COORDINATION.

Coordination is the ability to make an appropriate response to a stimulus. Implying that it is 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 mammals there are two major systems that convey information,

- Nervous system.
- Hormonal system.

- **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 of 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 STRUCTURE AND FUNCTIONS OF THE NERVOUS SYSTEM.

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 ACCORDING TO THE STIMULI THEY RESPOND TO.

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.

Mechano-receptors.

These receptors detect stimuli such as touch, sound, pressure, stretch and gravity inform of mechanical energy.

Photo-receptors.
These receptor detect light inform of electromagnetic energy.

Thermo-receptors.
Are receptors that detect changes in temperatures inform of thermal energy for example receptors located in the skin sensitive to warmth and cold.

Electro-receptors detect electricity inform of electro-magnetic fields e.g. in some fish

● **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 receptors on carotid sinus.

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 outside of the membrane of the receptor has more positive charges while the inside of the membrane has 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 is also called cat ions pump, it 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, At the same time, the membrane remains impermeable to outward flow of negative ions, this causes the outside of the membrane to become 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, at a threshold pores called sodium gates open in the membrane and allow a flood of sodium ions inside the cell 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. When action potential reaches its peak, the sodium gates close and no more sodium ions enter. Nerve impulse is then transmitted through sensory neurones to the central nervous system.

THE RESTING POTENTIAL.

Is the negative potential difference of about -70mV that exists across a membrane of receptors or neurons when they are at rest, while the outside of the membrane is more negative and the inside of the membrane is more negative (membrane is polarized).

The resting potential is the result of the distribution of four ions, potassium ions (K^+), sodium (Na^+), chloride(Cl^-) and organic ions (COO^-). Initially the concentration of potassium and organic anions (COO^-) is higher inside the neurone or sense cell, while the concentration of sodium (Na^+) and chloride ions is higher outside.

The membrane is considerably more permeable to potassium (K+) than any of the other ions. So, potassium ions diffuse rapidly outside.This outward movement of positive ions means that the inside becomes slightly negative relative to outside, resulting into an electrochemical gradient. As more potassium ions move out, in time an equilibrium is reached, at this time the rate at which potassium ions leave exactly balances with the rate of its entry. It is there fore the electrochemical gradient of potassium ions which largely creates the resting potential. However the sodium potassium pump mechanism also plays role in maintaining the resting potential.

CHARACTERISTIC FEATURES COMMON TO ALL RECEPTORS

● They transform stimulus energy into action potential. They are biological transducers.

●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.

● 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.

● 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.

● **Adaptation in receptor cells.**
This is where receptors initially respond to strong and repeated 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.

● They show precision by being able to transmit the precise and detail of information about the stimulus e.g. the eye will provide information about the intensities, duration, colour and source of light at the same time.

● 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.

● Each receptor neuron end into dendrons and dendrites.

● 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,

Sensory cells with variable 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.

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. This is because such receptors show summation.

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.

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.

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/buccal cavity.

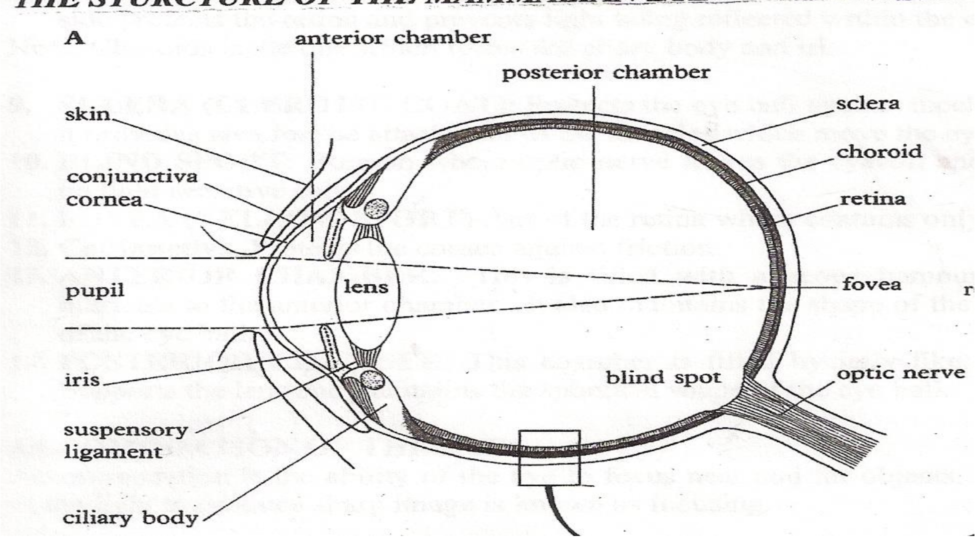
THE EYES AND RECEPTION OF LIGHT

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.

THE STURCTURE OF THE MAMMALIAN EYE



Assignment
Describe the functions of the different parts of the mammalian aye.

