# Receptors cells

These cells that convert energy associated with stimulus to an electrical impulse in the nerve or nerve impulses.

Receptors are classified according to the type of stimulus they respond to: -

(a) Chemoreceptors are stimulated by chemicals e.g. receptors mediating the sense of smell, taste and receptors that detect changes in levels of respiratory gases in the body.
(b) Mechanical receptors stimulated by mechanical stimuli e.g. touch, pressure, tension (stretch) and sound
(c) Photoreceptors stimulated by light e.g. eyes.
(d) Thermoreceptors are stimulated by heat.

**Mechanism of receptor cells**

When receptor cells receive appropriate stimulus, they develop a generator potential (local depolarization) depending on the size of the stimulus. However, when stimulus is strong enough, the generator potential may build up to fire an action potential in the adjacent nerve fibre. If the generator potential is maintained after an action potential has been conducted away, a second one will be fire off.

# Properties of receptors.

1. **Frequency of discharge**
   The higher the intensity of the stimulus, the larger the generator potential, the higher the frequencies of action potential. In other words, the total number of impulses fired off. For instance one responds more violently when hit by a stone than a fly

2. **Adaptation**
   If a steady stimulus is maintained, the generator potential gradually declines and frequency of action potentials decrease. Eventually the generator potentials fall below the threshold value discharged. In other words, the receptor stops responding to the stimulus. At this point, the receptor is said to be adapted to the stimulus.

The speed at which a receptor adapts depends on the size and duration of its generator potential in relation to the firing threshold. These in turn depend on the properties of the membrane. Some receptors adapt slowly while other adapt fast.

The importance of adaptation is that it protects the organism from excessive discharge of impulses in the sensory nerve. For instance prevents the tinkling sensation of a course sweater from remaining for long.

3. If a receptor cell is stimulated repeatedly the stimuli can be detected separately only if the frequency is not too great. If the stimuli exceeds a certain frequency, they appear to fuse into one continuous stimulus that separate stimuli cannot be detected.

Properties of receptors

1. .**Frequency of discharge**

The higher the intensity of the stimulus, the larger the generator potential, the higher the frequencies of action potential. In other words, the total number of impulses fired off. For instance one responds more violently when hit by a stone than a fly

2. **Adaptation**

If a steady stimulus is maintained, the generator potential gradually declines and frequency of action potentials decrease. Eventually the generator potentials fall below the threshold value discharged. In other words, the receptor stops responding to the stimulus. At this point, the receptor is said to be adapted to the stimulus.

The speed at which a receptor adapts depends on the size and duration of its generator potential in relation to the firing threshold. These in turn depend on the properties of the membrane. Some receptors adapt slowly while other adapt fast.

The importance of adaptation is that it protects the organism from excessive discharge of impulses in the sensory nerve. For instance prevents the tinkling sensation of a course sweater from remaining for long.

3. If a receptor cell is stimulated repeatedly the stimuli can be detected separately only if the frequency is not too great. If the stimuli exceeds a certain frequency, they appear to fuse into one continuous stimulus that separate stimuli cannot be detected.

4. **Transduction:**

All receptors are capable of converting a physical stimulus into electrical impulses. This ensures that each stimulus is registered in form of an electrical impulse.

5. **Sensitivity**:

