CO-ORDINATION SYSTEMS IN MAMMALS

There are two main distinct coordination systems in mammals

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.

1. **The nervous system**; which is a network of message conducting cells called neurone cells are 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.

The interaction of the systems of the body in order to regulate internal functions and behaviour is called **coordination**. The nervous system and endocrine system effect the coordination, integration and control of physiological activities. For example, during exercise when the body needs more oxygen and food, the ventilation rate increases and the heart beats faster in order to send a greater volume of blood rich in oxygen and glucose to the muscles.

TACTIC RESPONSES

This is a type of response where the organism moves in response to a directional stimulus.

The organism may move towards (positive taxis) or away (negative taxis) from a unidirectional stimulus. This response is common in lower organisms such as chlamydomonas, chlorella, and antheroziods of moss, and in animals such as earthworms and wood lice.

TYPES OF TACTIC RESPONSES

i. ***Photo taxis;*** this is the movement of the whole organism in response to unidirectional light.

Positive photo taxis is when the organism moves towards the direction of light for example white ants and grass hoppers, chlorella

Negative photo taxis is when the organism moves away from the direction of light for example earthworms and wood lice.

ii. ***Chemo taxis;*** this is the movement of the whole organism in response to unidirectional chemical agents.

Insects are negatively chemo tactic to insect repellants and insecticides

Male sheep and goats are positively chemo tactic to hormones in urine of females

iii. ***Thermo taxis;*** this is the movement of the whole organism in response to unidirectional extreme of temperature.
Blowfly larvae (maggots) are negatively thermo tactic and they always move away from extremes of temperature

iv. ***Thigmo taxis;*** this is the movement of the whole organism in response to touch that is unidirectional.
Most insects such as cockroaches, and other invertebrates like earthworms are negatively Thigmo tactic.
Domestic cats and dogs tend to exhibit positive Thigmo taxis

v. ***Hydro taxis;*** this is the movement of the whole organism in response to water or moisture that is unidirectional.
Wood lice show positive hydro taxis while cats tend to be negatively hydro tactic

Importance of tactic responses

- Negative thermo taxis enables organisms to avoid desiccation due to extreme high temperatures, such as maggots.
- Organisms that are negatively Thigmo tactic are able to escape predation
- Organisms such as chlorella obtain sufficient light for photosynthesis since they are positively photo tactic
- Negative chemo taxis enables insects to survive death that may be caused by pesticides.

Title/aim: An experiment to show negative photo taxis in wood lice

Materials

- Large petri dish
- Black marker
- Large Petri dish cover with central hole
- 5 Wood lice

Procedure

- One half of the base of petri dish and half of petri dish cover are painted black using a black marker.
- Petri dish is covered with petri dish cover such that the painted halves overlap.
- Set up is placed under light
- Wood lice are slid in through the central hole of cover and set up left for 5 minutes

Observation

- ***More wood lice found on dark side than illuminated side***

Conclusion: *wood lice are negatively photo tactic*

THE ENDOCRINE SYSTEM (HORMONAL SYSTEM)

This is the system of ductless glands that produce chemical substances called hormones to target organs.

- The ***pituitary gland*** controls most though **not all** endocrine glands and is therefore known as the **MASTER GLAND**.

*A hormone is a specific chemical substance produced by a gland, enters the blood stream and is transported to a **target organ**, causing a response.*

- 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.

Characteristics of hormones

- ✓ They are either protein or steroid in nature
- ✓ They work best in small quantities
- ✓ They are secreted directly into blood streams
- ✓ Their site of action is far from where they are produced
- ✓ They are only effective at the target organs or cells
- ✓ 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 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 organs through 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:

1) Pancreas releases pancreatic juice.
2) Salivary gland has salivary duct that carries saliva into the mouth cavity.
3) Sweat glands
4) Tear glands

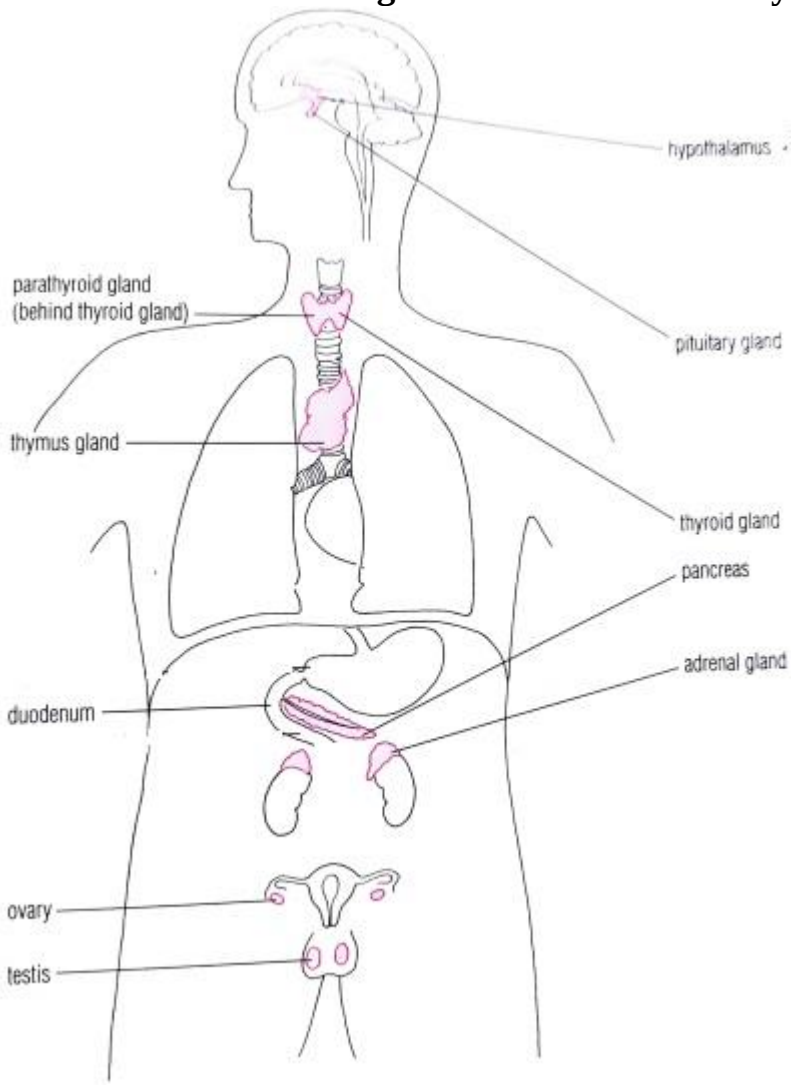
NOTE: *The focus of this topic however are the **endocrine glands***

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 glands** i.e. have no ducts e.g. pituitary gland, thyroid gland, islets of Langerhans in pancreas, etc.

Location of endocrine glands in the human body



HORMONES OF THE ENDOCRINE GLANDS AND THEIR FUNCTIONS

1. Pituitary gland

Found at the base of the brain immediately above roof of mouth. It's mainly controlled by the **hypothalamus**.

- Controls activities of other glands thus called master gland.
- Consists of two parts; anterior pituitary and posterior pituitary
- Secretes two types of hormones i.e. trophic hormones and non-trophic hormones
- Trophic hormones control secretion of other hormones by endocrine glands e.g. thyroid stimulating hormone, follicle stimulating hormone etc.
- Non trophic hormones affect activity of non-endocrine tissues. They are only three i.e. growth hormone, oxytocin and antidiuretic hormone(ADH)

Table showing effects of hormones produced by the pituitary gland

HORMONE	Abbreviation	FUNCTION
Thyroid stimulating hormone	TSH	✓ Stimulates thyroid gland to produce thyroxinee hormone
Follicle stimulating hormone	FSH	✓ Stimulates sperm formation in testis ✓ Stimulates formation and development of Graafian follicle in females
Interstitial cell stimulating hormone	ICSH	✓ Stimulates secretion of testosterone from testis
Luteinizing hormone	LH	✓ Causes ovulation ✓ Stimulates development of corpus luteum from Graafian follicle
Antidiuretic hormone	ADH	✓ Controls water reabsorption in kidney tubules
Growth hormone	GH	✓ Controls growth of bones and muscles ✓ Controls general body metabolism. Over secretion leads to ***gigantism.*** Under secretion leads to ***dwarfism***
Prolactin		✓ Induces production of milk in pregnant/lactating females
Oxytocin		✓ Induces uterine contraction to cause birth (parturition) ✓ Induces lactation. Release of milk from nipple

2. The thyroid gland.

Found in the neck close to the larynx (voice box). This produces a hormone **thyroxine**.