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,

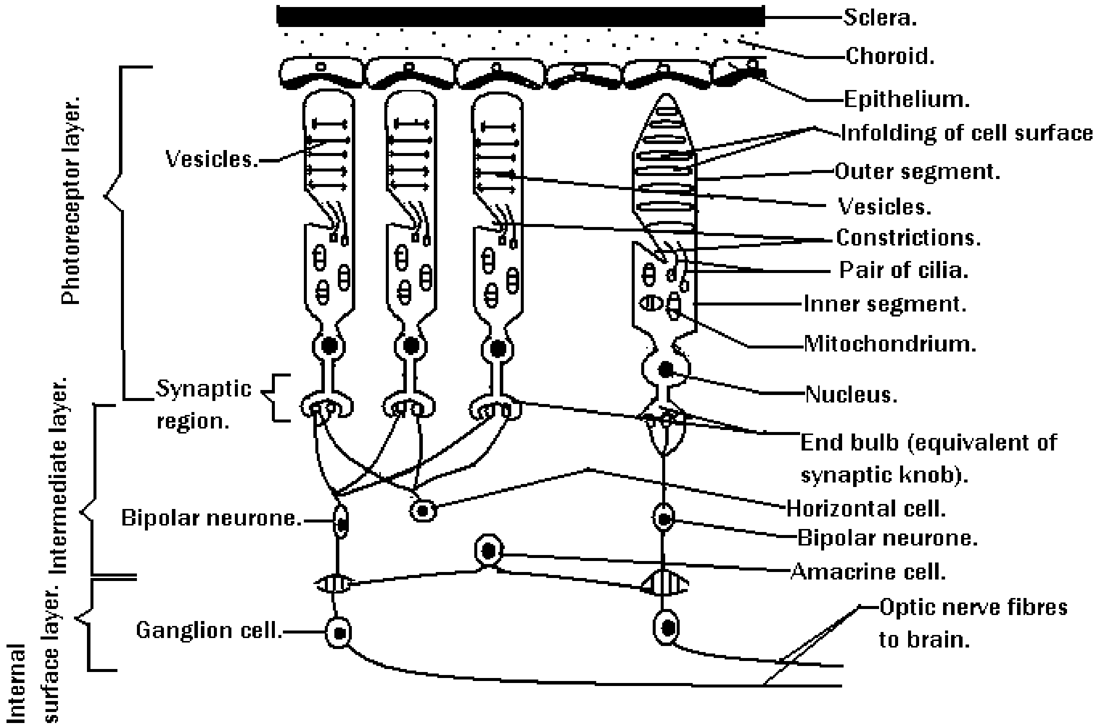
• **Outer segment**.
The outer segment is made up of flattened membranous vesicles containing photosensitive pigments. Cones have fewer vesicles than the rods. In cones the outer segment is cone shaped and contains iodopsin, while in rods it is rod shaped and contains Rhodopsin.

• **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**
▪ Are more concentrated in the eye. ▪ Are evenly distributed except at fovea. ▪ Have outer segment rod shaped.	▪ Are less concentrated in the eye. ▪ Are tightly packed at fovea. ▪ Have cone shaped and sometime pyramidal outer segment.
▪ Are relatively smaller. ▪ The light sensitive pigment is rhodopsin, ▪ Light sensitive pigment occurs in one form only.	▪ Are relatively larger. ▪ The light sensitive pigment is iodopsin. ▪ Light sensitive pigment occurs in three forms.
▪ Light sensitive pigment is affected by light of low intensities. (i.e. for night vision)	▪ Light sensitive pigment is affected by light of high intensities (i.e. for day vision)
▪ Do not distinguish colours. ▪ Show retinal convergence (i.e. synapse with bipolar neuron occurs in groups)	▪ Distinguish colours. ▪ Do not show retinal convergence (i.e. synapse with bipolar neuron occurs individually.
▪ Are more sensitive to light. ▪ When broken their regeneration processes is faster.	▪ Are less sensitive to light. ▪ When broken their regeneration is slower

SIMILARITIES BETWEEN RODS AND CONES.

- Both have light sensitive pigments in the outer segment.
- In both the outer and inner segments are separated by a constriction.
- In both the cytoplasm of the constriction contain a pair of cilia.
- In both the inner segment contain numerous mitochondria, nucleus and other organelles.
- Both are connected to a bipolar neurone.
- In both the light sensitive pigments are bleached by light energy.
- Both are found on the Retina of the eye.
- Both have vesicles in the outer segments containing light sensitive pigments.

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.

MECHANISM 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.

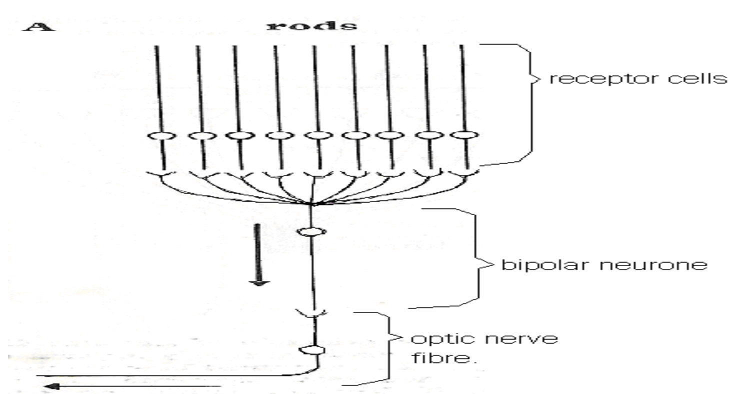
During the day, most of the rods are bleached and this is why it takes a person some time to see after moving into the a dark place from a well lit one because it takes some brief moment for the Rhodopsin to get resynthesised from its constituents protein scotopsin and free retinene and the iris too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

WHY RODS ARE MORE SENSITIVE THAN THE CONES.

▪ 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.
▪ 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 in cases 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.

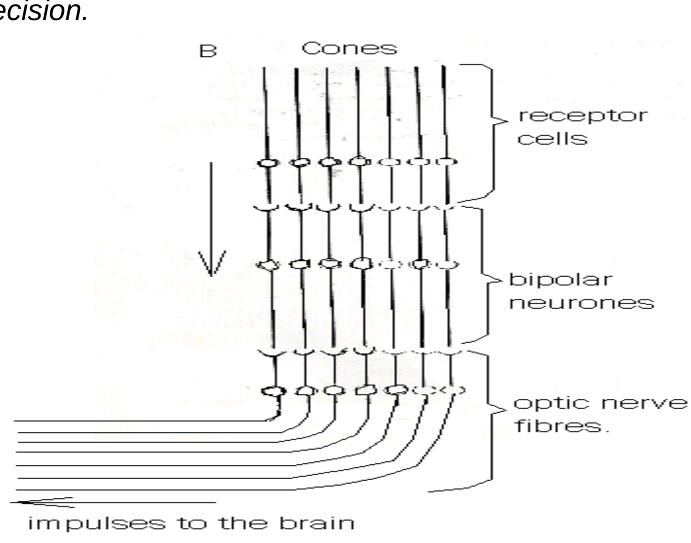
PRINCIPLE OF PRECISION AND VISUAL ACUITY ILLUSTRATED BY CONES IN RETINA OF EYE:

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 horizontal cells receive stimuli of exactly equal intensity from two Rods, they cancel out (inhibit) the stimuli. This enhances contrast between weakly stimulated areas and those strongly stimulated. This makes features such as edges of objects stand out more clearly.