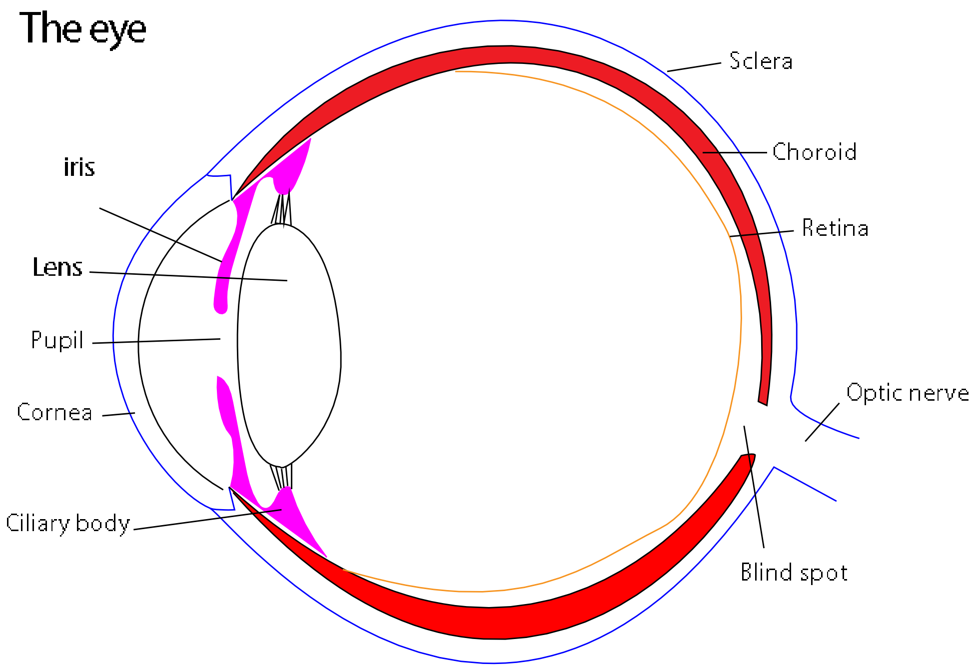
Sensitive receptors detect slight stimulus for which they are meant. In this way, they have a low threshold of stimulation so that even small changes in a stimulus can be registered and transduced into an electrical impulse.

6. Precision:

Receptors are precise in transmission of information. They receive and transmit the exact information about a stimulus without any alteration. This ensures that they send the exact information to the brain about the changes in the environment.

7 **.Inhibition.**

The transmission of certain impulses in the receptors can be inhibited. This is important because it ensures that the receptors transmit only that information which is of use to the organism it a particular time.




**Functions of the parts of the eye**

1. Lens refracts light to the retina
2. Iris adjust the size of the pupil
3. Retina is where the image forms
4. Pupil allows light to pass through into the eye.

**Controlling amount of light entering the eye**

The amount of light entering the eye is controlled by the iris.

In bright light, the iris circular muscles to contract and pupil constricts.

In dim light iris radial muscles contract and the pupil widens

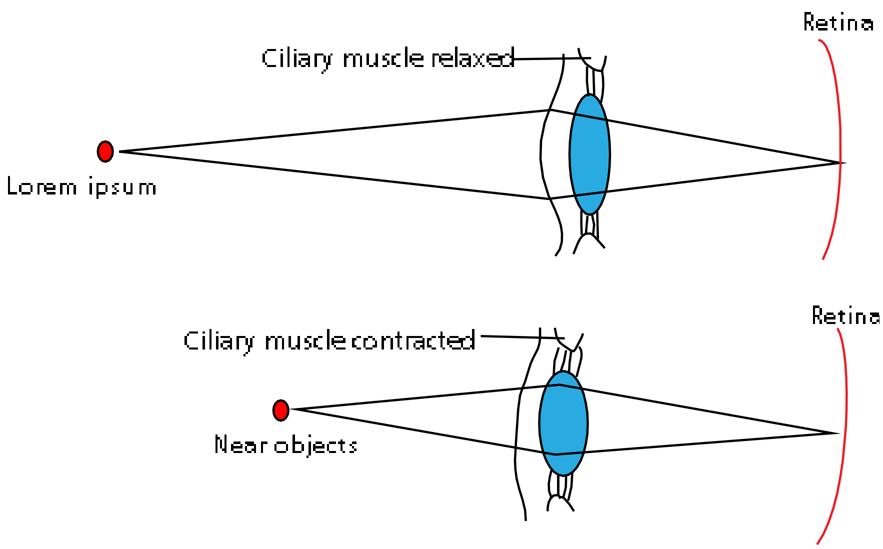
## Accommodation

Is the ability of the eye to view near and far objects.

(a) To see near objects, the ciliary muscle contract releases the tension on the lens allowing it to adopt a more spherical shape. The lens then refracts light strongly.

(b) To view distant objects, the lens is flattened by relaxation of the ciliary muscle which springs outwards.

