CORDINATION AND CONTROL

Coordination is the ability of an organism to respond to changes in their internal and external environment

It also refers to linking together of all activities in the body. Coordination is carried out by two systems.

Nervous system
Endocrine system

The nervous system is a network of conducting tissue running to all parts of the body and it transmits impulses while the endocrine system is a number of glands in the body, which produce chemicals known as hormones.

Definitions of important terms

Irritability; this is the ability of an organism to detect and responds to a stimulus in the environment.

Stimulus; this is a change in the external or internal environment to which an organism responds.

Response; this is a change shown by an organism in reaction to a stimulus

Impulse; this is a nervous information transported along nerves in a nervous system.

Effectors; these are cells or organs in an organism where a response to a stimulus occurs.

Receptors; these are cells or organs that receive the stimulus and change it into a nervous impulse.

Internal environment; this is the immediate surroundings of cells. In animals the internal environment is the tissue fluid.

External environment; this is the surrounding of the entire organism.

COORDINATION AND IRRITABILITY IN PLANTS

Coordination and control in plants is carried out by hormones. Plants lack the nervous system and information is carried by hormones especially ***auxins.***

Plants do not move from one place to another. Their response involves growth movements of part of the plant and turgor changes within cells. Parts of the plant move towards or away from a stimulus due to changes in auxins concentration in the parts concerned.

Plant responses are divided into three categories.

Nastic responses.

This is the movement of part of the plant in response to a non-directional stimulus. This can be observed in the closing of the leaves of *mimosa pudica* when touched (thigmonasty)

Tactic responses

This is a type of response where the whole organism moves towards or away from a unidirectional stimulus. This response is common in lower plants such as chlamydomonas and chlorella.

3. Tropisms

This is a growth movement of part of the plant towards or away in response to a unidirectional stimulus.

Note;

Tactic responses and tropisms can be described as negative if movement is away from the stimulus or positive if the movement is towards the stimulus. The responses are of different types depending on the nature of the stimulus.

TROPISMS

This is the growth movement of the plant part in response to the direction of stimulus. The direction of response is related to stimulus and the plants move towards or away from it.

Characteristics of tropisms

It involves growth
It is a slow response
It occurs at the shoots and root tips
It is related to the direction of stimulus
It is induced by directional stimulus

Importance of tropisms to plants

It enables plants leaves to trap maximum sunlight by enabling plant shoots to grow upright.

It enables plants to become firmly anchored in the soil by the roots growing towards the ground.

It enables plant roots to absorb or obtain water which is necessary for plant growth.

It enhances fertilization in plants since the pollen tubes grow towards the chemicals of the embryo sac.

It enables climbing plants to gain support by twinning around the support.

Tropisms allow plant parts to alter direction in response to changing conditions in the environment.

TYPES OF TROPISMS

Tropisms are divided into different types depending on the nature of the stimulus.

The table below shows the name of tropism and corresponding stimulus

Name of tropism	Stimulus
1. Hydrotropism	Water

2. Thigmotropism / haptotropism	Touch
3. Chemotropism	Chemicals
4. Geotropism	Gravity
5. Phototropism	Light
6. Aerotropism	Air

Hydrotropism; this is the growth movement of part of a plant towards or away from water.

Thigmotropism; this is the growth movement of part of a plant in response to touch.

Chemotropism; this is the growth movement of part of the plant towards or away from a particular chemical e.g. pollen tube grows towards the embryo sac through the style during fertilization by responding to the source of chemicals produced by the embryo sac.

Geotropism; this is the growth movement of part of the plant in response to gravity.

Aerotropism; this is the growth movement of part of the plant towards or away from air.

The table below shows some of the tropic movements shown by plants

Type of tropism	**Stimulus**	**Positive response**	**Negative response**
Phototropism	Light	Shoot	Root
Geotropism	Gravity	Root	Shoot
Hydrotropism	Water	Roots	Shoots
Chemotropism	Chemicals	Pollen tube	-
Thigmotropism	Touch	Tendrils of passion fruits	Root tips when in contact with an obstacle

PHOTOTROPISM

This is the growth movement of part of the plant in response to unidirectional light. Plant shoots are positively phototropic that is, they grow towards the direction of light while the roots are negatively phototropic (they grow away from the direction of light).

AUXINS AND PHOTOTROPISM

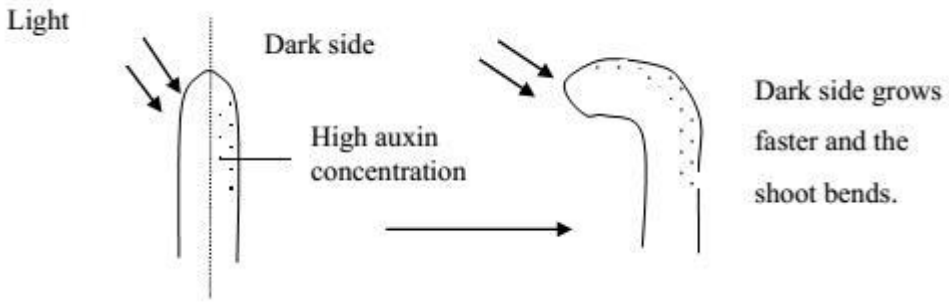
Light from one direction of the shoot causes auxins on that side to escape to the opposite side without light.

The side without light receives more auxins than one receiving more light.

A high concentration of auxins on the side with little or no light increases the rate of cell division and elongation on that side.

This causes the shoot to bend towards the direction of light (positive phototropism)

Illustration



However, high auxins concentration limits growth in plant roots

EXPERIMENT TO SHOW THE EFFECT OF UNIDIRECTIONAL LIGHT ON GROWTH OF THE PLANT SHOOT

Materials

2 Potted plants, 2 opaque boxes, klinostat and Razor blade

Procedure

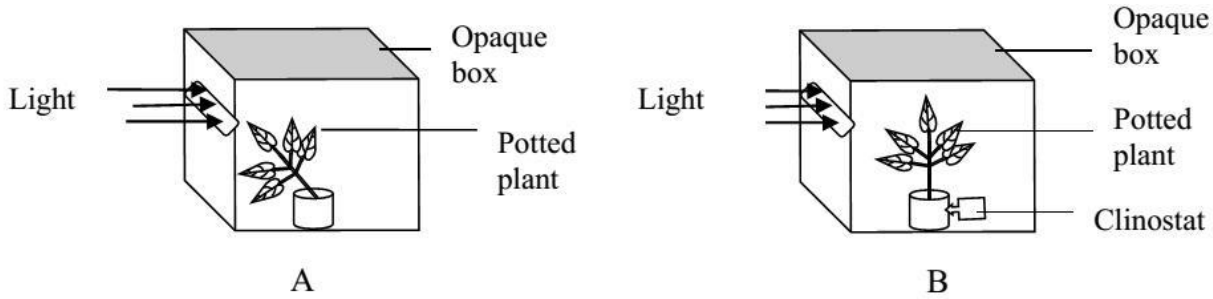
Get two opaque boxes and using a razor blade cut a small hole on one side of each.

Get two potted plants of equivalent size.

Place one in box A and another in box B but fixed on a klinostat to serve as the control experiment. Place both boxes in light and start the klinostat to rotate the plant in box B.

Leave the experiment for 3-4 days.

Setup



Observation:

The shoot in A bent towards the direction of light while that in B continued to grow straight.

Explanation:

Light coming from one direction in A made the stationary shoot to bend towards the direction of light. Because the shoot in B was rotating on a clinostat all of its sides received equal amounts of light and there was no effect on growth.

Conclusion:

The shoot responds positively towards light.

PHOTOPERIODISM

This is the response of an organism mainly plants to the relative length of light and dark periods. It mainly affects the production of flowering hormone florigen.

Some plants need a relatively longer period of light for flowering. Such plants have a rich vegetative growth if the light period is long. (long day plants)

Some plants need a short period of light of flowering e.g. tomatoes, such plants have a rich vegetative growth if the light period is short (short day plants)

Duration of light has no effect on some plants e.g. sun flower in any season (day neutral plants)

Due to the above facts, particular plants are grown in particular seasons.

GEOTROPISM

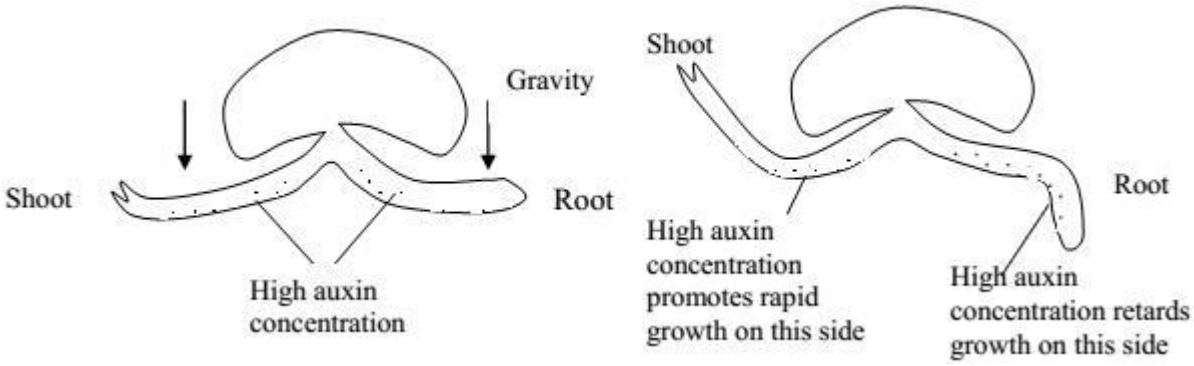
This is the growth movement of the plant part in response to the direction of the force of gravity. Roots grow towards the direction of force of gravity hence positive geotropism.

AUXINS AND GEOTROPISM

When a shoot is placed horizontally on the surface, auxins move in response to the gravitational force to the lower side. Cell division and elongation takes place more on the lower side than the upper side. This makes the shoot to bend upwards away from the gravitational pull (negative geotropism)

In the root, a higher concentration of auxins on the lower side reduces the rate of cell division and elongation in the root. The upper side grows faster than the lower side causing the root to bend in the direction of the gravitational force (positive geotropism)

Illustration:



EXPERIMENT TO DEMONSTRATE GEOTROPISM IN PLANT ROOTS (THE EFFECT OF GRAVITY ON ROOTS)

Materials

Cotton wool, Seeds, Petridishes, Water, clinostat, Plasticin

Procedure

Place seeds in two petridishes and cover them with moist cotton wool.

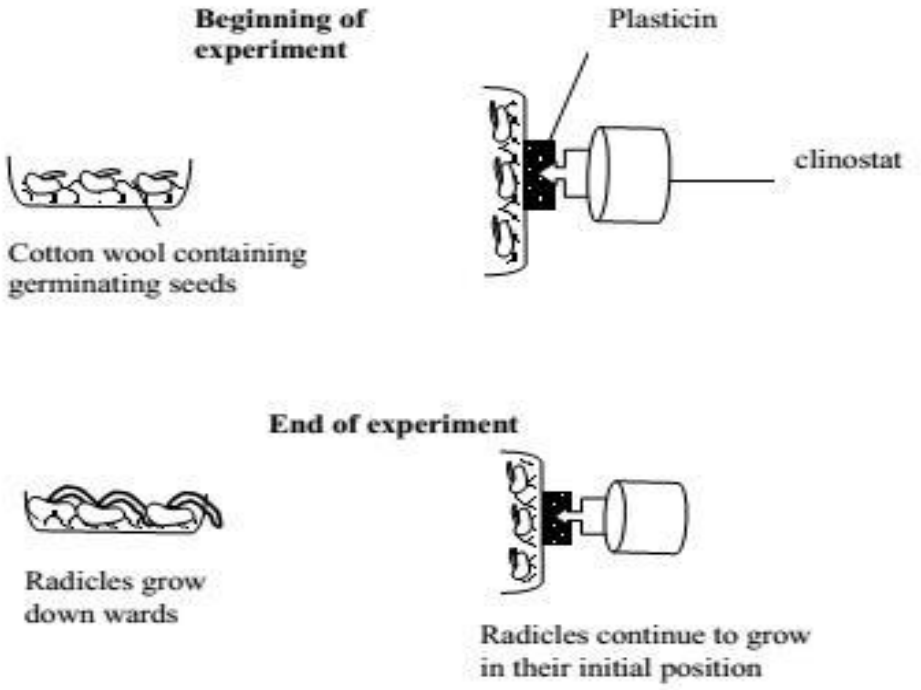
Leave the seeds for about 3 days to develop radicles.

Place one petridish in plasticin perpendicular to the ground making the radicles horizontal to the surface.

