Control and Coordination

Endocrine Glands and their Functions

We salivate when we see delicious food; we feel tense or anxious while making important decisions; we digest different types of food that we ingest; children grow taller during the early years of their life; voices of boys crack during puberty; lactation begins during motherhood. **Do you know why these changes occur? How does the body control these functions? Is there another system governing these complex functions?** Let us explore.

Hormones

A hormone is a chemical messenger that regulates physiological processes in living organisms. It is secreted by a gland.

The regulation of the physiological processes, control and coordination by hormones is governed by the endocrine system. The nervous system, along with the **endocrine system** in our body, controls and coordinates the physiological processes.

Characteristics of hormones:

- Hormones act as chemical messengers.
- They are secreted by living cells/tissues or organs called **glands**.
- They are secreted in very small quantities by glands.
- They act upon specific cells, tissues, or organs called the **target sites**.
- They are generally slow in action, but have long lasting effects.
- They either accelerate or inhibit a reaction.

Glands

A cell, tissue, or an organ that secretes hormones required for a specific function is called a **gland**. You are familiar with the pancreas, pituitary gland, and thyroid gland. Glands are mainly divided into two broad categories -**endocrine and exocrine**.

Exocrine gland	Endocrine gland

These glands possess ducts (enclosed passage or channel for conveying a substance) for discharging their secretions into the body surface. The sebaceous glands present in the skin, salivary glands present in the buccal cavity, and gastric glands present in the walls of the stomach etc. are a few examples of exocrine glands.	These glands do not discharge their secretions through ducts. Hence, they are also known as ductless glands. They discharge their secretions directly into the bloodstream. Their secretions are known as hormones. The pituitary gland, thyroid gland, adrenal gland etc. are a few examples endocrine glands.

Do you know that the term 'hormone' was first introduced by Ernest Starling? Secretin was the first hormone to be discovered. Ernest Starling and William Bayliss are credited for its discovery.

Importance of hormones

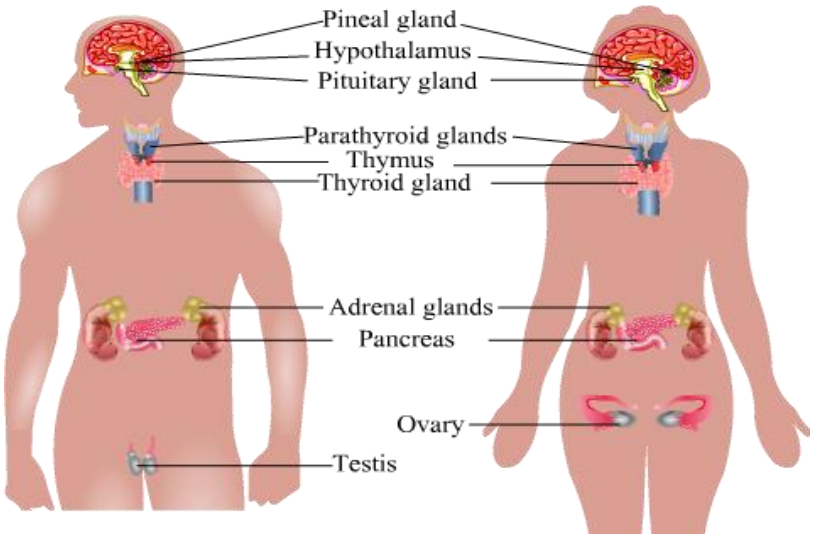
We have often heard people complaining that they suffer from sugar. Do you know which condition they are referring to? How do we treat this condition?

They are referring to the condition called **diabetes**. It is a chronic condition characterized by high levels of sugar (glucose) in the blood.

What is the reason for the increase of sugar in the blood? How are other activities such as sleep, hunger, stress, body temperature etc. regulated? Let us explore.

Hormones in the human body

There are different kinds of hormones found in the human body. However, we will discuss only a few.



Pituitary Gland

It is a tiny pea sized gland located near the hypothalamus of the brain. It is known as master gland as functions of many other endocrine glands are regulated by the pituitary gland. The gland is divided into two lobes- anterior lobe also called **adenohypophysis** and posterior lobe also called **neurohypophysis**.

Functions of the pituitary Gland

- It influences the secretion of other glands like thyroid gland, adrenal gland, mammary glands, gonads etc.
- It controls the excretion of water from kidneys and contraction of muscles of uterus.
- It also influences the development of testes and ovaries.
- It secretes the **growth hormone (GH)** that is involved in the growth and development of the human body.

The secretion of the growth hormone should be properly maintained in the body. Over secretion of the growth hormone prior to puberty (in children) results in abnormal growth of the body known as **gigantism**. This is characterised by the excessive growth and increase in height of the person. On the other hand, its low secretion results in retarded growth and this condition is called **dwarfism**.

The oversecretion of the growth hormone in the adults causes a disease called **acromegaly**. This results in the excessive growth of the bones especially in jaws, nose, hands and legs.

Thyroid Gland

The thyroid gland is situated close to the trachea in the neck. It secretes a hormone called thyroxin. It regulates carbohydrate, fat, and protein metabolism in our body. It indirectly affects the growth of the body by promoting growth and differentiation of tissues. Hence, it is also known as the personality hormone.

