CO-ORDINATION IN ANIMALS AND PLANTS.

CO-ORDINATION AND CONTROL IN ANIMALS.

Coordination is defined as a system of communication in which animals or organisms detect sudden changes in the specific conditions of their external and internal environment and responds accordingly.

The sudden changes in the environmental conditions that cause responses in the whole organism or its parts are known as **stimulus**. Examples of common stimuli include;

- Light.
- Chemicals.
- Heat.

Sound, touch, stretch (Mechanical stimuli)

The special cells or body tissue in an organism which detects stimulus is called **Receptors**. Most receptors detect only one type of a stimulus.

Response. Is the change in behaviour or activity of an organism or its parts in reaction to a stimulus.

Effector. Is the body structure or organ of an organism that responds to a stimulus. examples of effectors in organisms include;

- Muscles.
- Glands.
- Cilia.
- Chromatophores.

In very small, minute animals like amoeba, the detection and response to stimulus occurs within a single cell and so no need for very well developed system of coordination. However in large multicellular animals such as mammals, stimuli are detected by sense organs, while the effectors respond. Due to large size, sense organs and effectors may be in quite different parts of the body. In addition responses usually involve the coordinated actions of many different parts of the body. To achieve effective coordination, one part of the body must be able to pass information to another part. In mammals there are two major systems that convey information,

- *The nervous system.*

In this type of coordination, information is passed in chemical and electrical forms. Transmission of messages is rapid and causes rapid responses. The changes they cause or their effects are localized and short lived.

- *Hormonal system.*

This is the type of coordination where information are transmitted inform of chemical messengers called hormones. Transmission messages and responses are slow but the changes that the y cause or their effects are wide spread and long term (lasts for longer periods).

SIGNIFICANCE OF CO-ORDINATION SYSTEMS TO ORGANISMS.

(i) Adapt organisms to changing environmental conditions, promoting survival values. It also provide animals with a precise information about their environment.

(ii) Enable animals to sense and escape from predators.

(iii) Important in nutrition. Enable animals detect food sources, capture their preys. It also controls intake of food, secretion of enzymes and egestion.

(iv) Reflex actions enable animals avoid injuries, body harm.

(v) Determines certain behavioral patterns in animals. For example migration, hibernation/aestivation, fight or flight behaviours.

(vi) Important in reproduction. It controls reproductive cycles and reproductive behavioral patter in animals for example menstrual cycles, lactation, courtship, oestrus, etc.

(vii) Stimulates muscular contractions which are important in the process of locomotion and support.

(viii) Important in control of Homeostasis.

(ix) Maintenance of blood circulation and heart beat.

THE NERVOUS SYSTEM IN MAMMALS, CLASSIFICATION, STRUCTURE AND

FUNCTIONS

Nervous system of mammals consists of,

(i) Central nervous system.

(ii) And Peripheral nervous system.

Central nervous system (CNS) further consists of **brain** and **spinal cord**. The main role of central nervous system is to coordinate and controls many activities of the body.

Peripheral nervous system further consists of **sensory nervous system** and **motor nervous system**. Sensory system consists of nerve fibres that convey informations from sense organs to the central nervous system. While motor system consists of nerve fibres that carry informations from Central Nervous System to effector organs such as muscles and glands.

Motor system consists of,

(i) Somatic nervous system.

(ii) Autonomic nervous system.

Somatic nervous system consists of nerve fibres (neurones) that convey informations (impulses) from central nervous system (CNS) to voluntary organs (effectors) especially the skeletal muscles.

The Autonomic nervous system (ANS) consists of nerve fibres (neurones) that convey impulses (electrical informations) from the Central nervous system (CNS) to involuntary internal organs of the body such as smooth muscles, cardiac muscles and glands. Autonomic nervous system is concerned with control of internal environment. It is further divided into,

(i) **Sympathetic nervous system**. It basically increases rate of most metabolic activities in the body.

(ii) **Parasympathetic nervous system**. It basically decreases rate of most metabolic activities in the body.

The basic structure of Nervous system consists of Receptors protected within supplementary structures called **the sense organs** where the receptors are best placed to detect stimuli. Receptors convert stimuli into form of electrical impulses in a process known as **transduction**. Impulses are transmitted through specialized nerve cells called Sensory neurones. These

impulses are transmitted across junctions that occur at certain points between neurones called **synapses**. The impulses are systematically transmitted from receptors, via synapses to the central nervous systems. Central nervous system consists of Brain or spinal cord, where they are received, correlated and interpreted (Intergrated) in the CNS, the interpreted impulses are transmitted by **motor neurones** via **synapses** to either effector organs mostly under conscious control such as the skeletal muscles or to effectors organs such as smooth muscles, cardiac muscles and glands which are not under conscious control (involuntary organs). Transmission of the impulses from the CNS to involuntary organs through motor neurones is called the **autonomic nervous system**. Autonomic nervous system further consists of **sympathetic nervous system** that increases many metabolic activities and the **parasympathetic nervous system** that decreases many metabolic activities.

BASIC FUNCTION OF RECEPTORS

The basic function of all receptors is to transform stimulus energy into an electrical responses or nerve impulse or action potential (chemical energy) in a neurone in a process known as Transduction. In this respect receptors act as biological transducers. The action potential (nerve impulses) is the form in which information can be transmitted in nerve cells to the central nervous system and successfully interpreted.

CLASSIFICATION OF RECEPTORS

Receptors are broadly classified according to the following categories.

- **(i)** According to their structure.
- **(ii)** According to their position in the body.
- **(iii)** According to the type of stimulus they respond to.
- **(iv)** According to the distance at which they are able to detect stimuli e.g. distance and contact receptors).

CLASSIFICATION OF RECEPTORS ACCORDING TO THEIR STRUCTURE.

The simplest and most primitive type of receptors consists of a single sensory neurone which is capable of detecting the stimulus and giving rise to a nerve impulse passing to central nervous for example skin mechano receptors such as the pacinian corpuscle.

More complex receptors are known as sense cells, consists of modified epithelial cells able to detect stimuli. They form synaptic connections with their sensory neurones which transmit

impulses to the central nervous system for example mammalian taste buds.

The most complex receptors are in sense organs, they are receptor cells found in the eyes and ears. These are composed of a large number of sense cells, sensory neurones and associated accessory structures.

CLASSIFICATION OF RECEPTORS ACCORDING TO THEIR POSITION IN THE BODY

In this case there are exteroceptors and interoceptors (proprioceptors). Exteroceptors detect external stimuli e.g. Receptor cells in the ears, skin, eyes where as interoceptors detect internal stimuli within the body. They are important in animals in achieving equilibrium and coordinated locomotion. E.g. muscle spindles, mechano-receptors in the vestibular apparatus of the inner ear, chemoreceptors on the carotid artery, aortic arch and stretch stretch receptors on carotid sinus.

CLASSIFICATION OF RECEPTORS ACCORDING TO THE TYPE OF STIMULUS DETECTED.

They include the following;-

i. **Chemo-receptors**: These receptors detect humidity, smell and taste inform of chemical energy e.g. receptors detecting senses of smell and taste, chemo-receptors detecting changes in the levels of Carbondioxide in the body.
ii. **Mechano-receptors**; These receptors detect stimuli such as touch, sound, pressure, stretch and gravity inform of mechanical energy.
iii. **Photo-receptors**. These receptor detect light inform of electromagnetic energy.
iv. **Thermo-receptors.** Are receptors detect changes in temperatures inform of thermal energy for example receptors located in the skin sensitive to warmth and cold.
v. **Electro-receptors** detect electricity inform of electro-magnetic fields e.g. in some fish

THE MECHANISM OF TRANSDUCTION (HOW RECEPTORS WORK).

Transduction is the process by which a receptor converts a stimulus into nerve impulse (action potential).

Receptor cells are bounded by cell membranes and when a receptor cell received no stimulus (no stimulation of the receptor cell), the inside of the cell membrane has more positive charges than the outside of the membrane with more negative charges. The cell membrane is said to be **polarized** and as a result, a certain negative voltage (a negative potential difference) exists

across the cell membrane. This negative potential difference is known as **the resting potential.**

The negative resting potential is basically maintained by **sodium-potassium pump mechanism** which actively pumps three molecules of sodium ions out of the membrane of the receptor cell and actively transports two molecules of the potassium ions inside, while potassium ions passively diffuse out since the protein channels for potassium are open and those for sodium are closed. At the same time, the membrane remains impermeable to outward flow of negative ions, this causes the outside of the membrane to be more positive while the inside more negative, resulting into the negative potential difference across the membrane of about -60mV to -70 mV to exist called resting potential.

On arrival of stimulus, the receptor responds causing a local break down of the sodium-potassium pump mechanism. The protein channels specific to sodium ions open, while protein channels specific to potassium ions remain closed, sodium ions rapidly diffuse into the receptor cell across specific region on the membrane, the inside of the membrane becomes more positive (has more positive charges) and the outside of the cell membrane becomes more negative in a region of the membrane of the receptor, a process known as **depolarization**. Depolarization of the membrane results into formation of a new potential difference across a specific region on membrane called a **generator potential**. The generator potential developed causes an increase in the permeability of the sensory cell membrane to sodium and potassium ions and sodium and potassium ions diffuse rapidly down their electro-chemical gradients. The magnitude of the generator potential increases with the strength of the stimulus until a thresh hold value is reached and this causes other parts of the membrane to undergo series of depolarization (wave of depolarization) resulting into formation of positive potential difference across the entire cell membrane of the receptor known as action potential. The action potential is transmitted as waves of depolarization along the cell membrane of the receptor as nerve impulses. Nerve impulse is then transmitted through sensory neurones to the central nervous system.

CHARACTERISTIC FEATURES COMMON TO ALL RECEPTORS

(i) They transform energy into action potential. They are biological transducers.

(ii) They are specialized in structure and function i.e. they are stimulus specific e.g. photoreceptors in the eye are stimulated only by light energies but not sound. So, the

eyes can see but not hear.

(iii) Each receptor creates a generator potential when stimulated. ***A generator potential*** is a localised non-conducting electrical charge that exists at a point on the membrane of a neurone or an axon, resulting from the depolarization of the membrane a cross the receptor cell.

(iv) Each and every receptor has a threshold value of stimulation. **A threshold value** is a specific potential difference reached during depolarisation that results into an action potential.

(v) Adaptation in receptor cells.

This is where receptors initially respond to strong and constant stimulus by producing a high frequency impulses but the frequency of the impulses gradually declines with time untill no impulses is produced. In this case no action potential results from repeated stimulations of the receptor e.g. a finger kept in cold water for sometime does not feel cold, it becomes adapted to the new situation, since it arouses no sensation.

There are two types of receptors. ***Rapidly adapting receptors (Phasic receptors)*** are receptors that produce high frequency impulses to changes in the levels of stimulus that is on and off stimulus. ***Slowly adapting (Tonic) receptors*** are receptors that respond to a constant stimulus b initially producing high frequency impulses which gradually declines with time.

Repeated and prolonged stimulation of receptors decrease permeability of the receptor membrane to sodium ions. This decreases concentration of sodium ions diffusing into the receptor cell in response to repeated stimulation. This progressively reduces the size or magnitude and duration of generator potential which then falls below the threshold level and the sensory cell become unable to generate action potential. Adaptation can provide animals with precise information about the environment.

(vi) They show precision by being able to transmit the precise and detail of informations about the stimulus e.g. the eye will provide information about the intensities, duration,

colour and source of light at the same time.

(vii) They can be inhibited. This is where impulses are prevented from being transmitted. This can be of advantage to the organism in particular situation. Such inhibitions operate through synaptic connections with other neurons from which inhibitor impulses are received but not transmitted.

(viii) Each receptor neuron end into dendrons and dendrites.

(ix) All receptors are sensitive to low intensity stimulation.

OTHER PROPERTIES COMMON TO RECEPTORS THAT INCREASE THEIR EFFECTIVENES AND SENSITIVITY

The various ways in which the effectiveness of receptors can be increased include,

(i) Sensory cells with carious threshold values.

Some sense cells or receptors such as stretch receptors in muscles are composed of many sense cells which have arrange of thresholds. A cell with a low threshold responds to a weak stimulus, as the strength of the stimulus increases, they respond by increasing the frequency of impulses in the sensory neurones leaving the cell. At a given time, saturation occurs and the frequency of the impulses in the sensory neurone can not be increased any more, any further increase in the intensity of the stimulus will excite sense cells or receptors with higher threshold to produce impulses with higher frequency. In this way, receptors can respond to wide range of stimuli in the environment increasing effectiveness.

(ii) Convergence and summation.

Convergence is where several sense cells or receptor cells that are small, numerous and sensitive are connected to (converge on) a single sensory neurone. This increases the degree of sensitivity of receptors cells.

Summation is where simultaneous stimulations of several cells sum up or add up together to cause response where stimulation of a single cell of these cells would not produce a response in the sensory neurone. This increases the sensitivity of the receptor cells.

(iii) Spontaneous Activity.

This is where some receptors produce nerve impulses in sensory neurones in the absence of stimulation. It provides two advantages,

- Increases sensitivity of the receptor by enabling it to make a response to a stimulus that would normally be too small to produce a response in the sensory neurone.
- Increase or decrease in frequency of the response is used to detect direction of change of stimulus For example infra red receptors in the pits in the face of rattle snake, is used to find direction and location of preys and predators.

(iv) Feed back control of Receptors.

The threshold of some sense organs can be raised or lowered by efferent or outward impulses from the central nervous system, this resets the sensitivity of the receptor to respond to different ranges of the stimulus intensities. For example Iris of the eye.

SENSE ORGANS

A sense organ is supplementary structure whose functions are to protect the receptor cells (sensory cells) and ensure that they receive the right stimulations they are adapted to. Examples of sense organs include;

- Skin.
- The eyes.
- The ear.
- Nose.
- Tongue.

SKIN.

A number of receptors are present in the dermis of the skin while a few in the epidermis. These are,

• Mechano-receptors.

The mechanoreceptors in the mammalian skin are primitive type of receptors and respond to range of mechanical stimuli such as touch, pressure, vibrations and stretching. Theses include,

(i) Meissner s corpuscle.

These are situated immediately beneath epidermis in the skin. They are specialized sense organs which consist of a single twisted ending of a neurone enclosed within s fluid filled capsules. They respond to touch.

(ii) Pacinian corpuscle.

This consists of the ending of a single neurone surrounding by many layers of connective tissues in the dermis of the skin, they respond to pressure and vibrations (Rapid movements).

(iii) Free nerve endings beneath the skin that detects touch and pressure.

(iv) Bulb of Krause found in the dermis of the skin detects touch and pressure.

(v) Organ of Ruffini found deeper in the skin and detects heavier pressure on skin.

(VI) PROPRIOCEPTORS.

Mammalian muscles contain proprioceptors called ***muscle spindles***. These are stretch receptors sensitive to the position of and movement of parts of the body. They respond to changes in the state of contraction of muscles and act as stretch receptors in all activities associated with the control of muscular contraction. Muscle spindle has three main functions,

- Provide information to the Central nervous system on state of and position of muscle and structure attached to them (Static function).
- Initiate reflex contraction of the muscles and return it to its previous length when stimulated by a load (Dynamic function)
- Alter state of tension in the muscle in the muscle and resets it to maintain a new length (Dynamic function)

• **Thermoreceptors**.

These are free nerve endings in the epidermis of the skin, they detect changes in temperatures (hot/cold).

HOW TOUCH, STRETCH AND PRESSURE RECEPTORS FUNCTION.

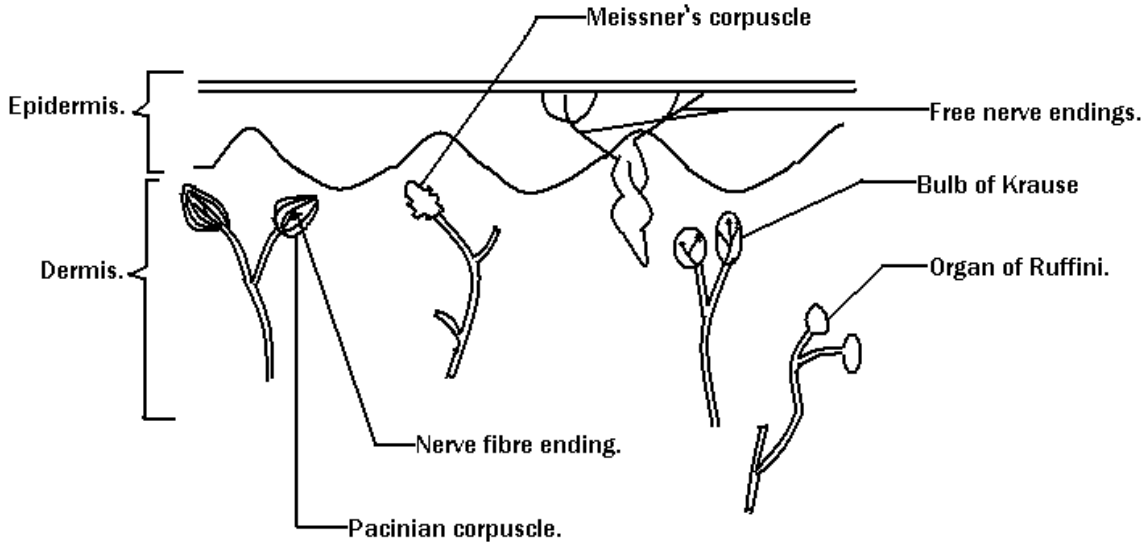
It is thought that when these receptor cells are touched or pressed or any pressure applied on them, they become deformed and distorted and this increases the permeability of their cell membranes to sodium ions. Sodium ions diffuse rapidly inside the membrane which becomes

depolarized, a generator potential is formed across the membrane. It builds up until a threshold value and then action potential generated.

NOTE:

- Touch receptors are also found in other regions of the body and accounts to increased sensitivities in these regions.
- Pacinian corpuscle is also found in joints, tendons, muscles and gut areas.

DIAGRAM SHOWING RECEPTORS IN THE MAMMALIAN SKIN.

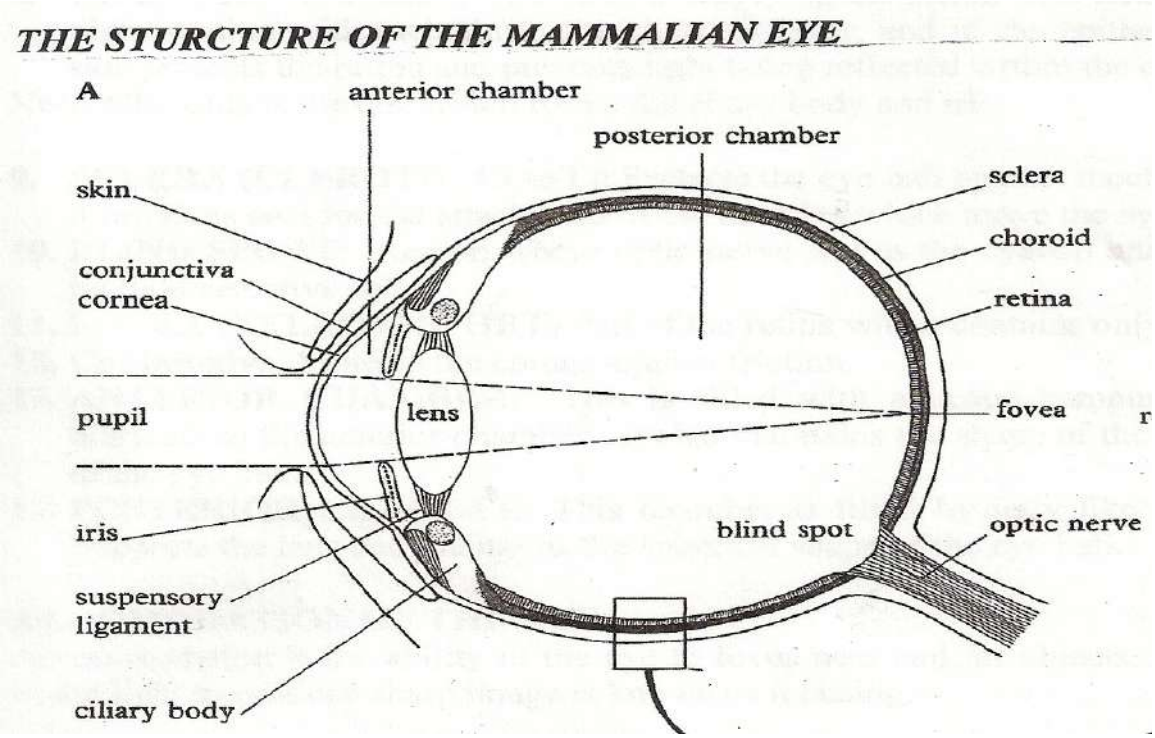


THE EYES AND RECEPTION OF LIGHT

Eyes are the sense organs which can receive light stimulations. In this category, there are two examples.

(i) The mammalian eye.

(ii) The insect's compound eye.



PARTS OF THE EYE AND THEIR FUNCTION

(i) LENS

Is a transparent rubber balloon like structure filled with Jelly like material. It focuses light on to the retina.

(ii) IRIS

It contains the black pigment melanin which absorbs some of the light, thus reducing the amount of light passing. Iris functions to control the size of the pupil. It is a structure, continuous with a cilia body. It contains circular and radial muscles whose contraction and relaxation varies size of the pupil.

(iii) ***PUPIL***; is the passage for light.

(iv) ***CORNEA***; Is a thick, transparent layer protecting the front of the eye. It also allows passage of light and refracts light rays. The front of the cornea is covered by a thin layer of epithelium which is continuous with the conjunctiva.

(v) ***SUSPENSORY LIGAMENT***:

Are slender fibres attached to the lens at one end and the ciliary body at the other end. The suspensory ligament maintains and holds in position the lens.

(vi) CILIARY BODY

It encircles the lens. It contains a complex set of smooth muscles which are mainly circular and radial muscles. Alternate contractions and relaxations of these muscles causes changes in the shape of the lens and its optical density (focal length). This permits images of objects at varying distances to be focused on the retina.

(vii) ***RETINA***: It contains the light sensitive cells the rods and cones. The cones are packed in fovea, where they perceive the surrounding environment in conditions of good illumination, while the rods do so, in condition of low illumination. It also contains the black pigment melanin which helps in the absorptions of some light.

(viii) ***CHOROID:*** Contains blood vessels supplying the retina with nourishment. Heavy pigmentation with melanin in the choroids layer, and in the epithelium on its inner side protects the retina and prevents light being reflected within the eye.

Note: Choroids is the one which forms the ciliary body and iris.

(ix) ***SCLERA (SCLEROTIC COAT)***; Protects the eye ball against mechanical injury and it provides area for the attachment of the muscles which move the eye.

(x) **BLIND SPOT**: Region where optic nerve leaves the eyeball and where there are no light sensitive cells.

(xi) ***FOVEA (YELLOW SPOT)*** Part of the retina which is packed with only cones.

(xii) ***CONJUNCTN*A.** Protects the cornea against friction.

(xiii) ***ANTERIOR CHAMBER***: This is filled with aqueous hamour. This supplies nutrients to the anterior chamber. It also maintains the shape of the anterior chamber of the eye ball.

(xiv) ***POSTERIOR CHAMBER***: This chamber is filled by jelly like vitreous humour. Supports the lens and maintains the spherical shape of the eye ball.

THE RETINA AND LIGHT RECEPTION.

STRUCTURE OF THE RETINA.

Retina is composed of characteristic type of cells, the photosensitive cells, they are the rods and cones located within photoreceptor layer partially embedded in the pigmented epithelial cells of the choroids. The intermediate layer contains bipolar neurones and two other cells that include horizontal and amacrine cells that enable lateral inhibition to occur. There are ganglion cells with dentrites in contact with bipolar neurones and axons of the optic nerve found in the internal surface layer (third layer).

Each photosensitive cell (Rods or Cones) has four regions,

• ***Outer segment***.

The outer segment is made up of flattened membranous vesicles containing photosensitive pigments. Cones have fewer vesicles than the rods. In cones the outer segment is cone shaped and contains iodopsin, while in rods it is rod shaped and contains Rhodopsin.

• ***Constriction.***

Is an infolding of the outer membrane separating the inner from the outer segment. The two

regions remain in contact by a cytoplasm containing a pair of cilia with no known function.

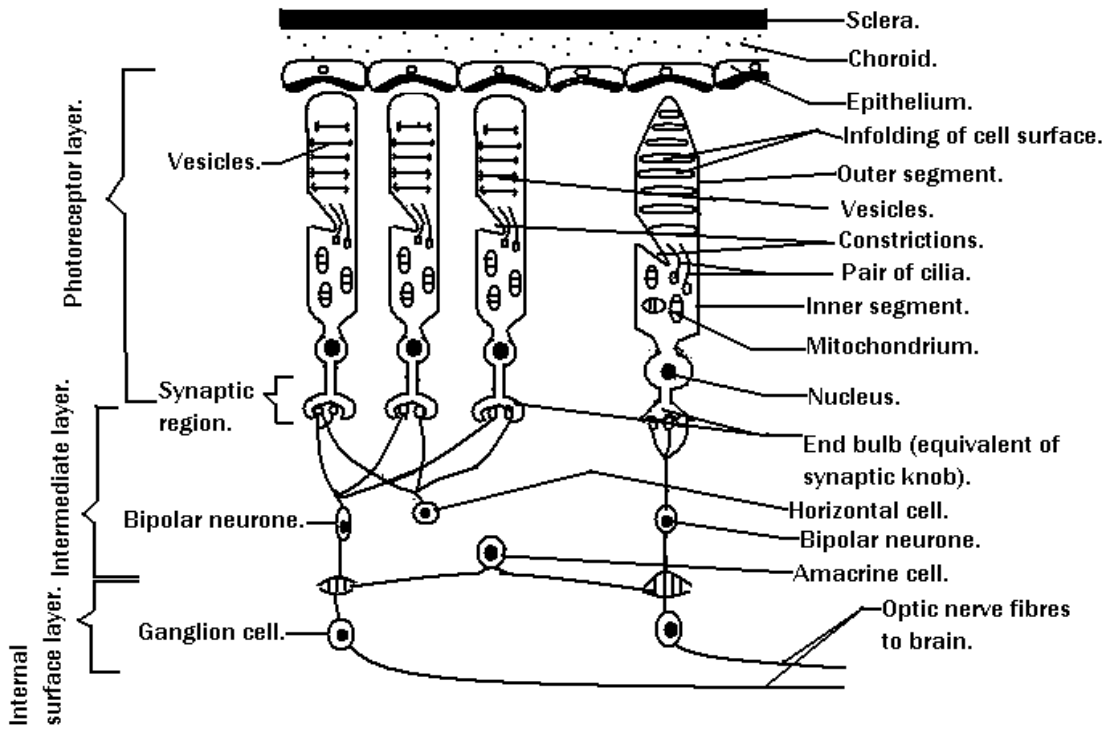
• Inner segment.

This is a region containing nucleus and is metabolically active region that contains numerous mitochondria for energy production and has Ribosomes (polyribosomes) providing site for protein synthesis, the proteins are utilized for synthesis of membranous vesicles and photosensitive pigments.

• Synaptic region.

Here cells form synapses with bipolar cells. Some bipolar cells have synapses with several rods (Synaptic convergence). Other bipolar cells link one cone to one ganglion cell (Visual acuity) Horizontal cells and amacrine cells link certain numbers of rods together and cones together. This allows a certain amount of processing of visual information to occur before it leaves the retina. These cells are involved in lateral inhibition.

DIAGRAM SHOWING THE STRUCTURE OF THE RETINA IN HUMAN EYE



THE CONES AND RODS

These are light sensitive cells (photo receptors) which are located in the retina. The cones are packed together in fovea, where their function is to perceive the surrounding environment accurately in day-light vision (condition of good illumination).

Cones contain photochemical pigments which are mainly bleached by light of very high intensity. They are also capable of colour perception and high visual acuity. And this is because they are densely packed and are in the centre of the fovea, with each having its own connection with an optic nerve fibre.

The rods lie outside the fovea in the more peripheral parts of the retina. Their main function is night vision i.e. perceive environment in condition of low illumination. They contain he pigment Rhodopsin which is stimulated and then bleached by light of low intensity and are rapidly regenerated. They show retinal convergence and therefore sensitive to operate in semi-darkness. They have relatively poor visual acuity.

DIFFERENCES BETWEEN RODS AND CONES:

RODS	***CONES***
(i) Are more concentrated in the eye.	(i) Are less concentrated in the eye.
(ii) Are evenly distributed except at fovea.	(ii) Are tightly packed at fovea.
(iii) Have outer segment rod shaped.	(iii) Have cone shaped and sometime pyramidal outer segment.
(iv) Are relatively smaller.	(iv) Are relatively larger.
(v) The light sensitive pigment is Rhodopsin.	(v). The light sensitive pigment is iodopsin.
(vi) Light sensitive pigment occurs in one form only.	(i) Light sensitive pigment occurs in three forms.
(vii) Light sensitive pigment is affected by light of low intensities. (i.e. for night vision)	(Vii).Light sensitive pigment is affected by light of high intensities (i.e. for day vision)
(viii) Do not distinguish colours.	(viii) Distinguish colours.
(ix) Show retinal convergence (i.e. Synapse with bipolar neuron occurs in groups.	(ix) Do not show retinal convergence (i.e. synapse with bipolar neuron occurs individually.
(x) Are more sensitive to light.	(x). Are less sensitive to light.

(xi) When broken their regeneration processes is faster.	(xi). when broken their regeneration is Slower

(Note list the similarities between the rods and cones)

LIGHT RECEPTION IN RODS:

The rods contain a light sensitive pigment in their outer segments known as Rhodopsin (visual purple) Rhodopsin is a complex protein opsin or scotopsin conjugated with a simple light absorbing component called retinene. Retinene is an aldehyde of vitamin A (Carotene) it exists in two different isomeric forms known as "Cis" and "trans" isomers. The Cis form exists during the dark and the "trans' form during the light. In the dark retinene changes from "trans" to "cis" forms and Rhodopsin exists in its complex form of opsin or scotopsin conjugated with retinene. During the day, rods receive low light stimulus. Rhodopsin absorbs the light energy, retinene changes from "cis" to "trans" forms. Rhodopsin then splits into its constituents, scotopsin (opsin) and free retinene in a process known as ***Bleaching***. Bleaching stimulates series of other reactions and changes in the rods that will result into action potential and transmission of nerve impulses via optic nerves to the brain.

HOW CHANGES IN RHODOPSIN IN RODS CAUSE ACTION POTENTIAL.

(PROCESS OF TRANSDUCTION IN THE ROD CELL).

In the dark, rods receive no light stimulus and the Rhodopsin in the outer segment of the rod is not bleached into its constituents, scotopsin and free retinene. Sodium ions are actively pumped out constantly out of the inner segment. While the membrane of the outer segment of the rods remains permeable to sodium ions and sodium ions are allowed to diffuse back into the rods via the outer segment. This reduces the negative charge inside the rod cell from -70mV to about -40mV. In this state, the membrane of the rod cell is normally polarized. Rod cells respond by releasing special transmitter substance glutamate (Glutamic acid) into the surrounding tissue fluid. This has an effect in maintaining the membranes of the bipolar neurone and the ganglion cell at the resting potential. No action potential is generated in the ganglion cell.

In the light, rods receive light stimulus and Rhodopsin in the outer segment of the rod absorbs light energy. Rhodopsin is bleached into its constituents, scotopsin (opsin) and free retinene. The membrane of the outer segment becomes impermeable to sodium ions and diffusion of sodium ions back into the rod cell stops, while the inner segment continues to actively pump out sodium ions. The inside of the membrane of the rod become even more negative than the usual negative resting potential and the membrane of the rod is said to be ***hyperpolarised***. The Hyperpolarisation has an effect of rod cells reducing the rate of release of Glutamate (Glutamic acid) and excitatory transmitter substance into the surrounding tissue fluid. This causes the membrane of the bipolar neurone that synapses with the rod cells also to become hyperpolarised but the membrane of the ganglion cells of the optic nerve supplied by the bipolar neurone become depolarized. A generator potential is formed across the membrane of the ganglion which builds up to reach a threshold value and action potential is generated. The action potential is transmitted as nerve impulses via optic nerves to the brain.

