1. CONTROL AND COORDINATION

The environment around us keeps on changing with the changing time. Throughout the year the weather changes and the living organisms keep on adjusting with the changing environment. For example, the plants shed their leaves in spring season.

Stimuli are the changes in the environment to which an organism reacts. For e.g. light, heat, cold, sound, smell, etc.

The response of an organism to the stimulus perceived is a characteristic property of living organisms. Specialized cells and tissues are involved in control and coordination.

Plants and animals show different types of method of reaction to stimuli i.e. response to stimuli in plants and animals differs significantly. Let us discuss it with the help of an example.

2. CONTROL AND COORDINATION IN PLANTS

Plants lack nervous system and sense organs as animals have them eg. eye, ear, etc. Plants react to the environmental changes by using hormones called **Phytohormones.**

Growth regulator is a broader term applied to all naturally occurring hormones along with those which are synthetic substances. Plants show change in shape by changing the amount of water in their cells.

2.1 PHYTOHORMONES (PLANT HORMONES)

In plants, the growth and development is controlled by various plant hormones i.e. phytohormones. The growth and development is coordinated and managed by one hormone by affecting or controlling the one or the other aspect of plant growth.

The growth of a plant is divided into following three stages :

(a) Cell division
(b) Cell enlargement
(c) Cell differentiation

The various aspects of plants which are controlled by plant hormones are as follows :

(i) Promotion of dormancy
(ii) Breaking of dormancy
(iii) Stomatal control
(iv) Falling of leaves
(v) Fruit growth
(vi) Ripening of fruits
(vii) Ageing in plants

PHYTOHORMONES

S.No.	Hormone	Function
1.	Auxin	· Shoot elongation. · Promotes cell enlargement and cell differentiation. · Responsible for bending of stem.
2.	Gibberellins	· Promotes cell enlargement and cell differentiation, towards light causes stem to elongate.
3.	Cytokinin	· Promotes cell division i.e. cytokinesis. · Present in areas of rapid cell discission (fruits and seeds).
4.	Abscisic Acid (A growth inhibitor)	· Promotes the closing of stomata. · Promotes the wilting and falling of leaves. · Inhibits growth.

2.2 PLANT MOVEMENT

Plant shows movement in its different parts, when it is subjected to any external stimuli such as light, force of gravity, water, etc.

Have you ever thought why a plant bends towards light when you put a potted plant in a dark room and allow light to enter in the room via window.

Auxin is the hormone which shows cell enlargement and cell division. When a plant is subjected to the above mentioned condition, due to the direct sunlight on one side the auxin synthesis increases which enhances the growth of stem on the other side thereby bending the plant towards light, which we call **"plant movement"**.

Plant movement is broadly studied under following two heads.

1. Tropism or Tropic movement: Direction specific, growth related, slower.
2. Nasties or Nastic movement: Not direction specific, not growth related faster.

2.2.1 Tropism or Tropic movements

Tropic movement is the directional movement of the part of plant in response to external stimuli. The direction of response is determined by the direction of stimulus. The direction of movement of plant can be towards the stimulus i.e. **positive tropism** or can be away from the stimulus. i.e. **negative tropism.**

(a) Types of Tropism: Depending upon the type of stimuli, different types of tropism are classified. There are five types of well recognized stimuli studied and tropisms are also studied in response to them. They are

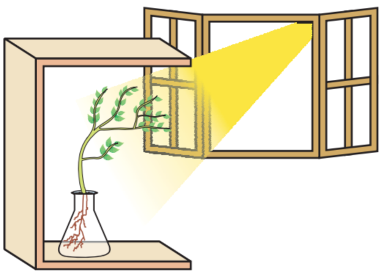
- Light
- Chemicals
- Water
- Gravity
- Touch

Similarly, the types of tropisms are

Phototropism	In response to light
Chemotropism	In response to chemical
Hydrotropism	In response to water
Geotropism	In response to gravity
Thigmotropism	In response to touch

(i) Phototropism: It can be defined as **"the movement of plant parts in response to light"**. When the plant parts move towards the light it is called **positive phototropism** and if it moves away from light, it is called **negative phototropism**.

For example, stem / shoot shows movement towards the light, which means shoot shows **positive phototropism**. Root shows movement away from the light i.e. **negative phototropism**.



Phototropism in Plants

Experiment and explanation: Let us discuss one experiment before discussing the role of hormones.

When a plant is grown in a dark room, with its window open (the only source of light to the stem the plant) tends to bend towards light coming through window. This is because of the positive phototropism shown by plant.

