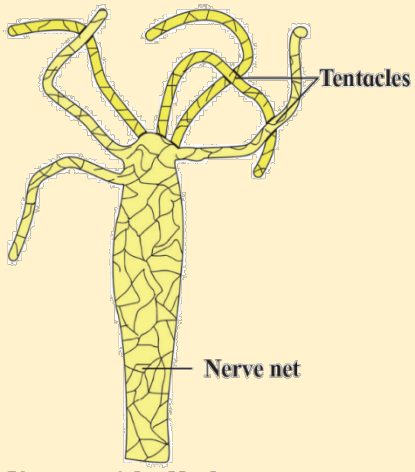
Later in the higher animals, phyla the different cells forms tissues, organs and systems, which must work in coordination with each other for smooth internal functioning of the body. Also, the organism must be able to respond and coordinate with respect to various stimuli or changes in the external environment.

In the lower animals like *Hydra* and *Planaria* the control and co-ordination is carried out by nervous system, while in higher more complex animals, it is done by two coordinating systems - the **nervous (electrical) system** and **endocrine** (**chemical) control system**.

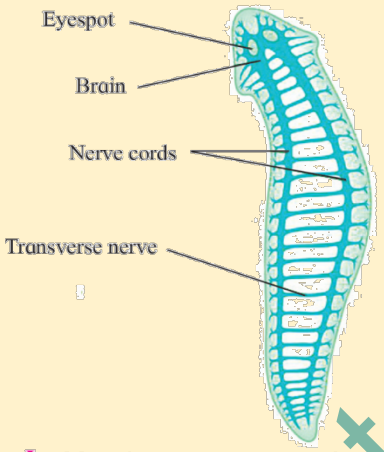
NERVOUS COORDINATION

Nervous System in *Hydra*:

- *Hydra*, a cnidarian shows **primitive nervous system** in the form of diffused nervous system.
- The cnidarians are the first animal group showing **true simple nervous system**.
- It consists of the sensory cells and the nerve cells or neurons along with their fibers.
- The nerve cells are distributed throughout the body and interconnected to each other by synapses between their fibers to form the **nerve net**.
- There are two nerve nets present in the **mesoglea (hydrostatic skeleton)**-
  a.one connected towards the **epidermis**
  b. second towards the **gastro-dermis**.
- There are sensory cells scattered in the body wall and tentacles, but sense organs are absent.
- Neurons have fibers but there are no sensory and motor nerves.
- The nerve impulse shows **no polarity or direction**.
- In *Hydra,* **activation of sensory cells produced at any point**, and from this point impulse can be carried throughout the body **in any direction**, thus bringing movements of the body or tentacles e.g. catching of prey during feeding.
- The diffused type of nervous system is the first important landmark in the nervous system.
- It is seen in the phylum Ctenophora as well as in the enteric system or gut wall of higher animals including man.



Nerve net in Hydra



Ladder type nervous system in Flatworms e.g. Planaria

Nervous System in *Planaria* (flatworm):

1. *Planaria* is a flatworm belonging to the phylum **Platyhelminthes**.
2. It is the most **primitive animal with a central nervous system** (CNS) located on the **ventral side of body.**
3. It consists of a mass of **cerebral** or **cephalic ganglion** appearing like an inverted U-shaped brain.
4. These lie in the anterior or head region and from **each ganglion arise nine branches** towards the outer side.
5. Ventrally from cerebral ganglia arise a **pair of Ventral Nerve Cords** (VNC) which runs posteriorly, are inter connected to each other by **transvers nerve or commissure** in a ladder like manner.
6. From the ventral nerve cord arises **peripheral nerve plexus**.
7. The **PNS include sensory cells** arranged in lateral cords in the body.
8. A pair of **photo sensory** structure, the **eyes** are located on dorsal side of the brain and single sensory cells scattered in the body.

There is a high level of specialization in the formation of neurons as electrically signaling 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.

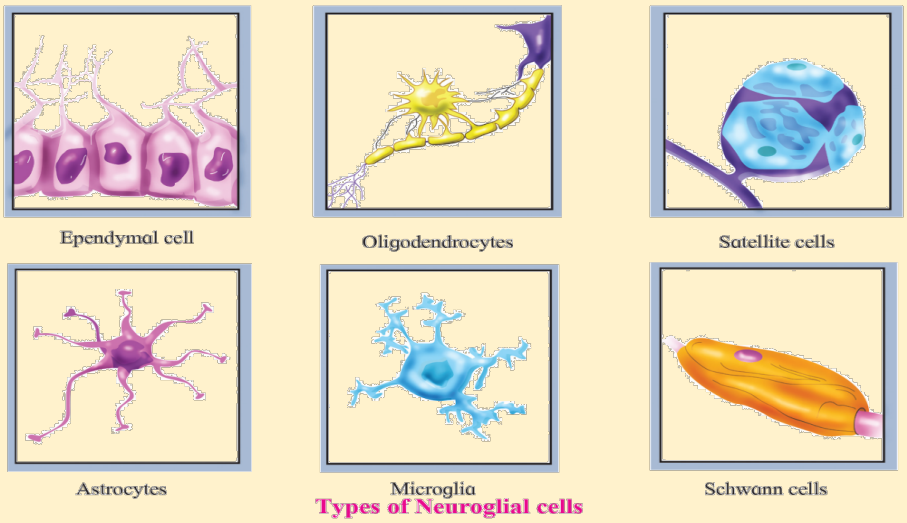
This has led to centralization of various sense organs assisting in coordinating the internal environment with that of the external environment. There evolution of a complex networking system which efficiently transmits signals between one part or organ of the body and another.

Neural tissue

The neural tissue consists primarily of two types of cells –

a) neurons
b) neuroglia or glial cells.

c) Nerve is a **bundle of axons**.
d) The bundle of axons outside the CNS is called as **'nerve'** is while inside the CNS called **tract**.
e) The nerves may be **sensory or motor or mix type.**
f) mixed nerve having both the types - **sensory and motor fibers.**
g) All these along with nervous organs make up the nervous system of the higher animal and bring about co-ordination and control of various activities of the body.
h) This is done by the receptors which bring in sensory inputs towards the central nervous system.
i) Processing is carried out in the CNS and then by the motor commands, the response is sent to effector organ.
j) The nerves arising from the cytons of the CNS, travel throughout the body transmitting the nerves impulses to or from the CNS.



Types of Neuroglial cells

Neurons/Nerve cells:

1. These are the **structural and functional units** of the nervous system.
2. Each multipolar neuron has three parts –
   a. cyton or cell body
   b. dendron
   c. axon.

a) cyton-

1. The **cyton** has a distinct central nucleus with a nucleolus and Neuroplasm.
2. A clear film of cytoplasm surrounds the nucleus around which there are neurofibrils, Nissl's granules and other cell organelles.
3. **Nissl's granules** are riboprotein components. They play an important role in the **synthesis of the enzyme required for formation of the neurotransmitter.**
4. **Neurofibrils** play an important role in **transmission of nerve impulse**.

b)Dendrons–

1. These are many small **conical processes arising from the cyton**.
2. These are highly branched into **fine dendrites**.
3. **Nissl's granules and neurofibrils** both can be seen at the base of the dendrons, **which transmit message towards the cyton.**

c)Axon:

1. It consists of a bundle of neurofibrils.
2. Nissl's granules are absent.
3. Terminally, the axon gives out branches called telodendrons.
4. The axons carry the messages away from the cytons.
5. The axons may give out lateral branches called collaterals.
6. The terminal branches attach to a muscle, gland, skin or telodendrites of another neuron.
7. The interconnection between two neurons or neuron with motor organ is called **synapse**. It is usually axo-dendronic or may be axo-axonic, axo-somatic or dendro-dendronic.
8. The cytons are generally found inside the brain, spinal cord (CNS) and in the ganglia.
9. Small groups of cell bodies inside the white matter of brain are called **basalnuclei**.
10. 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.
11. Conduction of impulse by the medullated nerves is 50 times faster than in the non-medullated nerves.
12. The connective tissue covering around the nerve fascicule is called **endoneurium**.
13. 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**.
14. Blood is supplied to all the nerves to provide oxygen and nutrients.
15. Itis a single long, usually unbranched process arising from the cyton at the axon hillock.

Neuroglial cells:

1. The neuroglial cells are **more in number than the neurons**.
2. Most of the supporting cells of the nervous system are derived from the **embryonic tissue layer(ectoderm)** that produces neurons.
3. The term neuroglia is the **supporting cells of the Central Nervous System (CNS) and Peripheral Nervous System (PNS).**

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.

Synapse:

a) It is a **junction between two nerve cells**.
b) In between two nerves a minute gap **-synaptic cleft** is present which **allows transmission of impulse by a neurotransmitter bridge.**

1. Properties of nerve fibers:

a. Excitability/Irritability -
nerve fibers are highly excitable tissue respond to various stimuli and Capable of generating electrical impulse.

b. Conductivity–
action potential is generated in the nerve fiber, which is propagated along its entire length to the axon terminal.

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.

Threshold stimuli –
the stimuli by which the axons with low threshold fibers are stimulated and a small potential change recorded.

Subliminal (weak) stimulus-
will have no effect

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 continuous manner, 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.

f. Refractory period–

It is the duration after an effective stimulus, when a second stimulus is applied, there will be no response for the second stimulus.

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.

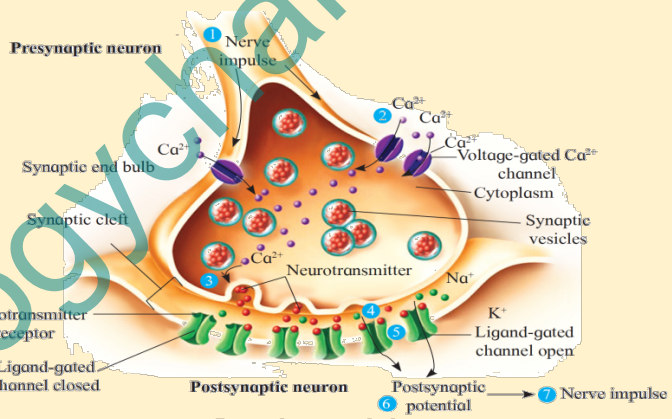
i. Velocity -

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 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.



Synaptic transmission

2. Types of synapses

1. Electrical synapse:

1. The synapse gap between the neighboring neurons is very narrow.
2. The synapse between such closed neurons is mechanical.
3. The electrical conductive link is formed between the pre and post synaptic neurons.
4. At the gap junction, the two cells are within almost 3.8 nm distance of each other.
5. Transmission across the gap is faster but depends on the connection located at the gap junctions between the two neurons.
6. 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.