FUNCTION

- ❖ Control growth and development in young ones e.g. metamorphosis in tadpoles
- ❖ Controls cellular respiration in organisms, being high when secreted and low when little quantity of hormone is present

NB: among adults, too little secretion of thyroxine leads to **overweight** and **sluggishness** and too much of it causes thinness and over activity. Deficiency of thyroxine in infancy cause a type of mental deficiency known as **cretinism** which can be cured if identified early by administering thyroxine in the body.
Thyroxine contains iodine. Lack of iodine results into little or no production of thyroxine and causes the thyroid gland to increase in size a deficiency disease called **goiter.**

3. Adrenal gland.

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

a) Cortex; this is the outer region of the adrenal gland. The adrenal cortex produces a hormone cortisone

Function:

- Cortisone stimulates conversion of fats into glucose for cell respiration
- Cortisone stimulates conversion of amino acids into glucose for cell respiration

b) Medulla; this is the inner region of the adrenal gland.

The adrenal medulla is stimulated by nervous impulses to produce a hormone known as **adrenaline**. Adrenaline is produced in situations of anxiety, excitement, feeling or when facing of danger.
Adrenaline when secreted has the following effects;

i) It increases the rate of heartbeat.
ii) It increases the breathing rate.
iii) It widens the pupils of the eyes.
iv) It brings about conversion of glycogen to glucose in the liver.
v) It increases the rate of respiration in order to ensure adequate supply of energy to body muscles.
vi) Reduces blood supply to the skin and alimentary canal with more blood channeled to the muscles.

Due to effects above, adrenaline is referred to as **"freight or fight" hormone.**

4. The pancreas.

This consists of a tissue I***slets of Langerhans*** *consisting of two groups of cells;* ***α cells*** *and* ***β cells***.
β cells secrete **insulin** hormone which *stimulates the liver cells to convert* ***excess glucose*** *into* ***glycogen*** *for* ***storage***.
α Cells secrete ***glucagon*** *hormone which stimulates the liver cells to convert* ***glycogen*** *to* ***glucose.*** *The glucose may be used during cell respiration to produce energy.*

5. The duodenum.

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

6. The reproductive organs/ Gonads (testes and ovaries)

The ovary in females produces two major hormones. These are **oestrogen** 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 produced by the corpus luteum after ovulation and is responsible for

- Thickening the endometrium for implantation
- vascularization the endometrium for implantation
- maintaining the endometrium for implantation
- Prevents constriction of uterus until baby is due to be born.

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

i) Deepening of the voice.
ii) Growth of beards.
iii) Toughening of muscles.
iv) Widening of the chest.
v) Enlargement of reproductive organs.
vi) Growth of pubic hairs.
vii) Sperm production.

7. Parathyroid gland

It secretes parathormone which has the following functions:

- ✓ Raises blood calcium levels.
- ✓ Lowers blood phosphate levels.

8. Thymus gland

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

It's responsible for formation of lymphocytes which defend body against pathogens.

MECHANISM OF COORDINATION BY THE ENDOCRINE SYSTEM

The endocrine system controls body activities and responses by a feedback mechanism. There are basically two feedback mechanisms;

a) ***Negative feedback mechanism***: - here, a level of a factor in the body beyond the norm or set point stimulates a corrective mechanism. For example

i. When there is too much glucose over and above the set point of 90mg/cm^3 of blood, this is detected by β cells which then release the hormone insulin. Insulin stimulates processes that result into lowering of blood glucose concentration such as conversion of excess glucose to glycogen and soon the set point is restored. This results into a feedback as blood moves through the pancreas such that no more insulin is secreted

b) ***Positive feedback mechanism***:- here, an increase in the level of a factor results into further increase in the same direction, for example

i. Towards the end of gestation period in females, oxytocin hormone is secreted by the pituitary gland. This results into contractions to expel the baby during birth, however, the contractions of the uterus stimulate further production of oxytocin hormone which in turn increases the intensity of uterine contractions such that parturition occurs.

Comparison between hormones and enzyme

Similarities

- Both are required in minute concentrations for action
- Both are specific in action; enzymes work on specific substrate while hormones affect only target organs and tissues
- Both affect body metabolism

Differences

HORMONES	ENZYMES
✓ May be proteins or steroids	✓ Are protein in nature
✓ Site of action different from site of production	✓ Site of action either at or away from site of production
✓ Transported through blood to target organ	✓ Not transported through blood but in ducts
✓ Secreted only by endocrine glands	✓ Secreted by all body cells

THE NERVOUS SYSTEM

This is a system of nerve cells or neurones and sensory organs that carry out co-ordination by transfer of impulses. Impulses transmitted may either be **electrical** or **chemical**.

Organisms need to detect changes in their environment and respond to them

Key terms

- ***Stimulus:*** *this is a change in the internal or external environment of an organism*
- ***Receptor:*** *this is a structure which detects a stimulus e.g. nerve endings in skin, rod cells and cone cells in eye*
- ***Effector:*** *these are structures which carryout response to a stimulus e.g. glands and muscles*
- ***Response:*** *this is a change in activity or process due to change in the environment for example sneezing upon inhaling of dust.*

STRUCTURE OF THE NEURONEE

A neurone is an impulse transmitting cell made up of a cell body consisting of a small mass of cytoplasm and a nucleus, branching cytoplasmic filaments called dendrites and a single long cytoplasmic tubular structure called axon. In some cases the axon and dendron may be surrounded by an insulating sheath made of fatty material called **myelin**.

NOTE: basing on presence or absence of myelin sheath, there are two types of neurones; **myelinated neurones** and **non-myelinated neurones**

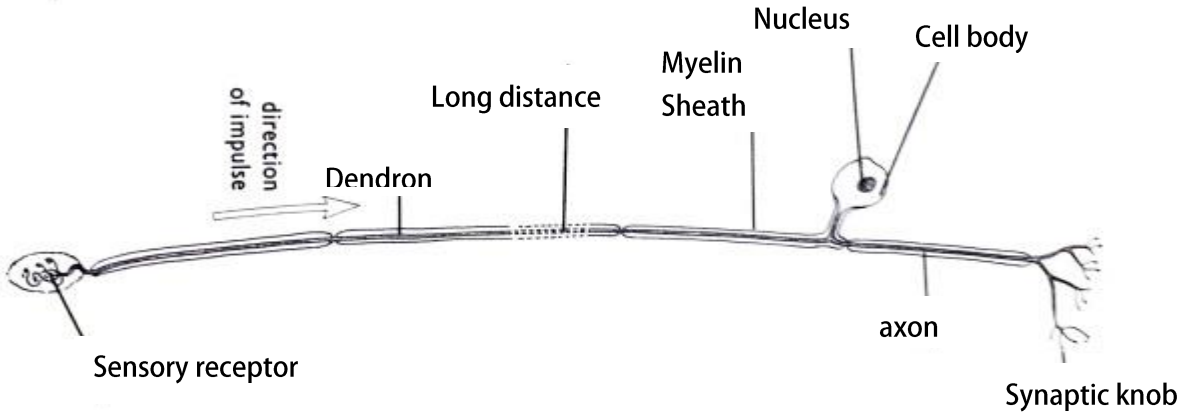
There are three types of neurones.

1. Sensory neurone
2. Motor neurone
3. Intermediate neurone or multipolar neurone or relay neurone

SENSORY NEURONE

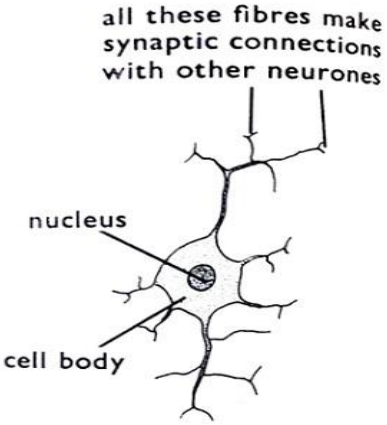
These are neurones that transmit impulses from the receptors to the central nervous system. A sensory neurone has a single elongated dendrite called a **dendron** consisting of a fluid filled cytoplasmic tube. It has a cell body at the junction of the short axon and dendron.

STRUCTURE OF THE



INTERMEDIATE NEURONE (RELAY NEURONE)

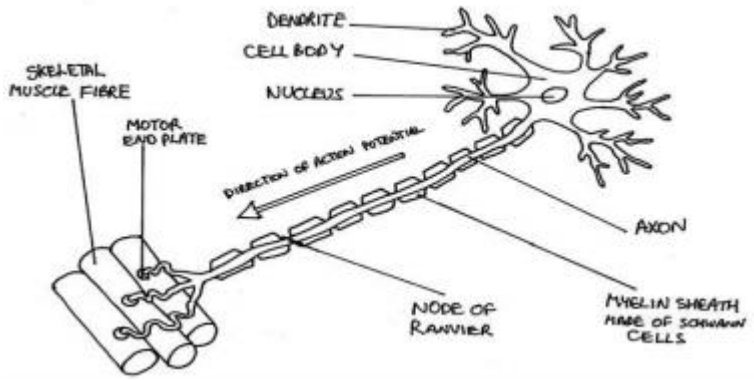
This is a neurone found in the central nervous system and carries impulses from the sensory neurone to the motor neurone.



