**COORDINATION continuation…………**

## IV. GENERAL PRINCIPLES OR RECEPTION AND RESPONSE IN ANIMALS

### RECEPTION OF STIMULI BY THE RECEPTORS IN ANIMALS

### BASIC FUNCTION OF RECEPTORS

The basic function of all receptors is to transform stimulus energy into an electrical response 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.

### TYPES AND CLASSES OF RECEPTORS

The various types here are classified according to their structures, and these are.

- The simplest and most primitive type of receptors consists of a single sensory neurone which is capable of detecting the stimulus and giving rise to a nerve impulse passing to central nervous system for example skin mechano receptors such as the Pacinian corpuscle.
- More complex receptors are known as sense cells, consists of modified epithelial cells able to detect stimuli. They form synaptic connections with their sensory neurones which transmit impulses to the central nervous system for example mammalian taste buds.
- The most complex receptors are in sense organs, they are receptor cells found in the eyes and ears. These are composed of a large number of sense cells, sensory neurones and associated accessory structures. The different types of the most complex receptors include,

Most complex receptors are those classified according to the stimuli they detect and these include,

- **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 Carbon dioxide in the body.
- **Mechano-receptors**; These receptors detect stimuli such as touch, sound, pressure, stretch and gravity inform of mechanical energy.
- **Photo-receptors**. These receptors detect light inform of electromagnetic energy.
- **Thermo-receptors.** Are receptors 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 cations 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 therefore 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

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

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

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

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

**(v)** **Adaptation in receptor cells:** This is where receptors initially respond to strong and repeated stimulus by producing a high frequency impulse but the frequency of the impulses gradually declines with time until 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 some time does not feel cold, it becomes adapted to the new situation, since it arouses no sensation.

As far as adaptation is concerned, there are two types of receptors.

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

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

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

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

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

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

**OTHER PROPERTIES COMMON TO RECEPTORS THAT INCREASE THEIR EFFECTIVENES AND SENSITIVITY**

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

**(i) Sensory cells with 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 cannot be increased any more, any further increase in the intensity of the stimulus will excite sense cells or receptors with higher threshold to produce impulses with higher frequency. In this way, receptors can respond to wide range of stimuli in the environment increasing effectiveness.

**(ii) Convergence and summation.**

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

**(iii) Spontaneous Activity.**

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

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

**(iv) Feedback 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.

## MAMMALIAN SKIN.

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

**1. Mechano-receptors.**

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

- **Meissner's corpuscle:**
  These are situated immediately beneath epidermis in the skin. They are specialized sense organs which consist of a single twisted ending of a neurone enclosed within s fluid filled capsules. They respond to touch.
- **Pacinian corpuscle.**
  This consists of the ending of a single neurone surrounding by many layers of connective tissues in the dermis of the skin, they respond to pressure and vibrations (Rapid movements).
- **Free nerve endings** beneath the skin that detects touch and pressure.
- **Bulb of Krause** found in the dermis of the skin detects touch and pressure.
- **Organ of Ruffini** found deeper in the skin and detects heavier pressure on skin.

2. **Proprioceptors.**

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

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

**3. Thermoreceptors**.

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

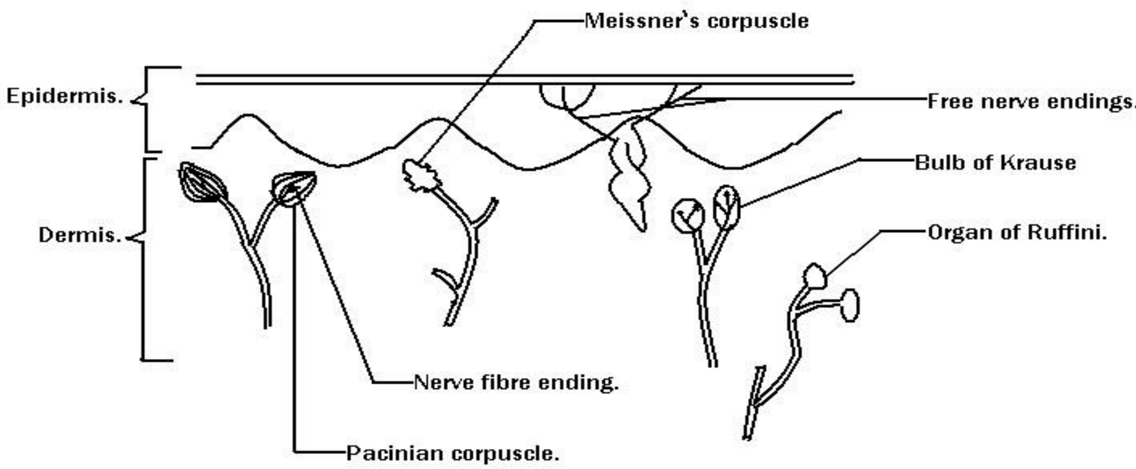
**HOW TOUCH, STRETCH AND PRESSURE RECEPTORS FUNCTION.**

It is thought that when these receptor cells are touched or pressed or any pressure applied on them, they become deformed and distorted and this increases the permeability of their cell membranes to sodium ions. Sodium ions diffuse rapidly inside the membrane which becomes depolarized, a generator potential is formed across the membrane. It builds up until a threshold value and then action potential generated.