The principle hormone taking part in phototropism is **"Auxin"**. The flowchart explaining the mechanism of auxin action is as follows:

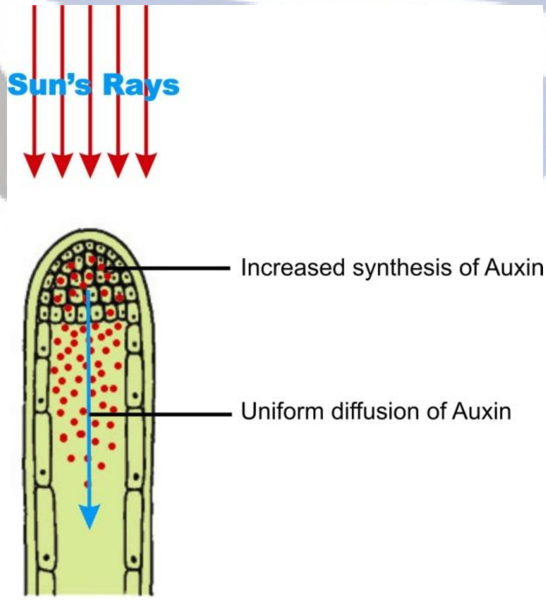
Mechanism of Auxin action

Normal growth

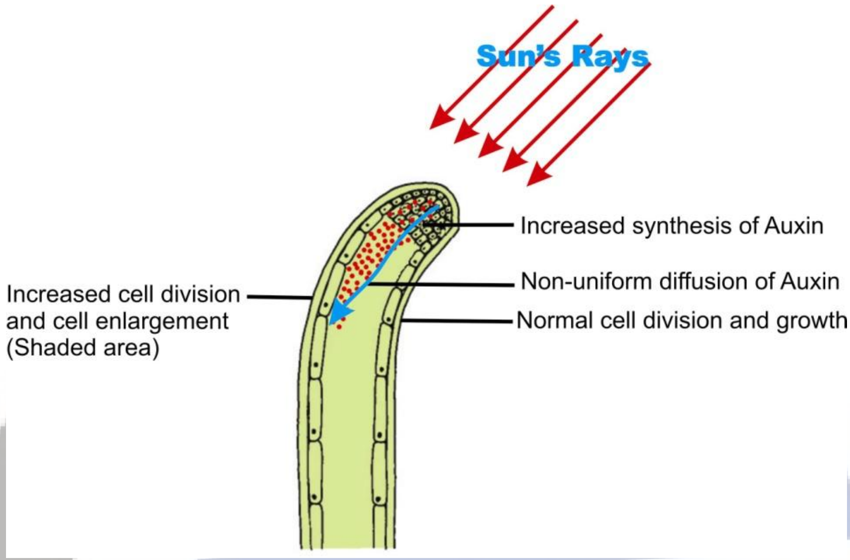
Shoot tip
↓ incident sun light
Auxin distributes down the stem uniformly
↓
Shoot grows uniformly

In experimental condition

Shoot Tip
↓ sun light incident on tip
Auxin is produced on the side facing light
↓
Auxin diffuses towards shaded plant part
↓
Increases cell division and cell enlargement
↓
Shaded area elongates
↓
Shaded area grows faster than lighted area
↓
Shoot bends towards light



Mechanism of Auxin Action (Normal growth)

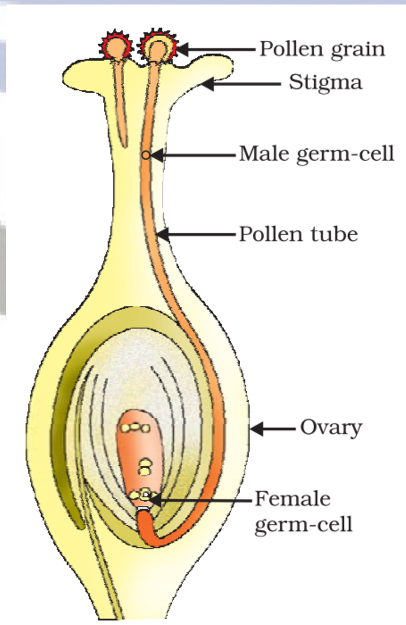


Mechanism of Auxin Action (in experimental condition)

In case of root: The effect of auxin on root is just opposite to that of shoot.

(ii) Chemotropism: It can be defined as **"the movement of plant parts in response to chemicals".** When the plant parts move towards the chemical it is called **"positive chemotropism"** and if it moves away from the chemical then it is called **"negative chemotropism"**.

For example, during the process of fertilization, the pollen tube grows towards the ovule, because stigma produces a chemical in response to which pollen tube grows towards ovule.



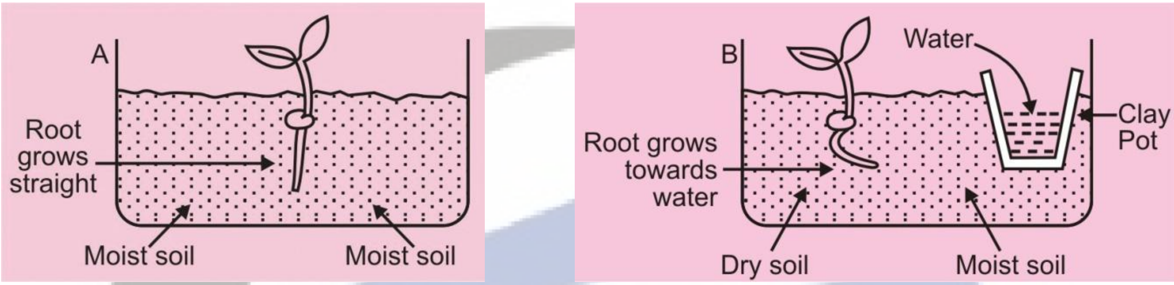
Pollen grains moving towards ovule (Chemotropism)

The growth of pollen tube towards ovule is one of the finest examples of chemotropism in plant kingdom.

