Nervous System

Nervous Coordination

Do you know what the unique property of all living organisms is?

The living organisms possess the unique property of responding to the changes in the environment. This unique ability to respond the changes in the environment is called **irritability**.

Examples,

• When we touch an earthworm, it moves away.

• When a plant is placed in the shade, it grows towards the source of light.

• When a person sees a snake, he runs away from it.

In the first example, touch is a stimulus and moving away of earthworm is a response.

In the second example, source of light is a stimulus and growth of plant towards it is a response.

Similarly in the third example, a snake is a stimulus and running away from it is a response.

Thus, from the above examples, it is clear that all living organisms posses a special mechanism to identify and respond the changes in the environment (stimulus).

Do you know which organ systems have the ability to bring about this response? There are two special systems known as nervous system and endocrine system that help multicellular animals to control and coordinate various organ systems of the body and bring about the required response to the stimuli.

The organisation of these systems and the way in which various living organisms receive stimuli differs from one organism to other.

Nervous system

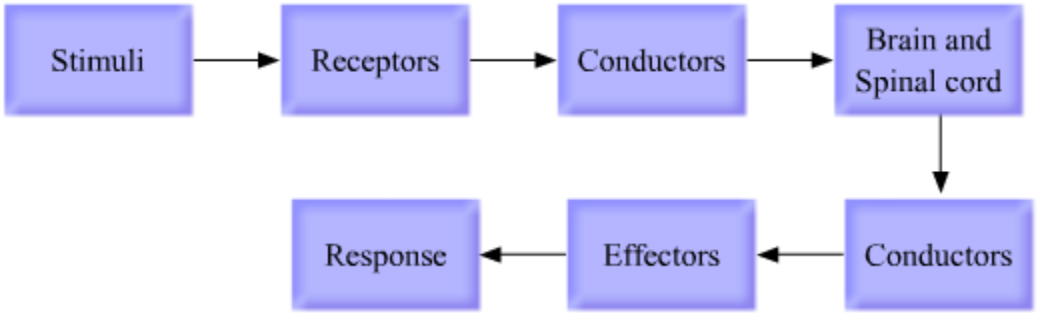
In living organisms, there are three main constituents of nervous system and these are **receptors**, **effectors** and **conductors**.

Receptors– Receptors are the structures/organs that receive **stimulus** from the environment. **Stimulus** is defined as any change in the surrounding environment that would usually result in change in the activity of our body, for example when we touch a hot object, the heat acts as a stimulus. In higher animals, the sense organs act as receptors.

Effectors are the structures/ organs that show visible response to the stimulus. **Response** may be defined as the activity of our body which is shown in response to a stimulus.

For example, on touching a hot object, we immediately withdraw our hand away from it. This withdrawing of hand is the response to the stimulus, which is heat. In higher animals, muscles and glands act as effectors.

Conductors are the tissues that connect receptors and effectors and help in conduction of stimulus to the control centre of the body (brain in higher animals). In higher animals, conductors are nerves formed by nervous tissue/nerve cells (neurons). They conduct the message to and fro in the form of impulses. **Impulse** is a wave of electrical disturbance that runs through the nerves.



Need of Nervous System

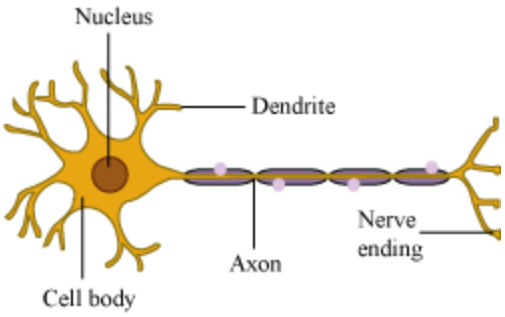
- It helps us in remembering and thinking, and making decisions.
- It keeps us informed about changes in our surrounding through sense organs.
- It controls the activities of voluntary muscles.
- It also regulates the involuntary activities of different muscles.

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**.



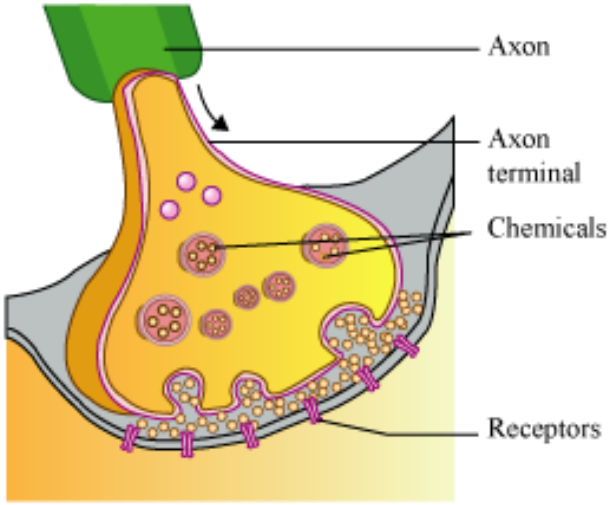
Structure of a neuron

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.