The figure shows the lens shape changes depending o whether a distant or near object is being viewed



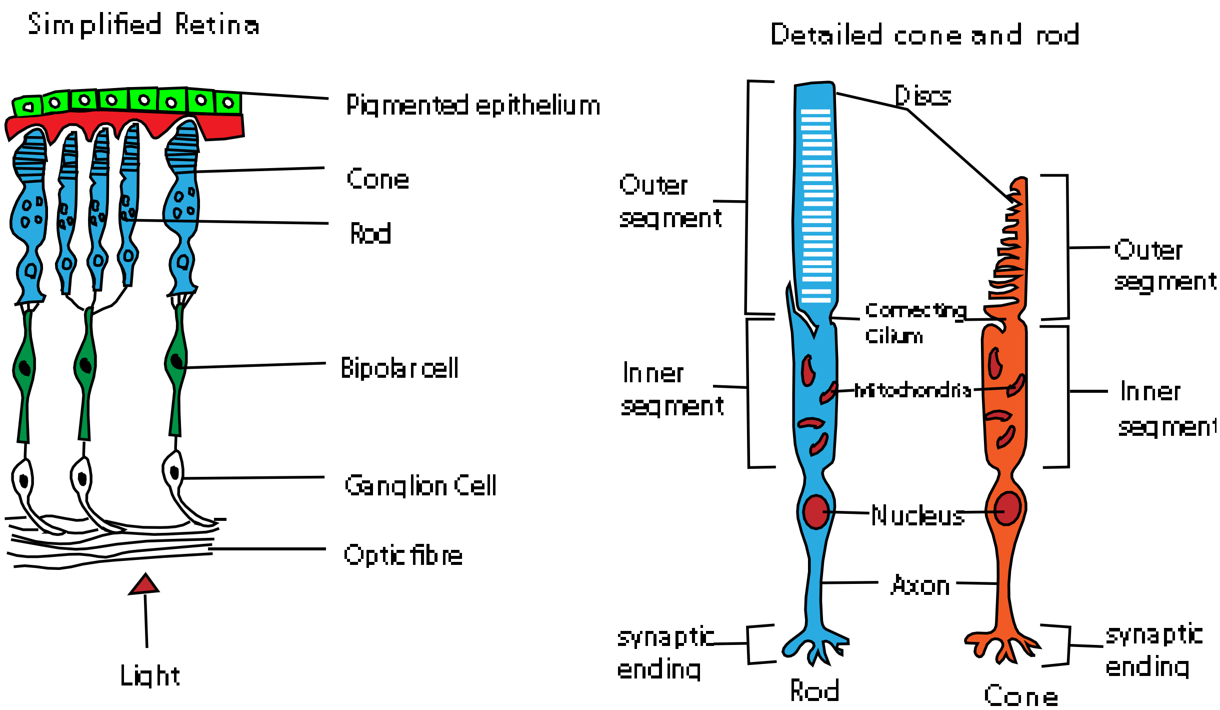

## The retina

The retina contains two types of photoreceptor cells: rods and cone.

The cones are found over most of the retina but are particularly concentrated in the centre directly behind the lens. This called the **fovea**. The rods on the other hand lie outside the foveal region in the more peripheral part of the retina.

The cones enable us to perceive the environment in good illumination and is responsible for daylight vision. They enable us to see things clearly and sharply and in color. However, they are relatively insensitive to low light intensities and this is why they will only work in good light.

The rods enable us to perceive the environment in conditions of low illumination. In other words, they are responsible for night vision. They are sensitive to very small light intensities of light, which is why they can operate at low-level illumination. Rods do not register things as clearly and sharply as the cones do, and  they cannot respond to different colours so they only allows to see things in black, white or various shades of grey.




Notice that

(a) A group of rods converges on to a single optic nerve fibre. This allows summation to occur and increases overall sensitivity.
(b) A single cone is connected to a single bipolar cell, which allows precision.

## Differences between rods and cones

| Rods | Cones |
|---|---|
| Outer segment rod shaped | Outer segment cone shaped |
| Rods occur in large number | Concentrated in fovea |
| Have low visual acuity | Have high visual acuity |
| Very sensitive to light | Low sensitivity to light |
| Insensitive to color | Sensitive to color |
| Has one form of rhodopsin | Has three forms of rhodopsin |

**Mutual or Lateral inhibition**

This occurs when the activity of one cell suppresses the activity of a nearby cell or when activation of one cell by light impairs or prevents neighboring cells from being activated.

**Importance of mutual or lateral inhibition**

1. This causes the edges between light and dark areas to appear more prominent than they would be otherwise
2. **Lateral inhibition** disables the spreading of action potentials from excited neurons to neighbouring neurons in the **lateral** direction.