2. Chemical synapse:

1. 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.
2. Synaptic gap is larger than that in electrical synapse and it is 20-40 nm.
3. A chemical synapse between a motor neuron and a muscle cell is called a neuromuscular junction.
4. 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)
   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.

Transmission of nerve impulse:

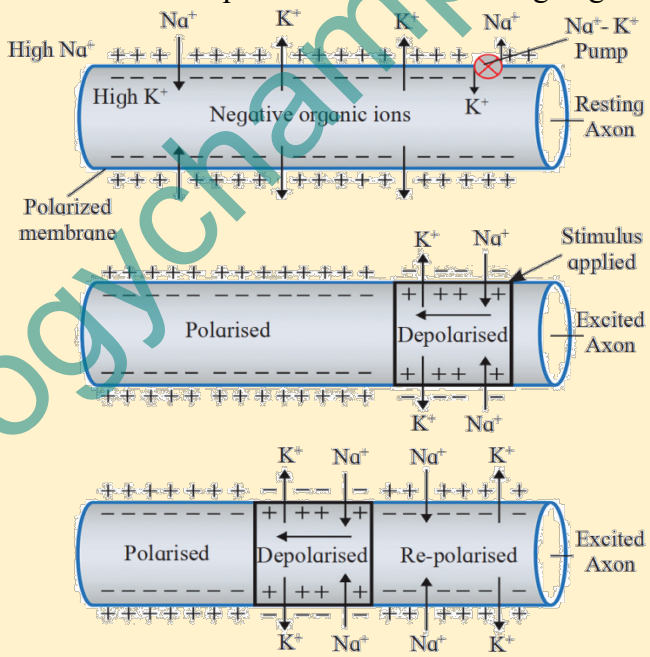
1. The neurons are cells with some specials features.
2. The cells can be excited.
3. The nerve impulse is a wave of bioelectrical or electrochemical disturbances passing along a neuron.
4. The transmission of the nerve impulse along the long nerve fiber/axon tube is a result of electrical charges across the neuronal membrane during conduction of an excitation.
5. Each neuron has a charged cellular membrane with a voltage which is different on the outer and inner side of the membrane.
6. The plasma membrane separates the outer and inner solutions of different chemical compounds but having approximately the same total number of ions.
7. The external tissue fluid has both Na^+ and K^+ but there is predominance of Na^+ and Cl^-, while K^+ is predominant within the fiber or in the intracellular fluid.
8. This condition of a resting nerve is also called a polarised state and it is established by maintaining an excess of Na^+ on the outside.
9. On the inside there is an excess of K^+ along with large negatively charged protein molecules and nucleic acid.
10. 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.
11. Against the concentration and electrochemical gradient, Na^+ is being forced out and K^+ is being forced inside the membrane.
12. This process is called **sodium pump** or **Na-K exchange pump**.
13. This active process requires ATP energy. The difference in distribution of Na_+ and K_+ on the two sides of the membrane produces a potential difference of -50 to -100 millivolts (average is -70 millivolts).
14. 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^+.
15. This results in slightly more K^+ diffusing out than Na^+ moving inside and causing slight difference in polarity.
16. 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.

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

Generation of nerve impulse:

1. Depolarization:

i) The origin and maintenance of resting potential depends on the original perfect state.
ii) Any change or disturbance to the membrane will cause Na^+ to enter into the membrane and lower the potential difference (lesser than -70 millivolts).
iii) This makes the membrane more permeable to Na^+,so there will be rapid influx of Na^+.
iv) This property is peculiar to a nerve membrane.
v) The voltage gated Na^+/K^+ channels are special in 2 ways:
   a) They can change the potential difference of the membrane as per the stimulus received
   b) The gates operate separately and are self-closing.
vi) During resting potential, both gates are closed and resting potential is maintained.
vii) However during depolarization the Na^+ gates open but not the K^+ gates.
viii) This causes Na_+ to rush into the axon and bring about a depolarization (opposite of polarity).
ix) Extra cellular fluid (ECF) becomes electronegative with respect to the inner membrane which becomes electropositive.
x) The value of action potential is +30 millivolts to +60 millivolts.
xi) This triggers depolarization in the next part while it itself starts going to repolarization.



Polarisation and Depolarisation along a nerve

2. Re-polarization:

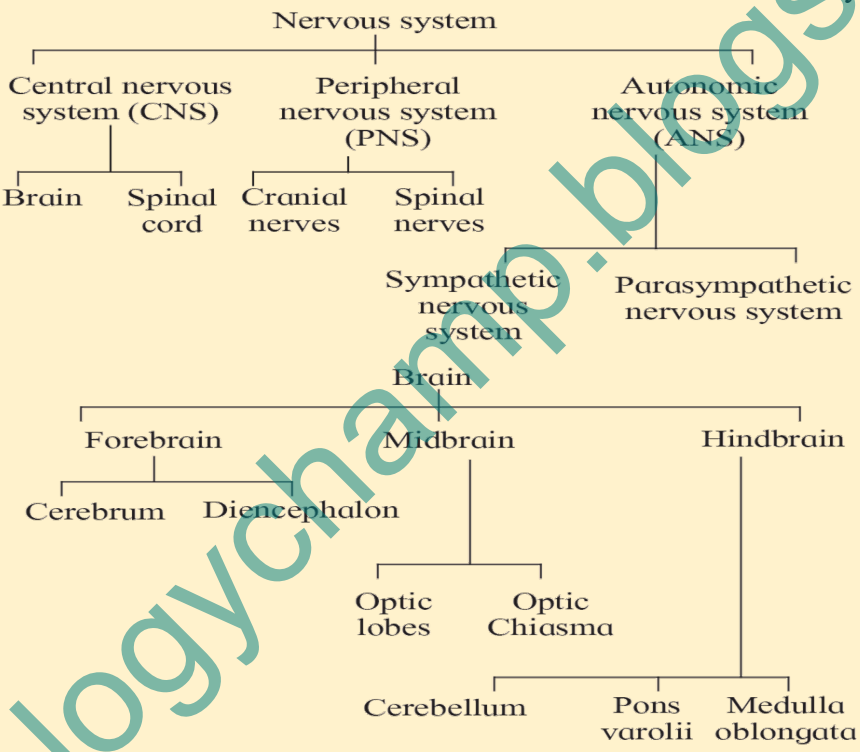
i) Change in the polarity from depolarized, back to the original state is done by the process of repolarization.
ii) It occurs after a short interval called **refractory period**.
iii) The large number of Na^+ on the inside causes a drop in the permeability of membrane to Na^+ and at the same time making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

v) In this period, Na^+ gates are closed, K^+ gates are open and Na^+ - K^+ pumps becomes operational.
vi) This process of producing a wave of stimulation ⟶ causing depolarization ⟶ repolarization is repeated continuously up to the end of axon terminal.
vii) It is a self-propagating process.
viii) In medullated nerves, the insulating fatty myelin sheath prevents flow of ions between the axoplasm and ECF.
ix) The transport pump and gated channels can operate only in the region of nodes of Ranvier, where myelin sheath is absent.
x) The action potential cannot travel as a wave of membrane depolarization it has to jump from node to node.
xi) This process called **saltatory conduction** is at the rate of 120 m/second.
xii) It is faster than the continuous conduction in non-medulated fiber.

Human Nervous System:

Nervous system in humans is well developed and complex. It is broadly classified into three parts. –

1. Central Nervous system (CNS)
2. Peripheral Nervous system- (PNS)
3. Autonomous Nervous system (ANS)



1. Central nervous system (CNS):

i)central nervous system mainly consists of **brain and spinal cord** which are present along the mid dorsal axis.
ii) Brain is enclosed within the **brain box/cranium** of the skull, whereas the spinal cord runs through the canal of the **vertebral column**.
iii) brain and spinal cord are covered by three protective membranes called **meninges** which protectthe brain and spinal cord.
iv) These meninges are-

a) Dura mater: It is the **outermost tough, non-vascular, thick and fibrous** layer and is present near 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 **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):

1. 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.
2. 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.
3. The three openings in the roof of medulla oblongata help in draining out the CSF from brain to the outside.
4. CSF is slightly **alkaline** fluid with a specific gravity of **1.005**.
5. A total of **100 -120 cc** of CSF is present in and around the CNS.

Functions of cerebrospinal fluid-

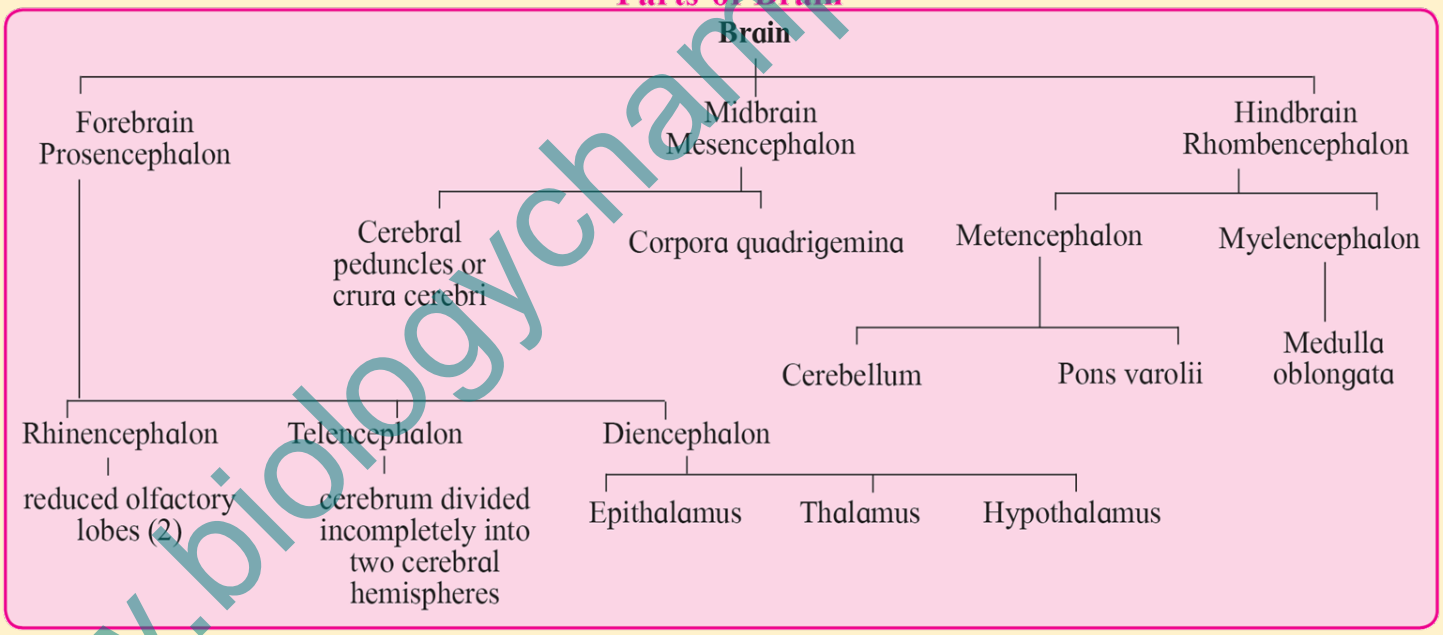
a. The meninges and CSF act as a **shock absorber and protect the brain and spinal cord from mechanical injuries**.
b. It also **maintains constant pressure** inside cranium.
c. It helps in **exchange of nutrients and wastes** between blood and brain tissue.
d. It helps in the **supply of oxygen** to the brain.
e. It **protects the brain from desiccation**.