Amacrine cells are stimulated by bipolar neurones that 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. This is because there are three types of cones present in the Retina of the eye, each cone has different light sensitive pigment called iodopsin with maximum light absorption within the red, green and blue cones. When iodopsin absorp light of particular wave length they are bleached and the cones are stimulated when a threshold value is reached.

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 of the three different types of red, green and blue cones present in the retina of the eye.*

Maximum 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 is 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.

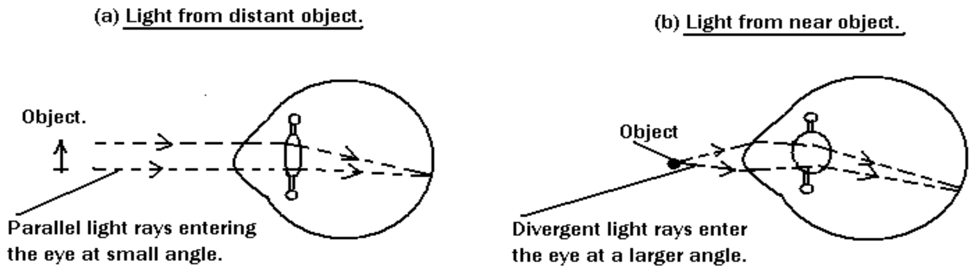
TO FOCUS DISTANT OBJECTS:

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.

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

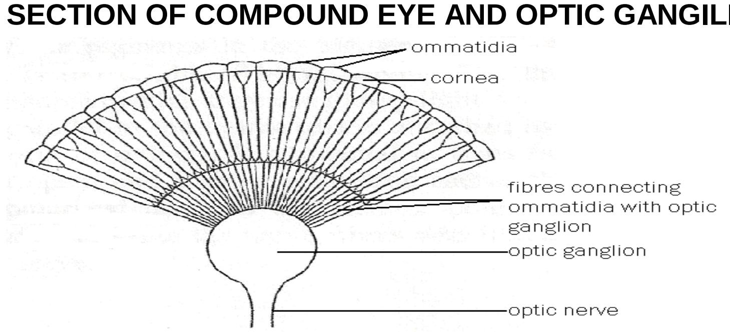


STRUCTURE AND FUNCTION OF THE COMPOUND EYE.

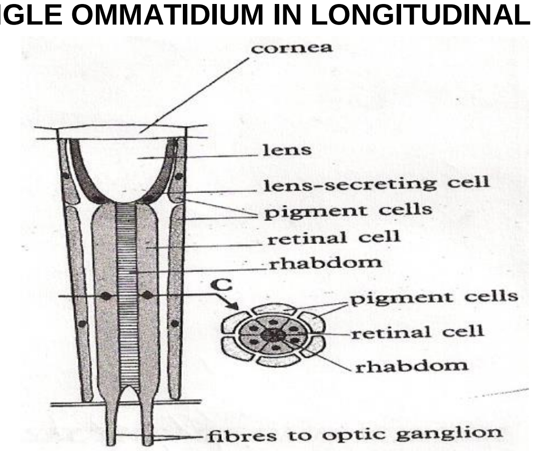
STRUCTURE OF THE COMPOUND EYE.

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.

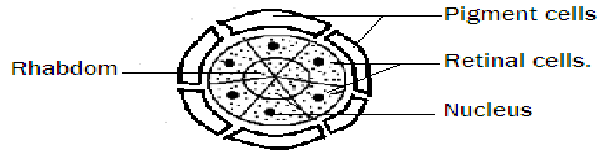
VERTICAL SECTION OF COMPOUND EYE AND OPTIC GANGILION.



STRUCTURE OF A SINGLE OMMATIDIUM IN LONGITUDINAL SECTION:



TRANSVERSE OR 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.

ASSIGNMENT

Give structural and functional similarities and differences that exist between the mammalian eye and the compound eye.

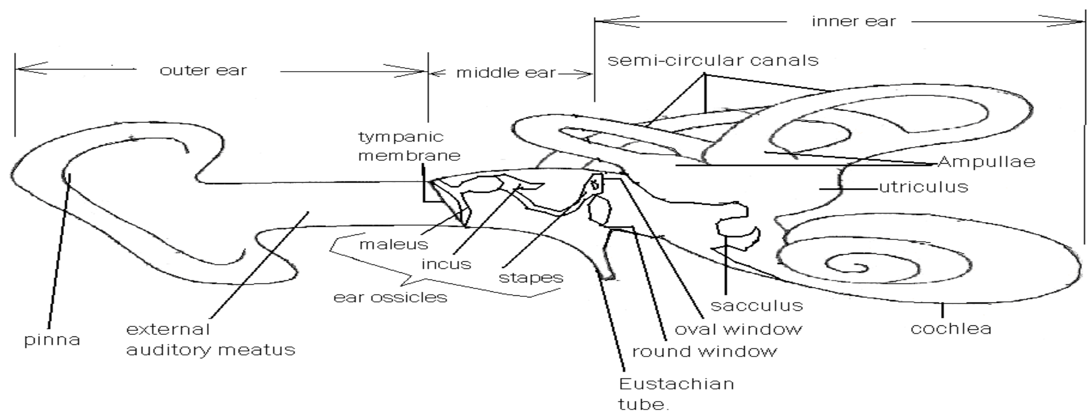
SOUND RECEPTION IN THE MAMMALIAN EAR

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.

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



FUNCTIONS OF THE PARTS OF THE EAR:

Pinna: Receives and concentrates sound wave. It is lobbed.