MOTOR NEURONE

This is a neurone that carries impulses from the central nervous system to the effectors. Motor neurones 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 neurone



General functions of the parts of a neurone

1. **Cell body**; this consists of a nucleus surrounded by a mass of cytoplasm.

Function: The nucleus controls all activities of the neurone.

2. **Axon**; this is one or more long cytoplasmic extensions running from the cell body.

Function: Axons carry impulses over long distances from cell body to tissues in the body. Each axon is filled with cytoplasm called **axoplasm**.

3. **Myelin sheath**; this is a fatty material that covers the axon. The myelin sheath is secreted by cells called **Schwann cells**.

Function: The myelin sheath insulates the axon and speeds up transmission of impulses.

4. **Dendrites**; these are fine cytoplasm structures on the neurone.

Function: they conduct nerve impulses towards the cell body

5. **Node of Ranvier**; this is the space on the axon between two adjacent myelin sheaths.

Function: It speeds up nervous transmission.

6. **Cytoplasm**; this is a site for chemical reactions in the neurone.
7. **Dendron**; elongated dendrite which transmits impulses to the cell body.
8. **Schwann cell**; this is a cell which secretes the myelin sheath.

Comparison between motor and sensory neurones

Similarities:

1. They both transmit impulses.
2. They both have a nucleus.
3. They both have an axon,
4. Both have dendrites
5. Both have cytoplasm in their cell bodies.
6. In both impulses move in one direction.

Differences:

Motor neurone	Sensory neurone
i) Has a longer axon	Has a shorter 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 dendrite	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 dendrites	It has one Dendron

vi) Terminal dendrites connect with effectors	Terminal dendrites connect to intermediate neurones.

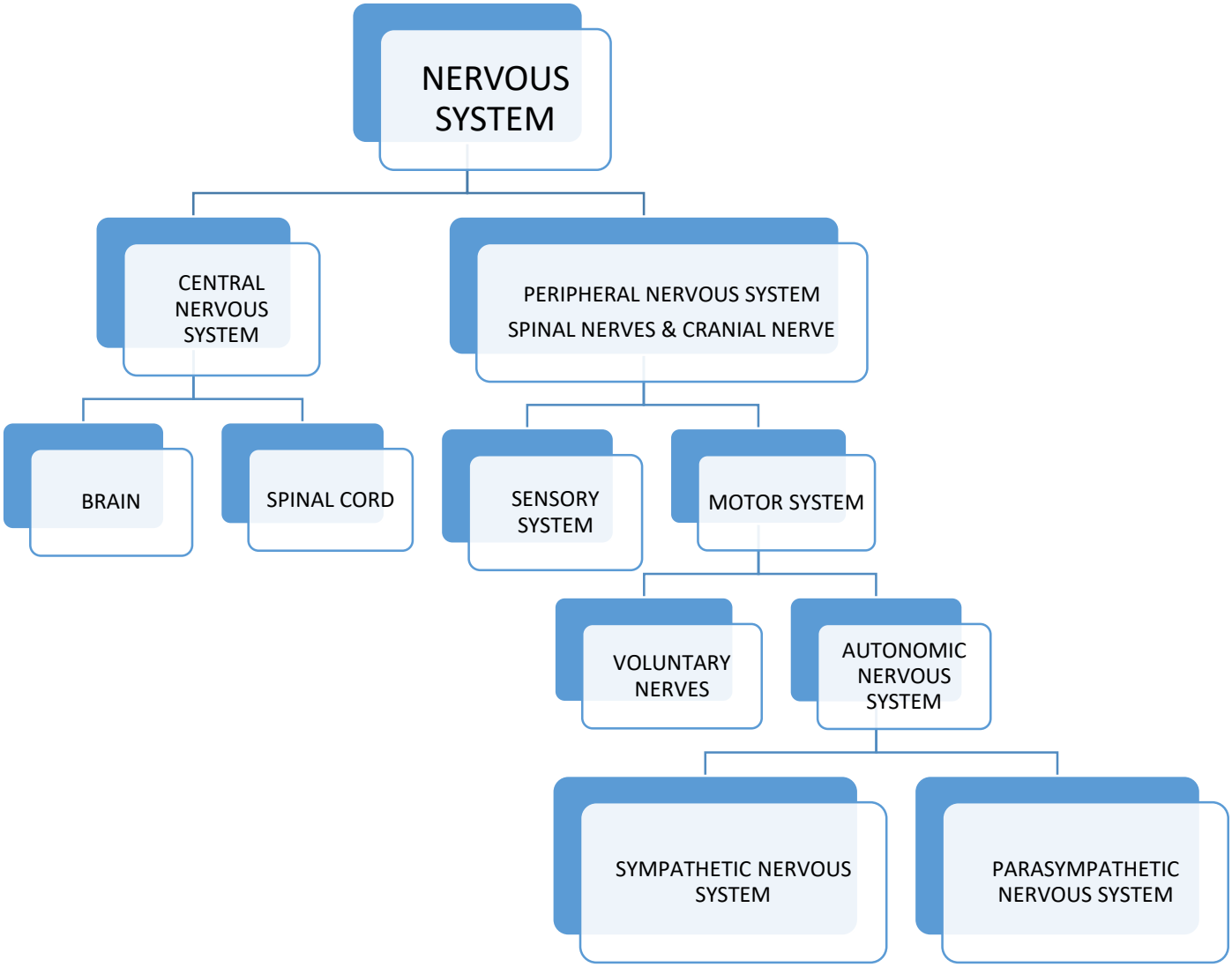
Questions

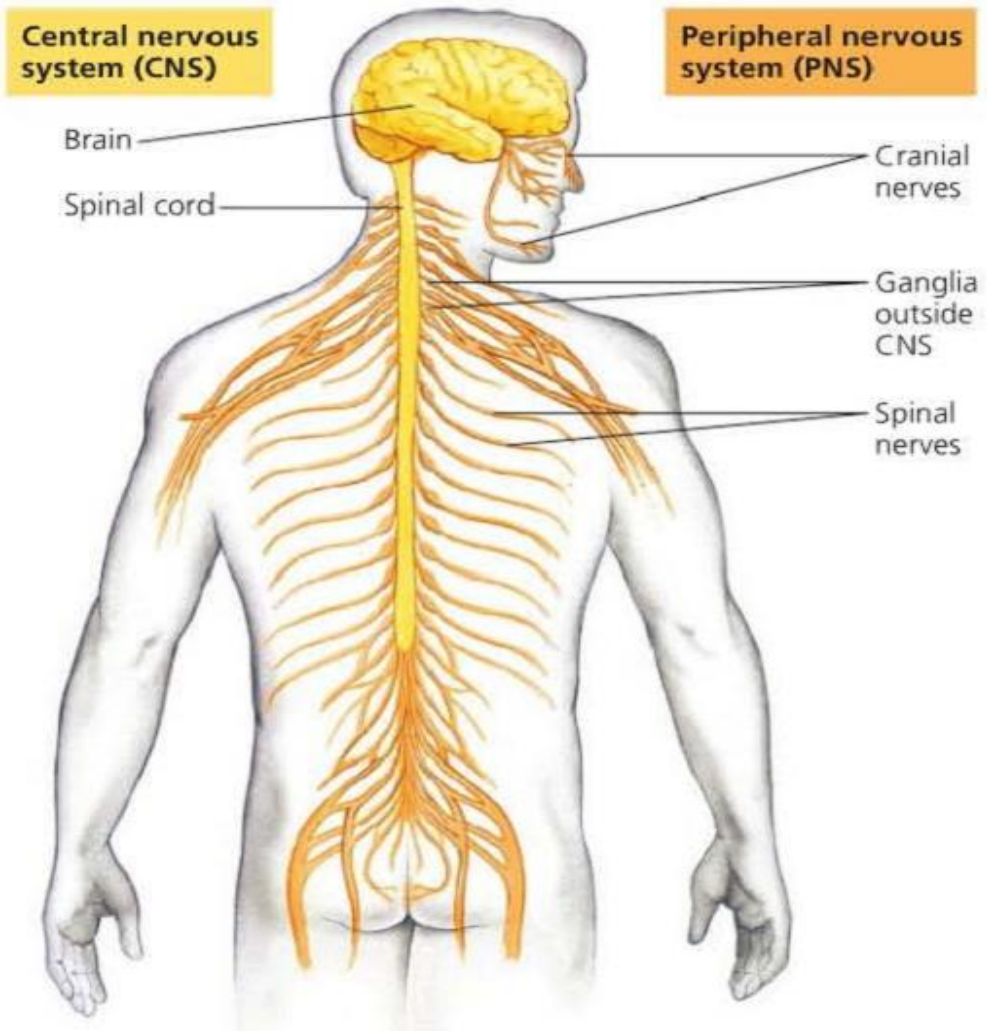
Compare

i) Sensory neurone and intermediate neurone

ii) Motor neurone and intermediate neurone

COMPONENTS OF THE NERVOUS SYSTEM


NERVOUS SYSTEM
CENTRAL NERVOUS SYSTEM
PERIPHERAL NERVOUS SYSTEM
SPINAL NERVES & CRANIAL NERVE
BRAIN
SPINAL CORD
SENSORY SYSTEM
MOTOR SYSTEM
VOLUNTARY NERVES
AUTONOMIC NERVOUS SYSTEM
SYMPATHETIC NERVOUS SYSTEM
PARASYMPATHETIC NERVOUS SYSTEM