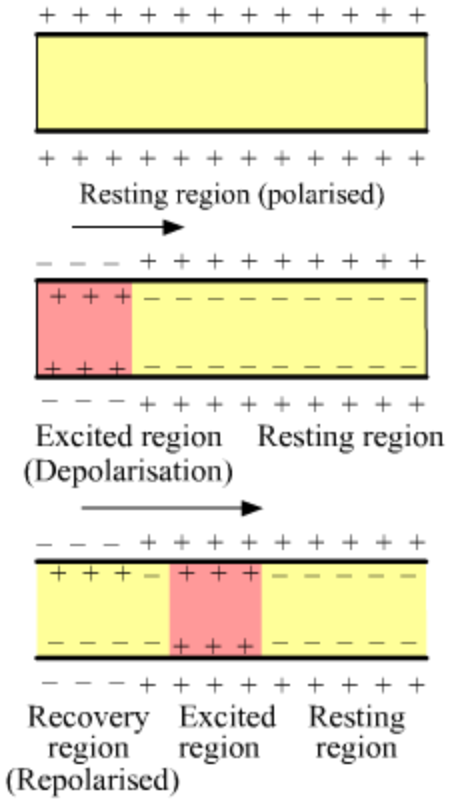
This impulse is transmitted from the dendrite to the cell body and then to the axon. From the axon, the impulse travels to its end, where the electrical impulse sets off the release of some more chemicals.

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?**

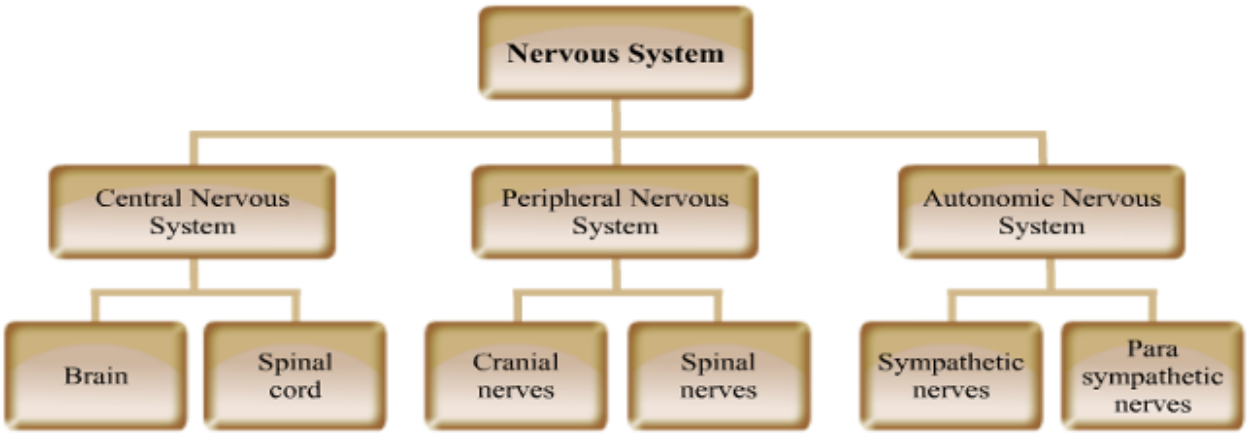
Do you know which organs make up the nervous system?

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)**.

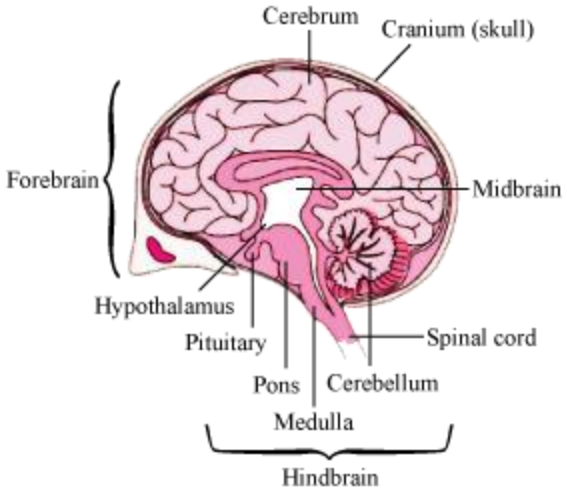
This fluid flows from the brain to spinal cord and then back to brain. It acts as a shock absorber and protects brain form injuries. It also provides nutrients to the cells in brain and spinal cord.