Place another petridish on a clinostat and make its radicles horizontal to the ground.

Start the clinostat to rotate such that all sides of the radicles receive the same gravitational pull.

Setup:



Observation:

The radicles in setup A bent downwards and those in B continued to grow horizontally.

Conclusion:

Roots are positively geotropic.

HYDROTROPISM

This is the growth movement of a plant and part in response to a unilateral source of water. The roots grow towards the source of water hence show positive hydrotropism. The shoots grow away from the source hence negatively hydrotropic.

EXPERIMENT TO SHOW HYDROTROPISM IN ROOTS

Materials:

Wire gauze
Water
Seedlings
Trough
Anhydrous $CaCl_2$

Procedure:

Place wire gauze horizontally above a trough containing water.

Place moisture cotton wool on the trough leaving some spaces through which the radicle can pass.

Place germinating seedlings on cotton wool.

For the control set up a similar experiment but with a trough containing anhydrous $CaCl_2$ instead of water.

Leave the experiment for 3 days.

Experimental set up

Observation:

In A, the radicle grow towards water while in B, they curve away from dry air.

Conclusion:

Roots positively respond to water i.e. positively hydrotropic.

Explanation:

The calcium chloride absorbs moisture from the bottom of the trough. The upper part of the trough remains moist hence the radicle bend upwards towards the moisture.

NOTE:

Consider the demonstration of hydrotropism below.

The empty porous pot was put in a dish containing moist saw dust. After elongation of the radicles, watering of the saw dust stopped and instead water is poured in the porous pot.

The experiment is then left to stand for 4 days.

Setup:

The control experiment for the above experiment is set up as above but without water in the porous pot.

Observation:

Where water was poured in the porous pot, the radicles grew towards the pot unlike in the control experiment.

Conclusion:

Roots (radicles) are positively hydrotropic.

CONTROL OF RESPONSES IN PLANTS

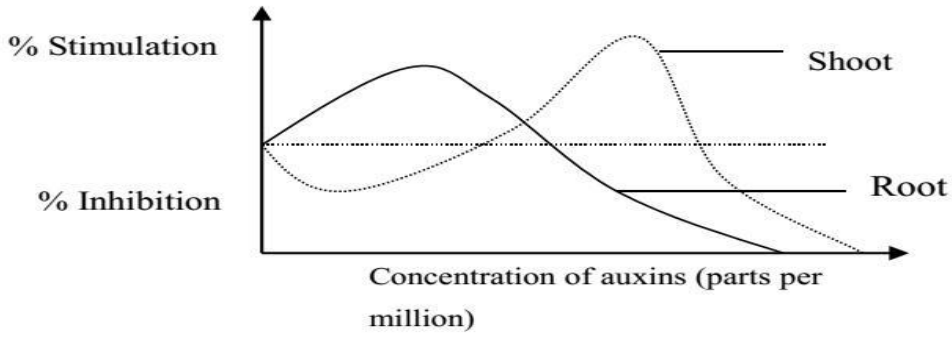
Responses in plants are controlled by a group of plant hormones especially auxins. These auxins are produced at the root and shoot tip and are transported in the phloem together with manufactured food.

Auxins control responses by controlling growth through stimulation of cell elongation. High auxins concentration stimulates faster growth in shoots and inhibits growth in roots.

Light affects the distribution of auxins. When the shoot tip is illuminated from one side, auxins diffuse to the dark side there by causing faster growth on the dark side becomes longer than the illuminated side. This causes the shoot to bend towards light.

Gravity also affects the distribution of auxins. If a seedling is lying horizontally, more auxins will diffuse on the lower side of the root and shoot due to gravity. In roots, the high concentration of auxins inhibits growth causing the lower side to grow slowly, while the upper side grows faster. This results in the roots bending towards gravity.

Graph showing the effect of auxins concentration on the growth of roots and shoots.



When the concentration of auxins increases, growth in the shoot also increases to a maximum beyond which, further increase in auxins concentration inhibit growth in shoots. Growth response in the root decreases with increase in auxin concentration.

Importance of auxins

Causes apical dominancy
Leads to parthenocarpy
Causes tropism
Causes rooting of the stem cutting.

PLANT GROWTH SUBSTANCES

1. Indole Ascetic Acid (IAA)

It is a naturally occurring growth substance in higher plants. It influences cell elongation and root initiation. It has a powerful effect on growth. It also brings about development of parthenocarpic fruits. It also checks formation of branches from side buds. If IAA is applied to the cut end of the main stem, the side buds don't develop into branches.

2. Gibberellins

They are produced by plants in varying amounts in seeds and young plants. If a solution of gibberellins is sprayed on a plant, it increases the water absorbing capacity of the cells. Gibberellins also contribute to flowering and growth of fruits.

3. Cytokinins

These promote cell division but only in the presence of auxins. They are also synthetic chemical compounds which are used for promoting or controlling growth. Some are used in killing weeds.

EXPERIMENTS TO SHOW THAT AUXINS ARE RESPONSIBLE FOR GROWTH

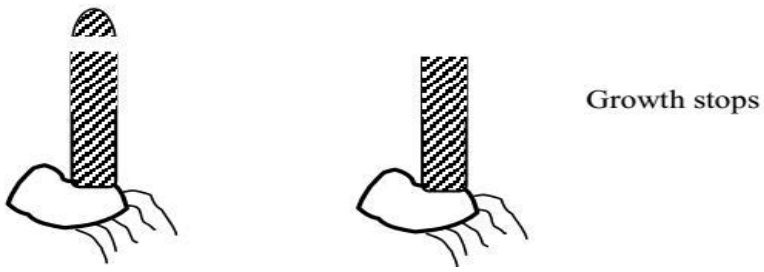
Materials

Coleoptiles (plant seedling)
Razor blade

Procedure

Using a razor blade cut off the tip of the coleoptile and leave it to stand for 3-6 days.

Setup



Observations

Growth stops taking place.

Explanation

The coleoptile tip produces new cells by cell division and it also produces a growth-promoting chemical. When the tip is cut off, growth stops.

EXPERIMENT TO SHOW THAT AUXINS ARE DIFFUSABLE SUBSTANCES

Tips of shoots are removed and then placed on an agar block.

Tips are then discarded or thrown away and the agar blocks placed on the decapitated shoot.

It is observed that growth continues.

If auxins are prevented from diffusing to the lower side by a razor blade or a mica plate curvature growth occurs. The shoot grows towards the side of the razor blade or the mica plate.

This is because the razor blade blocks the movement of auxins on that side therefore the side without the block grows faster than the side with the blade.

EXPERIMENT TO SHOW THAT CUTTING OFF THE COLEOPTILE ALONE DOES NOT STOP GROWTH

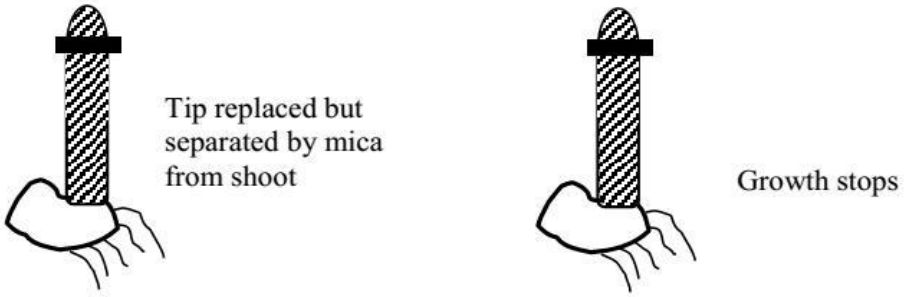
Materials

Coleoptile, Razor blade and Mica

Procedure

Using a razor blade cut off the tip of the coleoptile. Place a piece of mica on the cut surface of the shoot and replace the tip

Setup



Observation:

No growth takes place

Explanation:

Mica prevents both cells and auxins from getting down to the shoot.

EXPERIMENT TO SHOW THAT AUXINS OTHER THAN THE CELLS ARE RESPONSIBLE FOR GROWTH

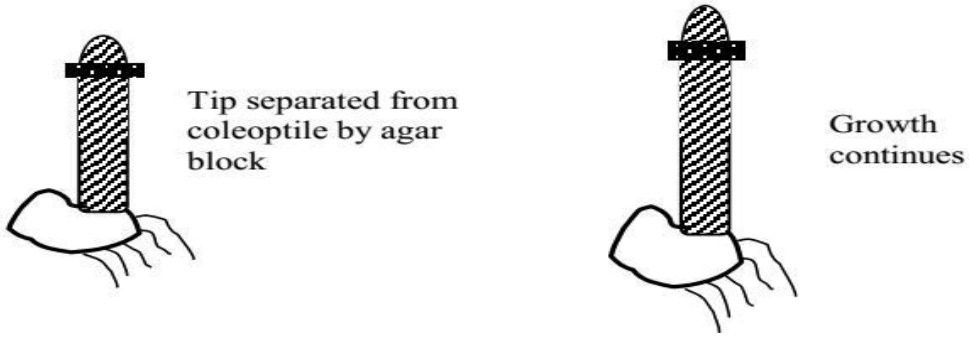
Materials:

Agar block, Coleoptile and Razor blade

Procedure:

Cut off the tip of the coleoptile using a razor blade. Place back the tip but separated from the coleoptile by the agar block.

Setup:



Observation:

Growth continued

Explanation:

This shows that auxins were able to diffuse from the tip to the coleoptile through the agar block whereas the agar block cannot allow cells to pass through.

EXPERIMENT TO INVESTIGATE THE EFFECT OF AUXIN DISTRIBUTION ON PLANT GROWTH

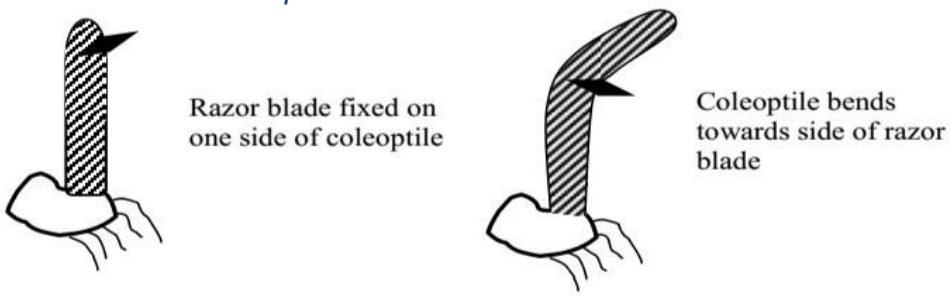
Materials:

Coleoptile and Razor blade

Procedure:

Insert a razor blade on one side of the coleoptile tip and leave it to grow.

Setup



Observation:

The coleoptile continues to grow bending towards the side with the razor blade.

Conclusion:

The side without a razor blade grows faster than the one with a razor blade causing the coleoptile to bend towards the side with a razor blade.

Explanation:

In equal illumination, auxins are equally distributed in the shoot. The insertion of a razor blade on one side prevents auxins from moving down on that side. Unequal distribution of auxins causes uneven growth of the shoot.

EXPERIMENT TO SHOW THAT UNEQUAL AUXIN DISTRIBUTION IS RESPONSIBLE FOR BENDING

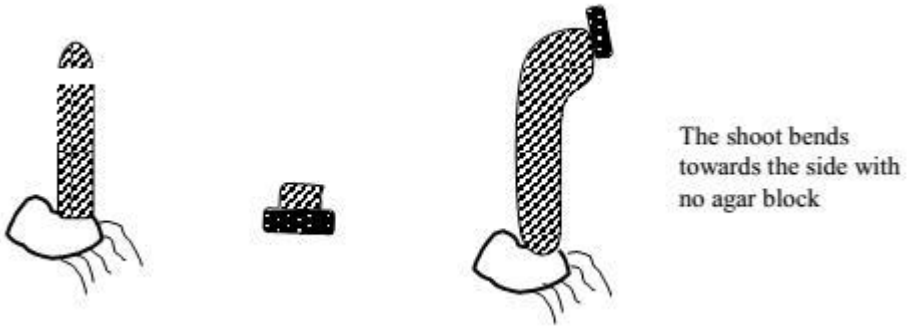
Materials

Agar block, Coleoptile and Razor blade

Procedure

Using a razor blade cut the coleoptile tip and place it on a piece of agar for 1 hour for auxins to penetrate it. Place the agar block on one side of the cut end of the shoot. Leave the experiment for 3-4 days.

Setup



Observation

The shoot bends to the side with no agar block

Conclusion

Unequal distribution of auxins is responsible for unequal growth of the plant shoot.