The nervous system consists of;

i) Receptors:

These detect the stimuli e.g. sensory endings in the skin, rods and cones

ii) The central nervous system (CNS)

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

iii) Peripheral nervous system

This consists of spinal and cranial nerves which are either voluntary or involuntary nerves. The involuntary nerves form the autonomic nervous system

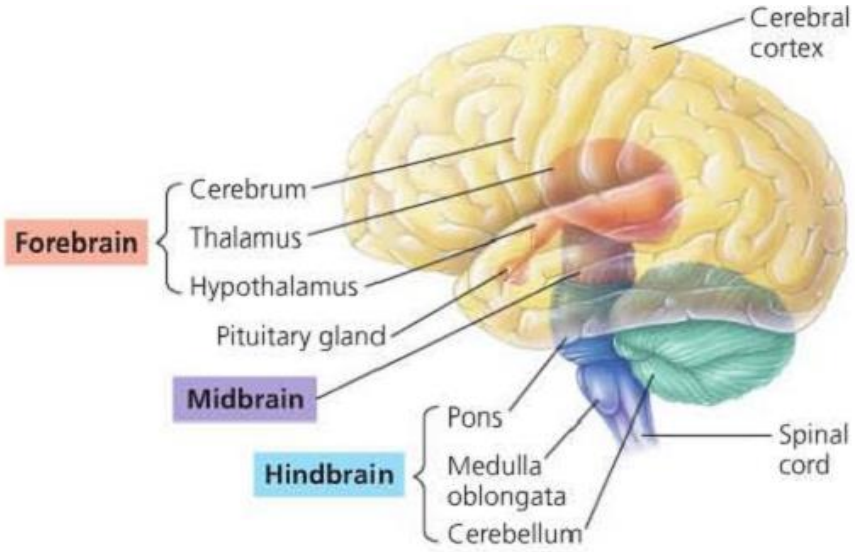
- **autonomic nervous system**

This consists of the sympathetic and parasympathetic nerves.

THE CENTRAL NERVOUS SYSTEM

This is made up of the brain and spinal cord.

THE BRAIN



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

Functions of the brain

2. It receives impulses from all receptors and sends back impulses to the effectors.
3. It integrates and coordinates all activities in the body such that the body works efficiently.
4. It stores information.
5. 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
2. Mid brain
3. Hind brain

1. **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.

ii) 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:

i) 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.

ii) Hypothalamus

It is a centre of many activities controlling unconsciousness. 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.

iii) 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.***

iv) Optic lobes

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

3. Hind brain

It is made up of:

i) Cerebellum

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

ii) 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 through to the tail and protected by the vertebral column.

In cross section, the spinal cord consists of grey matter and the outer white matter to form a roughly H shaped structure.

The grey region consists of cell bodies while the white region consists largely of nerve fibers.

Each pair of spinal nerves that connect to the spinal cord divide into two, forming two dorsal roots through which sensory nerves move to the spinal cord and two ventral roots though which motor neurones leave the spinal cord.

The dorsal roots have a ganglion, appears to be a swelling and it contains cell bodies if sensory neurone. This is called the **dorsal root ganglion**.

Functions of the spinal cord

1. It transmits impulses between the peripheral nervous system to the brain.
2. It is a center for control of simple spinal reflex actions
3. Relay impulses up and down the body

PERIPHERAL NERVOUS SYTEM

This consists of the **spinal nerves** and the **cranial nerves**. These nerves comprise the sensory nerves and motor nerves. The motor nerves control either voluntary or involuntary responses by transmitting impulses to effectors.

The involuntary responses are controlled by the autonomic nervous system. It consists of the sympathetic and parasympathetic nervous system

.

Comparison between the effects of sympathetic and parasympathetic nervous systems

Sympathetic nervous system	Parasympathetic nervous system
Increases cardiac output	**Decreases cardiac output**
Increases blood pressure	**Decreases blood pressure**
Dilates bronchioles	**Constricts bronchioles**
Increases breathing rate	**Decreases breathing rate**
Dilates pupils of eyes	**Constricts pupils of eyes**
Contracts urinary bladder sphincter	**relaxes urinary bladder sphincter**

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 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 and are normally effected by skeletal muscles.

Involuntary actions *are the ones that occur without conscious thoughts e.g. breathing, pumping action of the heart, vasodilation and vasoconstriction etc. these are controlled by the autonomic nervous system i.e. sympathetic and parasympathetic nervous systems. Involuntary actions or responses are effected by the smooth muscles*

Functions of the nervous system

1. It receives stimuli about changes in internal and external environment.
2. To process information received from receptors
3. Integrates information from sensory structures in relation to previous experiences
4. It coordinates various stimuli from different sensory organs
5. It sends messages to effectors to cause response.

THE SYNAPSE

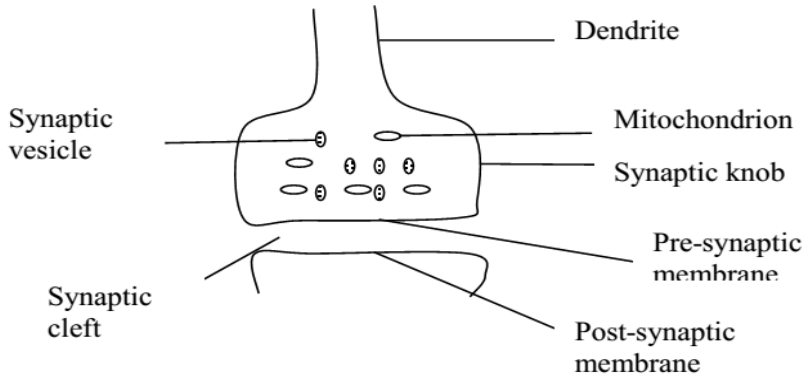
A synapse is a junction between the terminals of two adjacent neurones.

Junction links a dendrite of one neurone to a dendrite of another adjacent neurone.

Description of synapse

- Consists of presynaptic neurone whose axon expands to form a **synaptic knob**.
- The synaptic knob contains numerous **mitochondria** and **synaptic vesicles**
- The **synaptic vesicles** contain a **neurotransmitter** chemical e.g. acetylcholine
- The presynaptic neurone has a presynaptic membrane from which neurotransmitter diffuses into a gap, the **synaptic cleft**
- On the opposite end of the synaptic cleft is the presynaptic membrane of the adjacent neurone.

Structure of a synapse



Functions of a synapse

1) It enables propagation (movement) of an impulse from one neurone to another.
2) It ensures that an impulse moves in one direction by having vesicles on one side of the synapse.
3) The synapse acts as a junction in the nervous system which enables multiple presynaptic neurones to transmit information to a single post synaptic neurone.
4) Important in filtering out low level stimuli
5) Allows adaptation to intense stimulation.

NERVE IMPULSE

An impulse is an electric or chemical message transmitted along nerve fibers. A nerve impulse is initiated by stimulation of receptors by a stimulus e.g. light, sound etc. the stimulus causes buildup of a potential to threshold level, resulting into an action potential being generated such that the impulse is transmitted. If the stimulation does not reach the threshold, no impulse is transmitted and that stimulus is not detected.

Transmission of an impulse

When a stimulus reaches a receptor cell and is large enough to reach threshold, an action potential is generated. The impulse generated is passed to the cell body of a sensory neurone. The impulse is then transmitted along a dendron to a cell body in the CNS. The impulse then moves along the axon to reach the presynaptic membrane.

The arrival of an impulse at the presynaptic membrane triggers synaptic vesicles to release neurotransmitter substance into the synaptic cleft. This diffuses across the cleft, transmitting the impulse which stimulates the post synaptic membrane of post synaptic neurone to generate an impulse hence the impulse being passed on along the axon.

After the passage of an impulse across the synapse, the neurotransmitter substance is broken down by an enzyme.

