CO-ORDINATION IN PLANTS AND ANIMALS

All living organisms detect changes in their environment and respond appropriately.
Irritability is the ability of an organism to detect, interpret and respond to changes in the environment.
A stimulus is a change in the external or internal environment to which an organism responds to.
A response is a physiological, muscular or behavioral activity that is initiated by a stimulus.

COORDINATION AND IRRITABILITY IN PLANTS

Plant responses involve growth movements of part of the plant, turgor changes within cells and very limited movements. They respond to light, water, gravity, chemicals, obstacles and touch. The stimulus causes parts of the plant move towards or away from a stimulus. Plant responses are divided into two categories i.e. nastic responses and tropic responses.

NASTIC RESPONSE

This is the movement of part of the plant in response to a non-directional stimulus. Nastic responses involve changes in turgidity and growth to some extent. This can be observed in the folding of the leaves of the sensitive plant (*Mimosa pudica)* when touched (thigmonasty). The touching of the plant causes water to be quickly withdrawn from the leaf cells into the pulvinus cells which have large air spaces, therefore causing the leaf or petiole to collapse due to change in turgidity.
Nastic response are named depending on the type of stimulus i.e. Photonastic if the stimulus is light.
Hydronasty if the stimulus is water.
Thigmonastic if the stimulus is touch.

Characteristics of a nastic response

- 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 responses

- Opening and closing of flowers in response to light e.g. morning glory.
- Sudden folding of the sensitive plant's (*Mimosa pudica*) leaves in response to touch.
- Closure of leaves of insectivorous plants e.g. butter walt and pitcher plant when the insect lands on the leaf. Such plants are found in nitrogen deficient soils.

TROPIC RESPONSE (TROPISM)

Tropism is a growth movement of part of the plant organ in response to an external unidirectional stimulus. Growth movement towards a stimulus is referred to as ***positive tropism*** while growth movement away from a stimulus is referred to as ***negative tropism***.

Characteristics of a tropic response

- 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.

Examples of tropisms

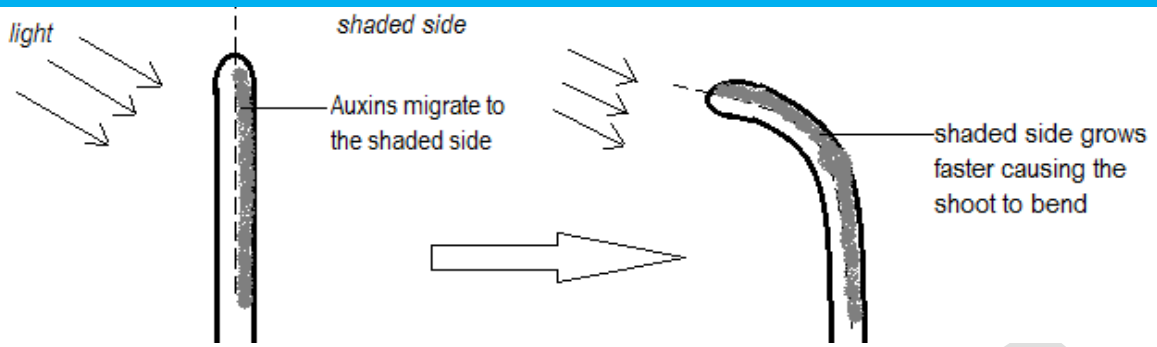
Example of tropism (response)	Stimulus
1. Hydrotropism	Water
2. Thigmotropism / haptotropism	Touch
3. Chemotropism	Chemicals
4. Geotropism	Gravity
5. Phototropism	Light

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). The shoot apex detects a light stimulus. When a shoot apex is exposed to a unilateral source of light causes ***auxins***, which are plant growth hormones produced at the shoot apex to migrate to the shaded side. The higher concentration of auxins on the shaded side causes faster growth than on the illuminated side, hence the shoot curves towards the source of light.

Importance of phototropism

- The shoot grows towards light hence the leaves are able to carry out photosynthesis.
- Roots grow away from light into the ground from which water and mineral salts are absorbed and also provide support.



However, high auxins concentration limits growth in plant roots

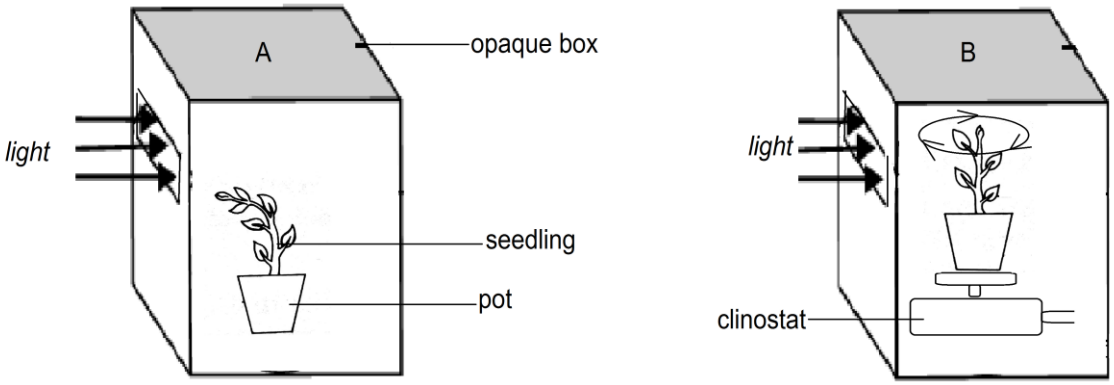
An experiment to show the effect of unidirectional light on growth of the plant shoot

Materials: Potted seedlings, 2 opaque boxes, clinostat and Razor blade

Procedure:

- Cut a small hole on one side of two opaque boxes using a razor blade.
- Place a potted seedling in box '***A***' and fix another potted seedling on a clinostat and put it in the second box '***B***'.
- Place both boxes in light and start the clinostat to rotate the plant in box ***B***.
- Leave the experiment for 3-4 days.

Observation: The seedling in box '***A***' bent towards the direction of light while that in box '***B***' continued to grow straight.



Conclusion: The shoot responds positively towards light.

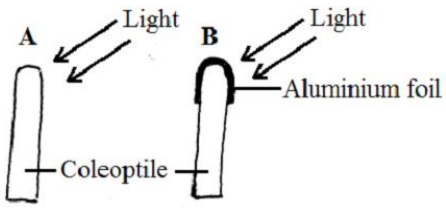
Explanation: Light coming from one direction in box '***A***' made the stationary shoot to bend towards the direction of light. The shoot in box '***B***' was rotating on a clinostat hence all of its sides received equal amounts of light and there was no effect on growth.

Revision question

1. *Distinguish between coordination and irritability.*
2. *An experiment was set up as shown in the figure on the right to investigate the effect of unidirectional light on the growth of a coleoptile.*

i) Explain the response of plant shoots A and B after exposure to unidirectional light for 6 hours.

ii) Explain how the response you have stated in (i) above can be important to plants.



GEOTROPISM

This is the growth movement of part of the plant in response to gravity. Roots grow towards gravity and are said to be positively geotropic. Shoots of plants grow away from gravity and are said to be negatively geotropic.

When a seedling is placed in a horizontal position and left in place for about 3 days, the shoot curves and grows vertically upwards and the roots grow and curve downwards.

This is so because auxins move and accumulate on the lower side of the seedling due to the force of gravity. The upper part of the seedling gets less auxins. The higher auxin concentration causes more elongation on the lower side of the shoot and the shoot therefore bends upwards away from the force of gravity.

In the root, the higher auxin concentration causes less elongation on the lower side. The upper side with lower auxin concentration elongates more. The root, therefore bends vertically downwards towards the force of gravity.

Importance of geotropism

- Roots grow towards the soil so that the root hairs can obtain water and mineral salts for use during photosynthesis.
- Ensures that plants are anchored in the substratum.
- Negative geotropism ensures that shoots grow upwards towards the sunlight.