**NOTE:**

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

**DIAGRAM SHOWING RECEPTORS IN THE MAMMALIAN SKIN.**



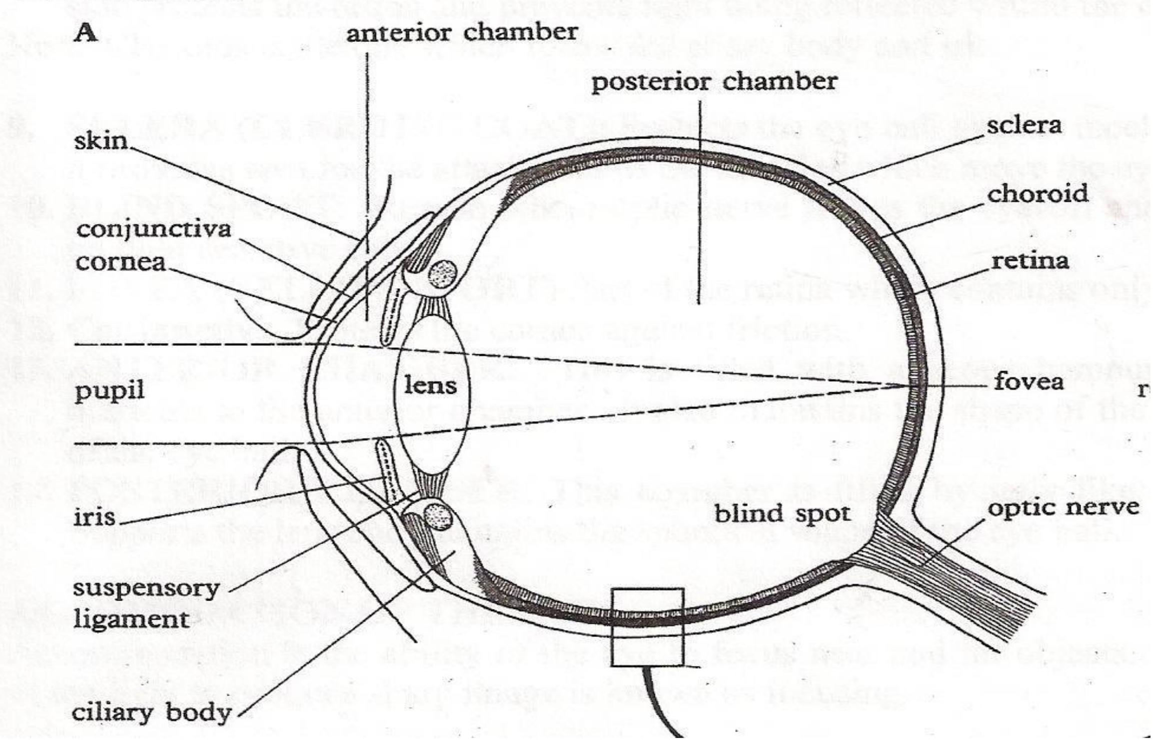
**THE EYES AND RECEPTION OF LIGHT**

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

**(i)** The mammalian eye.

**(ii)** The insect's compound eye.

***THE STURCTURE OF THE MAMMALIAN EYE***




**PARTS OF THE EYE AND THEIR FUNCTION**

**1. LENS**

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

**2. IRIS**

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

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

5. **SUSPENSORY LIGAMENT**: Are slender fibers attached to the lens at one end and the ciliary body at the other end. The suspensory ligament maintains and holds in position the lens.
6. **CILIARY BODY**

   It encircles the lens. It contains a complex set of smooth muscles which are mainly circular and radial muscles. Alternate contractions and relaxations of these muscles causes changes in the shape of the lens and its optical density (focal length). This permits images of objects at varying distances to be focused on the retina.
7. **RETINA**: It contains the light sensitive cells the rods and cones. The cones are packed in fovea, where they perceive the surrounding environment in conditions of good illumination, while the rods do so, in condition of low illumination. It also contains the black pigment melanin which helps in the absorptions of some light.
8. **CHOROID*:*** Contains blood vessels supplying the retina with nourishment. Heavy pigmentation with melanin in the choroids layer, and in the epithelium on its inner side protects the retina and prevents light being reflected within the eye.

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

9. **SCLERA (SCLEROTIC COAT)**; Protects the eye ball against mechanical injury and it provides area for the attachment of the muscles which move the eye.
10. **BLIND SPOT**: Region where optic nerve leaves the eyeball and where there are no light sensitive cells.
11. **FOVEA (YELLOW SPOT)** Part of the retina which is packed with only cones.
12. **CONJUNCTIVA.** Protects the cornea against friction.
13. **ANTERIOR CHAMBER**: This is filled with aqueous humour. This supplies nutrients to the anterior chamber. It also maintains the shape of the anterior chamber of the eye ball.
14. **POSTERIOR CHAMBER**: This chamber is filled by jelly like vitreous humour. Supports the lens and maintains the spherical shape of the eye ball.

**THE RETINA AND LIGHT RECEPTION.**

**Structure of the retina.**

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

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

• **Outer segment**.

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

**• Constriction.**

This is an in folding of the outer membrane separating the inner from the outer segment. The two regions remain in contact by a cytoplasm containing a pair of cilia with no known function.