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

THE REFLEX ACTION

This is a rapid automatic response to a stimulus by an organism and doesn't involve the brain.

Reflex actions take place without conscious control. A reflex action occurs as a result of impulses travelling along neurones in a path called a **reflex arc**. Examples of reflex action include;

- knee jerk reflex
- change in size of pupil in response to light intensity
- blinking when foreign particle falls on cornea
- sneezing in response to foreign particles
- corneal reflex
- hand/foot withdrawal reflex

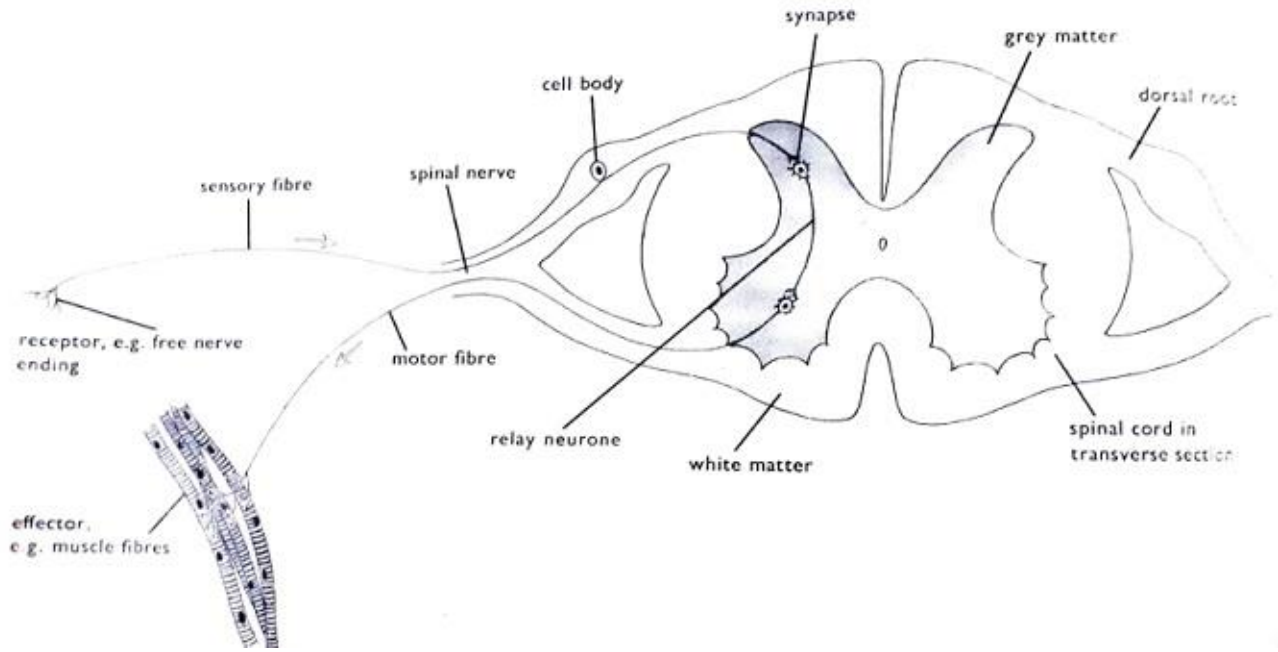
Reflex arc

This is a path taken by neurones involved in a reflex action.

DESCRIPTION OF A REFLEX ARC

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 transmits the impulse to a relay neurone across synapse. 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.

Diagram showing a reflex arc



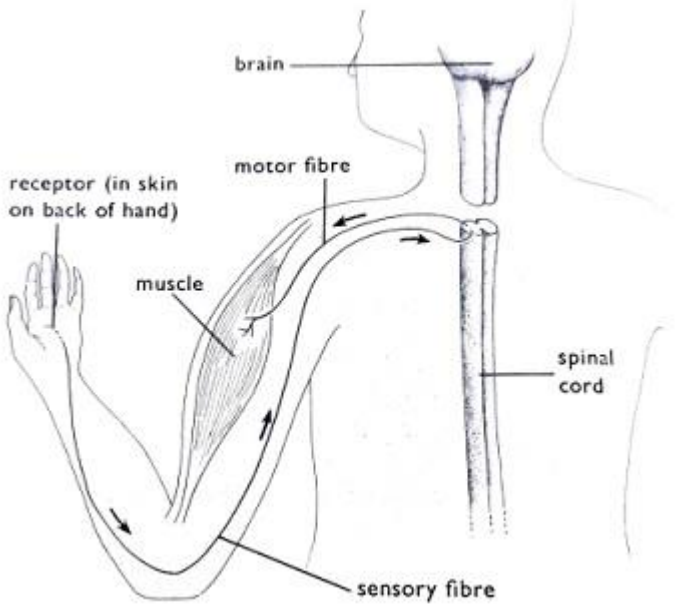
Characteristics of a reflex action

- ✓ It occurs rapidly i.e. the action occurs very fast.
- ✓ It is inborn (innate) but not learnt.
- ✓ It is 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 neurones are involved.

Example of a simple reflex action (what happens when one touches a hot object)

1. When one accidentally touches a hot body using a finger, the receptors in the finger receive the stimulus and an impulse is generated that travel along the sensory neurone to the spinal cord.
2. The impulse is transmitted to the relay neurone in the grey matter of spinal cord across a synapse.
3. The impulse is then relayed to the motor neurone across a synapse.
4. The motor neurone then carries the impulse from the spinal cord to the effector muscles of the hand for example the biceps. This causes the muscles to contract and the hand is withdrawn from the hot body.

Illustrative diagram



Advantages of reflex actions to animals

1. They help animals to avoid danger.
2. They control activities in the body, which we do not have conscious control over.
3. They form a basis of some animals' behaviour, e.g. amoeba.

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 a learned reflex which involves associating a meaningless stimulus to a desirable response, e.g. salivating whenever a bell is rung.

A scientist called Ivan Pavlov performed an experiment to demonstrate a conditioned reflex in a dog.

- In the experiment, food was presented to a dog at a particular time.
- The dog would salivate either after the smell, sight or taste of food (normal response). He then started ringing a bell before presenting food to the dog.
- After several times, the dog salivated when a bell was rang even without food being presented.
- Thus the desired response of salivating was conditioned to a meaningless stimulus i.e. sound of the bell

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 **temporar**y.

Characteristics of conditioned reflex action

- ✓ It is a temporary reflex
- ✓ It involves learning
- ✓ It takes a longer time to learn
- ✓ It is coordinated by 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 neurones 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 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.

Similarities between reflex and voluntary actions

- ✓ Both are coordinated 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 neurones	They involve three neurones

Similarities between the nervous and endocrine system

- ✓ Both affected by nature of stimulus
- ✓ Both cause a response
- ✓ Both result co-ordination in the body
- ✓ Both involve chemical transmission of messages
- ✓ Responses in both are both physiological and physical

Nervous system	Endocrine system
Nerve impulses are both electrical and chemical	Messages are only chemical
Responses are fast.	Responses are slow
Responses are shorter lived	Most responses occur over a longer time
Impulses are transmitted 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 organs and tissues only 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. Cerebro-malaria

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

6. Epilepsy

A patient loses consciousness suddenly and quickly. It is inherited

RECEPTION

As earlier discussed, a receptor is a structure; either tissue, organ or part which is capable of detecting a stimulus.

Examples of stimuli that result into responses include

- ***Light***
- ***Light intensity***
- ***Carbon dioxide concentration***
- ***pH***
- ***osmotic pressure***
- ***high temperature***
- ***low temperature***
- ***touch***
- ***chemicals***