SUMMARY OF LIGHT RECEPTION IN RODS (TRANSDUCTION OF LIGHT)

When light of low intensity is absorbed by the Rhodopsin in the outer segment of the rods, the retinene changes from the “cis” to the “trans”. Rhodopsin splits into its protein scotopsin (opsin) and free retinene. A process called bleaching. This causes the membrane of the rod cells to become hyperpolarised, the release of the transmitter substance glutamate by the rods into the tissue fluid is stopped and it results into Hyperpolarisation of the membrane of the bipolar neurone while the membrane of the ganglion cell become depolarized, a generator potential reaches a threshold value causing the action potential that is transmitted to the brain as nerve impulses via optic nerves.

In the absence of further light stimulations, Rhodopsin is immediately reformed where “trans” retinene is first converted into “cis” retinene and then recombined with scotopsin (opsin) a process called Dark adaptation.

During the day, most of the rods are bleached and this is why it takes a person some time to see after moving into the a dark place from a well lit one because it takes some brief moment for the Rhodopsin to get resynthesised from its constituents protein scotopsin and free retinene and the iris too takes time to adjust in dim light to widen the pupil to allow sufficient light onto the retina.

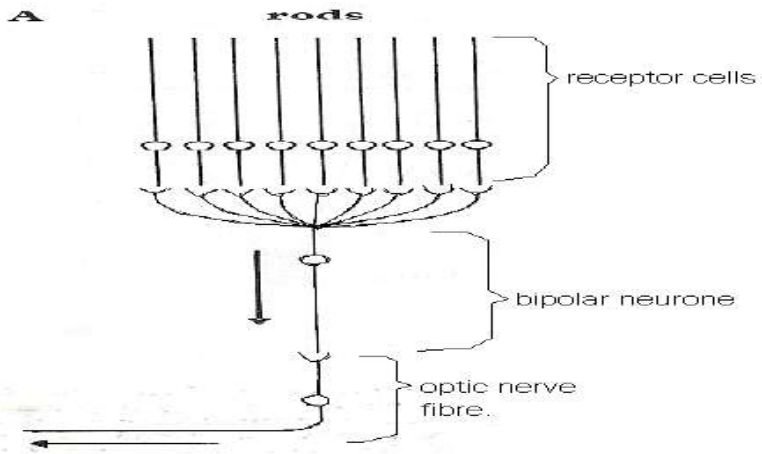
WHY RODS ARE MORE SENSTIVE THAN THE CONES.

(i) The rhodopsins in rods are readily broken and regenerate faster than that of the cones. This also explains why they are most suitable for vision during conditions of very low illumination e.g. at night.

(ii) They show retinal convergence i.e. many rods make synaptic connection with a single bipolar neurone which in turn connects with the cell body of a single optic nerve fibre. Stimulations of a separate rods, therefore adds up together (i.e. summated) to bring about a response even incases where separate stimulation would not be sufficient to build a generator potential up to a threshold value which results into action potential in the rods.

PRINCIPLE OF SENSITIVITY (RETINAL CONVERGENCE ILLUSTRATED BY THE ROD.

*In **A** below groups of rods converge onto a single optic nerve fibre, there by increasing sensitivity*



LIGHT RECEPTION IN CONES.

The cones contain a photo-chemical pigment in their outer segment called iodopsin. iodopsin is

a complex protein (Opsin) conjugated with light absorbing pigment called iodide. How ever, this pigment requires a greater a mount of light to be bleached that is to split into its constituents, protein opsin and free iodide. When a light of high intensity strikes cones, the iodopsin in the outer segment absorps light and the molecule of iodopsin slowly split to into its constituents, protein opsin and free iodide, a process called bleaching. This causes membrane of the cone cells to be hyperpolarised. The Hyperpolarisation causes the cone cells to reduce release of transmitter substance glutamate into the surrounding tissue fluid. Absence of this transmitter substance causes the membrane of the bipolar neurone also hyperpolarised while the membrane of the ganglion become depolarized, a generator potential develops, If this potential is above the threshold value, then an impulse (action potential) is generated in the ganglion cell which is transmitted to the optic nerve which leads to the brain.

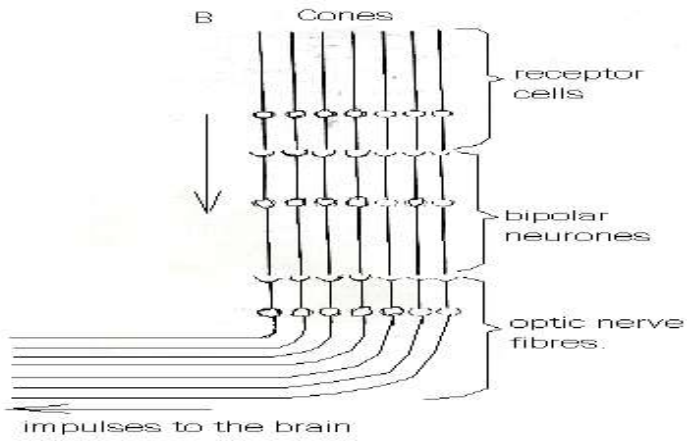
PRINCIPLE OF PRECISION AND VISUAL ACUITY ILLUSTRATED BY CONES IN RETINA OF EYE:

Each cone has its own optic nerve fibre in the centre of the fovea, thereby increasing precision and visual ***acuity.***

Precision is the clarity of the images formed on the retina of the eye and visual acuity is the ability of the eye to distinguish between two objects that are very close together. In the other hand, the combination of precision and visual acuity of the eye, is the measure of its ***solving*** power, defined as the ability of the eye to perceive clearly two very close objects as distinct and separate.

NON-RETINAL CONVERGENCE IN CONES:

*In **B** below, in the centre of the fovea each cone has its own optic nerve fibre, thereby increasing precision.*



THE ROLE OF HORIZONTAL CELLS AND AMACRINE CELLS IN THE RETINA.

Horizontal cells synapse with several bipolar neurones, they are responsible for lateral inhibition. This increases both sensitivity and visual acuity. If the cells receive stimuli from two Rods which are of equal intensity, they cancel out (inhibit) the stimuli. This enhances contrast between are that weakly stimulated and areas that are strongly stimulated. This makes features such as edges of objects stand out more clearly.

Amacrine cells are stimulated by bipolar neurones and synapse with ganglion cells. They transmit information about changes in the level of illumination.

COLOUR VISION.

The human eye absorbs light from all wave lengths of the visible spectrum and perceives this as six broad colours red, orange, yellow, green, blue and violet. There are three types of cones present in the Retina of the eye, each cone has different light sensitive pigment with maximum light absorption within the red, green and blue cones.

The most accepted theory of colour vision is the **Trichromatic theory** which states that *different colours are produced by the degree of stimulation of each type of cone of the three types of cones red, green and blue present in the retina of the eye.*

Stimulations of only a single type of cones that are sensitive to only one type of wave length of light called differential stimulation, will lead to generation of action potential that will lead to the perception of the primary colour by the brain. For example, differential stimulation of a cone

sensitive to red wave length will result into an action potential that will lead to perception of red colour. And when cones sensitive to more than one different wave lengths are simultaneously stimulated, it will lead to an action potential that will lead to perception of a secondary colour by the brain. for example simultaneous stimulations of cones sensitive to red and green wave lengths of light, will generate an action potential when transmitted to the brain will be perceived as yellow/orange colours.

The perception of different colours by the brain according to the trichromatic theory is as shown below;

CONES STIMULATED	*COLOUR PERCEIVED*
(i). Red only	- Red
(ii). Green only.	- Green
(iii). Blue only.	- Blue.
(iv). Red and green only.	- Orange/yellow
(v) Green and blue only.	- Cyan.
(vi). Red and blue only.	- Magenta (violet)
(vii). All the red, green and blue.	- White.
(viii) No cones.	- No colour (black)

COLOUR BLINDNESS

Colour blindness is in ability to distinguish between certain colours. It is due to complete absence of a particular type of cone or a shortage of one type for example a person that lacks the red or green cone will be unable to distinguish between the red and green colours and said to be red-green colour blind where as a person with a reduced number of either cones will have difficulty in distinguishing a range of red-green shades.

BINOCULAR AND STEREOSCOPIC VISION.

Binocular vision occurs when the visual fields of both eyes overlap so that the fovea of both eyes are focused on the same object. It provides the basis of stereoscopic vision.

Stereoscopic vision is where two eyes producing slightly different images on the Retina at the same time which the brain interprets as one image. The resolution of these two retinal images occurs in the area of the brain called visual cortex.

Eyes more placed in front will have greater overlap and cause stereoscopic vision. The eyes placed in front will also have fovea centrally situated which produces good visual acuity, it promotes good vision of size, perception of depth and distance of objects.

Stereoscopic vision is found in predatory animals for example members of cat family, hawks and eagles. It enables them clearly see their prey when in the process of capturing or pouncing the prey. Preys have laterally placed eyes hence use monocular vision to examine details of near objects, monocular vision also provides wide visual fields but restricted stereoscopic vision for example Rabbit.

ACCOMODATION OF THE EYE

Accommodation is the ability of the eye to focus light rays from near and far objects on the retina. While, refractions of the light to produce sharp image is known as focusing.

The lens is the structure which has a big role in accommodation because of its ability to change its shape and therefore change its optical density (focal length). Other structures of the eye such as conjunctiva of the eye such as conjunctiva, cornea, aqueous humour and vitreous humour all have different optical densities and refract light but they are unable to change their optical densities because they are fixed structures and can not change their shape.

PROCESS OF ACCOMODATION BY THE EYE

Accommodation involves two processes and these include,

(i) Control of the amount of light entering the eye (Reflex adjustment of pupil size)
(ii) Refraction of light rays by the cornea and lens from far and near objects.

CONTROL OF THE AMOUNT OF LIGHT ENTERING THE EYE:

The eye must always be able to control the amount of light entering it. This is because of the following reasons.

i. The light intensities are always variable in the environment.
ii. The light sensitive cells in cones and rods may be over stimulated or even damaged by much light.
iii. Too little light may not stimulate the light sensitive cells at all.

The amount of light entering the eye is controlled by controlling the size of the pupil which is achieved by the contraction and relaxation of the circular and radial muscles in the iris. The activities of these muscles are controlled by autonomic nervous system but the hormone adrenalin can also influence their movements.

During dim light, the radial muscles contract, while the circular muscles relax. The size of the iris shortens and the pupils widens more light is allowed to enter the eye.

During bright light, the circular muscles contract, while the radial muscles relax, the size of the iris is elongated, and the pupil become narrower, little light is allowed to enter the eye.

Note: Narrowing the pupil has a second advantage to us. It makes the focus of the light on the retina sharper and clearer image is formed on the retina.

REFRACTION OF LIGHT RAYS FROM FAR AND NEAR OBJECTS ON THE RETINA.

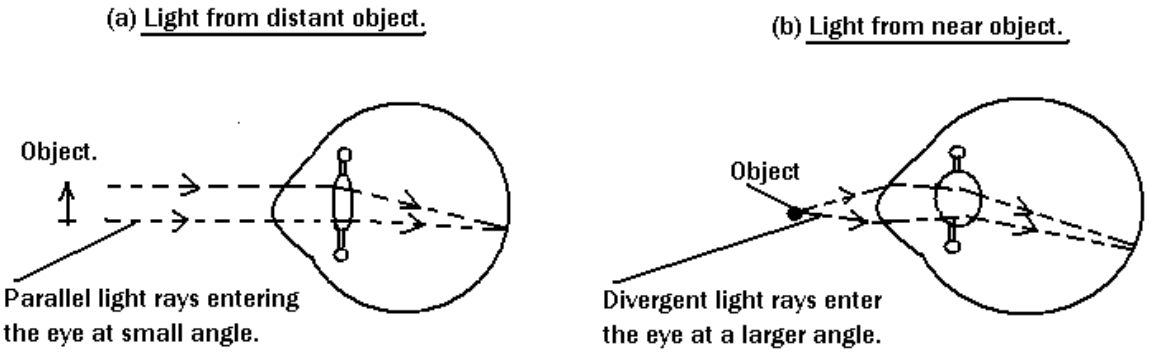
(i) TO FOCUS DISTANT OBJECTS:

Light rays from distant objects (more than 6metres) are parallel and enters the eye at a smaller angle, first refraction occurs when this light rays pass through cornea onto the lens, the circular ciliary muscle relax, while the radial ciliary muscle contracts, the tension on the suspensory ligament is increased (suspensory ligament taut), the lens is pulled out wards and it attains a flattened shape and the lens becomes thin, light is now focused on retina by a small refraction.

(ii) TO FUCUS NEAR OBJECT.

Divergent light rays enter the eye at a larger angle, cornea refracts (bends) light onto a lens, circular ciliary muscles contract, while the radial ciliary muscles relax. The tension in the suspensory ligament is eased or released (suspensory ligament slack). The lens returns to a more spherical shape and becomes thick. Light rays are now focused on the retina by a bigger refraction.

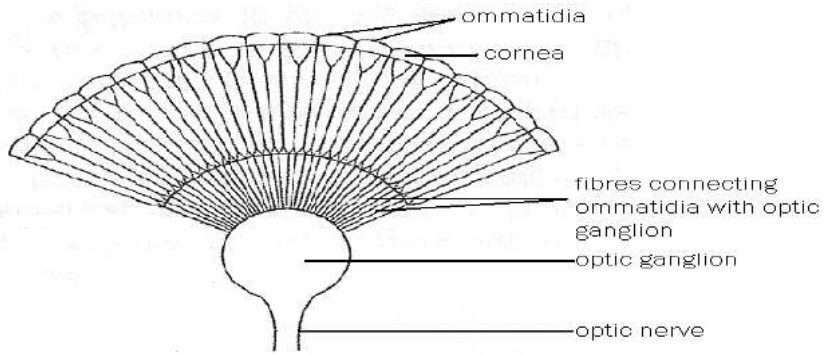
DIAGRAMS SHOWING LIGHT RAYS FROM DISTANT AND NEAR OBJECT



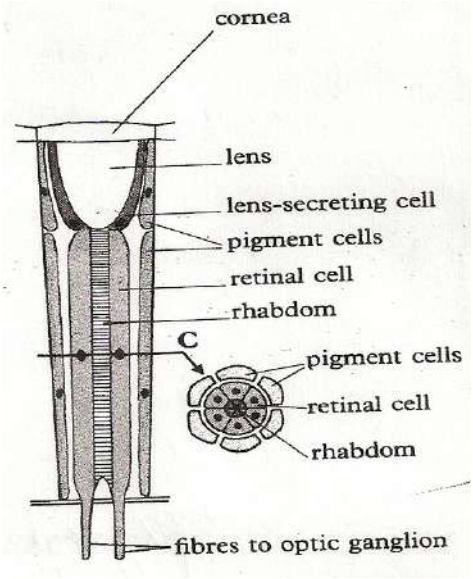
STRUCTURE OF THE COMPOUND EYE.

It consists of numerous mini eyes "called ommatidia. Ommatidia are the functional and structural unit of compound eye. Each ommadium consist of a convex crystalline lens, the lens is protected to the outside by the transparent cornea. There are lens-secreting cells besides the lens. Connected to the lens are group of retinal cells surrounded by pigment cells. Retinal cells contain the Rhabdom which is an elongated structure formed by the fusion of densely packed microvilli on the inner side of each retinal cell. Rhabdom is light-sensitive part of the ommatidium. Rhabdom contains the light sensitive pigment Rhodopsin.

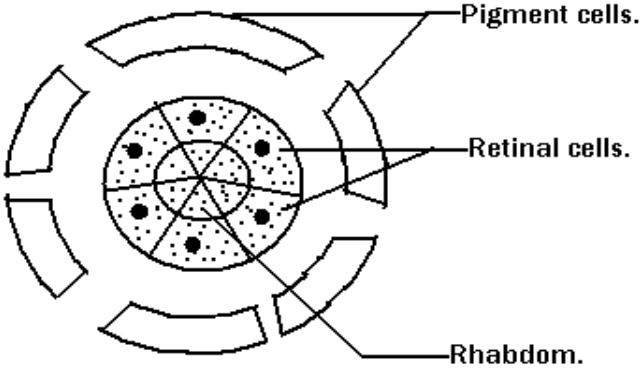
VERTICAL SECTION OF COMPOUND EYE AND OPTIC GANGILION.



STRUCTURE OF A SINGLE OMMATIDIUM IN LONGITUDINAL SECTION:



CROSS-SECTION OF OMMATIDIUM



LIGHT RECEPTION IN THE COMPOUND EYE

Only light entering the Ommatidia parallel to their long axis reaches the microvillii extensions of the retinal cells forming the rhabdom. Any light entering at an angle to them is absorbed by the pigments in the pigmented cells which work like the iris by absorbing light if it is too bright. The microvillii and the rhabdom have the photo- sensitive pigment Rhodopsin which they use to trap light.

The light entering parallel to the ommatidia is absorbed by the photosensitive pigment rhodopsin; the Cis form of retinene is converted to trans form this initiates the split of rhodopsin to protein opsin (scotopsin) and free retinene, this causes the membranes of the retinal cells to become depolarized and and a generator potential develops, if it exceeds a threshold, impulses are fired into the nerve fibres which lead them to the optic ganglion and then to the optic nerve.

STRUCTURAL DIFFERENCES BETWEEN THE MAMMALIAN EYE AND THE COMPOUND EYE:

COMPOUND EYE	*MAMMALIAN EYE.*
(i) Has no cones and rods as photo-sensitive cells.	(i) Has rods and cones as photosensitive cells.
(ii)Has no melanin, light absorbed by the pigment cells.	(ii) Has light absorbing pigment melanin.
(iii) Has ommatidium as the functional unit with each unit functioning on its own.	(iii).Has no ommatidia the whole eye functions as a single unit.
(iv) Has lenses which are crystalline and in-elastic.	(iv) Has lenses which are membraneous and elastic
(v) Has no muscles attached to it and is Immobile.	(v) Has muscles attached to it and is movable.
(vi) Has no external structures that protects the eye.	(vi) Has eye lids for protection externally.

(vii) Light sensitive pigments are contained in the rhabdom.	(vii) Light sensitive pigments are contained In the outer segment.

STRUCTURAL SIMILARITIES BETWEEN THE MAMMALIAN EYE AND THE COMPOUND EYE:

(i) Both contain convex lenses.
(ii) Both contain photosensitive cells.
(iii) Both have cornea.
(iv) Both possess retinal cells.
(v) Both have nerve fibres to the brain.

FUNCTIONAL DIFFERENCE BETWEEN THE COMPOUND EYE AND THE MAMMALIAN

COMPOUND EYE.	**MAMMALIAN EYE.**
(i) Can not accommodate (has a fixed focus.	(i)Can accommodate (has adjustable focus)
(ii) Form blurred images due to greater overlap of images.	(ii) Forms clearer images due to smaller over lap of images.
(iii) Detects light that is parallel to its long axis.	(iii) Detects light reaching it at an angle.
(iv) Has less ability for colour vision.	(iv) Has greater ability for colour Vision.
(v) Has a quicker detection of movement (pattern vision)	(v)Has slower detection of movement.
(vi) Has poor dark adaptation (poor vision at night)	(vi) Has better dark adaptation.
(vii) Shows near sightedness.	(vii) Can show both near and far Sightedness

FUNCTIONAL SIMILARITIES BETWEEN THE COMPOUND EYE AND THE MAMMALIAN EYE

(i) Both are able to perceive colour in the environment (colour vision)
(ii) Both function in bright and dim light.
(iii) In both light, sensation is by light stimulating photosensitive cells which then generate impulses sent to the brain via optic nerves.
(iv) In both there is overlap of images.

REASONS FOR POOR RESOLVING ABILITY OF THE COMPOUND EYE

(i) The Ommatidia are larger than rods and cones and therefore few can be packed in the same area.
(ii) There is greater overlap of images.

REASONS FOR NEAR SIGHTEDNESS OF THE COMPOUND EYE;

(i) It has a poor resolving ability.
(ii) It can not accommodate.

The quicker detection of movement of the compound eye is due to the fact that, the time taken to receive a stimulus, fires an impulse and recover, is shorter than in the rods and cones.
The poor dark adaptation of the compound eye is due to its poor resolving ability

SOUND RECEPTION IN THE MAMMALIAN EAR

Sound is a physiological sensation perceived by the ear. Sound is transmitted as longitudinal waves through air, water or any solids. sound reception is known as hearing. And this role is played by special structures called ears. The ear is not present in fish and the main sound receptor is the lateral line, some times assisted by the swim bladder.

STRUCTURE OF THE MAMMALIAN EAR.

The mammalian ear performs both function as an organ of hearing and balance. It is divided into three regions the outer ear, middle ear and inner ear.

(i) The outer ear. This consists of;

- Pinna.
- External auditory meatus.
- Tympanic membrane (ear drum)

(ii) The middle ear.

It consists of the following;

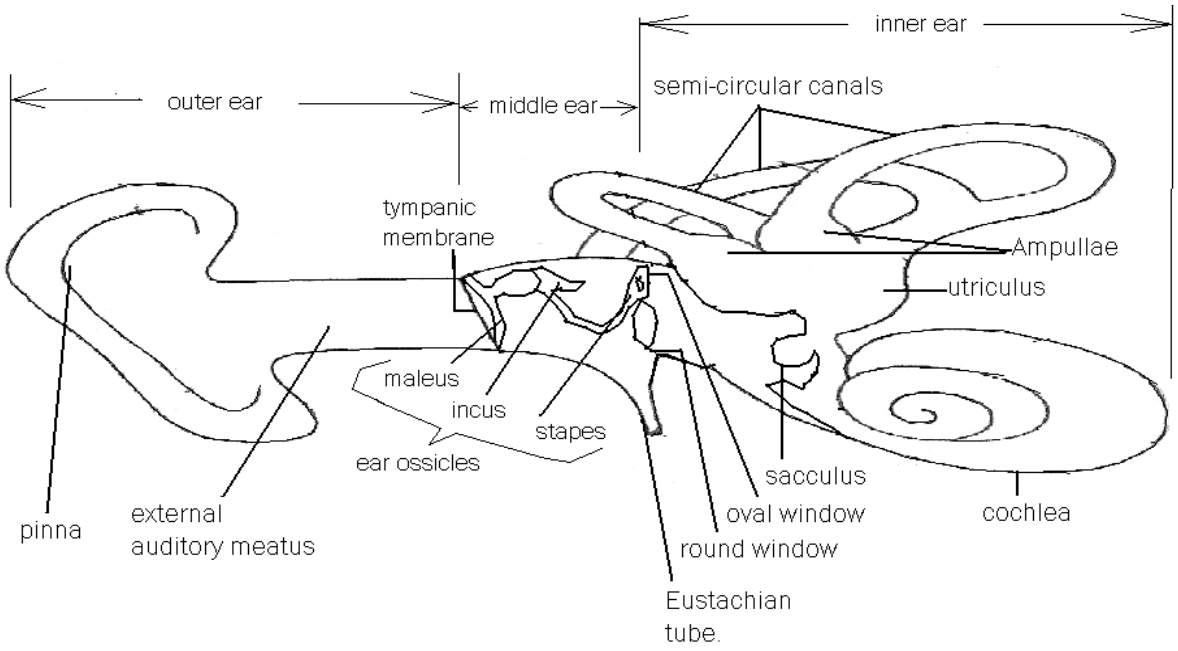
- Ear ossicles (malleus, incus, stapes)

(iii) The Inner Ear.

It consists of;

- Semi-circular canals.
- Ampulla.
- Utriculus.
- Sacculus.
- Cochlea.
- Eustachian tube.
- Auditory nerve.

STRUCTURE OF THE MAMMALIAN EAR SHOWING THE OUTER, MIDDLE AND INNER EAR.



FUNCTIONS OF THE PARTS OF THE EAR:

(i). ***Pinna***: Receives and concentrates sound wave. It is lobbed.

(ii) Auditory canal (external auditory meatus): For passage of sound waves to the middle ear.

- Its walls produce wax which prevents insects, solid particles, bacteria and dust from reaching the ear drum.
- Have hairs on the walls which prevent dust form entering the ear.

(iii) Tympanic membrane (ear drum)

- Vibrates according to the intensity of sound waves. Vibrations are then sent to the inner ear.
- Separates the outer and inner ears.

(iv) Ear ossicles

Transmit sound vibrations from the eardrum to the oval window. and through the ear

ossicles which are held in position by muscles.

(v) Eeustachian tube

Equalizes air pressure on both sides of the ear drum so that tympanic membrane is not stretched as it may reduce the amplitude of its vibrations and make the sense of hearing dull.

The middle ear is air filled and the Eustachian tube connects the middle ear to the pharynx. It is usually during swallowing that air enters or leaves the middle ear.

(vi) Oval window

Receives sound vibrations from the ear ossicles and transmits them to the cochlea.

(vii) Round window

Equalizes fluid pressure in the cochlea.

(viii) ***Vestibular apparatus*** (Sacculus, utriculus, ampulla and semi-circular canal)

- Contains gravity recetptors.
- Contain receptors for head movements.

(ix) Cochlea

Contains sound receptors

(x) ***Auditory nerves***:

- Transmit impulses to the brain.

The main functions of the ear are three,

- To respond to sound vibrations(hearing)
- To respond to changes in gravity (balance)
- To detect movement of the head.

This means that the ear consists of three mechano-receptors located in different areas in the inner ear which converts the mechanical energy into impulses which is then transmitted to the brain via the auditory nerve.

The mechano-receptors are;

i. The sensory cells of the organ of corti in the cochlea for hearing.
ii. The macula cells attached to the otolith in the utriculus and saccuulus for gravity (i.e. balance)
iii. The crista cells attached to the cupula in the ampullae at the bases of the semi-circular canals for detecting the movement of the head.

THE BASIC STRUCTURE AND FUNCTION OF THE MECHANO-RECEPTORS:

All the three mechano-receptors have basically similar structures but performing slightly different functions. They consists of a group of cells (receptor cells) with cilia like projections called sensory hairs and the receptor cells carrying them are referred to as sensory hair cells. The sensory hairs are embedded in another structure. when the structure carrying the sensory hairs are moved or displaced; it causes the sensory hairs to stretch, resulting into depolarization of the membrane of the sensory hair cells. This produces a generator potential in the receptor cell and if it exceeds a threshold value, an action potential is produced and an impulse is transmitted in the nerve fibres leading to the auditory nerve.

THE PERCEPTION OF SOUND (HEARING)

When an object in the environment vibrates. The vibrations disturb particles in the medium around it and the vibrating particles collide with one another producing a sound wave. In the mammalian ears, the sound waves are received from the air where they are received and concentrated by the pinna. The sound waves are then directed to reach the tympanic membrane. It causes the tympanic membrane to vibrate. The vibrations are taken over by the ear ossicles from the malleus to incus and to the stapes and the vibrations in this way are amplified, this causes the oval window to vibrate in other words, small movement of the tympanic membrane produces large displacement of the oval window. The oval window is pushed in and out. This causes vibrations of the perilymph in the cochlea, especially vibrations of the perilymph in the vestibular canal. This results into displacement of the reissner's membrane which in turn displaces endolymph in the middle chamber (median canal). The endolymph displaces the basilar's membrane while the tectorial membrane remains fixed. This causes the sensory hairs to become stretched and the sensory hair cells become distorted. This causes depolarization of the membrane of the sensory hair cells, a generator potential is set-up and it exceeds a threshold value, an action potential is set-up and action potential is

conveyed to the brain along the branch of the auditory nerve. The sensory hair cells are contained within a structure called the organ of corti. It consists of the following:

(i) Sensory hair cells (receptor cells)

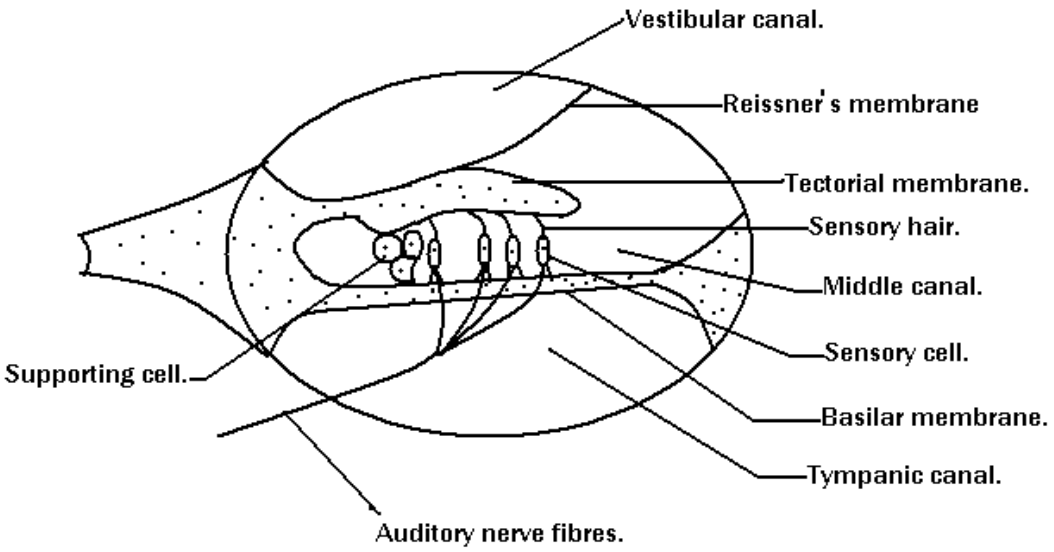
(ii) Supporting cells.

(iii) Tectorial membrane.

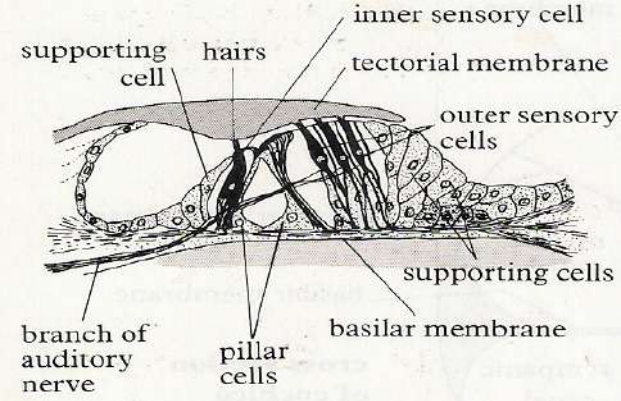
(iv) Basilar's membrane.

(v) Branch of auditory nerve.

TRANSVERSE-SECTION OF THE COCHLEA SHOWING ORGAN OF CORTI IN THE INNER EAR



DETAILED STRUCTURE OF ORGAN OF CORTI



The basilar membrane is quite elastic but the tectorial membrane is more rigid, this leads to movement of the basilar membrane, while the tectorial membrane remains quite rigid.

The disturbance of the basilar membrane causes displacement of the perilymph in the tympanic canal and since the perilymph is incompressible. The pressure waves resulting from these vibrations are taken up by the membrane covering the round window. It bulges outwards into the middle ear; because the middle ear is air filled and the inside is simply compressed.

DESCRIMINATION OF SOUND BY THE MAMMALIAN EAR.

Sound has three qualities that human ears can normally discriminate. And these are,

- pitch (frequency)
- amplitude (intensity).
- and tone.

DETERMINATION OF PITCH, TONE AND INTENSITY OF SOUND.

Sound travels as waves and the distance between identical points on these waves is known as the wave length. The longer the wave length the lower the frequency, the shorter the wave lengths, the higher the frequency. The frequency of sound waves is known as pitch, where as its loudness or amplitude is referred to as intensity. The pitch of a sound depends on its wave length while low tones are as a result of sounds of low frequency (long wave length)

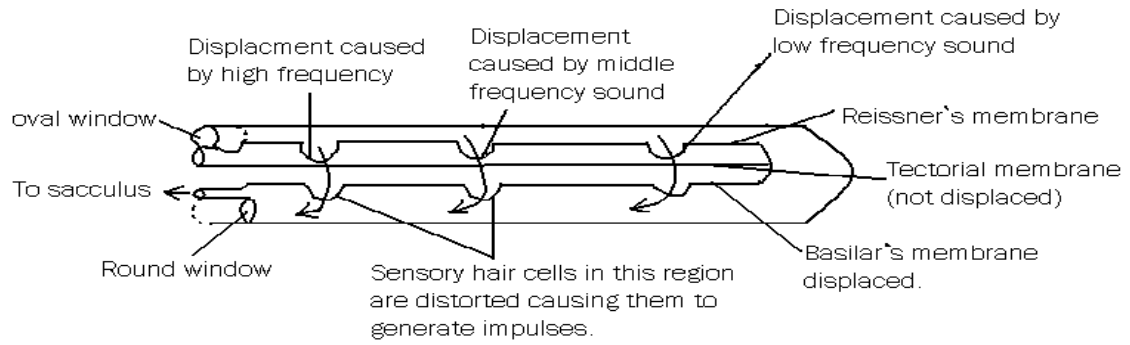
The pitch of a sound determines the frequency at which the basilar membrane vibrates. The structure of the basilar membrane is such that, it broadens and thickens the further away it is from the round window.