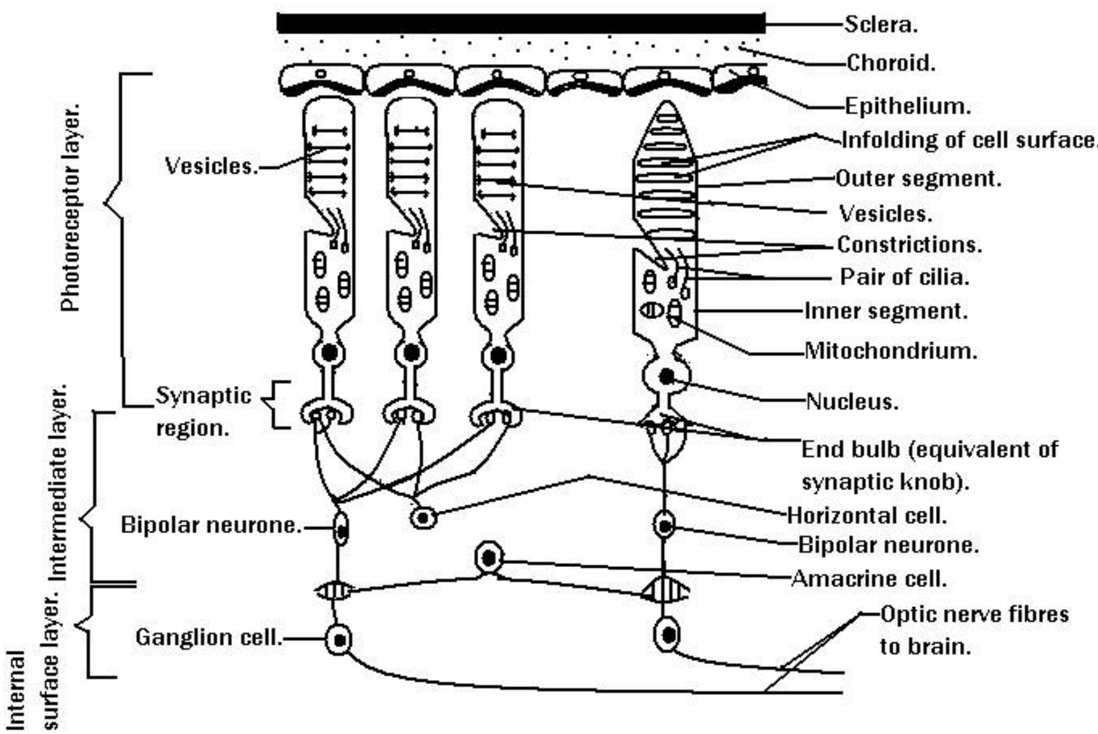
**• Inner segment.**

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

**• Synaptic region.**

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

**DIAGRAM SHOWING THE STRUCTURE OF THE RETINA IN HUMAN EYE**




**THE CONES AND RODS**

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

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

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

**DIFFERENCES BETWEEN RODS AND CONES:**

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

**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.

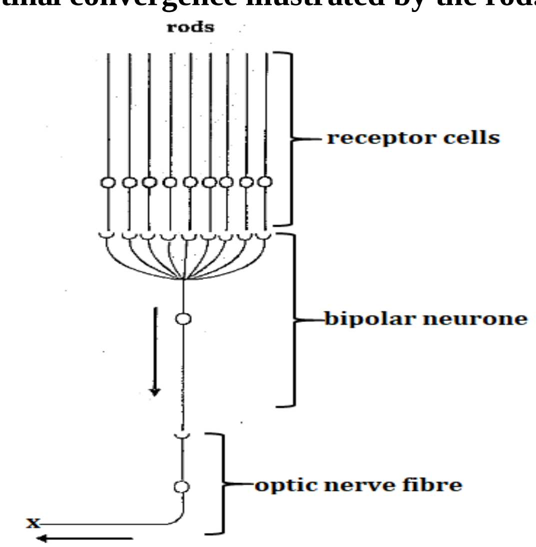
In the absence of further light stimulations, Rhodopsin is immediately reformed where "trans" retinene is first converted into "cis" retinene and then recombined with scotopsin (opsin) a process called Dark adaptation.

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.

***Qn. 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.**



*As seen from the figure above, groups of rods converge onto a single optic nerve fibre, thereby increasing sensitivity*

**LIGHT RECEPTION IN CONES.**

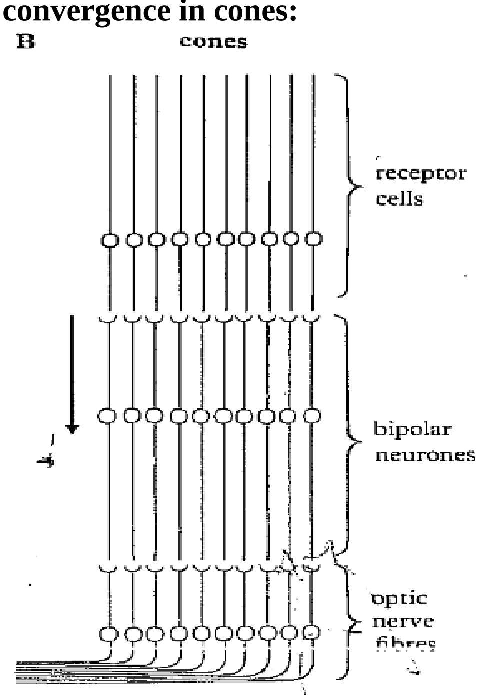
The cones contain a photo-chemical pigment in their outer segment called iodopsin. Iodopsin is a complex protein (Opsin) conjugated with light absorbing pigment called iodide. However, this pigment requires a greater amount of light to be bleached that is to split into its constituents, protein opsin and free iodide. When a light of high intensity strikes cones, the iodopsin in the outer segment absorbs 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 re***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 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 increase 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 cannot change their shape.