Explanation

The auxins diffuse from the agar into the side of the shoot where the agar is placed. This causes the cells on that side to divide and elongate faster causing the shoot to bend.

EXPERIMENT TO FIND OUT THE REGION OF ELONGATION IN A ROOT

Materials:

- Water
- Ink
- Cock
- Seedlings
- Conical flask
- Dark cup board
- Pin

Procedure:

Take bean seedlings with straight radicles.
On each seedling mark the radicle every 2mm with lines in black ink.
Pin the seedlings to the other side of the cork with the radicles hanging down wards.
Insert the cork into the neck of the flask containing little water.
Put the flask in the dark cup board for 3-4 days.

Experimental set up:

Observation:

Some lines on the radicle are 2mm apart while others are more than 2mm apart.

Conclusion:

The region where the lines are further apart is the zone of elongation (region of growth).

TACTIC RESPONSE (TAXIS)

This is the movement of whole organism or cell from one place to another in response to a directional stimulus.

It is a positive tactic response when the whole organism moves towards the stimulus and negative tactic when the organism moves away from the stimulus.

Types of taxis

Phototaxis in response to light
Chemotaxis in response to chemicals
Thigmotaxis in response to touch
Geotaxis in response to gravity

Examples of taxis

Unicellular organisms e.g. Euglena swim towards light hence positively tactic (phototactic)

Earth worms, wood lice and cockroaches move away from light hence negative phototactic.

Sperms swim towards the chemical produced by the ovum hence positively chemotactic.

White blood cell moves towards harmful bacteria in the body hence positively chemotactic.

NASTIC RESPONSE (NASTIC)

This is the movement of a plant part in response to a non-directional stimulus or it is a response in which plants are not related to the direction of stimulus but to its intensity.

Nastic response are named depending on the type of stimulus i.e. Photonasty if the stimulus is light.

Hydronasty if the stimulus is water
Thigmonastic if the stimulus is touch
Lastic movements do not involve growth.

Characteristics of nastic

It involves changes of turgidity of plant cells.
It is a rapid response.
It occurs in any part of a plant
The response is not related to the direction of the stimulus
It is induced by non-directional stimulus.

Examples of nastic response

Opening and closing of flowers in response to light e.g. morning glory.
Sudden closer of leaf lets of mimosa pudica in response to touch.
Closures of leaves of insectivorous plants e.g. butter walt and pitcher plant where the insect lands on the leaf. Such plants are found in nitrogen deficient soil.

Similarities between nastic and tropic movement

Both are brought about by external stimulus.
Both occur in plants
Both involves movement of plant parts.

Differences between tropisms and nastic responses

Nastic response	Tropism
i) Does not depend on the direction of the stimulus.	It depends on the direction of the stimulus
ii) It occurs in any part of the plant.	It occurs in growing tips of plants
iii) It does not involve auxins	It involves auxins
iv) Are usually faster	Are usually slower
v) It involve growth and turgor changes	It involves growth only.

CO-ORDINATION IN ANIMALS

All living organisms are sensitive to changes taking place within their surroundings. They detect the changes (stimuli) and respond to them appropriately. The ability of an animal's body to detect and respond appropriately to stimuli depends on the nervous system and endocrine system.

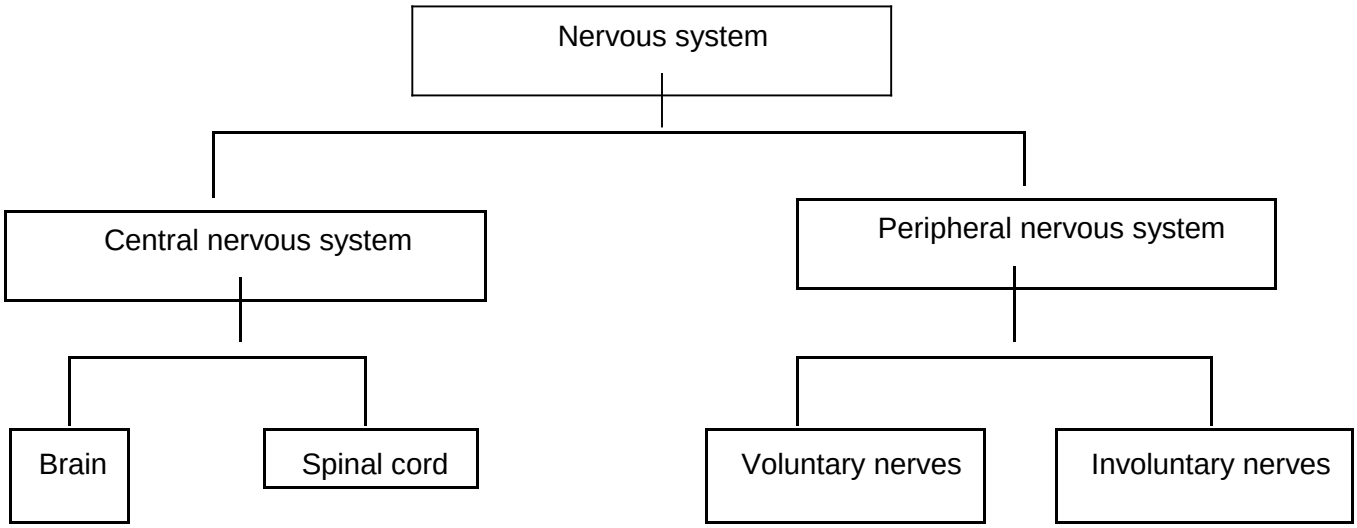
The stimuli may be within an animal's body or in its surrounding. Different parts of the body of an animal do not work independently of each other. They depend upon one another performing various functions as a single unit. The nervous system controls all the organs and makes them to work together.

THE NERVOUS SYSTEM

This is a system of nerve cells and sensory organs that carry out co-ordination by transfer of impulses.

+

COMPONENTS OF THE NERVOUS SYSTEM



The nervous system consists of;

Receptors:

These detect the stimuli e.g. sensory endings in the skin, eye and ear.

The central nervous system (CNS)

This interprets and determines the nature of the response. The CNS consists of the brain and spinal cord.

Peripheral nervous system

This consists of voluntary and involuntary nerves. **iv) Effectors**

These are organs that carry out the response.

Functions of the nervous system

It receives impulses from all sensory organs of the body.
It stores information
It correlates various stimuli from different sensory organs
It sends messages to all parts of the body making them function accordingly.
It's involved in temperature regulation.

The nervous system is made up of cells called neurons. A neuron is a functional unit cell of the nervous system that transmits an impulse or an electrical message.

STRUCTURE OF THE NEURONE

A neuron is made up of a small mass of cytoplasm, a nucleus in a structure called the cell body, branching cytoplasmic filaments called dendrites and a single long fiber called axon.

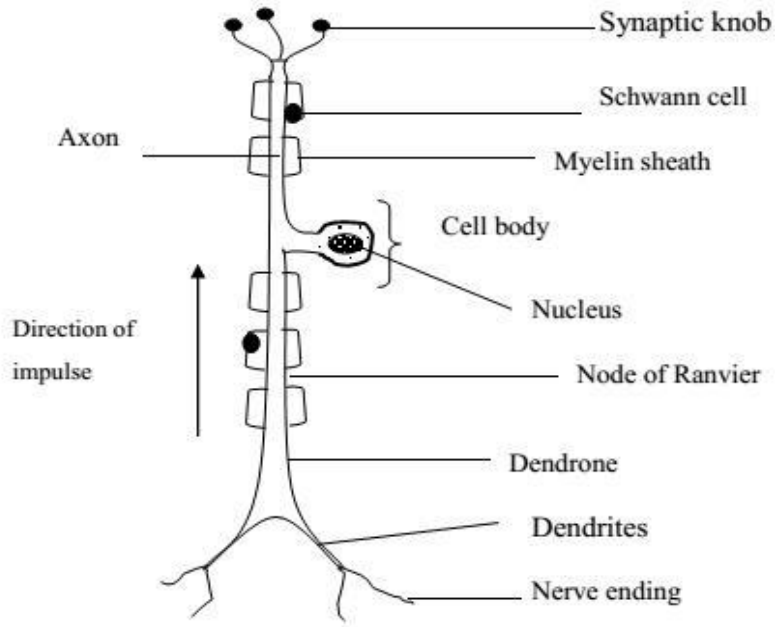
There are three types of neurons.

Sensory neuron
Motor neuron
Interneuron (relay neuron)

SENSORY NEURON

These are neurons that transport impulses from the receptors to the central nervous system. A sensory neuron has a single elongated dendrite called a dendron consisting of a fluid filled cytoplasmic tube. It has a cell body in the middle of a short axon and dendron. It is sometimes surrounded with myelin sheath. The myelin sheath increases the speed of the impulse in the neuron.

Structure of the sensory neuron



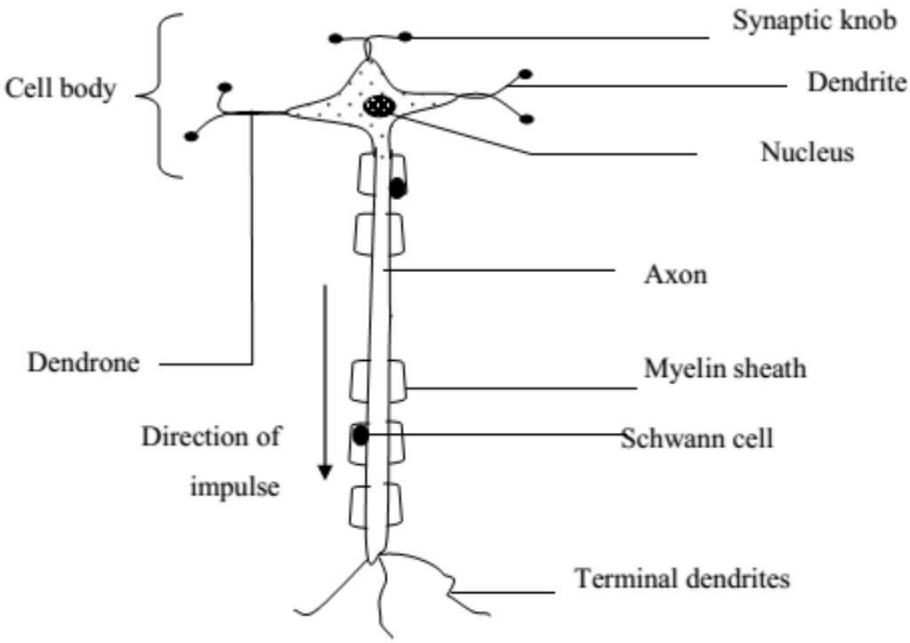
Characteristics of a sensory neuron

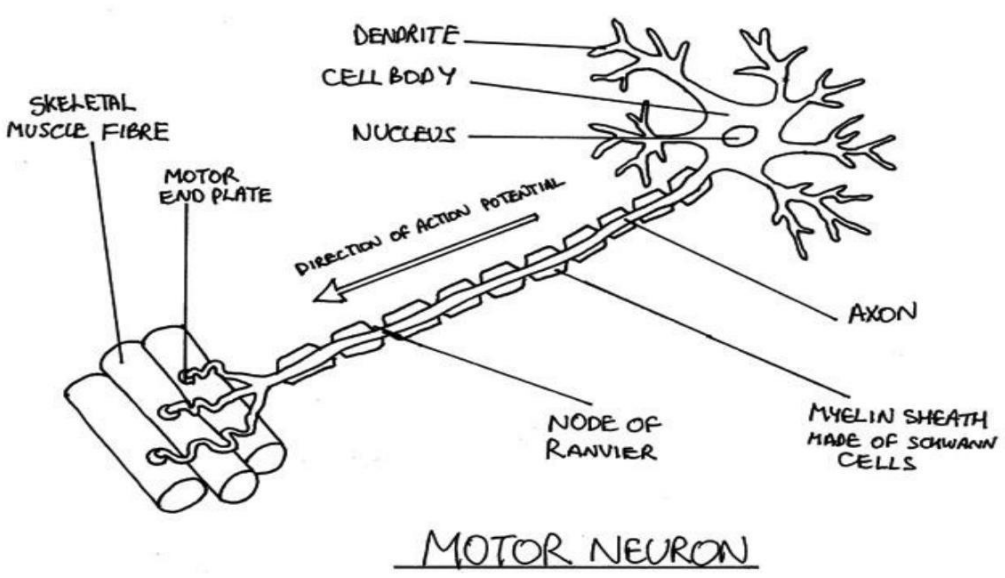
It has a cell body as a branch on the axil.
It has one dendron
The axon and dendron may be covered with myelin sheath.
The myelin sheath is broken at points called nodes of Ranvier.
It has a short axon
It has a long dendron
The terminal branches are embedded in the receptor.