SENSE ORGANS OR RECEPTOR ORGANS IN MAMMALS

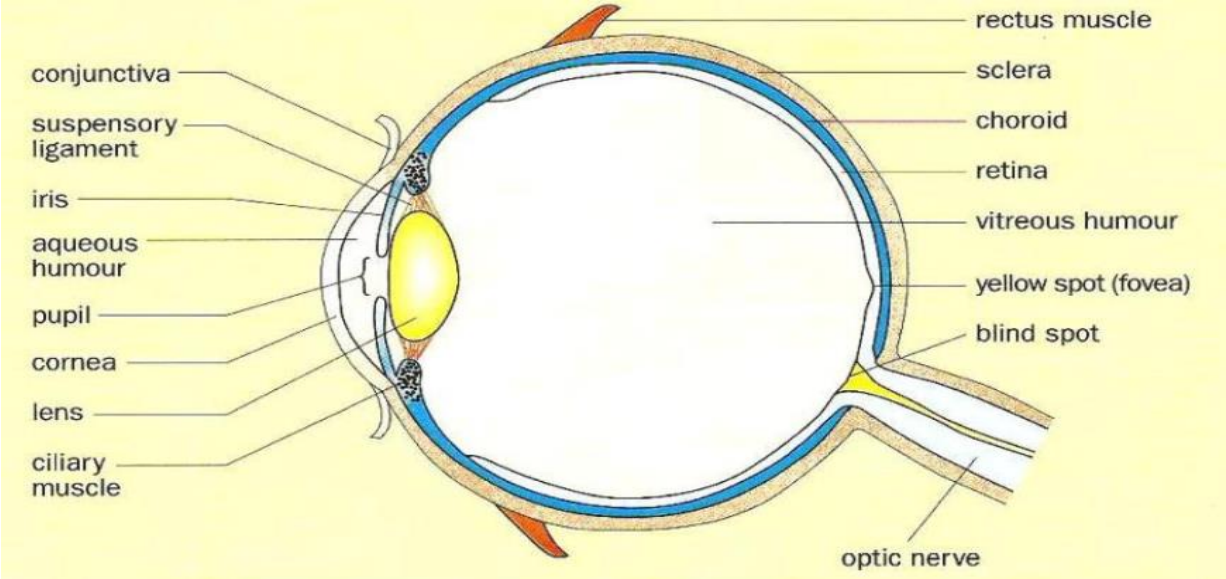
These are organs that perceive the stimulus and change it into nervous impulse, a process called **transduction**

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 detect.

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

1. The conjunctiva:

This is a thin transparent layer lining the inside of the eyelid, front of the sclera and is continuous with epithelium of cornea. It cushions, protects the eye and holds it in position.

It enables smooth movement of eye ball since it's moistened.

2. The sclera:

This is a tough inelastic outermost layer of 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 disc in the front of the sclera.

It refracts (bends) light into the eye.

4. The choroid layer:

It is a layer of tissue below the sclerotic layer.

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

It function to prevent internal reflection of light.

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

5. The aqueous humour:

It is a solution of sugar, salts and proteins in water.

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. Like aqueous humour, it's a solution of sugars, salts and proteins in water.

It is transparent and maintains the shape of the eye.

It refracts light to the retina.

7. The iris

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

The contraction of the opposing sets of circular and radial 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.

8. Pupil.

This is a round black hole in the iris. It allows light to pass into the eye to the lens.

9. The ciliary body:

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

10.Suspensory ligaments.

These are inelastic fibers that hold the lens in position.

11.The lens.

It is transparent and held by suspensory ligaments.

It refracts light to form an image on the retina.

12.The retina

This is a layer containing photoreceptor cells (light sensitive cells)

There are two types of light sensitive cells on the retina known as the ***rods*** and the ***cones.***

- ✓ *Th**e 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. They are functionally important even during night
- ✓ 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. This enables light perception
- ✓ 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.

- ***The retina is where the image is formed in the eye.***

13.Nerve fibers from the photoreceptor cells run to the brain via the **optic nerve**.

14.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 called a blind spot.

15.The fovea

This is a small depression in the center of the retina. It has only a high concentration of cones. Due to this, it produces the most accurate images in the eye.

16.Eye lids

These protect the eye. Regular blinking enables the spread of the fluid all over the exposed surface of the eye.

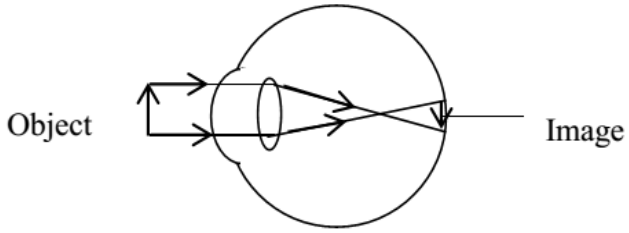
17.Eye lashes

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.*** The inversion of the image on the retina is corrected in the optical centre of the brain to form an impression of an upright image

Illustration



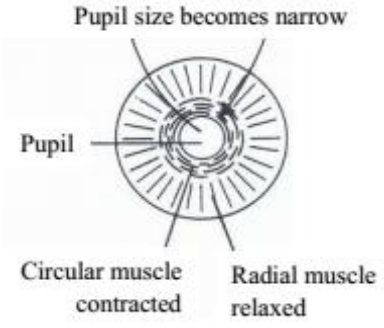
CONTROL OF LIGHT AMOUNT ENTERING THE EYE

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

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.

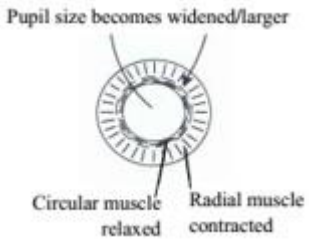
Control of the amount of light rays entering the eye when in dim light:

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



Control of bright light

- Circular muscles of the iris contract
- Radial muscles relax
- Pupil becomes narrower
- Less light enters the eye



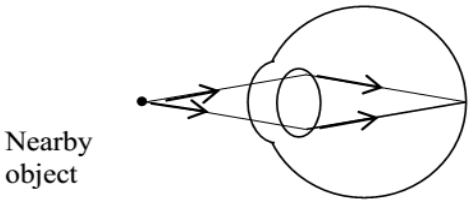
ACCOMMODATION OF THE EYE

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.

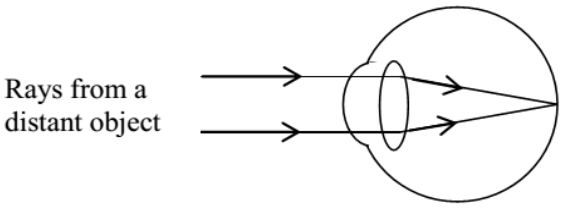
Illustration



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.
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.

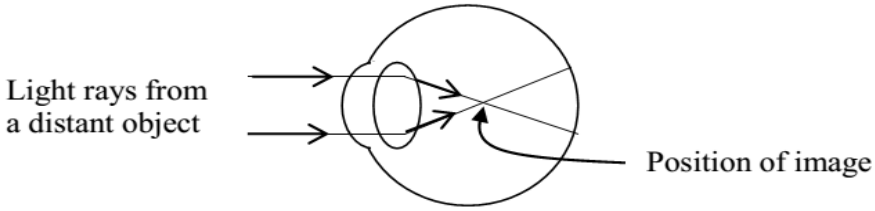
Eye defects

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:

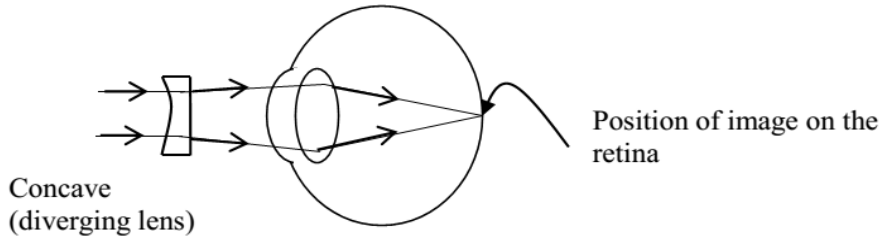
1. Short sightedness (myopia):

This is 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



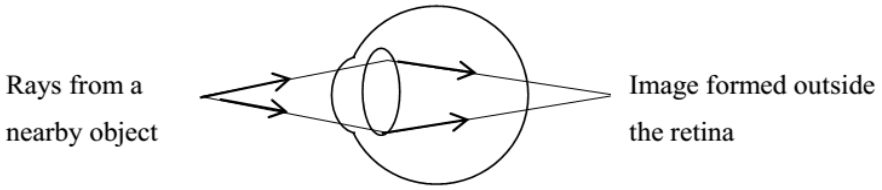
This can be corrected by putting on diverging (concave) lenses.



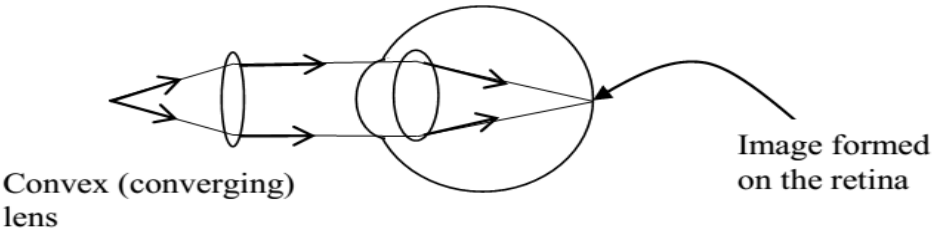
2. Long sightedness (hypermetropia):

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.

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

The ear is a receptor organ that contains receptor cells sensitive to sound vibrations, relative orientation of the head and general posture of an organism.
The ear performs two basic functions i.e.