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.

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.

Ear ossicles

Transmit sound vibrations from the eardrum to the oval window. and through the ear ossicles which are held in position by muscles.

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.

Oval window

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

Round window

Equalizes fluid pressure in the cochlea.

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

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

Cochlea

Contains sound receptors

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.

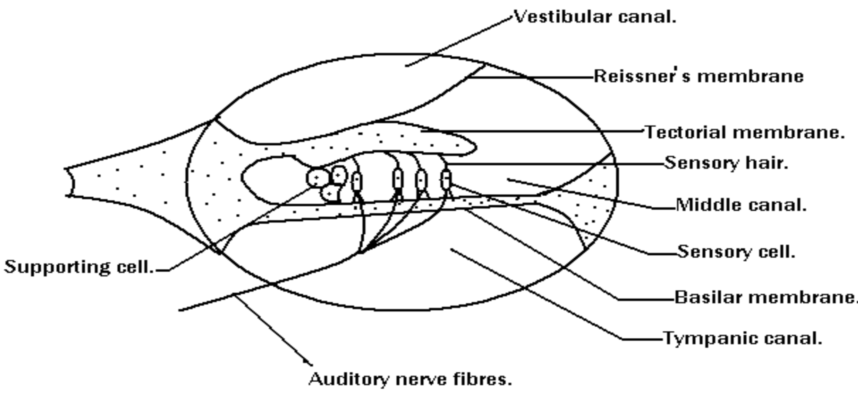
THE MECHANISM OF SOUND PERCEPTION (HEARING)

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:

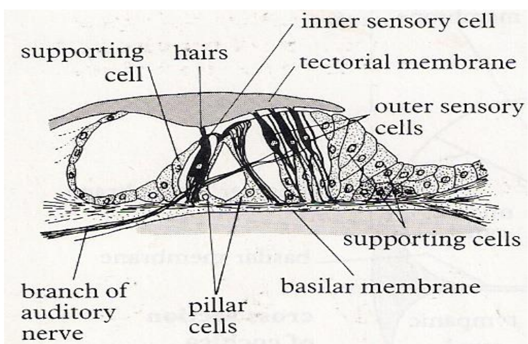
(i) Sensory hair cells (receptor cells)
(ii) Supporting cells.
(iii) Tectorial membrane.

(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.

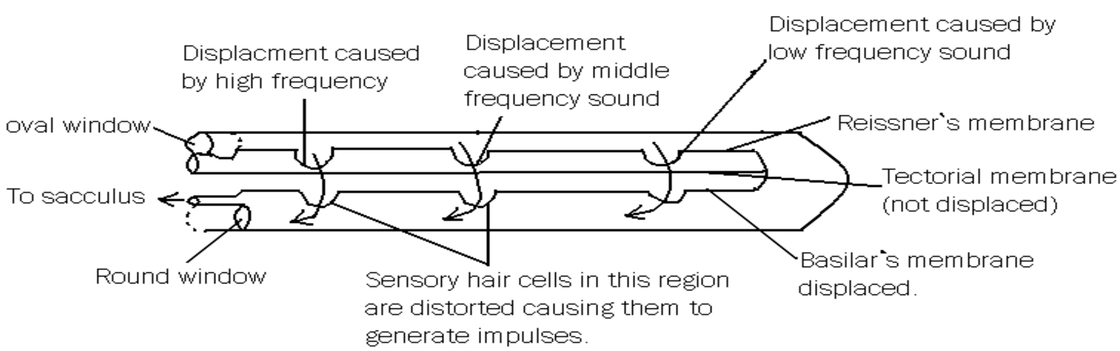
DETERMINATION OF PITCH, TONE AND INTENSITY OF SOUND.
Sound travels as waves and the distance between identical points on these waves is known as the wave length. The longer the wave length the lower the frequency, the shorter the wave lengths, the higher the frequency. The frequency of sound waves is 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

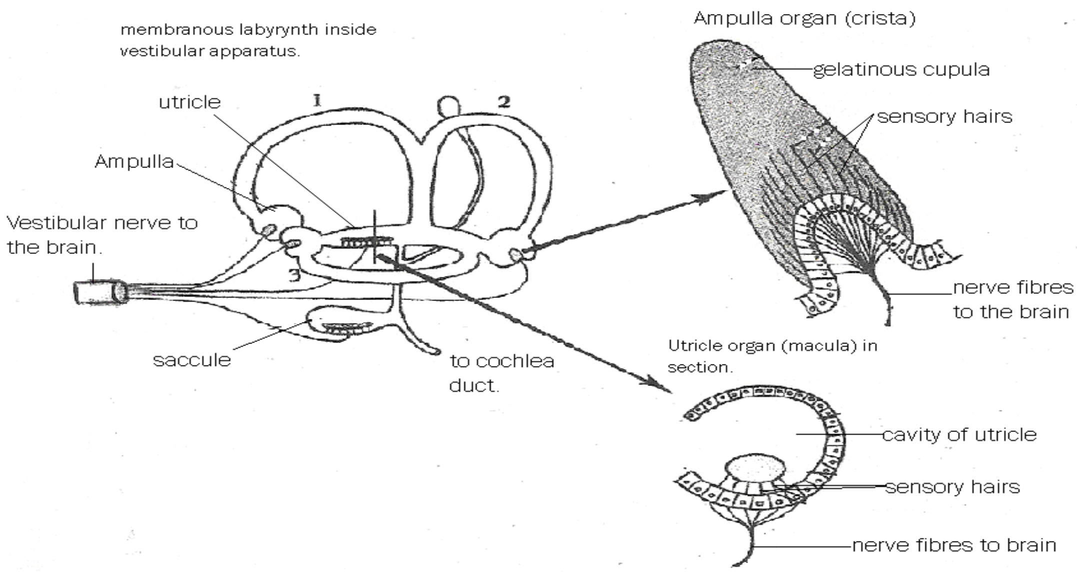
the tympanic membrane, the basilar's membrane is less displaced and fewer sensory hair cells are stimulated.