Experiment to demonstrate geotropism in plant roots (the effect of gravity on roots)

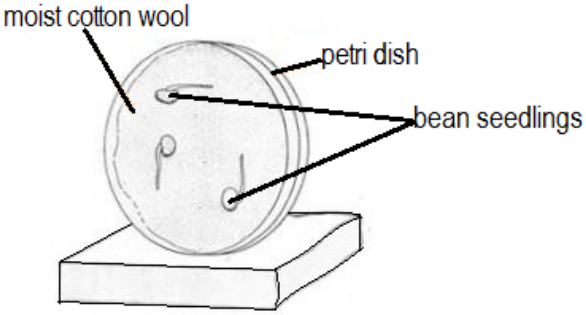
Apparatus: Petri dish**,** cotton wool and cupboard

Procedure:

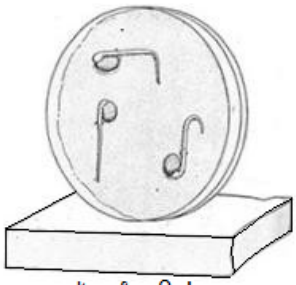
- Bean seeds are allowed to germinate and three seeds with straight radicles are selected.
- The seedlings are placed on moist cotton wool in a petri dish
- They are arranged so that the radicle of one is horizontal, the second radicle points vertically upwards and the third radicle points vertically downwards. The whole set up is placed in a dark cupboard for two days.

Observations:

- The horizontal radicle curves downwards towards the pull of gravity.
- The radicle that was pointing vertically upwards also curves downwards.
- The radicle that was pointing vertically downwards continues to grow downwards.

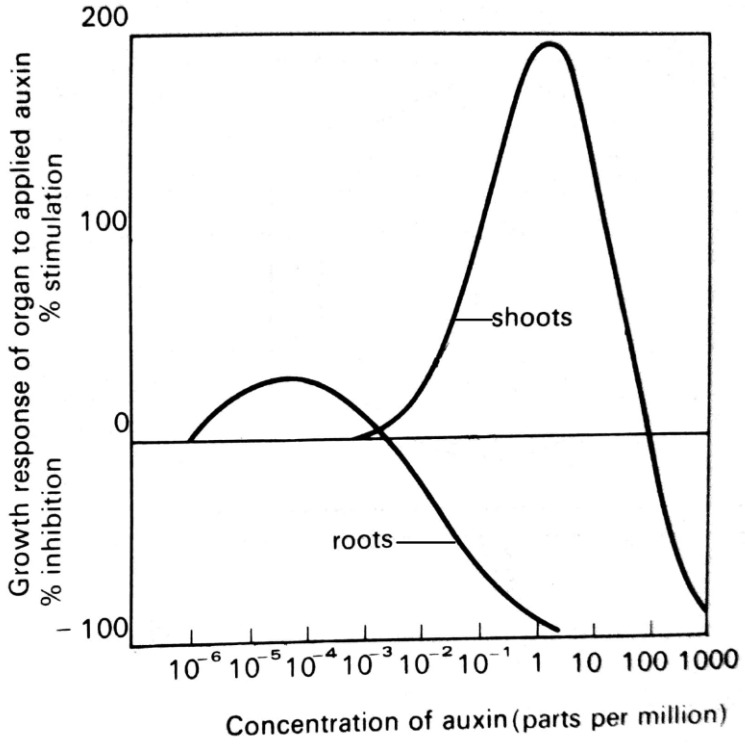


set up


results after 2 days

Conclusion: Roots are positively geotropic.

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



Observations:

Very low concentrations of auxins do not stimulate shoot growth. However, an increase in the amount of auxins brings about a rapid increase in the rate of growth of the shoot. If the amount of auxin in the shoot continues to increase, there comes a stage where the growth rate begins to slow down until at very high auxin concentration where growth is inhibited.

Roots are stimulated and inhibited by much lower concentrations of auxins than the shoots. Concentration of auxins which stimulate shoot growth inhibit root growth.

Very low concentrations of auxins stimulate root growth and high concentrations inhibit root growth.

Higher concentration of auxins stimulates growth of the shoot but inhibits growth of the root.

HYDROTROPISM

This is the growth movement of part of a plant in response to water. The roots of a plant grow towards water and are said to be positively hydrotropic.

When the root apex detects a unidirectional source of water, auxins move from the side without water to the side of water. Because growth in roots is favoured by a low auxin concentration, the side with a low auxin concentration grows faster than the side with high concentration hence causing the root to bend towards the source of water.

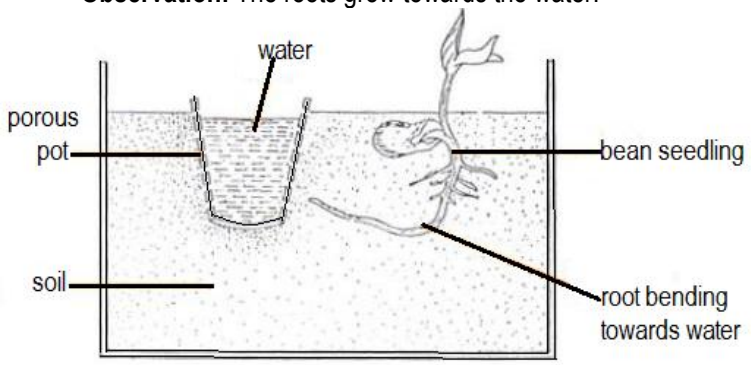
Roots enable a plant to absorb water and mineral salts through the root hairs. Water and mineral salts are used for processes like photosynthesis.

Experiment to show hydrotropism in roots

Materials:
Porous pot, viable seeds and Water

Procedure:
- Viable seeds are planted in a large pot, 6 cm from a porous pot.
- They are watered adequately until the radicles and plumule appear.
- The porous pot is then partially filled with water and the setup is left to stand for about 6 days.
- After the six days, the young plant is carefully uprooted and the hydrotropic root curvature observed.

Observation: The roots grow towards the water.



Conclusion: Roots are positively hydrotropic.

Revision question:

A biologist carried out an experiment to determine how auxins affect root and shoot growth. Different amounts of auxins in (ppm) were supplied to roots and shoots. The resulting growth responses of both shoots and roots are as follows in the table below. (Negative values are as a result of growth inhibition, while positive values are as result of growth stimulation).

Concentration of auxin /ppm	10^{-6}	10^{-5}	10^{-4}	10^{-3}	10^{-2}	10^{-1}	10^{0}	10^{1}	10^{2}	10^{3}
% growth response of shoots.	*0*	*0*	*0*	*0*	*20*	*100*	*200*	*100*	*0*	*-75*
% growth response of roots.	*0*	*25*	*30*	*10*	*-20*	*-60*	*-80*	*-100*	*-100*	*-100*

a) Using an appropriate scale(s) and on the same graph, draw graphs to represent the percentage growth response of shoots and roots with varying auxin concentration.
b) From your graph, describe the growth response of shoots and roots at different concentrations of auxin.
c) How does light influence the distribution of auxins, and what effect does this induce in shoots and roots?
d) Give the significance of the plant responses you have stated in (c) above to plants.

PLANT GROWTH SUBSTANCES

1. Indole Ascetic Acid (IAA)

Auxins are a group of plant growth hormones responsible for processes like growth, root formation and apical dominance. Auxins produced in plants include the ***Indoleacetic acid (IAA).***

Auxins are produced in small amounts in seeds, germinating embryos, buds, leaves and apices of roots, shoots and buds.

Effects of auxins on plant growth
- Promote elongation of young leaves.
- High auxin concentration stimulates the growth of the shoot but inhibits the growth of the root.
- They cause tropisms.
- They promote formation and growth of adventitious roots.
- They retard lateral buds in shoots.
- They promote apical dominance.

Commercial applications and uses of synthetic auxins
- Auxins are used to initiate rooting in stem cuttings.
- They are used to inhibit leaf fall when the leaf matures.
- They inhibit fruit fall.
- They inhibit the development of lateral buds hence reducing branching in plants. Removal of the apical buds therefore leads to branching.
- Synthetic auxins kill plants by disrupting growth hence used as selective weed-killers.
- Synthetic auxins stimulate fruit growth and parthenocarpic fruit development. Parthenocarpy is fruit development without fertilization.

2. Gibberellins
- They are produced by plants in varying amounts in seeds and young leaves and roots.
- They promote cell elongation.
- They promote germination in many seeds.
- Application of synthetic gibberellins to genetically dwarf plants causes bolting hence making dwarf plants grow taller.
- They also induce flowering in some plants.