A. Human brain:

The study of the brain is called **encephalology**. The brain can be divided into three main parts -

1. Forebrain / Prosencephalon
2. Midbrain / Mesencephalon
3. hindbrain. / Rhombencephalon

Parts of Brain



a. Forebrain: Forebrain consists of –

1. olfactory lobes
2. cerebrum
3. diencephalon.

1. **Olfactory lobes:**
   a) These are **highly reduced** in human brain and **hidden under cerebrum** except ventral side.
   b) Each lobe consists of an **olfactory peduncle** and **olfactory bulb**.
2. **Cerebrum:**
   a) It is a largest part of the brain, making up about **85 % of total brain**.
   b) It is **divided into right and left cerebral hemisphere** by means of a deep median fissure.

c) The two hemispheres internally connected to each other by a **thick band of nerve fibres** called **corpus callosum**.
d) The outer surface of cerebrum is called **cerebral cortex** while the deep inner part is **cerebral medulla**.
e) The cerebral cortex has outer **grey matter** and inner medulla composed of **white matter**.
f) The surface of each cerebral hemisphere is greatly folded by many convolutions or **gyri** and grooves called **sulci**.
g) These greatly **increases surface area** for accommodation of the large number of nerve cells.
h) Each cerebral hemisphere is further divided into **four main lobes by three deep sulci**. These are -
    1) **Centre sulcus** which separates frontal lobe from the parietal lobe.
    2) **Parieto-occipital sulcus** separates the parietal from occipital lobe.
    3) **The lateral** or **sylvian sulcus** separates 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.

    4) A fifth median lobe called **insula** or **insular cortex** is folded deep within the lateral sulcus.

i) The grey matter of cerebral cortex mainly consists of **cell bodies of billions of neurons along with non- medullated fibers and Dendron.**
j) The white matter mainly has **axons of myelinated nerves**.

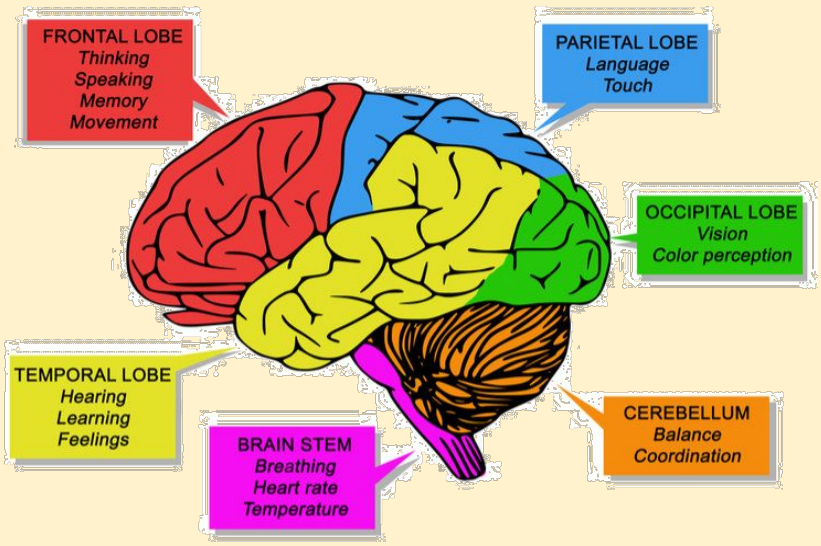
Functional areas of cerebrum:

1. Frontal lobes:
a) They have motor area which controls **voluntary motor activities or movements of muscles**.
b) The **premotor area is higher centre for involuntary movements and autonomous nervous system**.
c) **Association area** is for coordination between **sensation and movements**.
d) **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 somesthetic sensation of **pain, pressure, temperature, taste (gustatoreceptor).**

3. Temporal lobes: It contains centers 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 center for **Wernicke's area or intelligence center**.

It helps in the understanding of spoken and written words.

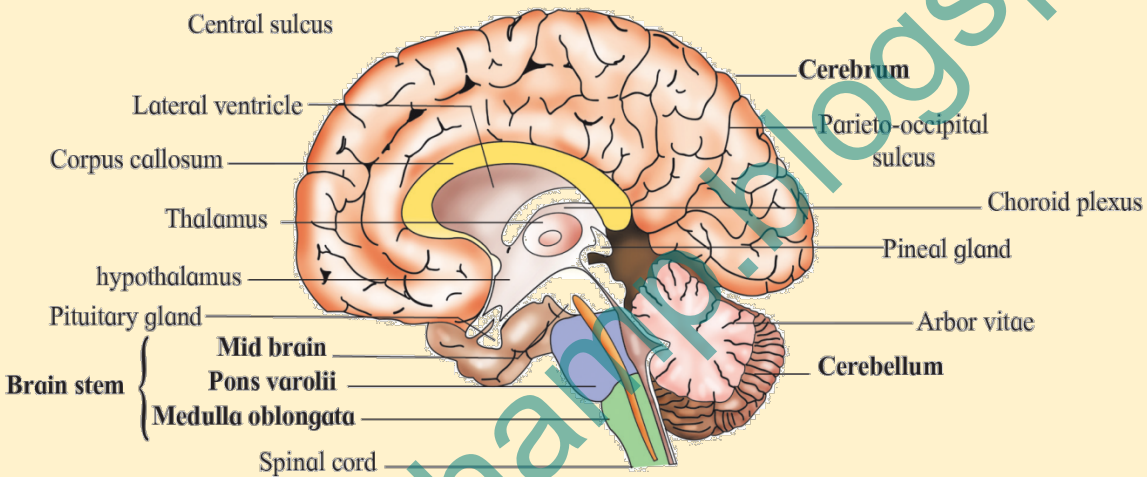
The cerebrum, thus shows all three types of areas sensory, motor and association area.

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.

3.**Diencephalon:**

a) Diencephalon mainly contains the **epithalamus, thalamus and hypothalamus**.
b) It lies **below the corpus callosum and above the midbrain**.
c) It encloses a single cavity termed **third ventricle/Diocoel** which **communicates with the two lateral ventricles or paracoel** of cerebrum through a narrow opening called **foramen of Monro**. While posteriorly to the **IVth ventricle or metacoel** through a narrow **duct of Sylvius or iter.**



Sagital section of brain

- **Epithalamus**is the anterior **thin non nervous roof of the diencephalon**.
  a) Epithalamus is fused with the piamater to form the **anterior choroid plexus** and it is connected to **pineal gland through a pineal stalk**.
  b) Earlier **pineal gland was thought to be vestigial, but** later it has been found to produce to hormone **melatonin** (sleep inducing hormone; also related to reproductive behavior).
- **Thalamus** is the lateral thick walls of diencephalon.
  a) They mainly contain **grey matter**.
  b) The **habenculor commissure** connects two thalami.
  c) Different parts of the brain are interconnected by the **RAS (Reticular Activating System)** through the thalamus, called **relay center** as it transmits all **sensory impulses except those of olfactory (smell) to the cerebrum**
- **Hypothalamus:**It forms a floor of the **diencephalon**.
  a) It is **richly supplied with blood vessels** (Hypothalamo-hypophyseal portal vein) helps in **feedback mechanism for hormonal control**.
  b) It maintains **homeostasis, internal equilibrium of the body and involuntary behavior control**.
  c) Like in the cerebrum, the hypothalamus also contains **hypothalamic nuclei in its white matter with neuro-secretory cells** involved in the **production of hormones oxytocin and vasopressin**.
  d) The hypothalamus is a **link between the nervous and the endocrine system**.
  e) It has higher **centers for endocrine system**.

f) It regulates **heart rate, respiration, blood pressure (B.P.), body temperature, water and electrolyte balance.**

g) It has centers for **hunger, thirst, sleep, fatigue, satiety centre, secretion of glands of stomach and intestine.**

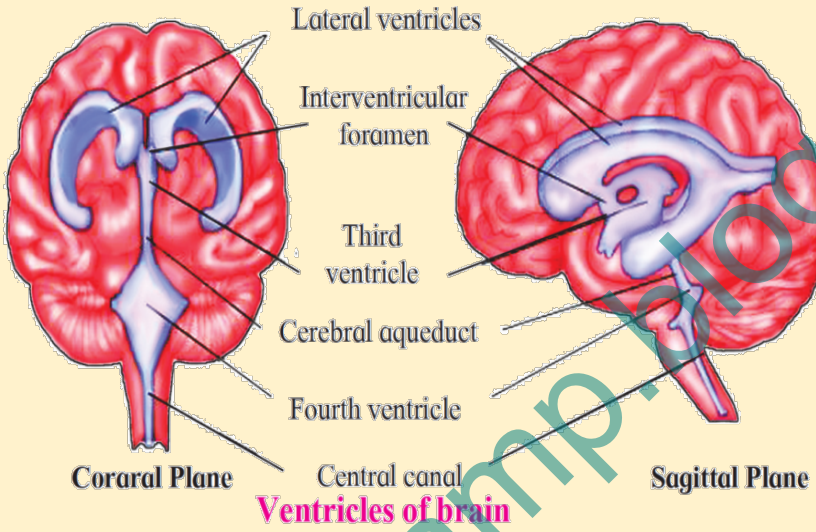
h) It also produces neurohormones that stimulate the pituitary gland.

i) A complex neuronal circuit called the **limbic system** is formed by the hypothalamus amygdala, parts of epithalamus and thalamus, hippocampus and other areas.

j) It appears to be responsible for **emotional reactions, motivational drives and memory**.

k) 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**.

l) The inferior surface of hypothalamus also bears the **optic chiasma** (crossing of the two optic nerves) and a **pair of mammillary bodies** important for memory



Ventricles of brain

b) Mid brain:

a) It is located **between diencephalon and the pons varolli**.

b) It contains the **cerebral aqueduct or iter** that connects the third and fourth ventricles.

c) The **corpora quadrigemina** are four rounded elevations on the dorsal surface of the mid brain formed by **two superior colliculi and two inferior colliculi**.

d) The **two superior colliculi** are involved in **visual reflexes** and the two **inferior colliculi** are relay centers for **auditory reflexes** that operate when it is necessary to move the head to hear sounds more distinctly.

e) The mid brain on its inferior surface two thick fibrous ascending and descending nerve fibres are present called as **cerebral peduncles or crura cerebri.**

f) These tracts of ascending and descending nerve fibres from **Reticular Activating System** (RAS) and connect the cerebrum with mid brain.

g) Near the centre of the mid brain is a **mass of grey matter scattered within the white matter**. It is called the **red nucleus**.

h) It plays an important role in controlling **posture and muscle tone**, modifying **some motor activities and motor co-ordination.**

c) Hind brain:

a) The posterior region of the brain is called **hind brain**.

b) It consists of **pons varolli, cerebellum and medulla oblongata**.