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

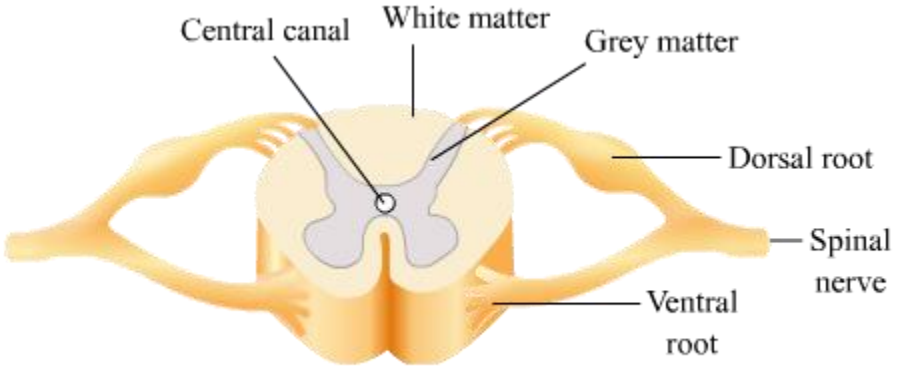
It is the continuation of the medulla oblongata and runs through the vertebral column. The spinal cord is made up of two similar halves fused together to form a central canal containing the

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.

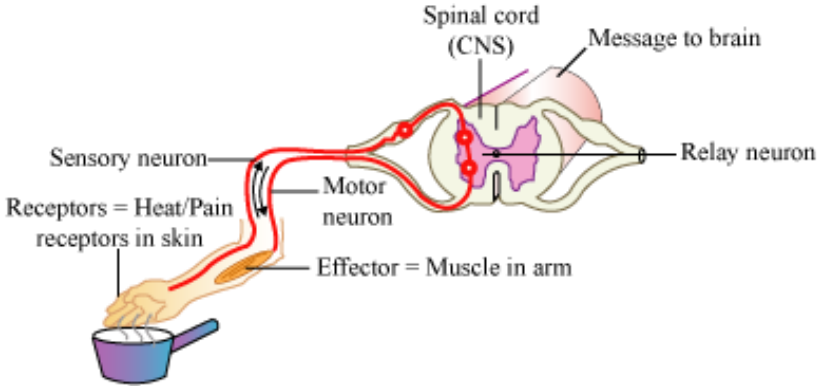
The **reflex actions**, however, show sudden responses and do not involve any thinking. This means that unlike involuntary actions, these actions are not under the control of the brain.

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.

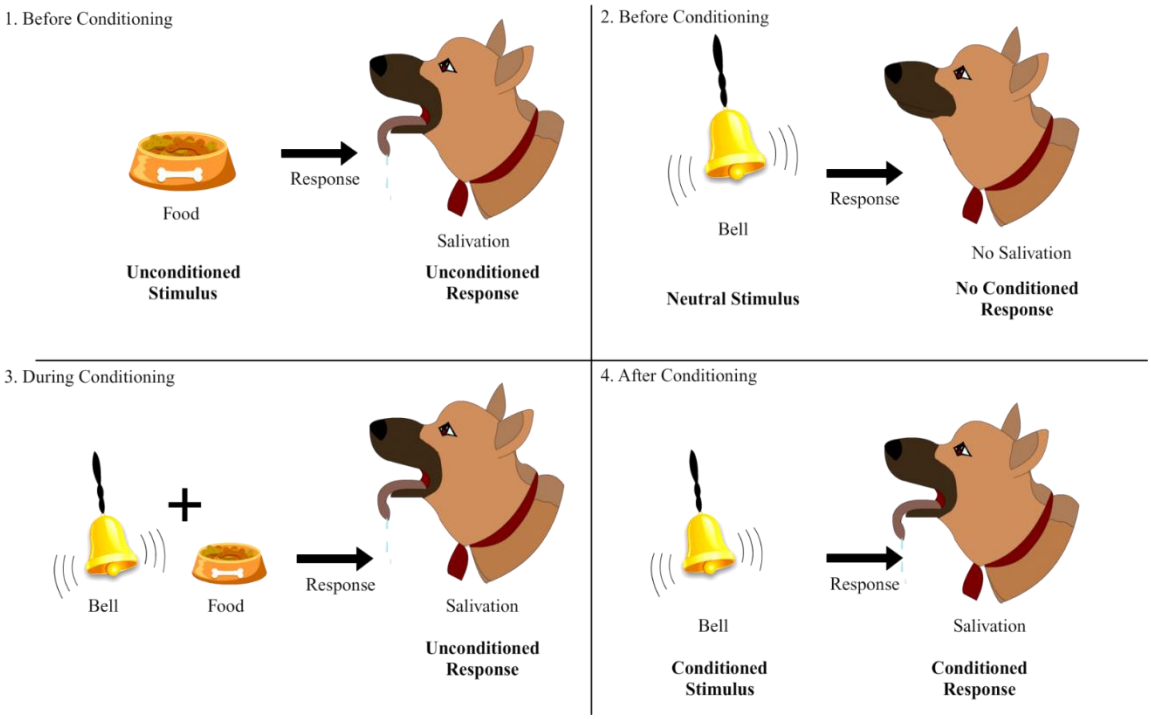
Condition Reflexes − Such responses are acquired during the life time of an individual. These responses are different for different organisms. These responses can be easily induced or lost depending upon the environmental conditions.

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.