- ❖ Hearing
- ❖ Balance of body

✓ There are three basic regions of the ear

- Outer ear
- Middle ear
- Inner ear

1. The outer ear:

This consists of a flap of elastic cartilage covered by skin called **pinna** and an auditory canal, a tube connecting the outer ear to the middle ear.
FUNCTION: *receive sound vibrations and to channel sound vibrations to the ear drum (middle ear)*

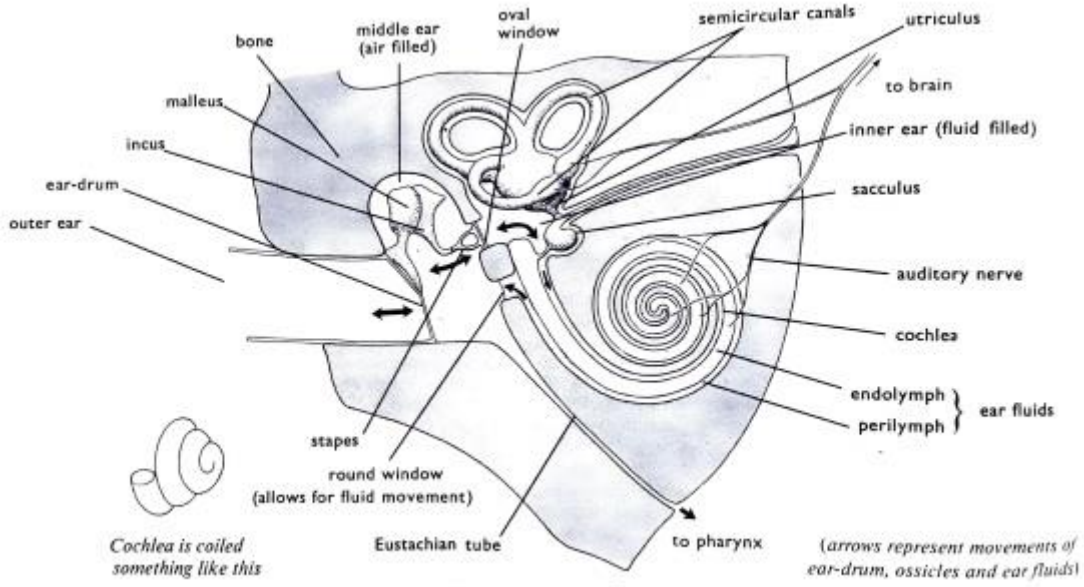
2. The middle ear:

This is a cavity in the skull filled with air. Consists mainly of **ossicles** namely malleus, incus and stapes found between the ear drum and the oval window. The middle ear also comprises the Eustachian tube which open into the pharynx.
FUNCTION: *Transmit sound vibrations to the inner ear and to balance air pressure in ear.*

3. The inner ear:

The inner ear is filled with a fluid and consists of mainly a coiled tube, the **cochlea**, **semicircular canals**, **sacculus**, **utriculus** and the **auditory nerve**
FUNCTION: *convert sound vibrations into nerve impulses for interpretation and maintain posture and balance*

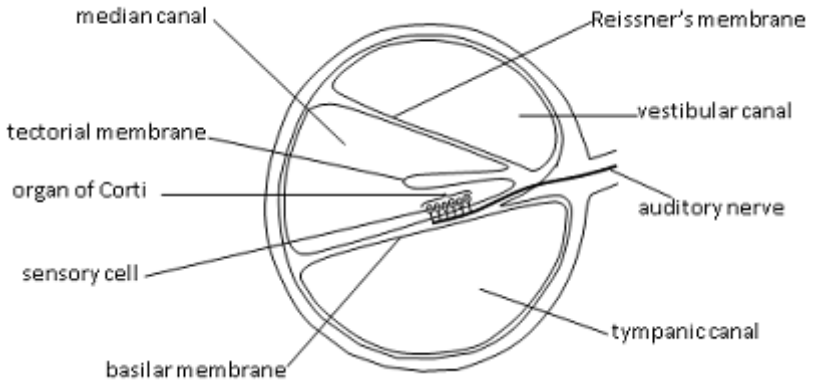
Structure of the ear



FUCNTIONS OF PARTS OF THE EAR

i. **Pinna**. Receive and concentrate sound waves.
ii. **Auditory canal** has hairs and wax that trap foreign bodies.
It transmits sound waves to the **eardrum** (**tympanum**),
iii. **Ear drum** is a thin membrane. The eardrum transmits sound vibrations to the middle ear.
iv. **Ossicles**. Amplify sound vibrations,
They transmit sound vibrations from the eardrum to the oval window.
v. **Eustachian tube**. It equalizes the air pressure on either side of the eardrum.
vi. **Oval window** (**fenestra ovalis**) transmits sound vibrations to the inner ear.
vii. **Semi-circular canals**, **utriculus** and **sacculus** form the **vestibular apparatus**, which controls body balance and orientation.
viii. **Cochlea** contains two fluids, the perilymph and endolymph and hair cells sensitive to sound vibrations.
It is in the cochlea that impulses regarding sound are generated and sent to the brain to facilitate hearing.
ix. **Round window** (**fenestra rotunda**) equalizes pressure in the cochlea.
x. **Auditory nerve** transmits impulses to the brain where sound is interpreted.

Diagram to show transverse section of the cochlea



Process of hearing

- The pinna receives and concentrates the sound waves.
- Sound waves move through auditory canal to the eardrum, which vibrates.
- The vibrations of the eardrum are transmitted to the ossicles that vibrate.
- The vibrations are transmitted to the fluids in the cochlea via the oval window.
- These vibrations stimulate sensory hair cells to generate an impulse which travels along the auditory nerve to the auditory centre in the brain
- Sound is interpreted

Questions: *What prevents pressure waves from reverberating within the ear and causing prolonged sensation?*

Once pressure waves travel through the vestibular canal, they pass around the apex (tip) of the cochlea. The waves then continue through the tympanic canal, dissipating as they strike the round window. This damping of sound waves resets the apparatus for the next vibrations that arrive.

Maintenance of balance by Semi-circular canals

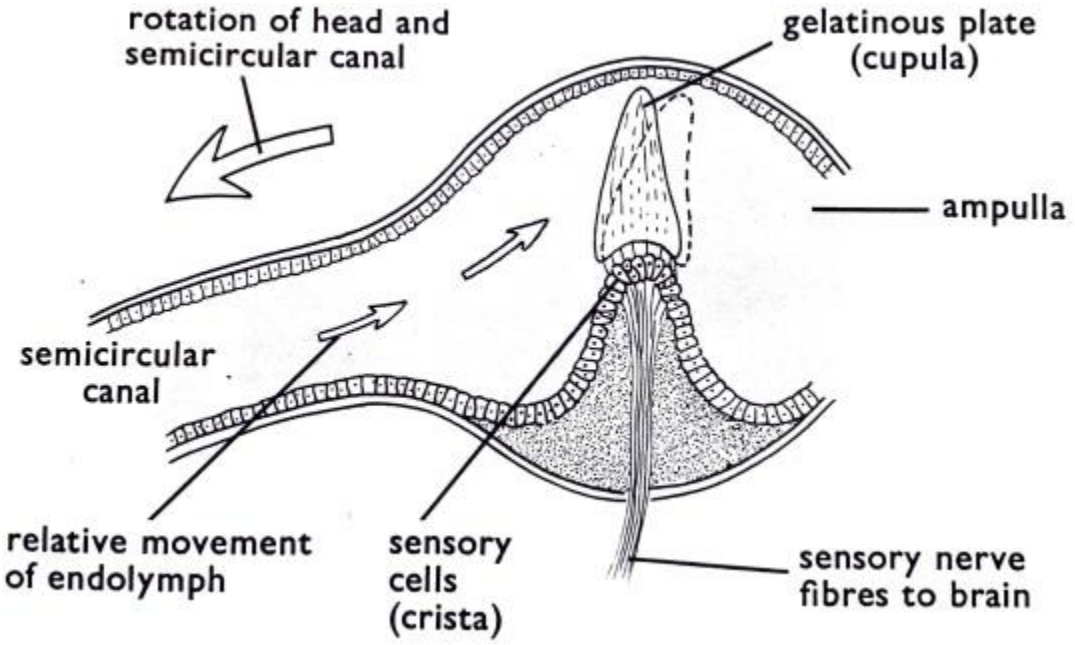
The semi-circular canals are important in maintaining balance especially when in motion (dynamic equilibrium). There are three semi-circular canals, two orienting vertically and one orienting horizontally thus detect motion in three different planes. Each semi-circular canal terminates in a swelling known as the **ampulla**, which contains the **cupula** (dome-shaped, gelatinous structure). The cupula is in contact with sensory hairs.

The canals are filled with fluid called endolymph.

When the head rotates, the endolymph remains stationary and only moves when one is still but in a direction opposite to initial head rotation thus deflecting the cupula. This stimulates the **cristae** (sensory cells), which generate impulses. The impulses

are transmitted by sensory nerve to the brain upon which interpretation results into balance.