Thyroid disorders:

The deficiency (hypothyroidism) or excess secretion (hyperthyroidism) of this hormone results in certain disorders.

Hypothyroidism- The condition in which thyroid gland does not produce enough thyroxin to meet the normal requirements of the body. This condition causes abnormalities like simple goitre, myxoedema and cretinism.

Simple goitre- It is usually caused by deficiency of iodine in diet and results in swelling in the neck region due to enlargement of the thyroid gland. People living near coastal regions usually do not suffer from this disease as sea water and soil are rich in iodine. People suffering from goitre are suggested to increase their intake of iodine with food and water.

Myxoedema- It is mainly caused in adults due to under activity of the thyroid gland and symptoms include low metabolic rate, loss of mental and physical vigour, increase in weight, thickening of the skin and lower rate of heart beat. This condition is cured by giving proper doses of thyroxin to the person.

Cretinism- It is found in children born with improperly functioning thyroid gland. Its symptoms include stunted growth, retarded mental development, bow legs, defective teeth, protrusion of the tongue and loose skin. These effects can be prevented by providing proper treatment in time.

Hyperthyroidism- It is caused due to the excess secretion of thyroxin. It results in high metabolism, protrusion of the eye balls, high BP, nervous tension, irritability, profuse swelling, weight loss and fatigue. This can also be cured by giving proper treatment in time.

Thyroxine hormone not only plays an important role in humans but also in frogs. It is required for the completion of life cycle of frogs. The process of conversion of larva into an adult is called metamorphosis. This process is controlled by the thyroxine hormone in frogs. In the absence of this hormone, tadpoles cannot develop into adult frogs.

Parathyroid Gland

There are four parathyroid glands present on back side of thyroid glands that secrete parathyroid hormone or parathormone (PTH). This hormone regulates the level of calcium ions in the bloodstream.

The deficiency of this hormone results in the painful muscle cramps. On the other hand its over secretion removes calcium from the bones making them soft and spongy.

Adrenal Glands

The adrenal (suprarenal glands) gland, is situated at the anterior part of the kidneys. Each adrenal gland consists of two parts- **outer cortex** and **inner medulla.**

Adrenal cortex secretes two hormones- **Aldosterone** and **cortisol** while adrenal medulla secretes hormone- **adrenaline (epinephrine) and noradrenaline (norepinephrine).**

In case of danger, emergency, or stress, **adrenaline** is secreted in large quantities to prepare the body to face the situation. For this reason, it is also known as ‘emergency hormone’. This hormone is secreted even in normal situations, but in small quantities.

Adrenaline is secreted directly into the blood and is transported to different parts of the body. The specific tissues/organs on which this hormone acts also includes the heart. This results in faster heartbeats. Hence, more oxygen is supplied to the muscles. The breathing rate also increases due to contractions of the diaphragm and rib muscles.

Pancreas

Pancreas is a mixed gland i.e. both exocrine and endocrine in function. The cells of pancreas which are endocrine in function are known as **islets of Langerhans** and secrete two hormones- **insulin** and **glucagon.**

Insulin regulates the blood sugar level in the human body. It increases the permeability of the cell membrane for glucose and accelerates the passage of glucose into the cells from the bloodstream.

In case of deficiency of insulin, the level of glucose in blood increases and is excreted through urine. This condition is known as **diabetes mellitus.** Other symptoms of the disease include frequent urination and thirst. The treatment of diabetes mellitus includes oral pills or injections of insulin.

Glucagon is antagonistic hormone to insulin and is secreted when blood glucose levels are low. It helps in conversion of glycogen into glucose. This glucose is released into the blood and supplied to the tissues.

Gonads

Gonads (testes and ovaries) are both involved in producing gametes and are also endocrine (produce hormones) in function. Testes secrete **testosterone** and ovaries secrete the hormones **estrogen** and **progesterone**. These are also known as male sex hormones and female sex hormones respectively.

Testosterone is responsible for the growth and development of male secondary sexual characters.

Deficiency of testosterone results in under-sexed individuals whose masculine characters are not properly developed.

Estrogen is responsible for the development of secondary sexual characters in females like development of mammary glands etc.

Deficiency of estrogen causes infertility.

Progesterone helps in regulation of menstrual cycle and maintaining pregnancy.

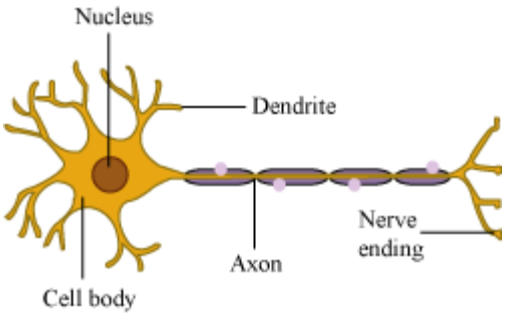
The human body contains 30 amazing hormones, which regulate activities such as sleeping, body temperature, hunger, and managing stress.

Components of Nervous System

Do you know which organs make up the nervous system?