High frequency sound causes vibrations of the basilar membrane near the base of the cochlea and round window, at this point, the basilar membrane of the cochlea is narrower and under high tension and the basilar membrane then vibrates at high frequency.

Low frequency sound causes vibrations of basilar membrane near the apex of the cochlea but far away from the round window. At this region the basilar membrane is broad and under lower tension and vibrates at lower frequencies. The vibrations of the basilar membrane cause the sensory cells in that region to be stimulated, when the generator potential generated reach a thresholds, an action potential or impulses are formed and transmitted to the brain for interpretations via auditory nerves. Sound waves of different frequencies tend to stimulate different regions of the cochlea. By determining which region of the cochlea is sending the impulses, the brain can interpret the pitch of sound entering the ear.

A pure sound stimulates only one region of the basilar membrane, a sound of several frequencies will stimulate many regions of the basilar membrane. In this way the ears detect the tone or quality of the sound.

DETECTION OF PITCH



Note: the arrows show the direction of movement of the fluid endolymph, this displaces the membranes.

The intensity of the sound depends on the amplitude of the sound waves hitting the tympanic membrane which are then transmitted to the basilar's membrane. Thus, the sounds of high intensity results in large amplitude in the vibrations of the tympanic membrane and a large displacement on the basilar's membrane resulting into the stimulation of greater number of

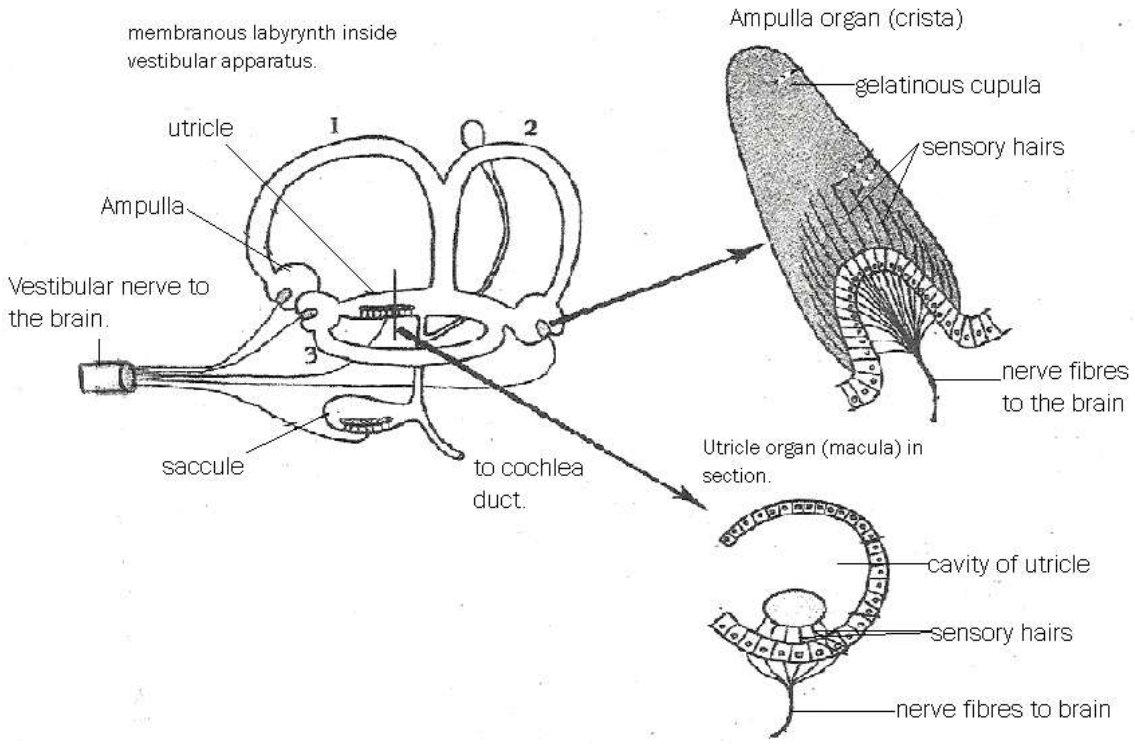
sensory hair cells and in case of sounds of low intensity results into low amplitude vibrations of the tympanic membrane, the basilar's membrane is less displaced and fewer sensory hair cells are stimulated.

At any point, along the basilar's membrane there are a number of different sensory hair cells, each with a different threshold at which it can be stimulated. The louder the sound at any one frequency, the greater the number of sensory hair cells which will be stimulated at that one point on the basilar's membrane. The less loud the sound, the fewer the number of sensory cells stimulated at one point on the basilar's membrane.

MAINTENANCE OF BALANCE

The parts of the ear concerned with balance are the semi-circular canals which connect with the middle chamber of the cochlea via the utriculus and sacculus. They collectively form the vestibular apparatus, which is the largest part of the membranous labyrinth (system of fluid filled inter connecting tubes which make the inner ear)

STRUCTURE OF THE VESTIBULAR APPARATUS:



NB:

- Semi-circular canals numbered 1,2 and 3.
- The whole of the vestibular apparatus is filled with endolymph. The vestibular apparatus

consists of semi-circular canal; utriculus and sacculus.

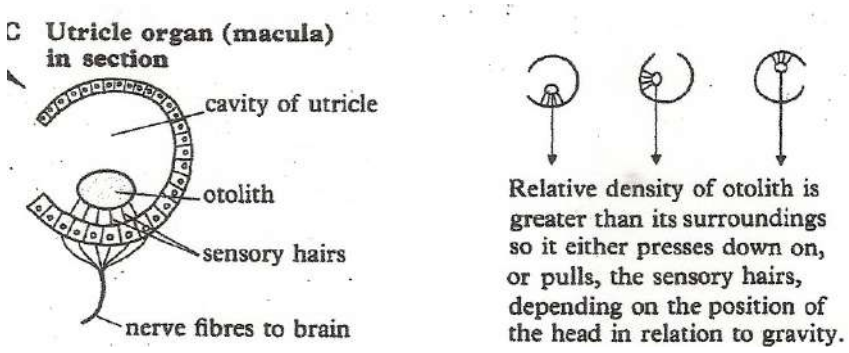
The maintenance of balance is achieved through one of the following

- Perception of gravity (position of head)/static equilibrium
- And perception of the movement of the head/motion equilibrium.

PERCEPTION OF GRAVITY (POSITION OF THE HEAD)

This is the function of both the utriculus and sacculus which contain group of mechano-receptor cells in structures known as maculae (single, macula) on the inside of their walls. The sensory cells in the maculae have hair like projections (sensory hairs or stereocilia) which are embedded in a thick mass of Jelly like glycoprotein layer covered by calcium carbonate crystals called otolith (otolithic membrane). These Otoliths are affected by gravity and in this way they are able to detect and give information to the brain about the position of the head as well as the changes in position due to acceleration and deceleration. The maculae of the utriculus are on the floor and responds to the vertical movements, while that of the sacculus is on the side walls and responds to the lateral (horizontal) movements.

STRUCTURE OF AN OTOLITH AND MACULA.



When the head is upside down, the Otolith of the utriculus fall away from the macula. The result is that they exert a pull as a result of which the sensory cells are distorted and depolarization a cross the membrane of the sensory hair cells occurs, a generator potential is produced if it reaches a threshold value, an action potential is fired and impulses are transmitted to the brain via the vestibular nerves.

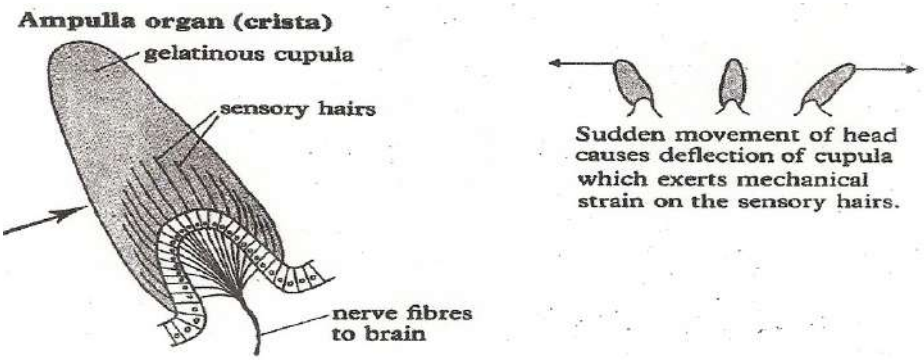
And when the head is on one side, the Otolith especially the sacculus sensory hairs are

stretched. The way the sensory projections are stretched determines the patterns of impulses reaching the brain via the sensory neurons. No impulses are generated if the head is on normal position.

PERCEPTION OF MOVEMENT OF THE HEAD

This is the function of the semi-circular canals. The semi-circular canals are arranged so that they lie at right angles to one another. This arrangement enables movements of the head in any direction to be detected. Each semi-circular Canal has an Ampulla in which the receptor cells are located in groups known as crista. The sensory cells of the crista have sensory hairs embedded in a jelly like structure known as the cupula.

SECTION THROUGH AMPULLA



The swollen portion of each semi-circular canal is known as the Ampulla, within which there is a flat gelatinous plate the cupula. The movement of the endolymph displaces this Ampulla in the opposite direction to that of the head movement. The sensory hairs are stretched, causing depolarization along the membrane of the sensory hair cells, resulting into the generator potential and then action potential and transmission of impulses to the brain via the vestibular nerves.

NOTE: In spinning movements, one becomes dizzy for sometime, because the spinning of the endolymph still continues even when that of the body has stopped.

The activity of the vestibular apparatus also depends on the following;-

- The eyes which provide information about the horizontal and vertical planes that, they are moving in.
- The pressure receptors in the soles of the feet; in man which prevent us from falling over

when we are standing upright.

- Stretch receptors in the muscles (muscle spindles) and in tendons which provide information on the state of stretch of the muscles.

ECHOLOCATION IN BATS

Bats are able to use sound for orientation in the environment and this explains why they can move about safely at night without colliding with objects in their paths. They use echoes of the sound they produce to detect objects in their path a phenomenon known as echolocation.

Bats produce sounds of high frequency (short wave lengths) which are far beyond what man can perceive and man does not hear the sound used in echolocation. Using sounds of high frequency has two advantages;

(i) High frequency waves spread little and their echoes are so refined that, they pin point the objects on which they are being reflected quite accurately as opposed to low frequency waves which spread widely and their reflections are too diffuse to pin point accurately the location of objects.

(ii) Being short wave length they allow location of even small objects because the shorter the wave length the smaller the minimum size of the object that will reflect it.

DIFFERENCES BETWEEN HEARING IN BATS AND IN MAN

Hearing in Bats	*Hearing in man.*
1. Depends mainly on sound produced by themselves and reflected by some objects. 2. Has no ability to discriminate between sounds due to smaller size of brain but only eliminate noise in the environment from their echoes. 3. Are able to detect sound of very high frequency.	1. Depends mainly on sounds produced from a vibrating object in the environment (and rarely from themselves. 2. Has ability to discriminate between sounds due to larger brain. 3. Un able to perceive sounds of higher frequencies above (150,000Hz)
4. Can readily estimate distance from which sound is coming, by echolocation. 5. Can locate obstacles and pinpoint	4. Can not estimate distance from which sound is coming. 5. Can not locate obstacles of other objects by emitting sounds in the

emitted echoes from them in the dark.	dark.

SENSE OF TASTE AND SMELL (CHEMO-RECEPTION)

The sense organs for taste and smell are the mouth and nose respectively. They have specific chemoreceptors which detect chemicals that reach the sense organs

In mammals taste and smell play a role in the following,

• In nutrition, where it is important for location and selection of food.

• In reproduction where it is important for finding mates i.e for sex attraction in many mammals except man. And for detection of mother by the young ones.

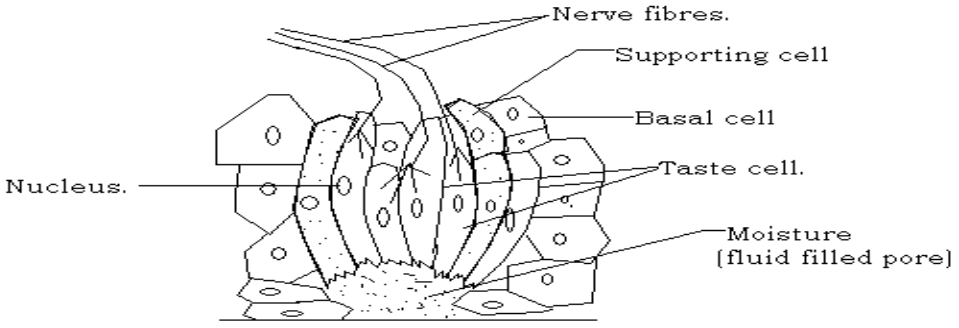
• Establishment of territories, where the animals mark and defend territories using their urine or excreta.

• It can also be used for protection purposes, where it is used for detection of danger such as fire or presence of a predator.

SENSE OF TASTE.

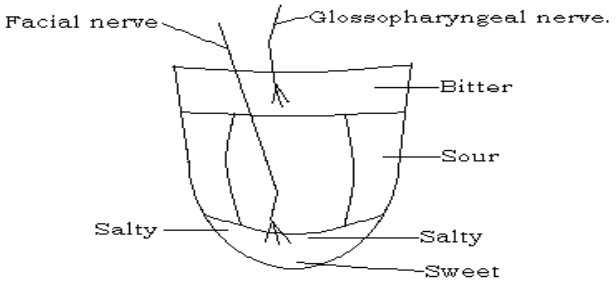
Taste is detected by special taste receptor cells, located on the tongue and roof of the mouth. Humans have four types of taste cells, each responding to chemicals that cause sensations of sweet, sour, bitter and salts. Most of these taste cells do not respond to only one specific type of stimuli but to a range of them but giving maximum response to only one of them.

VERTICAL SECTION OF THE TASTE BUDS.



Taste receptors are found in taste buds. These are located on the surfaces of the tongue and also on the walls of the pharynx parts of the soft palate at the back of the mouth, in areas called taste areas. Each taste bud responds maximally to one of the four sensations. The various

areas of taste buds on the tongue are shown below.

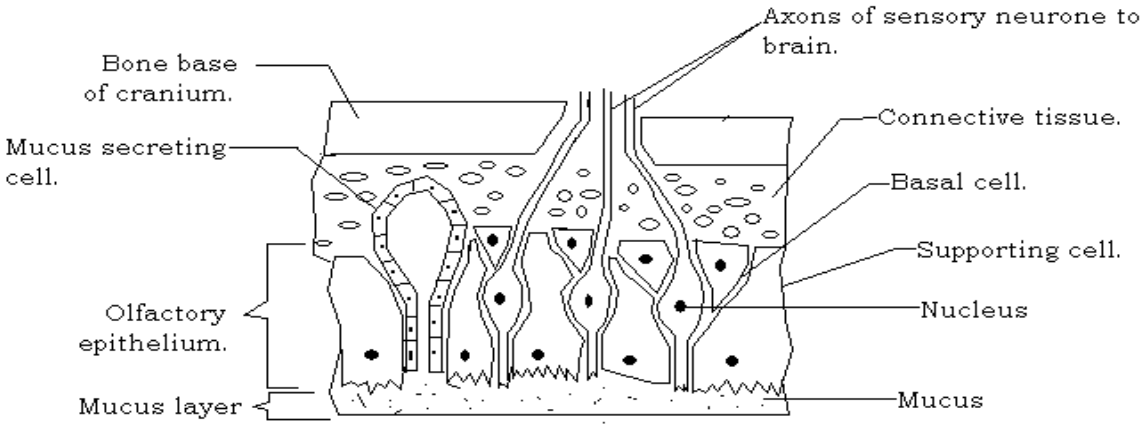


Chemicals taken to the mouth are detected when dissolve in the moisture of the tongue and pharynx. This stimulates appropriate sensory cells via their hairs and impulses are sent into the nerves leading to the brain (cerebral cortex and thalamus) where the taste is interpreted.

SENSE OF SMELL

Smell is detected by olfactory cells in the roof of the nasal cavity. The sense of smell results from vapours drawn into the nasal passage. a few receptor cells (about seven only) can detect very many types of odour. These receptors are stimulated by very low concentrations of vapours.

VERTICAL SECTION OF OLFACTORY CELLS OF MAMMALS.



During chemo-reception, air is drawn in through the nostrils (nasal passage) and over the olfactory epithelium, where the molecules of any chemicals in it dissolves in the mucus covering the epithelium and they excite the olfactory cells whose membranes are depolarized setting up generator potentials which build up to form impulses which are conducted to the olfactory lobes of the brain. The brain then determines the type of odour. The repeated stimulation of the olfactory cells causes them to adapt.

In general, volatile, fat soluble and readily absorbable substances are easily detected. The brain is able to quickly adapt to strong odours and this explains why one soon loses the trace of perfume he/she has applied or a stinging environment.

The sense of olfaction is poorly developed in man but better developed in mammals such as carnivores i.e. cats, dogs, etc.

NEURONES AND SYNAPSES

These are the basic structural components of the nervous system.

NEURONES

Are the basic structural and functional components of the nervous system. There are three types of neurons and they are the following motor, sensory and intermediate neurons.

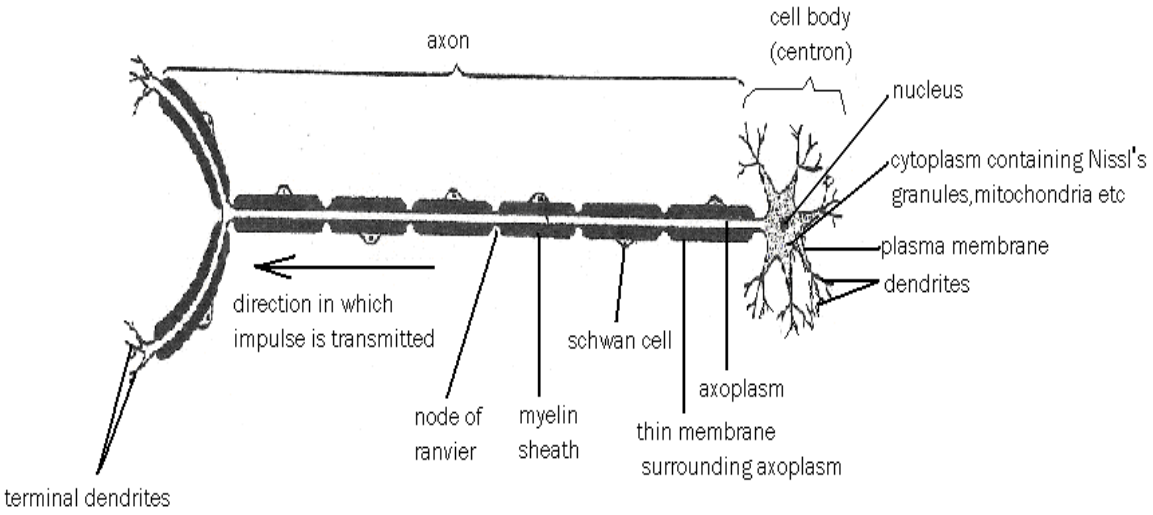
MOTOR NEURONES

They are also called effectors or efferent neurons. They transmit impulses from the central nervous system (CNS) to muscles and glands. They possess more than two cytoplasmic extensions and are referred to as multi-polar neurons.

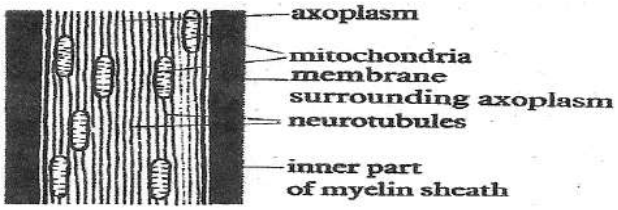
THE STRUCTURE OF THE MOTOR NEURONES

It contains nucleus, mitochondria, cell membrane, etc. Its cytoplasm contains granules called Nissl's granules, which are group of ribosomes concerned with protein synthesis. The nucleated part called the cell body (centron) is located within the CNS and is connected with neighbouring neurons by slender dendrites. One of the dendrites is drawn to form an axon (nerve fibre) which enters a peripheral nerve and terminates in a muscle or glands. A fatty myelin sheath, this is not part of the neurone but the membrane of another cell.

STRUCTURE OF MOTOR NEURONE



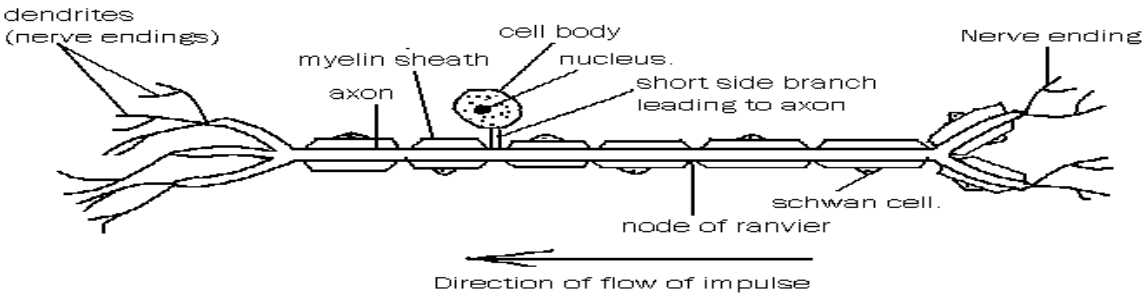
CROSS-SECTION THROUGH THE AXON



SENSORY NEURONES

These are also called receptor or afferent neurons. They transmit impulses from receptors to the central nervous system (brain and spinal cord). Their cell bodies are located in the dorsal root ganglia of the spinal nerves. They possess only one cytoplasmic extension and are referred to as unipolar neurone.

DIAGRAM OF VERTEBRATES SENSORY NEURONE

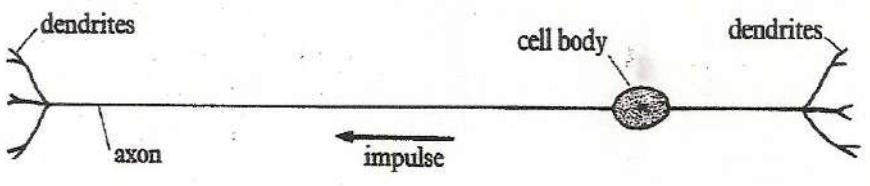


INTERMEDIATE NEURONES

These are also called relay or internuncial or associate neurons. They are found in the central

nervous system (CNS) where they connect sensory and motor neurons with each other. They possess two cytoplasmic extensions and are referred to as bi-polar neurone.

SIMPLIFIED DIAGRAM OF INTERMIATE NEURONE:



Note: All neurons possess similar essential parts as shown in motor neurone.

BASIC STRUCTURE AND FUNCTIONS OF THE PARTS OF A NEURONE

(i) Dentrites and dendrons

These are cytoplasmic extensions of the cell body; they transmit impulses to the cell body.

(ii) Axoplasm

Transmit the nerve impulses. It contains numerous mitochondria which provides the required energy and it also possesses the neutrotubules

(iii) **The cell body**: Contains all the cell organelles e.g. Mitochondria, ribosomes, endoplasmic reticulum and the nucleus which controls the activities of the cell etc

(iv) ***Schwan cells***: Produce the myelin sheath.

(v) ***Myelin sheath***: Speeds up the transmission of the impulses.

(vi) ***Synaptic knobs***: Release chemical transmitters that allow impulses to cros the synapse.

THE NERVE IMPULSE

A nerve impulse is electrical in nature but with an ionic basis. It can also be referred to as action potential. Nerve impulses are transmitted along cells called neurones. The neurone consists of a cell body which contains nucleus and other cell organelles. Cell body is connected to long structure called the axon which carries the nerve impulses away from the cell body. The second branching of the neurones are the dendrites which carry the nerve impulses towards the cell body. Neurones maintain a potential difference called the membrane potential across their membrane. They are unique from other living cells in that they have the ability to alter this membrane potential.

THE RESTING POTENTIAL.

When a neurone (nerve cell) is at rest, the inside of its membrane is more negative while the out side of the membrane is more positive, the membrane is said to be polarized, resulting into formation of a potential difference across the membrane of the neurone (axon) that is at rest referred to as **a resting potential**. And its magnitude is about -70mV (-60mV to -70mV). This membrane potential is maintained by **sodium-potassium pump mechanism.** The pump is carrier proteins that exist across the membrane of the nerve cell and it can alter its shape to actively pump 3 molecules of sodium ions out and 2 molecules of the potassium ions into the membrane. While the membrane remains impermeable to outward diffusion of the negative ions such as the chloride ions which are retained inside (in the axoplasm). This creates more positive charges outside the membrane and more negative charges inside the membrane. The membrane is polarized and there exists the resting potential across the membrane.

The nerve cell has a higher concentration of positive ions like sodium and potassium ions outside the cell than the inside, while concentrations of negative ions like the chloride ions is higher inside than outside. This is because the membrane of the neurone is impermeable to outward diffusion of chloride ions and inward diffusion of sodium ions while at rest. In addition, the membrane is permeable to outward diffusion of potassium ions while at rest. The inside of the membrane has a higher concentration of potassium ions than sodium and the surrounding tissue fluid (outside of the membrane) has a higher concentration of sodium and low concentration of potassium ions. This creates a gradient across known as electrochemical gradient. The electrochemical gradient of an ion is due to its electrical and chemical properties. The electrical property is its charge, where attractions and repulsions can occur. While, the property of the ion is due to concentrations of the ion.

The value of the resting potential is largely determined by the potassium ion electrochemical gradient. This is because the membrane is more permeable to outward movements of potassium and less permeable for movement by diffusion of sodium ions inside, so, potassium ion loss from the axon is greater sodium ions gain by passive diffusion. Across the membrane are channels proteins with pores. The sodium ion channels and the potassium ion protein channels are called gated channels. These protein channels can be opened or closed with polypeptide chains called gates. When the neurone is at rest, sodium gates are closed, while the potassium gates remain open.

NOTE: Resting potential is determined largely by rapid diffusion of potassium ions outside the membrane to maintain high concentration of positive charges out the membrane.

THE ACTION POTENTIAL.

When the nerve cell (neurone) is at rest (no stimulus). The inside of its membrane is more negative, while the outside is more positive and there exists a potential difference across the membrane called the **resting potential** maintained by the activities of the sodium-potassium pump that actively pumps 3 molecules of sodium ions out and 2 molecules of potassium ions inside.

When the neurone receives a stimulus, sodium- potassium pump mechanism breaks down (Ceases in its functions), some sodium gates open, while the potassium gates close. The permeability of the membrane of the axon to sodium ions increases. Sodium ions diffuse rapidly inside the axon. The inside of the membrane become more positive and the out side become more negative and the membrane become depolarized. The sodium gates are sensitive to slight depolarisation and responds by more sodium gates opening, allowing more sodium ions into the axon, resulting into formation of a new potential difference across the membrane which increases to reach **a threshold value**, causing a greater wave of depolarisation across the entire membrane of the axon called **action potential.** In this case depolarisation is propagated along the axon such that one point depolarizes the next until the synapse is reached. This leads to transmission of a nerve impulse.

Action potential is a new potential difference (Positive voltage) that exists across the membrane of an axon of the neurone, due to the existence of more positive charges inside and more negative charges outside the membrane (due to depolarisation of the membrane/sudden reversal of the resting potential) when the neurone receives stimulus. And **an impulse** is the propagated negative charges on the outside of the membrane caused by wave of depolarisation. A threshold value is the maximum potential difference across membrane of receptor cells and neurones or axons which when reached, causes generation of action potential and leads to transmission of impulses. It peaks at about +40mV.

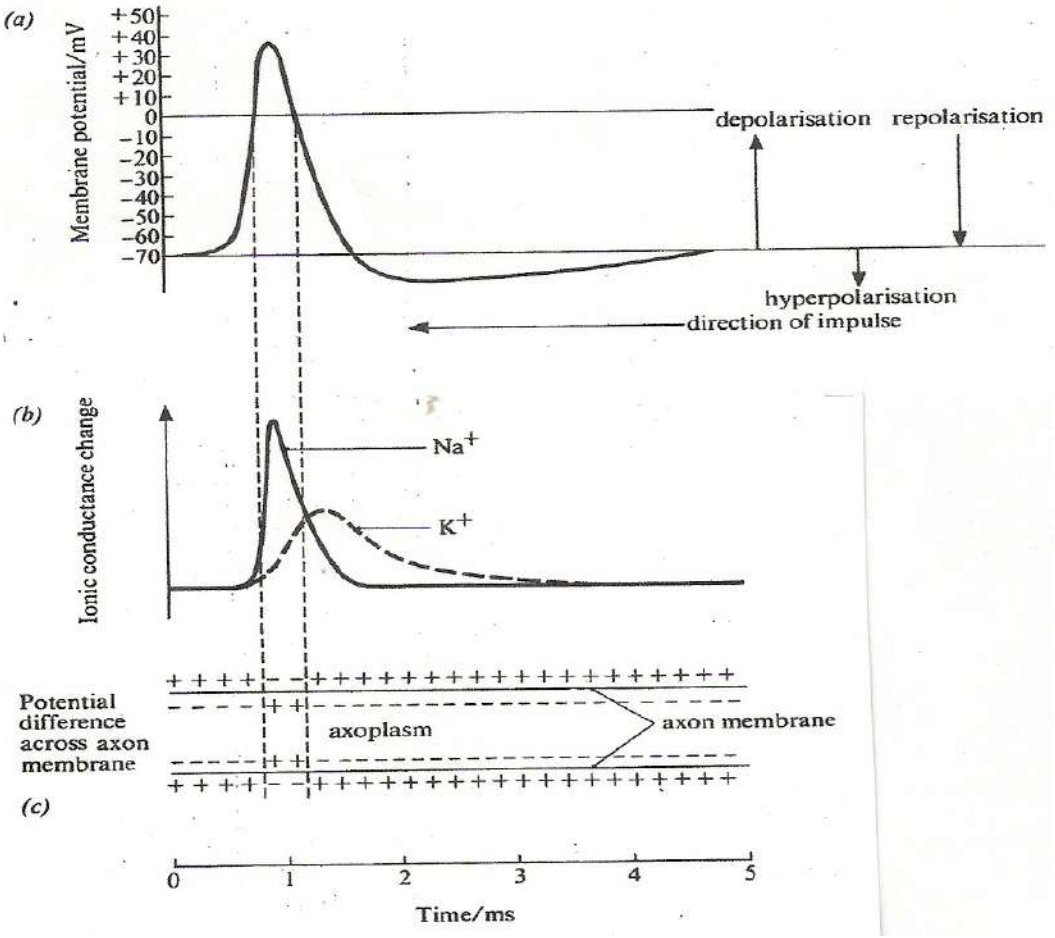
After the action potential, the **process of repolarisation** of the membrane begins to restore the resting potential before the next impulse is allowed to be transmitted. In this process certain

events occur, at the peak of the action potential, the sodium gates begin to close again, the potassium gates open, potassium ions begin to rapidly diffuse outside the nerve cell. This makes the outside of the membrane to build more positive charges, this starts the repolarisation process. The sodium-potassium pump mechanism resumes to actively pump 3 molecules of sodium ions out and 2 molecules of potassium ions inside. The inside of the membrane once again become more negative, while the outside more positive, resulting into the restoration of the original potential difference across the membrane called resting potential. The process of repolarisation starts with rapid diffusion of potassium out side, since they are positive ions, they begin to build up more positive charges out side the membrane.

In the process of repolarisation, the inside of the membrane may become even more negative than usual due to excessive lose of positive ions (both sodium and potassium ions) outside the membrane, resulting into a more negative potential difference across the membrane than the original resting potential. This phenomenon is called **Hyperpolarisation.** The excessive lose of positive ions outside the membrane is due the slight delay in closing all the potassium gates compared to the sodium gates (This condition explain why graph of potassium starts to fall after the sodium graph as shown in the graphs below)

NOTE: The action potential is determined largely determined by rapid diffusion of sodium ions inside the membrane, this makes the inside more positive, while the outside more negative.

DIAGRAM SHOWING EXCHANGE OF IONS ACROSS THE MEMBRANE OF AN AXON BEFORE, AFTER AND DURING TRANSMISSION OF AN IMPULSE



TRANSMISSION OF THE NERVE IMPULSES IN NEURONES (NERVE CELLS).