EXPERIMENTS ABOUT AUXINS

Experiment to show that auxins are responsible for growth

Materials: Coleoptiles (plant seedling) and razor blade
Procedure: Using a razor blade cut off the tip of the coleoptile and leave it to stand for 3-6 days.
Observation: Growth stops taking place.

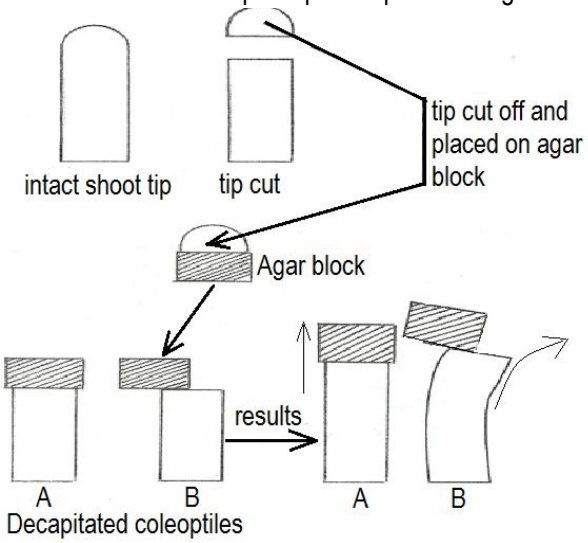
Explanation: The coleoptile tip produces new cells by cell division and it also produces a growth-promoting chemical, auxins. When the tip is cut off, the shoot no longer produces auxins hence growth stops.

Experiment to show the effect of unequal distribution of auxins and to show that auxins are diffusible

Apparatus/Material: Maize seedlings with coleoptiles, agar block (gelatinous substance through which auxins diffuse) and razor blade.

Procedure:

- Two maize seedlings with coleoptiles at least 2cm long are exposed to light for at least 4 hours.
- Cut the coleoptiles tips and transfer each on to an agar block and leave them for 24 hours.
- Remove the coleoptile tips and place the agar blocks on fresh decapitated shoot tips as shown below.



Observation:
Shoot A grew straight upright while shoot B grew bending away from the side with agar block.

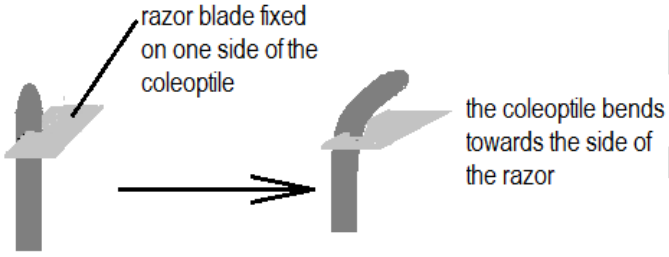
Explanation:
Auxins diffused from the coleoptile tips into the agar block. Thus auxins are evenly distributed on the agar block.
In shoot A- Auxins diffuse from the agar block into the decapitated shoot. All sides receive same concentrations of auxins. Cell elongation occurred and growth took place evenly with the shoot growing up right.
In shoot B- Auxins diffused on one side of the shoot. I.e. the side covered with agar block. There was faster cell elongation and hence faster growth on the side compared to the uncovered side. This resulted to the growth curvature observed.

Experiment to investigate the effect of auxin distribution on plant growth

Materials: Seedling coleoptile and Razor blade.

Procedure: Insert a razor blade on one side of the coleoptile tip and leave it to grow for about 3 days.

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.

Other examples of Tropic responses

1) **Thigmotropism**: This is also called haptotropism. It is the growth movement of part of a plant in response to touch. It occurs in plants which wind their stems round a support. E.g. passion fruits. Most of these plants have tendrils by which they cling to a support. When the tendril touches an obstacle, it twins round it. The climbing roots of certain figs and vanilla also show haptotropism.
2) **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.

Importance of tropisms to plants

i) Phototropism enables plant leaves trap maximum sunlight by enabling plant shoots to grow towards light.
ii) Geotropism enables plants to become firmly anchored in the soil by the roots growing towards the ground.
iii) Hydrotropism enables plant roots to absorb or obtain water which is necessary for plant growth and photosynthesis.
iv) Chemotropism enhances fertilization in plants since the pollen tubes grow towards the chemicals of the embryo sac.
v) Thigmotropism enables climbing plants to gain support by twinning around the support.
vi) Tropisms allow plant parts to alter direction in response to changing conditions in the environment.

Similarities between nastic and tropic movements

- Both are brought about by external stimuli.

- Both occur in plants
- Both involve movement of plant parts.

Differences between tropisms and nastic responses

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

Revision questions

1. *Explain what you understand by the terms irritability, stimulus and response.*
2. *a) Distinguish between a tactic and a tropic response.*
   b) Explain the survival values of tactic and tropic responses.
   c) What type of response would you expect in roots of a plant that are subjected to dry conditions on one side of the soil while the other side is moist?
3. *a) Name three plant hormones.*
   b) In which parts of a seedling are hormones produced?

The length of lateral shoots were measured at intervals of two days. The table below shows data on the growth of the four lateral shoots.

Time from the start of experiment (days)	*Length of lateral shoot (mm)*			
	A	*B*	*C*	*D*
0	*1.8*	*1.8*	*1.8*	*1.8*
3	*1.8*	*5.8*	*2.0*	*4.0*
5	*1.85*	*6.2*	*2.0*	*15.0*
7	*1.85*	*8.0*	*2.0*	*32.0*
9	*1.85*	*10.0*	*2.5*	*66.0*
11	*1.90*	*40.0*	*2.5*	*110.0*

a) i) Plot the results on a graph.
ii) With reference to the graph, describe the effects of each treatment in A, B, C and D.
iii) Give reasons to support your observations above.
b) i) State two precautions which should be taken when carrying out this experiment.
ii) Suggest one practical application of the results obtained in this experiment.

CO-ORDINATION IN ANIMALS

Animals have the ability to sense their environment and respond appropriately. The stimuli in animals include touch, pressure, sound, etc. The response made to a stimulus is usually a movement. When the whole organism moves, the movement is called a tactic movement (taxis). Most plants are fixed, and in their case, only part of the organism responds to the stimulus. Taxes are therefore, characteristic of animals rather than plants.

Protozoans, worms, arthropods and euglena respond to a unidirectional stimulus by a positive or negative tactic movement. *(Stone and Cozens: New biology for tropical schools, third edition)*

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 tactic movements

i) Phototaxis is movement in response to light.
ii) Chemotaxis is movement in response to chemicals.
iii) Thigmotaxis is movement in response to touch.
iv) Geotaxis is movement in response to gravity.

Examples of tactic movements

i) Unicellular organisms e.g. Euglena moves to areas of optimum light intensity and carries out photosynthesis hence positively phototactic.
ii) Earth worms, wood lice and cockroaches move away from light hence negative phototactic.
iii) Sperms of ferns and mosses swim towards the chemical produced by the ova hence positively chemotactic. This increases the chances of fertilization raising the chances of survival of these plants.
iv) White blood cell moves towards harmful bacteria in the body hence positively chemotactic.

v) Aerotaxis is a response to air. The atmospheric oxygen acts as the stimulus where the motile bacteria move towards oxygen.
vi) When pollen grains germinate on the stigma, the pollen tube exhibits negative aerotaxis thus grows into the stigma.

COORDINATION SYSTEMS IN MAMMALS

There are two main distinct coordination systems in mammals

1. **The nervous system**; which is a network of message conducting cells called neuron cells connected to all body parts.
2. **The endocrine system;** which is made up of a system of glands that produce chemical substances (hormones) for coordination.