THE MOTOR NEURONE

This is a neuron that carries impulses from the central nervous system to the effectors. Motor neurons consist of short dendrites with a cell body at one end of a long axon. It is also sometimes surrounded by the myelin sheath.

Structure of the motor neuron





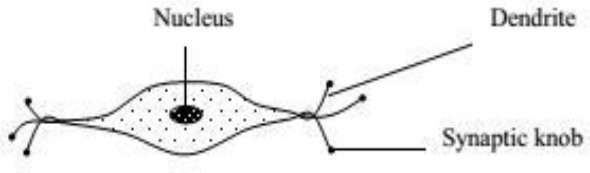
Characteristics of motor neuron

At one end there is a thick part called the cell body which contains the nucleus and cytoplasm.
The cell body has dendrones which branch into dendrites.
From the cell body is a long fibre called axon.
The axon may be covered with myelin sheath.
The myelin sheath is broken at points called nodes of Ranvier.
The axon ends in branching terminals or end branch.
It has many dendrones
The terminal branches are connected to an effector.
It has a short dendron

THE INTERNEURONE (RELAY NEURON)

This is a neuron found in the central nervous system and carries impulses from the sensory neuron to the motor neuron.

Structure of the relay neuron



Characteristics of relay neuron

Its fibres are not insulated i.e. have no myelin sheath.
Its cell body is in the middle of the fiber.

General functions of the parts of a neuron

Cell body; this consists of a nucleus surrounded by a mass of cytoplasm. The nucleus controls all activities of the neuron.

Axon; this is one or more long cytoplasmic extensions running from the cell body. Axons carry impulses over long distances in the body. Each axon is filled with cytoplasm called **axoplasm**.

Myelin sheath; this is a fatty material that covers the axon. The myelin sheath is secreted by cells called **Schwann cells**. The myelin sheath insulates the axon and speeds up transmission of impulses.

Dendrites; these are fine structures on the neuron that link up nerve cells to form a complex network of communication.

Schwann cell; this is a cell which secretes the myelin sheath.

Node of Ranvier; this is the space on the axon between two adjacent myelin sheaths. It speeds up nervous transmission.

Cytoplasm; this is a site for chemical reactions in the neuron.

Dendrone; it is a branch through which impulses are transmitted to the body.

Comparison between motor and sensory neurons

Similarities:

They both transmit impulses.
They both have a nucleus.
They both have an axon, dendrites and cytoplasm.
In both impulses move in one direction.

Differences:

Motor neuron	Sensory neuron
i) Has a long axon	Has a short axon
ii) It has a cell body at the terminal end of the axon	Has a cell body located on the axon branch.
iii) It has a short dendron	It has a long dendron
iv) It carries impulses from the central nervous system to the effectors	It carries impulses from the receptors to the central nervous system.
v) It has several dendrones	It has one dendron
vi) Terminal dendrites connect with effectors	Terminal dendrites connect to interneurons.

THE NERVE IMPULSE

An impulse is an electric message transmitted along the nerve fibres. It moves very fast as ions. The nerve impulse is initiated by stimulation of receptors by a given stimulus e.g. light, sound etc. the stimulus causes enough stimulation to a point that triggers off an impulse called the threshold level. If the stimulation does not reach the threshold, no impulse is formed and that stimulus is not detected.

TRANSMISSION OF AN IMPULSE

When a stimulus reaches a receptor cell, it generates an impulse which is passed to the cell body of a neuron. The impulse is then transmitted from one the dendrites of another neuron via a gap called the ***synapse***.

The arrival of an impulse at the end of an axon triggers the release of the transmitter substance into the synapse. This diffuses across the gap and stimulates the dendrites of an adjacent neuron to form an impulse hence the impulse being passed on.

After the passage of an impulse across the synapse, the transmitter substance is destroyed and a new one is made within the axon.

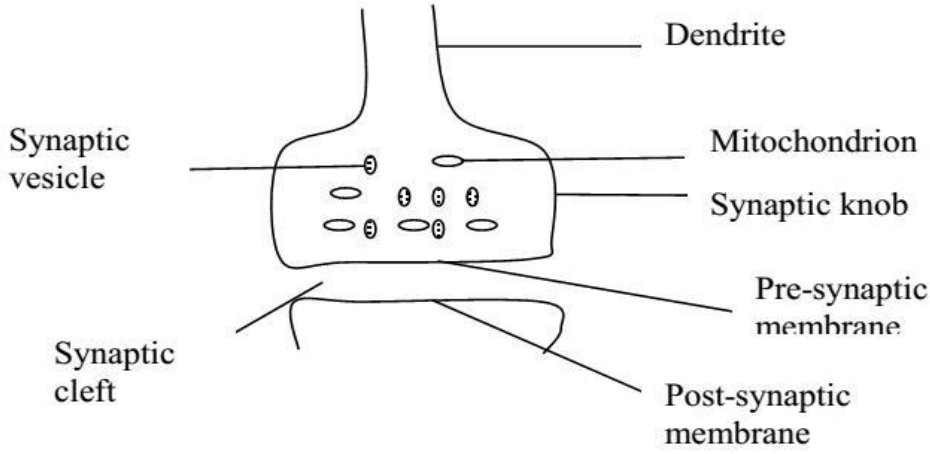
The mechanism ensures that an impulse travels only in one direction across a synapse.

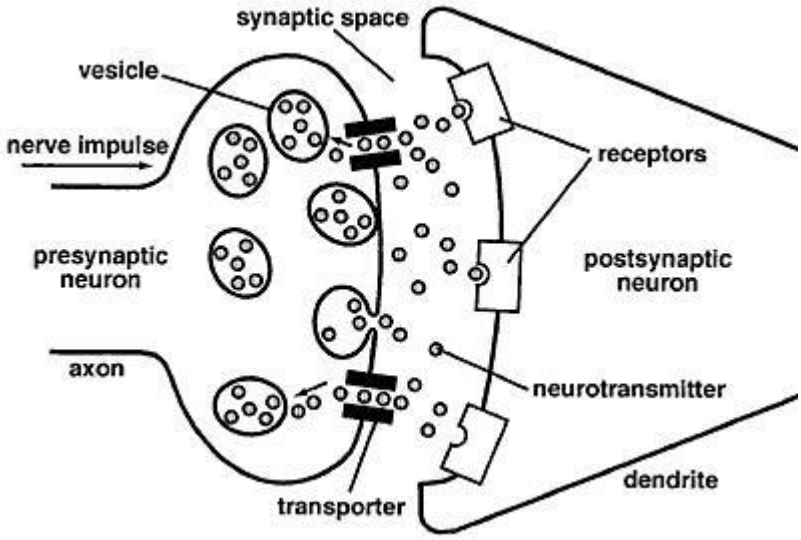
THE SYNAPSE

A synapse is a junction or space between the terminals of two adjacent neurons. This junction links the dendrites of one neuron to the dendrites of another adjacent neuron. Movement of impulses across the synapse occurs by secretion

of a chemical called a transmitter chemical in the space known as the synaptic cleft.

Structure of a synapse





A single impulse may fail to get across the synapse and it may require two or more impulses arriving quickly in succession (one after the other); ***temporal*** or

simultaneously (at the same time) from two or more neurons. This is termed as **summation**.

Sometimes inhibitory chemicals are secreted into the synapse and when an impulse comes, it gets blocked. This is referred to as **inhibition**.

Functions of the synapse

It enables propagation (movement) of an impulse from one neuron to another.

It ensures that an impulse moves in one direction by having vesicles on one side of the synapse.

The synapse acts as a junction in the nervous system that can diverge, or converge information.

It prevents continuous stimulation of body organs.

PARTS OF THE NERVOUS SYSTEM

THE CENTRAL NERVOUS SYSTEM

This is made up of the brain and spinal cord.

THE BRAIN

Structure of the brain

The brain is covered and protected externally by the skull (cranium) and internally by membranes called meninges.

Functions of the brain

It receives impulses from all receptors and sends back impulses to the effectors.

It integrates and coordinates all activities in the body such that the body works efficiently.

It stores information.

It is involved in cranial reflex actions but it does not initiate them.

The brain is divided into three major regions, that is;

1. Fore brain

Mid brain
Hind brain

The fore brain

It consists of:

i) The cerebrum (cerebral hemisphere)

This is the largest part of the brain.

It is made up of 2 hemispheres i.e. the left and the right cerebral hemispheres. The right hemisphere controls the activities of the left side of the body while the left hemisphere controls the activities of the right side of the body. The 2 hemispheres are joined by a fibre known as ***corpus collosum*.**

It controls all voluntary activities

It is a center of memory and reasoning.

It receives impulses from the sense organ of smell, touch, sight, taste and sound.

The olfactory lobes:

These are paired lobes located ventrally at the base of the cerebrum.

They are small in size. They receive impulses from the olfactory nerves bringing about the sense of smell.

2. The mid brain

It consists of:

Thalamus

It integrates sensory impulses from the eyes, skin and ear and sends them to the cerebral cortex of the cerebrum.

It also directs impulses from all parts of the body to particular areas of the brain.

Hypothalamus

It is a centre of many activities. It is below the thalamus.

It controls involuntary activities e.g. water and salt balance (osmoregulation)

Controls body temperature, CO_2, levels in blood, appetite, sleep, hunger, wakefulness, sex drive and produces hormones e.g. oxytocin and ADH which are stored in the pituitary gland.

Pituitary gland

It secretes a number of hormones like the thyroid stimulating hormone, FSH, LH, ADH, etc. which control various activities.

It also controls other endocrine glands in the body thus called the ***master gland.***

Optic lobes

These are paired lobes. Their main function is to interpret sight.

3. Hind brain

It is made up of:

Cerebellum

This is concerned with maintenance of balance, locomotion and posture. It receives impulses from the skeletal muscles.

Medulla oblongata

This controls involuntary actions like yawning, vomiting, blinking of the eye, etc. any injury to this region leads to instant death.

THE SPINAL CORD

This is part of the central nervous system that runs from the brain to the tail through and covered by the vertebral column.

Functions of the spinal cord

It connects the peripheral nervous system to the brain.
It is a center for simple spinal reflex actions
Receives impulses from receptors
Interprets messages especially in reflex arc
Sends impulses to the receptors.

VOLUNTARY AND INVOLUNTARY ACTIONS

The nervous system controls several actions in the body. Such actions may be voluntary or involuntary.

A voluntary action *is one initiated consciously under the direct control of the brain i.e. they are actions one at will e.g. dancing, laughing, stealing, etc.* These actions are performed consciously by an animal. In such actions the animal chooses to do or not to do something.

Involuntary actions *are the ones that occur without conscious thoughts e.g. breathing, etc.*

THE REFLEX ACTION

This is a rapid automatic response of an organism, which is not initiated by the brain. Reflex actions take place without the awareness of the individual. A

reflex action occurs as a result of impulses travelling along neurons in a path called a reflex arc.

Characteristics of a reflex action

It occurs rapidly i.e. The action occurs very fast.
It is inborn (innate) but not learnt.
It is co-ordinated by either the brain or spinal cord but usually initiated by spinal cord.
It occurs without one's will.
It is a repeated response to a similar stimulus.
Three neurons are involved.

Examples of reflex actions

Blinking when a foreign body falls on the eye
Withdraw of the arm when someone accidentally touches a hot body.
Sneezing
Knee jerk i.e. a relaxed leg gives a forward kick when tapped slightly below the patella.
With draw of the foot from a sharp object.

Example of a simple reflex action

When one accidentally touches a hot body using a finger, the receptors in the finger receive the stimulus and change it into nervous impulses that travel along the sensory neuron to the spinal cord and then cross the synapse.

The impulse is then handed over to the relay neuron in the spinal cord (gray matter) and then cross another synapse.

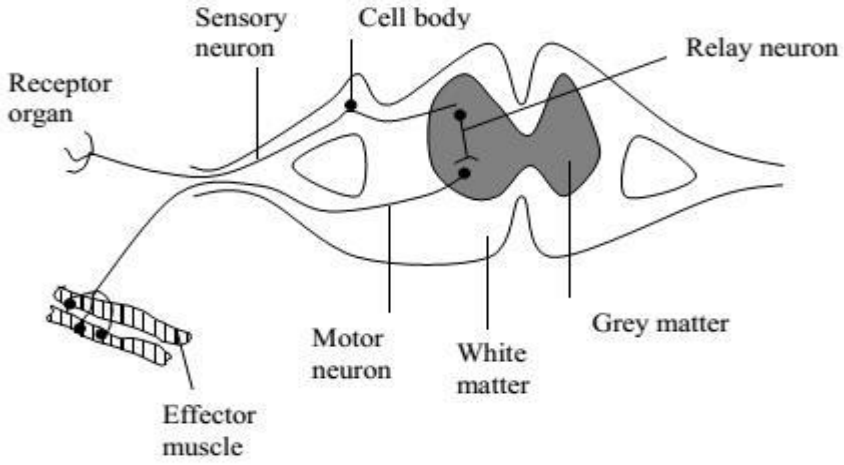
The relay neuron in turn hands over the impulse to the motor neuron.