At the rest, the membrane of the nerve cell is polarized, the out side is more positive, while the inside is more negative. This results into a potential difference across the membrane known as resting potential. This membrane potential is maintained by sodium-potassium pump actively pumps sodium ions out and potassium ions out while negative chloride ions are retained inside. At resting potential there is also a high concentration ions outside and a high concentration of potassium ions inside.

When the neurone is stimulated, sodium-potassium pump mechanism stops to function, sodium gates open, potassium gates close. Sodium ions rapidly diffuse into the axon along a

concentration gradient. The inside of the membrane becomes more positive, while the outside more negative. This causes depolarisation of the membrane. A localised electrical circuits are established which cause further influx of sodium ions and so a wave of depolarisation across the entire membrane resulting into an action potential and therefore transmission of the impulse.

Behind the impulse, potassium ions begin to leave the axon along a concentration gradient. As the impulse progresses, the outflux of potassium ions causes the neurones to become repolarised behind the impulse. After the impulse has passed and the neurone is repolarised sodium is once again actively expelled in order to increase the external concentration and allow the passage of another impulse.

PROPERTIES/FEATURES OF NERVE IMPULSES OR ACTION POTENTIAL.

(i) **Stimulation.** Generally impulses are set-up in nerve cells as a result of excitation (stimulation) of receptors.

(ii) **Propagation (Conduction) of nerve impulse.** Nerve impulse is propagated as wave of depolarisation that moves along the surface of a nerve cell as local currents.

(iii) ***The all or nothing law***, it states that the magnitude of response of an excitable unit such as the axon is independent of the intensity of the stimulation provided the threshold is reached, in other words the size of impulse does not depend on the size of the stimulus.
If the strength of the stimulus is below certain threshold intensity, no action potential is evoked. If however, the stimulus is above the threshold, a full-sized action potential is generated.
Threshold is the minimum strength of stimulus at which or above which action potential is transmitted in the axon/receptors.
The weak and strong stimuli can be determined by determining the frequency of the action potential.

(iv) ***Transmission speed***, neurone impulses are transmitted very rapidly along the axon. The transmission of an impulse along the axon is determined by two factors.

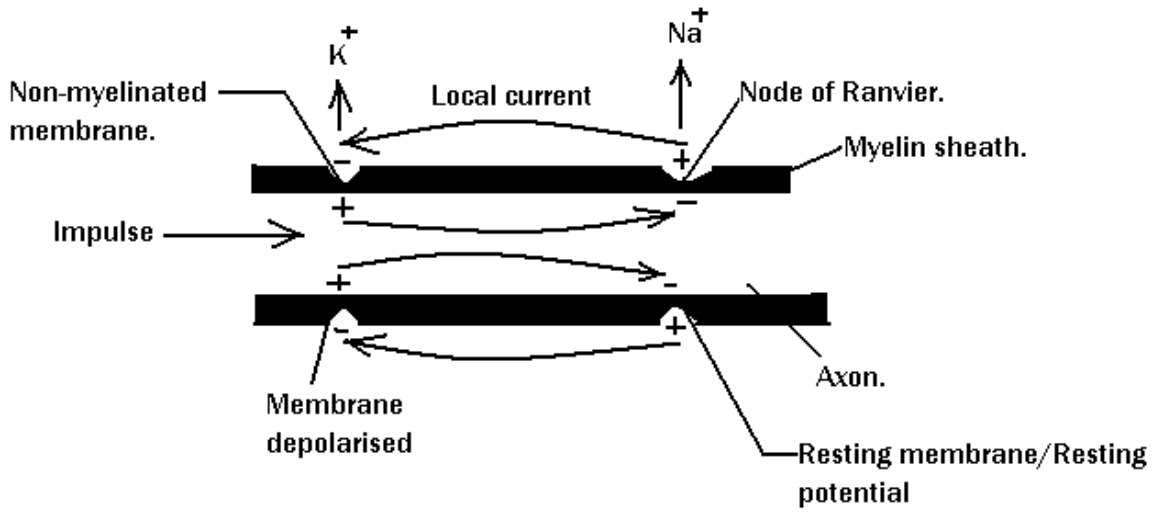
- Possession of myelin sheath.
- and the diameter of the axon.

Myelin sheath;

Nerves possessing myelin sheath are said to be myelinated, while those without it are said to be non-myelinated. The speed of transmission is faster in myelinated nerve and slower in a non-myelinated one of the same size. The reason being that myelin sheath is an insulator (being a lipid sheath) and so when myelinated axon is transmitting an impulse, only the membranes at the nodes of ranvier undergoes depolarization, and ionic exchange occurs at that point of the membrane of the axon. And in this case, the action potential jumps from one node of ranvier to another, thereby speeding up its transmission along the axon. A condition referred to as **saltatory conduction**. So, rapid transmission in most vertebrates is achieved by myelination.

In non-myelinated neurones, the action potential occur as series of small local currents across the entire membrane, slowing down the speed of transmission of action potential.

DIAGRAM SHOWING HOW AN IMPULSE IS TRANSMITTED A LONG MYELINATED AXON.



Axon diameter (cross-sectional area)

The greater the diameter, the faster the speed. The thicker the axon the faster it will transmit impulses. This is because there will be greater area of membrane over which ionic exchange can take place and less resistance is offered.

The development of giant axon is adaptation found mainly amongst the invertebrates e.g. Annelids (earthworms, marine worms) Cray fish, prawns, crustacean squids (cephalopod mollusc). Giant axons are associated with rapid escape responses which occur due to quick transmission of impulses from receptors to muscles.

Note: - Myelination provides greater speed of transmission of impulse.

- Speed of transmission of impulse is higher in endotherms than ectotherm.

Speed of transmission is higher in fast moving than slow moving animals.

(v) ***REFRACTORY PERIOD***; This is a very brief moment of about 1-3 milliseconds immediately after action potential when an axon is incapable of transmitting the next impulse or any further action potential can not be generated in an axon (neurone). This is because for about one millisecond after an action potential the inward movement of sodium is prevented in that region of the neurone. The membrane does not undergo depolarisation, a threshold value is not reached and no further action potential generated.

IMPORTANCE OF THE REFRACTORY PERIOD

(i) It ensures that an impulse can only flow in one direction along an axon since the portion of the axon behind the impulse can not be depolarized again.

(iii) It limits the frequency with which successive impulses can pass along axons. This together with transmission speeds will determine the pattern of muscular responses and that of other effectors.

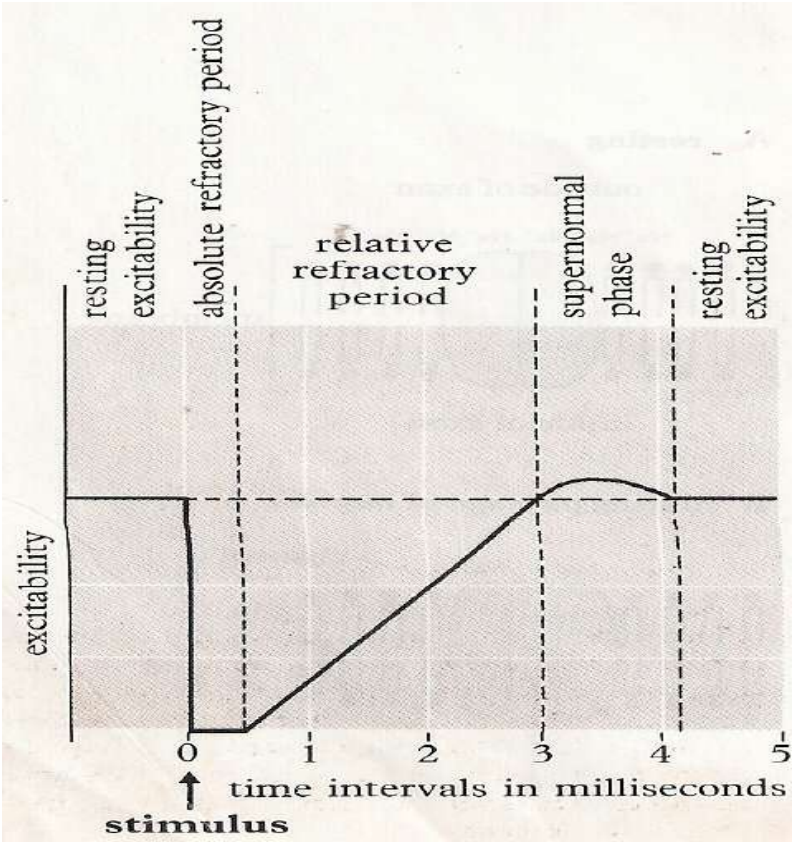
Refractory period is further divided into two,

- Absolute refractory period.
- Relative refractory period.

Absolute refractory period is the brief period immediately after an action potential or passage of an impulse when the axon can not completely generate new action potential or transmit new impulses however intense the stimulus.

Relative refractory period is a brief period immediately after an action potential was generated, during which new action potential or impulses can only be generated if the stimulus is more intense (stronger) than normal threshold value.
It lasts for about 5 milliseconds.

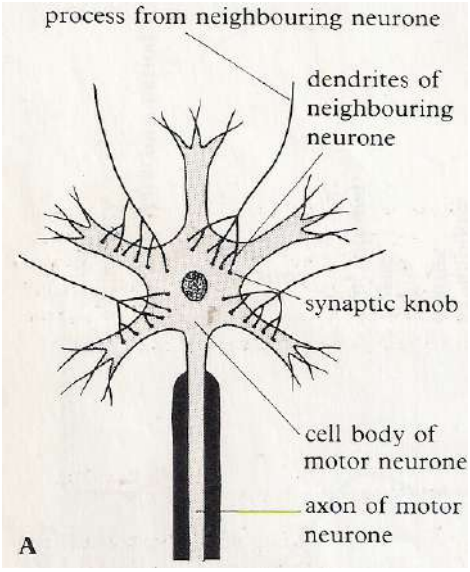
A GRAPH SHOWING RELATIVE REFRACTORY PERIOD



THE SYNAPSE

A synapse is the precise point where one nerve cell connects with another. In other words. It is a junction between two neurons; this junction is not air tight but leaves a gap in between the two neurons known as the synaptic cleft. The axon terminal of a neuron ends in a small bulb-like structures known as synaptic knobs.

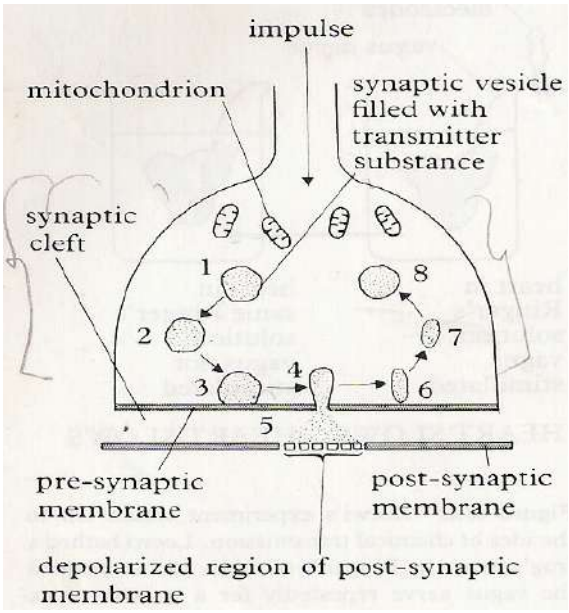
DIAGRAM SHOWING NERVE CELLS CONNECTING WITH A SYNAPSE.



Synaptic connections are of two types;

- Nerve to nerve synapses.
- Nerve to muscle (Neuro-muscular) synapse/junction

STRUCTURE OF NERVE-NERVE SYNAPSE



FUNCTIONS OF PARTS OF THE SYNAPSE

(i) **Synaptic vesicles**; store neuro-transmitter substance (acetylcholine).
(ii) **Neuro-transmitter substance**; conduct impulses across the synapse.
(iii) **Mitochondria**; provide energy required for the ionic movements at the synaptic membranes (the sodium –pump mechanism).
(iv) **Synaptic cleft**; contains a high concentration of calcium ions which are diffusing into the synaptic knob, excite movement of synaptic vesicles to move and fuse with pre-synaptic membrane and release neuro-transmitter substance into the synaptic cleft.
(v) **Post –synaptic membrane**; has receptor sites for the neuro transmitter substance. Has enzyme which hydrolyses the neuro-transmitter substance. Determines whether synapse is excitory or inhibitory.
(vi) **Pre-synaptic membrane** offer sites for the fusion of synaptic vesicles.

HOW ASYNAPSE FUNCTIONS (TRANSMISSION OF NERVE IMPULSES ACROSS A NEURONE TO NEURONE JUNCTION).

The transmission of an impulse across a synapse is by chemical means.
When an impulse arrives at the synaptic knob, it causes the presynaptic membrane to become more permeable to calcium ions. Calcium ions diffuse into the synaptic knob from the synaptic cleft. These calcium ions cause the synaptic vesicles to move towards the pre-synapitc membrane. The vesicles attach themselves to the membrane and discharge the transmitter substance into the synaptic cleft (exocytosis). The transmitter substances then diffuse a cross the synaptic cleft and attach to its specific receptor sites on the post synaptic membrane.

In excitatory synapse, the attachment of transmitter substance on specific receptors, causes the specific receptors to change their configuration and their protein channels are openned up, allowing sodium ions to diffuse into post synaptic neurone, causing depolarization of the post synaptic membrane resulting into excitatory post synaptic potential (EPSP). This builds up until a threshold is reached and action potentials are fired into the post synaptic neurone.

In inhibitory synapses, the change in the configuration of the specific receptors following the attachment of transmitter substance into them, results in opening up of only those protein channels which are specific to chloride and potassium ions. Potassium ions diffuse from the post synaptic knob into the synaptic cleft, while chloride ions diffuse from the synaptic cleft into the post synaptic knob. This makes the post synaptic membrane more polarized, the resulting polarization is known as the inhibitory post synaptic potential (IPSP), which makes it more

difficult for the threshold needed to generate action potential in it to be reached and thus no impulses pass cross. Therefore wether a synapse is excitory or inhibitory depends on the nature of the receptor sites on the post-synaptic membrane rather than the nature of the transmitter substances. E.g. the transmitter substance acetylcholine has inhibitory effect on heart muscle and gut muscle but an excitory effect on the skeletal muscles.

Note: After it has performed its function, the neuro-transmitter is hydrolysed by enzymes located on the post synaptic membrane.

THE NEURO-MUSCULAR JUNCTION (NERVE –MUSCLE SYNAPSE)

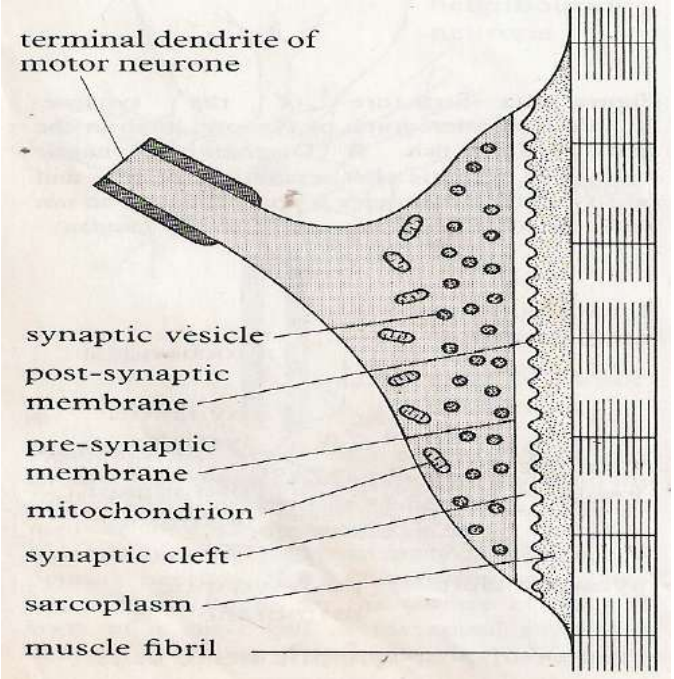
This is a junction (synapse) found between a motor neurone and skeletal muscle fibres. Each muscle fibre has a specialized region, the motor end plate, this is where the axon of the motor neurone divides and forms fine branches ending in synaptic knobs. The branches lack a myelinated sheath. The Neuro-muscular junction includes both motor end plate and synaptic knob., the membrane of the muscle is the muscle fibre (sarcolema).

TRANSMISSION ACROSS THE NEURO MUSCULAR JUNCTION

This is a special kind of synapse and the transmission at the nerve muscle junction takes place in the same way as at the synapse-synapse junction.

When an impulse arrives at the nerve-muscle junction, the pre-synaptic membrane become permeable to calcium ions. Calcium ions diffuse into the pre-synaptic knob, this causes the synaptic vesicles to move and attach on the pre-synaptic membrane and it releases the neuro-transmitter substance known as acetylcholine into the synaptic cleft. The acetylcholine then attaches on specific receptor sites on post synaptic membrane which are caused to change their configuration resulting into their protein channels to open. This allows sodium ions to diffuse into the sarcoplasm, causing depolarization of the muscles end plate. End plate potential (EPP) results, which builds up to reach threshold and an action potential is fired.

DIAGRAM OF NEURO-MUSCULAR JUNCTON



There are three possible ways of removing neurotransmitters from synaptic from the synaptic clefts,

- Reabsorbtion by the presynaptic membrane.
- Diffusion out of the cleft.
- Hydrolysis by the enzymes.

PROPERTIE / ROLES OF A SYNAPSE.

1. SUMMATION.

This is where excitatory post synaptic potentials (EPSP) add up together or build up as more transmitter substances are released until depolarisation occurs to exceed threshold value and so generate an action potential in the post in the post-synaptic neurone where a single EPSP is un able to cause sufficient depolarisation to reach threshold value to generate action potential. There are two types of summation.

(i) Spatial summation.
(ii) Temporal summation.

Spatial summation.

This is where neurotransmitter substances released simultaneously from two or more different synaptic knobs of neurones, cause two or several Excitatory post synaptic potential that add up together to sufficient levels to produce sufficient depolarisation on the same post synaptic membrane of a neurone that enable a threshold value to be reached and action potential generated.

Temporal summation

This is where the same synaptic knob of a neurone is strongly and repeatedly stimulated to release sufficient transmitter substances that generate individual Excitatory post synaptic potentials (EPSP) that add up together to produce sufficient depolarisation to reach threshold value and cause action potential on the post synaptic membrane of a neurone.

2. FACILITATION.

This is where Excitatory post synaptic potential (EPSP) creates an effect and increases sensitivity and responsivess of the post synaptic membrane, giving chance to the subsequent weaker EPSP to cause depolarisation that is sufficient to reach threshold and causes action potential, where the first single EPSP was unable to produce sufficient depolarisation to reach the threshold required to cause an action potential.

3. INHIBITION.

Is where arrival of impulse at certain synaptic knobs makes the inside of the post-synaptic nerve cells more negative and the out side more positive than usual preventing passage of an impulse across. The negative charge which builds up is called the inhibitory post-synaptic potential (IPSP); making it difficult for the threshold to be reached to generate action potential. This is caused b the activities of some neurotransmitters or drugs.

4. ADAPTATION AND FATIQUE..

This is where the amount of transmitter substance released by a synapse slowly reduces in response to constant stimulation for a long time until the supply of the transmitter is exhausted and the synapse is described as fatigued or accommodated or adapted. This occurs because the supply of transmitter substance gets exhausted and its resynthesis can not keep pace with the rate at which impulses reach the synapse.

FUNCTIONS OF SYNAPSES.

(i) Transmit information between neurones.

(ii) It ensures that nerve impulses (action potential) pass only in one direction. As the transmitter substances can only be released from one side of a synapse that is from presynaptic knob and the receptor molecules are only on the postsynaptic membrane. This gives precision to the nervous system, allowing nerve impulses to reach their destinations.

(iii) **Amplification**. Release of transmitter substances due to each nerve impulses that can at times add up together to produce response where a single nerve impulse from a weak stimulus could not, increases sensitivity of the system.

(iv) **Adaptations and fatique**. This is where the amount of the transmitter substance released by a synapse gradually declines or falls in response to constant stimulation until the supply of transmitter substance is exhausted. The synapse is said to be fatiqued, no impulses are transmitted after until recovery. This prevents damage to effectors through over stimulation.

(v) **Integration, convergence and spatial summation**. A postsynaptic neurone may receive impulses from several excitatory and inhibitory presynaptic neurones. This is known as **convergence.** The postsynaptic neurone can add together these stimuli from all the presynaptic neurone to reach threshold that is sufficient to causes depolarisation and action potential at the post synaptic membrane. This is known as **spatial summation**. Spatial summation enables the synapse to act as centre for integration of stimuli from a variety of sources and the production of a coordinated response.

(vi) **Facilitation.** This is where the first stimulus that reaches the synapse presynaptic neurone may not cause depolarisation of the post synaptic membrane of the neurone but leaves an effect or leaves the postsynaptic neurone more responsive to the next stimulus.

(vii) They act as filters by filtering off weak or low frequency impulses and allow only the perception of strong stimuli. This is important if the nervous system is to relay useful information about the organism and its environment.

(viii) Synapses in the brain play an important part in **learning and memory.** Modification in

the pattern of synaptic transmission provides means by which information from different sense organs are associated and stored within the brain.

PROBLEMS RESULTING FROM A SYNAPSE.

(i) They slow down the rate of transmission because the process of release, diffusion and effect of the transmitter substance takes longer time than conduction of action potential along the axon. So, the passage of impulse from one neurone to the next is delayed.

(ii) They are highly susceptible to drugs and fatigue which may inhibit transmission.

NERVE-TRANSMITER SUBSTANCES.

In the mammalian nervous system, there are several neuro-transmitter substances. These include;

a) Acetylcholine.

This is an ammonium base (a nitrogenous organic base). It is formed from a combination of an acetyl CoA and choline in the presence of the enzyme choline-acetyl transferase. It is the most widespread transmitter substance. Neurones which produce acetyl choline are known as cholinergic nerves and these include all the parasympathetic nerves. In neuromuscular junctions and in some areas of the central nervous system (CNS), autonomic nervous system as well as membranes, normally hydrolysed by the enzyme acetyl cholinesterase present in the synaptic cleft to choline and Ethanoic acid. These two compounds are then reabsorbed by the pre-synaptic membrane and stored in the synaptic vesicles ready for use again

b.Noradrenalin.

This is found in the autonomic nervous system. It is a monoamine hormone secreted by the adrenal gland and a neurotransmitter in the sympathetic nervous system which prepares the body for action. It also exists in the brain, increasing alertness and helping to maintain the state of arousal. It enhances response to new stimuli.

Nerves which produce noradrenalin are known as **adrenergic nerves.** It works the same way as acetylcholine and is also destroyed by oxidation in the presence of an enzyme, mono-amine oxidase, it is then after absorbed into the pre-synaptic knob. It is inhibited by drugs like mescaline and lysergic acid diethyl amide (LSD)

***c)Some* other minor transmitter substances** include,

• Amino acids.

- The major excitatory neuro-transmitter in the brain is the amino acid glutamate (Glutamic acid).

- Glycine is inhibitory causing chloride channels to open in postsynaptic membrane and resulting in hyperpolarisation, preventing transmission of impulses. Glycine is important in the spinal cord where it helps control skeletal movements by making muscles relax (preventing their stimulation). Another transmitter strychnine blocks effects of glycine and allows muscle contraction.

- GABA is the most common neurotransmitter in the brain, it is also inhibitory and helps control muscle movements

• Monoamines.

- Noradrenaline. Amphetamine is a drug that increase the level of noradrenaline in the brain
- Monoamine oxidase inhibitor treats depression by prolonging the effects of noradrenaline. It also promotes activities of all monoamines.
- Dopamine. Is concerned with voluntary control of complex muscular movements. Its deficiency results into Parkinson's disease. Dopamine is also involved in emotional responses in the cerebral cortex and has been linked with schizophrenia. It can also stimulate the "pleasure" centre of the hypothalamus. Amphetamines trigger the release of dopamine.
- Serotonin. Is associated with control of moods, depression, elation and mania. It is also involved in the onset of sleep, sensory perception and temperature regulation in the hypothalamus.

THE EFFECTS OF DRUGS AND POISONS

Any chemical that destroys acetylcholine, inhibits its formation or prevents its action, will stop synaptic transmission. They fall into two categories according to the way in which they affect transmission,

Excitatory drugs.

These increase the process of synaptic transmission in the following ways,

(i) By acting on the receptor molecules of the postsynaptic neurone in exactly the same way as the natural transmitter does that is they mimic the transmitter.

(ii) By stimulating the release of more of the natural transmitter.

(iii) By slowing down or even preventing the normal breakdown of the transmitter thus leaving it to continue to stimulate the post synaptic neurone. Examples.

- **Nicotine.**

They stimulate nicotinic receptors found in sympathetic and parasympathetic nervous system. Nicotine causes vasoconstrictions in guts and limbs, slowing heart rate, causes muscular contractions as they mimic acetylcholine, stimulate release of dopamine which is associated with stimulation of reward and pleasure pathways.

- **Poisonous nerve gases**; this also enhance synaptic transmission and upon nerve gas poisoning, the individual gets convulsive muscular contractions.

- **Caffeine.**

Is a stimulant but relatively weak, it causes release of dopamine in brain and therefore stimulates reward pathways. It also accelerates cell metabolism leading to the release of more natural transmitters like dopamine.

- **Amphetamine** which mimic the action of noradrenaline by causing its release from nerve endings.

Inhibitory drugs.

These decrease the process of synaptic transmission in one of the following ways,

(i) By preventing release of the synaptic transmitter.

(ii) By blocking the action of the transmitter at the receptor molecules on the postsynaptic neurone. Examples,

- **Atropine.**

It stops acetylcholine from depolarizing the post-synaptic membrane and cause synaptic block.

- **Curare**. This is a poison, which prevents acetylcholine from depolarizing the post-synaptic membrane especially on nerve-muscle junctions.

- **Eserine**: it prevents the enzyme acetyl cholinesterase from destroying acetylcholine and so enhances and prolongs the effects of acetylcholine.

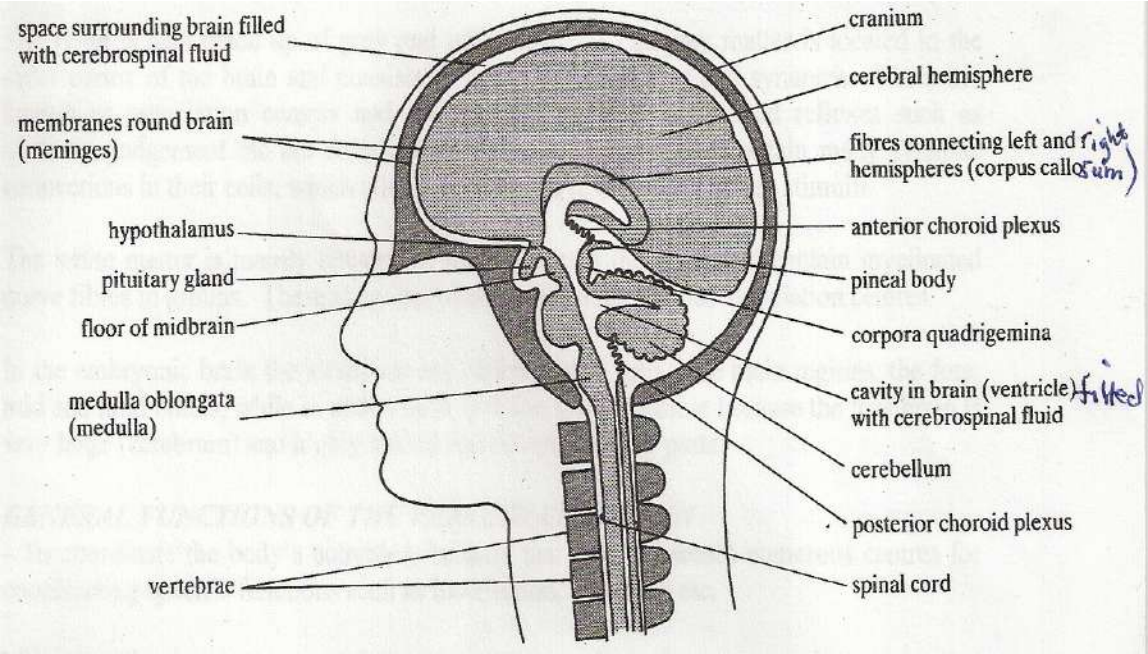
- **Propanol** is one of a group of substances known as Beta-blockers.

- **LSD (Lysergic acid diethyl-amide)** and **mescaline** are drugs that inhibit release and effects of noradrenaline. They have similar effects to the serotonin and are drugs known to cause hallucinations in humans.

THE CENTRAL NERVOUS SYSTEM (CNS)

The central nervous system consists of the **brain** and the **spinal cord.**

VERTICAL STRUCTURE OF THE HUMAN BRAIN



The entire central nervous system is enveloped by a system of membranes called meninges. The inner most membrane, called the pia matter, is a very delicate layer of connective tissue and capillaries. The outermost membrane is the dura matter. Is tougher. These two membranes are separated by a narrow space called the arachnoid layer, containing a net work of delicate fibres filled with cerebrospinal fluid, the arachnoid layer cushions and protects the CNS.

The cerebrospinal fluid is produced by vascular membranes which are anterior and posterior choroids plexuses. They form the roof of tween-brain and hind brain respectively. The roof tissues here are so thin that the pia matter lies very close to the ventricles. The pial blood vessels are well developed in these areas and cerebrospinal fluid is formed from them by mainly the process of utra-filtration. The whole of CNS and its meninges are enclosed within the cranium protecting the brain and the cranium is pierced by holes called foramina, through which passes the peripheral nerves and blood vessels. Blood vessels supply the CNS with oxygen and nutrients.

The brain is also made up of grey and white matter. The grey matter is located in the inner cortex of the brain and consists of group of cell bodies and synapses. These are known as association centres and are the areas where conditioned reflexes such as memory, judgement etc are coordinated. This is because they contain many synaptic connections in their cells, which allows a variety of responses to given stimuli.

The white matter is mainly situated in the interior of the brain and contains myelinated nerve fibres in groups. These carry impulses between the various association centres.

In the embryonic brain the structures are differentiated into three main regions, the fore, mid and hind brains, while in adults such division is not possible because the fore brain is very large (cerebrum) and highly folded and covers up other parts.

GENERAL FUNCTIONS OF THE VERTEBRATES BRAIN

(i) To coordinate the body's activities, because the brain possesses numerous centres for coordinating specific functions such as locomotion, breathing etc.

(ii) Brain receives impulses from sensory receptors and from the whole body via the spinal cord and the 12 cranial nerves.

(iii) The association centres in the brain correlates the sensory impulses with past experiences within the stored memory that is it rehearses the possible consequences of different responses. It also intergrates (interpretes) the impulses from the sense organs. This is the integration of stimuli.

(iv) It initiates the activities of the effectors by sending impulses to the effector organs such as muscles and glands.

(v) The brain stores information and builds up the memory.

(vi) It is important in the process of learning. It enables individuals to imagine, create, plan, calculate, predict. So it is seat for personality and emotions.

FUNCTIONS OF THE MAIN PARTS OF THE BRAIN IN MAMMALS

(i) ***CEREBRUM***: Is the most superficial layer of the cerebral hemisphere, it is also called cerebral cortex its function include;-

- Controls the body's voluntary activities such as learning, walking, reasoning, personality and memory (center of intelligence and higher activities of the brain.
- It controls the two senses of smell and sight.
- Forms the bulk of human brain.

- Consists of nerve cells and myelinated nerve fibres.
- Coordinate the body's voluntary and involuntary activities.
- The bulk of the front part of the cerebral hemispheres is concerned with personality, thought (Imagination) and intelligence.
- Interior part controls emotions, behaviour and memory.
- The base of the cerebrum concerned with muscular contractions connects to other parts of the brain.

Note: An animal whose cerebral cortex is removed is known as decorticated animal.

(ii) ***CORPUS CALLOSUM***; Connects the left and right cerebral hemispheres allowing the two sides of the cerebrum to communicate. Note. Cerebrum is divided into left and right halves known as cerebral hemispheres. These are joined by the corpus callosum. The outer and largest part of cerebral hemisphere is called cerebral cortex.

(iii) ***THE THALAMUS***: It forms an important relay centres, connecting other regions of the brain. It functions to process all sensory impulses before relaying them to the appropriate part of the brain. (i.e. cerebral hemispheres). It is also responsible for perception of pain and pleasure.

(iv) ***THE HYPOTHALAMUS***; this is the main controlling regions for the autonomic nervous system. It has two centres, one for the sympathetic nervous system and the other for the parasympathetic nervous system.