**Transduction of light**

(i) Photo-transduction is the process in which light is converted into electric signal in rods and cone cells of the retina.

(ii) Both rod and cone cells contain a photopigment Rhodopsin.

(iii) Rhodopsin contains retinal (aldehyde of vitamin A) a light sensitive molecule covalently linked to a protein called opsin.

(iv) When struck by light retinal (in cis form) Isomerizes to a trans- form.

(v) Isomerization of retinal activates rhodopsin to start a cascade of events leading to firing of an impulses to the brain.

(vi) After depolarization, trans form of retinal is converted back to the cis form to be reused using ATP energy.

Sensitivity

Rod are more sensitive to light than cones because

(a) their photochemical pigment of rods responds to very low light intensities.

**(b)** Numerous rods make synaptic contact with a single bipolar neuron which in turn connects with cell body of a single optical nerve fibre. A phenomenon called **Retinal convergence.** Retinal convergence increases the sensitivity of the eye because simultaneous excitation of a number of rods is more likely to generate an impulse in the optical nerve than excitation of a single rod would not.

Precision

The ability of the eye to distinguish between two distant points as distinct points is called **visual acuity**. Visual acuity is due to cones.

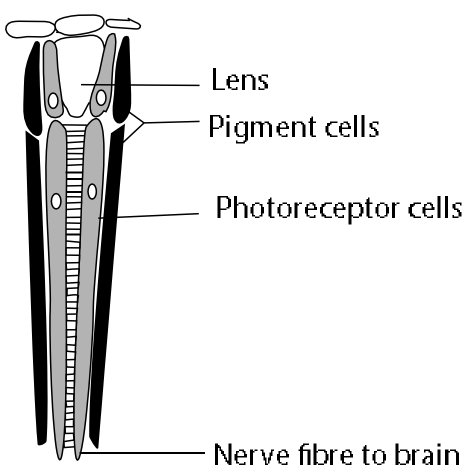
**Color vision**

There are three types of cones each corresponding to light of different wavelength. Each cone absorbs light of either red, green or blue and this has given rise the trichromatic theory which state that different colors are produced by the degree of stimulation of each type of cone.

Compound eye

The compound eyes is composed of numerous “mini eyes” ommatidia. Each ommatidia contain a group of photoreceptor cells which function as a unit.

Ommatidia in detail



## Comparison of compound and human eye

similarity
1. both have lenses
2. have light sensitive cells allow eye to collect data that is interpreted by brain to form images

| Character | Human eye | Compound eye |
|---|---|---|
| Field of view | Narrow | Wide because it covers a big part of the head |
| Number of visual unit | One per eye | Many (omatia) per eye |
| Regulation of light into the cell | Light is regulated by iris | Does not regulate light |
| Visual acuity | High visual acuity due to high density of sensitivity cells in the retina | Low visual acuity due to<br>(i) low density of light sensitive cells (omatidia)<br>(ii) small lenses leading to high diffraction of light<br>(iii) have small brain that can not interpret detailed images. |
| Critical flicker frequency | Low | High |
| Color vision | Distinguish between colors | Not all compound eyes can distinguish between colors |

### Definition.
Critical flicker frequency threshold is defined as the frequency at which a flickering light is indistinguishable from steed light.

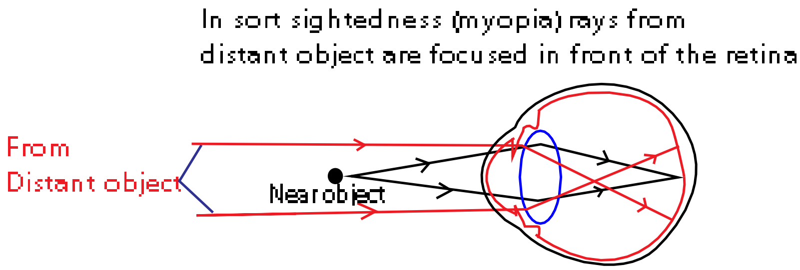
Insects have high critical flicker frequency because the they can process light fast because
- (i) their rhodopsin is easily resynthesized
- (ii) their eye is closer to the brain.
- (iii) they form simpler images