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.

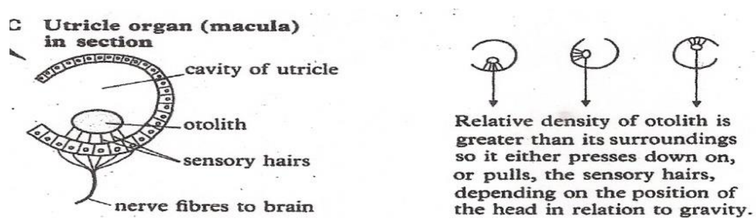
The maintenance of balance is achieved through one of the following

- 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.



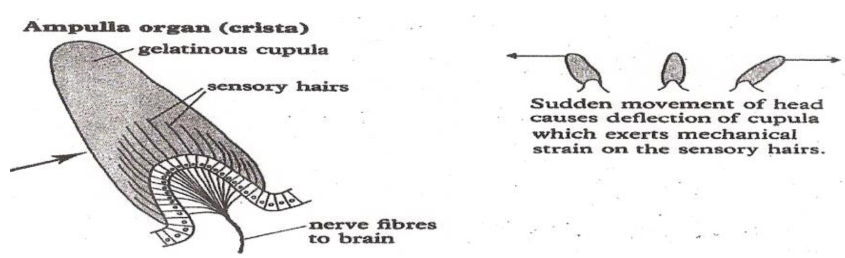
When the head is upside down, the Otolith of the utriculus fall away from the macula. The result is that they exert a pull as a result of which the sensory cells are distorted and depolarization a cross the membrane of the sensory hair cells occurs, a generator potential is produced if it reaches a threshold 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 called **cupula**. The movement of the endolymph displaces this cupula 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 (Semi-circular canal) 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.	4. Can not estimate distance from which sound is coming.

5. Can locate obstacles and pinpoint emitted echoes from them in the dark.	5. Can not locate obstacles of other objects by emitting sounds in the 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.

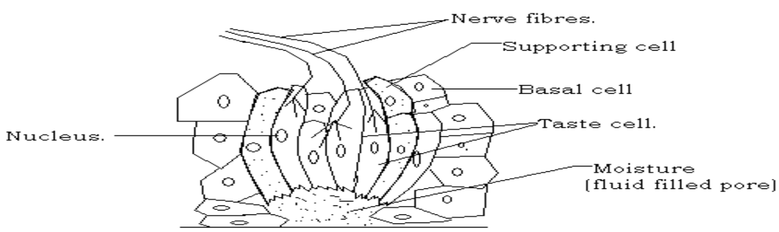
• Establishment of territories, where the animals mark and defend territories using their urine or excreta.

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

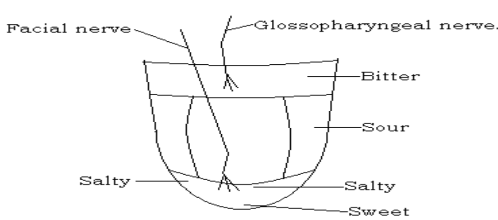
SENSE OF TASTE.

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.

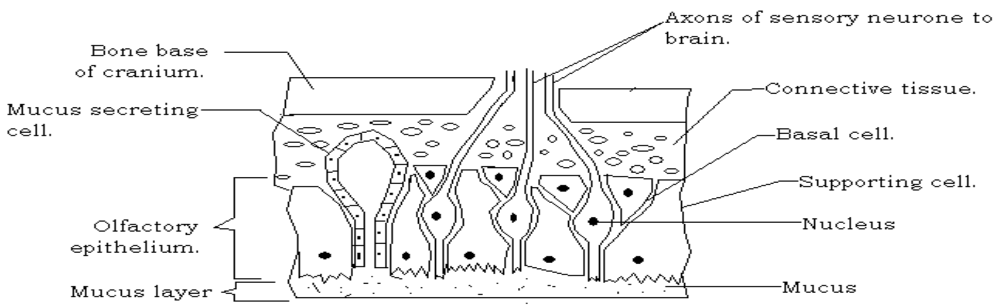


Chemicals taken to the mouth are detected when dissolve in the moisture of the tongue and pharynx. This stimulates appropriate sensory cells via their hairs and impulses are sent into the nerves leading to the brain (cerebral cortex and thalamus) where the taste is interpreted.

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.

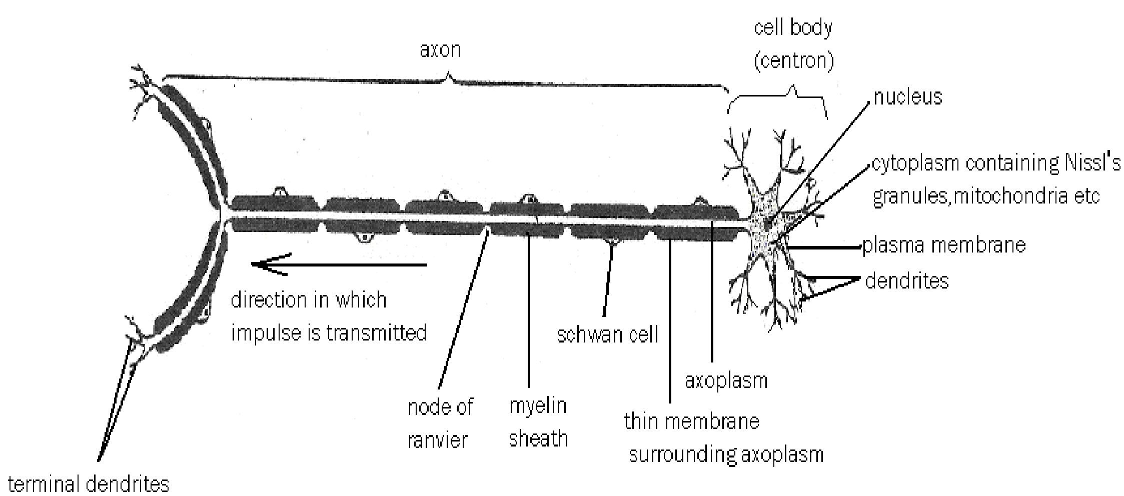
MOTOR NEURONES

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.