- The hypothalamus contains centre controlling such functions as sleep and wakefulness, feeding and drinking, speech, body temperature and Osmo-regulation, it also controls hunger, thirst, aggression, behaviour and reproductive behaviour.

- Regulates the activities of the pituitary gland through production of release factor like.

(i) Thyrotrophin releasing hormone (TRH), stimulates the anterior pituitary to release thyroid stimulating hormone (TSH)

(vi) Luteinising hormone releasing hormone (LHRH)/Gonadotrophin releasing hormones which stimulates the anterior pituitary to secrete the lutinizing hormone (LH) and FSH.

(vii) Growth hormone release-inhibiting hormone (GHRIH)/ Somatostatin which inhibits secretion of the growth hormones by the pituitary and suppresses the secretion of the thyroid stimulating hormone.

(viii) Adrenocorticotrophin releasing factor stimulates the anterior of the pituitary gland to secrete Adrenocorticortrophic hormone.

(ix) Growth hormone releasing factor stimulates anterior pituitary gland to secrete growth hormone.

(x) Production of oxytocin, and antidiuretic hormone.(ADH)

CORPORA QUADRIGEMINA

Found in the mid brain, it controls eye movements and certain auditory reflexes.

On the floor of the mid-brain is a centre called red-nucleus. It plays an important part in controlling movement and posture of limbs and it also inhibits excessive contraction of the postural muscles. The destruction of the red nucleus results into a condition known as decerebrate rigidity. In which the extensor muscle of the limbs go into a state of tonic contraction, the limbs are held out rigidly from the body.

MEDULLA OBLONGATA; it contains reflex centres for control of blood circulation (i.e. heart rate, blood pressure) and breathing. It also controls swallowing, salivation, vomiting, coughing and sneezing.

PONE; contains centres which relay impulses to the cerebellum.

CEREBELLUM;

- It is responsible for maintenance of posture and equilibrium and the fine adjustment of movement. Receives information from the muscles and take care about posture and balance.

Coordinate smooth movements.

Note: parts of forebrain include; cerebrum, corpus callosum, the thalamus, and the hypothalamus,

- The mid brain include, corporaquadrigemina

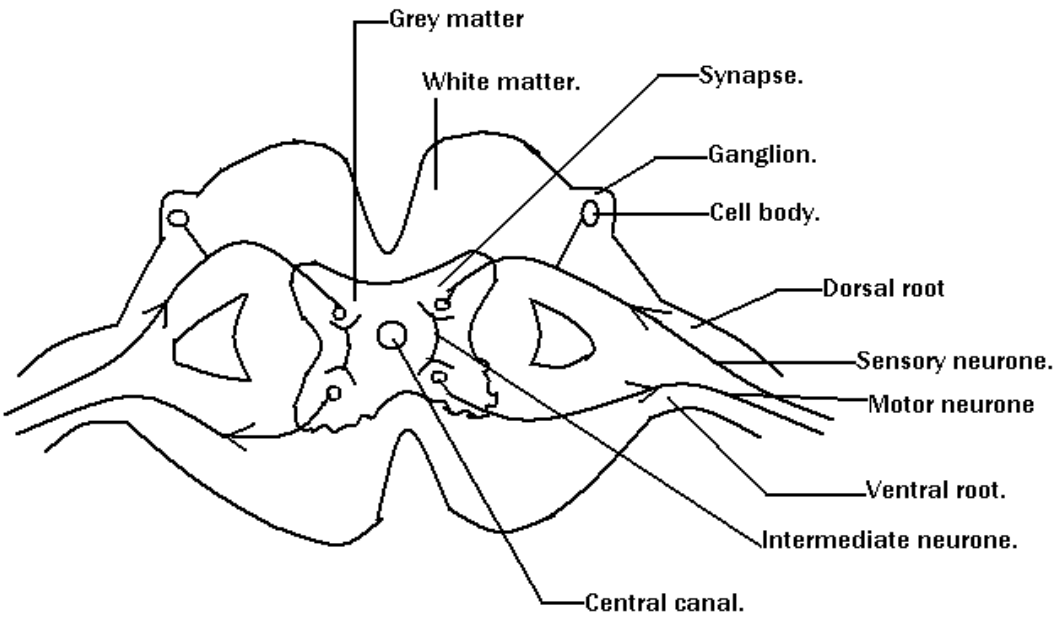
- Hind brain include, medulla oblongata, pone and cerebellum.

THE SPINAL CORD.

It is a cylindrical structure with a tiny central canal. It runs dorsally along the length of the body. The central canal is filled with cerebrospinal fluid. The canal is continuous with the ventricles of the brain. The inner and central part of the cord is the grey matter; it contains cell bodies, synapses and non-myelinated relay neurones. The outer part of the cord is the white matter. It contains myelinated fibres running longitudinally. Spinal cord is enclosed and protected by the vertebrae. Between two vertebrae is a pair of spinal nerves arises.

Each spinal nerve joins the spinal cord at two roots (points). The sensory fibres enter through the dorsal root. Motor fibres leave through the ventral root.

STRUCTURE OF THE SPINAL CORD



Note: numerous reflex arcs do exist corresponding to the series of spinal nerves. The reflex

arcs, are inter connected by longitudinal neurones located in the white matter of the cord. The longitudinal tracts also connect the spinal cord to the higher centres of the brain.

FUNCTIONS OF SPINAL CORD

(i)To relay impulses in and out of at any particular point along the cord..

(ii) It connects the peripheral nervous system to the brain by way of interneurones and transmits the appropriate action potential to the effector via motor nerves.

(iii) It is a coordinating centre for simple reflexes like knee Jerk and withdrawal reflex. Center for conditioned reflex. Is the type of response which is modified by past experience.

(iv) Receives impulses from sense organs and relay them to the brain, they also receive impulses from the brain and them to effector organs.

THE REFLEX ACTION

Is a rapid, simple, automatic response resulting from nervous impulses initiated by a stimulus. A reflex action involves the central nervous system that consists of the brain and spinal cord, involves sensory and motor neurones and it controls involuntary activities. Examples; opening and closing of the pupil coordinated by the brain, knee jerk reflex coordinated by the spinal cord.

THE VERTEBRATE REFLEX ARC

Reflex arc represents the series of units through which impulses have to pass in order to bring about a reflex action. Reflex arc consists of receptors, whose stimulations results in impulses being generated in sensory (afferent) neurones located in the peripheral nerves. These impulses enter the spinal cord (CNS) Via the dorsal roots. The sensory neurones make synaptic connection with the intermediate (internuncial) neurones within the grey matter. These in turn connect with motor (efferent) neurones in the ventral roots and eventually reach the effectors usually glands or muscles, which are caused to respond accordingly.

What happens in the spinal reflex response is shown during the withdrawal of ones' hand from a hot object. Stimulation of pain receptors in the skin fires off impulses in sensory neurones contained in the nerve supplying the hand. These impulses enter the spinal cord via dorsal roots, traverse the intermediate neurones, the grey matter and leaves spinal cord via the

appropriate motor neurones in the ventral roots. Eventually they reach the flexor muscles in the arm which contract accordingly and the arm is lifted.

Note: The structure of the spinal cord provides a good example of a vertebrate reflex arc. Most reflexes are involuntary.

The simplest form of response in the nervous system is the **reflex action**. A more complex reflex involves the sensory neurones in the spinal cord with a secondary sensory neurone which passes to the brain. The brain identifies this sensory information and can store it for further use or send a motor nerve impulse via a motor neurone to cause response in an effector.

Conditioned reflexes. These are forms of reflex actions where the type of response is modified by the past experience. These reflexes are coordinated by the brain. **Learning** forms the basis of all conditioned reflexes, such as in toilet training, salivation on the sight and smell of food and awareness of danger.

Another reflex system exists for the control of involuntary activities. This is the **Autonomic nervous system**. Most of the activities of the autonomic nervous system is controlled within the spinal cord or brain by reflexes known as **visceral reflexes**. And does not involve the conscious control of higher centres of the brain.

IMPORTANCE OF REFLEXES TO ORGANISMS

- Are important in making involuntary responses to various changes in both the internal and external environment in this way homeostatic control of body posture is maintained.
- Control of breathing, blood pressure and their systems are made effective through a series of reflex responses. This provides a greater survival value to an organism.
- Constriction or dilation of the Iris diaphragm of the eye in response to changes in light intensity is another example of reflex response which enables the organism to have a clear view of vision of its environment.
- Brain reflexes are called conditioned reflexes which play a role in the process of learning, memory and perception.

THE PERIPHERAL NERVOUS SYSTEM

Consists of all the sensory nerves of the body entering the CNS and motor neurones leaving the central nervous system. There are two types of peripheral nerves.

- Spinal nerves.
- Cranial nerves.

Spinal nerves arise from the spinal cord. They carry both sensory and motor neurones and are described as mixed nerves.

Cranial nerves arise from the brain and supply effectors and receptors of the head except the vagus nerve that supply parts of the body other than the head. There are 12 pairs of cranial nerves in mammals numbered I – IX. Examples of cranial nerves include

• Optic nerves (*cranial nerve II*).
This is cranial nerve running from the retina to the brain.

• Oculomtor nerve (*cranial nerve III*)
This is a motor nerve running from the brain to the four eye muscles and controls eye movements.

• Vagus nerve (*cranial nerve X*)
This is a mixed nerve. It runs between the brain and the heart, gut and part of the respirator tract and decreases heart rate, it stimulates peristalsis and is concerned with speech and swallowing. It includes an important motor nerve of the autonomic nervous system supplying the heart, bronchi and gut.

THE AUTONOMIC NERVOUS SYSTEM (ANS*)*

It is part of the peripheral nervous system. It is concerned with controlling the body's involuntary activities such as the beating of the heart, movements of the gut, and secretion of sweat. It consists of neurones that convey impulses from Central nervous system (CNS) to smooth muscles, cardiac muscle and glands which are not under conscious control. It controls **involuntary actions** and internal environment. Nerve fibres of the Autonomic nervous system run from CNS to the various internal organs like the heart, lungs, intestines and glands. The Autonomic nervous system is composed of two types of neurone a preganglionic neurone which leaves the central nervous system in the ventral root before synapsing with several

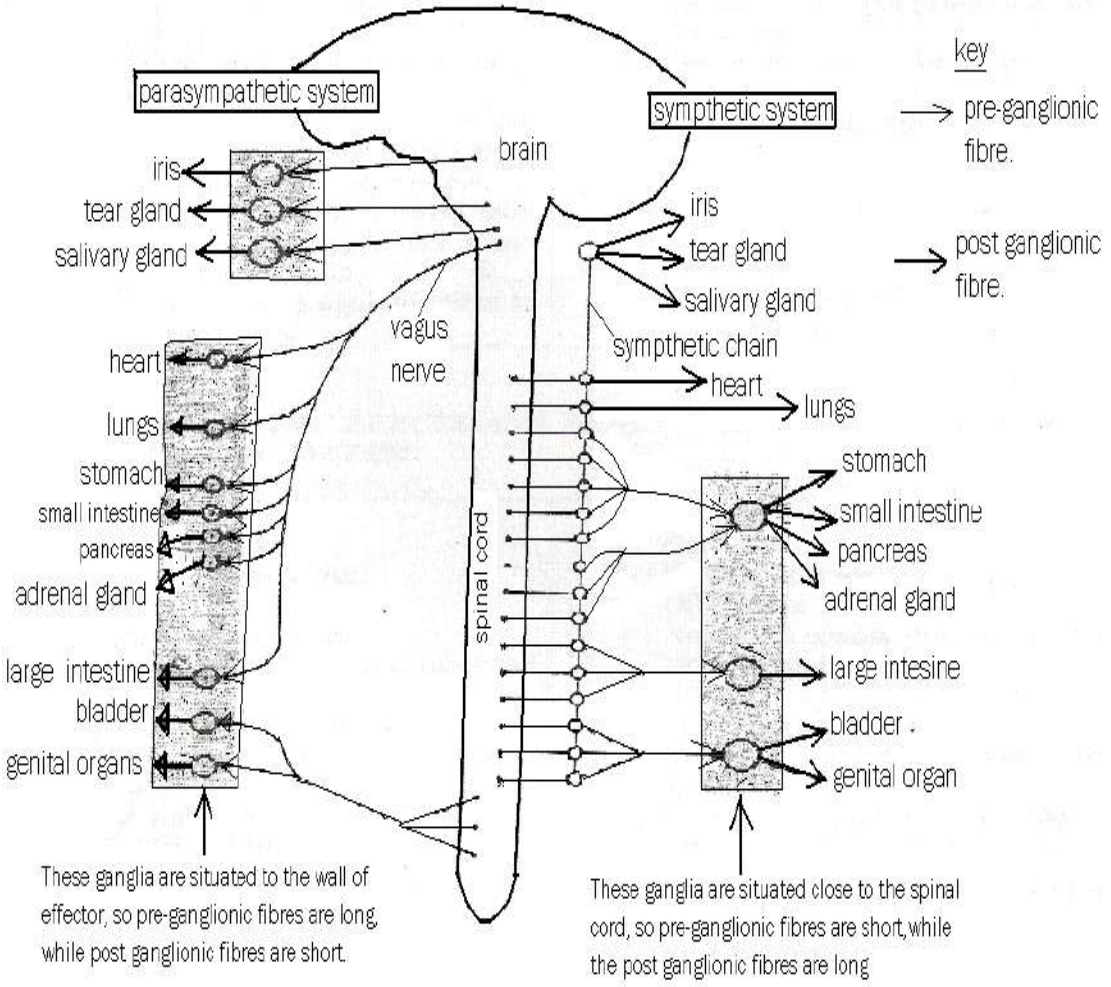
postganglionic neurones leading to effectors. **Ganglion** is a mass of nervous tissue containing many cell bodies and synapses enclosed in a connective tissue sheath.

The autonomic nervous system is divided into two parts;

i. Sympathetic systems.
ii. Parasympathetic systems.

The sympathetic and parasympathetic nervous are antagonistic effects on organs they supply and enables the body to make rapid and precise adjustments of involuntary activities in order to maintain a steady state. The structures of the two systems differ in the organization of their neurones.

DIAGRAM SHOWING SUMMARY OF THE MAIN FEEATURES OF MAMMALIAN AUTONOMIC NERVUS SYSTEM.



COMPARISON BETWEEN THE STRUCTURE OF THE PARASYMPATHETIC AND SYMPATHETIC NERVOUS SYSTEM

SIMILARITIES

- Both consist of pre-ganglionic and post ganglion nerve fibres.
- Both consist of ganglia.
- In both nerves originate from the central nervous system (brain or spinal cord)
- In both pre-ganglionic fibres secrete acetylcholine.
- Both systems mainly consists of motor neurones.

DIFFERENCES

Sympathetic nervous system.	*Parasympathetic nervous system*

(i) Nerves emerge from mainly spinal cord, (consists of only spinal nerves) (ii) Ganglion close to spinal cord. (iii) Pre-ganglionic fibre shorter, while post ganglionic fibre long. (iv) Pre-ganglionic fibre cover wide area. (v) Effects diffuse. (vi) Releases noradrenaline at the effector. (vii) Excites homeostatic effect. (viii) Dominant during anger, stress and controls reactions to stress. (ix) Increases metabolism, sugar level, heart rate, sensory awareness. (x) Sympathetic chains present (Ganglia form a series of inter connected chains)	(i) Consists of mainly the cranial Nerves especially vagus nerves, though spinal nerves are too present. (ii) Ganglion close to effectors. (iii) Pre-ganglionic fibre is longer, while post ganglionic nerve fibre is shorter. (iv) Pre-ganglionic fibre cover small area. (v) Effects are localised. (vi) Releases acetylcholine at the effectors. (vii) Inhibitory homeostatic effect. (viii) Dominant during rest and controls routine body activities. (ix) Decreases metabolism, levels sugar, heart rate, sensory awareness. (x) No sympathetic chain (Ganglia do not form a series of interconnected chain)

DIFFERNECES IN THE EFECTS AND FUNCTIONS OF PARASYMPATHETIC AND SYMPATHETIC SYSTEM.

PARASYMPATHETIC	*SYMPATHETIC SYSTEM*
- Slows heart rate. - Dilates arterioles.	- Accelerates heart rate. - Constricts arterioles.

- Constricts bronchioles. - Constricts iris. - Stimulates tear gland. - Causes flow of saliva and other gut secretions. - Speeds up gut movements. - Relaxes bladder and anal sphincters. - Causes contraction of bladder. - No comparable effect. - No comparable effect.	- Dilates bronchioles. - Dilates Iris - No known comparable effect. - No comparable effect. - Slows gut movement. - Contracts bladder and anal sphincter. - Causes relaxation of the bladder. - Contracts erector pilii muscles. - Increases sweat secretion.

HORMONAL COMMUNICATION (ENDOCRINE SYSTEM)

The endocrine system is made of a number of glands called endocrine glands. A gland is a structure which secretes a specific chemical substances. There are two types,

(i) Exocrine gland.

Is a gland which secretes its product into a duct. For example sweat gland, pancreas etc.

(ii) Endocrine gland.

Is a gland that secretes chemical substances called hormones. Endocrine gland has the following characteristics,

- It secretes chemicals called hormones.
- It has no duct (a ductless gland)
- It has a rich supply of blood with a relatively large number of blood vessels.

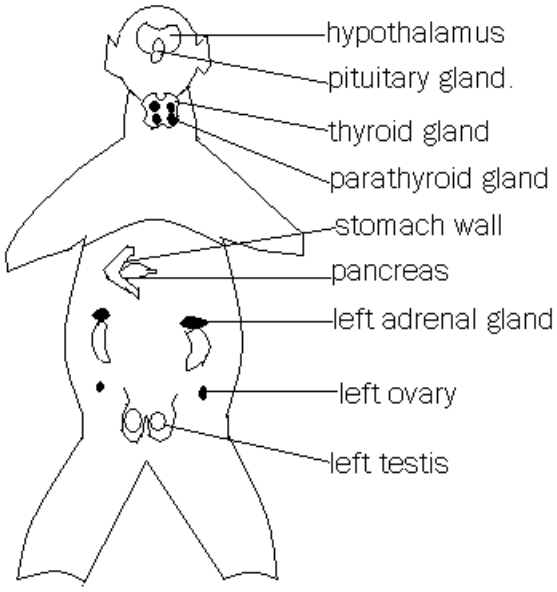
Some glands can possess both exocrine and endocrine functions for example pancreas.

A hormone is a chemical messenger or a substance that causes a response in specific cells or organs called target cells or organs. Hormones have the following properties,

- It is carried in blood.
- It has its effect on the site different from the site where they are secreted that is they exert their effects on target cells at a site different from where they are secreted.

- They are specific in their actions. This is because they have active sites that fit precisely into specific receptor molecules on the target cells.
- It is small soluble organic molecule.
- It works best in minute or low concentrations.

DIAGRAM SHOWING THE LOCATION OF THE MAJOR ENDOCRINE GLANDS IN MAN.



GENERAL FUNCTIONS OF HORMONES (SIGNIFICANCE OF HORMONE ACTION)

i. Regulation of growth and development.
ii. Controls homeostasis e.g. in osmoregulation/thermo regulation etc.
iii. Regulation of metabolism e.g. digestion storage and utilization of food substances.
iv. Development of the skin coloration.
v. Enabling the body to withstand shock, tension, wounding etc and to recover from it.
vi. Together with the nervous system it provides for effective responses to all kinds of stimuli both internal and external.

MECHANISM OF HORMONE ACTION (HOW HORMONES WORK)

There are two mechanisms which describe how hormones work,

- Use of a second messenger mechanism/Peptide hormone mechanism.
- Steroid hormone mechanism.

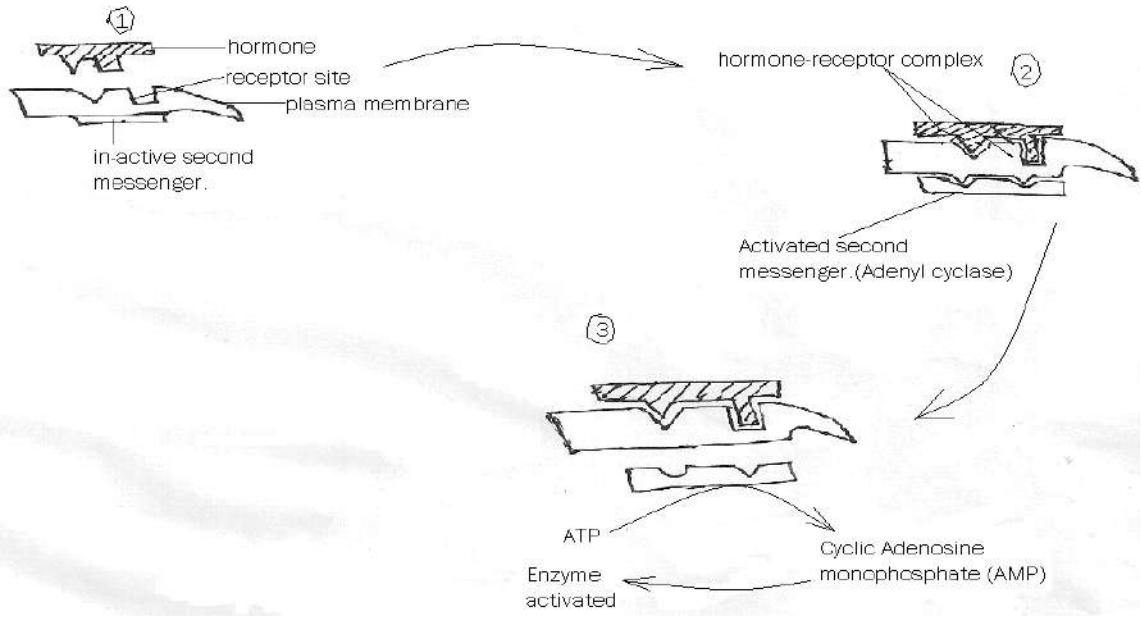
USE OF A SECOND MESSENGER (PEPTIDE) HORMONE MECHANISM.

Most of these hormones affect their target cells by **a signal-transduction mechanism**. The hormone binds onto receptor molecules in the cell membrane, a hormone–receptor complex is formed, which activates a G-protein (Guanine nucleotide-binding protein) in the cell membrane, the G-proteins further activate the enzyme adenyl cyclase which within the cytoplasm of the cell. This enzyme formed catalyses conversion of ATP to a second messenger cyclic Adenine Monophosphate (cAMP). Hormone is the first messenger. The Cyclic Adenine monophosphate activates an enzyme that that catalyses a reaction which ends with activation of another enzyme, resulting into a complex chain reaction known as **cascade effect** that amplifies the response to the first messenger the hormone that is few molecules of the hormones on the cell membrane triggers production of a very large response. In this reaction each enzyme molecule activates many molecules of its substrate into becoming the next enzymes in the chain catalyzing further reactions.

In the case of action of hormone Adrenaline, cyclic AMP activates the enzyme protein kinase which in turn activates a phosphorylase enzyme. Phosphorylase enzymes then catalyses break down of glycogen to glucose phosphate molecules. The later enters a glycolytic pathway and systematically broken down to release energy inform of ATP molecules.

Examples of hormones that work under peptide mechanism include Adrenaline, Glucagon, Parathyroid hormone, Noradrenaline and oxytocin. These hormones are small hydrophilic molecules.

DIAGRAM SHOWING THE SECOND MESSENGER MECHANISM



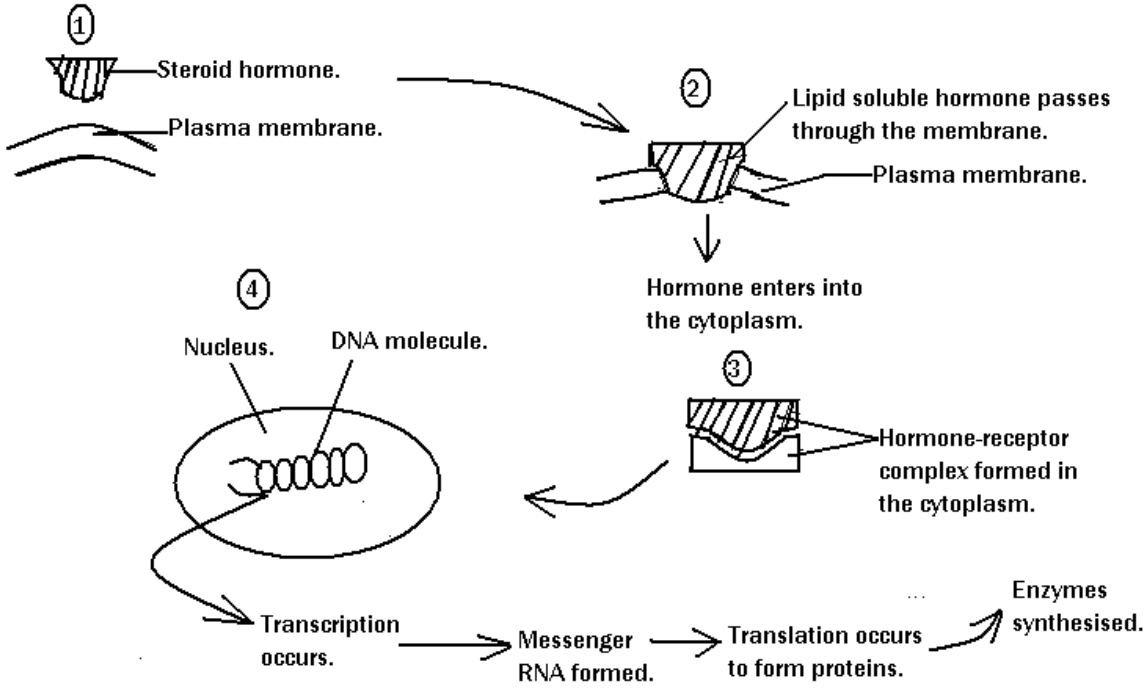
STEROID HORMONE MECHANISM.

The hormones are lipid soluble and enter the cell by passing through the cell membrane into the cytoplasm. While in the cytoplasm of the cell, the hormone combines with specific receptor proteins to form a hormone-receptor complex. The receptor protein moves the hormone into the nucleus. The hormone-receptor complex enters the nucleus, the hormone-receptor complex attaches on a DNA molecule of the target cell, triggering transcription of messenger RNA from specific gene. The target cell makes specific proteins such as enzymes and other hormones that produce a response.

Target cells are those cells whose response is caused by hormones.

Examples of hormones that work under the steroid hormone mechanism include Oestrogen, progesterone, testosterone, thyroxine, corticosteroids, etc.

STEROID HORMONE MECHANISM ACTION



Hormones exert their influence by acting on the molecular reactions in cells. They achieve this by one or more of the following cells processes.

i. Protein synthesis e.g. growth hormones.
ii. Enzyme activity e.g. Adrenaline.
iii. Exchange of materials across the cells membrane e.g. insulin.

FACTORS CAUSING RELEASE OF HORMONES

Hormones are released into the blood stream as a result of;

i. Stimulation of the endocrine gland directly by the nervous system e.g. the sympathetic nervous system causes secretion of adrenaline by the adrenal medulla.
ii. The levels of particular metabolites in the blood e.g. glucose levels trigger the release of insulin.
iii. Presence of other hormones called releasing hormones mostly produced in anterior pituitary e.g. TSH stimulates the release of thyroxin by the thyroid gland.
iv. Environmental changes such as high or low temperatures effects activities of the pituitary gland.
v. Animals' general mental states do affect the activity of the pituitary gland.

THE PITUITARY GLAND

It is also referred to as the master gland. This is because the larger number of hormones produced by pituitary gland directly stimulates other endocrines glands to secrete their hormones. The hormonal secretion by the pituitary glands intern depends upon the information received from the hypothalamus. The pituitary gland is further divided into two distinct portions and these include.

i. Anterior pituitary.
ii. The posterior pituitary.

The pituitary gland is closely influenced by the hypothalamus of the brain. In this ways, environmental changes, and the animals general mental state do influence hormonal activity. The hypothalamus communicates with the Pituitary by means of nerve impulses and chemical substances called impulses and chemical substances called releasing factors.

THE ANTERIOR PITUITARY

Is a region of glandular tissue which communicates with the hypothalamus by means of tiny blood vessels. It produces hormones which directly influences the activities of other endocrine glands. These hormones are called trophic hormones. The only non trophic hormone is growth hormone which affects body tissues in general

THE POSTERIOR PITUITARY.

This is an out growth of the hypothalamus and communicates with the hypothalamus by nerves. This portion of the pituitary gland stores two hormones.

- Anti-diuretic hormone (ADH) or vasopressin
- And oxytocin

Both hormones are secreted by the hypothalamus and stored in the posterior pituitary gland.

HORMONES SECRETED BY PITUTARY GLAND, THEIR FUNCTIONS AND EFFECT OF DEFICIENCY/EXESS.

HORMONES FROM THE ANTERIOR POTUITARY GLAND

These include the following;-

(i) Thyrotrophic hormones (thyroid stimulating hormone, (TSH)
- This causes thyroid glands to secrete thyroxine. Deficiency of TSH results into less thyroxine secreted and excess of TSH causes more thyroxine secreted. The secretion of TSH is controlled by levels of thyroxine in blood (-ve) feed back)
- Stimulates the growth of the thyroid gland

(ii) Adreno-corticotrophic hormone (ACTH)
- This causes the adrenal cortex to secrete adrenal cortical hormones.
- Regulates the growth of the adrenal cortex.

(iii) Human Growth hormone;
- Stimulates growth.
- Increases level of blood sugar.
- Promotes growth of skeleton and muscles.
- Controls protein synthesis and general body metabolism.

Deficiency of growth hormone causes dwarfism in young children and its excess causes gigantism in young children and acromegaly in adults.

(iv) Prolactin (luteotrophic hormone)
- Stimulates mammary glands to secrete milk in pregnant women.
- Maintains progesterone production from corpus luteum.
- Production is inhibited by high level of oestrogen and progesterone.

(v) Follicle stimulating hormone (FSH)
- Causes spermatogenesis in male.
- Causes development of Graafian follicle and secretion of oestrogen in female.
- Excess of FSH causes damage to seminiferous tubules.
- Its production is controlled by levels of oestrogen and progesterone (inhibition)

(vi) Leutenising hormone (LH) or interstitial cells stimulating hormone (ICSH)

- Causes secretion of androgens in males.
- Causes ovulation and developmental of corpus luteum in female.

Oestrogen stimulates production of LH and ICSH, while progesterone inhibits their production.

Note: Follicle stimulating hormone (FSH), Leutenising hormone (LH) or interstitial cells stimulating hormone are collectively referred to as Gonadotrophic hormones.

HORMONES FROM POSTERIOR LOBE OF PITUITARY GLAND

a. Anti-Diuretic hormone (***ADH***) or vasopressin.
    i. Causes reabsorption of water in kidney with accompanying rise in blood pressure.
    ii. Raises blood pressure by contracting arterioles.
    iii. Deficiency of ADH causes diuresis and low blood pressure. The secretion of ADH is controlled by solute concentration of blood.

b. Oxytocin (Pitocin)

- Causes contraction of uterus at parturition (birth).
- Stimulates secretion of milk by mammary glands.
- Deficiency of oxytocin causes delayed parturition, while the excess results into the premature parturition.
- Secretion of oxytocin is controlled by levels of oestrogen and progesterone (inhibits).

c. Melanophore-stimulating. (MSH)

- Causes expansion of melanin pigment in chromatophores (melanophores) in skin, particularly of amphibians etc.

THE HYPOTHALAMUS

It is found lying at the base of the brain; it is connected to numerous nerves. It performs many vital functions which include;-

(i) It regulates activities such as thirst, sleep temperature control, hunger feeding.
(ii) It monitors the level of hormones and other chemicals in the blood passing through it.
(iii) It controls the functioning of the anterior pituitary gland.
(iv) It produces anti-diuretic hormone and oxytocin which are stored in the posterior pituitary gland.

The hypothalamus is the link between the nervous and the endocrine system. By monitoring the

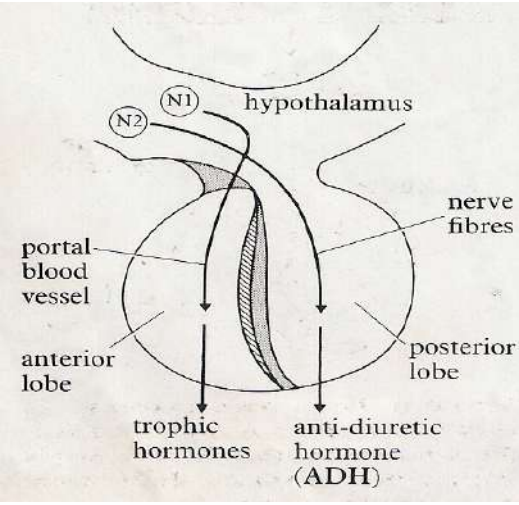
level of hormones in the blood, the hypothalamus is able to exercise homeostatic controls of them. E.g. controls of thyroxine production by the thyroid gland.