1.Pons varolli–

a) is a rounded bulge on the underside of the brain stem **(brain stem consists of mid brain, pons and medulla and continues up to spinal cord)**.

b) **pons varolli** contains a cross band of nerve fibres connecting **cerebrum, cerebellar lobes, medulla oblongata and spinal cord.**
c) It also contains **several nuclei**.

2. <u>cerebellum</u>–

a) Cerebellum is the second largest part of the brain and consists of two **lateral hemispheres and a central vermis.**
b) Outer part of cerebellum is made up of gray matter while inner part is white matter.
c) White matter projects outside & forms a branched tree like structure known as **Arbor Vitae**.
1. The surface of cerebellum shows convolutions **(gyri and sulci)** a number of nuclei lie deep within each lateral or cerebellar hemisphere.
2. Over 30 million neurons lie in the cortex.
3. Three pairs of <u>myelinated nerve bundles</u> called **cerebullar penduncles** connect cerebellum to the other parts of CNS.

<u>Function</u>-

1. It is an important center which maintains **equilibrium of body, posture, balancing orientation, moderation of voluntary movements, and maintenance of muscle tone.**
2. It is a regulatory center for **neuromuscular** activities and controls the rapid activities like **walking, running, speaking** etc.
3. All activities of cerebellum are involuntary

3. <u>medulla oblongata</u>–

1. Medulla oblongata is the posterior conical part of the brain and continues as the spinal cord.
2. It has inner grey matter and outer white matter.
3. It controls involuntary vital functions like **heartbeat, respiration, vasomotor activities and peristalsis**.
4. It also controls **non-vital reflex activities** like **coughing, sneezing, swallowing, vomiting, yawning etc**.
5. The cavity of medulla is called **IVth ventricle or metacoel**.
6. Its roof of medulla oblongata forms posterior **choroid plexus** which secretion of **CSF**.
7. The posterior choroid plexus also shows 3 openings –
   a pair of lateral **foramen of Luschka**
   a median **foramen of Magendie**.

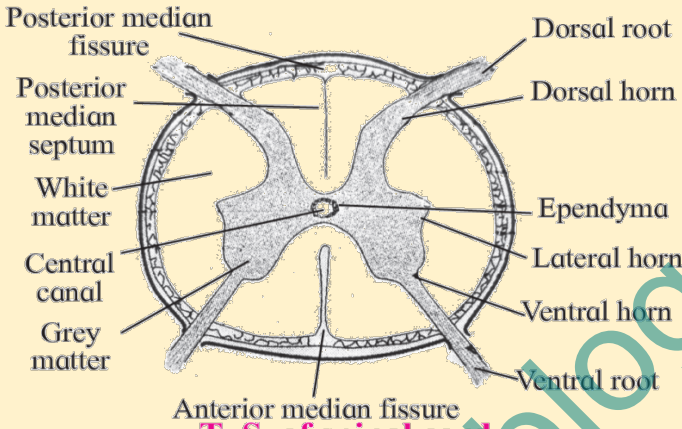
B. Spinal Cord:

1. Medulla oblongata posteriorly continues as spinal cord..
2. It lies within the neural canal of the vertebral column and is surrounded by three meninges - dura mater, arachnoid mater and pia mater.
3. The **Cerebro Spinal Fluid (CSF)** secreted by pia mater, forms a fluid cushion <u>around the spinal cord and within it inside the central canal.</u>
4. Externally, the spinal cord appears as long cylindrical rod, 42 to 45 cm long and 2.0 to 2.5 cm broad.
5. The spinal cord is broadest at its anterior end gradually tapers as **conus medullaris** (at L1 to L2) and continues as a thread like **filum terminale** end posteriorly.
6. The bunch of nerves in the hind part of the spinal cord along with the filum terminale appears like a horse's tail, so called **cauda equina**
7. From the spinal cord arises**31 pairs** of spinal nerves.
8. These nerves are concentrated in the cervical and lumbar regioncalled **cervical and lumbar swelling** and also concentrated around the **conus medullaris**.

T. S. of spinal cord:

- The spinal cord is **dorso-ventrally flattened** due to the presence of deep, **narrow posterior median fissure and shallow, broad anterior median fissure.**
- At the centre **central canal** is present.

- 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.
- The dorsal root is connected to the dorsal root ganglion.
- It has an aggregation/collection of unipolar sensory neurons.



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 fiber 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:

1. The spinal cord is the main centre for the most reflex actions.
2. 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):

1. The peripheral nervous system connects the central nervous system to the different parts of the body having receptors and effectors.
2. Depending on the connection to the CNS, the peripheral nerves are classified into two main types -

Cranial nerves –nerves arising from the brain.
Spinal nerves – nerves arising from the spinal cord.

Cranial Nerves:

1. These nerves arise from the brain.
2. In all amniotes (**reptiles, birds and mammals**). There are **12 pairs of cranial nerves** which are denoted by Roman numbering I to XII.
3. According to their function, these are classified as –
   a) **sensory** (I, II, VIII)
   b) **motor** (III, IV, VI, XI, XII)
   c) **mixed** (V, VII, IX, X

	Name	Nature	Function	Distribution
1)	Olfactory	Sensory	Smell	From nose
2)	Optic	Sensory	Vision	From eye
3)	Oculomotor	Motor	Eye movement	To muscles of eye ball
4)	Trochlear	Motor	Eye movement	To muscles of eye ball
5)	Trigeminal	Mixed	Sensitive and jaw movement	From and to face, teeth, lips, tongue, jaws
6)	Abducens	Motor	Eye movement	To muscles of eye ball
7)	Facial	Mixed	Taste sensation, jaw movement	From taste buds, to salivary glands and face
8)	Auditory	Sensory	Hearing and balance	From ear
9)	Glossopharyngeal	Mixed	Muscle movement and sensations	From and to pharynx, from taste buds' Salivary glands
10	Vagus	Mixed	Sensory to chest and abdomen	From and to visceral organs
11	Spinal	Motor	Movement of shoulder muscles	To shoulder muscles
12	Hypoglossal	Motor	Movement of tongue	To tongue

On Occasion Of Party Ten Attractive Faces Are Girl Visitors Sang Happily
Some Says Money Matters But My Brother Says Big Brain Makes Matter

Spinal Nerves:

a) These nerves arise from spinal cord
b) There are 31 pairs of spinal nerves originate from the spinal cord.
c) 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.

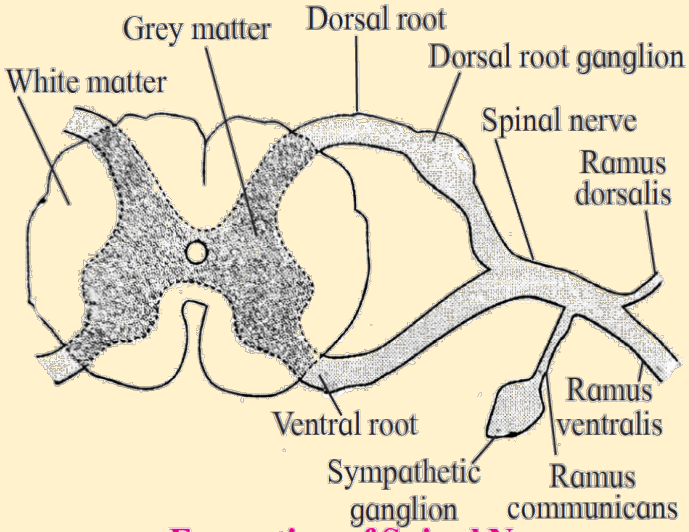
Group	No. of pairs	Region of origin from vertebral column
Cervical	8 (C1-C8)	Neck
Thoracis	12 (T1-T12)	Thorax
Lumbar	5 (L1-L5)	Abdomen
Sacral	5 (S1-S5)	Pelvis
Coccygeal	1 (Co1)	Coccyx

Number and types of spinal Nerves

Formation of a typical spinal nerve:

i. All spinal nerves are of the **mixed type** i.e. they have some nerve fibre as sensory and some motor
ii. Each spinal nerve is formed **inside the neural canal of vertebral column**
iii. From the **dorsal side of spinal cord** arises the dorsal root which is **sensory** in nature.
iv. From the **ventral side of spinal cord** arises ventral root which is **motor** in nature.
v. The **dorsal sensory root and ventral motor root units with each other** to form the spinal nerve which is mixed type.
vi. From the spinal nerve arises 3 branches. they are as follows
vii. Ramus dorsalis
viii. Ramus ventralis
ix. Ramus communicance

1)**Ramus dorsalis: -** It is supplied to skin and muscles of the back.
2)**Ramus ventralis: -** It is supplied to skin and muscles of lateral and ventral side of body wall
3)Ramus communicance: -It is connected with the sympathetic ganglia of the autonomous nervous system



Formation of Spinal Nerve

Reflex Action: It is the quick, automatic, involuntary response to the stimulus is called as reflex action.

Reflex arch

The path followed by the reflex action is known as **reflex arch**.
The reflex action is carried inside the spinal cord.
The reflex arc having following components ------

i) Sensory organ or Receptor
ii) Sensory or Afferent neuron
iii) Adjustor neuron
iv) Motor or Efferent neuron
v) Effector organ

i) Sensory organ or Receptor: -
It is the organ which receives the stimulus. these are the organs like eyes, skin, nose and tongue.
ii) Sensory or Afferent neuron: -
It is the neuron which carry the impulse from the sensory organ to the central nervous system.
iii) Adjustor neuron: -
It is the neuron which connects the sensory neuron to the motor neuron and present inside the grey matter.
Use- for analysis and interpretation.
iv) Motor or Efferent neuron: -
it is the neuron which carry impulses from central nervous system to effector organ.
v) Effector organ: -
it is the organ which receives impulse from motor neuron and gets excite to give response to the stimulus.
e.g. muscle and glands.