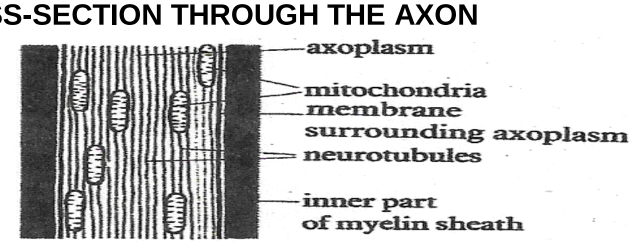
THE STRUCTURE OF THE MOTOR NEURONES

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



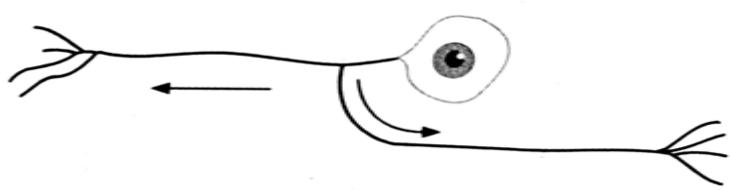
CROSS-SECTION THROUGH THE AXON



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.

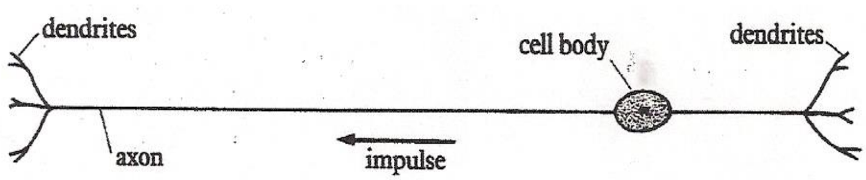
SIMPLIFIED DIAGRAM OF VERTEBRATES SENSORY NEURONE



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

Dentrites and dendrons

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

Axoplasm

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

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

Schwan cells

Produce the myelin sheath.

Myelin sheath.
Speeds up the transmission of the impulses.

Synaptic knobs.
Release chemical transmitters that allow impulses to cross 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 than 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, this means that, the influx of of sodium ions begin to depolarize the membrane and this depolarization in turn increases the membrane permeabiolity to sodium, leading to greater influx and further depolarization, which is an example of positive feed back, 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.
And when sufficient sodium ions have entered to create a positive charge inside the membrane permeability of the membrane to sodium ions start to decrease decrease.

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.

REPOLARISATION.

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. The recovery period of resting potential when the next impulse can not be transmitted is called **refractory period**.Repolarisation occurs in two stages.

STAGES OF REPOLARISATION.

FIRST STAGE.

First the membrane permeability changes back to it's original stage. The potassium ion (K^+) gates open while sodium ions (Na^+) gates close. Potassium ions diffuse out of the cell more easily. The negative charge outside the depolarized cell membrane also attracts the potassium ions. As the potassium ions diffuse rapidly outside the membrane, the outside of the membrane builds a more positive charge and this starts the repolarisation process.

Duirng this first stage of recovery, it is impossible for a second impulse to be generated because the membrane is not yet repolarised. The time required for repolarisation is called the absolute refractory period.

SECOND STAGE.

It is marked by restoration of ionic balance across the membrane. It is brought about by the sodium the sodium-potassium exchange pump. 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 full restoration of the original potential difference across the membrane called resting potential.

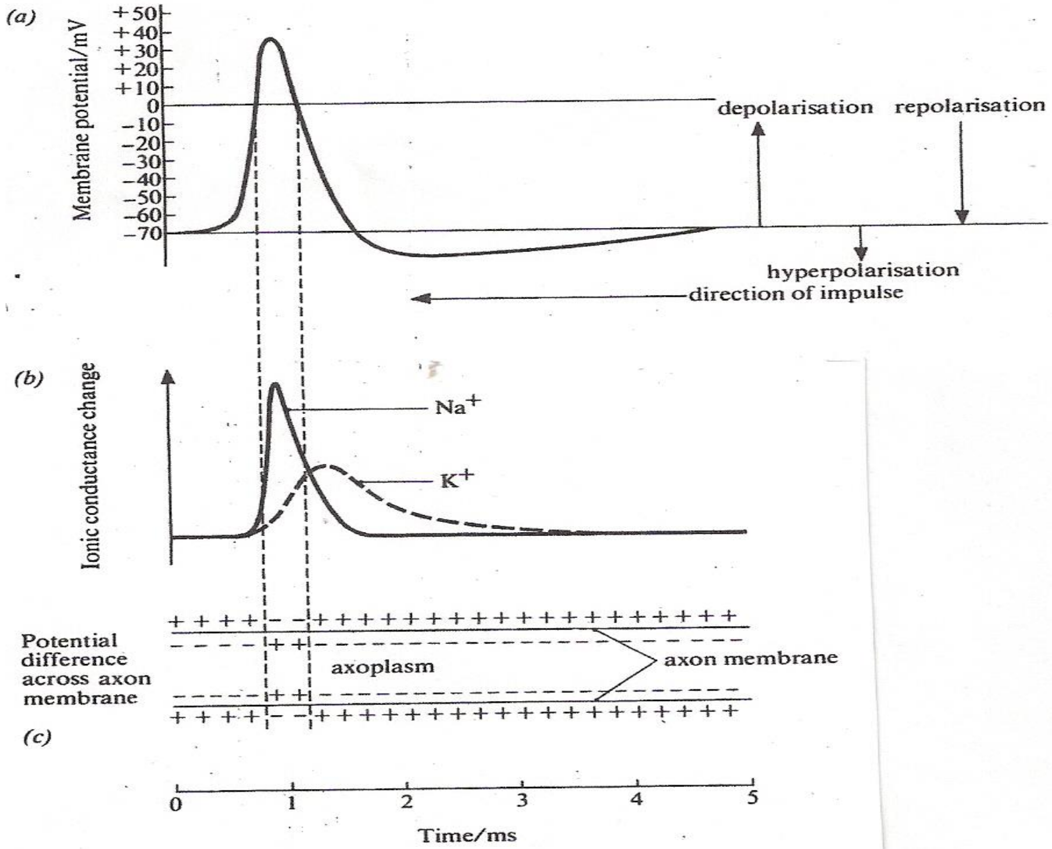
During the second stage, it is possible to generate an impulse before membrane recovery is completed. This can occur if a stimulus applied is strong enough to produce the threshold trans-membrane potential. This second stage is called relative refractory period.