The nervous system is made up of the brain, spinal chord, and nerve cells or neurons.

Let us first study about the structure of the functional units of the nervous system i.e., the **neurons**.



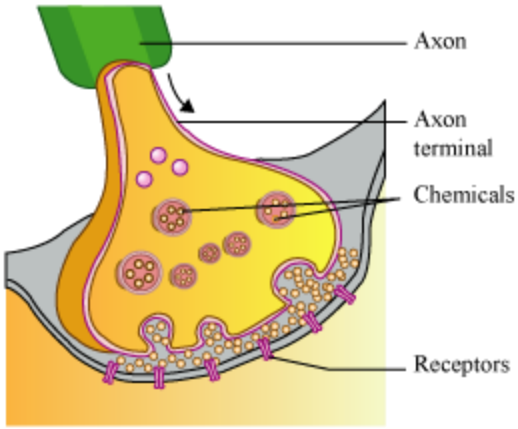
Structure of a neuron

The three main parts of a neuron are the axon, dendrite, and cell body. The **axon** conducts messages away from the cell body. The **dendrite** receives information from the next cell and conducts it towards the cell body. The **cell body** contains the nucleus, mitochondria, and other organelles. It is mainly concerned with maintenance and growth of the cell.

Arrangement of neurons

Neurons are arranged end to end, forming a chain. This helps in the continuous transmission of impulses. Each neuron receives an impulse through its dendrite and transmits it to the next neuron in a sequence through its axon.

Neurons are not connected. **Synapse** or a small gap occurs between the axon of one neuron and dendron of the next neuron.



A synapse in the muscle fibre is also known as **neuromuscular junction**. Let us discuss the working of a synapse in detail.

Nerve
A nerve is a collection of nerve fibres (or axons) enclosed in a tubular medullary sheath. This sheath acts as an insulation and prevents mixing of impulses in the adjacent fibres.

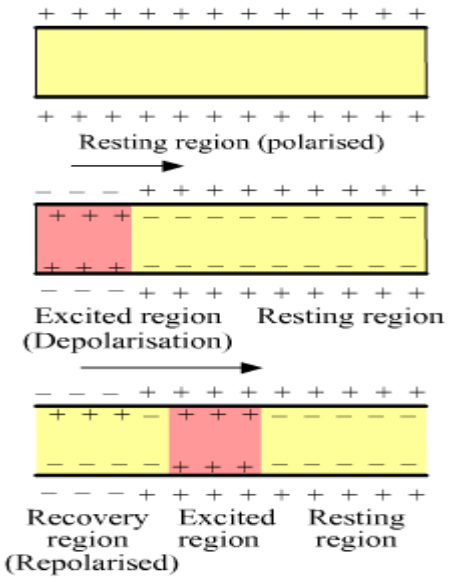
Types of neurons

Neurons are of three types.

How does a nerve impulse travel?

The dendrite end of the neuron collects information and triggers a chemical reaction, which results in an electric impulse. This impulse is transmitted from the dendrite to the cell body and then to the axon. From the axon, the impulse travels to its end, where the electrical impulse sets off the release of some more chemicals. These chemicals cross the synapse and start a similar electrical impulse in the dendrite of the next neuron. In this way, impulses are transmitted from one neuron to another to finally reach the brain.

Under normal conditions, the outer side of the nerve fibre consists of positive charge as more Na+ ions are present outside axon membrane. The neuron is then said to be in polarised state. On stimulation, the membrane becomes more permeable and Na+ ions move inside causing depolarisation. Such a region is known as excited region. The point of depolarisation behaves as stimulus for the neighbouring area and this goes on. In the mean time, the previous area becomes repolarised due to active transport (using ATP) of Na+ ions with the help of **sodium pump**.



Conduction of nerve impulse through a nerve fibre

In a similar manner, impulses are transmitted from the brain to muscle glands.

Human Brain - Structure and Function

The body performs various activities. **All these activities are controlled by the brain. How does the brain control all activities? Are there any divisions in the brain, which take over the control of different activities?**

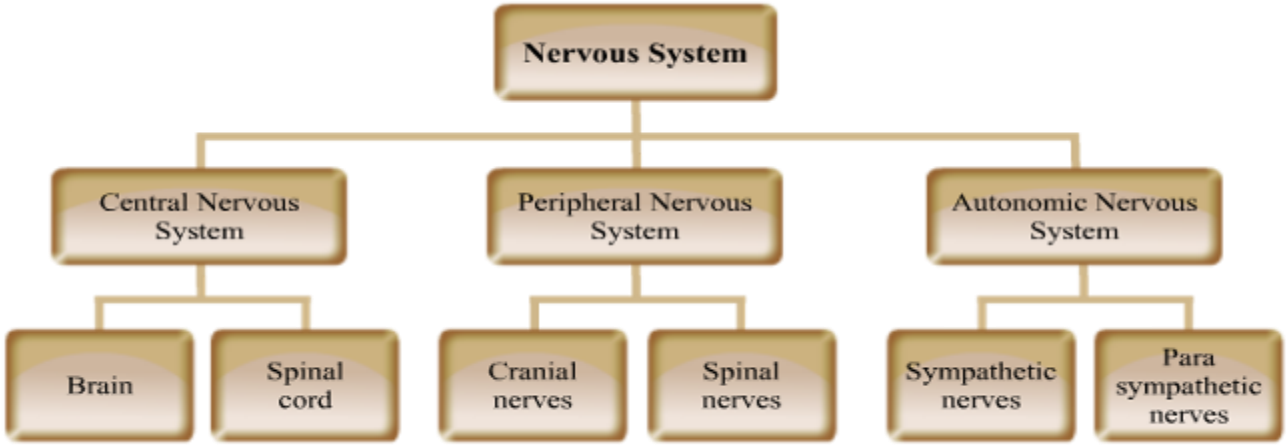
Do you know which organs make up the nervous system?