CHEMICAL COORDINATION IN VERTEBRATES

This is the endocrine system of glands that secrete chemical substances called hormones.
This system is under the control of ***pituitary gland*** which is therefore known as the **MASTER GLAND** in the body because it controls the activities of all the glands in the body through the hormones it secretes.
*A hormone is a specific chemical substance produced by glands and is transported to a **target organ** to regulate physiological activities in the body.*

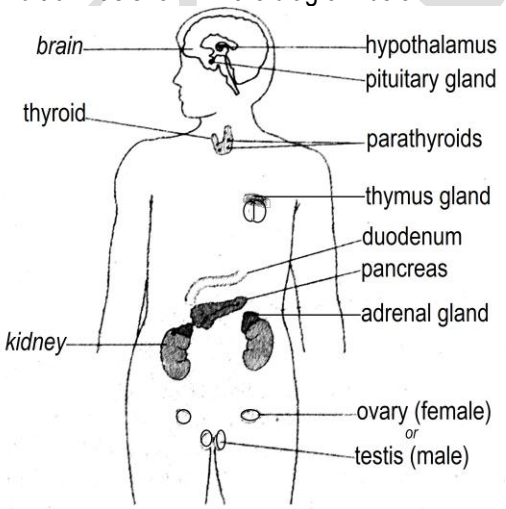
Characteristics of hormones

- They are protein in nature.
- They are produced and work best in small quantities.
- Their site of action is far from where they are produced.
- They are secreted by glands.
- Their effect on the target organ is either by stimulation or inhibition i.e. they regulate the activities of the target organs.

Hormones are secreted by endocrine glands and transported to the target organs by the blood.
These are tissues or organs that produce and secrete chemical substances. There are 2 types of glands i.e. ***endocrine*** and ***exocrine.***
Exocrine glands secrete hormones into ducts that transport the hormones to their target organ hence they are called **duct glands.** Examples include the pancreas which secrets pancreatic juice, salivary glands secret through ducts into the mouth cavity, sweat glands and tear glands.
Endocrine glands 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, pancreas, etc.
Endocrine glands are stimulated to secrete hormones either by impulses from the motor nerves or by hormones from other endocrine glands. The endocrine system is linked to the nervous system by the hypothalamus, which controls the activities of the pituitary gland.

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.

i) It produces antidiuretic hormone (ADH), which controls the amount of water and salts reabsorbed into the blood stream by the kidneys.
ii) It produces follicle-stimulating hormone (FSH), which causes the development of graafian follicles in the ovary.
iii) It produces thyroid-stimulating hormone (TSH), which stimulates the thyroid gland to secrete thyroxin.
iv) It produces adrenal cortical stimulating hormone (ACSH), which stimulates the adrenal gland to produce a hormone called cortisone.

v) It produces interstitial cell stimulating hormone (ICSH), which stimulates the testes to produce their hormone called testosterone.
vi) 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.***
vii) It produces luteinizing hormone (LH), which causes ovulation.
viii) Prolactin which stimulates milk production in pregnant females.
ix) 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 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 Langerhans***.
Insulin is produced from the β- islets of Langerhans***. 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 Langerhans 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 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 effects:

- 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 immunity in young mammals.

Revision questions

1. *What is meant by a hormone?*
2. *A student was frightened by a snake and immediately made an alarm.*
   i) *Giving a reason, suggest the hormone that is most likely to be found in the student's blood at a higher concentration.*
   ii) *State the effect of that hormone to the student's body.*
3. *Explain why*
   i) *The pituitary gland is referred to as the master gland.*
   ii) *The pancreas is both an exocrine and endocrine gland.*
4. *Draw a well labeled diagram showing the location of the glands in the endocrine system in man.*
5. State one function of at least one hormone secreted by each endocrine gland.
6. *A child sees a fierce lion and gets frightened, describe the events that occur in the child's body to escape this lion.*

NERVOUS COORDINATION IN MAMMALS

This is comprised of the nervous system which is a system of nerve cells and sensory organs that carry out co-ordination by transfer of impulses.
The nervous system consists of;
Receptors: These are organs detect ***stimuli*** to which the animals respond. E.g. sensory endings in the skin, nose, tongue, eyes and ears.
Stimuli create impulses which are relayed to the coordinating system.
Impulses: these are electrical transmissions or chemical stimuli sent from the receptors to the coordinating center. The coordinating center interprets the impulses before a response is made.
Effectors: These are organs that respond to the stimuli and carry out the response.
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 the vast network of spinal and cranial nerves linking the body to the brain and spinal cord.

Functions of the nervous system

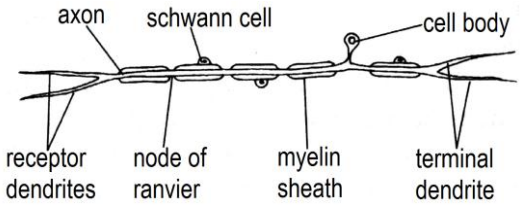
1. It receives impulses from all sensory organs of the body.
2. It stores information.
3. It correlates various stimuli from different sensory organs.
4. It sends messages to all parts of the body making them function accordingly.
5. It's involved in temperature regulation.

STRUCTURE AND FUNCTIONS OF THE NEURONE

A neurone 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 neurones i.e. Sensory neurone, Motor neurone and Relay neurone

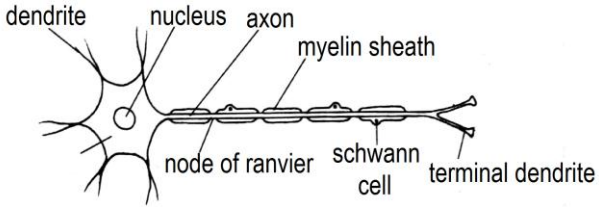
Sensory neurone

Sensory neurones are cells that transmit impulses from the receptor cells to the central nervous system.



Motor neurone

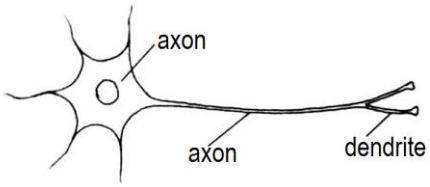
This is a neurone that transmits impulses from the central nervous system to the effector organs such as muscles and glands, where a response is made. The muscles respond by contracting while glands respond by secreting substances.



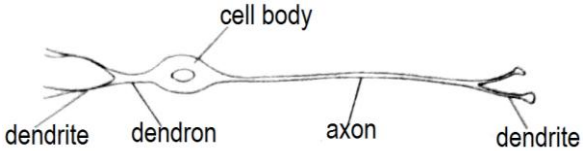
Relay neurone

This is a neuron located in the central nervous system and transmits impulses from the sensory neurone to the motor neurone. The axon extends towards the motor neurone. It is also referred to as an intermediate neurone. A relay neurone is either unipolar, bipolar or multipolar.

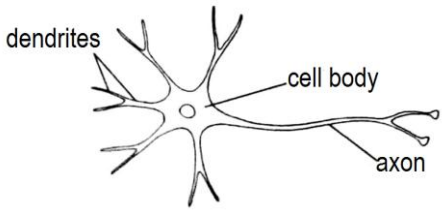
Unipolar neurone:



Bipolar neurone:



Multipolar neurone:



Functions of the parts of a neurone

Cell body: This consists of a nucleus surrounded by a mass of cytoplasm. The nucleus controls all activities of the neuron.
Axon: Transmits 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 the transmission of impulses.
Dendrites: These are hair-like structures surrounding the cell body. They conduct incoming signals.
Node of Ranvier: This is the space on the axon between two adjacent myelin sheaths. It speeds up nervous transmission.
Dendron: It is a branch through which impulses are transmitted to the body.

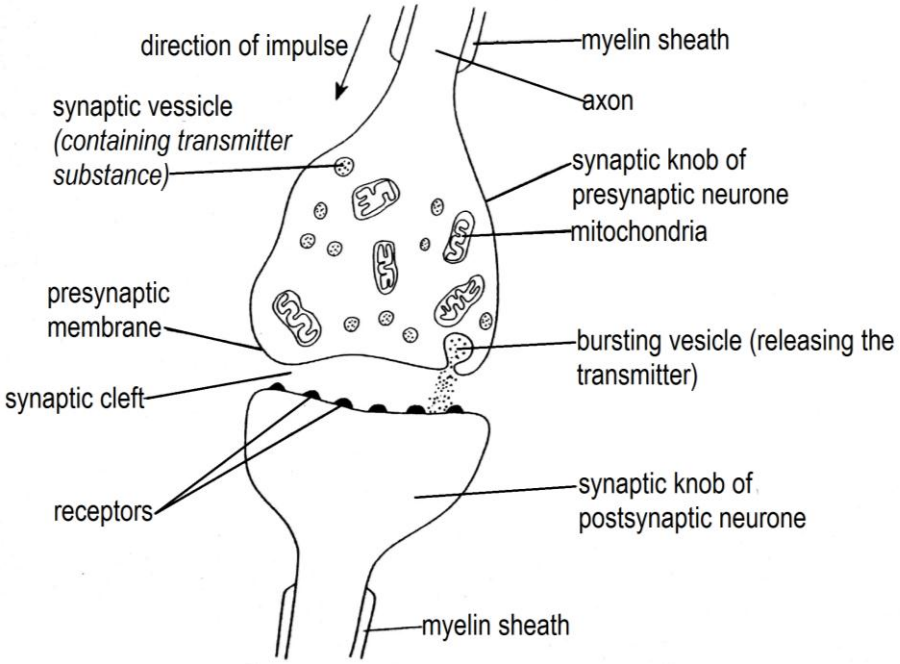
Differences between motor and sensory neurons

Motor neuron	Sensory neuron
Has a long axon.	Has a short axon.
It has a cell body at the terminal end of the axon.	Has a cell body located on the axon branch.
It has a short dendrons.	It has a long dendron.
It carries impulses from the central nervous system to the effector organ.	It carries impulses from the receptor cells to the central nervous system.
It has several dendrons.	It has one dendron.
Terminal dendrites connect with effector organ.	Terminal dendrites connect to relay neurones.