## PROCESS OF ACCOMODATION BY THE EYE

Accommodation involves two processes and these include,

(i) Control of the amount of light entering the eye (Reflex adjustment of pupil size)

(ii) Refraction of light rays by the cornea and lens from far and near objects.

## CONTROL OF THE AMOUNT OF LIGHT ENTERING THE EYE:

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

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

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

During dim light, the radial muscles contract, while the circular muscles relax. The size of the iris shortens and the pupils widens more light is allowed to enter the eye.
During bright light, the circular muscles contract, while the radial muscles relax, the size of the iris is elongated, and the pupil become narrower, little light is allowed to enter the eye.
***Note:*** Narrowing the pupil has a second advantage to us. It makes the focus of the light on the retina sharper and clearer image is formed on the retina.

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

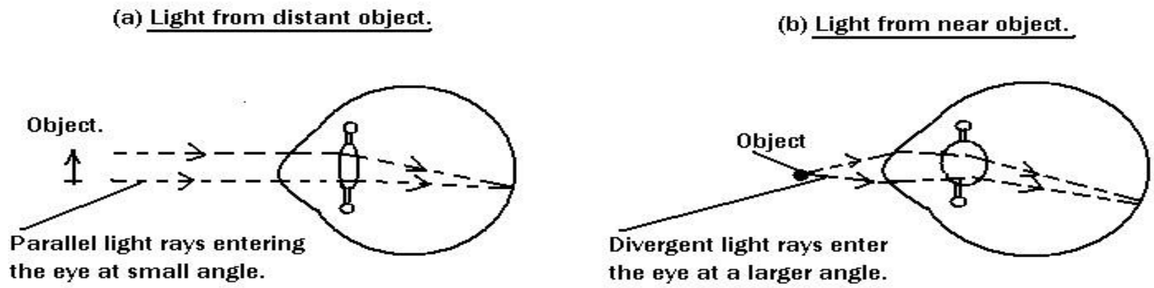
**(i) To focus distant objects**:

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

**(ii) To focus 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.

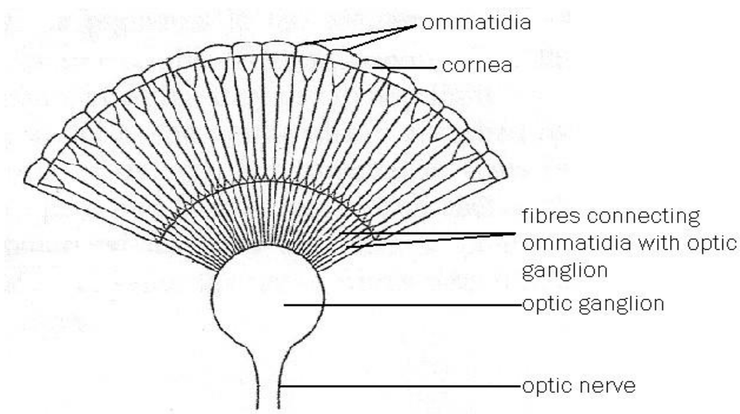
**Diagrams showing light rays from distant and near object**