Let us explore.

The nervous system is divided into - **central nervous system (CNS) and peripheral nervous system (PNS)**. The **CNS** consists of the brain and spinal chord while the **PNS** consists of the nerves that connect the central nervous system to different parts of the body.

The central nervous system receives information from all parts of the body and also sends information to the muscles. Communication between the **CNS** and body parts is facilitated by the nerves of **PNS**.

The important components of nervous system are:



Components of human nervous system

The Central Nervous System

The central nervous system consists of the brain and the spinal cord. The brain is enclosed in a bony box called the **cranium** and spinal cord is protected by **vertebral column.** The brain and spinal cord are externally covered by protective covering called **meninges**. It is made up of three layers namely **duramater** (outer layer), **arachnoid** (middle layer), **piamater** (inner layer). The space between meninges is filled by a watery fluid called **cerebro-spinal fluid (CSF)**. This fluid

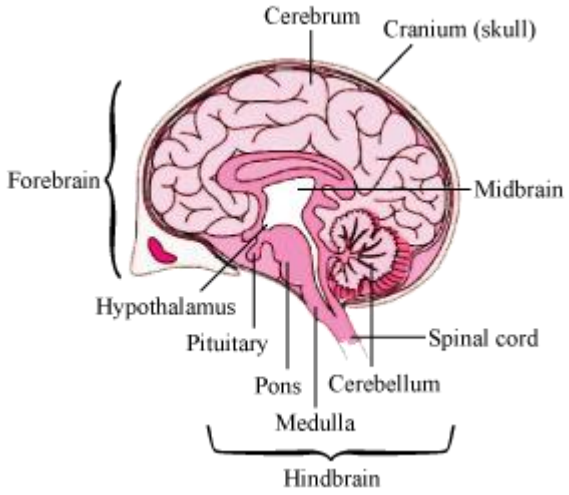
flows from the brain to spinal cord and then back to brain. It acts as a shock absorber and protects brain form injuries. It also provides nutrients to the cells in brain and spinal cord.

Human Brain

The brain is the main coordinating centre of the body. It is a part of the nervous system, which controls and monitors every organ of the body. The weight of the brain of an adult is about 1400 grams.

Different regions of the brain

The brain is divisible into three main regions—forebrain, midbrain, and hindbrain.



Forebrain

It is the main thinking part of the brain. It consists of the cerebrum, thalamus and hypothalamus. The forebrain has sensory regions, which receive sensory impulses from various receptors. It also has motor regions, which control the movement of various muscles such as leg muscles. There are separate areas in the forebrain specialized for hearing, smelling, seeing, general sensations such as pain, touch, taste, etc.

Cerebrum: The cerebrum is the largest part of the brain and constitutes four-fifth of its weight. It is divided by a deep cleft into two equal parts called left and right cerebral hemispheres.

Cerebrum has two regions, an **outer cortex** and **inner medulla**. The inner cortex is made up of cytons (nerve cell body) that give it a greyish appearance, so it is also called as **grey matter**. The medulla is composed of nerve fibres (axons and dendrites) that give it an opaque white appearance due to presence of myelin sheath covering, so is also called a **white matter**.

The cortex is provided with ridges called convolutions that increase the surface area of the cerebrum. The well developed cortex is responsible for the high degree of intelligence of the humans.

The information obtained through sense organs is stored in the cerebrum and used when needed. This ability to store information helps in retaining the memory.

A certain part of the cerebrum primarily controls intelligence, learning, memory, emotions, consciousness, thinking, and the ability to articulate speech. The forebrain is also known as the main thinking part of the brain.

In cerebrum, the nerves that come from the right side of the body are connected to the left side of cerebral hemisphere and the nerves that come from the left side of the body are connected to the right side of the cerebral hemisphere. Therefore, organs of the right side of the body are controlled by left hemisphere and organs of the left side are controlled by the right hemisphere. Thus, injury in the left side of cerebral hemisphere results in the paralysis of organs on right side of the body and vice-versa.

Dienchephlon

It is the part of the forebrain located below the cerebrum. It includes both thalamus and hypothalamus.

Thalamus is situated between cerebral cortex and mid brain. It receives the nerve impulse form sense organs and transmits them to the upper region. It coordinates the sensory and motor signaling.

The **hypothalamus** contains many areas that control the body temperature, urge for eating and drinking, etc. Some regions of the cerebrum along with hypothalamus are involved in the regulation of sexual behaviour and expression of emotional reactions such as excitement, pleasure, fear, etc.