(iii) Hydrotropism: It can be defined as **"the movement of plant parts in response to water"**. When the plant parts move towards water, it is called positive hydrotropism and when it moves away from water, it is called negative hydrotropism.

Have you ever pulled off a plant? You will notice that roots grow in all directions, this is because in response to water they grow towards it, i.e. "hydrotropism".

Let us try to understand the process of hydrotropism by a simple experiment.



Trough 1 Trough 2

Experiment showing Hydrotropism

Experiment and explanation: Take two glass troughs and label them 1 and 2. Plant a tiny seedling in both of them. In trough 2 make a small "well" and fill it with water. Water trough '1' uniformly but in case of trough '2', put water in the well.

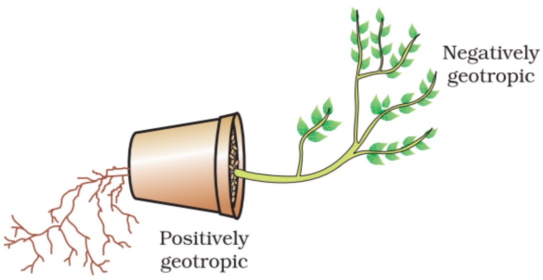
After few days dig the soil without disturbing the root. We will notice that in case of trough 2 the root bends towards water where as in trough 1 root grows straight uniformly.

(iv) Geotropism: It can be defined as **"the movement of plant parts in response to gravity"**. When the plant parts move towards the direction of gravity then it is termed as **"positive geotropism"** and when it moves away from the gravity, then it is termed as **"negative geotropism"**.

Shoot shows negative geotropism and root shows positive geotropism.

Have you ever thought of why stem grows upward against the gravity and root grows against the gravity?

Experiment and explanation: Let us understand the phenomenon with the help of an experiment. Take two potted plant namely 1 and 2. Keep one of them say 1 in normal condition and put 2 in horizontal condition.



You will notice that after some days the plant in pot '2' bends i.e. stem away from earth and root towards the earth.

(v) **Thigmotropism:** It can be defined as **"the movement of plant parts in response to touch"**.

Stem tendril showing Thigmotropism

Have you ever seen a vine yard? The grape vine climbs on the provided support. Do you know why?

Experiment and explanation: The grape vine has a weak stem, so it cannot stand erect. To stand erect it needs support to which tendril (an outgrowth on the stem) binds. The tendril grows as it touches the support. The side of the tendril which touches the support grows slowly as compared to the other side which is not in contact. This phenomenon in response to touch is called as **"thigmotropism"**.

Usefulness of Tropic Movement: Considering all the tropic phenomenon we can conclude that these phenomenon are necessary for the plant to survive. If tendril would not have responded to the support, vine yard would not have been possible. If roots would not have responded to water, plant would have died.

Growth of tendrils is an example of directional movement.

2.2.2 NASTIES OR NASTIC MOVEMENT

Nastic movement can be defined as, **"the movement of plant part in response to an external stimuli in which the direction of response is not determined by the direction of stimulus"**. It is usually shown by flat structure of plant such as leaf.

One of the best studied example of nastic movement is "response of ***Mimosa pudica*** on touch".

Nastic movement may or may not be growth movement. The opening of flower by the action of sun light is a growth phenomenon where as folding of leaf on touch as in case of ***Mimosa pudica*** is not a growth phenomenon.

(a) Types of nastic movement

(i) **Thigmonasty:** Thigmonasty is the nastic movement of a plant part in response to touch. For example – ***Mimosa pudica*** responds to touch by folding its leaves. The stimulus here is touch.

Normal condition (before touch) *After touch*

Thigmonasty shown by Sensitive Plant (Mimosa pudica)

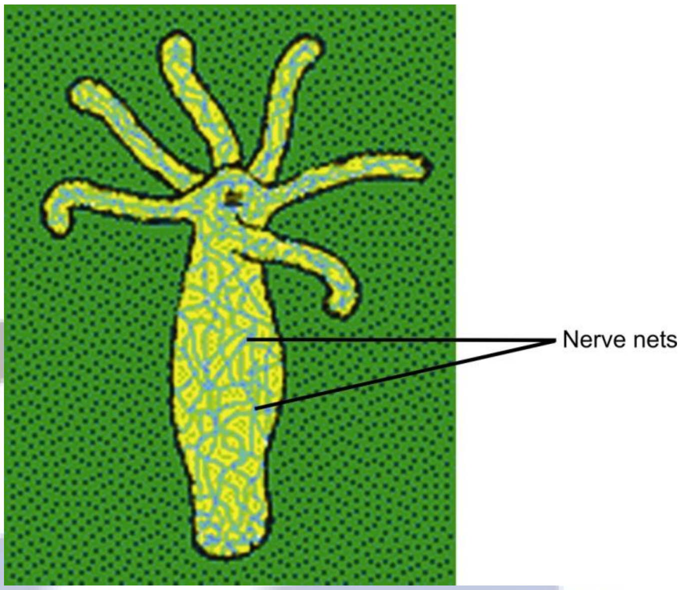
Photonasty (in sunflower)

(ii) Photonasty: Photonasty is the movement of plant part in response to light. The stimulus here is light. In case of dandelion flower it opens in the morning with the rising sun and as the sun sets flower also closes. But in case of moon flower it opens with the setting of sun and closes with the rising of sun. You can also see movement in sunflower which responds to the movement of sun.