The motor neuron then carries the impulse from the spinal cord to the effector muscles of the hand. This causes the muscles to contract and the hand is removed from the hot body.

At the same time, the original message is sent to the brain which then interprets it as pain or heat.

Note; these processes occur rapidly in the body without the awareness of the individual

Illustration



Advantages of reflex actions to animals

They help animals to avoid danger.

They control activities in the body, which we do not have conscious control over.

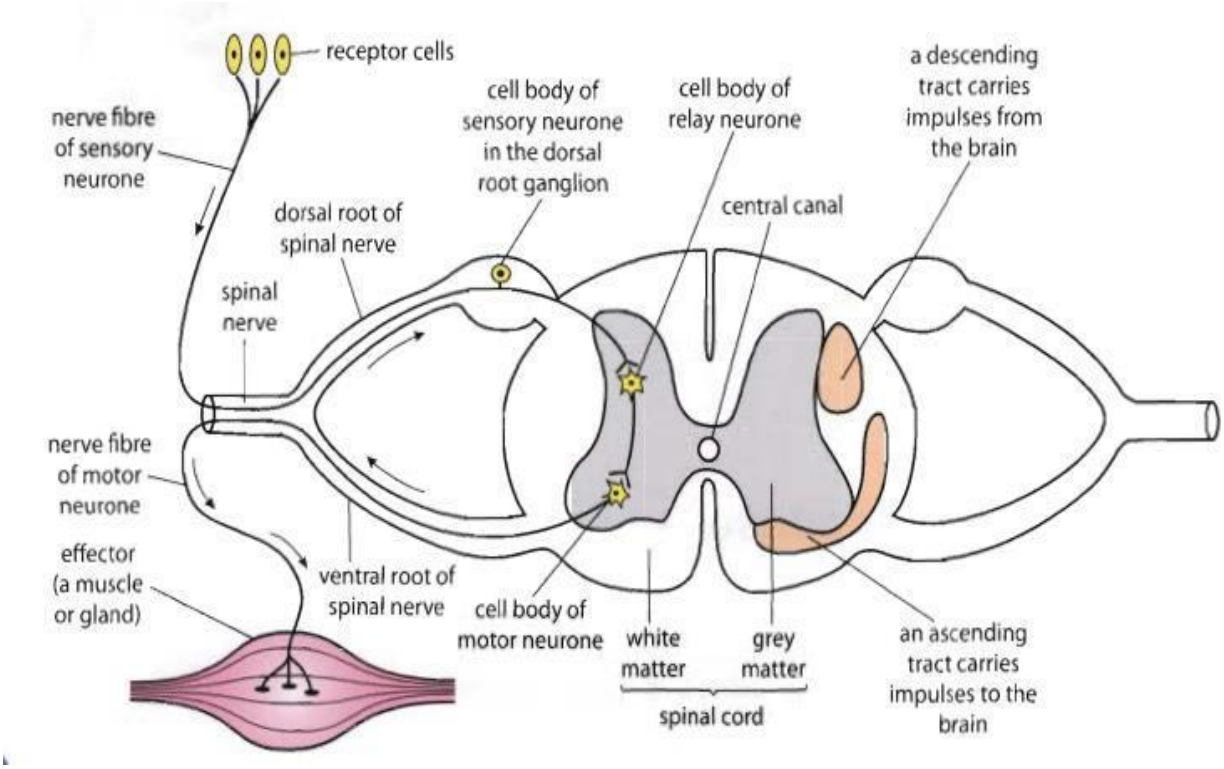
They form a basis of some animals' behaviour, e.g. amoeba.

THE REFLEX ARC

This is a description of processes, which take place within the body during a reflex action.

The stimulus is perceived by the receptors, which change it into nervous impulse (transduction). The impulse travels along the sensory neuron to the spinal cord. In the grey matter of the spinal cord, the sensory neuron makes synaptic connections to the relay neuron and impulses move from the sensory neuron to the relay neuron across synapses. The relay neuron in turn transmits the impulse to the motor neuron across a synapse. The impulse then moves from the spinal cord to the effector muscles through the motor neuron. The impulse causes the muscles to contract or relax depending on the stimulus.

Diagram illustrating a reflex action



Routes/path of reflex arc

The reflex arc has 5 paths/routes

1. Receptors:

This is the organ or structure that receives the stimulus e.g. the sensory endings in the skin.

2. Sensory nerve:

This is the part of the reflex arc that carries impulse from receptors to the spinal cord or to the brain.

3. Relay neuron:

It connects the impulse from the sensory neuron to the motor neuron.

4. Motor neuron:

This carries impulses from the relay neuron to the effectors (muscles)

5. Effectors:

These are the parts of the reflex arc that carries out a response.

Types of reflex actions

They can be grouped according to 2 ways:

1) Spinal reflexes

These are reflex actions that pass through the spinal cord and are interpreted there e.g. withdrawing a hand from a hot object.

2) Brain/cranial reflexes

These pass through the brain and are interpreted there e.g. closing of the eye when an object is approaching, coming of tears when one is cutting onions, etc.

3) Instinctive/simple reflex actions

These are reflexes that do not require learning but are inborn e.g. suckling in human infants, making of a web by a spider, withdrawing a hand from a hot object.

Characteristics of simple reflexes

They are rapid responses
A given stimulus brings about the same response
They are not learnt but instinct (inborn)

CONDITIONED REFLEX

This is the type of reflex which involves learning organisms learn to respond to strange (meaningless stimulus) by associating it with another meaningful/familiar stimulus, e.g. ***the Ivan Pavlov's experiment.***

A scientist called Ivan Pavlov performed an experiment to demonstrate a conditioned reflex in a dog. In the experiment, he used to give the dog food at a particular time. The dog would salivate either after the smell of food or taste of food (normal response). He then started ringing a bell before giving the dog food. He did this several times. After several times, the dog salivated when a bell was rang even without food being presented (conditioned response).

For a conditioned reflex to be established, the brain is necessary thus the dog in Pavlov's experiment learnt to associate the sound of the bell with food.

When Pavlov rang the bell without food for a long time, the dog later stopped salivating implying that the conditioned reflexes are temporary.

Characteristics of conditioned reflex action

It is a temporary reflex
It involves learning
It takes a longer time to learn
It is co-ordinated in the brain
It involves more than one stimulus
It involves association of stimulus

It is reinforced by repetition
Responses are involuntary

Similarities between simple and conditioned reflexes

They both involve the central nervous system particularly the brain.
Both are autonomic responses
Both are associated with a stimulus.
Both involve neurons for the transmission of impulses

Differences between simple and conditioned reflexes

conditioned	simple
Stimulus and responses are not directly related	Stimulus and response are related
More than one stimulus is required to cause a response	Only one stimulus is needed to cause a response
It involves learning	No learning but in born
Takes time	Takes a very short time
It is co-ordinated in the brain only	Co-ordinated in either the brain or spinal cord
Responses occur as a result of repetition and practice.	Responses occur instantly after a stimulus.

Similarities between reflex and voluntary actions

Both are co-ordinated by central nervous system.
Both occur as a result of impulse transmission.

Differences between reflex actions and voluntary actions

Voluntary actions	Reflex actions
Are not spontaneous	Occur spontaneously
Are relatively slow	Occur very fast
Are initiated by the brain	The brain does not initiate them.
They involve many neurons	They involve three neurons

THE ENDOCRINE SYSTEM (HORMONAL SYSTEM)

This is a system of ductless glands that produce chemical substances called hormones. They are chemical substances that regulate body metabolic activities.

Characteristics of hormones

They are protein in nature
They are produced and work best in minute quantities
They are secreted directly into blood streams
Their site of action is far from where they are produced
The site of action is called the target organ
They are produced by endocrine glands
Their effect on the target organ is either by stimulation or inhibition i.e. they regulate the activities of the target organs.

GLANDS

These are tissues or organs that produce and secrete chemical substances. There are 2 types of glands i.e. ***endocrine and exocrine.***

EXOCRINE GLANDS

These are glands that secrete their substances to their target organ through their ducts i.e. these glands have ducts that connect and carry their chemical substances to their target organs hence they are called **duct glands.**

Examples:

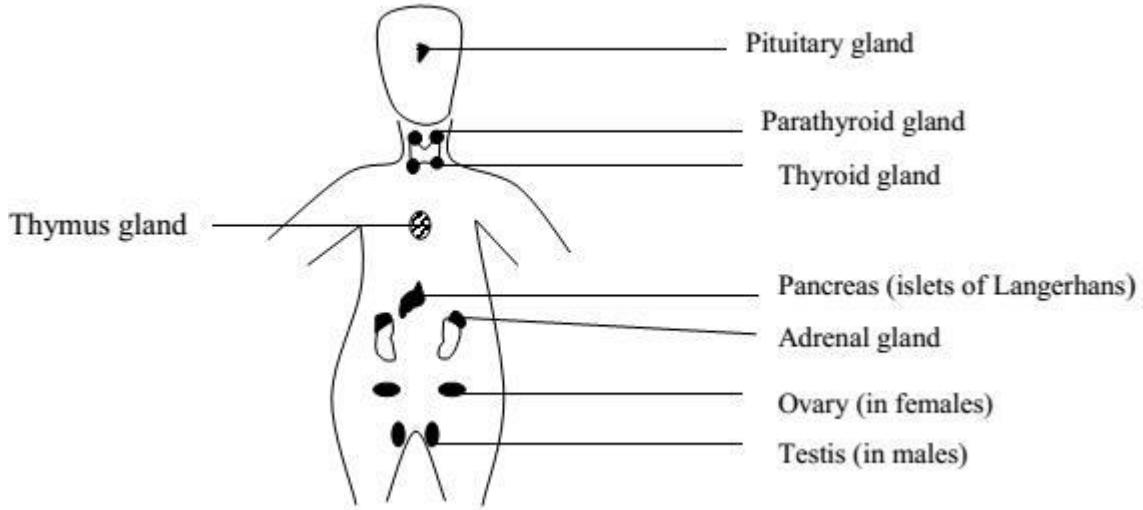
Pancrease releases pancreatic juice.
Salivary gland has salivary duct that carries saliva into the mouth cavity.
Sweat glands
Tear glands

ENDOCRINE GLANDS

These are ductless glands that secret their hormones directly into the blood stream. The blood carries the hormones from the glands to their target organs hence endocrine glands are called ductless because they have no ducts e.g. pituitary gland, thyroid gland, pancrease, etc.

Location of endocrine glands

Endocrine glands are situated in the head, neck, and trunk as shown in the diagram below.



HORMONES OF THE ENDOCRINE GLANDS AND THEIR FUNCTIONS

1. PITUITARY GLAND

This is an outgrowth at the base of the brain. The pituitary gland releases several hormones most of which stimulate the production of other hormones from other endocrine glands. Because of this it controls other endocrine glands and it is referred to as the master gland.

The pituitary as a master gland:

The pituitary gland acts as a master gland because it produces several hormones most of which stimulate other endocrine glands to produce their hormones. Because of this, the pituitary controls other endocrine glands.

Hormones produced by the pituitary gland.

It produces antidiuretic hormone (ADH), which controls the amount of water and salts reabsorbed into the blood stream by the kidneys.

It produces follicle-stimulating hormone (FSH), which causes the development of graafian follicles in the ovary.

It produces thyroid-stimulating hormone (TSH), which stimulates the thyroid gland to secrete thyroxin.

It produces adrenal cortical stimulating hormone (ACSH), which stimulates the adrenal gland to produce a hormone called cortisone.

It produces interstitial cell stimulating hormone (ICSH), which stimulates the testes to produce their hormone called testosterone.

It produces a growth hormone, which controls the growth of bones and other tissues. Over secretion of growth hormone causes ***gigantism.*** Under secretion of growth hormone causes ***dwarfism.***

It produces luteinizing hormone (LH), which causes ovulation.

Prolactin which stimulates milk production in pregnant females.

Oxytocin which causes the contraction of uterus thus inducing birth. It also stimulates milk flow from the mammary gland.

2. THE THYROID GLAND.

This produces a hormone known as **thyroxin**, which in young organisms controls growth and development for example in tadpoles it brings about metamorphosis.