Section showing movement of endolymp relative to head rotation



Maintenance of posture by Utriculus and sacculus

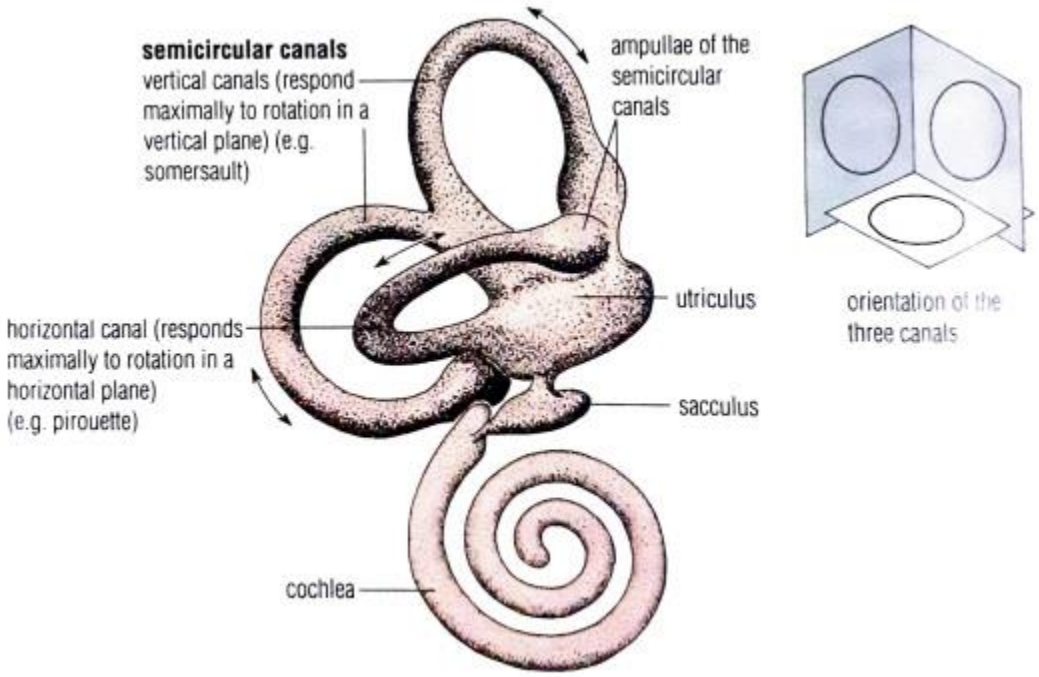
The utriculus and sacculus each contain a structure called **macula** which maintains body posture (static equilibrium).

Each macula consists of a patch of sensory cells with the free ends embedded in **otoliths** i.e. calcium carbonate granules.

Process

When the head is tilted, the otoliths move, pulling the nerve fibres thus an impulse is generated. The impulse travels through the sensory nerve to the brain where it is interpreted such that the head returns to its normal position.

Structure of the vestibular apparatus



Care to the ears

- Washing with clean water
- Reducing on wax with a blunt instrument or index finger when it accumulates
- Avoid inserting sharp instruments into the ear

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 becomes perforated. The discharge may lead to permanent deafness.

2. Deafness:

This is caused by

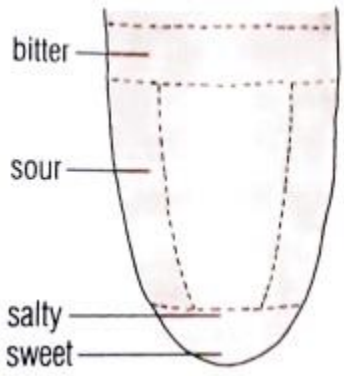
- Accumulation and hardening of wax in the outer auditory canal that presses against the eardrum.
- Blocking of the Eustachian tube,
- Exposure to loud noise over a long period of time can damage the organ of corti leading to deafness.
- Also damage to the cochlea or the hearing centre of the brain can also cause deafness.

THE TONGUE

The tongue is the receptor organ for the sense of taste.

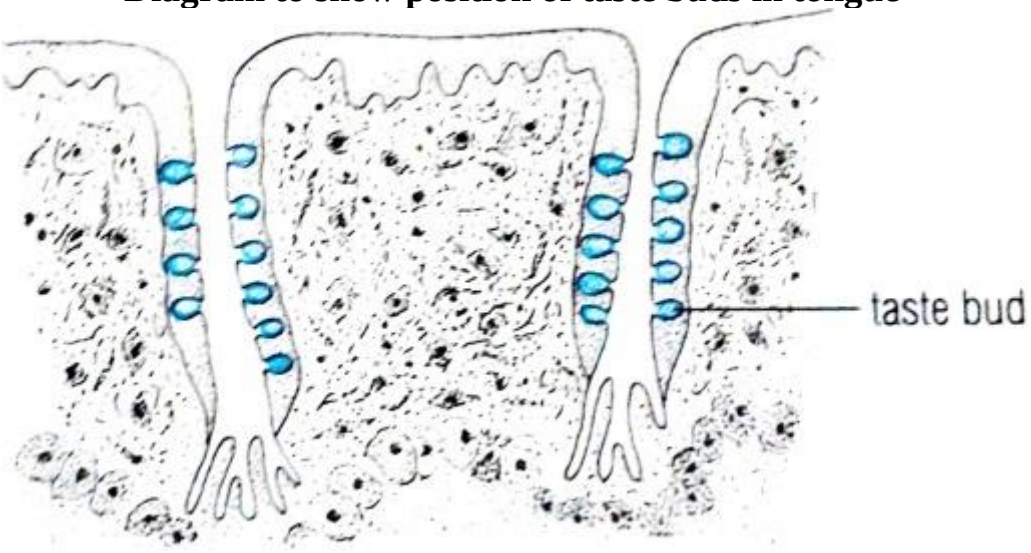
- ✓ It detects chemicals in the mouth which stimulate generation of nerve impulses.
- ✓ The tongue contains taste buds, which contain chemo-receptor cells.
- ✓ The chemo-receptors upon stimulation generate nerve impulses which are sent to the brain for interpretation such that taste is identified.
- ✓ 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.

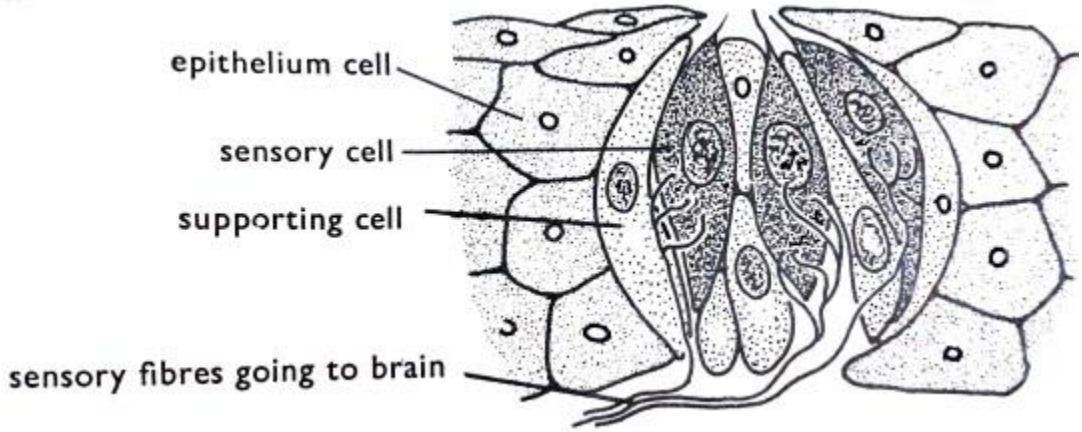


When a chemical is placed in the mouth, it dissolves in the moisture (saliva) in the buccal cavity. The dissolved chemicals then stimulate the taste buds in the different parts of the tongue depending on the type of taste. Impulses are then sent from the tongue through a sensory neurone to the brain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

Diagram to show position of taste buds in tongue



Structure of a taste bud



THE NOSE

The nose is the receptor organ for smell. It is also contains chemo-receptor cells and it is stimulated by chemicals in air. This helps the organism to respond to chemical stimuli at a distance.

Process

- ✓ When air containing a chemical enters the nose, it dissolves in the moisture (mucus) in the nasal cavity.
- ✓ In this form, it is detected by chemo-receptor cells in the nose which generate impulses.
- ✓ These cells send nervous impulses through a sensory neurone 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, excretory role and reception by the skin has been discussed under ***excretion and osmoregulation***.

CARE FOR THE SENSE ORGANS

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.

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, tell your parents about it so they can take you to a 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, call a doctor.

Nose and Tongue

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