3. CONTROL AND COORDINATION IN ANIMALS

Control and coordination are provided by nervous and muscular tissues. Multicellular organisms have specialized organ system to coordinate their activities. Simple multicellular organism like *Hydra* consists of a network of nerve cells. Thus *Hydra* has only nervous system to coordinate its activities.

The control and coordination in higher animals (Human) takes place through combination of nervous system and hormonal system, i.e. neuro-endocrine system.



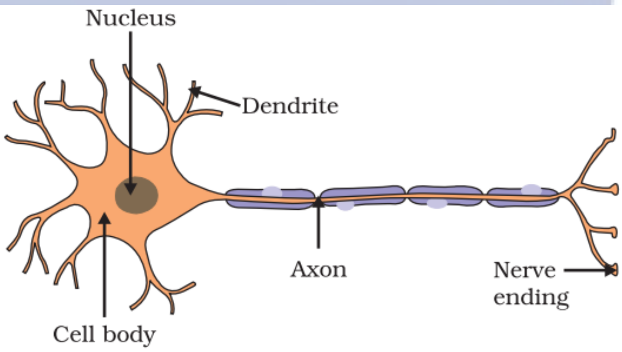
Nervous system of Hydra

3.1 NERVOUS SYSTEM IN ANIMALS

Nerve cells are the fundamental unit of nervous system. They are the specialized cells responsible for carrying information across the body. A nervous system consist of millions of nerve cells communicating through neurotransmitters among themselves. It is the longest cell in the body.

3.1.1 Structure of Neuron

A neuron consist of two components



1. **Cyton (Cell body):** It is like a typical animal cell, which contains cytoplasm and nucleus. Small processes stretches out from the cell body called dendrites.
2. **Axon:** It is a cylindrical structure arising from cyton and branched at its terminal ends. It has an insulating and protective sheath of myelin (made of fat and protein) around it. It is also known as nerve fibre. Longest process arising from cyton. Axon ending in the nerve ending.

3.1.2 Receptor and Effector

There are five sense organs in our body: eyes, ears, nose, tongue and skin. In a sense organ a **receptor** is present, which is a cell or group of cells sensitive to a particular type of stimulus (change in environment) such as light, heat, sound etc. We detect a stimulus through specialized tips of cells called receptors.

Types of receptors

S.No.	Receptor	Types of Stimulus	Sense organ
1.	Photo receptors	Detects light	Eye
2.	Phono receptors	Detects sound	Ear
3.	Olfactory receptors	Detects smell	Nose
4.	Gustatory receptors	Detects taste	Tongue
5.	Thermo receptors	Detects heat or cold	Skin

The part of a body which can respond to stimulus according to the instruction sent from the nervous system is called **effector**. Effectors are mainly muscles and glands.

If we touch something hot (or smell something tasty) we need to detect it and this is done by specialized tips of some nerve cells located in our sense organs. This information is then transmitted to central nervous system (brain and spinal cord) from where the response of the same is conveyed to the effector organs (muscles and glands). The whole process is done by a set of 3 neurons.

3.1.3 Types of Neuron

There are three types of neurons

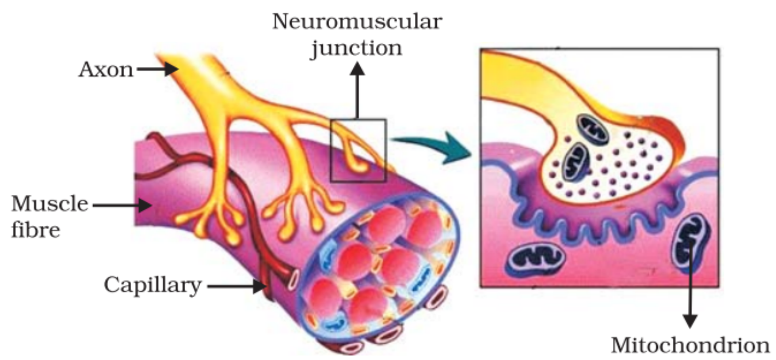
(a) Sensory neuron: It transmits information from receptors (sense organs) towards central nervous system (brain and spinal cord).

(b) Motor neuron: It transmits information from central nervous system to effectors (muscles or glands).

(c) Inter or Relay neuron: It occurs in central nervous system and serves as link between other neurons.

3.1.4 Transmission of Nerve Impulse

The messages that are transmitted in the nervous system are in the form of electrical or chemical signals called **nerve impulses**. The nerve impulses are transmitted from one neuron to another in a nervous system. There is a microscopic gap between two neurons over which nerve impulses pass while going from one neuron to the next and it is called **synapse**. A chemical substance called **neurotransmitter** (e.g. Acetylcholine) helps in carrying nerve impulses over synapse.