THE SYNAPSE

A synapse is a junction between the terminals of two adjacent neurones. This junction links the dendrites of one neurone to the dendrites of another adjacent neurone. Movement of an impulse across the synapse occurs when the synaptic vesicles carrying a transmitter substance acetyl choline moves towards and fuses with the presynaptic membrane to release acetylcholine into the space known as the synaptic cleft. The movement of synaptic vesicles towards the presynaptic membrane is aided by calcium ions. Once the transmitter substance acetylcholine is in the synaptic cleft, it attaches onto the receptors on the postsynaptic membrane to regenerate the impulse in the axon of the postsynaptic knob.

Structure of a synapse



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 synaptic 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.
- Filter out low levels of stimulus e.g. back ground stimuli at a constantly low level are filtered out, such impulse may be low which the body may not need to respond to.

Disadvantages of synapse

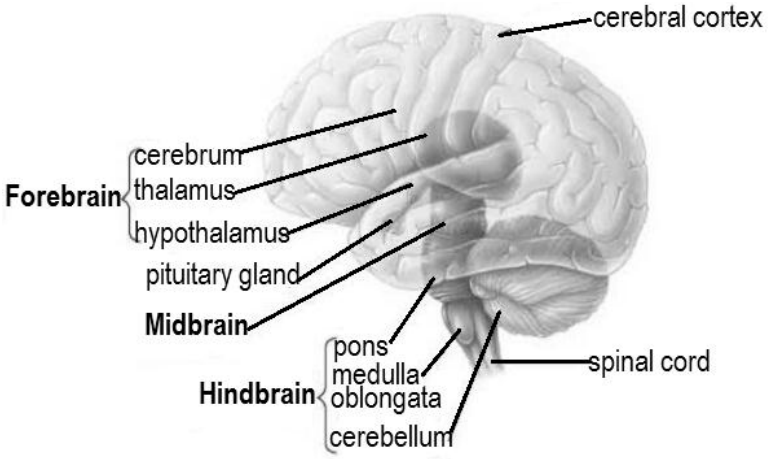
- Slows down the speed of transmission.
- Are highly prone to drugs and fatigue which may inhibit impulse transmission.

THE CENTRAL NERVOUS SYSTEM

This is made up of the brain and spinal cord and it coordinates all the neutral functions.

THE BRAIN

The brain is covered and protected externally by the skull (cranium) and internally by membranes called meninges. It is made up of three distinct areas namely the forebrain, midbrain and hindbrain.



Functions of the parts of the brain

1. **The fore brain**

It consists of:

i) The cerebrum (cerebral hemisphere):

It consists of right and left cerebral hemispheres which are interconnected by the corpus callosum. It is covered by a thin layer of cerebral cortex.

The right hemisphere sends and receives impulses from the left side of the body while the left hemisphere receives impulses from the right side of the body.

It coordinates learning, memory, reasoning, conscience and personality. It is responsible for intelligence.

ii) Thalamus: It transmits impulses of sensations received from sense organs to the cerebral cortex.

iii) Hypothalamus:

It controls activities of the pituitary gland

It also coordinates and controls the autonomous nervous system.

2. **The mid brain**

It relays audio and visual information.

It is also responsible for movement of the head and the trunk.

3. **Hind brain:** It is made up of:

i) Cerebellum: It is responsible for balance and muscular coordination.

ii) Medulla oblongata: It controls heartbeat, blood pressure, breathing rate, coughing and sneezing.

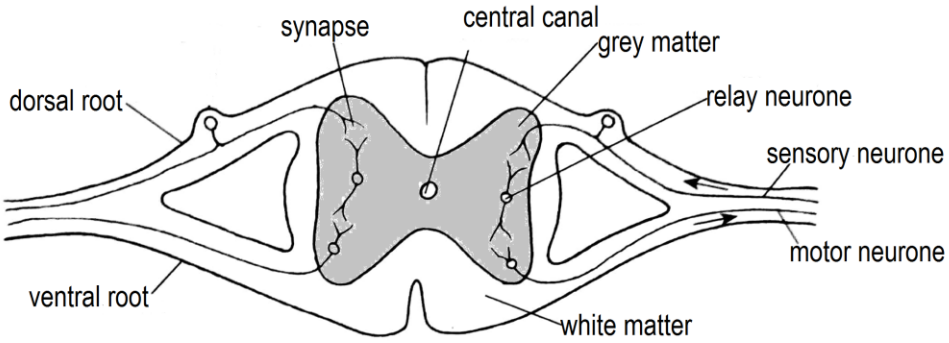
Functions of the brain

- 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 SPINAL CORD

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

Transverse section through the spinal cord



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 effectors.

THE PERIPHERAL NERVOUS SYSTEM

It is made up of neurones that link the brain and spinal cord to muscles and organs such as the eyes and ears.
It is divided into autonomic nervous system and somatic nervous system. The autonomic nervous system is responsible for the ***involuntary*** control of internal organs, blood vessels, smooth muscles and cardiac muscles.
The somatic nervous system is responsible for the ***voluntary*** control of skin, bones, joints and skeletal muscles.

Voluntary and involuntary actions

A voluntary action *is one initiated consciously under the direct control of the brain i.e. they are actions one does 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.*

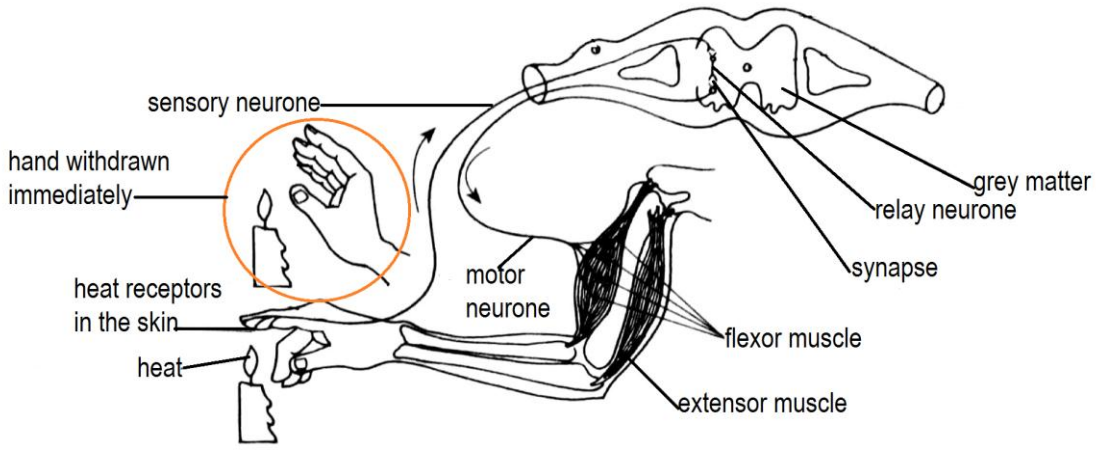
THE REFLEX ACTION

A reflex action is an automatic (involuntary) response to a particular stimuli. 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***. A reflex action can either be **simple** or **conditioned reflex**

SIMPLE REFLEX ACTION

This is an involuntary quick response to a stimulus without conscious thought. It is also known as an ***instinctive reflex*** which does not have to be learnt. They include sneezing, coughing, salivating, the knee jerk and removal of a hand from a hot flame. For instance, when one steps on a sharp object, the knee jerk enables the removal of the foot thus avoiding further injury.