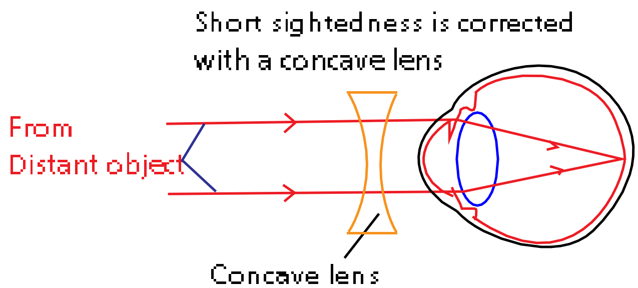
The high flicker frequency in insects allows then to detect movement faster than man.

### Eye defects
Short sightedness is inability to see distant objects clearly because rays from a distant object are focus in front of the retina.

Causes (i) Lens too strong
(ii) eyeball too long

Correction: by use of a concave or diverging lens



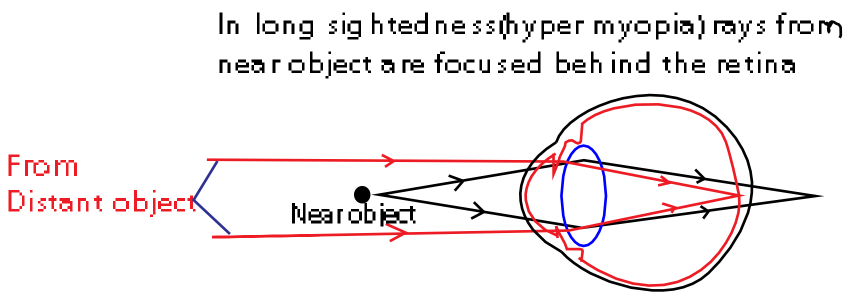



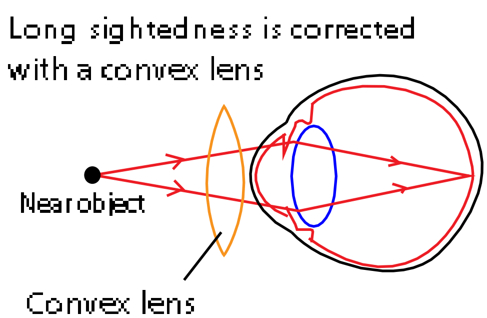

Long sightedness is inability to see near objects clearly because rays from a near object are focused behind the retina