In adults thyroxin controls the rate of respiration.

In adults too little thyroxin leads to overweight and sluggishness and too much of it causes thinness and over activity.

Deficiency of thyroxin in infancy cause a type of mental deficiency known as **cretinism** which can be cured if identified early by administering thyroxin in the body.

Thyroxin is made up of an amino acid containing iodine. Lack of iodine causes the thyroid gland to increase in size as a way of producing more thyroxin. This leads to a disease known as **goiter.**

3. ADRENAL GLAND.

There are two adrenal glands situated above each kidney. The gland is made up of two parts.

Cortex; this is the outer part of the adrenal gland.

Medulla; this is the inner part of the adrenal gland.

The adrenal cortex produces several hormones including a hormone known as **cortisone**, which is responsible for conversion of proteins to glucose. The adrenal gland is stimulated by the adrenal cortical stimulating hormone produced by the pituitary to produce cortisone.

The adrenal medulla is stimulated by nervous impulses to produce a hormone known as **adrenaline**. Adrenaline is produced when the animal feels frightened or excited. Adrenaline brings about the following changes in the body.

It increases the rate of heartbeat.

It increases the breathing rate.

It widens the pupils of the eyes.
It brings about conversion of glycogen to glucose in the liver.
It brings about the growth of goose pimples on the body.
It increases the rate of respiration in order to ensure adequate supply of energy to body muscles.

Due to the abundance of energy, there is increased muscle contraction making the animal to feel stronger. This hormone prepares the animal to fly or run away or to fight with another. This hormone is therefore known as a **"flight or fight" hormone.**

4. THE PANCREAS.

In addition to production of digestive enzymes, the pancreas produces two hormones known as ***insulin*** and ***glucagon***. These hormones are produced from groups of cells in the pancreas known as ***islets of estrogen***.

Insulin is produced from the β- islets of estrogen***. Insulin stimulates the liver to convert excess glucose into glycogen for storage***. If the pancreas produces little or no insulin, the amount of sugar increases in blood resulting into a disease called **diabetes mellitus**. The disease is controlled by continuous injection of insulin in the body.

Glucagon is produced from the α- islets of estrogen in the pancreas. When released in blood, ***glucagon moves to the liver and stimulates the liver to convert glycogen to glucose.***

5. THE DUODENUM.

The presence of food in the duodenum stimulates the lining to produce a hormone called **secretin**. Secretin moves in blood to the pancreas and stimulates it to produce pancreatic digestive enzymes. This ensures that the enzymes are produced when food is present.

6. THE REPRODUCTIVE ORGANS (TESTES AND OVARIES)

The ovary in females produces two major hormones. These are **estrogen** and **progesterone**.

Oestrogen controls secondary sexual characteristics in females such as;

Development of breasts.
Growth of pubic hairs.
Widening of hips.
Enlargement of reproductive organs.
Softening of muscles.
Softening of the voice.

Oestrogen also causes repair of the uterine lining after menstruation.

Progesterone is responsible for maintaining the endometrium prior to implantation.

In males the testes produce a hormone known as **testosterone**. This hormone brings about male sex characteristics, which include;

Deepening of the voice.
Growth of beards.
Toughening of muscles.
Widening of the chest.
Enlargement of reproductive organs.
Growth of pubic hairs.
Sperm production.

7. PARATHYROID GLAND

It secretes parathormone which has the following functions:
Controls the distribution of calcium and phosphorus in the body.
It affects development of bones.

8. THYMUS GLAND

This gland is close to the heart and well developed in young mammal but greatly reduced in adults.

It provides defense (immunity) in young mammals.

Similarities between the nervous and endocrine system

Both are affected by change in stimulus
Both cause a response
They provide a means of co-ordination in the body
In nature, the messages transmitted are chemical
Both systems transmit messages.

Nervous system	Endocrine system
Nerve impulses are electrical	Impulses are chemical
Responses are fast as the impulses are carried fast.	Responses are slow but long lasting
Impulses go along nerve fibres	Hormones are carried in blood
This effect is more localized (specific)	Effect is wide spread in the whole body
Stimulus arises from any part of the	Stimulus arises from specific places

body where sensory receptors are only localized.	e.g. endocrine glands.

DISEASES OF THE NEURO-ENDOCRINE SYSTEM

1. Poliomyelitis

It can kill or cripple people. It is caused by a virus which affects the motor nerve cells in the central nervous system. It enters the body through breathing or eating contaminated food.

2. Tetanus

It is caused by bacteria which enter the body through open cuts on the skin. It damages the nervous system causing the muscles of the skin to become stiff and the jaws immovable.

3. Meningitis

It is caused by bacteria that attack the cerebro spinal fluid.

4. Leprosy

It's caused by bacteria that enter the body through skin contact and mucus.

5. Celebro malaria

It's caused by malarial parasites i.e. plasmodia

6. Epilepsy

A patient loses consciousness suddenly and quickly. It is inherited

SENSE ORGANS OR RECEPTOR ORGANS IN MAMMALS

These are organs that perceive the stimulus and change it into nervous impulse (transduction).

Receptor organs are made up of cells called receptor cells. There are different types of receptor cells depending on the nature of the stimulus they perceive and the organ in which they are contained.

Receptor organs and their functions

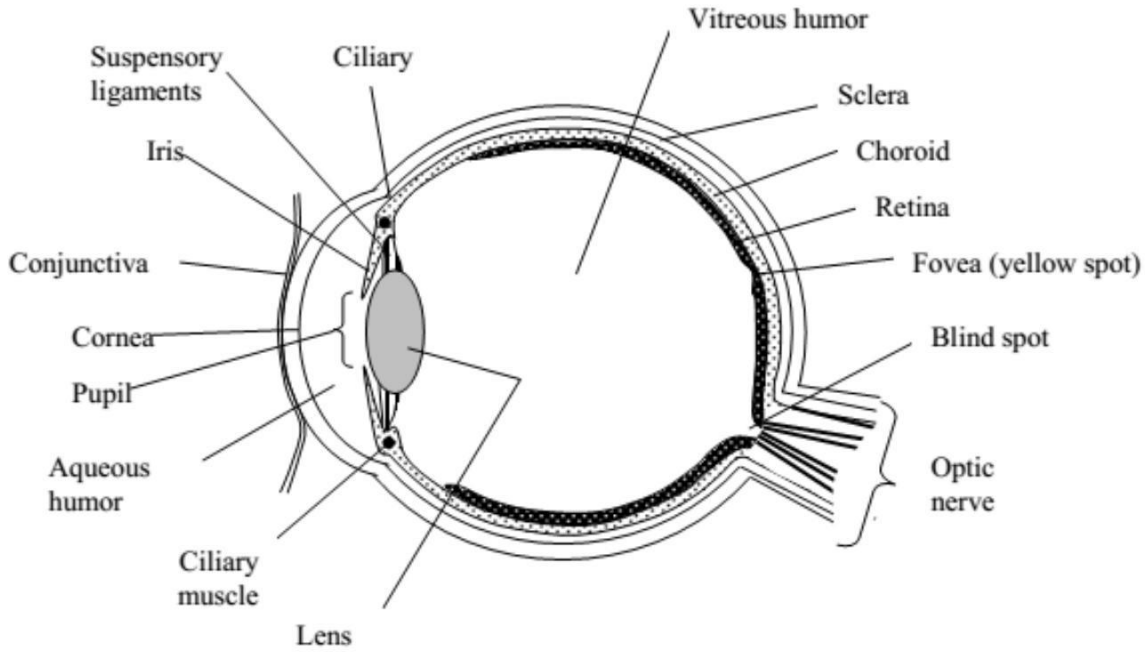
Receptor cell	**Nature of stimulus**	**Receptor organs**	**Function**
Photoreceptors	Light	Eye	Vision
Mechanoreceptors	Sound and gravity	Ear	Hearing and balancing

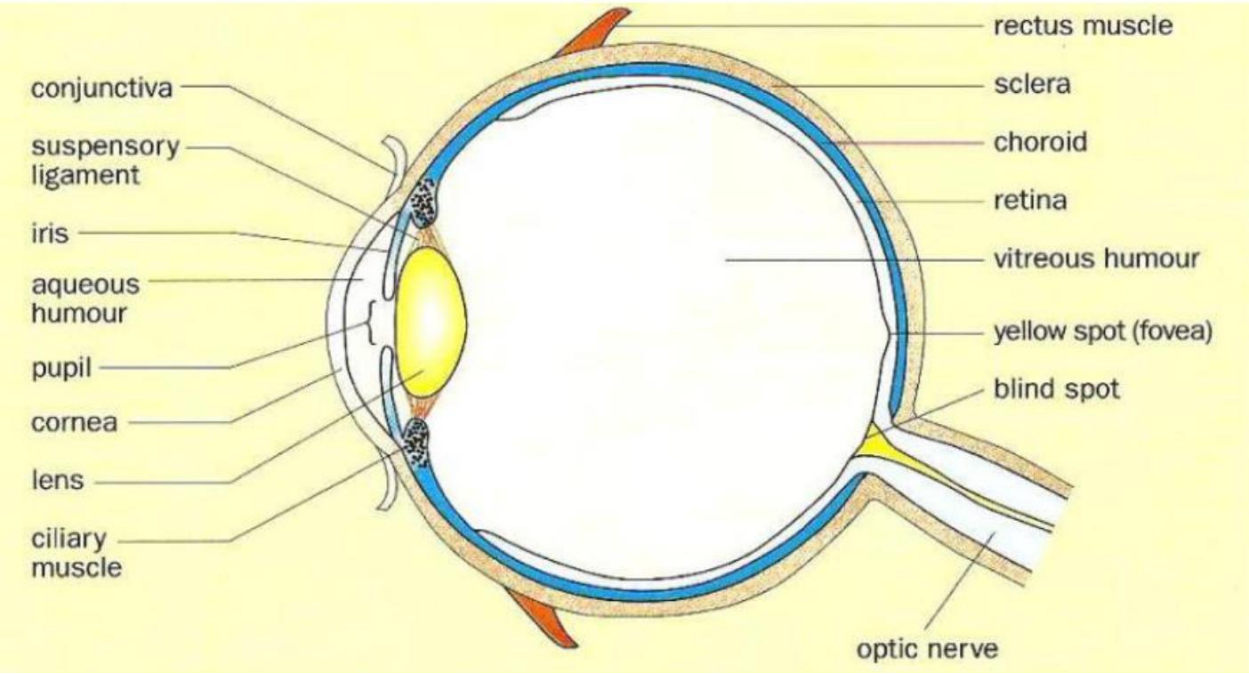
Chemo receptors	Chemicals	Nose	Smelling
Thermo receptors	Temperature	Skin	Detecting temperature
Chemo receptors	Chemicals	Tongue	Tasting
Mechanoreceptors	Pressure	Skin	Detecting pressure changes.

THE MAMMALIAN EYE

The mammalian eye is a receptor organ responsible for sight. It contains photoreceptor cells, which perceive the light stimulus and change it into nervous impulse.

Structure of the mammalian eye





Parts of the eye

The conjunctiva:
This is a thin transparent layer lining the inside of the eyelid.

It protects the eye and holds it in position.
It enables the eye ball to move easily by secreting mucus.

The sclera:

This is a tough inelastic layer that gives shape to the eye.
It protects the inner most delicate parts.
It provides attachment for the muscles of the eye.

The cornea:

This is a transparent layer in front of the eye.
It refracts (bends) light into the eye.

The choroid layer:

It is below the sclerotic layer.

It is pigmented and mainly contains black pigment which stops reflection of light rays.

It prevents internal reflection of light.

This contains a network of blood vessels supplying oxygen and food to the eye.

The aqueous humour:

It is a solution of sugar, salts and proteins.

The aqueous humor is a watery fluid which maintains the shape of the eye.
It also refracts light into the pupil and the lens.

The vitreous humuor:

It is a jelly-like substance that fills the inner cavity of the eye.
It is transparent and maintains the shape of the eye.
It refracts light to the retina.

The ciliary body:

This contains ciliary muscles, which control the size of the lens during viewing nearby or distant objects.

The lens.

It is transparent and held by suspensory ligaments. It
refracts light to make an image on the retina.

The iris

This is made up of an opaque tissue the center of which is a hole called pupil that allows in light to form an image on the retina.

The contraction of the muscles of the iris increases the size of the pupil and relaxation decreases the size of the pupil.

It is therefore responsible for controlling the amount of light entering the eye.

10. The retina

This is a layer containing photoreceptor cells (light sensitive cells) There are two types of light sensitive cells on the retina

Rods
Cones

The cones are sensitive to coloured light and are responsible for colour vision. They are also sensitive to light of high intensity and are used during daytime.