Reflex arc of a hand being withdrawn from a hot flame



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

Characteristics of a simple reflex action

- ✓ It occurs rapidly i.e. the action occurs very fast.
- ✓ It is inborn (innate) but not learnt.
- ✓ It is coordinated 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 simple reflex actions

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

How a hand is withdrawn from a hot object (an 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 neurone to the spinal cord and then cross the synapse.
The impulse is then handed over to the relay neurone in the spinal cord (gray matter) and then cross another synapse.
The relay neurone 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

Importance of simple 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.

CONDITIONED REFLEX ACTION

This is the type of reflex action which involves learning. Organisms learn to respond to strange or meaningless stimuli by associating it with other meaningful/familiar stimuli, e.g. ***the Ivan Pavlov's experiment.***
A scientist called Ivan Pavlov performed an experiment to demonstrate a conditioned reflex action in a dog.
In his experiment he noticed that the sight or smell of food triggers off salivation reflex in a dog.
When Pavlov gave his dog food, the taste made the dog salivate. He later modified the experiment by ringing a bell each time he fed the dog. The two unrelated stimuli, that is sound and taste, were sensed simultaneously.
After several presentations of the two stimuli, he discovered that the dog salivated when the bell was rang even without the presentation of food. The dog had learned to associate the ringing of the bell to food, to a point whereby ringing the bell alone caused salivation.

Characteristics of a conditioned reflex action

- It is a temporary reflex
- It involves learning
- It takes a longer time to learn
- It is coordinated in the brain
- It involves more than one stimuli
- It involves association of stimuli
- It is reinforced by repetition
- Responses are involuntary

Similarities between simple and conditioned reflex actions

- 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 reflex action	Simple reflex action
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 coordinated 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.
Is an inborn, automatic response	Is a learned, automatic response
It is always constant	Can be reinforced through rewards or punishment.

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.
- Both systems transmit messages.

Differences:

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 body where sensory receptors are located.	Stimulus arises from specific places only e.g. endocrine glands.

Revision question:

a) Explain three ways in which the body benefits from effects of adrenaline.
b) Compare nervous and hormonal control systems.
c) Describe an experiment which can be set up to investigate the response of plant shoots to light coming from one direction.
d) How do shoots benefit from responding to unidirectional light?

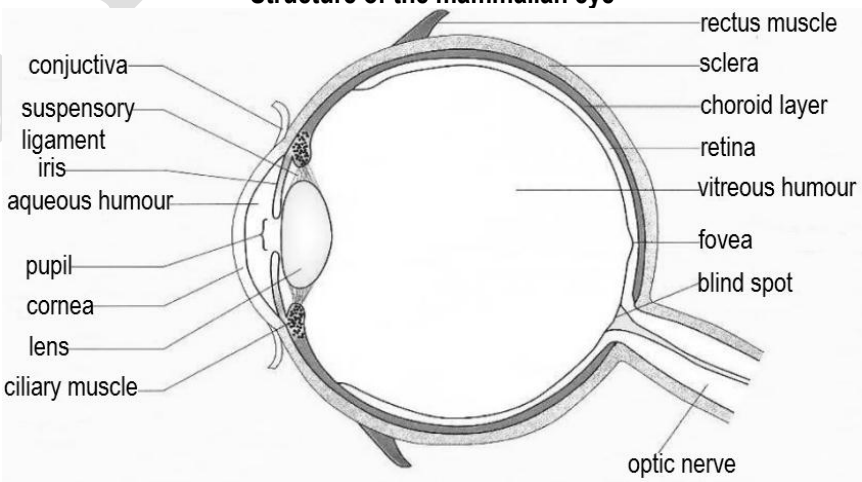
RECEPTOR ORGANS IN MAMMALS

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.

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

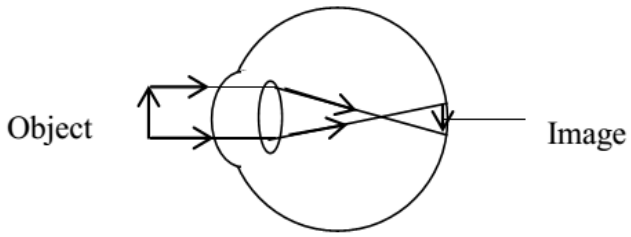


Parts of the eye and their functions

1. **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.
2. **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.
3. **The cornea:** This is a transparent layer in front of the eye.
   - It refracts (bends) light into the eye.
4. **The choroid layer:** It is pigmented and mainly contains black pigment.
   - It prevents internal reflection of light.
   - This contains a network of blood vessels supplying oxygen and nutrients to the eye.
5. **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.
6. **The vitreous humour:** 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.
7. **The ciliary body:** This contains ciliary muscles which control the size of the lens during viewing nearby or distant objects.
8. **The lens:** It refracts light to make an image on the retina.
9. **The iris:** It is responsible for controlling the amount of light entering the eye.
10. **The retina:** The retina is where the image is formed in the eye. This layer contains photoreceptor cells (light sensitive cells) the ***rods*** and the ***cones.***
    The cones are sensitive to coloured light and are responsible for colour vision. They are stimulated by high intensity light are hence 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 mainly used during night vision. Rods view objects only in black, white and sheds of grey that's why objects in dim light like at night appear in black and white.
    Nerve fibers from the photoreceptor cells run to the brain via the optic nerve.
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 tears 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.***



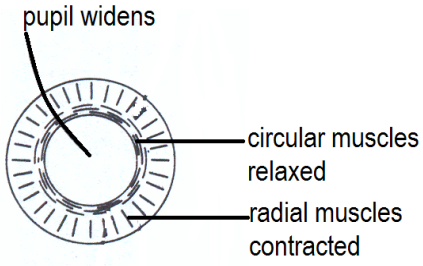
Control of light amount entering the eye

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

Kugonza

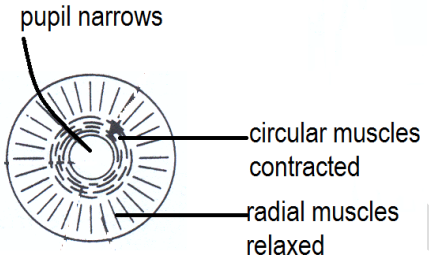
Control of the amount of light rays entering the eye in dim light

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



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 hence less light is admitted into the eye.

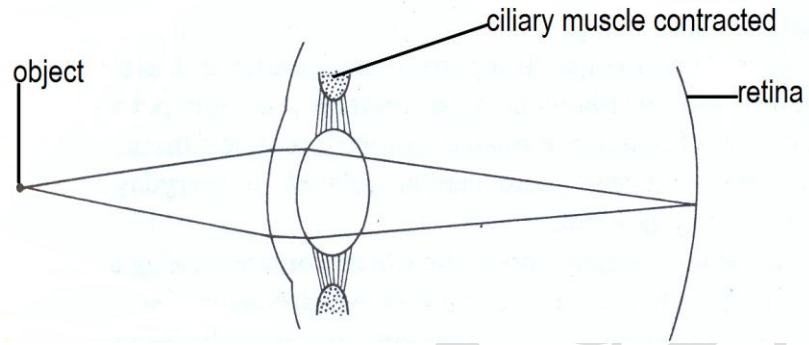


Accommodation of the eye

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

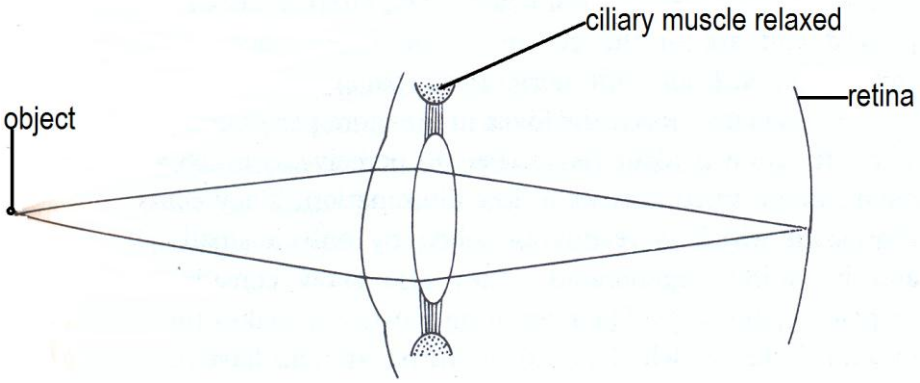
Accommodation for a nearby object:

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.