Importance: -

i) it gives quick response to the stimulus by which the organism adjust itself with the surrounding environment.
ii) It gives relive to the brain because most of reflex action are carried inside the spinal cord.
iii) Reflex action gives quick response to the harmful stimuli which protects the body from the danger.

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)

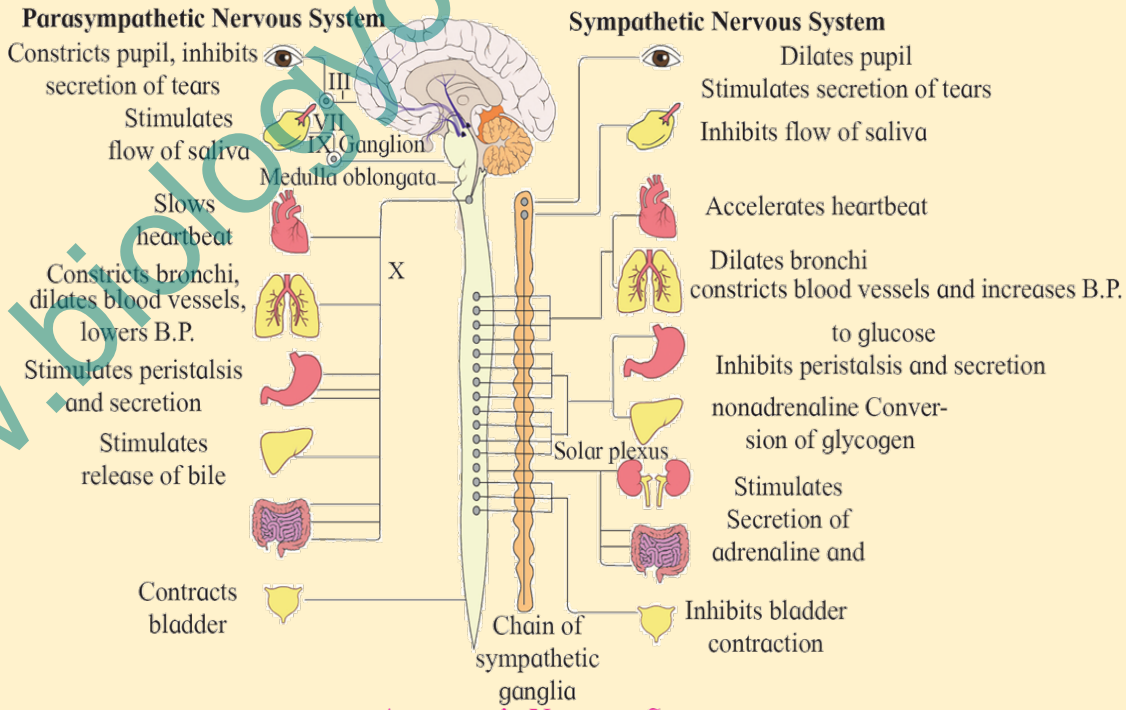
3. According to number of synapses involved

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.

3. Autonomic Nervous System (ANS):



Autonomic Nervous System

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

2) ANS consists of a special set **of peripheral nerves that regulate the activities of involuntary organs like cardiac muscles, smooth muscles, glands etc**.

3) It is generally formed by two types of neuron - 1. Preganglionic neuron
2. Postganglionic neuron

4) In this, impulses are conducted from the Central Nervous system by an axon that **synapses with an autonomous ganglion.** It is known as **preganglionic neuron**.

5) 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.**

6) Autonomic nervous system consists of **sympathetic and parasympathetic nervous system**.

a) **Sympathetic Nervous System (SNS):**

i. It is also called thoraco-lumbar outflow.

ii. 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.

iii. The **pre-ganglionic nerve fibers 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 **Adrenergicfibres**.

Function:

a) Sympathetic nervous system controls body activities during emergencies (**fight or flight response**).

b) It has **excitatory and stimulating** effect on most organs of the body except in the digestive and the excretory organ.

b) Parasympathetic Nervous System:

i. It is also called **cranio-sacral outflow**.

ii. It consists of the branches arising from **the cranial (III, VII, IX, X) nerves, sacral (II, III) and spinal (IV) nerves.**

iii. It consists of **ganglia which are very close or within the wall of the effector organs**.

iv. From these ganglia arises two types of nerves-

A. The **pre-ganglionic nervesare long**

B. **post-ganglionic nervesare short**.

v. **Acetyl-choline** is produced at the terminal end of post-ganglionic nerve at the effector organ, hence these are also called **cholinergic fibres**.

Function:

a) 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**.

b) **It has an inhibitory effect on most organs**.

c) The activities like those associated with **digestion, peristalsis and micturition**, **which are inhibited by sympathetic systems are thus accelerated by the parasympathetic system.**

Autonomous nervous system is useful for homeostasis of body.

i) the autonomous nervous system contains sympathetic and parasympathetic nervous systems.

ii) The sympathetic nervous system is preparing the body for fight and flight by increasing the rate or heartbeat, breathing, flow of blood to skin.

iii) The parasympathetic nervous systems on another side decreases the rate of heart beat, breathing, flow of blood to skin and muscles of the body.

These shows that contains sympathetic and parasympathetic nervous systems through dual control mechanism maintains the homeostasis.

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

Sensory Receptors:

1. Sensory Receptors are some specialised structures in the body to receive the various stimuli from the external or internal environment.
2. The nature of the receptor is defined by a type of stimuli.
3. Sensory receptors producestimulus.
4. 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.
5. These impulses are conducted to the different functional areas of the brain for processing and interpretation.

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.

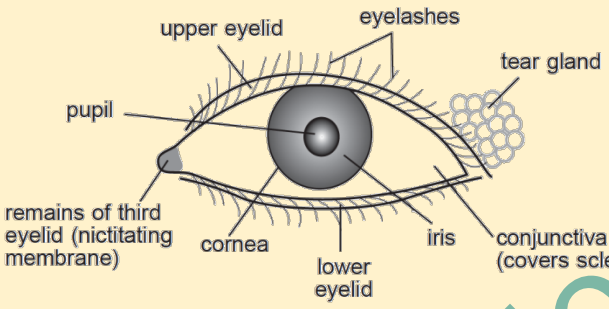
Types of receptors

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

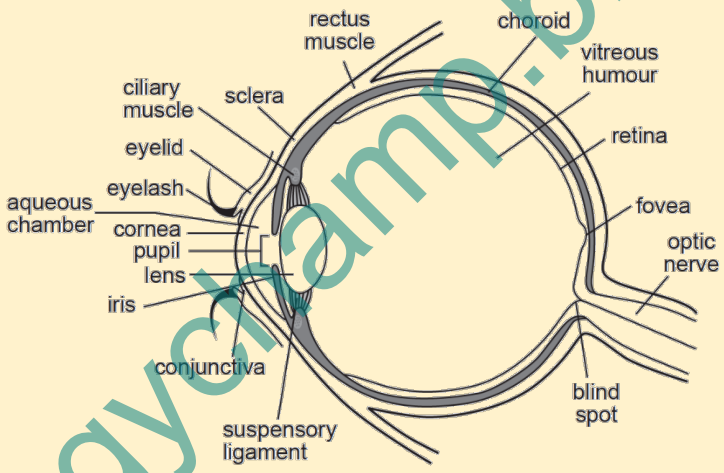
Eye:

1. The eyes are a pair of sensory organs of vision.
2. These are located in the orbit of skull with a cushion of fat around them.
3. Each eye is spherical/rounded and called eyeball.
4. The eyes are protected bones, eyebrows, upper and lower eyelids with eyelashes and the lacrimal/ tear glands.
5. **Movement of the eyeball within the orbit is controlled by 6 sets of muscles.**
6. Wall of the eyeball is made up of 3 layers -

(1) sclera,
(2) choroid
(3) retina



Structures at the front part of the eye



Vertical section of the eye

1. Sclera/scelrotic:

a) It is the outermost layer made of **dense fibroelastic connective tissue with collagen fibers**.
b) It provides **attachment to the eyeball muscles**.
c) The anterior thick, transparent part of sclera is **cornea**.
d) It is slightly bulged out for **focusing light on the retina**.
e) The sclera is **provided with blood vessels but absent in the cornea**.
f) Cornea is nourished by **aqueous humour and also by lacrimal secretion**.
g) The exposed part of sclera and the entire Cornea are covered by a transparent membranous covering called **conjuctiva**,which provides**protection and lubrication to the cornea**.

2. Choroid /Uvea:

i. 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:

i. It lines the **sclera**.

ii. It shows **pigmented nature by which it prevents internal reflection**.
iii. The blood vessels of choroid provide **nutrition and oxygen to the retina**.

b. Ciliary body:

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

c. Iris:

i. 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.**
ii. It is perforated in the middle by an aperture called **pupil.**
iii. Smooth muscles of the iris help in regulating the size of pupil depending on the intensity of light entering the eyeball.
iv. The **pigment in the iris determines the colour of the eye**.

3. Lens:

i. It is a transparent, elastic, **biconvex structure**.
ii. It is suspended in the eyeball by the **suspensory ligaments**.
iii. 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.**
iv. **It maintains shape of the eyeball and maintains pressure for keeping the lens in position**.

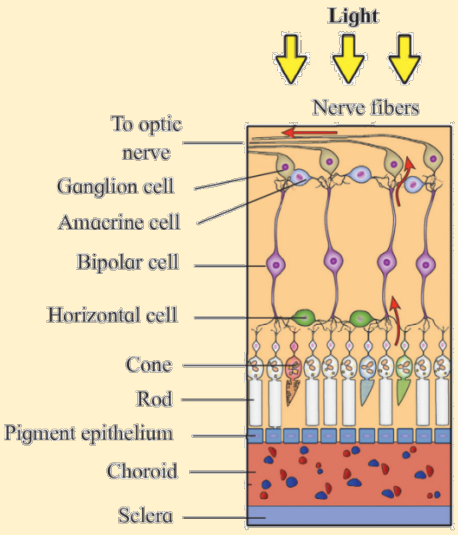
4. Retina:

i. It is the innermost, delicate, non-vascular light sensitive layer.
ii. It has 2 regions- (a) outer layer of pigmented non sensory part lining the iris and ciliary body (b) inner sensory part lining the choroid.
iii. 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**.
iv. The nerve fibers from the basal end of the ganglion cells collectively form the **optic nerve**.
v. **Blind spot** is the area of retina from where the optic nerve and blood vessels leave the eyeball, where **rod and cone cells are absent**.
vi. An area, lateral to the and above the blind spot is called **yellow area or macula lutea**.
vii. At its center is a depression called **fovea centralis**.
viii. **fovea centralis** has maximum density of cone cells and is the **place of formation of sharpest vision.**

5. Photo receptor cells:

i. These are of two types-
(a) Rod cells
(b) cone cells.
ii. Photoreceptor cells contain light sensitive proteins termed as **photopigments**.
iii. The **cones are responsible for daylight (photopic) visionand colour vision**. While the **rods function in dim light (Scotopic) vision.**
iv. The **purple red protein called rhodopsin** is present in the rods which is **vitamin A derivative**.
v. The cones are of **three types**, which contain their own characteristic photopigments that respond to **red, green and blue** lights.
vi. Various combinations of these cones and their photopigments produce sensation of different colours.
vii. **The sensation of white light is produced due to the simultaneous equal stimulation of these three types of cones**.
viii. The Optic nerve consists of the fibers arising from the base of ganglion cells.

ix. It leaves the eye ball from the posterior side and carries visual impulses from the retina to the brain.