Steps for transmission of nerve impulse

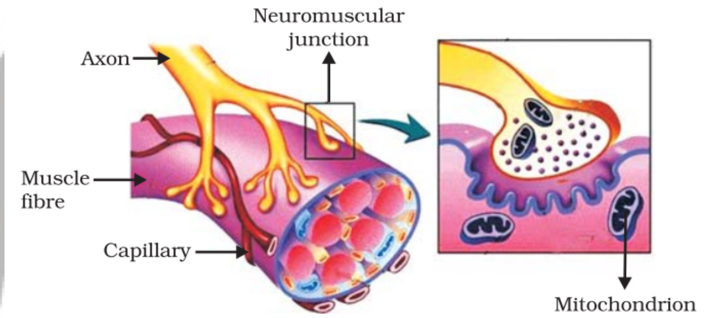
- When a stimulus acts on a receptor, an electrical impulse is initiated.
- This impulse is transmitted from the dendrite of a sensory neuron to the terminal endings of its axon.
- At the synapse (gap between 2 neurons), the neurotransmitter is released which undergoes a chemical reaction resulting in initiation of a similar impulse in the next neuron.
- This impulse is again transmitted to the terminal endings of the next neuron and the process continues till it reaches the relay neuron in spinal cord and brain.

- From the brain and spinal cord arises a set of motor neurons which transmits electrical impulses in the similar way to the effectors like muscles and glands.

3.1.5 Action caused by Effectors due to Nervous Tissue

The nerve impulse received by the muscles cause action or movement (removing our hand away from a hot object). Muscles are made of muscle cells containing special proteins (actin and myosin) which change their arrangement when stimulated by electrical impulses. This causes the muscle to change shape and contract. When the muscles contract, they pull the bones and make it move.

3.1.5.1 The **neuromuscular junction** i.e., the area of contact between a nerve fibre and sarcolemma is similar to axon-dendron junction or synapse. When a nerve impulse reaches the end of a nerve fibre, a neurotransmitter is released and it creates a similar electrical disturbance in the muscle cell bringing about its contraction.



Neuromuscular Junction

To sum up, the transmission of nerve impulse and action by effectors can be shown as follows.

Information detected by dentrite tip of a nerve cell

A chemical reaction sets up

Creates an electric impulse in the Neuron

Electrical impulse travels from dendrite to the axon ending

Remember information is acquired at dendrite travels through Axon
converted to chemical signal at the end of Axon.

Starts a similar electrical impulse in next neuron and so on.

Transmits nerve impulse to a muscle cell or gland through neuromuscular junction (synapse)

Action by muscle or gland.

3.1.6 Human Nervous System

Human nervous system is one of the most highly developed nervous system among living organisms on this planet.

The human nervous system can be further divided.

Nervous System

- Central Nervous System (CNS)
  - Brain
    - Fore-Brain
      - Cerebrum
        - Frontal lobe
        - Temporal lobe
        - Parietal lobe
        - Occipital lobe
      - Olfactory lobes
    - Mid-Brain
    - Hind-Brain
      - Cerebellum
      - Pons
      - Medulla oblongata
  - Spinal cord
- Peripheral Nervous System (PNS)
  - Cranial Nerves (12 pairs)
  - Spinal nerves (31 pairs)
- Autonomic Nervous System (ANS)
  - Sympathetic Nerves
  - Parasympathetic Nerves

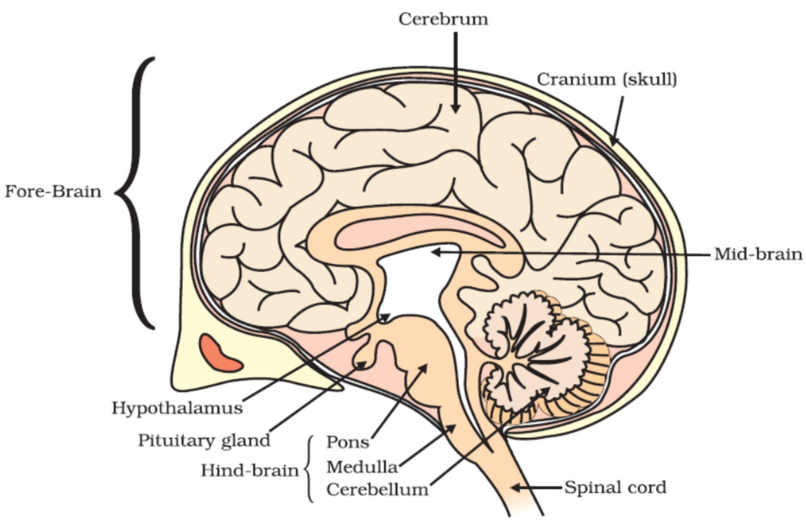
(a) Central Nervous System

It occupies the central axis of the body and enables a person to give a suitable response to various situations.

It consists of the

(i) Brain (ii) Spinal Cord

(i) Brain: The brain is located in a bony case (skull) called **cranium** or **brain box**. Inside the cranium, the brain is further surrounded by three membranes called **meninges**. The space between the membranes and brain is filled with **cerebrospinal fluid** (CSF). The cranium, meninges and cerebrospinal fluid protects the brain from mechanical shocks and injury. It floats in the cerebra spinal fluid.



Human brain

The brain is broadly divided into three regions.

Fore Brain: It consists of

- **Olfactory lobes:** A pair of bodies covered by cerebrum. It is not so developed in humans. It is concerned with olfaction (smell).
- **Cerebrum:** It forms about two-third of the brain. Different areas of cerebrum perform different functions. **Association areas** control learning, reasoning, intelligence, personality, thinking, memory, etc. **Sensory areas** give us sensation by receiving information from eyes, ears, nose, tongue, skin. **Motor areas** give instructions to muscles for various voluntary actions.