Refraction between successive impulses limits the frequency with which impulses can be conducted.

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 inside while negative chloride ions are retained inside. At resting potential there is also a high concentration of sodium 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. This influx of sodium ions begin to depolarize the membrane, the inside of the membrane becomes more positive, while the outside more negative resulting into a localised electrical circuits across the membrane and this depolarization in turn increases membrane's permeability to sodium ions leading into greater influx of sodium ions and this causes further depolarization of the membrane. This is an example of positive feed back. A threshold is reached and a wave of depolarisation occurs 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.

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

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.

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.

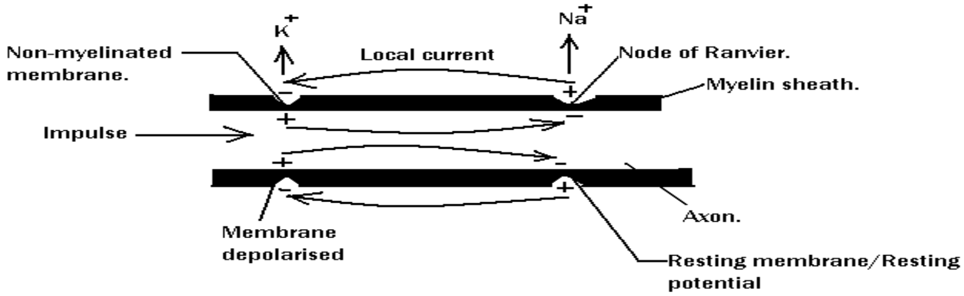
High speed of transmission; neurone impulses are transmitted very rapidly along the axon. The transmission of an impulse along the axon is determined by two factors.

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

MYELIN SHEATH.
Myelin sheath consists of 70% lipid and 30% proteins in a usual bimolecular layer of the cell membrane. 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.

Gradual degradation of myelin myelin sheath leaving some areas bare(demyelinated) and can not conduct impulses is referred to as **multiple sclerosis(MS)**. It mainly affects optic nerves, cerebellum, cervical, spinal cord, areas around ventricles of brain. However peripheral nerves are not affected. Symptoms of multiple sclerosis(MS) include, weakness of the limbs, pins and needles, blurring of vision and pains in the eyes.

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

- 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.
- 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.

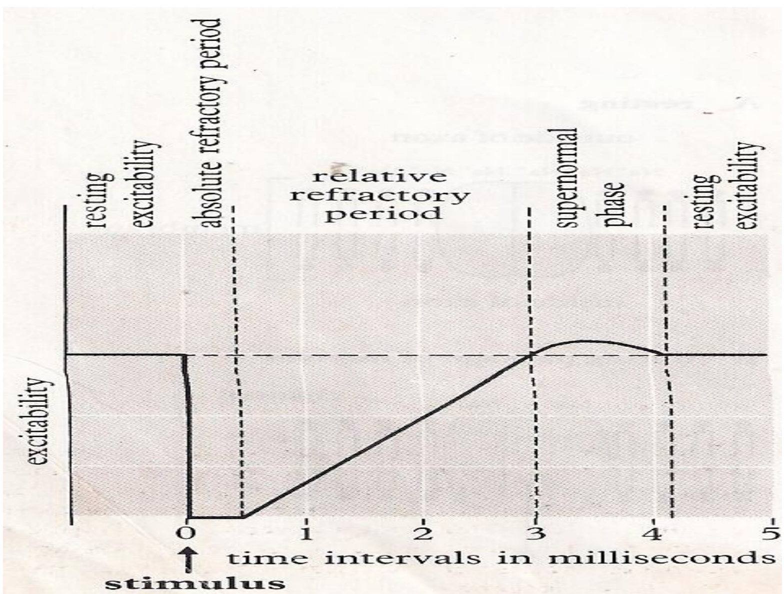
Refractory period is further divided into two,

- Absolute refractory period.
- Relative refractory period.

Absolute refractory period is the brief period immediately after an action potential or after 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.

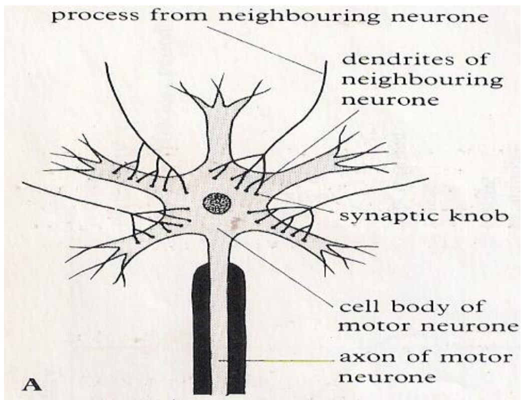
A GRAPH SHOWING RELATIVE REFRACTORY PERIOD



THE SYNAPSE

A synapse is the precise point where one nerve cell connects with another or with muscle fibrils. 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.