Midbrain

It is the small region of the brain that connects cerebrum with the hind brain . It has regions that are concerned with the sense of sight and hearing. Some regions of the midbrain transmit motor impulses to the limbs.

Hindbrain

It consists of three parts namely **pons varoli, cerebellum** and **medulla oblongata**.

Pons varoli consists of the nerve fibres that connect various portions like cerebrum, cerebellum and medulla oblongata of the brain. It has the control centers for facial expression, respiration

and mastication etc. Among the twelve pairs of cranial nerves, four pairs originate from the pons varoli.

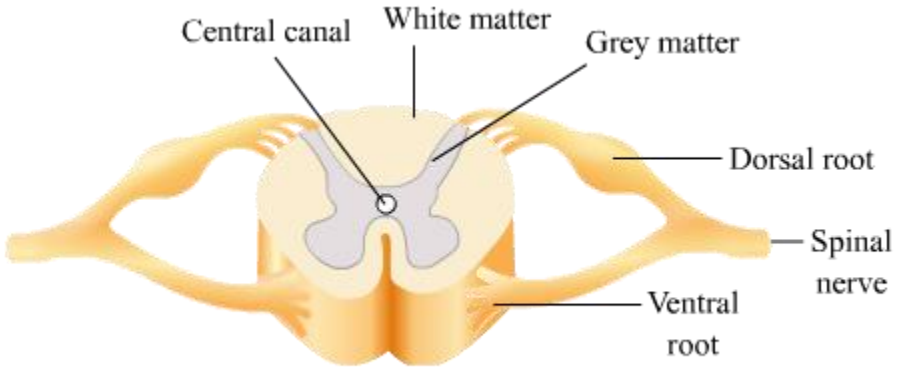
The **cerebellum**, which is a part of the hindbrain, is responsible for maintaining the posture and equilibrium of the body. It also coordinates the contraction of voluntary muscles, according to the directions of the cerebrum.

Medulla is the posterior most part of the brain and is connected to the spinal cord. Most involuntary actions such as heart beat, blood pressure, movement of food in the alimentary canal, salivation, etc. are controlled by the medulla of the hindbrain.

Spinal Cord

It is the continuation of the medulla oblongata and runs through the vertebral column. The spinal cord is made up of two similar halves fused together to form a central canal containing the cerebrospinal fluid. The outer portion of the spinal cord is known as the **white matter**, which consists of nerve fibres and the inner portion contains the cell bodies of neurons and is known as the **grey matter**. There are thirty one pairs of spinal nerves that arise from the spinal cord. These nerves are divided into branches that reach to several parts of the body like, heart, lungs, stomach, urinary bladder, sex organs etc. The movement of limbs in the body are controlled by the spinal cord through reflex actions.

The spinal cord tapers at the end at the last vertebrae where from a collection of nerve roots originate, which are horsetail-like in appearance and hence called the **cauda equina.**



Cross section of spinal cord

Protection to the brain and spinal cord

The brain, being an important organ, requires protection. Therefore, it is enclosed in a bony box called the **cranium**. The brain inside the brain box is also surrounded by a fluid-like material, which acts as shock absorber and thus, provides further protection to the brain. Spinal cord is protected by a bony, vertical rod with several curves called the **vertebral column**.

Do You Know?

- **The brain transmits messages at a rate of 240 miles per hour!**
- **There are 10 million nerve cells in our brain.**
- **The brain uses more than 25% of the oxygen used by the human body!**
- **As compared to other animals, the ant has the largest brain in relation to its body**.

Peripheral Nervous System

It consists of the nerves arising from the brain and the spinal cord, which links the CNS to the rest of the body. It consists of two types of nerves.

- **Cranial nerves:** There are 12 pairs of cranial nerves and they emerge from the brain and reach the organs in the head region.
- **Spinal nerves:** There are 31 pairs of spinal nerves that emerge from the spinal cord and reach various parts of the body.

Messages are transferred from the brain to the spinal cord and then to the rest of the body and similarly messages from the rest of the body reach the spinal cord from where they are transferred to the brain. The spinal cord also controls all reflex actions.

Autonomic Nervous System

The autonomic nervous system helps to carry out the orders of the medulla, which controls the vital body functions.

It consists of two networks:

- **Sympathetic system**: The sympathetic nerves lead to all vital internal organs and glands. They regulate the actions of smooth muscles such as that of the stomach, intestine, and the heart.
- **Parasympathetic system**: This system is made up of the vagus and the pelvic nerves.

The sympathetic system speeds up the body functions and prepares the body for combat and escapes while the parasympathetic system counteracts to that of the sympathetic system and slows down the body functions.

Responses of the Nervous System

What happens when the following takes place?

- Bright light is focused on our eyes
- We accidentally touch a flame
- We are hungry and we think about our favourite meal

For all the situations mentioned above, the response would be quick and automatic. We would

- close our eyes immediately when bright light is focused on our eyes
- withdraw our hand from the flame
- start salivating on thinking about our favourite meal

This automatic action or response provoked by a stimulus is known as a **reflex action.**

The responses of the nervous system can be classified into voluntary, involuntary, and reflex actions.