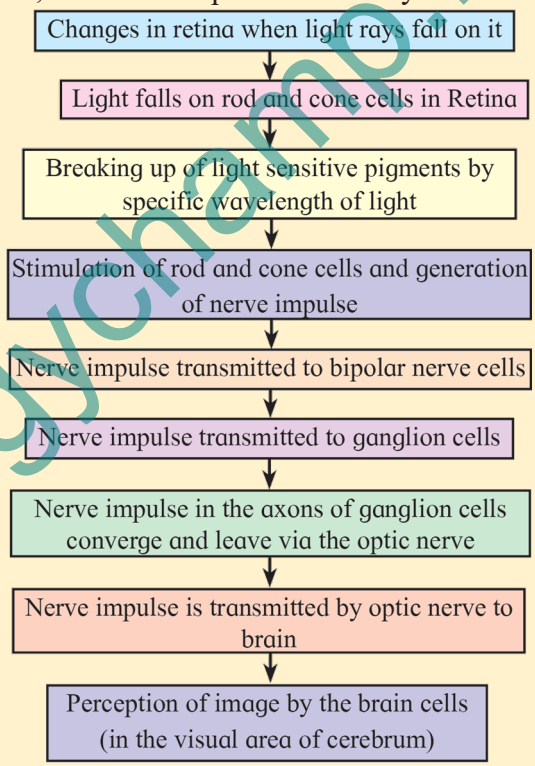


Structure of retina

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.

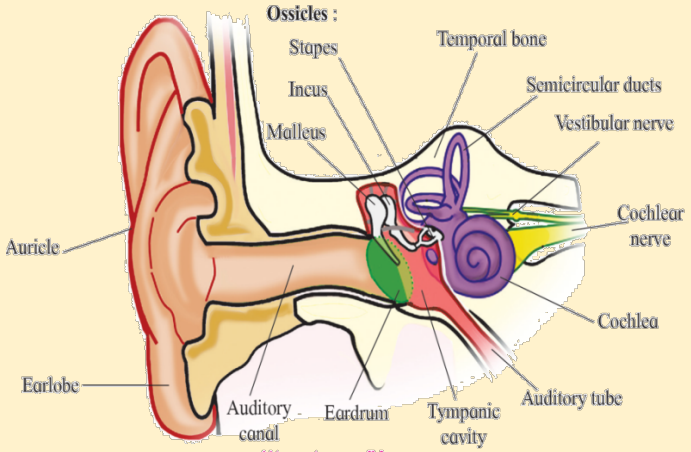
In the visual area of cerebrum, the nerve impulses are analysed and the image formed is recognized.



Ear:

a) The human ear is called **stato-acoustic organ**

b) it has two functions - hearing and body equilibrium.



Structure of human ear

c) Anatomically the ear is made up of three parts: -

1. external ear
2. middle ear
3. inner ear.

1. External ear:

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

2. Middle ear:

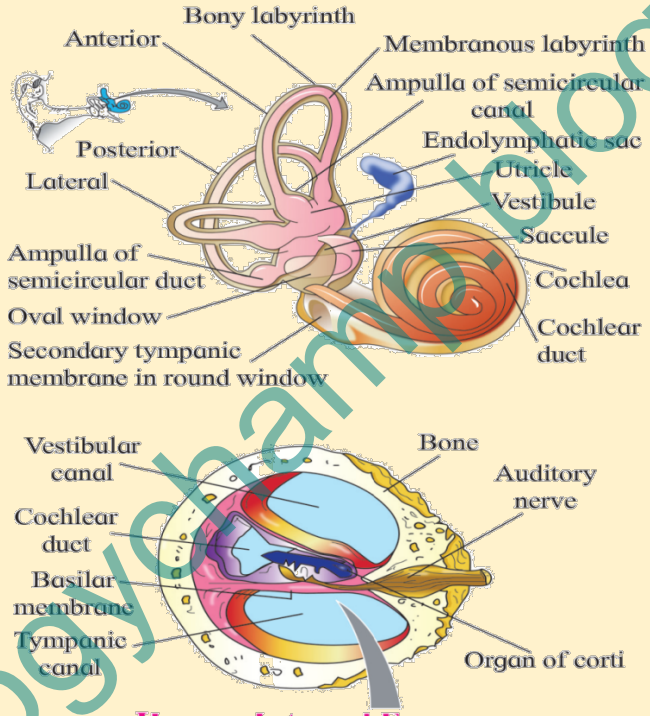
a) It consists of chain of three ear ossicles called **Malleus** (hammer), **Incus** (anvil) and **Stapes** (stirrup-the smallest bone).
b) when vibrations are received from the tympanic membrane, the ear ossicles amplify the vibrations and transfer these to the **cochlea**.
c) A short **eustachiantube** connects the middle ear to the pharynx. It **equalizes air pressure on both sides of the ear drum.**

3. Internal ear:

a) Internal ear consists of the **labyrinth and vestibular apparatus**.
b) The **labyrinth consists of bony labyrinth** filled with **perilymphand membranous labyrinth**filled with **endolymph**.
c) The coiled portion of the labyrinth is **cochlea**.
d) The **cochlea contains fluid filled three chambers** separated by **Reissner's membrane and basilar membrane.**
e) The upper chamber towards vestibul is called **scala vestibuli**filled with **perilymph**and the bottom chamber **scala tympani** are **filled with perilymph**.
f) The middle chamber is the **scala media**. It is filled with endolymph
g) The **organ of Corti** is a pea sized structure located on basilar membrane (floor of scala media).
h) The organ of corti has a **sensory epithelium over the basilar membrane**.
i) 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**.
j) Hair cells have long stiff microvilli called **stereocillia** on their apical surfaces.
k) **Above these stereocellia,** is a jelly like membrane called **tectorial membrane**.
l) 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 macula of utricle**.
- The **macula consists of hair cells and supporting cells**.
- Tips of the **hair and cilium project into a thick gelataneous sheath otolithic membrane**.
- This membrane secret minute particle **otoliths or otoconia**.
- 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 a way 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 static/linear balance these are in the maculae of utriculus and sacculus.



Human Internal Ear

Mechanism of Hearing:

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

Disorders of nervous system:

1. Psychological disorders:

They are 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.

2. 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**.

3. 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 organisms communicate with each other through chemical signals. Also, they are broadly of four types as follows:

1. **Autocrines :** Cells release secretion to **stimulate itself**.
2. **Paracrines:** Cells release secretion to **stimulate neighboring cells**.
3. **Endocrines:** Cells release secretion to **stimulate distant cells**.
4. **Pheromones:** Organs release secretions to **stimulate another 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**.

Endocrine system:

a) The endocrine system controls body activities by means of chemical messengers called **hormones**.
b) Hormones are released directly into the blood.
c) 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:

1. They act as chemical messengers and are **effective in very low concentration**.
2. Hormones can function as regulators that **inhibit or stimulate or modify specific processes.**
3. Some hormones **interact with receptors present on plasma membrane of target cells** where as some **enter the nucleus to interact with genes.**
4. **Hypersecretion or Hyposecretion of hormones leads to various disorders**.
5. These are **metabolized after their function**. Thus, cannot be reused.
6. Hormone secretion is **regulated by positive or negative feedback mechanism**.

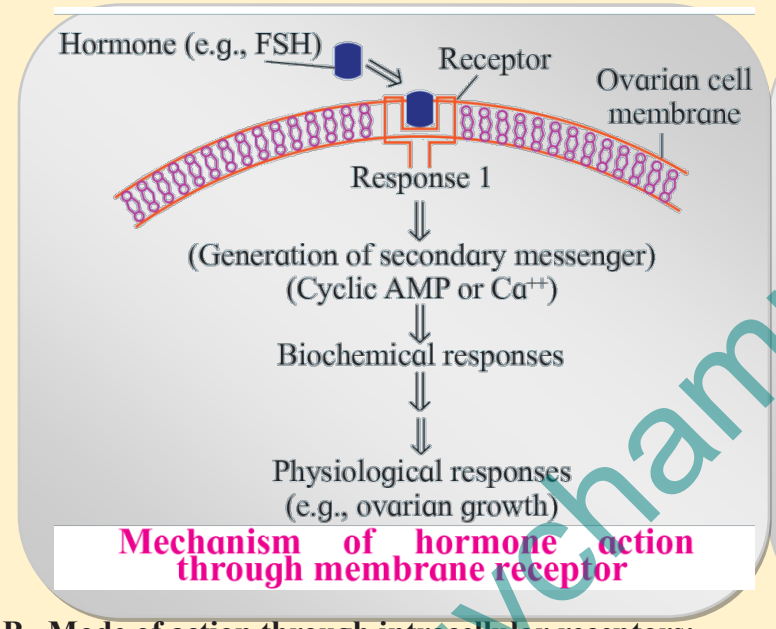
Mechanism of hormone action:

a) Hormones are released in a very small quantity.

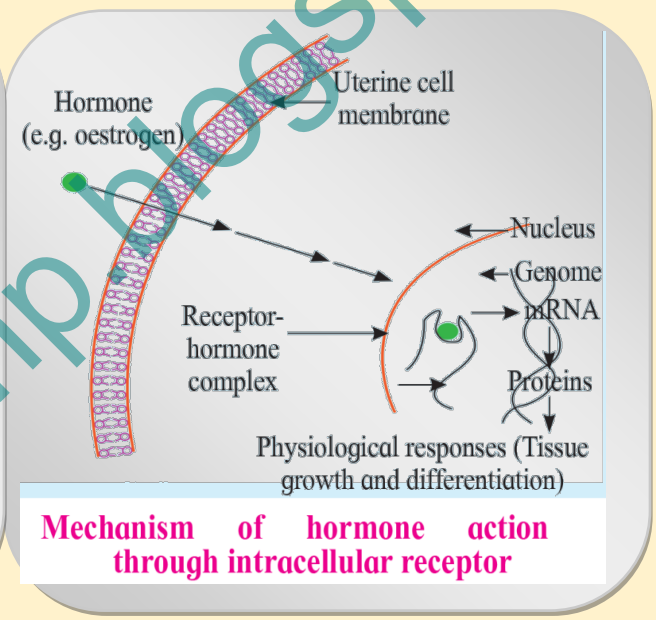
b) They produce their effect on the target organs cells by binding to hormone receptors.
c) The hormone receptors may be on the cell membrane or may be intracellular.
d) A **hormone-hormone receptor complex** is formed and this leads to biochemical change in the target tissue.