Hypothalamus

- Hunger centre, thrist centre

Midbrain

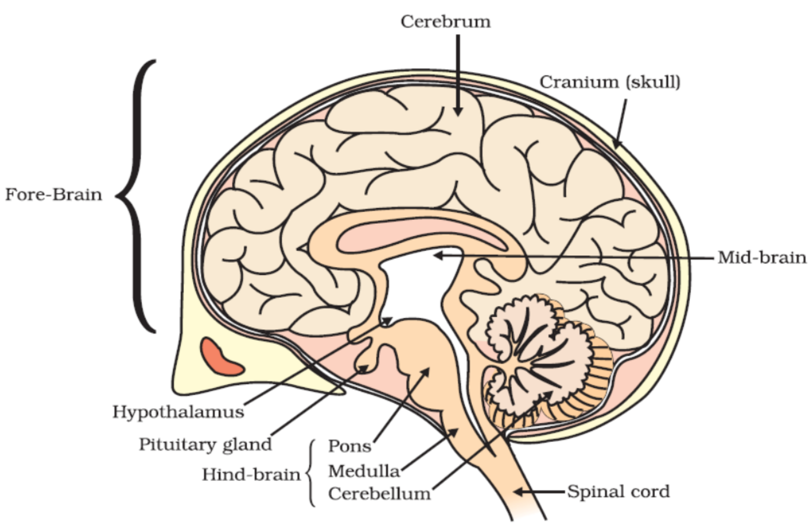
- It controls reflex movements of the head, neck, eye muscles, etc. in response to visual or auditory stimuli.

Hind brain: It is further sub divided

- **Pons:** It takes part in regulating respiration.
- **Cerebellum:** (Precision movements, posture balance) It helps in maintaining posture and balance. It also coordinates smooth body movements like walking, riding, etc., picking up a pencil blood pressure.
- **Medulla Oblongata:** It controls various involuntary actions such as heart beat, blood pressure, salivation, breathing, peristaltic movements, etc. Medulla also controls reflex actions like, swallowing, sneezing, vomiting, etc.

CNS

- Our performs voluntary, reflex and Involuntary actions:
- **Voluntary:** Under control, thought out actions like moving a chain.
- **Involuntary:** (Controlled by mid brain and hind brain) Salivation, vomiting, blood pressure.
- **Reflex:** Change in size of pupil.



Different regions of brain showing different functions

(ii) Spinal Cord: It is rod-like structure extending downwards in continuation with medulla. It is enclosed in a bony cage called **vertebral column** and is also surrounded by meninges.

- It is concerned with reflex actions and conduction of nerve impulses to and from the brain.

3.1.7 Peripheral Nervous System

All the nerves arising from brain and spinal cord forms the peripheral nervous system. Nerves arising from the brain are called **cranial nerves** which are twelve pairs. There are 31 pairs of nerves arising from the spinal cord **(spinal nerve)**. Cranial nerves are either sensory, motor, or mixed in nature. All the spinal nerves are mixed.

3.1.8 Autonomic Nervous System

It comprises of a set of two (sympathetic and parasympathetic) network of nerves antagonistic (anti/opposite) to each other. These nerves are attached to the smooth muscles of internal organs and controls involuntary actions.

For example: Sympathetic nerves increase the rate of heart beat and parasympathetic decrease the rate of heart beat.

4. REFLEX ACTION AND REFLEX ARC

4.1 REFLEX ACTION

A reflex action may be defined as **a spontaneous, automatic and mechanical response to a stimulus, acting on a specific receptor, without the will of an animal.**

Blinking of eyes, moving our foot away when we step on something sharp, etc. are examples of reflex action. In reflex action we are not aware of the things which is going to happen to us. In reflex action, spinal cord is involved for quick response to specific stimulus. However for thinking process, the information also goes to the brain for further reference.

Some reflex action which involves brain are called cerebral reflexes. For example, the contraction of pupil of our eye automatically in the presence of bright light.