The actions that can be controlled voluntarily are called **voluntary actions.** The signal or message for these actions is passed to the brain. Therefore, they are consciously controlled.

On the other hand, the movement of food in the alimentary canal or the contraction and relaxation of the blood vessels are **involuntary actions** i.e.they cannot be consciously controlled.

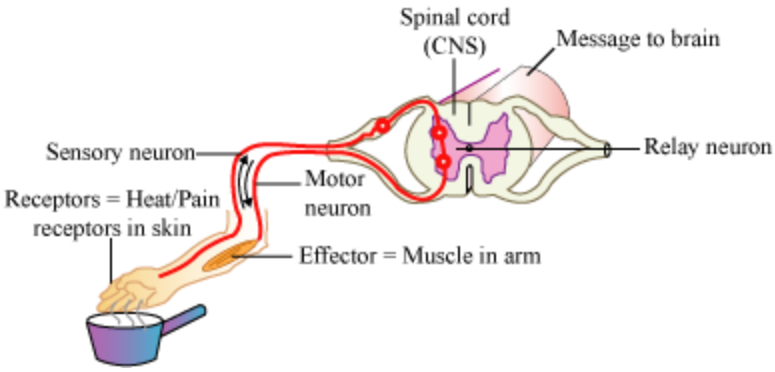
The **reflex actions**, however, show sudden responses and do not involve any thinking. This means that unlike involuntary actions, these actions are not under the control of the brain.

Reflex arc

When we accidentally touch a hot object, we withdraw our hands immediately without thinking. If we do not do this, our hands will burn.

The sensory nerves detect the heat. They are connected to the nerves, which move the muscles of the hand. Such a connection of detecting the signal from the nerves (input), and responding to it immediately (output) is called a **reflex arc**. In other words it is the pathway along which nerve impulse travels during the reflex action.

A reflex arc makes instant and automatic responses possible. It connects the input nerve and output nerve, and meets in a bundle in the spinal chord. In fact, nerves from all over the body meet in a bundle in the spinal cord, on their way to the brain. Therefore, the information input reaches the brain.



The reflex arc consists of five distinct parts and these are:

1. Receptor: It includes sense organs that receive stimulus.

2. Sensory neuron: It conducts the nerve impulse from receptor to the spinal cord or brain.

3. Association neuron: It helps to transmit nerve impulse from sensory neuron to motor neuron.

4. Motor neuron: It transmits nerve impulse to the effector organs like muscles or glands.

5. Effector: It includes muscles or glands where action takes place in response to stimulus.

Types of Reflexes

Ivan Pavlov classified all reflex responses in two categories – Unconditional and conditional reflexes.

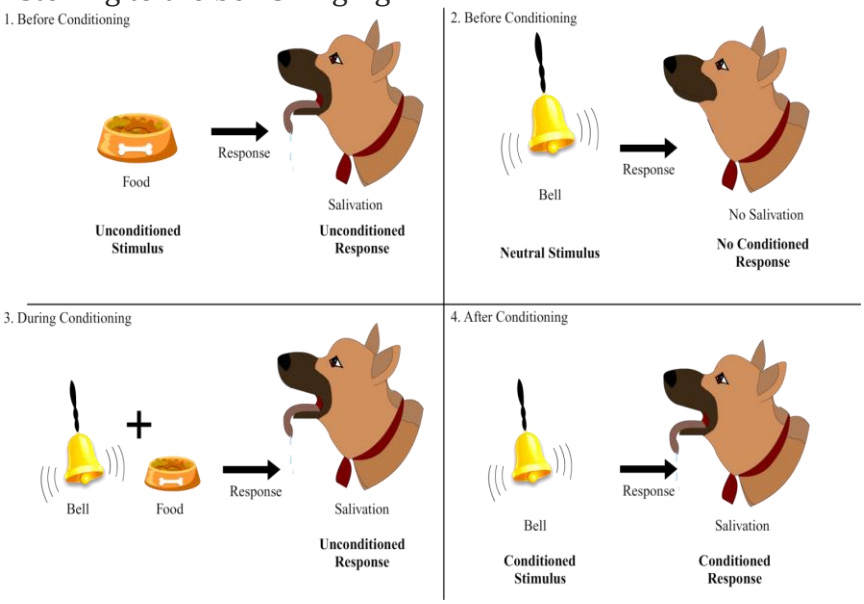
Unconditional Reflexes – These are the inborn, unconscious responses to a given stimuli which are transferred to the next generation as well.

Some of the examples of such unconditional responses are suckling of the mother's breast by a new born body blinking of eyes when an object is brought very close to the eyes.

Condition Reflexes – Such responses are acquired during the life time of an individual. These responses are different for different organisms. These responses can be easily induced or lost depending upon the environmental conditions.

Pavlov's Experiment on a Dog
In this experiment the Russian famous biologist, Ivan Pavlov tested the conditional reflexes. He used a dog as his experiment subject and tested for the secretion of saliva in response to ringing of a bell. Under normal condition, dog will not secret saliva on listening the ringing of a bell or any other sound. In his experiment, Pavlov brought food and rang the bell simultaneously for a prolonged period of time.