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.



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.
Ciliary muscles in the ciliary body contract.	Ciliary muscles in the ciliary 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.

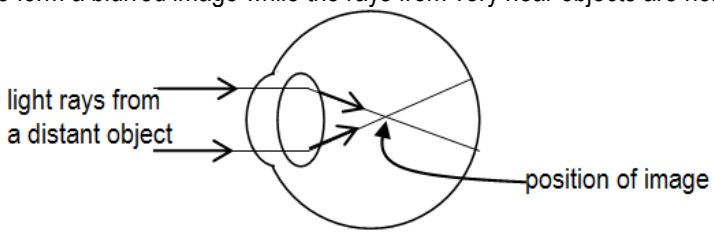
Light rays are refracted to the retina.	Light rays are refracted to the retina.

Eye defects

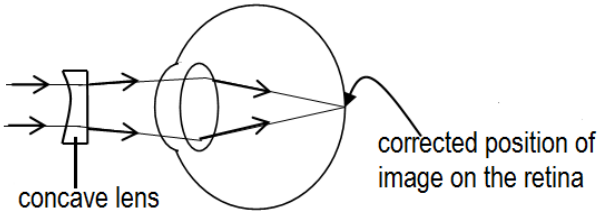
An eye defect is a condition where the eye fails to focus an object well unless aided by external lenses. The common eye defects include:

1. Short sightedness (myopia):

This is an eyesight abnormality whereby an individual focuses clearly on nearby objects. Distant objects are not clearly focused. It is usually caused by a large eyeball. Light rays from a distant object are brought to a focus before they reach the retina, and hence form a blurred image while the rays from very near objects are normally converged so as to produce a clear image.

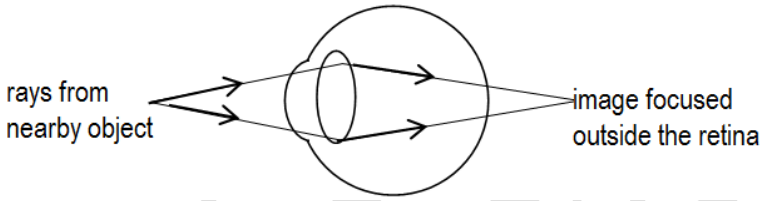


This can be corrected by putting on diverging (concave) lenses.

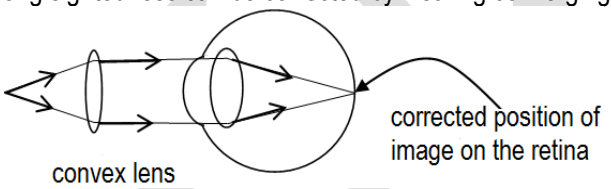


2. Long sightedness (Hypermetropia):

This is an abnormal condition in which vision for distant objects is better than for near objects. It is caused by a small or short eyeball or a very weak lens such that a close object is focused far behind the retina.



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



3. Astigmatism:

This is a defect in which light rays from a single point fail to converge in a single focal point. It 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 is farsightedness/long sightedness resulting from reduced ability to focus caused by loss of elasticity of the crystalline lens with age. It is a defect of vision due to old age. It produces difficulty of accommodation and recession of the near point of vision so that objects very near the eyes cannot be seen clearly without the use of convex glasses.

5. Cataract:

This is a clouding of the natural lens of the eye which prevents the passage of the rays of light and destroys the sight.
It is corrected by surgical removal of the thin opaque layer of the lens.

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 sensitive cones alone gives green colour.

Stimulation of red sensitive cones produces red colour. Equal stimulation of both green and red sensitive cones gives yellow colour. Equal stimulation of the entire three cones gives white colour and when no cone is stimulated, no colour (black) is perceived. This is known as the **trichromatic theory.**

Revision question

1. *The table below shows the changes in the diameter of the pupil of the eye in different light intensities.*

Light intensity (a.u.)	*0*	*5*	*10*	*15*	*20*	*25*
Diameter of pupil (mm)	*8.0*	*8.0*	*7.1*	*6.3*	*5.4*	*4.5*

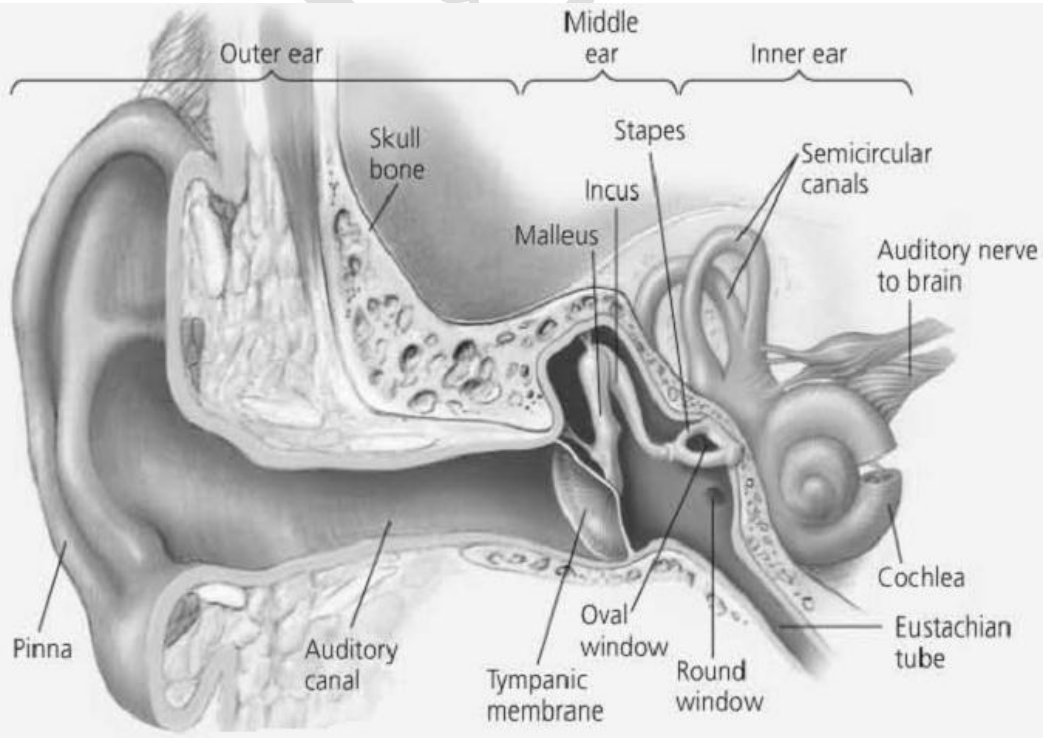
   a) *Plot a graph to represent the information in the table.*
   b) *Describe the effect of increasing light intensity on the diameter of the pupil.*
   c) *Explain how increasing light intensity affects the diameter of the pupil.*
   d) *The changes in the diameter of the pupil are because of a nervous response.*
      i) *The type of nervous response to which the pupil responds.*
      ii) *Two features of the nervous response to which the pupil responds.*
      iii) *Three benefits to the organism of eyes responding to light.*
2. What is meant by accommodation?
3. Describe with the aid of a well labeled diagram events that occur in the eye to focus and see clearly;
   i) An aero plane in the sky.
   ii) An apple while seated on a dining table.
4. Explain how footballer during a match is able respond to the sound of a whistle made by the referee.
5. What is accommodation of the eye?
6. Explain how eyes adjust to see:
   i) Nearby objects
   ii) Far objects
7. State the causes of at least two eye defects among humans.