4.2 REFLEX ARC

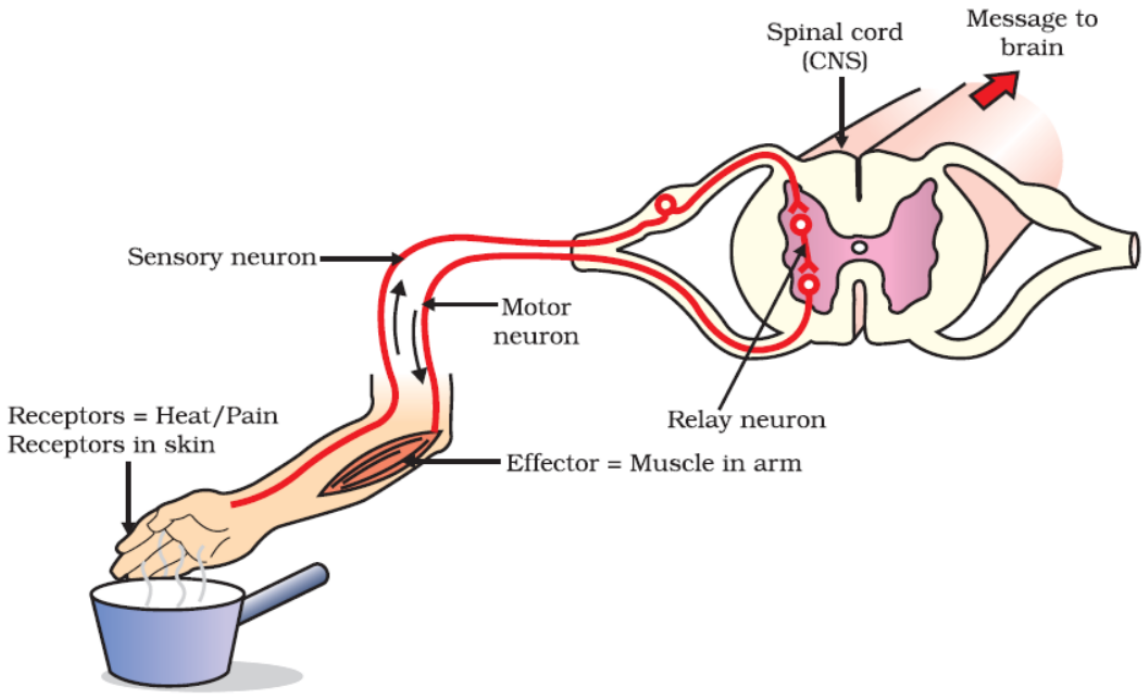
The path taken by nerve impulses in a reflex action is called reflex arc.

When we accidentally touch something hot, the heat is sensed by the receptors present in the skin. A nerve impulse is triggered for the same in the sensory neuron which transmits message to the spinal cord. In the spinal cord, impulse is passed to the connector neuron which in turn passes it to the motor neuron. The motor neuron transmits the instruction to a muscle of our arm. The arm muscles contracts and pulls other hand away from the hot object.

5. HOW DOES NERVOUS TISSUE CAUSE ACTION?

The nervous tissue collects information, sends it around the body, processes information, makes decisions based an information and conveys decision to muscles for action.

Muscles act by moving. At the cellular land, muscle cells move by changing their shape. They have special proteins that can change their shape and arrangement in the cell. This makes contract and cause movement.



Reflex arc

5.1 LIMITATIONS OF ELECTRICAL IMPULSES

(i) Cannot reach all the cells. Only reach the cells connected by nervous tissues.

(ii) Once an electrical impulse is generated in a cell and transmitted, the cell will take some time to reset its mechanisms before generating a new impulse. Cells cannot send nerve impulses continuously.

6. HORMONAL SYSTEM (ENDOCRINE SYSTEM)

In addition to the nervous system, the endocrine system also helps in coordinating the activities of our body. It overcomes the limitations of nervous system.

Hormones are transported through blood. They can potentially reach all cells. They can be sent continuously.

A group of endocrine glands which produces various hormones forms the **endocrine system**. It is also known as **hormonal system**.

The various endocrine glands in human body are – Hypothalamus, Pituitary, Thyroid, Parathyroid, Pancreas, Adrenal, Pineal, Thymus, Testes (in males) and Ovaries (in females).

Gland is a cell, tissue or an organ which secretes a specific substance in the body.

TYPES OF GLAND

- **Exocrine Gland** → These glands have ducts for secretion of their products → E.g. Sweat and salivary gland
- **Endocrine Gland (Ductless glands)** → These glands lack ducts and pass their secretions into the surrounding blood for transport t o the site of action. → E.g. Pituitary and thyroid
- **Heterocrine gland** → These glands consist of both exocrine and endocrine tissue and perform both functions. → E.g. Pancreas and gonads are mixed glands. The endocrine parts of pan creas secrete hormones like insulin and glucagons. The exocrine portion secr etes pancreatic juice containing digestive enzymes.

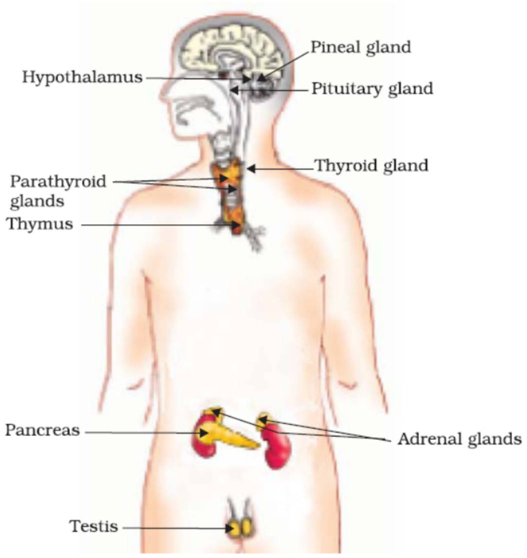
6.1 HORMONES

The term '**hormone**' was introduced by **Bayliss** and **Starling**.

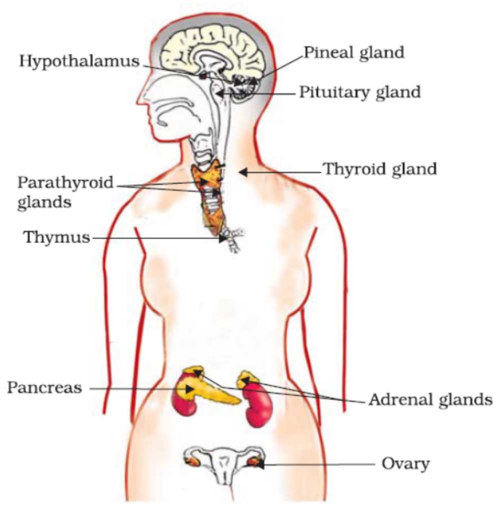
Hormones are the **chemical messengers** which coordinate the activities of living organisms.