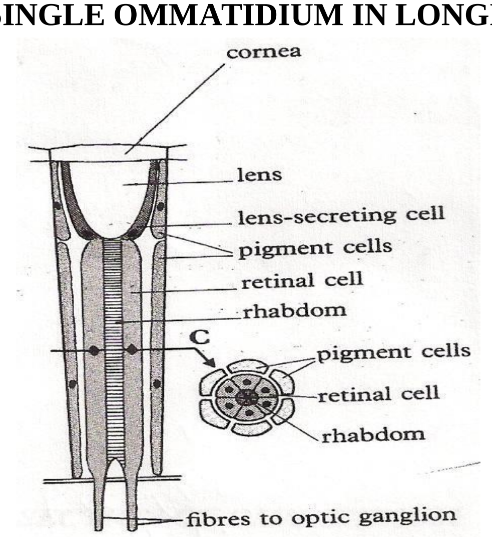

**STRUCTURE AND FUNCTION OF THE COMPOUND EYE.**

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**



**LIGHT RECEPTION IN THE COMPOUND EYE**

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

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

**STRUCTURAL DIFFERENCES BETWEEN THE MAMMALIAN EYE AND THE COMPOUND EYE:**

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

**Structural similarities between the mammalian eye and the compound eye:**

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

**Functional difference between the compound eye and the mammalian**

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

**Functional similarities between the compound eye and the mammalian eye**

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

**Reasons for poor resolving ability of the compound eye**

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

**Reasons for near sightedness of the compound eye;**

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

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

## SOUND RECEPTION IN THE MAMMALIAN EAR

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

## STRUCTURE OF THE MAMMALIAN EAR.

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

**(i)** **The outer ear**. This consists of;
- Pinna.
- External auditory meatus.
- Tympanic membrane (ear drum)

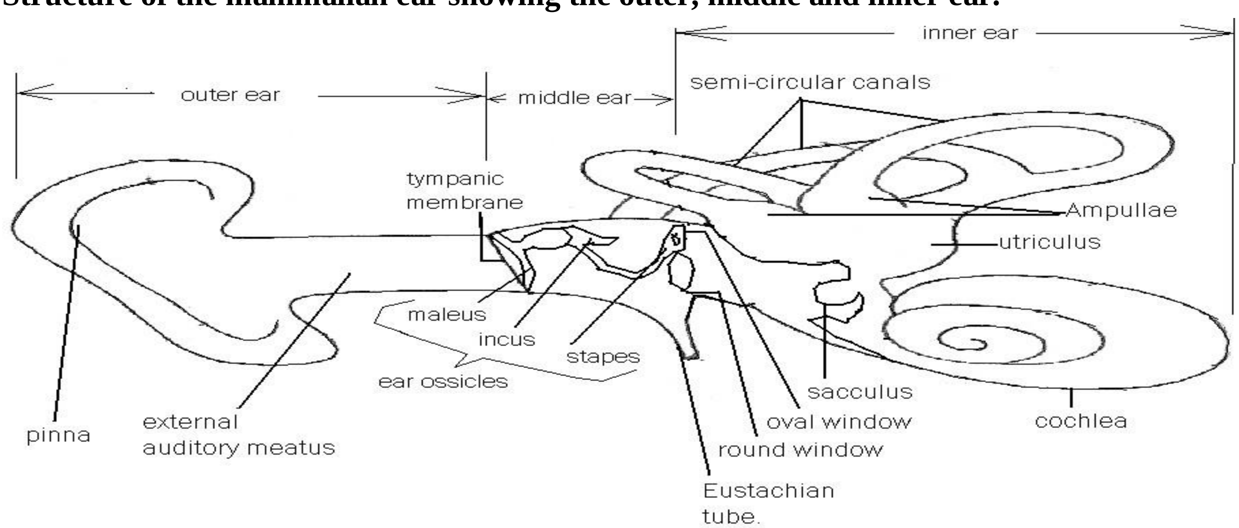
**(ii)** **The middle ear.**

It consists of the following;
- Ear ossicles (malleus, incus, stapes)

**(iii)** **The Inner Ear**.

It consists of;
- Semi-circular canals.
- Ampulla.
- Utriculus.
- Sacculus.
- Cochlea.
- Eustachian tube.
- Auditory nerve.

**Structure of the mammalian ear showing the outer, middle and inner ear.**



**FUNCTIONS OF THE PARTS OF THE EAR:**

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

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

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

**(iii)** **Tympanic membrane (ear drum)**

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

**(iv)Ear ossicles**

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

**(v)Eeustachian tube**

Equalizes air pressure on both sides of the ear drum so that tympanic membrane is not stretched as it may reduce the amplitude of its vibrations and make the sense of hearing dull. The middle ear is air filled and the Eustachian tube connects the middle ear to the pharynx. It is usually during swallowing that air enters or leaves the middle ear.

**(vi)Oval window**

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

**(vii)Round window:** Equalizes fluid pressure in the cochlea.

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

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

**(viii)Cochlea:** Contains sound receptors

**(ix)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 consist 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 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)

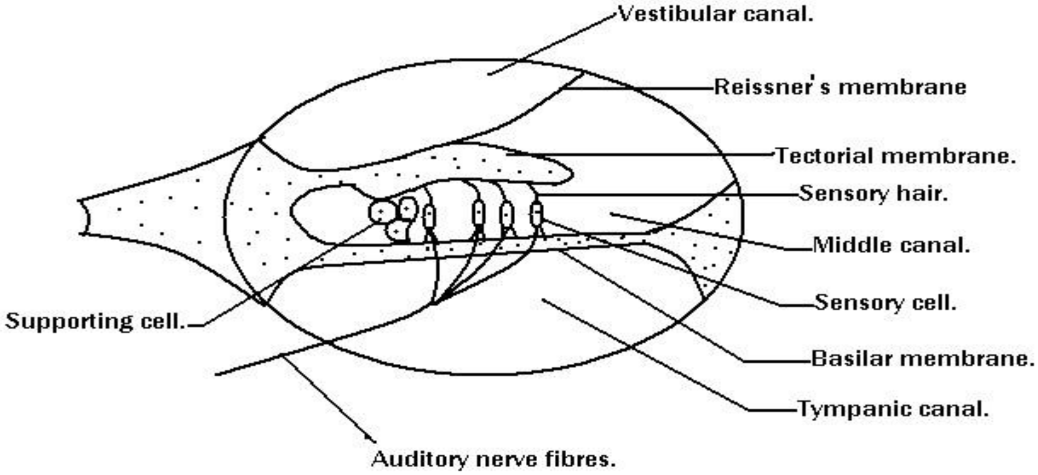
(ii) Supporting cells.

(iii) Tectorial membrane.

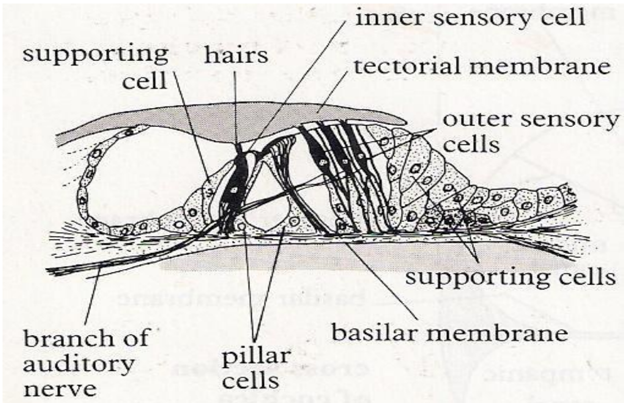
(iv) Basilar membrane.