Most cones on the retina are concentrated on the fovea or yellow spot.

The rods are incapable of perceiving coloured light and are sensitive to light of low intensity (dim light). They are used during night vision.

Nerve fibers from the photoreceptor cells run to the brain via the optic nerve. The rods contain a pigment rhodopsin which is rapidly bleached by even a small amount of light but at the same time it is rapidly generated.

The cones contain a pigment called iodopsin which is less sensitive to light and is not bleached so quickly.

The retinas of nocturnal animals have mainly rods. Due to this, nocturnals can't perceive different colours.

Therefore the retina is where the image is formed in the eye.

11. Pupil.

This is a round black hole in the center of the eye lying behind the cornea. It allows light to pass into the eye to the lens.

12. Suspensory ligaments.

These are inelastic fibers that hold the lens in position.

13. The blind spot:

This is a region where the nerve fibers leave the eye to enter the optic nerve. It has no light sensitive cells. When an image falls on this point, it is not taken to the brain thus blind spot.

14. The fovea

This is a small depression in the center of the retina. It has only cones in a high concentration. It is therefore a region on the retina that contains the largest number of sensory cells. Due to this, it produces the most accurate images in the eye.

15. Eye lids

These protect the eye and remove any foreign bodies that enter it. Regular blinking enables the spread of the fluid all over the exposed surface of the eye.

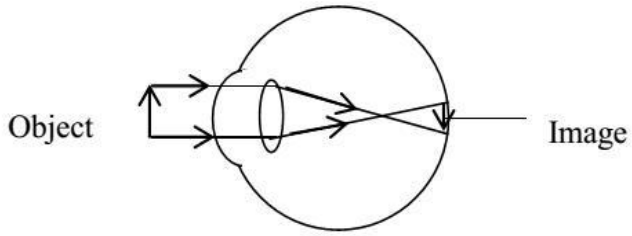
16. Eye lashes

They prevent dust particles and other objects from entering the eye.

IMAGE FORMATION AND VISION

Light from an external object enters the eye. It is refracted by the cornea into the aqueous humour. The aqueous humour then refracts it to the lens. The lens refracts it to the vitreous humour. The vitreous humour finally refracts light and focuses it to the retina making an image on the retina. The photoreceptors in the retina change the light stimulus into a nervous impulse. The impulse travels along the optic nerve to the brain where interpretation of the image is made. The image formed on the retina is smaller to the real object and it is ***upside down.***

Illustration



CONTROL OF LIGHT AMOUNT ENTERING THE EYE

The iris controls the amount of light entering the eye. It is made up of circular and radial muscles.

When the circular muscles of the iris contract, the size of the pupil is reduced and less light is allowed in.

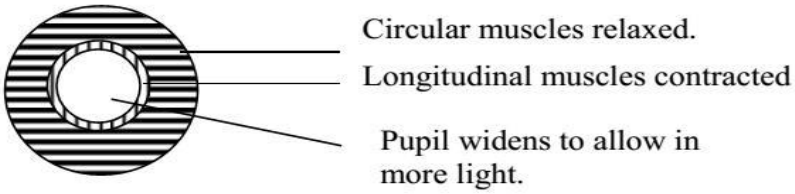
Contraction of the radial muscles widens the pupil so allowing more light to enter the eye.

In light of low intensity, the pupil widens and in bright light, the pupil reduces in size. This is done to protect the retina from damage by bright light and the wide size of the pupil during dim light allows in enough light of low intensity.

Control of the amount of light rays entering the eye when in dim light:

In dim light, radial muscles contract,
Circular muscles relax,
Pupil widens and more light is admitted into the eye.

Dim light:

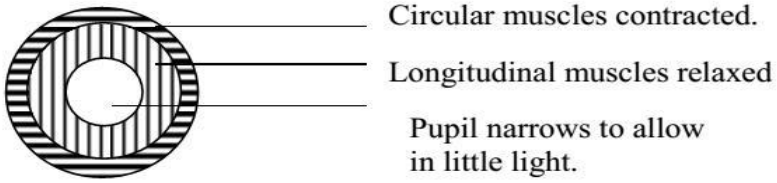


Control of amount of light rays entering the eye in bright light:

Circular muscles of the iris contract,
Radial muscles relax,

Pupil becomes smaller and narrower,
Less light is admitted into the eye.

Bright light:



ACCOMMODATION OF THE EYE

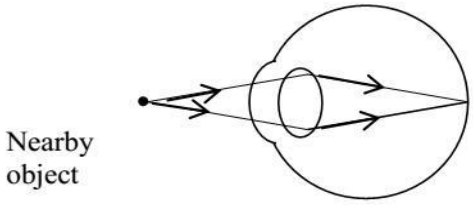
This is the ability of the eye to change the focal length of the lens when viewing distant or nearby objects.

Accommodation for a nearby object:

When looking at a nearby object, the ciliary muscles in the ciliary body contract, the suspensory ligaments slacken. This makes the lens short and thick.

This increases the ability of the lens to refract light and reduces the focal length of the lens for the nearby object to be seen clearly.

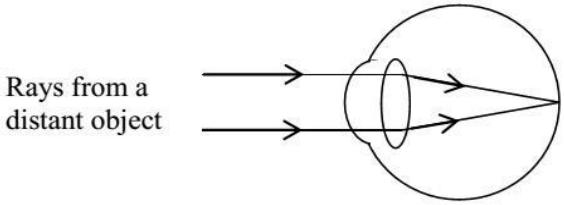
Illustration



Accommodation for a distant object:

When viewing a distant object, the ciliary muscles in the ciliary body relax. This causes tension in the suspensory ligaments. The suspensory ligaments pull the lens apart making the lens thin and long. This makes the lens to refract less and increase the focal length of the lens.

Illustration



Summary of accommodation

Nearby object	Distant object
Diverging light rays from a nearby object are refracted by cornea.	Parallel light rays from a distant object are refracted by the cornea.
Cilliary muscles in the cilliary body contract.	Cilliary muscles in the cilliary body relax.
Suspensory ligament slacken	Suspensory ligaments develop tension
The lens become short and thick	The lens becomes thin and long
The focal length of the lens decreases	The focal length of the lens increases.
Light rays are refracted to the retina	Light rays are refracted to the retina.

EYE DEFECTS

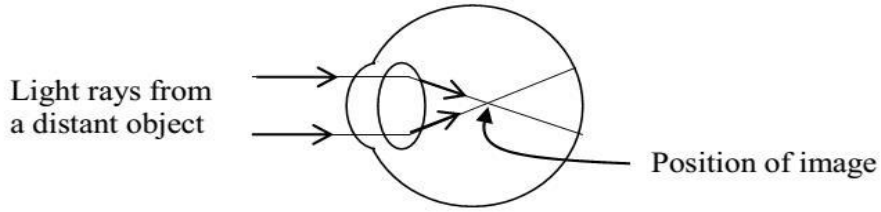
An eye defect is a condition where the eye fails to focus an object well unless aided by external lenses.

The common eye defects include:

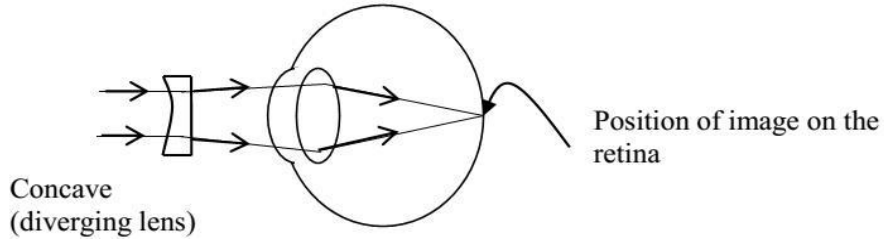
1. Short sightedness (myopia):

This is usually caused by a large eyeball or a very strong lens. Light from a distant object is focused in front of the retina. The individual can only see nearby object but not distant ones.

Illustration



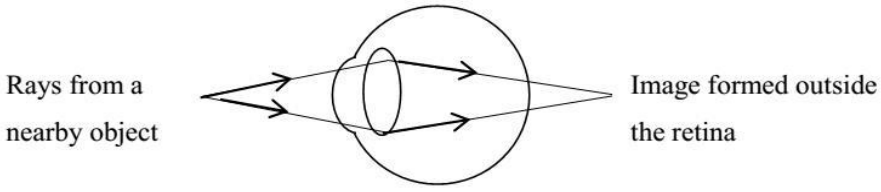
This can be corrected by putting on diverging (concave) lenses.



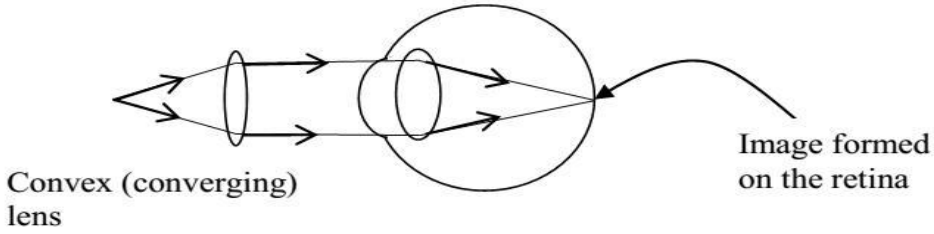
2. Long sightedness (hypermetropia):

This is caused by a small or short eyeball or a very weak lens such that a close object is focused far behind the retina. The individual can see distant objects but cannot see nearby objects.

Illustration



Long sightedness can be corrected by wearing converging (convex) lenses.



3. Astigmatism

This is caused by unequal refraction of the cornea and lens due to uneven curving in them. It results into some parts of the object being well focused on the retina and some not to be focused. It is normally due to old age. This can be solved by wearing cylindrical lenses.

4. Presbyopia

This condition occurs when the lens hardens due to old age and does not focus. It can be corrected by wearing spectacles with convex lenses or often 2 pairs of spots may be necessary i.e. a pair with convex lenses for close vision and a pair of concave lenses for distant vision or the 2 types of lenses can be combined into one pair known as bi-focal spectacles.

5. Cataract

It is a condition which occurs when an individual is aging. It is caused by the eye lens becoming opaque due to a thin covering formed on it. It is corrected by surgical removal of the thin opaque layer of the lens.

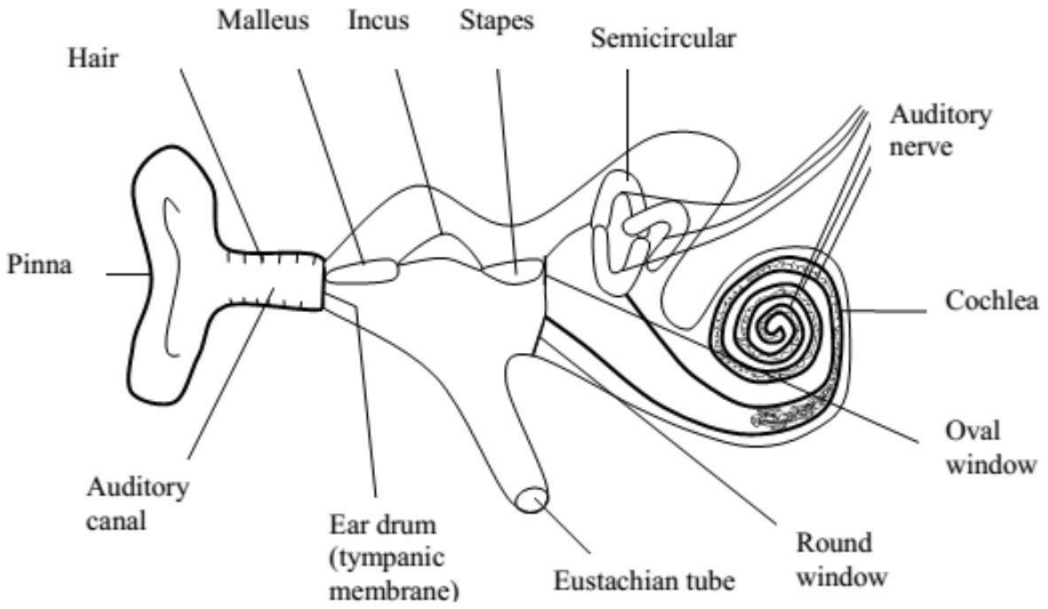
Other eye defects include trachoma, conjunctivitis, colour blindness and glaucoma.