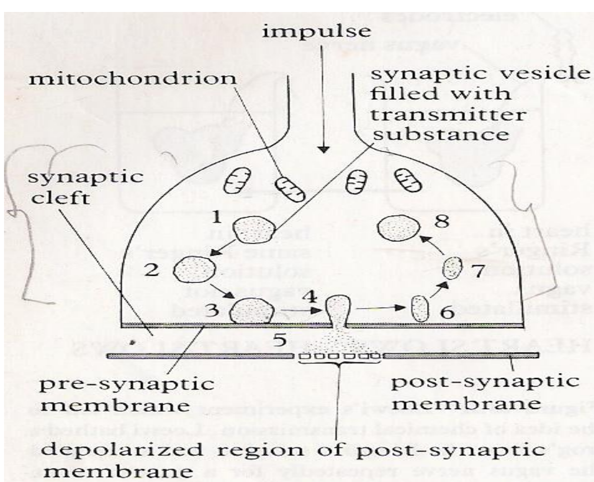


Synaptic connections are of two types;

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

STRUCTURE AND FUNCTIONS OF SYNAPSES.

STRUCTURE OF NERVE-NERVE SYNAPSE



STRUCTURE AND FUNCTIONS OF PARTS OF THE SYNAPSE

♦ **Synaptic vesicles**; store neuro-transmitter substance (acetylcholine).
♦ **Neuro-transmitter substance**; conduct impulses across the synapse.
♦ **Mitochondria**; provide energy required for the ionic movements at the synaptic membranes (the sodium –pump mechanism).

♦ **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.

♦ **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.

♦ **Pre-synaptic membrane** offer sites for the fusion of synaptic vesicles.

HOW A SYNAPSE 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 neuro-transmitter substances then diffuse a cross the synaptic cleft and attach to its specific receptor sites on the post synaptic membrane. This process takes about 0.5ms. The empty vesicles move back into the cytoplasm where they are later refilled with neuro transmitter substances

In excitatory synapse, neuro-transmitter substance bind onto specific receptors on postsynaptic membrane, causing the specific receptors to change their configuration and their protein channels specific to sodium ions (sodium gates) open up, allowing sodium ions to diffuse into post synaptic neurone, causing depolarization of the post synaptic membrane resulting into excitatory post synaptic potential (EPSP). The excitatory post synaptic potential build up as more neuro-transmitter substances arrive until sufficient depolarization occurs to exceed the threshold value, causing generation of action potential in the postsynaptic neurone. This additive effect is called summation.

Once acetylcholine has depolarized the postsynaptic neurone, it is hydrolysed by the enzyme acetylcholinesterase which is found on postsynaptic membrane to form choline and ethanoic acid acid(acetyl). This prevents successive impulses merging at the synapse. The choline and acetyl(ethanoic acid) diffuse back across synaptic cleft and are actively transported into the synaptic knob of presynaptic neurone, where they are recoupled together to regenerate the neuro-transmitter substances. This process consumes energy.

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.

Inhibitorey synapses in central nervous system are important in nerve pathways and control antagonistic 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)

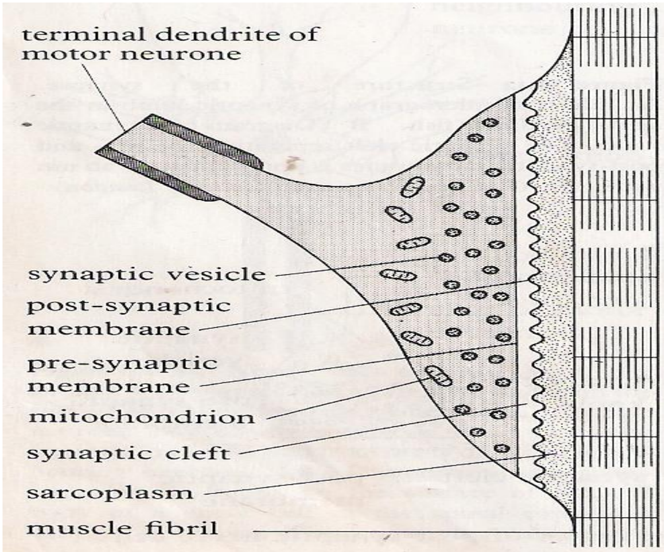
This is a point where the effector nerve meets a skeletal muscle. It is also referred to as the end plate. Each muscle fibre has a specialized region, the motor end plate, this is where the axon of the motor neurone divides and forms fine branches ending in synaptic knobs. The branches lack a myelinated 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 the synaptic clefts,

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

PROPERTIES / ROLES OF A SYNAPSE.

SUMMATION.

This is where more neuro-transmitter substances released from presynaptic knob causes several excitatory post synaptic potentials (EPSP) that add up together or build up until depolarisation occurs to exceed threshold value and so generate an action potential in the post-synaptic membrane of a 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 pre-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 neurotransmitter substances released from strongly and repeatedly stimulated same and single presynaptic knob 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 where neuro-transmitters released from a single stimulation of the presynaptic knob will not cause sufficient depolarization to reach a threshold and no action potential occurs.

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.

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 by the activities of some neurotransmitters or drugs.

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 substances 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 A SYNAPSE.

▪ Transmit information between neurones and between motor neurones and muscle fibres.

▪ 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.

▪ **Increases sensitivity of the central nervous system by 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.

Act as junctions. Through spatial summation, responses to a single stimulus may be coordinated.

▪ It prevents damage to effectors through over stimulation. Achieved through **adaptations and fatique**. Synapses allow adaptation to intense stimulation. Powerful stimulus cause high frequency impulses in the presynaptic neurone, this causes considerable release of neuro-transmitter substances into the synaptic cleft, continued high level stimulation may result into the rate of release of transmitter exceeding the rate at which it can be reformed. In this case the release of neuro-transmitter ceases and hence any response to the stimulus also stops. The synapse is said to be fatiqued. The purpose is to prevent over stimulation which would damage an effector.

▪ **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.

▪ **Facilitate transmission of impulses by 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 and sensitive to the next stimulus.

▪ 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.

▪ 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;

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

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)

SOME OTHER MINOR TRANSMITTER SUBSTANCES

These 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 substances 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.