(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,

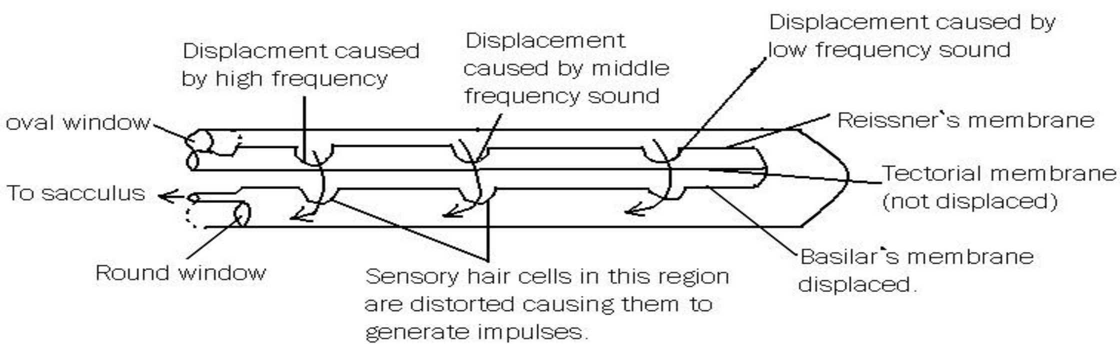
- pitch (frequency)
- amplitude (intensity).
- and tone.

## 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 threshold, 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.

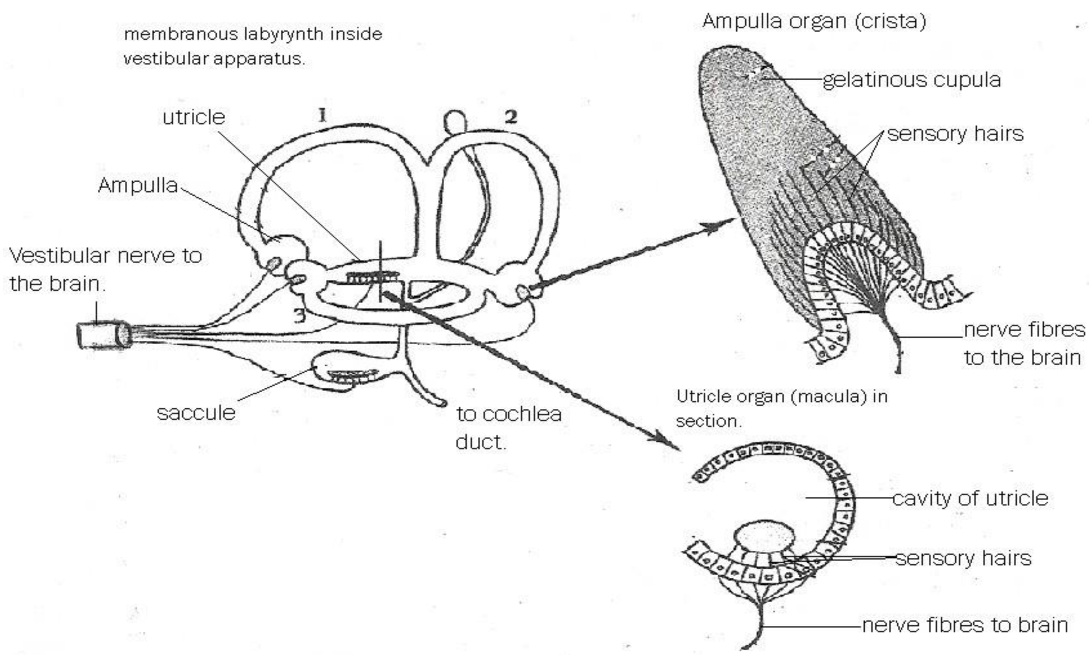
The intensity of the sound depends on the amplitude of the sound waves hitting the tympanic membrane which are then transmitted to the basilar membrane. Thus, the sounds of high intensity results in large amplitude in the vibrations of the tympanic membrane and a large displacement on the basilar's membrane 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 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 membrane. The less loud the sound, the fewer the number of sensory cells stimulated at one point on the basilar 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.

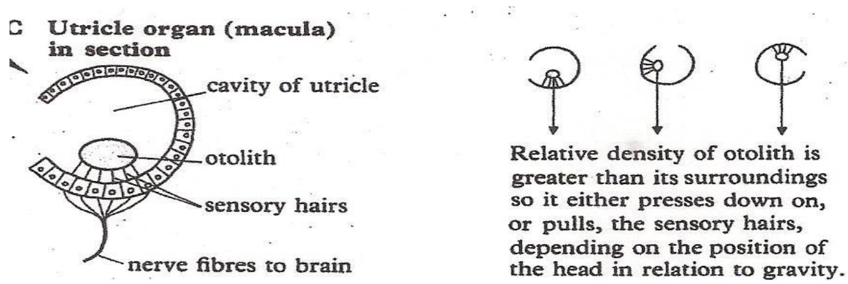
The maintenance of balance is achieved through one of the following