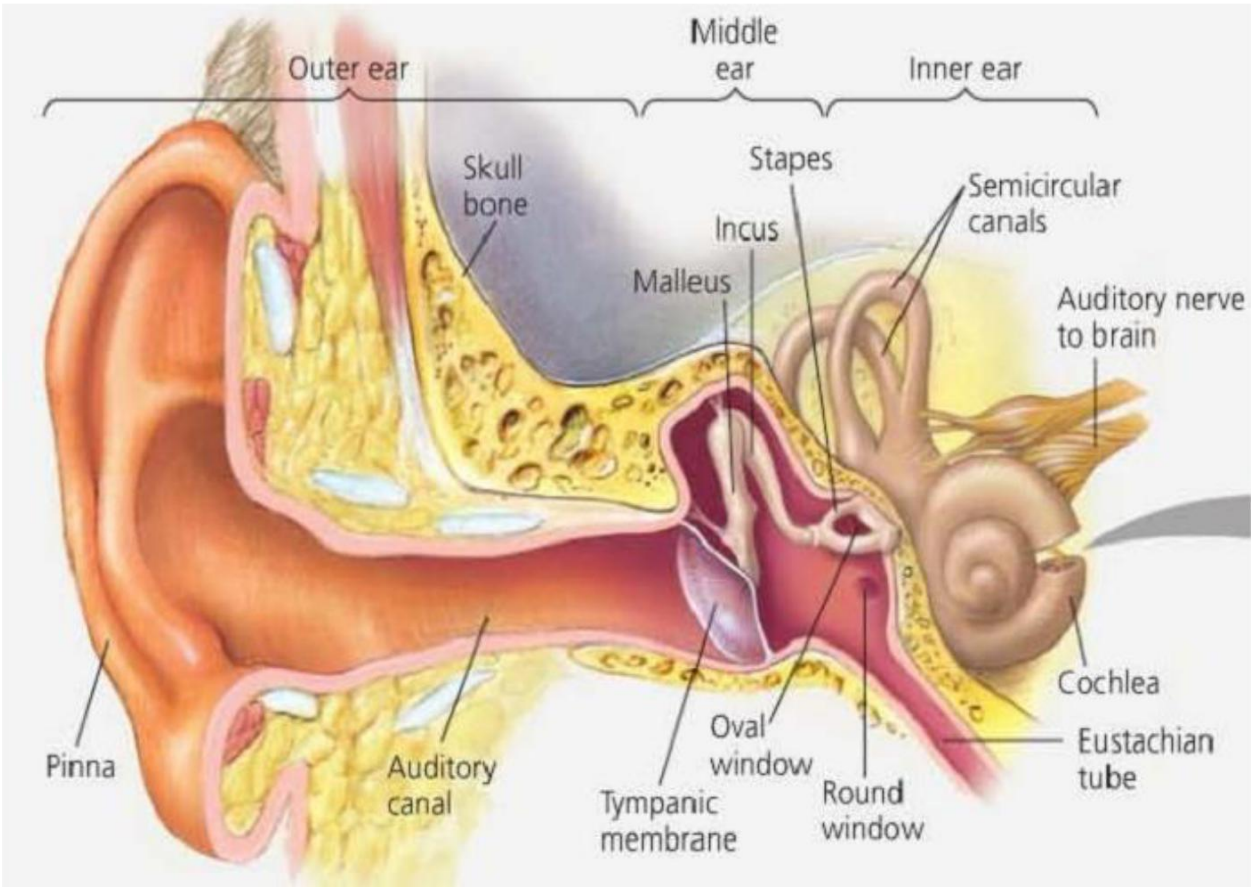
Colour vision

The cones are photoreceptor cells on the retina, which are concerned with colour vision. There are three types of cones, which are sensitive to three primary colours i.e. the blue sensitive cone, green sensitive cone and red sensitive cone. When blue sensitive cones alone are stimulated, blue colour is perceived. Stimulation of green alone gives green colour. Stimulation of red cones produces red colour. Equal stimulation of both green and red gives yellow colour. Equal stimulation of the entire three gives white colour and when no cone is stimulated, no colour (black) is perceived. This is known as the **trichromatic theory.**

THE EAR

Structure of the ear





The ear has sensory receptors for hearing and balancing. These are mechano-receptors because they respond to pressure and gravity. The ear is made up of three areas i.e. the outer ear, middle ear and inner ear.

1. The outer ear:

This is the tube opening to the side of the head and inwards stopping at the eardrum. It has an outer extension called the pinna. The pinna concentrates and directs the sound vibrations into the ear through the auditory canal. This makes the ear drum to vibrate.

2. The middle ear:

This is a cavity in the skull filled with air. It communicates with the mouth cavity through the Eustachian tube. There are three small bones called ossicles in the middle ear which link the eardrum and the opening of the skull called oval window that leads to the inner ear.

3. The inner ear:

The inner ear is filled with a fluid and consists of mainly a coiled tube known as the cochlea. The cochlea has sensory nerve endings leading to the brain. These transmit nervous impulses from the ear to the brain.

Functions of parts of the ear

Pinna:

Ear ossicles:

These are 3 tiny bones in the middle ear. They are:

Malleus (hammer)
Incus (anvil)
Stapes (stirrup)

They are joined like a chain and they transmit sound vibrations across the middle ear from the ear drum to the oval window. They amplify sounds of low tones.

3. Eustachian tube:

It connects the middle ear to the pharynx of the mouth.

Its function is to equalize air pressure on both sides of the ear drum so that it can vibrate freely.

It opens when one is swallowing and yawning.
It prevents the eardrum from bulging.

The Eustachian tube is used to balance the pressure inside the ear with that outside the ear.

When the pressure of air in the middle ear is higher than that of the atmosphere, yawning takes place and air escapes from the middle ear through the Eustachian tube to the mouth where it is lost. This reduces the pressure back to normal.

When the pressure of air in the middle ear is lower than that of the atmosphere, yawning takes place to allow the atmospheric air to go into the middle ear through the mouth and Eustachian tube. This raises the pressure back to normal.

4. Oval window (fenestra ovalis):

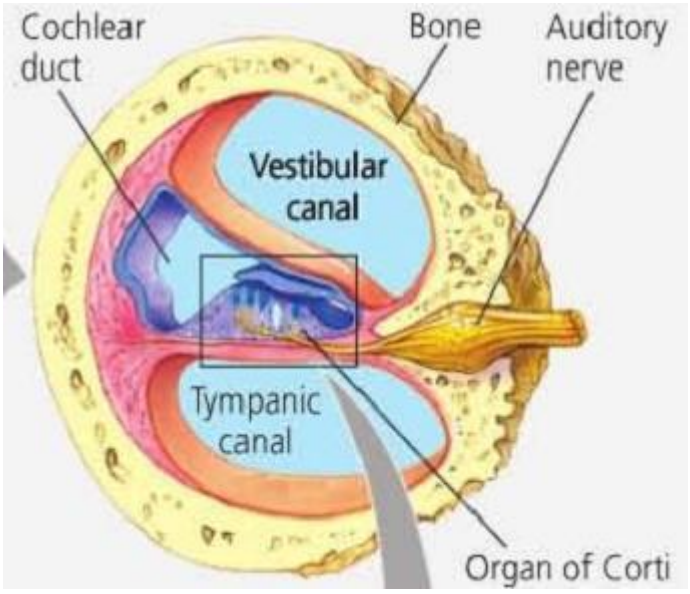
It is a flexible membrane which vibrates and sets up vibrations in the fluids of the ear called perilymph in the cochlea.

It receives impulses from the steps and transmits them to the cochlea.

5. Round window (fenestra rotunda):

It is a flexible membrane which controls the displacement in the cochlea created by vibrations of ossicles by releasing pressure when it bulges out wards.

Structure of the semi-circular canals and cochlea



6. Cochlea:

It is a 3 chambered fluid filled tube which is coiled. It contains sensory cells which pick up vibrations in the fluid and transmit them to the auditory nerve. The sound vibrations move along the auditory nerve and reach the brain where they are interpreted as sound. Its 3 chambers include:

Vestibular canal (scala vestibuli)

It is the upper canal which starts from the oval window. It contains perilymph.

Tympani canal (scala tympani)

It is the lower canal which ends in a smaller membrane called the round window. It also contains perilymph.

Middle canal (scala media)

It is located between the vestibular and tympanic canal. It is filled with a fluid called endolymph. It contains sensory cells which detect sound. These cells form the hearing apparatus called the organ of corti. The organ of corti is connected to the auditory nerve.

Cross section of a cochlea

7. Semi-circular canal (organ of balance):

These are 3 semicircular canals which are at right angles to each other. They contain a fluid called endolymph. At one end of the canal, there is a swelling called ampulla. It contains sensory cells.

When the person moves the head or whole body, the endolymph, in the semi-circular canals moves in the opposite direction. The moving fluid strikes the sensory hair cells which are stimulated and sends impulses to the brain.

The 3 semicircular canals give information about the direction of movement of the body e.g. if a person spins around in one direction and then stops suddenly, the fluid continues to flow around the sensory hair cells. This gives a sensation of the ground spin around of the group spinning in the opposite direction.

Section through the ampulla

The process of hearing

Sound waves are collected and concentrated into the ear by the pinna.

They are then directed to the tympanic membrane (ear drum) through the auditory canal.

This causes the eardrum to vibrate.

The vibrations of the eardrum are amplified and transmitted by three ossicles starting from the malleus, incurs and finally the stapes hands them over the oval window that leads to the inner ear.

Vibrations in the oval window make the fluid in the inner ear and cochlea to vibrate.

Receptors in the cochlea (organ of corti) receive the information, change it into impulses and the impulses are taken to the brain via the auditory nerve.

The process of balancing

The semi-circular canals, utriculus and sacculus in the inner ear are all concerned with the sense of balance and positioning.

The three semi-circular canals are filled with a fluid and each lies in a different plane.

One is horizontal and two are vertical but at right angles to each other.

At the end of each semi-circular canal is a swelling known as the ampulla, which contains sensory cells.

Within the ampulla is a structure covered by sensory cells with hairs on their upper surfaces. The hairs are embedded in a corner of jerry known as cupulla. The semicircular canals are stimulated by rotation of the head and body in their respective planes.

The utriculus and sacculus have gelatinous plates in their fluid filled cavities, which contain granules called otoliths.

The otoliths are attached to sensory fibres. When the head is tilted, the otoliths pull on the sensory fibres. This causes an impulse to be fired off from these organs to the brain. A reflex is then set off which causes the body to return to its normal posture.

Note:

The utriculus responds to vertical movement of the head while the succulus responds to lateral movement of the head.

Internal structure of the semicircular canal

Common ear disorders

1. Ear ache and ear discharge:
It is usually due to an inflammation in the middle ear.

It occurs when microorganisms reach the middle ear via the Eustachian tube. Due to severe inflammation, pus may be formed in the middle ear and the ear drum become perforated. The discharge may lead to permanent deafness.

2. Deafness:
This is caused by accumulation and hardening of wax in the outer auditory canal which presses against the eardrum.

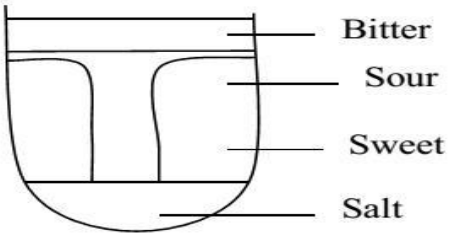
Blocking of the Eustachian tube, exposure to loud noise over a long period of time can damage the organ of corti leading to deafness.

Also damage to the cochlea or the hearing centre of the brain can also cause deafness.

THE TONGUE

The tongue is the receptor organ for the sense of taste. It changes chemicals in the mouth into nervous impulses. It contains chemo-receptors, which carry out this function. The tongue contains taste buds, which contain the chemo-receptor cells. The tongue distinguishes between four different kinds of tastes, i.e. ***sweet, sour, salt and bitter***.

The taste buds for the different tastes are located in different parts of the tongue as shown in the diagram below.



When a chemical is placed in the mouth, it dissolves in the moisture (saliva) in the buccal cavity. The dissolved chemicals then stimulate the taste buds in the different parts of the tongue depending on the type of taste. Impulses are then sent from the tongue through a sensory neuron to the brain and the brain interprets the type of taste.

THE NOSE

The nose is the receptor organ for smell. It is also made up of chemo-receptor cells and it is stimulated by chemicals in air. This helps the organism to respond to chemical stimuli at a distance. When air containing a chemical enters the nose, it dissolves in the moisture (mucus) in the nasal cavity. In this form, it stimulates the chemo-receptor cells in the nose. These cells send nervous impulses through a sensory neuron to the olfactory lobe of the brain where interpretation occurs.

THE SKIN

The skin is a sense organ responsible for the senses of pain, touch, pressure and temperature. The structure and excretory role of the skin has been discussed under **EXCRETION AND OSMOREGULATION**.