Characteristics

1. They are secreted in small amounts by endocrine glands.
2. They are poured directly into the blood and carried throughout the body by blood.
3. They act on specific tissues or organs known as **target organs**.
4. The target cells detect their presence through receptors.
5. Hormone action is generally slower than nervous action.
6. Hormones are synthesized at places away from where they act. They diffuse to area of action.



(a)



(b)

Endocrine glands in human beings (a) male, (b) female

S.No.	Name of Gland	Hormones	Functions
1.	Hypothalamus	Releasing hormones	Regulates the secretion of hormones from the pituitary.
2.	Pituitary	Growth hormone	Regulates the development of bones and muscles.
		Oxytocin	Regulates the secretion of milk during lactation and regulates uterine contractions.
		Vasopressin	Regulates the water and electrolyte balance in the body.
		Prolactin	Regulates the function of mammary gland.
		Trophic Hormones	Regulates the secretion of hormones from other endocrine glands like thyroid, adrenal, ovary and testis.
3.	Pineal	Melatonin	Maintains circadian cycle of sleep and wakefulness.
4.	Thyroid	Thyroxin	Regulates the metabolism of carbohydrates, fat and proteins in the body.
		Calcitonin	Controls calcium and phosphorus balance.
5.	Parathyroid	Parathormone (PTH)	Regulates calcium and phosphorus balance in the blood.
6.	Adrenal	Corticoids	Regulates carbohydrate, fat and protein metabolism and maintains electrolyte balance.
		Adrenaline	Regulates heart rate, breathing rate, blood pressure and carbohydrate metabolism.
7.	Pancreas	Insulin	Lowers the blood sugar level
		Glucagon	Increases the blood sugar level
8.	Testes	Testosterone	Regulates the development of male reproductive organs and accessory sexual characters like beard, moustache, etc.
9.	Ovaries	Estrogen	Regulates the development of female reproductive organs and accessory sexual characters like development of mammary gland.
		Progesterone	Maintenance of Pregnancy.

6.2 SOME INTERESTING HORMONES AND THEIR ROLE

When squirrels are in a scary situation. It has to choose between fighting or sunning away (fight or flight). Some common preparations need to be done to perform these actions (fight or flight). Nervous impulses would have a limited action, so hormone in used **Adrenaline**.

(a) Adrenaline as an 'Emergency Hormone': Adrenaline hormone is usually secreted in small amounts but when a person is under stress like he is frightened, it is secreted in large amounts. It prepares the body for action as it speeds up heart beat and breathing, raises the blood pressure and allows more glucose to go into the blood to give us a lot of energy to combat the stress situation.

This happens as follows : When the heart beats faster, it supplies more O_2 to our muscles. The blood to the digestive system and skin is reduced due to contraction of muscles around small arteries in these organs. This diverts the blood to our skeletal muscles. The breathing rate also increases because of the contractions of the diaphragm and rib muscles. All these responses together enable the animal body to be ready to deal with the situation.

(b) Growth Hormone: Growth hormone is one of the hormones secreted by pituitary gland. This regulates the growth and development of the body.

1. If there is deficiency of this hormone in childhood, it leads to **Dwarfism.**
2. If there is excess of this hormone in childhood, it leads to **Gigantism.**

(c) Thyroxin: Thyroid gland secretes the hormone Thyroxin. Iodine is essential for the synthesis of Thyroxin by the thyroid gland. So, if iodine is deficient in our diet, less thyroxin hormone is there leading to a disease called **Goitre**. The main symptom of goitre is that neck of the person becomes swollen due to enlargement of thyroid gland. That is why it is advised to take iodised salt in the diet so as to prevent goitre.

(d) Insulin: Insulin hormone, produced by pancreas functions to lower the sugar level of the blood. If it is not secreted in proper amounts, the glucose level in the blood rises causing **Diabetes**. Then, people suffering from diabetes are advised to take less sugar in diet. They might be taking injections of insulin as a part of treatment.

6.3 FEEDBACK MECHANISM

It is important that hormones should be secreted in precise quantities because both excess or deficiency of hormones has an harmful effect on the body. So we need a mechanism through which this is to be done. The timing and amount of hormone released by various glands are controlled by **'Feedback mechanism'** which is inbuilt in our body.

For e.g. When we eat a carbohydrate rich meal, the glucose level of the blood rises. It is detected by the cells of pancreas, which respond by producing and secreting more insulin into the blood. In this way, blood glucose level is brought back to normal.

And if the blood sugar level falls below normal, insulin secretion by pancreas decreases automatically. This is an example of feedback mechanisms.

FEEDBACK CONTROL OF BLOOD GLUCOSE LEVEL

Carbohydrate rich meal

↓

Glucose-level rises in Blood

↓

Pancreas secretes Insulin

↓

Glucose is utilized or stored

↓

Glucose level falls in Blood

Inhibits insulin synthesis