- 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.**



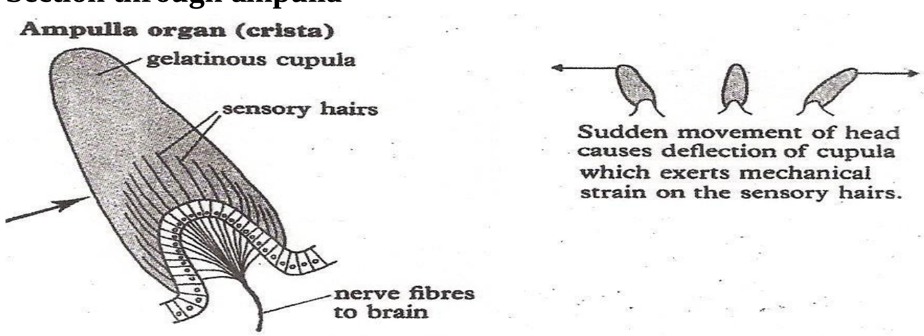

When the head is upside down, the Otolith of the utriculus fall away from the macula. The result is that they exert a pull as a result of which the sensory cells are distorted and depolarization a cross the membrane of the sensory hair cells occurs, a generator potential is produced if it reaches a threshold 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 some time, 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.** |
|---|---|
| ➢ Depends mainly on sound produced by themselves and reflected by some objects. | ➢ Depends mainly on sounds produced from a vibrating object in the environment (and rarely from themselves. |
| ➢ Has no ability to discriminate between sounds due to smaller size of brain but only eliminate noise in the environment from their echoes. | ➢ Has ability to discriminate between sounds due to larger brain |
| ➢ Are able to detect sound of very high frequency. | ➢ Un able to perceive sounds of higher frequencies above (150,000Hz) |
| ➢ Can readily estimate distance from which sound is coming, by echolocation. | ➢ Cannot estimate distance from which sound is coming. |

| | |
|---|---|
| ➢ Can locate obstacles and pinpoint emitted echoes from them in the dark. | ➢ Cannot 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

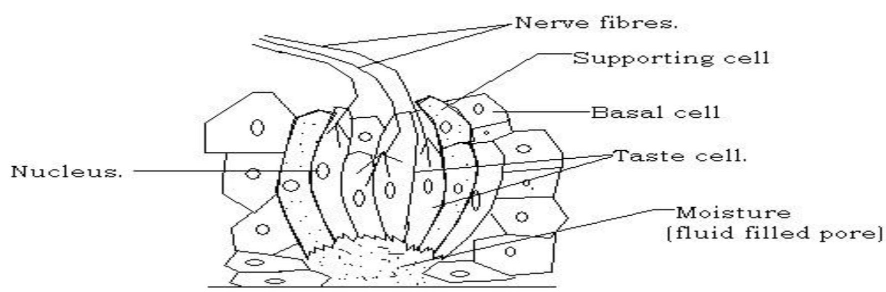
In mammals taste and smell play a role in the following,

- 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.

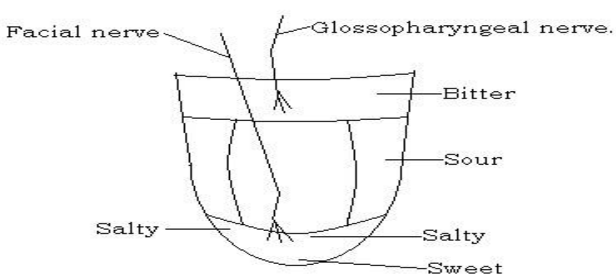
**SENSE OF TASTE**.

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.

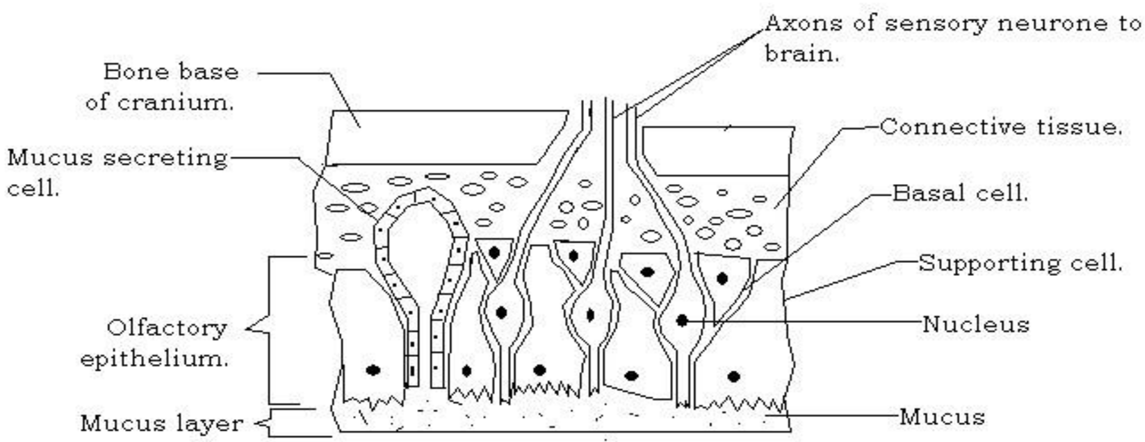


Chemicals taken to the mouth are detected when dissolve in the moisture of the tongue and pharynx. This stimulates appropriate sensory cells via their hairs and impulses are sent into the nerves leading to the brain (cerebral cortex and thalamus) where the taste is interpreted.

**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.

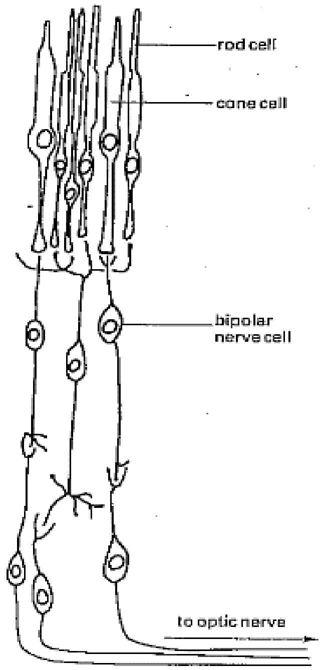
In general, volatile, fat soluble and readily absorbable substances are easily detected. The brain is able to quickly adapt to strong odours and this explains why one soon loses the trace of perfume he/she has applied or a stinging environment.