CONNECTION BETWEEN THE PITUITARY GLAND AND THE HYPOTHALAMUS OF THE BRAIN

The anterior and the posterior parts of the pituitary project down the tween brain, the hypothalamus. In the hypothalamus there are two nerve centres referred to as N_1 and N_2. N_1 is connected to the anterior lobe of pituitary by the portal blood vessels which has capillaries at both ends when N_1 is stimulated hormones known as releasing factors are secreted into the portal vessels by cells in the hypothalamus. The releasing factors are then carried by the blood in the portal vessel to the anterior lobe where they regulate the secretion of its various hormones. There is specific releasing factor for each hormone produced by the anterior lobe of pituitary N_2 is connected to the posterior lobe by nerve fibres (axons) which perform two functions which are;

- They carry anti-duiretic hormone (ADH) from N_2 to the posterior lobe where it is stored and appropriately transmit nerve impulses from N_2 to the posterior lobe, causing the ADH to be released.

DIAGRAM SHOWING CLOSE CONNECTION BETWEEN PITUITARY AND HYPOTHTALAMUS OF THE BRAIN



NEURO-SECRETION

Is the release or production of specific hormones by nerve cells and the nerve cells that do it are called neuro secretory cells. For example the hormones shed from the posterior lobe of the pituitary gland such as the anti-diuretic hormone (ADH) and the oxytocin. Neuro-secretion also occurs in insects where the insects brain produce brain hormone called prothoracicotrophic

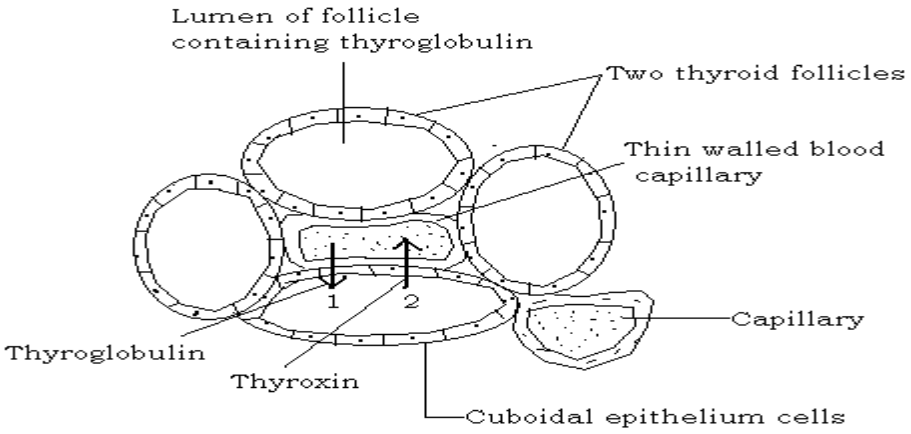
hormone; neurones of sympathetic nervous system produce noradrenaline.

THE THYROID GLAND.

The thyroid gland consists of numerous follicles in close association with thin walled blood capillaries. Iodine taken up into the follicles by active transport a cross the cells, is combined with tyrosine and stored in the follicle in combination with a protein as thyroglobulin. It is liberated into the blood streams as thyroxine.

The iodine required for the synthesis of the thyroxine is obtained from the diet and it's taken up into cells from blood stream by active transport. The follicles contain an in active precursor of the hormone, thyroglobulin which is thyroxine conjugated with a protein

STRUCTURE OF THYROID GLAND



The thyroid gland produces three hormones triiodothyronine (I_3). Thyroxin (I_4) and calcitonin. Triiodothyronine and thyroxine are derivative of the amino acid tyrosin and both contain iodine.

Thyroxine possesses four iodine molecules while triiodothyronine has only three. In shortage of iodine triiodothyronine is produced in preference to thyroxine.

FUNCTIONS OF HORMONES OF THYROID GLAND

(i) Thyroxine/triiodothyronine
- Controls basal metabolic rate.
- Promotes metamorphosis in amphibians.
- Regulate the growth and development of cells.
- Increase the rate at which glucose is oxidized resulting to the generation of heat. The hormone thyroxine is produced when an organism is exposed to severe cold. Emotional stress, and hunger may elicit the similar production of the hormone. The overall effect is to control the metabolic rate of cells and as such the hormone thyroxine works in close connection with insulin, adrenaline and cortisone.

(ii) Calcitonin is concerned with calcium metabolism. It works with the parathormone to control the levels of calcium ions (Ca^{2+}) in blood. Calcitonin is produced in response to high levels of Ca^{2+} in blood and it causes reduction in the calcium ions concentration.

CONTROL OF THYROXINE PRODUCTION

Thyroxine production is controlled by the hypothalamus of the brain by the process of the negative feed back. The shedding of thyroxin into the blood stream is triggered by thyrotrophin releasing factor (TRF) produced by the hypothalamus of the brain. TRF passes to the pituitary gland along the portal blood vessels. The TRF stimulates the anterior pituitary gland to produce thyroid stimulating of hormones (TSH) or thyrotrophic hormone . TSH then stimulates the thyroid gland to produce thyroxin. A slight excess of thyroxin in blood, inhibits the anterior lobe of the pituitary gland which responds by secreting less thyrotrophic hormone. (Thyroid stimulating hormones) This in turn reduces the activity of the thyroid gland, leading to decrease in the amount of thyroxine produced. This removes the inhibitory influence on the pituitary so that more thyroids stimulating hormone will be produced again.

Note: Thyroxine is responsible for controlling the basal metabolic rate and therefore important in growth.

Basal metabolic rate (BMR) Is the minimum amount of energy required to maintain basic body

physiological functions such as blood circulation; breathing and the body temperature.

ABNORMALITIES OF THE THYROID GLAND

There are two main thyroid abnormalities and these are;

(i) Hyperthyroidism.
(ii) Hypothyroidism.

HYPERTHYROIDISM

Is an increased activity of the thyroid gland, producing in excess the hormone thyroxine. It is caused by the blood protein which stimulates the thyroid gland to increase its production of thyroxine and triiodothyronine.

Hyperthyroidism can have the following effect in an organism

- Increased metabolic rate, resulting into increased heart and ventilation rate and raised body temperature.
- Nervousness, restlessness and irritability occur.
- Agoitre may become apparent.
- Heart failure may occur in extreme cases, a condition called thyrotoxicosis.

Control of hyperthyroidism is a achieved by the surgical removal of the thyroid gland or administration of radioactive iodine.

HYPOTHYROIDISM

Is the decreased rate of activity of the thyroid gland, produce less amounts of the hormone thyroxine. It is caused by insufficient supply of thyroid stimulating hormone. It has a marked effect in both young and adult individuals and these include;

In young, individuals the effects include;

- Mental and physical retardation and sluggishness occur, condition called cretinism.

In adults, it has the following effects;

- Mental and physical sluggishness.
- Reduced metabolic rate which results into reduced heart and ventilation rate and lowered body temperature and obesity. A condition known as myxoedema.
- A swelling around the neck (throat) called goiter may arise. Hypothyroidism can be controlled by taking thyroxin orally.

THE PARATHYROID GLANDS

They produce a single hormone parathormone. This hormone maintains the level of blood calcium at sufficiently high levels to permit normal muscle and nervous activity. It raises the levels of calcium ions in the blood in three ways;

- Increases the rate of calcium reabsorption by the kidney at the expense of phosphate ions.
- It increases the rate of calcium absorption from the gut.
- It causes the release of calcium reserves from the bones.
- Excess of parathormone leads to excessive removal of calcium from bones which thus becomes brittle and liable to fracture. Excessive calcium is removed by the kidneys causing the formation of kidney stones.

Under production of parathormone results in a low level of blood calcium, leading to nervous disorders and uncontrolled contraction of muscles known as tetany.

THE ADRENAL GLANDS

These are situated above each kidney. The size of the adrenal gland is closely linked to the out put of ACTH and the ability to withstand stress. They have two separate and independent parts and these are;

1. The Adrenal cortex.
2. The Adrenal medulla.

THE ADRENAL CORTEX

This is the outer region of the gland. It makes 80% of the gland. All the hormones are steroid hormones and are collectively called **corticoids (Adrenal cortical hormones)**. All steroid hormones are formed from a molecule called cholesterol which the cortex is able to synthesis and also take up from the blood circulation following absorption from the diet. Steroid hormones function under the steroid hormone mechanism. They are divided into two groups.

(i) Glucocorticoids.

(ii) Mineraloccarticoids.

GLUCOCORTICOIDS (CORTISOL).

They have the following functions,

- **In carbohydrate metabolism.**
  (i) Promote gluconeogenesis, this is the breakdown of proteins and fats to glucose and conversion of lactic acid to glucose.
  (ii) Promote liver glycogen formation.
  (iii) Raise blood glucose level.

- **Protein metabolism.**
  (i) Promote breakdown of plasma protein.
  (ii) Increases availability of amino acids for enzyme synthesis in the liver.

- **Other functions,**
  (i) Prevent inflammatory and allergic reactions.
  (ii) Decrease antibody production.

Overactivity of the adrenal cortex can be caused by over production of Adrenocorticotrophic hormone (ACTH) by the anterior pituitary gland, resulting into higher concentration of the glucocorticoid (cortisol) hormones in the blood stream. It leads to Cushings' disease and the patients show the following,

- Abdominal obesity.
- Wasting of muscles.
- High blood pressure.
- Diabetes.
- And increased hair growth.

Underactivity of the adrenal cortex is caused by the low production of ACTH by the pituitary gland and results in low levels of the hormone glucocorticoid in blood and the victim suffers a condition called Addison's disease syndrome as shown by,

- Muscular weakness.
- Low blood pressure.
- Decreased resistance to infection.
- Fatique.
- And darkening of the skin.

THE MINERALOCORTICOID HORMONE (EG. ALDOSTERONE).

This includes the hormone aldosterone which regulates water retention by controlling the relative concentration of sodium ions (Na^+) and potassium ions (K^+).

It controls water and salt content of the body by stimulating cations pumps in the membranes to conserve sodium and chloride ions and remove potassium ions. It prevents excessive sodium ion loss in sweat, saliva and urine and maintains concentration of body fluids at a steady state.

Low levels of sodium ions in blood or a reduction in the total volume of blood causes special cells in the kidney to produce renin, which activates a plasma protein called angiotensin. This stimulates production of aldosterone from the adrenal cortex. Both water and sodium ions are conserved. Angiotensin also affects centres in the brain creating a feeling of thirst and water is taken, which helps restore the blood volume to normal.

Over production of aldosterone is caused by tumour and leads to excessive sodium retention by tissues high blood pressure and head ache fall in levels of potassium ions arises causing weakness.

Under production of aldosterone leads to a fall in level of sodium in the tissues; retention of potassium ions water loss and fall in blood pressure.

SEXCORTICOIDS (ANDROGENS)

These are also steroid hormones, they promote development of testes and male secondary sexual characteristics. Their deficiency results into weakness; circulatory failure; addison's disease, etc while its excess causes sexual precosity in young male.

CONTROL OF CORTICAL HORMONE RELEASE.

- Mineralocorticoid (aldosterone) release is stimulated by the activity of the rennin and angiotensin as described above.

- Glucocorticoids are secreted in response to Adrenocorticotrophic hormone (ACTH). An example of the role of ACTH in regulating the release of the glucocorticoid hormone cortisol is an example of cascade effect.

Cortisol is mainly produced in response to stress. In stressful conditions like shock, pain, emotional distress, extreme cold or infection, the hypothalamus induces the anterior pituitary gland to secrete ACTH. This stimulates the adrenal cortex to increase secretion of glucocorticoid hormones including cortisol, where the stress is prolonged the size of the adrenal gland increases. The glucocorticoid hormones combat (reduce) stress in the following ways,

- Raise the blood sugar level by inhibiting insulin and increasing formation of glucose from fats and proteins.
- Increasing the rate of glycogen formation in the liver.

Increase uptake of aminoacids by the liver.

THE ADRENAL MEDULLA

Is the inner region of the adrenal gland. It produces two hormones, the adrenaline and noradrenaline. These hormones are also called "flight or fight hormones." The effects of both hormones are to prepare the body for exertion and heighten its response to stimuli.

THE EFFECTS OF ADRENALINE SECRETION TO THE BODY

Adrenaline is secreted only during times of excitement, fear or stress. The table below shows the importance of some of its effects in the body

Effects.	*Purpose.*
1. Dialates bronchioles.	- More air inhaled into the lungs and oxygen made available for respiration.
2. Dialates pupils of the eye.	- Increases range of vision and allows increased perception of visual stimuli.
3. Increases mental awareness	- Allows rapid response to stimuli and decision made faster.
4. Increases heart rate and stroke volume	- Increases transport of metabolites and oxygen supply to cells and removal of wastes.
5. Vaso-constriction of most arterioles.	- Increased blood pressure.

6. Conversion of glycogen to glucose in the liver.	- More glucose available for cell respiration.
7. Peristalsis and digestion inhibited	- Allows blood to be delivered to vital organs e.g. brain, heart, muscle.
8. Hair erector-pillii muscles contract.	- Hair stands upright, gives impression of increase size, frightens away enemies.

THE PANCREAS

Alpha cells of the islets of langerhans produce the hormone glucagon. This raises blood sugar by stimulating the break down of glycogen to glucose. While the beta (β) cells of the islets of langerhans produce the hormone insulin. This lowers the levels of blood sugar by stimulating the conversion of glucose to glycogen and subsequent oxidation of glucose to provide energy.

TESTES

Produces the hormone testosterone. This produces male secondary sex characteristics and promote growth and activity of male reproductive organs.

OVARIES

The follicle cells of the ovary produce the hormone oestrogen. It has the following function.

- Promote development of female reproductive organs and secondary sexual characteristics.
- Repair uterus following menstruation.
- Promote development of mammary glands but prevent milk secretion. Its excess causes loss of appetite and feeling of nausea controlled by FSH.

Corpus luteum of the ovary produce the progesterone hormone. This hormone promotes proliferation and thickening of uterine wall and development of mammary glands. It inhibits ovulation and secretion.

PINEAL BODY

This produce the melatonin. It is thought to promote sexual development in males and causes concentration of melanin in pigment cells of frog.

WALLS OF STOMACH

Secrets the hormone gastrin which causes secretion of gastric juice by gastric glands in stomach wall.

WALL OF DUODENUM

- Secretin causes secretion of non-enzymatic component of pancreatic juice by pancreas and production of bile by liver.
- Cholecystokinin causes bile to flow from gall bladder to duodenum by causing contration of gall bladder and relaxation of sphincter muscles where bile duct joins duodenum, it also causes pancreas toproduce enzymes.

Note: Cholecystokinin-pancreozymin, has similar functions to cholecystokinin.

- The hormone enterogastron; inhibits secretion of acid by the stomach wall.

PLACENTA

Produces chorionic gonadotrophin; it maintains the presence of the corpus luteum in the ovary. Corpus luteum secretes progesterone, a role which is taken over by placenta at later stage of gestation.

TABLE SHOWING CHEMICAL NATURE OF THE MAJOR HORMONES OF THE BODY.

CHEMICAL GROUP	HORMONES	MAJOR SOURCE.
(i) Peptides and proteins	• Growth hormones, oxytocin, ADH (vasopressin),	• Posterior pituitary gland.
	• Parathormone	• Parathyroid gland.
	• Calcitonin	• Thyroid gland.
	• Insulin, glucagon	• Islets of langerhans (pancreas)
	• Gastrin,	• Stomach mucosa.

	• secretin	• Duodenal mucosa.
(ii) Amines.	• Adrenaline. • Noradrenaline • Thyroxine and Triiodothyronine. • Releasing and inhibiting hormones and factors of the hypothalamus. • Follicle stimulating hormone, Luteinising hormone, prolactin, Thyroid stimulating hormone and Adreocorticotrophic hormone.	• Adrenalin medulla • Sympathetic nervous system and adrenal medulla. Thyroid gland. • Hypothalamus. • Anterior pituitary gland.
(ii) Steroids	• Testosterone. • Oestrogen, progesterone • Corticosteroids.	• Testis. • Ovary and placenta. • Adrenal cortex.
(iii) Fatty acids.	• Prostaglandins.	• Many tissues.

INSECT HORMONES

Most invertebrate hormones are neurosecretory substances. In insects they are important in the control of ecdysis (moulting). These are two main hormones

- Ecdysone (moulting hormone)
- and neotinin (Juvenile) hormone.

In insects with complete metamorphosis (holometabolous) all moults require ecdysone. But if neotinin is also present in high concentration the larval moult produces larval stage. At low concentration of neotinin, the ecdysone causes the larva to moult into pupa.

In the absence of neotinin; ecdysone causes the pupa to moult into an imago (adult)

The production of ecdysone and neotinin is controlled by the brain of the insects as follows;-

The brain produces brain hormone called prothoracicotrophic hormone which passes to a pair of bodies called the corpora cardiaca which lie next to the brain. This is where the hormone is stored.

In response to external stimuli e.g. day length, temperature, food supply, the brain sends nerve impulses to the corpora cardiaca stimulating them to release their stored brain hormone.

The prothoracicotrophic hormone released, passes to the prothoracic glands, which are stimulated to produce ecdysone (moulting hormone).

Neotinin (Juvenile hormone) is produced by a region behind the brain called corpus allatum. The production of neotinin diminishes during the insects development but is resumed in the a adult.

COMPARISON BETWEEN HORMONAL AND NERVOUS COORDINATION

SIMILARITIES:

1. Both provide a means of communication and coordination in the body.
2. In both the information transmitted is triggered by a stimulus and produces a response.
3. Both involve chemical transmission.
4. Both are controlled by the brain.

DIFFERENCES

HORMONAL COORDINATION	NERVOUS COORDINATION
1. The speed of transmission is slower.	1. The speed of transmission is more rapid.

2. The duration of effect is long lasting. 3. The message is chemical in nature. 4. Hormones are transmitted in blood. 5. The site of origin of message is specific endocrine gland.	2. Is short lived. 3. The transmission of message is electrical in nature. 4. Impulses are transmitted in nerves (neurones) 5. The site of origin of the message is all over the body.

PLANT RESPONSES

The ability of plants to respond to stimuli is called irritability.These responses are are mainly

growth responses.The plant responses are of three types.

- Tropism
- Nastic
- Taxis

TROPISM.

These are growth movements of plant organ in response to external unidirectional stimulus.The stimuli which bring about tropism are,

- Light(phototropism)
- Gravitational force (geotropism)
- Water (hydrotropism)
- Touch (thigmotropism)
- Air (aerotropism)
- Chemicals (chemotropism)

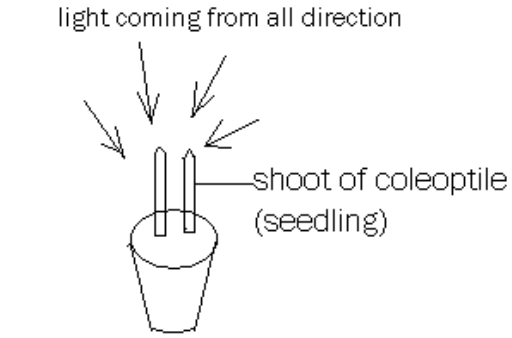
PHOTOTROPISM.

This is the growth response of the plant shoot towards a unidirectional light. The shoot is said to be positively phototropic as it grows towards light.

EXPERIMENT TO SHOW THE EFFECT OF LIGHT ON THE SHOOT OF A PLANT

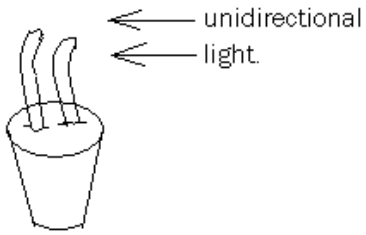
Two seedlings are exposed to light, one seedling exposed to light coming from all direction, while the other illuminated from one side.

DIAGRAMS AND OBSERVATIONS.



observation.

- Tip of the shoot does not bend.



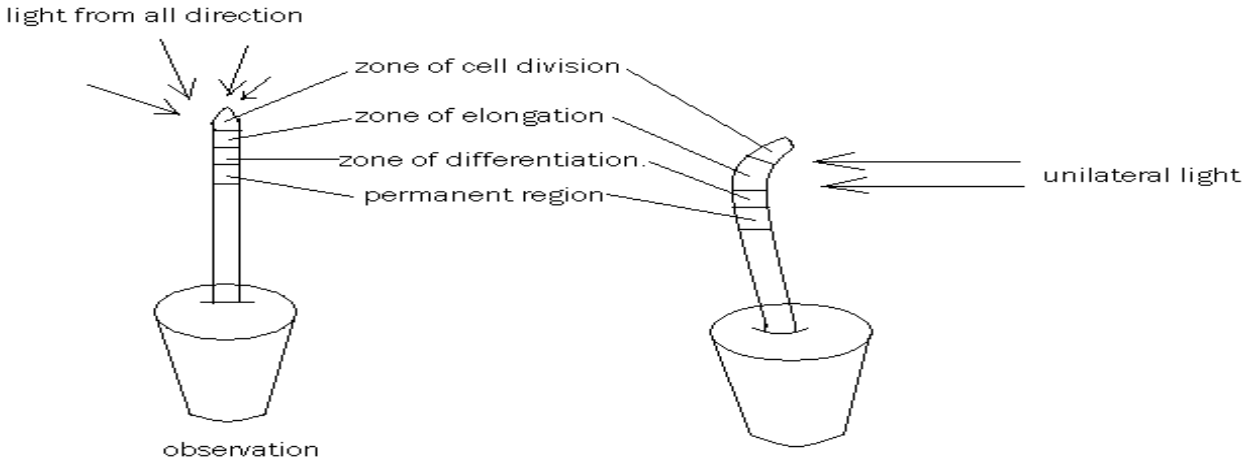
observation

- Seedlings illuminated from one side have tip of the shoot curving towards unilateral light.

EXPLANATIONS

The part of the plant which curves towards the light is the zone of elongation. This is shown by marking the stems of the growing seedlings at regular intervals and then placing the marked seedlings grow in evenly distributed light source and others in the unilateral light. The results are shown in the diagrams below.

DIAGRAMATIC ILLUSTRATIONS



observation

- the tip of the coleoptile showed no curvature

observation

- curvature occured at the zone of elongation.

The results show that the plants response to a unidirectional light is a growth response. Once the growing plant has well established leaves the phototropic response is shown by the leaves.

This is called sun tracking or heliotropism. Once the stem has passed the seedling stage, it grows in natural condition responding to gravity rather than the unidirectional light.

GEOTROPISM.

This is the growth response of plant shoot or root towards a unidirectional gravitational force.
The tip of plant (shoot) grows away from the pull of the gravity thus showing negative geotropism and root grows towards the force of the gravity and thus shows positive geotropism. Lateral roots grows and stems grow at an angle to the direction of gravitation, this is referred to as plagiotropism.

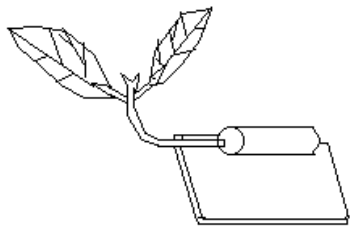
EXPERIMENT TO SHOW RESPONSE TO GRAVITY.

PROCEEDURE

Two potted plants are got, one is inserted in a klinostat while the other plant is placed on the ground on its pot. The one in the clinostat is also placed horizontally on the ground but the clinostat makes it move clockwise, this is to have the effect of gravity equally distributed throughout the shoot. This is used as a control experiment. The two set ups are left in the same environment for a week.

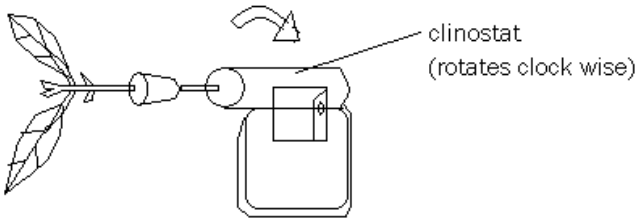
DIAGRAMS.

SHOOT GROWING HORIZONTALLY
ON THE GROUND



- stem has grown vertically
(negattivelly georopic)

SHOOT GROWING ON THE CLINOSTAT



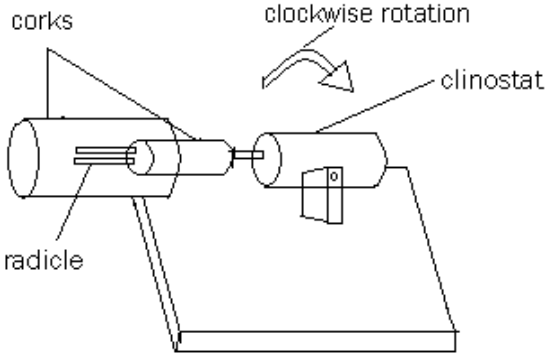
- stem continued to grow horizontally

EFFECT OF GRAVITY ON THE ROOT(EXPT USING RADICLES)

Two corks are got and growing seeds are pinned in each of them and allowed to develop. One cork is placed in a clinostat while the other is fixed in a jar like structure and laid horizontally to ground. The same experiment is left within the same conditions for four days.

DIAGRAMS

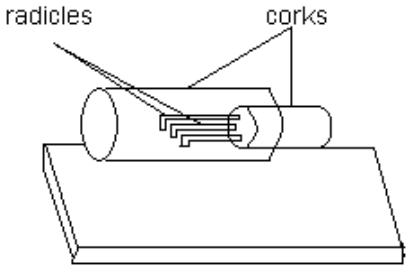
ROOTS PLACED IN A CLINOSTAT



observation

- roots (radicles) continue to grow horizontally.

ROOTS GROWN HORIZONTALLY



observation

- roots (radicles) grown downward (positively geotropic)

OBSERVATTIONS

The shoot in the clinostat showed no curvature after sometime while the shoot which was left stationary and horizontal to the ground grew upwards showing a negative response to

gravity.Hence negatively geotropic.

Similarly,the root in the clinostat showed no curvature,while the root left stationary and horizontally grew downwards towards the force of gravity,and therefore positively geotropic.

CHEMOTROPISM

This is a growth response of part of plant towards a unidirectional chemical.eg the growth of pollen tube towards chemicals produced by the micropyle.The pollen tube is also said to be negatively aerotropic since it grows away from the air.

HYDROTROPISM

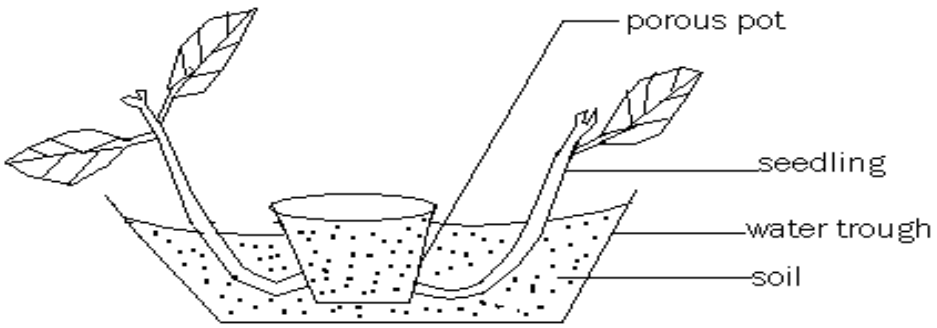
This is the growth response of part of plant towards a unilateral water.

EXPERIIMENT TO SHOW THE RESPONSE OF ROOTS AND SHOOTS TO WATER.

A trough is filled with soil and a porous pot is placed in the centre,some seedlings are grown near the pot,the soil watered until after the plumule appear, then the watering is stopped.The porous pot is filled partly with water.

Leave the experiment for some days and dig out the seedlings without damaging the roots.

DIAGRAM.



OBSERVATIONS

The plant roots grew towards the porous pot,while the shoot grew away from the pot.

CONCLUSIONS.

Plant roots are positively hydrotropic, while the shoots are negatively hydrotropic.

THIGMOTROPISM(HAPTOTROPISM)

This is a growth response of part of plant or it’s organ towards a unilateral touch. This type of

response is shown by pants which wind their stems around for support. Roots may also be thigmotropic. Plants that show positive thigmotropism are yams, morning glory, passion fruits etc Tendrils and other climbing organs of climbing plants are thigmotropic. These plants use tendrils or roots, others like the figs and wild peppers have climbing roots.

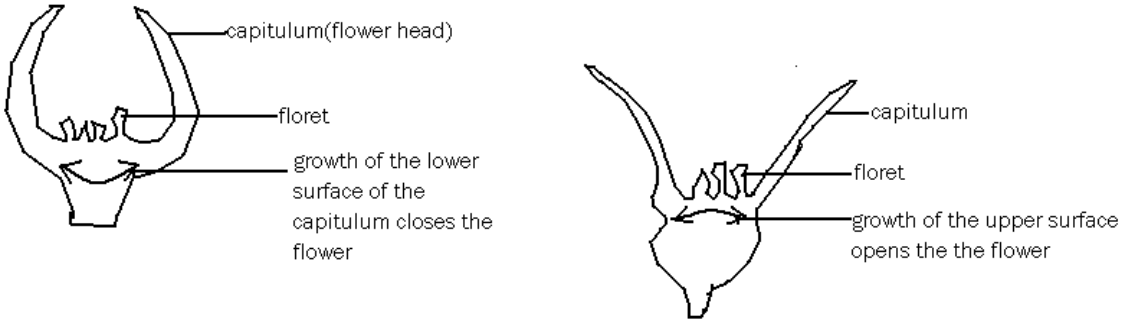
THE NASTIC RESPONSES OF PLANTS.

This is the growth response of part of plant or its organ towards a non-directional stimulus.In such response the direction of the response of the plant organ is not determined

By the direction of the stimulus.E.g the adendelion flower head opens up in the light and closes up in the dark (low light) .This type of response is refered to as photonastic.

Flowers like the tulip and the crococcus make similar responses but stimulated by changes in temperatures,such responses are refered to as thermonastic.The opening and the closure of flowers for such responses is due to localized growth in particular part of the flower or inflorescence.During the day the upper surface of the capiculum of the dandelion flower grows more than the lower one and the flower head opens.While at night the lower surface of the capitulum grows more than the upper one and the flower head closes.

DIAGRAM SHOWING PHOTONASTIC RESPONSE IN FLOWER.



The leaves of the plant known as memosa pudica fold their leaves when touched.This is because depolarisattion occurs across the membrane of the cells of the leaflet touched,action potential is developed and transmitted via the phloem and across the plasmodesmata to reach the group of parenchyma cells called motor cells,found at the base of the leaflets called pulvinus.potassium ions are actively transmited out the of the cells,the water potential in the cell is increased and the cells lose water by osmosis to the surrounding region,the cells become flaccid and the leaflets are pulled forward and upwards and leaflets close.The leaflets open when the motor cells gain

water and become turgid,the leaflets are pulled downwards and outwards and leaflets open.This type of response due touch is reffered to as thigmonastic.

COMPARISON BETWEEN TROPISM AND NASTIC RESPONSE.

Differences

Tropic response	nastic response
1. Direction of the response is determined by the that of the stimulus.	1. Direction of response is not determined by that of the stimulus
2. Stimulus direction is specific (unidirectional)	2. Stimulus direction is not specific(non-directional)
3.Response is slower	3.Response is faster
4. Mainly chemical in nature .	4. Electrical and mechanical in nature.

Similarities.

- Both are growth response.
- Both occur in a part of plant or plant organ.
- Both responses are triggered by stimuli.

TACTIC RESPONSE(TAXIS).

This is type of response where the whole organism moves towards a unilateral stimulus.the direction of response is determined by the direction of the stimulus.E.g the movement of the motile male gamete towards the stationary female one(ovum) in bryophytes.The male gamete is attracted by achemical secreted by the femle reproductive part.This type of response is refered to as chemotactic.

DISCOVERING PLANT GROWTH SUBSTANCES.

There where four experiments done to find the substances responsible for growth and these are;

i) Darwin's experiment.

ii) Boysen-jensen experiment.

iii) Paal's experiment

iv) Went's experiment.

DARWIN'S EXPERIMENT.

This experiment is to discover the position of the substance responsible for growth .This substance is auxin. In his experiment he used a metal cap to find the position of the growth substance.

STEP ONE:

Light was allowed to strike coleoptile shoot from one direction as in **A** after some time he found that the shoot bent towards light.