After an adequate period of training, it was observed that the dog started secreting saliva just by listening to the bell's ringing.



Conditional reflexes are controlled by cerebral cortex.

Some of the examples of conditional or acquired reflex are learning, playing piano, typing on a computer, etc.

Functions and Regulation of Hormone

Feedback mechanism regulates the action of the hormones

The glucose present in blood is broken down to produce energy required for the body. If it is present in an excess amount in the blood, then it is converted into glycogen.

How does the body know when to convert glucose into glycogen or to breakdown glycogen into glucose?

Hormones control most physiological reactions.

How is the timing and the quantity of hormones released regulated? Is there any mechanism to control the system?

The endocrine glands secrete hormones depending upon the need of the organism. The amount of hormones secreted should be in an accurate amount. The regulation of the quantity of the hormones and the timing of its release are controlled by **feedback mechanisms**.

There are two types of feedback mechanisms—**positive** and **negative** feedback.

Positive feedback: In this mechanism, the response accelerates after the feedback. The effect is further intensified in the same direction. It helps in speeding up the process occurring in various body systems. It is the opposite of negative feedback.

Negative feedback: In this mechanism, the information given by the feedback causes a reverse response. It occurs when the system needs to slow down or completely stop a process.

Illustrations to understand the two types of mechanisms

1. Child birth

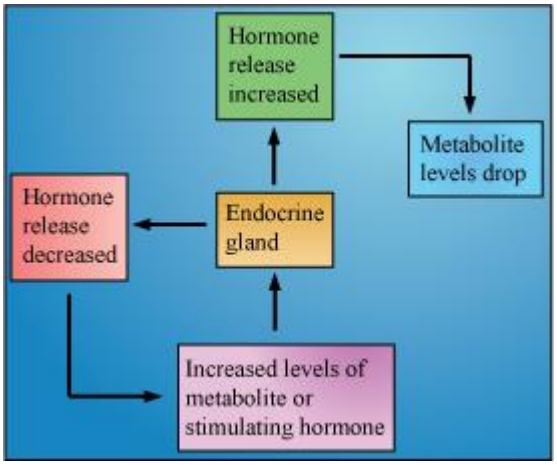
Uterine contractions occur during the onset of labour pain. These contractions stimulate the release of a specific hormone called **oxytocin** (from the pituitary gland), which intensifies the contractions. The contractions further stimulate the production of oxytocin and this cycle stops only after the birth of the baby.

This is an example of positive feedback.

2. Insulin

When you consume a carbohydrate-rich diet, it is digested into glucose. The glucose is then absorbed by the blood. This results in the increase of blood-sugar level and leads to the stimulation of the pancreas to secrete insulin. Insulin stimulates the target cells to take up the extra glucose from the blood. This glucose is either used during respiration or stored as glycogen. Thus, the level of glucose in the blood is maintained. This is an example of negative feedback.

The negative feedback loop is shown in the following illustration.



3. Thyroid Stimulating Hormone (TSH)

The negative feedback loop can also be observed in case of regulation of thyroid hormones. In this particular regulation, the hypothalamus secrete Thyroid Releasing Hormone (TRH) which stimulates anterior pituitary to produce TSH. TSH further activates the cells of thyroid glands and consequently, thyroid hormones are released in the blood. A gradual rise in the concentration of thyroid hormones serves as an inhibitory signal for hypothalamus and it stops producing TRH. In response to inhibition of TRH, TSH production is also lowered and eventually, the secretion of thyroid hormones is lowered.

Some Interesting Facts:

- **Do you know that insulin was first extracted from dog pancreas in 1921 in the University of Toronto?**

- **Human insulin (Humulin) is produced by using human genes in the bacterium called *E .coli*.**

Functions of Hormones

- To regulate the metabolic activities
- To regulate the morphogenic activities such as growth, development, etc.
- To regulate mental activities, growth maturation, reproductive activities, etc.
- To control the activities of other endocrine glands
- To maintain homeostasis

Movement in Plants

In animals, control and coordination is governed by the nervous system. However, plants do not have a nervous system.

Then, how do plants respond to stimuli?

Plants respond to stimuli by showing movement.

Have you ever seen any movement in plants?

- When you touch a sensitive plant such as *touch- me- not (Mimosa pudica)*, the plant folds its leaves and droops.

- When a seed germinates, the root grows down in the soil and the stem grows up in the air.

In the first example, touch is the stimulus and the plant responds by folding its leaves. Therefore, the plant shows movement by folding its leaves.

In the second example, the seed germinates and shows directional movement.

In the first example, movement is independent of growth i.e. there is no growth involved. However, in the second example, the movement of the seedling is caused by growth. If the seedling is prevented from growing, then it will not show any movement.

Thus, plants exhibit both growth-dependent and growth-independent movements.

Growth-independent movements

In plants (like animals), the information is carried from cells by electro-chemical means. However, there is no specialized tissue for the conduction of information. In fact, plants change their shape by changing the amount of water in them. This results in swelling and shrinking. This change of shape results in movement.