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

**Exercise**

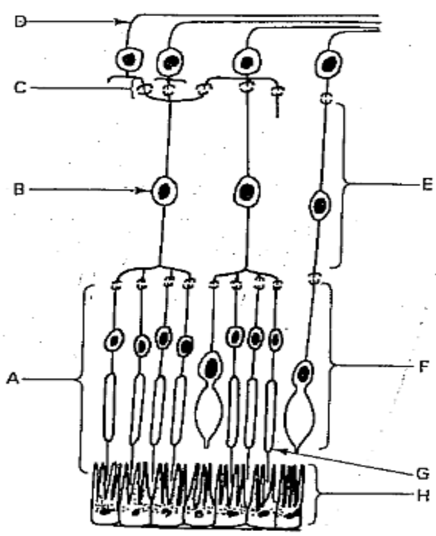
1. *Describe how each of the following is achieved in a mammal*
   - *(a) the control of light entering the eye*
   - *(b) Focusing on a distant object*
   - *(c) Colour perception*
2. *With reference to mammals , explain the role of*
   - *(a) The cochlea in the detection of sound and the discrimination of volume and pitch*
   - *(b) The retina in the detection of colour and discrimination of colour*

3. *The diagram shows part of the retina of a human eye*




*(a) Explain how*
*(i) light energy stimulates a rod cell*
*(ii) an axon in the optic nerve transmits a nerve impulse*
*(b) With the help of information in the diagram, suggest an explanation of each of the following*
*(i) cone cells are better than rod cells at distinguishing objects close together*
*(ii) rod cells are more sensitive than cone cells to very low light intensities.*
*(c) Explain the role of the retina in colour vision*

4. *the diagram below represents the retina of the human eye as seen in a section.*




*(a) name the parts A to H*
*(b) account for the following*
- ***(i)*** *rod cells produce an indistinct image.*
- ***(ii)*** *Rod cells are concerned with night vision*
- ***(iii)****Cone cells are capable of colour perception*
- ***(iv)*** *Visual acuteness is greatest at the region of the fovea*
- ***(v)*** *When a person enters a dimly lit room from bright sunlight, the room at first seems dark but gradually objects become visible*

5. *Figure 1 below shows the extent of stimulation of each type of cone in the human retina at different wave length of light. Use the information to answer questions that follow.*

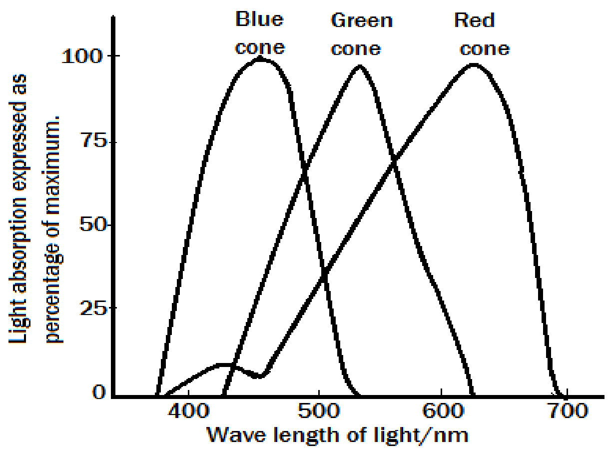



*Fig.1*

*(a) (i) Compare the light absorption of the three types of cones.(06 marks)*

*(ii) Suggest explanations for the observed patterns of the three absorption spectra. (07 marks)*

*(b) Describe the ways the cones of the retina are able to descriminate perception of each of the following types of light,*

*(i) Orange light. (02 marks)*

*(ii) Blue light. (02 marks)*

*(iii) Green light. (02 marks)*

*(c) Assuming that the wave length of 570nm is equivalent to yellow light. Using the data explain why equal stimulation of both green and red cones is perceived as yellow colour. (04 marks)*

*(d) Figure 2 below shows the number of cones and rods in the human retina along a horizontal line from the nasal side of the eye to the outer side of the eye.*

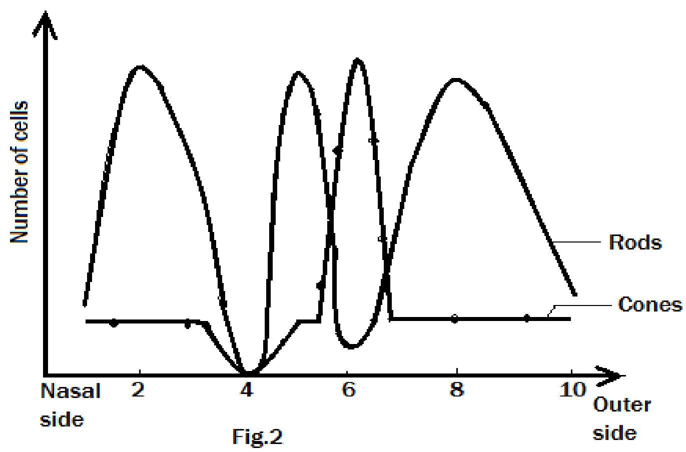



Fig.2

*(i) Describe the distribution of the rods and cone cells in the human retina. (05 marks)*

*(ii) Explain the distribution of rods and cones described in b (i) above. (08 marks)*

*(iii) Outline how the arrangements of rods in the retina allow increased sensitivity of the human eye. (04 marks)*

***END.***