A. Mode of hormone action through membrane receptors:

1. Hormones like **catecholamines, peptide and polypeptide hormones are not lipid soluble**. Therefore, they cannot enter their target cells through plasma membrane.
2. These non-steroid **water-soluble hormones interact with surface receptor**, which initiate metabolic activity.
3. Molecules of **amino acid derivatives, peptide hormones** bind to specific receptor molecules located on the plasma membrane.
4. The **hormone receptor complex** causes the release of an **enzyme adenylate cyclase** from the receptor site.
5. This enzyme forms **cyclic AMP** from ATP of the cell. cAMP activates enzymatic actions.
6. The hormone acts as the **first messenger** and cAMP is the **second messenger**.
7. Other kind of second messengers are **Ca^{++}, cGMP and IP_3 (Inositol triphosphate).**



Mechanism of hormone action through membrane receptor



Mechanism of hormone action through intracellular receptor

B. Mode of action through intracellular receptors:

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

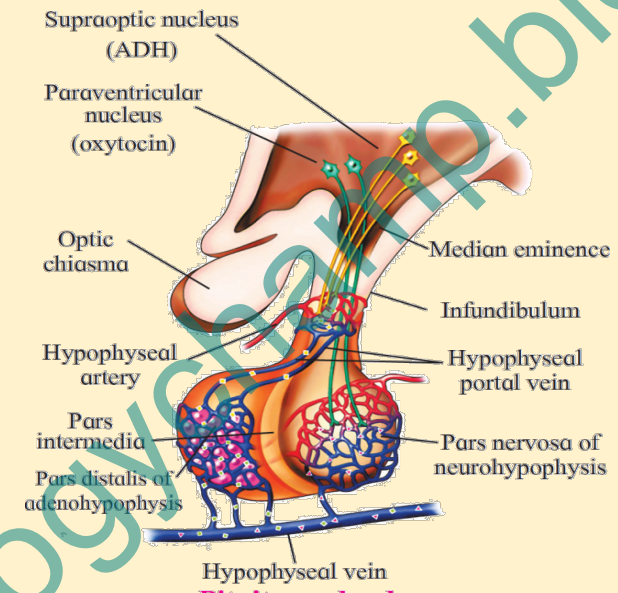
Major endocrine glands:

A. Hypothalamus:

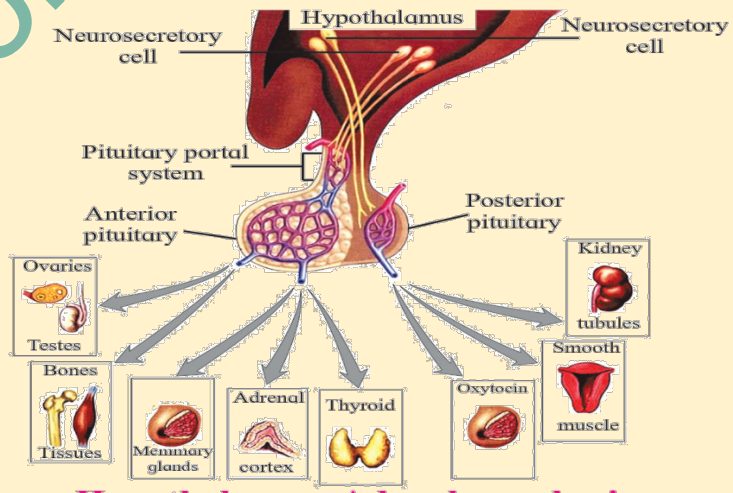
1. It is **ectodermal in origin**.
2. It is **located at the floor of diencephalon**.
3. Major function of hypothalamus is to **maintain homeostasis.**
4. It controls the **secretory activity of pituitary gland by the release and inhibiting hormones**.
5. All hormones of hypothalamus are **peptide hormones**.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

B. Pituitary gland or hypophysis gland:

1. The pituitary gland is the **smallest gland.**
2. Pituitary gland is a pea sized reddish-grey coloured gland.
3. It controls almost all other endocrine glands, hence earlier it was called **the master endocrine gland.**
4. It is located just below the hypothalamus and is attached to it by a stalk called **infundibulum** or hypophyseal stalk.
5. Pituitary gland remains lodged in a bony depression called **sella turcica** of the **sphenoid bone**.
6. Pituitary gland consists of two lobes –
   a) **anterior lobe (Adenohypophysis)**
   b) **posterior lobe (Neurohypophysis)**.
7. Both the lobes develop from different parts of embryo.Hence**it has of dual origin**.
8. Adenohypophysis is an outgrowth from the **roof of buccal cavity** which is known as **Rathke's pouch**. It grows upward towards the brain.
9. The **neurohypophysis grows as a downward extension of hypothalamus**.
10. The **two outgrowths together form the pituitary gland**.
11. The connection of Rathke's pouch with pituitray gland is **lost in embryo**.
12. **Intermediate lobe (Pars intermedia)** is a small reduced part lying in the cleft between the anterior and posterior lob.
13. Neurohypophysis is connected directly to the hypothalamus by **axon fibers**.
14. Adenohypophysis and intermediate lobes are connected to the hypothalamus through **hypophyseal portal system**.



Pituitary gland



Hypothalamus, Adenohypophysis and Neurohypophysis

Adenohypophysis:

1. It is the larger lobe of pituitary gland.
2. It is a highly cellular and vascular part of pituitary gland.
3. It contains various types of **epitheloid secretory cells, acidophils, basophils, chromatophores**.
4. It is differentiated into three parts –

a) pars distalis
b) pars intermedia
c) pars tuberalis.

The hormones of adenohypophysis are as follows:

1. **Somatotropin /Somatotropic Hormone / STH / Growth hormone / GH:**
   - **a)** This hormone stimulates **growth and development of all tissues by accelerating protein synthesis and cell division.**
   - b) Highest secretion the GH is seen till **puberty and then its secretion of becomes low**.However, it is continuously secreted throughout life for repair and replacement of body tissue or cells.
   - c) 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**.
   - d) 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:**
   - a) It stimulates adrenal cortex to produce and secrete its hormones.
   - b) It maintains functioning of **adrenal cortex**.
4. **Prolactin / Luteotropin / Mammotropin:**
   - **a)** Prolactin is unique among pituitary hormones as it is under **predominant inhibitory control from hypothalamus.**
   - b) Prolactin activates growth of **breasts during pregnancy** (mammotropin) and **stimulates the milk production and secretion of milk (lactogenic) by mammary gland after child birth**.
5. **Gonadotropin:**
   - **a. Follicle stimulating hormone/ FSH:**

     It stimulates growth of **ovarian** follicles in the females, it is concerned with the development of **seminiferous tubules in male**.
   - **b. Leutinizing Hormone/ LH:**
     - i. In female, the Leutinizing hormone helps in **ovulation** (discharge of ovum from graafian follicle).
     - ii. 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:**
     - i. In males, it acts on interstitial cells of testes to produce the **androgen called testosterone**.
     - ii. 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.

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

1. Oxytocin:

i. It **stimulates contraction of uterus during parturition**.

ii. 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. Antidiuretic Hormone (ADH)/ Vasopressin:

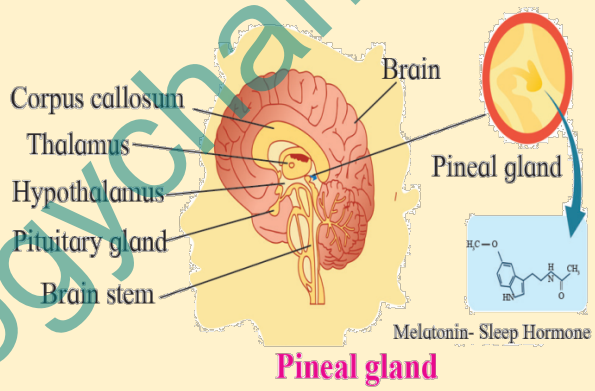
i. It stimulates the **re-absorption of water in distal convoluted tubuleand collecting ducts of uriniferous tubules** of the kidneys.
ii. It **decreases loss of water** by reducing the urine quantity.
iii. It **increases blood pressure by causing vaso constriction**.
iv. Deficiency of ADH reduces water re-absorption and increases urine output. This condition is called **diabetes insipidus**.
v. Excessive micturition causes excessive thirst. This condition is called **polydipsia**.

Pars intermedia:

i. It is **poorly developed in human beings**.
ii. It secretes **Melanocyte Stimulating Hormone** (MSH) in some lower vertebrates.
iii. MSH stimulates the **dispersion of melanin granules in melanocytes** and is responsible for **skin pigmentation.**

C. Pineal gland:

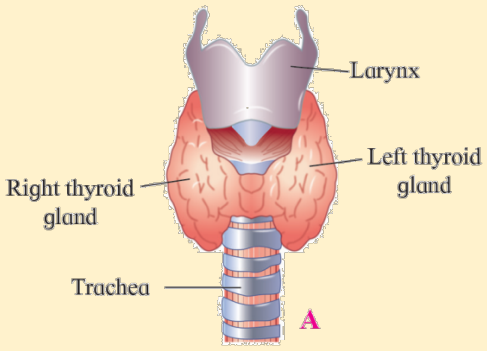
i. The pineal gland is arising from the **roof of diencephalon and is located between the two cerebral hemispheres.**
ii. The pineal gland is **sensitive to the biochemical signals of light**.
iii. It secretes a hormone called **melatonin** also known as sleep hormone.
iv. **Melatonin** is derived from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



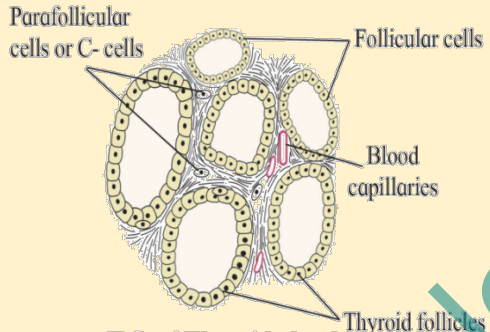
Pineal gland

D. Thyroid gland:

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



Thyroid gland



T.S. of Thyroid gland

a) Thyroid stimulating hormone (TSH). stimulate Thyroid gland to secrete its hormones.
b) The follicular cells of thyroid gland secrete two hormones -**Thyroxine/tetra iodothyronine/ T_4 (four atoms of iodine)** and **Triiodothyronine or T_3 (three atoms of iodine)**.
c) Thyroxine is synthesized by iodination (attaching iodine) to amino acid **tyrosine** by enzymatic action.
d) 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.
e) 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**.
f) **Thyroid gland is the only gland that stores its hormones**.
g) T_3 and T_4 hormones are stored before secretion and are regulated by **thyrotropin** of pituitary gland by **negative feedback mechanism**.
h) Thyroxine regulates the **basal metabolic rate of body**.
i) It also **regulates metabolism by stimulating protein synthesis and promotes growth of body tissues**.
j) It helps in **thermoregulation by increasing heat production**.
k) It **increases action of neuro transmitters- adrenaline and nor adrenaline**.
l) It also supports the process of **RBC production and maintenance of water and electrolyte balance**.
m) It also **regulates reproductive cycles in females**.
n) **Parafollicular cells or 'C' cells** produce **calcitonin hormone**, which regulates calcium metabolism.