STEP TWO:

He cut tip of the coleoptile shoot and allowed the shoot to grow in the same condition as in **B**. He found that there was no curvature(bending)This suggested that the tip is the region of the perception of the stimulus

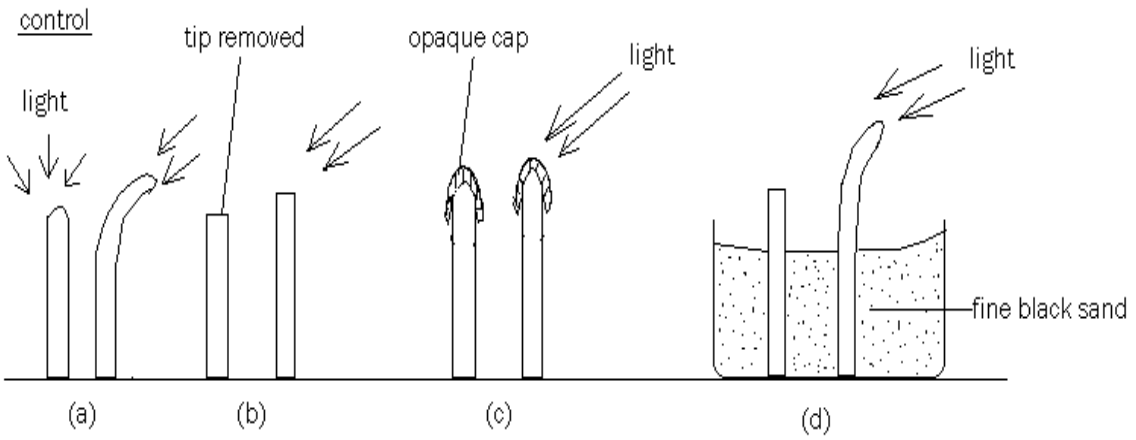
STEP THREE:

He covered the tip with an opaque cap and allowed the plants to grow in the same condition as in **C**. He found that no curvature took place. This confirmed that the stimulus is perceived at the tip of the shoot but not at region of the response.

STEP FOUR:

He buried the seedlings within the sand with only the tip exposed as in **D**. He found that the plant shoot bends towards light proving that the lower part of the same plant has no links with the response.

DIAGRAMATIC ILLUSTRATION

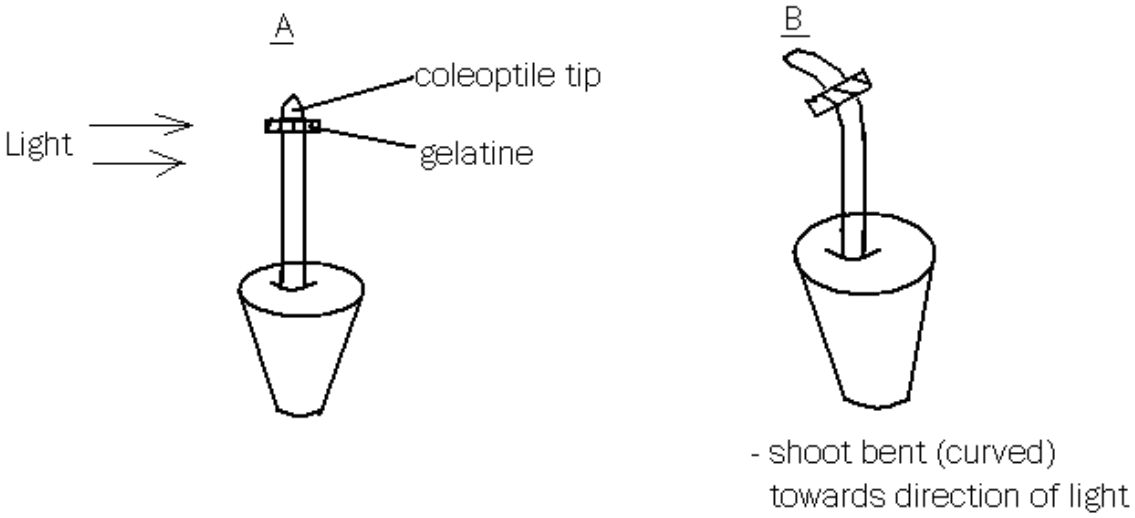


BOYSEN-JENSEN EXPERIMENT.

He investigated the transmittion of the growth substances from the tip of the shoot to the zone of elongation (region of response).

STEP ONE:

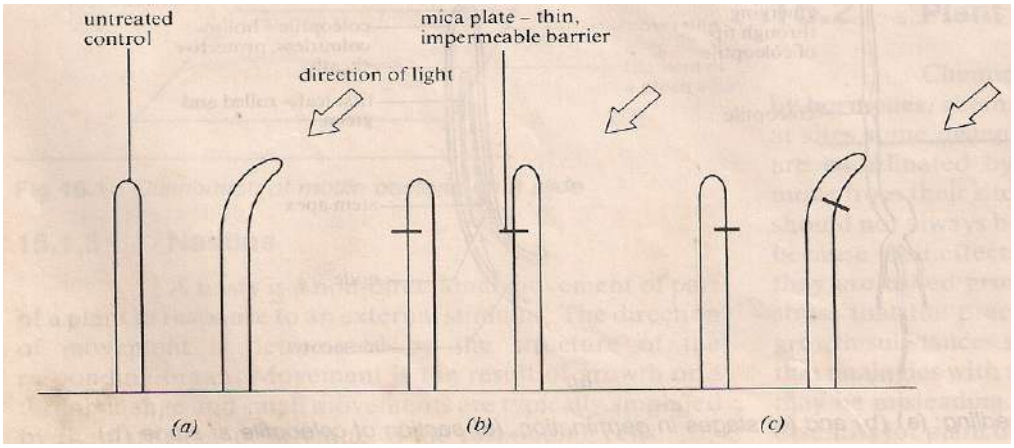
He cut a coleoptile tip and inserted a slice of gelatin between the decapitated tip and the lower part. The lower part curved towards the unilateral light in the same way as the normal coleoptile.



STEP TWO:

He inserted a mica plate on the shaded part of coleoptile, this prevented curvature in a unilateral light .He then inserted the mica plate on the illuminated side and curvature took place. This proved that the chemical substance (auxin) diffused from the illuminated the shaded part of the shoot and the shaded part experienced greater growth and hence curved.

DIAGRAMS



PAAL'S EXPERIMENT.

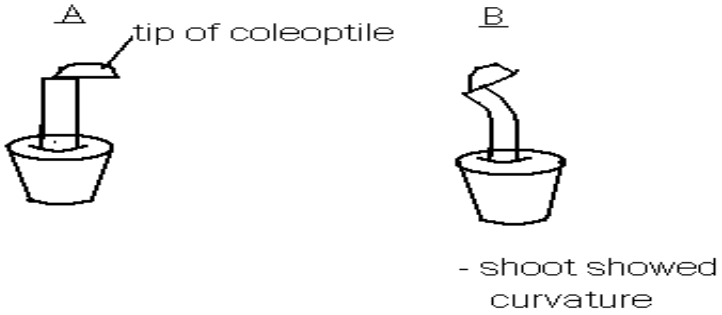
He tried to prove that hormones are responsible for the growth response but not light.

He performed the experiment by removing the coleoptile tip and replaced it but displaced to one side and placed in the dark.

OBSERVATION:

Coleoptile tip bends towards the side where no tip is present.

DIAGRAMS.



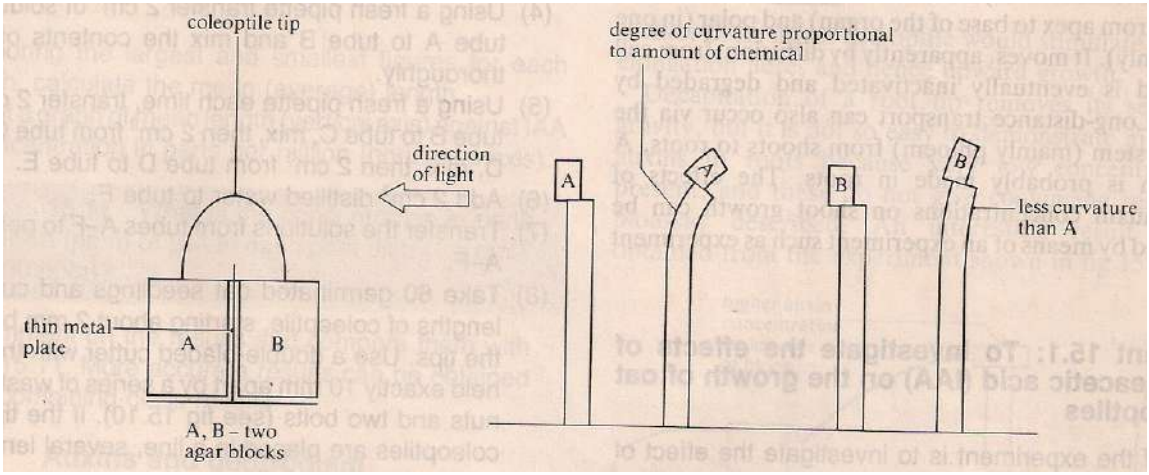
EXPLANATION.

Displacement of the coleoptile tip on one side means that the growth substance (auxin) diffused downwards on only one side where the tip was placed. Rapid cell elongation occurred on that side, this side grew more rapidly causing bending.

WENT'S EXPERIMENT

In this experiment, he cut the coleoptile tip and placed it on the a gar block allowed it to stand on the a gar block for 1-2 days to allow the chemical to penetrate.
The agar block is placed on one side of decapitated coleoptile.

DIAGRAMS



OBSERVATION:

Coleoptile bends towards side where no a gar block is present.

EXPLANATION.

The growth substance (auxin) from the coleoptile tip penetrated into the a gar block. When the agar was placed on decapitated coleoptile to one side, the hormone auxin moved downwards that side, increasing growth and causing bending. The degree of curvature is proportional to the amount of auxin.

PLANT HORMONES

Plant growth is regulated by a chemical substance like hormones. These chemical substances are called phytochromes, and are essential for plant growth and development. They exhibit the following characteristics,

- Required in minute quantities
- Their actions are specific

- They don,t move away from the site of synthesis
- They are short lived and do not accumulate in the cells and rapidly brokendown

The growth regulaters may affect growth in different ways. They may promote or inhibit a process. There are five types of growth hormones;

i) Auxins (associated with cell elongation)
ii) Gibberellin (associated with cell differentiation and elongation)
iii) Cytokinin (for cell division)
iv) Ethene (senescence or aging)
v) Abscicic acid (bud dormancy and resting state)

THE AUXINS

They increase the cell elongation at the tip of the shoot.The naturally occurring auxins in plants is known as indol acetic acid(IAA).

FUNCTION OF THE AUXIN(IAA)

(i) Cell elongation.

It brings about enlargement of shoot and root tips especially at apical meristem. It softens the cell wall of newly divided cells and loosens closely bound filaments of cellulose thus helping the turgor pressure to build and the cell elongates.

(ii)Fruitgrowth.

It promotes the enlargement of fruits by stimulating the cell wall to grow in more than one direction. It can induce fruiting in absence of pollination(parthenocapy)

(iii) Promotes cell division at the vascular cambium.

This is due he movement of the IAA from the developing shoots to reactivate the growth of cambium during the growing season.

(iv) Root initiation.

When applied to the roots of cuttings of vegetative propagation it promotes growth of roots.

(v) Apical dominance

This is where bud at the apex of the shoot produces auxin in sufficient concentration to inhibit

growth of lateral buds.On removal of the apical bud the lateral buds start moving into branches. This is the principle behind pruning of many plants.

(vi) Suppresses abscission of fruits and leaves

Abscission means the shading of leaves and fruits. There is an abscission zone at the base of the leaves and the fruits. This zone cuts off supply of nutrients and water from reaching the organ and the fruits and leaves fall by any force like wind etc. The concentration of auxins declines at the on set of abscission. Leaves and fruits must produce auxins continuously to prevent the formation of abscission zone. IAA work antagonistically to abscissic acid which promotes abscission. In unripe fruit the concentration of auxins is more but it declines on ripening and that of abscissic acid increases to enhance fruit dropping. Auxin prevents abscission because it maintains the structure of cell wall.

RELATIONSHIP BETWEEN GROWTH AND AUXIN CONCENTTRATION IN ROOTS AND SHOOT.

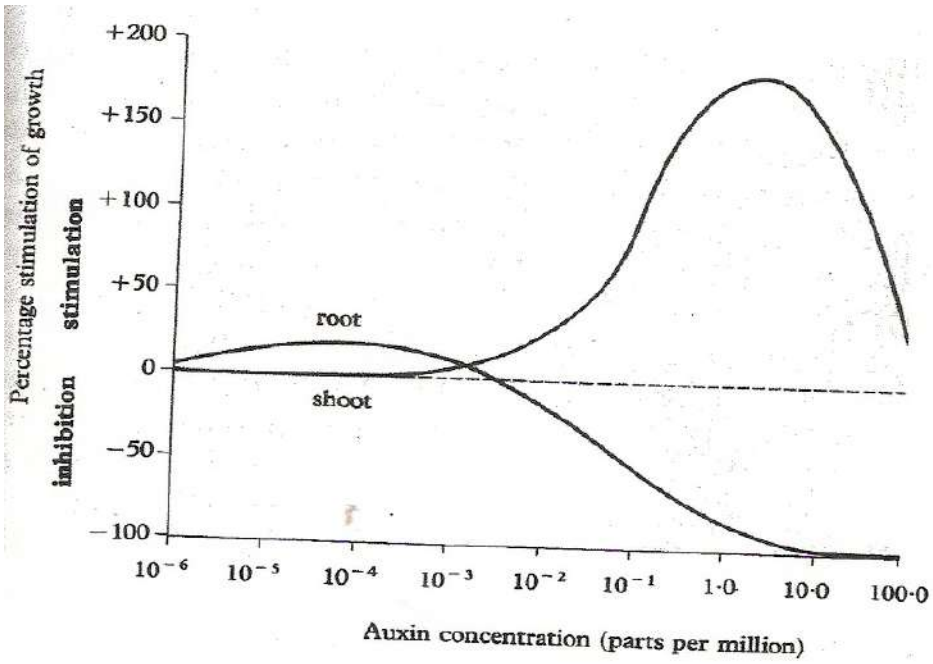
It is known that auxins at much higher concentration inhibit growth in both shoot and root. However, roots are more sensitive to auxin than stems. Roots only respond well to lower concentration of auxins . As the concentration of auxins increase,the growth of roots become inhibited while that of the stem is increased.

When a shoot of a plant seedling is exposed to a unilateral light the auxins is redistributed in higher concentrations in the shaded part and the rate of growth increases on that side and it bends towards light.

In horizontally placed root, the effect of gravity redistributes the auxins in higher concentrations at the lower surface, this inhibits growth on the lower side, and rate of growth becomes greater at the upper side than the lower side and the root bends downwards and towards the gravitational pull.

In horizontally placed shoot, auxins redistributes in higher concentrations at lower side, this promotes more growth at the lower side and the shoot bends upwards and away from gravitational pull. So, it is the redistribution of auxins which accounts for the response of shoots and roots.

A GRAPH SHOWING RELATIONSHIP BETWEEN GROWTH AND AUXIN CONCENTRATION IN ROOTS AND SHOOTS.



THE GIBBERELLIN

These are present in greatest concentration in mature seeds. They are abundant in root and shoot apex, buds and young apical leaves and young embryos. They are transported to other parts of plant through both xylem and phloem.

FUNCTIONS OF GIBBERELLIN.

(i) Internode elongation.

They bring about stem elongation by enlargement of cells in the same way as auxins.They also bring about leaf expansion but no effect on the roots. Dwarf variety pea and corn be induced to grow to normal height by the application of gibberellin.

(ii) Brings about bolting in rosette plants.

When gibberellin is applied to a rosette plant like cabbage it causes bolting i.e the internodal length increases and plant may flower. Plants like cabbage have a number of leaves around the shoot apex and the Internode length is reduced giving it a rosette appearance. Bolting does not occur if the cabbage plant is kept at warm temperatures due to the destruction of gibberellin.

(iii) Breaking of seed dormancy.

Gibberellin stimulates the synthesis of enzymes such as alpha-amylase during the seed germination. If a seed imbibes water the embryo is activated and it secretes the hormone gibberellin which diffuse to aleurone layer .In this layer it stimulates synthesis of various digestive enzymes.

(iv) Breaking the bud dormancy

It works to break bud dormancy in opposition to abscicic acid.

(v) Control of fruit growth and development.

They induce development of fruits without fertilization (parthenocapy). E.g in apples and pears.

(vii) Control of flowering in long day plants.

They also sometimes substitute red light and so induce flowering in long day plants and inhibit flowering in short day plants.

They can also change the sex of some flowers , like in monoecious plants.

THE CYTOKININ

This is the chemical substance which is required to stimulate the growing of the cells in the tissues by promoting cell division. They work in presence of auxins and gibberellin.

THE ROLE OF CYTOKININ.

(i) Promotes cell division in apical meristem.

Along with auxins they promote cell division in apical meristem as well as meristematic tissues.

(ii) Promotes cell differentiation in plants.

Where there is more cytokinin and less auxins shoot develops. Less cytokinnin and more auxins roots develop. Intermediate cytokinnin and auxins both roots and shoots develop, intermediate cytokinnin and less auxins activate mitotic division and no differentiation.

(iii) Control of apical dominancy.

While auxins stimulate apical dominancy. Cytokinnins stimulate growth of lateral buds.

(iv) Delaying of aging in plants.

Cytokinin delays the normal aging in leaves by controlling protein synthesis and mobilization of

resources. The chlorophyll does not disintegrate and so leaves remain green. Protein synthesis and carbohydrates break down continues. Cytokinnin is applied to harvested crops to extend their storage life.

ETHENE

It helps in the ripening of fruits. It is produced by all plants organs and escapes from the plant surface in gaseous forms.

THE ROLE OF ETHENE

(i). Fruit ripening.

It is associated with ripening of fruits like bananas, citrus, apples etc. Fruit ripening is a process of senescence when the respiratory activity is very high and large amounts of ethene are produced, when a fruit is enclosed in a bag. The ethene produced by the fruit it self forms a concentration layer hence causes ripening of the fruit.

(ii). Inhibition of the stem elongation.

It inhibits stem elongation and stimulates the transverse expansion and hence formation of swollen stem.

(iii). Sex determination in some plants.

Plants which bear both male and female flowers like cucumber, will have sex of one flower changed (male flowers changes to female) on application of ethene to young buds of male flowers.

(iv). Senescence.

Ethene promotes senescence and produced by the aging leaves and the ripening fruits and finally brings about their abscission.

(v). Abscission.

Along with abscissic acid ethene stimulates abscission of leaves. The enzymes produced by both dissolves the cell wall but hold the petal of the leaf. It is the same also in abscission of fruits.

(vi). Brings about the straigtening of the hypocotyls during seed germination as it breaks through the soil.

(vii). In horticulture ethene. Induces flowering in pineapples and ripening of fruits like tomatoes, grapes and bananas.They are first kept unripe and transported in ventilated compactments and in atmospheres without oxygen.

ABSCISIC ACID (ABA).

ROLES OF ABSCISIC

(i) Abscission of leaves and fruits.It works antagonistically to auxins and causes abscission of leaves and fruits.As the leaves or fruits ripen abscicic acid concentration increases and the auxin decreases.ABA causes the cell to die and hardens,this cuts off the nutrient supply just before falling.

(ii) Inhibition of mitosis.

It inhibits mitosis in vascular cambium as winter approaches.

(iii) Dormancy of seeds.

The dormancy of seeds is broken down only when ABA Level in the seed is reduced by increasing the level of gibberellin.It inhibits the formation of alpha-amylase in germinating cereal grains.

THE MECHANSM OF ACTION OF PLANT GROWTH SUBSTANCES

The abscissic acid and gibberellins combines with the receptor proteins on the surface of the cell membrane to form the hormone-receptor complex. The complex formed penetrates into the cells and exerts their effect by switching genes on and off.

Abscissic acid s also thought to stimulate the transcription of certain genes whose proteins products accumulate during desiccation. It is those proteins which appear to protect plant tissues during desiccation E.g n seeds.

Gibberellins are thought to stimulate transcription of genes which results in the production of those enzymes that are necessary for hydrolysis of the food reserves n cotyledon or endosperm thus enabling the embryo to grow.

COMMERCIAL USE OF PLANT GROWTTH SUBSTANCES.

1. **As selective herbicides(weed killer)** E.g 2,4-D which destroys broad leaved weeds from cereal fields, such are applied to the leaves from where they are translocated to the rest of the plant and disorganize the and the metabolism of the plant.

2. As growth promoters eg IAA as rooting powder which is applied to the stem cuttings which induce formation of roots in them. It also breaks seed and dormancy.

3. As growth retarders which retard growth of plants and limit them to heights where they are easy to harvest.

4. As flower inducers eg gibberellins and ethene can be used to induce early flowering in otherwise perennial crop.

5. As fruit inducers eg IAA when applied to un-pollinated flowers of tomato, fruits are formed without fertilization i.e by parthenocapy.

6. As fruit rippeners eg thene. If ethene is applied to fruits it causes them to ripen. It is particularly usefull in fruits like banana which are picked and shipped when green but have to be sold when ripe(yellow) so they are sprayed with ethene in transport.

7. Used in storage of potatoes or other crops since they inhibit sprouting or simply prolong seed dormancy

PHOTOPERIODISM IN PLANTS.

Photoperiodism in general term is the response of organisms to the changing lengths of the days and the night periods (light periods). In plants is where the activity in the plants such as flowering is influenced by the changing lengths of the days and the night periods.

Photoperiods refers to lengths of the day or the light periods.

Floowering plants are divided into three groups on the basis oof ttheir response tto the photoperiods.

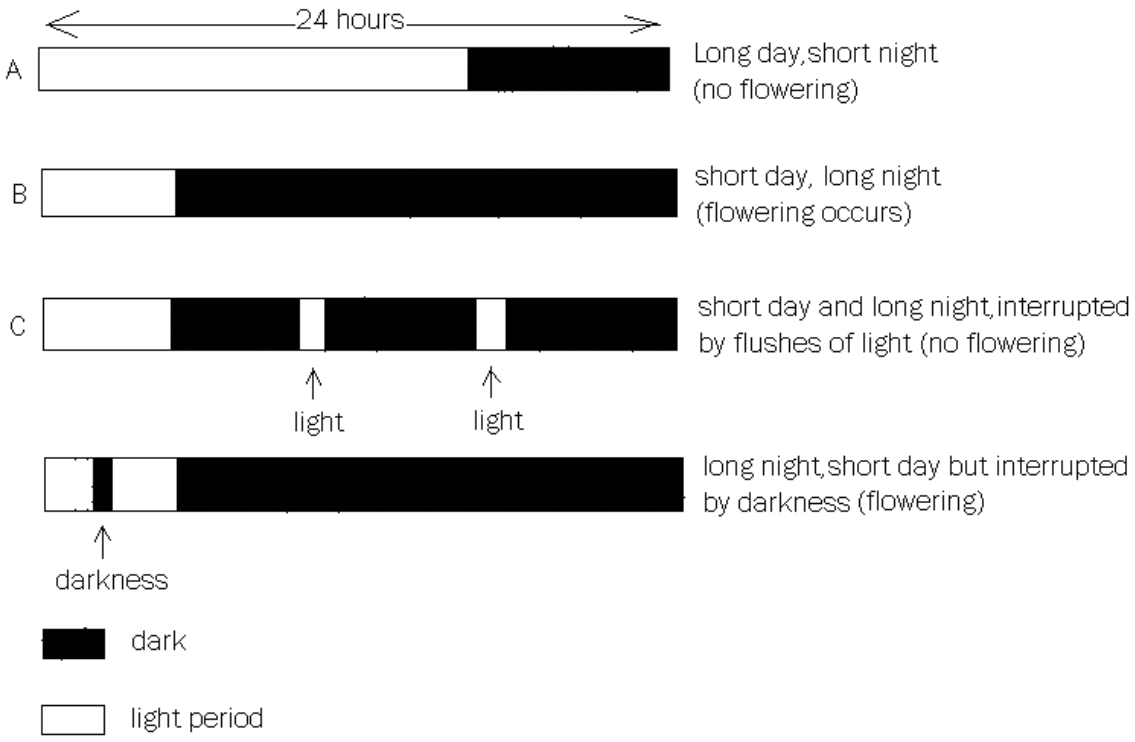
i) Short day plants.
ii) Long day plants.
iii) Day neutral plants.

THE SHORT DAY PLANTS

These are plants which only flower when day periods become shorter than the critical length of the day. Examples of such plants include, sugarcane,soya-beans etc. They have the follwing characteristics,

- They require short days and long nights.
- They flower only when the days become shorter than the critical length of the day.
- They need an uninterrupted long nights for flowering.
- The longer nights are more essential for flowering than the short periods of the day.
- They don't flower when exposed to short day and long nights interrupted by some flashes of lights at intervals.
- They flower when exposed to short days interrupted by intervals of darkness but the long night remained uninterrupted with flashes of lights.
- They flower during autumn and winter when the nights become longer and the days shorter.
- Flowering is promoted when all the phytochrome far red are converted to phytochrome red.

DIAGRAM SHOWING THE EFFECT OF DAY AND NIGHT PERIODS ON FLOWERING OF SHORT DAY PLANTS.

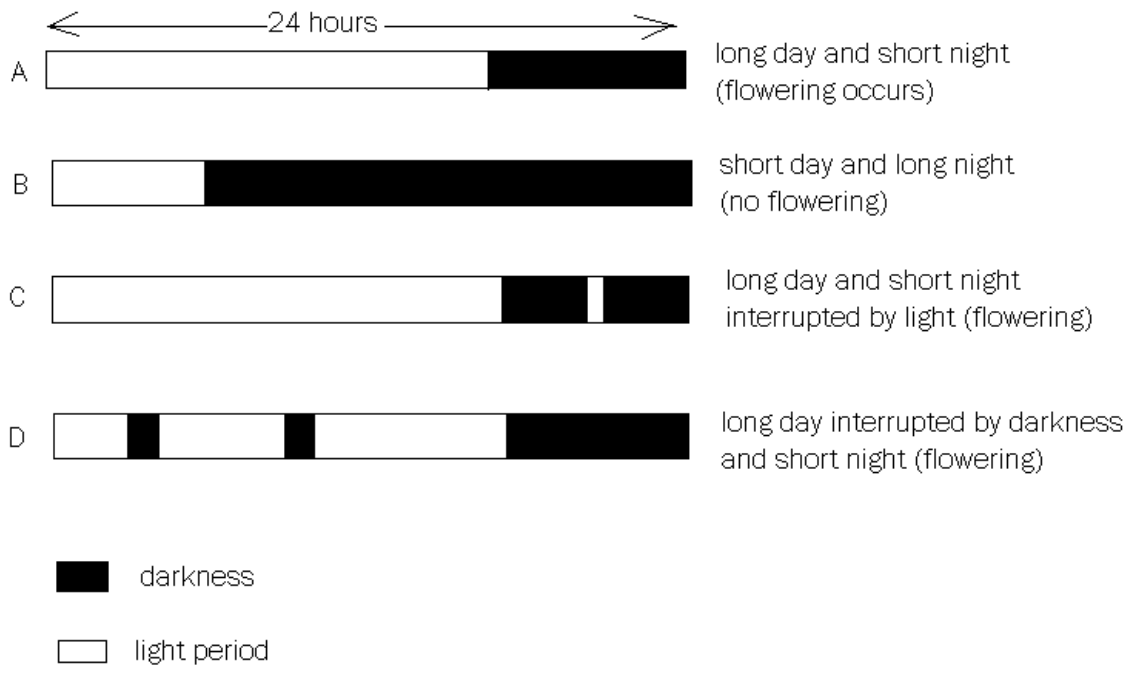


LONG DAY PLANTS.

These are plants which flower only when the light periods exceed the critical period of the night. Examples of such plants include,wheat,barley,lettuce,clover and radish. They have the following characteristics,

- They require long days and short nights.
- They flower only when the light periods exceed a critical period of the night.
- Shorter nights are more essential for flowering than the length of the day.
- They flower even when the short nights are interrupted by flashes of lights but the day remained uninterrupted.
- They show flowering when the long day is interrupted by just brief periods.
- They flower during summer when the days are longer than the night periods.
- Flowering is promoted by high levels of phytochrome far red.

DIAGRAM OF EFFECT OF DAY AND NIGHT PERIODS ON FLOWERING OF LONG DAY PLANTS.



DAY NEUTRAL PLANTS

These are plants which flower after a period of vegetative growth regardless of the changing length of day and the nights. Examples include tomatoes, cotton, and garden pea.

DIFFERENCES BETWEEN SHORT DAY AND LONG DAY PLANTS.

SHORT DAY PLANTS	LONG DAY PLANTS
1.Flowering is induced by longer nights 2.Flowering is inhibited by interruption of the night periods. 3. Uninterrupted longer nights is critical for flowering. 4. They flower in winter. 5. Flowering is promoted absence of Pfr and presence of Pr.	1.Flowering is induced by short nights 2.Flowering is not inhibited by the interruption of the night periods. 3. Shorter nights are critical for flowering. 4.They flower in summer. 5. Flowering is promoted in higher concentration of Pfr than Pr.

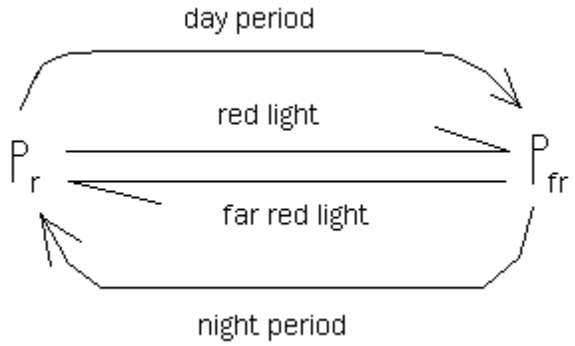
THE MECHANISM BY WHICH FLOWERING IS CONTROLLED IN PLANTS (PHOTOPERIODISM IN FLOWERING PLANTS)

This is controlled by the protein pigments called phyochromes present in the leaves. There are two types of phytochromes. Phytochrome red (Pr) or P_{660} and phyochromes far red (Pfr) or P_{730}. These phytochromes are interconvertible.

During the day, phytochrome red absorbs red light within the wave length of P_{660} nm and it is converted into phytochrome far red (Pfr).

During the night, phytochromes far red absorbs far red light within the wave length of P_{730} and are converted to phytochrome red (Pr).

DIAGRAM SHOWING INERCONVERTION OF PHYTTOCHROM SYSTEMS



In short day plants, the phytochrome far red in the leaves absorbs the far red light during the long night periods and they are all rapidly converted into phytochrome red. The absence of the phytochrome far red causes the florigen precursor to be converted to florigen. The hormone is then transported to the buds and it stimulates the buds to develop into flowers.

In long day plants, the phytochrome red in the leaves absorbs red light during the long day periods and it is rapidly converted into phytochrome far red (Pfr) which is chemically active. The phytochrome far red stimulates the conversion of florigen precursor to florigen which is then transported to buds to induce flowering.

Note: - Pfr is the chemically active form of the protein molecule, whereas the Pr is the in-active form. The absence of Pfr induces flowering in the short day plants, while it's presence in higher concentrations induces flowering in long day plants.

- Gibberellin, auxins, cytokinin, and ethene can also stimulate release of the hormone florigen in the same way phytochromes do.

DIFFERENCES BETWEEN THE EFFECTS OF Pr AND Pfr ON DIFFERENT PHYSIOLOGICAL PROCESSES.

PHYTOCHROME RED (Pr)	PHYTOCHROME FAR RED (P_{fr})
1. Inhibits germination of small seeds.	1. Promotes germination of small seeds.
2. Promotes growth of internodes.	2. Inhibits growth of internodes.
3. Inhibits chloroplast development.	3. Promotes chloroplast development.
4. Inhibits chlorophyll synthesis.	4. Promotes chlorophyll synthesis.
5. Inhibits leaf expansion.	5. Promotes leaf expansion.
6. Promotes lateral root growth.	6. Inhibits lateral root growth.
7. Inhibits flowering in long day plants.	7. Promotes flowering in long day plants.
8. Promotes flowering in short day plants.	8. Inhibits flowering in short day plants.
9. Promotes leaf fall in deciduous species	9. Inhibits leaf fall in deciduous species

VARNALISATION

This is the exposure of a plant to very low temperature requirements to induce flowering. In some plants like perennial and the biennials, the treatment to cold temperatures like 0oC to 4^{o}C from 4 days to 3 months inducing flowering depending on the plant. Varnalisation is also given to meristem and seeds to make their plants flower quickly. During Varnalisation the whole stimulus is received by the shoot apex in mature plants and by embryos in seeds but not by leaves as in Photoperiodism. Varnalisation induces flowering by increasing the gibberellins level.