Growth-dependent movements

You must have seen plants such as peas and grapes with tendrils. Movement in these plants occurs in the growing stem of the tendrils. When the tendrils come in contact with a supporting object, they coil and cling around it. Plants respond to stimuli slowly by growing in a particular direction. This type of growth is directional.

Nastic movements in plants

Nastic movements are the movements in plants that take place in response to the environment stimulus. One of the main feature of the nastic movement is that the direction of the movement is independent of the direction of stimulus.

For example, the movement of organs like leaves and petals that are directed by the touch as in the leaflets of touch me not plant, wherein the plant droops when touched from any side.
The various kinds of nastic movements shown by plants are:

Thigmonasty:
It is the movement of a plant in reponse to an external stimuli like touch, vibration etc. For example, *Mimosa* plant responds by "folding up of leaves" when touched. The sensitive part of the plant involved in this type of movement is called pulvinus which is a soft, swollen structure present at the base of the leaf.

Photonasty:
Some plants show movement in plant part in response to the light. For example, flowers of sunflower and lotus open in morning.

Thermonasty:
It is the movement of plant parts in response to the rise and fall in temperature. For example, flower of crocus and tulip open with a rise in temperature and close with a drop in temperature.

Do You Know?

- The Venus flytrap is an insectivorous plant, in which leaves act as trap lobes?
- The movement of these lobes traps the insects. Hence, it is an example of complex movement in plants.

Tropism in Plants

Tropic movements in plants

Tropism is the response to stimuli that comes from one direction.

If the movement of the plant part is towards the stimulus, then it is known as **positive tropism**. If the movement of the plant part is away from the stimulus, then it is known as **negative tropism**.

Types of tropisms

Phototropism

The growth movement in plants in response to light stimulus is known as **phototropism**. For example, the flower head of a sunflower is positively phototropic as it moves from East to West, along with the movement of the Sun.

In the above activity, the shoots show **positive phototropism,** while the roots show **negative phototropism.**

Curiosity Corner

Why fruits like groundnuts are formed underground?

The ovary stalk of groundnut is positively phototropic before fertilization, and becomes negatively phototropic after fertilization. This is the reason why fruits like groundnuts are formed underground.

Geotropism

The growth movement in plants in response to the force of gravity is known as **geotropism**. In geotropism, the roots of the plant always grow downwards, while the shoots always grow upwards, away from the earth.

Chemotropism

The growth movement in plants in response to chemical stimuli is known as **chemotropism**. For example, the growth of pollen tube towards the ovule in the ovary (through the stigma and style) is an example of positive chemotropism.

Hydrotropism

The growth movement in plants in response to water is known as **hydrotropism**. For example, the roots of some plants grow towards the water source, even when the water source is not present directly below it.

Thigmotropism

The growth movement in plants in response to a touch stimulus or contact with a solid object is known as thigmotropism. For example, in some plants, the coiling of tendrils occurs when they come in contact with objects for support.

Plant Hormones

Phytohormones

In plants, growth, development, and response to the environment is controlled and coordinated by a special class of chemical substances known as **phytohormones**. These hormones are produced in one part of the plant body and are translocated to other parts. For example, a hormone produced in the roots is translocated to other parts where they are required.

Thus, the growth hormones of plants are known as **phytohormones.** These are naturally occurring organic substances. They are synthesized in minute quantities in one part of the plant body and are translocated to other parts where they are required.

Types of phytohormones

There are five major types of phytohormones: auxins, gibberellins, cytokinins, abscisic acid, and ethylene. These phytohormones are either growth promoters such as auxins, gibberellins, cytokinins, and ethylene, or growth inhibitors such as abscisic acid.

Auxins

When the growing parts of a phototropic plant detect sunlight, auxins (synthesized at the shoot tips) help the cells grow longer. When light falls on one side of the plant, the auxins generally diffuse towards the shaded side of the shoot. This stimulates the cells in the shaded area to grow longer than the corresponding cells of the illuminated region. This results in the curvature of the plant stem tip towards the light.

Gibberellins

They are produced in the roots of a plant. They promote stem elongation by promoting cell division in the inter-nodal region.

Cytokinins

They promote cell division. Therefore, they are present in greater concentration in those areas of the plants where rapid cell division occurs. For example, tip of the shoot.

Abscisic acid

It promotes seed dormancy by inhibiting cell growth. It is involved in the opening and closing of stomata. It is also responsible for the shedding of leaves.

Ethylene

It regulates fruit ripening. It is produced during the ripening of fruits.

Fruit ripening

Ethrel (Ethephon) liquid is sprayed on plants to facilitate fruit ripening. It contains a dilute solution of 2-chloroethylphosphonic acid, which breaks down to release ethylene. It helps in the artificial ripening of commercially grown fruits such as pineapples, mangoes, bananas etc.

How is over ripening prevented?

CO_2 in high concentration prevents over ripening of fruits as it inhibits the production of ethylene.

Do you know that a sixth category of plant hormones has been recently discovered? This new category is popularly known as steroids. Steroids are not only involved in growth, but also in the regulation of plant activities such as responses to stress, invading pathogens, etc.