THE EAR

The ear has **mechanoreceptors** (receptors that detect physical transformation) associated with sound, gravity and displacement. The ear performs three basic functions i.e. detection of:

- Sound (hearing)
- Head movements
- Changes in gravity (balance or posture)

Structure of the ear



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 which 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 the parts of the ear

- The outer projecting portion of the outer ear is known as the **pinna**. Its function is to receive and concentrate sound waves.
- The **auditory canal** has hairs and wax that trap foreign bodies. It transmits sound waves to the **eardrum** (**tympanum**).
- The ear drum is a thin membrane; the eardrum transmits sound waves to the middle ear.
- The three small bones i.e. **hammer** (**malleus**), **anvil** (**incus**) and **stapes** (**stirrup**) are known as **ear ossicles**. They transmit acoustic vibrations from the eardrum to the inner ear.
- The **Eustachian tube** is a slender canal that connects the middle ear to the pharynx. It equalizes the air pressure on the two sides of the eardrum.
- The **oval window** transmits sound vibrations to the inner ear.
- The **semi-circular canals**, **utriculus** and **sacculus** form the **vestibular apparatus**, which controls body balance and posture. The canals are filled with fluid which moves as the body moves or when the head changes position.
- The **cochlea** facilitates hearing.
- The **round window** equalizes pressure in the cochlea.
- The **auditory nerve** transmits impulses to the brain.

The process of hearing in mammals

The pinna receives and concentrates the sound waves.

They are transmitted to the eardrum, which vibrates.

The vibrations of the eardrum are transmitted to the ossicles that vibrate and transmit the vibrations to the oval window at the entrance of the **vestibular canal** of the cochlea.

The **perilymph** (fluid in the vestibular canal) vibrates and causes **Reissner's membrane** to be displaced.

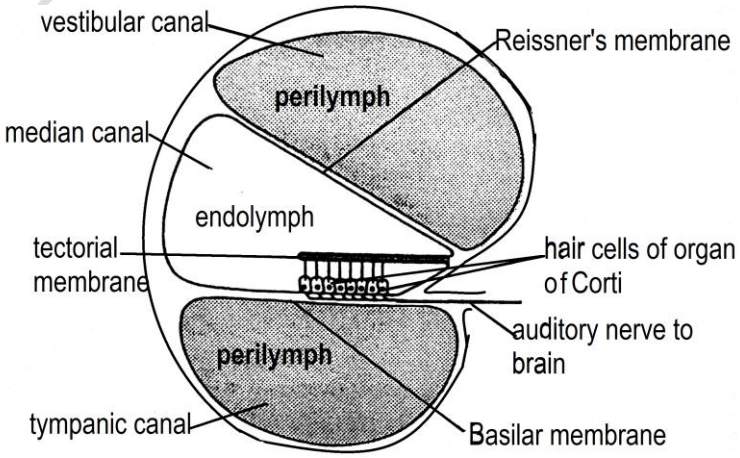
The displacement of Reissner's membrane causes the **endolymph** in the **median canal** to vibrate, which in turn causes the **basilar membrane** to vibrate.

The vibration of the basilar membrane stimulates sensory cells (in the **organ of Corti**), which generate impulses.

The impulses are transmitted by the auditory nerve to the brain, which interprets them into sounds.

The vibrations of the basilar membrane disturb the perilymph in the **tympanic canal**. The round window takes up these vibrations.

Transverse section of the cochlea



Deafness

Deafness is the inability to hear. It may be brought about by a defect in the nerves or the conduction of waves.

Causes of deafness

- ***Accumulation and hardening of wax in the outer auditory canal*** that presses against the eardrum. This can be controlled by use of cotton buds to remove excess wax after the wax has been softened using warm water.
- ***Blocking of the Eustachian tube*** as a result of accidents and certain infections such as the common cold, etc. This can be treated by use of antibiotics to kill the bacteria that caused the infection.
- Some individuals are born with ***thick eardrums*** that do not easily vibrate. This can be solved by use of hearing aids.
- ***Ruptured eardrum*** due to accidents and infections. Sometimes the eardrums heal on their own or a hearing aid can also be used.
- Damage to the cochlea as a result of ***exposure to loud noise over a long period of time***. This can be prevented by keeping sound volume low because once the cells of organ of Corti in the cochlea are damaged, they cannot be repaired.
- ***Fused ossicles*** due to infections that cause inflammation in the middle ear. Some individuals are born with fused ossicles. The ossicles do not hit each other when they vibrate. This can be treated by medication to kill the microorganisms that caused the infection or surgical operation to replace the ossicles.
- ***Damage to the hearing centre of the brain*** also causes deafness.

THE SKIN

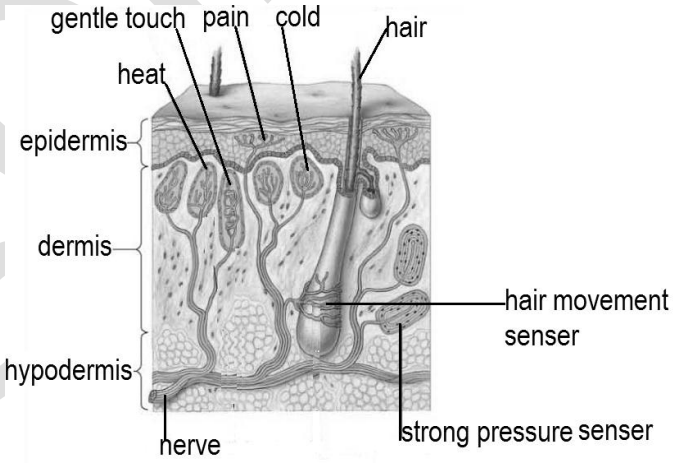
The skin is a sense organ responsible for the senses of pain, touch, pressure and temperature. The skin has mechanoreceptors, pain receptors and thermo receptors.

Mechanoreceptors sense physical deformation caused by forms of mechanical energy such as pressure, touch, stretch and motion. The sense of touch relies on mechanoreceptors that are dendrites of sensory neurons. Touch receptors are often embedded in layers of the skin. Other receptors sense movement of hairs. For example, cats and many rodents have extremely sensitive mechanoreceptors at the base of their whiskers which help them to detect the size of the tunnel and also get information about nearby objects.

Pain receptors detect stimuli that reflect harmful conditions like extreme pressure and temperature hence triggering defensive reactions such as withdrawal from danger.

Thermo receptors in the skin and hypothalamus detect heat and cold. *(**Note:** in essence, we describe spicy foods as 'hot' because they activate the same sensory receptors as do hot things).*

Structure of the skin as a sense organ showing the sense receptors

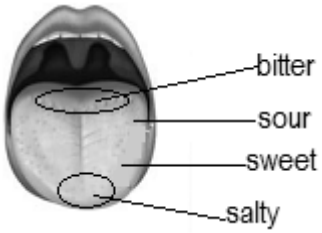


THE TONGUE

The tongue is a chemoreceptor organ for taste. It changes chemical stimuli 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 taste, i.e. *sweet, sour, salty and bitter*.

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.

Structure of the tongue showing the taste regions



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.

CARE FOR THE SENSE ORGANS

1. **Eyes:**
   - Eat yellow and orange fruits and vegetables. Good eyesight requires vitamin A found in these kinds of food.
   - Protect your eyes from too much sunlight.
   - Avoid reading inside a moving vehicle.
   - Avoid playing with sharp and pointed objects.
   - Do not rub your eyes if dirt gets into them.
   - Be sure there is sufficient lighting when you read.
   - Read with the light coming from over your shoulder and not from the front.
   - Sit upright when you read.
   - Rest your eyes by looking out of the window and focusing your sight on distant objects.

2. **Ears:**
   - Use soft cloth to clean your ears after taking a bath.
   - Never poke any sharp object into your ear.
   - Avoid listening to loud music in a closed room or through a headphone.
   - If you have an earache, visit the doctor.
   - If an insect is inside your ear, pour lukewarm water (*Lukewarm water* is water that has a temperature a little warmer than room temperature) into the affected ear.
   - If a foreign object inside an ear cannot be removed, see a doctor.

3. **Skin:**
   - Eat fruits and vegetables.
   - Take a bath daily.
   - Avoid too much sunlight.
   - In case of skin infection that takes a long time to heal, see a doctor for treatment.

4. **Tongue:**
   - Gently brush your tongue to remove tiny bits of food trapped between its folds.

5. **Nose:**
   - Use soft cloth or cotton balls to clean your nose after washing your face or taking a bath.
   - Avoid blowing your nose too hard.
   - Apply first aid in case of bleeding.

"There are no limitations to the mind except those we acknowledge"

Kugonza