DIFFERENCES BETWEEN PHOTOPERIOODISM AND VARNALISATION

PHOTOPERIODISM	VARNALISAION

1. Responses of plants to changing length of days and nights.	1. Responses of plants or seeds to low temperature requirements.
2. Perceived by leaves.	2. Perceived by shoot apex in plants and embryo in seeds.
3. Hormone involved is florigen	3. Hormone involved is varnalin.
4. can induce flowering	4. Can not induce flowering but prepares the plant for flowering.
5. Essential for short and long day plants.	5. Essential for short day, long day and day neutral plants.

SENESCENCE AND DEATH.

Senescence is the gradual decline in the normal functioning of an organism leading to it's death.

CHARACTERISTICS OF SENESCENCE

- Continued degeneration of cells occur.
- Chemical changes in protein molecules.
- Increase in metabolic failure.
- Frequent mutation leading to mistakes in protein synthesis.
- There is decrease in functional capacity

TYPES OF SENESCENCE.

1. **Whole plant senescence.**

This is where the whole plant including the stem,roots die at the same time after seed production.eg rice, beans, and maize etc.

Plants like bamboo live for several years but flower only once and then undergoes senescence and death.

2. **Progressive or sequential senescence**.

This is common in perennial plants where the older parts undergo senescence followed next aging and then the whole plant dies.

3.Shoot senescence.

This is where only the part of plant above the ground dies every year and the underground parts surviving and producing a new plant on the on set of favorable conditions eg yams, bananas, irish potatoes.

4.Decidous senescence.

Is where the leaves of the plants are shade simultaneously or at same time. It occurs in temperate decidous trees during autumn.

ADVANTAGES OF SENESCENCE.

1. It allows old and in-efficient organs to be replaced by new, young and developing organs like leaves, buds, flowers and fruits.
2. During senescence more nutrients are directed towards developing buds that need energy while the nutrients are withdrawn from the old aging plants.
3. It leads o to bud dormancy, leaf fall which are adaptations to survive unfavourable conditions like cold winter by reducing the metabolic needs and transpiration.
4. Leave fall brings about recycling of nutrients necessary to maintain growth and development.

BEHAVIOUR

The term behaviour refers to all the activities and responses of an organism as a result of changes in different environmental stimuli. And the study of behavior is generally known as ethnology.

TYPES OF BEHAVIOUR

Behaviour is broadly divided into categories.

(i) Instinctive (innate) behaviour.
(ii) Learned behaviour.

INSTICTIVE (INNATE) BEHAVIOUR

Is an inborn pattern of response or activity to one or more environmental stimuli. It has the following features (X-tics).

- It is inherited and highly specific and inflexible.
- It is an inborn pattern of behaviour and can not be altered.
- Some instinct (innate) behaviour can be modified to some degree in response to past experience.
- It is similar among all the members of the same species (species characteristic behaviour) except for slight differences between males and females of the same species.
- It is unintelligent and often accompanied by no appreciation of the purpose it serves.
- It is highly complex and consists of a chain of actions; the completion of each stage in chain acts as the stimulus for the commencement of the next stage.
- Instinctive behavours have much value in adapting the organism to its environment. Examples of the instinct (innate) behaviour include simple reflexes (reflex action ;) orientation, migration, territorial behaviour, nest building, mating, courtship and parental care.

TYPES OF INSTICTIVE BEHAVIOUR

This is divided into;

(i) Simple reflex (simple action)
(ii) Complex instinctive behaviours.

REFLEX ACTION

A reflex action is a simple act of behaviour in which some kind of stimulus evokes a specific automatic and short lived response. Reflexes are the simplest innate behaviour. Most reflexes are coordinated in the spinal cord and are known as spinal reflexes e.g. the knee Jerk. Withdrawal of hand from hot objects. Reflexes controlled through the brains are called cranial reflexes e.g. blinking of the eye. The escape response of the earth worm is an example reflex action in lower animals.

ORIENTATION

It is a simple behaviour pattern of lower organisms in response to specific environmental stimuli. Orientation response is important in the natural environment in that; it enables organisms to move towards desirable stimuli and away from harmful one. I.e. Flagellates are guided towards light; animals towards food parasites towards their hosts and spermatozoa towards the females eggs. Examples of orientation response include;

- Kinesis.
- Taxis.

KINESIS

Is a response or behavioral pattern exhibited by a lower organism in response to un-pleasant non-directional stimulus. The direction of the response is not dependant on the direction of the stimulus but its intensity. This kind of behaviour is seen in wood lice if wood lice are placed in a "Choice-chamber" half of which has a humid atmosphere and the other half a drier atmosphere; the animals move much faster in the dry half than the humid half on the humid side. Note in kinesis the animal does not move towards or away from the stimulus but instead it simply moves faster and changes direction when subjected to un-pleasant stimulus.

TAXIS

Is the movement of a whole organism in response to directional stimulus. In this case the organism orientates it self with respect to the source of the stimulus if an organism moves towards the stimulus it is positively tactic, while moving away is a negative taxis examples of taxis include. Swimming of euglena, and other green flagellates towards light (phototaxis) and movement of spermatozoa towards chemical substances secreted by eggs (chemotaxis).

COMPLEX INSTINCTIVE BEHAVIOURS

MIGRATION:

Is the movement of the whole population of species of organisms from one region to another

and their return to the habitat of origin at some other time. Examples of migratory behaviour are seen in salmon fish which migrates to the fresh water streams to breed, and returns to the sea for normal life. The young ones on attaining maturity also migrate to the sea. Many species of birds migrate between the North Pole in Europe and the south pole in South Africa or South America to escape un favourable winter seasons.

Migration in animals is said to be triggered by some stimulus in the environment such as changes in the day length; decreased temperature; food scarcity etc.

ADVANTAGES OF MIGRATION

(i) Provide better chances of finding better food supplies.
(ii) Provides better chances of finding good breeding grounds, such breeding grounds with enough food and without predators.
(iii) Allows the organism to avoid unfavorable environmental conditions.

The migrating animals find their route by any one of the following means.

- They follow prominent natural features like mountains ranges and water bodies.
- They orientate themselves in relation to the position of the sun.
- They have an in-born ability to sense direction e.g. homing ability of the pigeon.

TERRITORIAL BEHAVIOUR (TERRITORIALITY)

A territory is an area of the habitat which is occupied by an individual or group and defended from others of the same species. Most territories are defended for breeding purpose by use of passive means like.

- Urinating around it.
- Defecating around it.
- Use of other forms of signals like posture, odour etc.
- Use of specific sound.

IMPORTANCE OF TERRITORIAL BEHAVIOUR TO SURVIVAL OF ORGANISMS

(i) Provides defence of an area in which organisms live against other organisms of the same species.
(ii) The mating pair of organisms of the same species and their offspring's are well spaced to receive the available resources e.g. food, space etc.

(iii) The available resources are protected and shared amongst the population.

(iv) The species protect and achieve maximum utilization of the habitat

(v) Actual fighting between organisms which would be detrimental to the species is quite rare and replaced by mere threats.

(vi) Intraspecific competition is reduced.

(vii) Population growth is controlled.

(viii) They limit mating to only fit individuals and hence increase the over all fitness of the population.

(ix) They prevent epidemics since contact between very many animals is reduced.

(x) They permit improved defense of nest and the young ones.

DISADVANTAGES OF KEEPING TERRITORIES

(i) They limit the population density that can be attained in an area.

(ii) They may encourage in –breeding where it is possible among the organisms. This carried along the disadvantages of reduced biological fitness.

(iii) The sounds produced and some postures exhibited by animals in defence of their territory may easily expose them to their predators.

(iv) Animals are over restricted within an area; this may encourage spread of diseases.

(v) The weak individuals are denied chances of breeding and can not propagate some of their could be good genes, since only fit individuals are allowed to mate.

REPRODUCTIVE BEHAVIOUR

This is complex form of innate behaviour involving both pre-copulatory and post natal (birth) behaviours. The examples include;

(i) Courtship.

(ii) Parental care.

COURTSHIP BEHAVIOUR

Is a form of innate behaviour between male and female organisms which occurs before mating which eventually leads them to mate (copulate).

IMPORTANCE OF COURTSHIP BEHAVIOUR TO ORGANISMS

(i) It stimulates organism to sexual activity.

(ii) It synchronizes gonad development; enabling gametes to mature at the same time to

ensure fertilization occurs when mating takes place.

(iii) It strengthens the bond between mating pairs.

(iv) It leads to rise in levels of reproductive hormones.

(v) It synchronizes time to produce offspring in right seasons.

(vi) It induces mating of individuals who accept each other.

(vii) It ensures that mating occurs between sexually mature individuals.

(viii) It permits both parents to show same parental care to the young.

(ix) It suppresses other tendencies like the avoidance of body contact escape behaviour and even mate cannibalism e.g. in spiders.

PARENTAL CARE

Are the activities a parent animal does to ensure the survival and development of its young ones. Parental care is mostly developed in the higher animals; the birds and mammals. In birds it involves activities like feeding; warming; watering; nesting, protection against predators etc of the young.

In mammals it involves training the young on how to recognize predators find food and escape from danger.

In man, the highest form of parental care is exhibited; it involves cultural transmission and language. Parental care is instinctive and does not decrease as the animals mature just as reproduction. The activities associated with the parental care are of evolutionary significance for they ensure the survival of the species.

ADVANTAGES OF PARENTAL CARE TO ORGANISMS

(i) It strengthens the love bond between the parents and their offspring's.

(ii) It protects the young offspring's from predators.

(iii) It promotes the survival of the young offspring's until they reach maturity. This ensures continuity of the species.

(iv) During parental care, the young animals learn from their parents some behaviourial patterns of the species such as search for food. Feeding and recognition and escape from predators.

The instinctive (innate) behaviours (species characteristics behaviour) depend on stimuli and motivation.

TYPES OF STIMULI

There are three kinds of stimuli;

- Motivational stimuli.
- Releasing stimuli (releasers)
- Terminating stimuli.

MOTIVATIONAL STIMULI; are those changes in environmental conditions which determines the animals state of responsiveness e.g. temperature, light, smell.

Releasing stimuli (releasers) Are features of the environment. (Specific stimuli) which cause/elicit particular responses when the animals encounters them.

Terminating stimuli; are those features of the environment (stimuli) which bring an act of behaviour to an end.

In feeding behaviour, the smell of the food act as a motivational stimulus since they raise the animals' state of responsiveness while the sight of the food may act as a releasing stimulus, unleashing feeding behaviour and a full stomach may act as a terminating stimulus bringing feeding behaviour to an end.

In general, a releaser is any feature of the environment which can be shown to evoke a behaviourial response in courtship; the releasers may be features of an individual such as colour, shape or particular markings.

To respond to a specific stimulus, there must be a mechanism in the receptors or brain which filters out the relevant features of the stimuli from the irrelevant ones. This is referred to as stimulus filtering mechanisms.

THE FUNCTIONS OF RELEASERS

They serve as signals initiating appropriate behaviour and coordinating interactions between different individuals. This avoids open conflicts. E.g. in territorial behaviour the aggression involves a threat display by the aggressor, which intimidates a rival encroaching upon the animals' territory or its male; the rival accepts defeat and departs or may show appeasement display. E.g. in dogs.

In sexual reproduction releasers are important in changing an animal's normally aggressive behaviour to sexual behaviour. E.g. in spider the male waves its pedipalps to the aggressive female; this changes the female's behaviour from predatory to sexual.

It is also important to bring one act of behaviour to an end and sometimes the same stimulus may start another act of behaviour. Example in blood sucking bugs, the muscular abdominal pump stops operation, and sucking ceases when the pressure of blood in the abdomen reaches certain critical level. In mammals, a full stomach causes mechanical stretch which brings feeding to an end.

MOTIVATION:

Is the term used to describe the internal or physiological state which stimulates an act of behaviour. It results from the animal's internal physiological state such as levels of different hormones in the body. This is in turn determined by motivational stimuli such as temperature and light. E.g. in certain birds sexual behaviour in spring is brought about by increasing day-length (Photoperiodism) i.e. the eyes receive the light stimulus, which is transmitted to the brain; reaches the pituitary gland which secretes gonadotrophic hormones, the gonads are also activated to produce sex hormones, including reproductive behaviour. Courtship and mating in the stickle back only takes place in the spring when the female's sex urge reaches its height as a result of various environmental and physiological conditions.

PHEROMONES

A pheromone is a chemical substance produced by one animal which influences the behaviour of another animal. The best known pheromones are the secretions of mammals. The importance of pheromones to different animals include;

- In mammals they are important in marking out territories.
- Used in attraction of mates e.g. un mated female cockroaches secrete a chemical substance from the surface of their body which stimulates males to court them.
- They are also responsible for bringing the different sexes together in insects, marine worms etc.

In social animals like bees, they play an important part in directing the development and

behaviour of different castes in the colony. E.g. Pheromones produced by the queen bees called queen substance prevent workers from building queen cells in which a new queen would be received.

Pheromones also serve as releasers or build up motivation towards a particular type of behaviour.

THE ROLE OF HORMONES ON BEHAVIOUR

Hormones are involved in the building up of motivation and therefore it influences behaviour in the following ways.

(i) Hormones affects the growth of nervous connections in the brain.
(ii) It may alter the sensitivity of peripheral receptors. Example in rats, the male hormone enhances sexual behaviour by raising the sensitivity of the penis.
(iii) They may enhance or suppress the performance of effectors e.g. hormones may cause degeneration of a muscle; there by preventing a particular response.
(iv) Hormones may directly affect nerve cells and synapses within the central nervous system. This may block inhibitory or open up excitatory pathways.

Note: The specific region of brain which is influenced by hormone, leading to a particular behavioural pattern in organisms is the hypothalamus.

DISPLACEMENT ACTIVITY

Displacement activity is where an animal which is in state of stress or frustration will perform behaviour which is out of context or irrelevant or performs a behaviour in a wrong situation to try and ease the anxiety developed. For example two birds that are fighting may suddenly begin to peck at the ground. In humans when in tense situation we perform displacement activities such as stroking the fore head, scratching an ear, or walking up and down; after quarreling with a wife a man can resort to smoking cigarettes or drink alcohol.

There is another kind of displacement activity called the vacuum activity. This is when an animal is frustrated its motivation builds up but no sign stimulus is provided to release the

appropriate behaviour as a result it performs in the wrong situation. For example a cock deprived of a mate will display courtship behaviour to another object such as a bucket. A bird goes through motions of building a nest even if there is no nest materials available.

Displacement activity serves a useful purpose of preventing open conflict. It is also revealed that much of the courtship behaviour evolved from the displacement activities arising from frustration. This occurs when the males sexual motivation builds up but can not be released until the appropriate signal is given by the female so some of his sexual motivation is channeled into forms of behaviour which constitute courtship.

LEARNED BEHAVIOUR

Learned behaviour is behaviour which is acquired and modified in response to the past experience where as learning is defined as an adaptive change in behaviour resulting from past experience.

FEATURES X-TICS OF LEARNED BEHAVIOUR

(i) They are not inherited but acquired during life time of an individual
(ii) Learned behaviour tend to vary from one individual to another. Therefore not common among all members of the same species.
(iii) They are adaptable i.e. The learned bahavour can be modified if the environment changes.
(iv) Some learned behaviour are species specific and can not be altered once established, while others are very flexible.

TYPES OF LEARNING

Learning may be classified into five categories.

(i) Habituation.
(ii) Associative learning.
(iii) Imprinting.
(iv) Exploratory learning.
(v) Insight learning.

HABITUATION.

This is where an animal gradually stops or ceases to respond to repeated stimulation. It is the

simplest form of learning behaviour it is believed that habituation is caused by synaptic accommodation. An example of habituation is when a fan worm jerks back into their tubes when touched but when the tentacle is repeatedly stimulated the worm quickly stops reacting. This implies that habituation enables organism to ignore stimulus in the environment which is neither harmful nor beneficial e.g. wind.

ASSOCIATIVE LEARNING.

Is a type of behaviour where an animal learns to associate a particular response with reward or punishment (A response to two stimuli presented together). In associative learning the animal remembers its past experiences and modifies its behaviour accordingly. Its carried in the nervous system, below the level of the conscious part of the brain. There are two basic forms of associative learning

(i) The conditioned reflex.
(ii) Operant conditioning (trial and error learning).

THE CONDITIONED REFLEX

A conditioned reflex is shown by a classical experiment performed on dogs by Ivan pavlov.
In his experiment, Pavlov allowed dogs to hear the sound of a bell and observed that the dogs did not salivate at all.
He then presented the dogs with the taste of powdered meat and measured quantity of saliva produced. In another instance, he presented the powdered meat and immediately rang the bell. This was repeated many times.
He later, rang the bell alone without presenting meat and he observed that the dogs salivated in response to it, implying that the dogs had learned to associate the bell with food. He called the new stimulus (the bell) as conditioned stimulus and the response a conditioned reflex if however the bell is rang a lone without presenting of the food several times. It leads to reduction in quantity of the saliva produced until the conditioned stimulus failed to produce any conditioned response.
Conditioned reflex is also important in the wild in that predators learn to associate unpalatable animals with certain markings or coloration and will thus avoid eating them. In this way maximum rewards are obtained and punishment is avoided.

FEATURE OF A CONDITONED REFLEX

(i) It is the association of two stimuli presented together.

(ii) It is a temporary condition.
(iii) The response is involuntary.
(iv) It declines without repetition.
(v) Removal of the cerebral cortex causes loss of the response.

TRIAL AND ERROR LEARNING

Is a type of associative learning in which an animal learns by trying out several options, some right while others are wrong until it they solve the problems. It is also a type or conditioning though it differs from Pavlov classical conditioned reflex in the way that, it becomes established. It is called operant conditioning. Trial and error learning is confined to animals with well developed brains. In trial and error experiments, it is common that the animal is provided with a " choice" it is punished if it makes the wrong choice and it is rewarded if it makes a right choice For example suppose that a hungry dog is allowed to roam about the room. But as soon as it jumps onto certain chair, we reward it with food. The dog is observed to immediately go to the chair as soon as it enters the room. In this case the dog has learned to associate a reward with its own behaviour but not with other stimuli.

In another experiment, a rat is placed at the entrance to a complicated maze which has an empty food box at the other end. In the first trial the rat makes numerous blind routes as it traverses the maze. The rat is rewarded with food when eventually it reaches the end. In subsequent trials it makes fewer and fewer mistakes and gets through the maze and reaches its end much quicker until eventually it makes no mistakes at all.

The ability of an animal to learn by trial and error is reflected in three things;

- The speed with which it ceases to make errors.
- The length of time it can remember without repeated trials.
- The complexity of the situation to which it responds.

AGRAPH SHOWING THE RESULT OF MAZE LEARNING BY A RAT

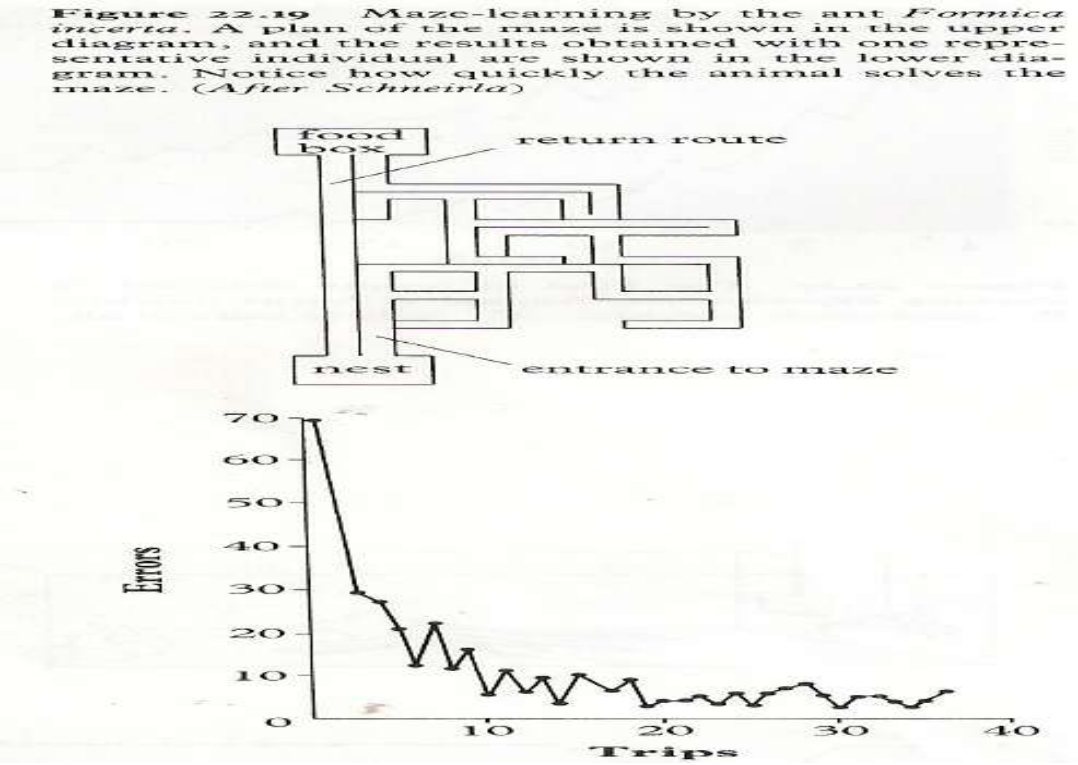


Figure 22.19 Maze-learning by the ant *Formica incerta*. A plan of the maze is shown in the upper diagram, and the results obtained with one representative individual are shown in the lower diagram. Notice how quickly the animal solves the maze. (*After Schneirla*)

GRAPHS SHOWING THE RESULTS OBTAINED IN DIFFERENT LEARNING EXPERIMENTS.

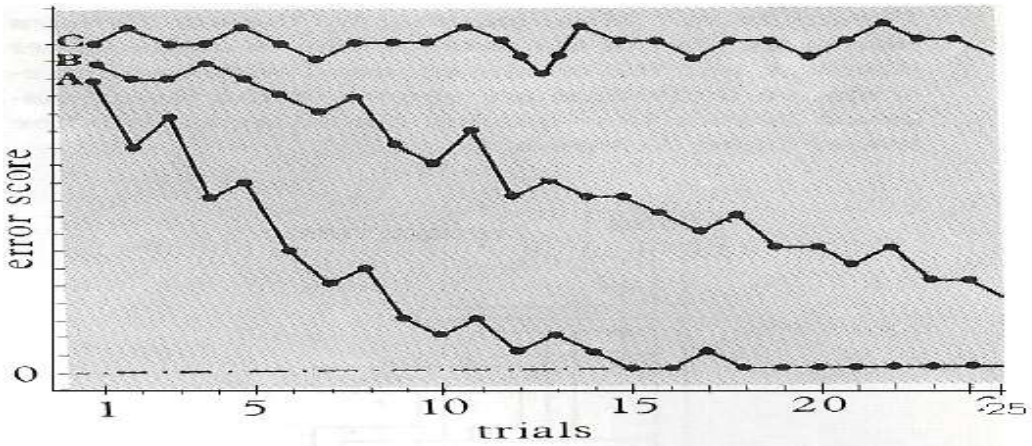


Figure 22.17 The kind of results obtained in learning experiments. Animal **A** learns quickly; **B** moderately quickly; **C** fails to learn at all.

Animal A learns quickly B moderately quickly and C fails to learn at all.

FEATURES OF TRIAL AND ERROR LEARNING

(i) The associative stimulus follows the action and the two are not necessarily simultaneous.
(ii) Repetition improves the response.
(iii) The action is involuntary.
(iv) It is temporary, but the association is less easily removed than in conditioned reflex.
(v) Removal of the cerebral cortex does not cause loss of the response.

The factors that affect learning of a new situation include the following,

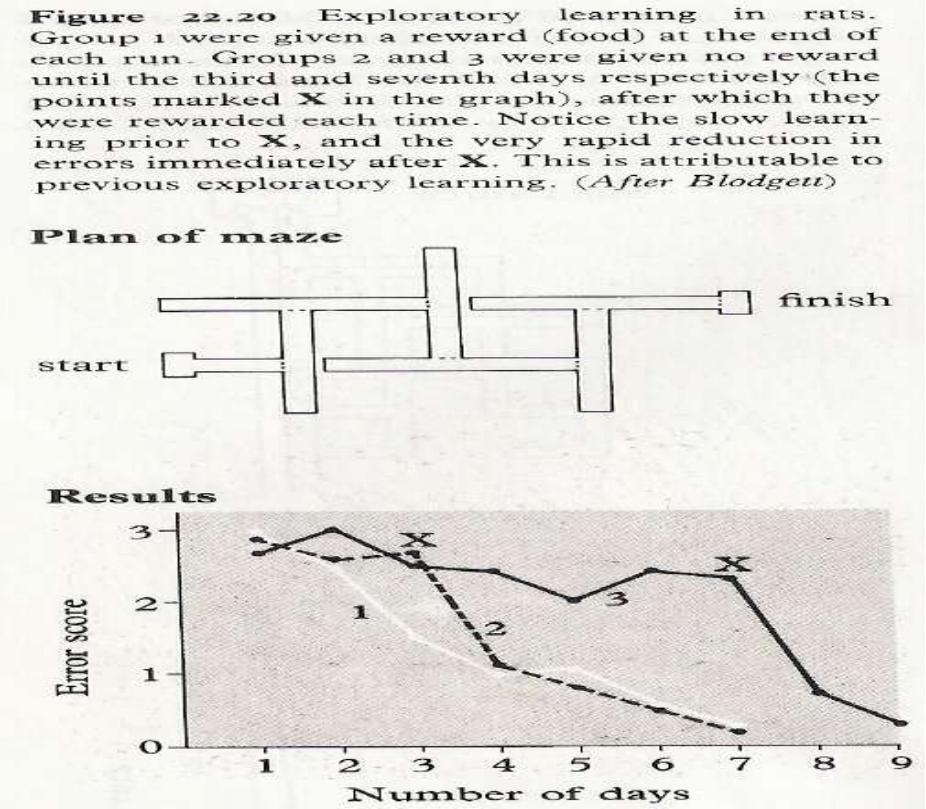
- Complexity of the situation eg. The maze.
- The type of motivation or reward, this is the readiness to learn.
- The level of development of the brain or spinal cord (Central Nervous System).

Note: (Read and make notes on the neutral and a biochemical theory of learning Functional App. P9 361

EXPLORATORY LEARNING (LATENT LEARNING)

This arises when an animal stores information while exploring its environment and uses it at some later time. Exploratory behaviour is important in the lives of many animals for it enables them to find their way out of their environment. Example a rat placed in a maze with no reward as a stimulus will later complete the maze, when a reward is present more rapidly than a rat which has never been in the maze.

EXPLORATORY LEARNING IN RATS.



Groups 1 were given a reward (food) at the end of each run. Groups 2 and 3 were given no reward until the third and seventh days respectively (the points marked X in the graph) after which they were rewarded each time.

It is noticed that there is slow learning prior to the X. This is attributable to previous exploratory learning.

IMPRINTING

This is where young animals tend to follow their parents. Unlike other forms of learning imprinting behaviour is fixed and not adapted. For example the young geese follow that first thing they see after they are born generally, this first objects they see is their mother but they can follow any other objects.

Imprinting is important in many ways which include;

- It permits the newly born young ones to be under full parental protection for their survival.

- It is used in training of animals for circus.
- It is applicable in psychiatry.

INSIGHT LEARNING

It is the immediate comprehension (understanding) and the response to a new situation without trial and error. It involves mental reasoning, intelligence. Insight learning is the highest form of learning. For example chimpanzees will acquire bananas fixed to the roof of their cage by piling up boxes upon which they can climb to reach them. In the same way sticks may be joined together to form along pole which is used to obtain bananas which is out of reach outside the cage. Insight learning is important to organisms in the following ways;-

- It enables organisms to sense danger easily and escape from it.
- They develop abilities to use tools.
- They improve the ability to solve problems not encountered before.
- Ability to change environment to its favour.
- Organisms become highly adaptable to change in environmental conditions.
- It leads to development of ability to get solutions to problems instantly (very fast).

SOCIAL BEHAVIOUR

Is where groups of organism of the same species live together and is completely dependant on one another for their survival. The organisms adapt their behaviour towards the interest of the group but not of an individual.

In social behaviour, there is the establishment of a social hierarchy (pecking order). This is where each individual has its own fixed status and role within the group. Example in boney bee colony, there is a caste system which consists of a queen which is the single fertile female; the remaining females are the workers which are all sterile. All the males are called drones and are fertile.

Honey-bees demonstrate complex social cooperation particularly in times of foraging for food. The worker bee returning from foraging mission reveal the location of food sources to other workers using communicate the direction of the food source from the hive and its distance away. These are two forms of the dance;

(i) A round dance performed if the food source is within 100m of the hive. But does not

indicate direction.

(ii) A waggle dance; is performed if the food source is greater than 100m.

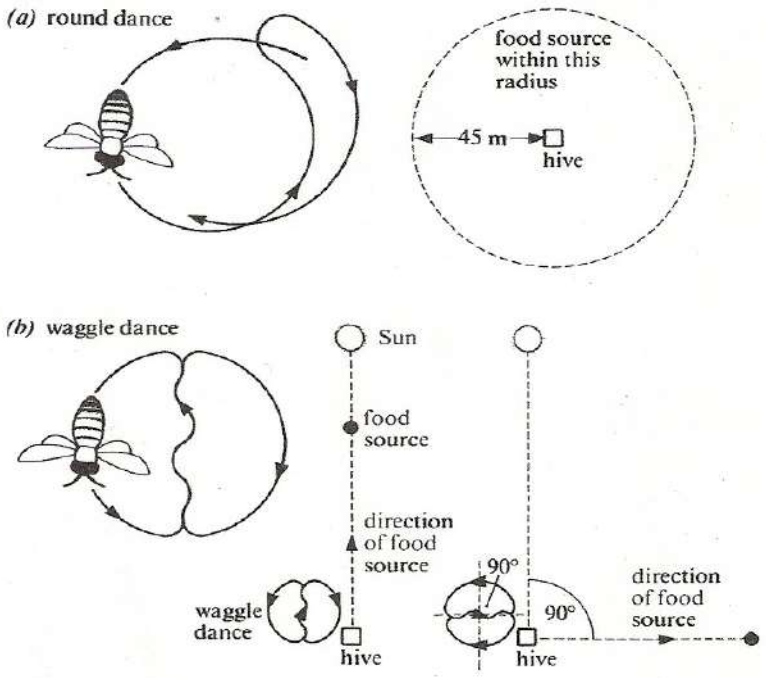
In both dances the speed at which it is performed is inversely proportional to the distance away from the hive that the food lies.

In the waggle dance the worker bee moves in an eight figure pattern, waggling its abdomen as it does so. The waggle part of the dance occurs as it moves a long the line between the two loops of the figure of eight. The number of waggles gives some indication of the quantity of food discovered the angle of the waggle relative to vertical angle to the sun gives the direction of the food source from the hive. However during a cloudy day. The bees are able to locate the position of the sun using the p lane of the polarized light penetrating the cloud. This is further assisted by the internal biological clocks existing in the bees permitting them to have the continually changing picture of sun's movement during the day.

The advantages of asocial group include;

- Increases chances for locating food.
- Provides better protection against predators.

ROUND AND WAGGLE DANCES OF THE HONEY BEE



ALTRUISTIC BEHAVIOUR (ALTRUISM).

Is the behaviour or activities carried out by one organism so as to promote the survival of other organisms of the same species, some times at the expense of its own life. Examples include, parental care to their young ones, defence of the bee hive and the queen by the worker bees. This behaviour ensures the continuity of the species in the population and the continuous transmission of their genes to the next generations.

RHYTHMICAL BEHAVIOURS

This is where animals carry out activities at regular intervals irrespective of the season or day length. They are described as time biology since they tend to indicate existence of biological clocks within the animals or organisms. Rhythms that are controlled by biochemical and physiological changes within the organisms are called endogenous rhythms. This involves nervous and endocrine system in animals. Rhythms that are controlled by external changes such day lengths (Photoperiodism) are called exogenous rhythms. Annual rhythmical behaviours include,

- Breeding seasons.
- Biannual migrations.
- Annual hibernation.
- Daily (circadian) rhythms.