Disorders related to thyroid gland:

a. Hyperthyroidism:

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

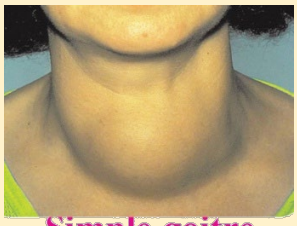
Bulging eyeballs

- **Grave's disease (Exophthalmicgoiter):**
  - Hyperthyroidism in adults, is characterized by protruding **eyeballs, increased BMR and weight loss.**
  - Increased BMR produces a range of effect like increased **heartbeat, 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 puberty and mental retardation**.
- **Myxoedema:**
  - It is the **deficiency of thyroid hormones in adults**.
  - It is characterized 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**.
- **Simple goiter :**(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 goiter.
  - **Size of the thyroid gland is increased but total output of thyroxine is decreased**.
  - This disease is common in **hilly areas**.
  - **Addition of iodine to table salt** prevents this disease.



Simple goitre

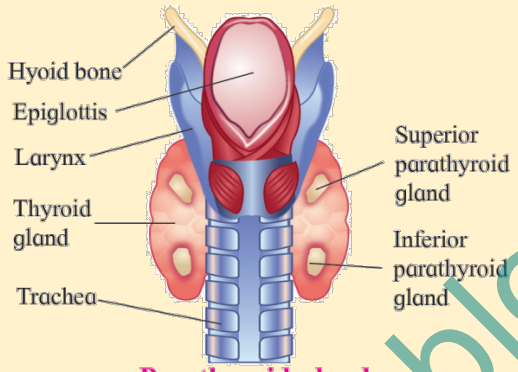
Calcitonin:

a. It is secreted by the **'C' cells or parafollicular cells**.
b. It regulates the **concentration of calcium and phosphorus in the blood**.
c. It functions under feedback control of plasma **calcium concentration in plasma**.
d. It is secreted when **concentration of calcium rises** in the blood.

e. 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:

a. Parathyroid gland is situated on the **posterior surface of the lobes of thyroid gland**.
b. Parathyroid glands are **four in number** and named as **superior and inferior parathyroid glands**.
c. The parathyroid glandsecretes a peptide hormone called **parathormone (PTH)**. It is also called **Collip's hormone**.
d. It regulates **calcium and phosphate balance between blood and other tissues**.
e. 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.**
f. Secretion of parathormone is under **feedback control of blood calcium level**.



Parathyroid gland

g. Concentration of calcium and phosphate is maintained by **parathormone and calcitonin of thyroid gland**.
h. These two hormones form an **antagonistic pair like insulin and glucagon**.
i. Hyposecretion of **parathormone lowers concentration of calcium in the blood** which**increases excitability of nerves and muscles causing muscle twitch and spasm**. This is called **parathyroid tetany** or **hypercalcemic tetany**.
j. **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**.

F. Thymus gland:

a. Thymus gland is located in the **upper part of thorax on the dorsal side of the heart**.
b. It is soft, pinkish, bilobed mass of **lymphoid tissue**.
c. It is a **prominent gland at birth but gets gradually atrophied in the adult**, so it is called **temporary gland or aging gland.**
d. It secretes the hormone **thymosin**.
e. It has an important role in the **development of immune system by maturation of T-lymphocytes**.
f. It also promotes **production of antibodies by providing humoral immunity**.

G. Adrenal gland/ suprarenal gland :

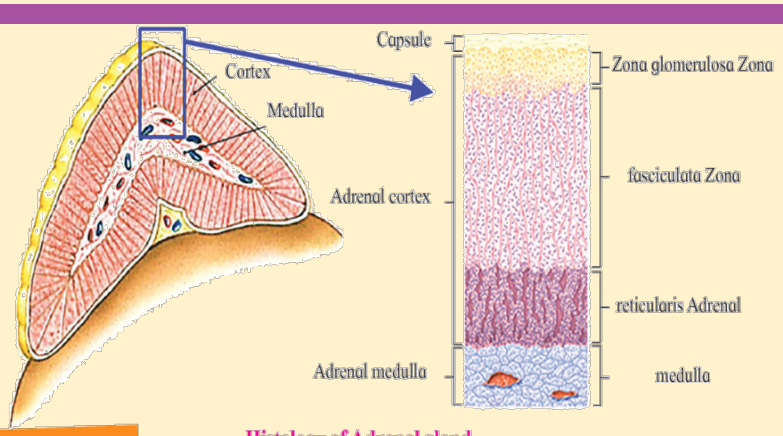
Adrenal glands have **dual origin** developed from **mesoderm and ectoderm**. They are located on the upper border of each kidney. Adrenal glands are small, conical yellowish glands and show two distinct regions-

1. **outer cortex**
2. **inner medulla.**

1. Adrenal cortex:

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

a. Outer thin **zona glomerulosa**
b. Middle thick **zona fasciculata**
c. Inner thin **zona reticularis**



Histology of Adrenal gland

G **zona glomerulosa – salt - Mineralocorticoids (Aldosterone)**
F **zona fasciculata - sugar – Glucocorticoid** (Cortisol)
R **zona reticularis - sex - Gonadocorticoids (Androgen)**

a. Outer thin **zona glomerulosa:**

i. It secretes **Mineralocorticoids.**
ii. They are useful for **regulating sodium and potassium ion concentration.**
iii. They also **regulate salt-water balance, blood volume and blood pressure**.
iv. **Aldosterone** (salt retaining hormone) is the main mineralocorticoid which **balances Na-K levels**.

b. Middle thick **zonafasciculata**:

i. It is responsible for secretion of cortisol like ***Glucocorticoids***.
ii. It regulates **metabolism of carbohydrates, proteins and lipids**.
iii. Cortisol is an important glucocorticoid. It is **responsible for increase in blood glucose level**.
iv. It is also **immune suppressive which suppresses synthesis of antibodies**. So, it is used in **treatment of allergy.**
v. It prepares animals to face emergencies in nature.

c. Inner thin **zona reticularis:**

i. It is responsible for production of **sex corticoids-Gonadocorticoids.**
ii. In males, they have a **role in development and maintenance of external sex characters**.
iii. **Excess sex corticoids** in **female causes adrenal virilism** (increased muscularity**) and hirsutism** (excess hair on face) while **in males it causes gynecomastia**i.e. Enlarged breast.
iv. 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–

- 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
- diarrhea.

b. Hyper secretion of glucocorticoids produces **Cushing's disease**.
Characteristic features of this disease–

- It leads to high blood sugar level
- excretion of glucose in urine
- rise Na^+ in blood volume
- high blood pressure
- obesity

- wasting of limb muscles.

2.Adrenal medulla:

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

H. Pancreas:

a. It developed from **endoderm**.
b. It is both exocrine (studied in Digestive System) and endocrine gland. Endocrine cells of pancreas form groups of cells called **Islets of Langerhans**.
c. Pancreas shows**four kinds of cells in islets of Langerhans** which secrete hormones.
1. **Alpha (□) cells** (20%) secrete **glucagon**. -It stimulates liver for **glucogenolysis** to increase blood glucose level.
2. **Beta (□) cells** (70%) secrete **insulin**. -It stimulates liver and muscles for **glycogenesis**. This lowers blood glucose level.
3. **Delta (□)** cell (5%) secrete **somatostatin -**It inhibits the secretion of glucagon and insulin. It also decreases the gastric secretions, motility and absorption in
4. **PP cells or F cells** (5%) secrete **pancreatic digestive tract. Polypeptide** (PP)- It inhibits the release of pancreatic juice.

Disorder related to pancreas:

❖ **Diabetes mellitus (Hyperglycemia)**

i. This is the most common **metabolic endocrine disorder of pancreas**.
ii. It leads to **increase in blood glucose level**.
iii. This is due to under activity of **Beta cells**, which results in reduced secretion of insulin.
iv. In children, such a condition is called **insulin dependent diabetes mellitus/ Type I (IDDM)**.
v. The other form of diabetes is **Non-insulin dependent diabetes mellitus/ Type II (NIDDM),**which is caused due to failure of insulin to facilitate the movement of glucose into cells.
vi. Reduced sensitivity to insulin is called **insulin resistance**.
vii. In both disorders, **blood glucose level increases. Some of the glucose is excreted in urine**.
viii. It also causes **excessive urination and dehydration of body tissues**.
ix. Degradation of fats increases formation of **ketone bodies (ketosis).**
x. **Administration of insulin lowers** blood glucose level.

I. Gonads:

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

i. **Ovaries:**They produce – **1. Estrogen**
2. Progesterone
3. Relaxin
4. Inhibin

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. Testis:

Testes secrete male sex hormones called androgens such as **testosterone**.

Testosterone:

a) It is secreted from **interstitial cells or Leydig cells** by the influence of luteinising hormone (LH).
b) **Rise in testosterone level in blood above normal inhibits LH secretion**.
c) It is also responsible for **secondary sexual characters** such as facial and pubic hair, deepening of voice, broadening of shoulders, male aggressiveness, etc.
d) It also helps in **maintenance of testes**.

J. Diffuse endocrine glands

Placenta:

a) It is the **intimate connection between foetus and uterine wall of the mother** for physiological exchange of the material.
b) Placenta is a **temporary endocrine gland**.
c) During pregnancy, placenta secretes hormones such as **estrogen, progesterone, hCG (Human Chorionic Gonadotropin) and human placental progesterone**.
d) 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:

a) In the gastrointestinal mucosa, certain cells are endocrine in function.
b) 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 **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**which 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.**

Thank you ……