Cause (i) lens too weak

(ii) eyeball too short

Correction: by use of a convex lens



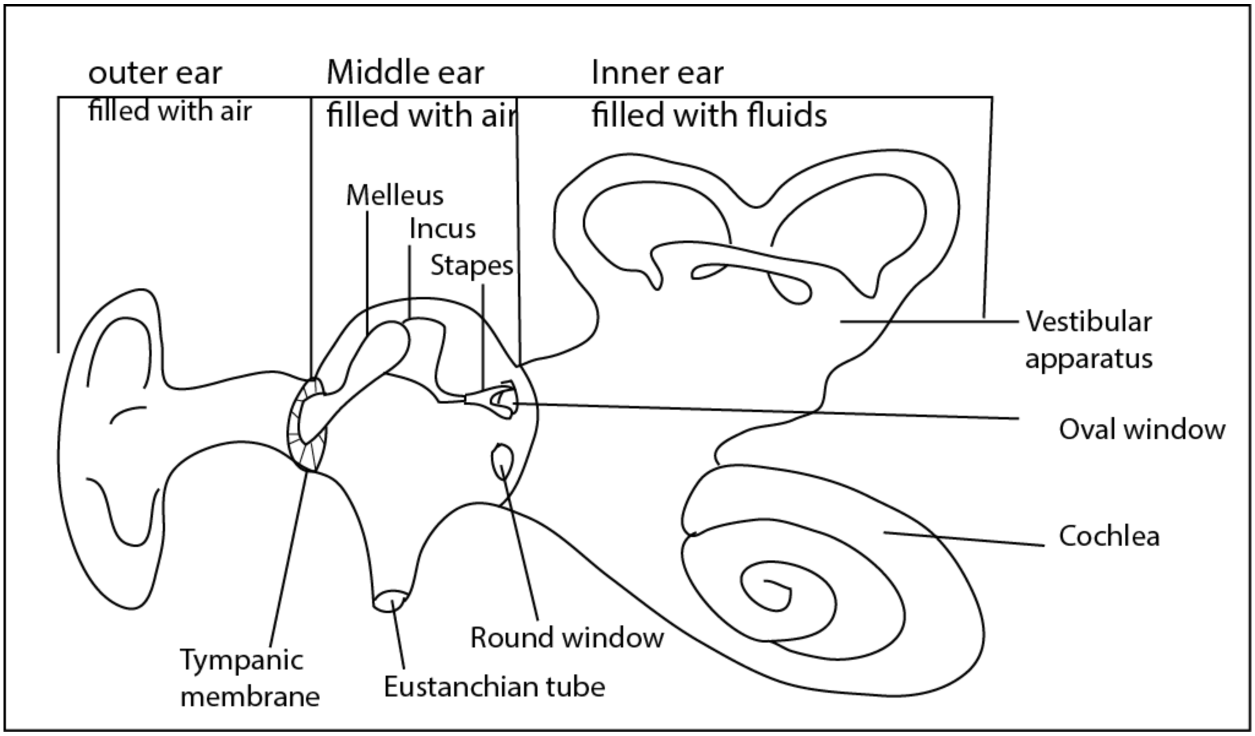



## The human Ear

The mammalian ear has two major functions

(a) Detecting sound
(b) Maintenance of body balance

## Structure of mammalian ear




The has three main parts

(a) Outer ear
(b) Middle ear
(c) Inner ear

The middle ear is separated from the outer ear by **tympanic membrane, or ear drum**. The middle ear is separated from the inner ear by an **oval window (fenestra ovalis)** and **round window (fenestra rotunda)** both of which are covered by membranes.

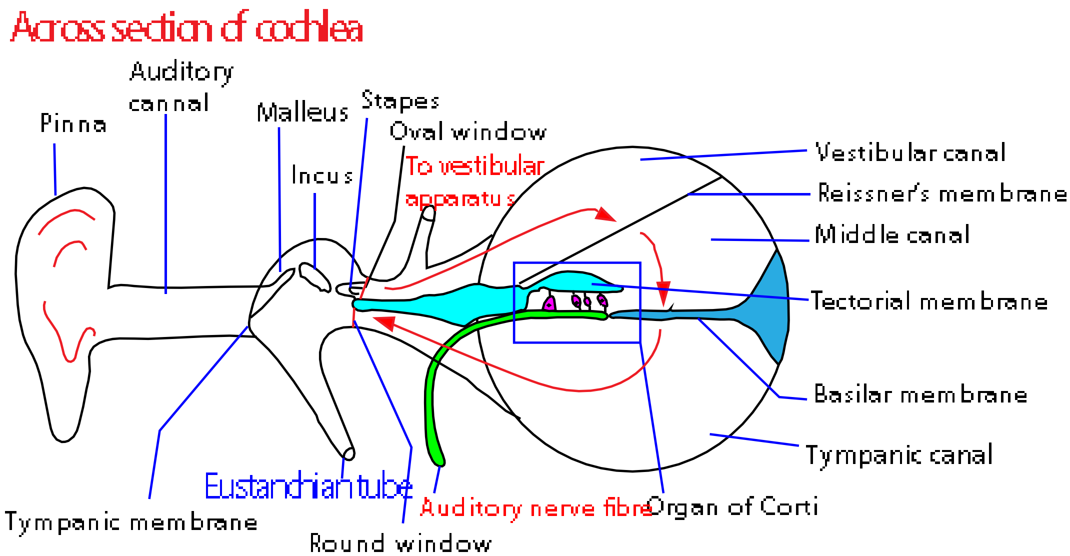
Spanning the middle ear from the tympanic membrane to the oval window are three tiny bone called **ossicles** (the **malleus**, **incus** and **stapes**). The Eustachian tube, which connects the middle ear with the pharynx, ensures that the air pressure on the both side of the tympanic membrane are equal.

The inner ear is made up of two parts, the **vestibular apparatus** and the **cochlea.** These two parts of the inner ear are continuous with each other though they carry out separate functions. The entire inner ear is filled with a fluid called **endolymph** and is separated from the wall of the skull by another fluid called **perilymph**. The vestibular apparatus is responsible for the sense of balancing while the cochlea is for hearing.

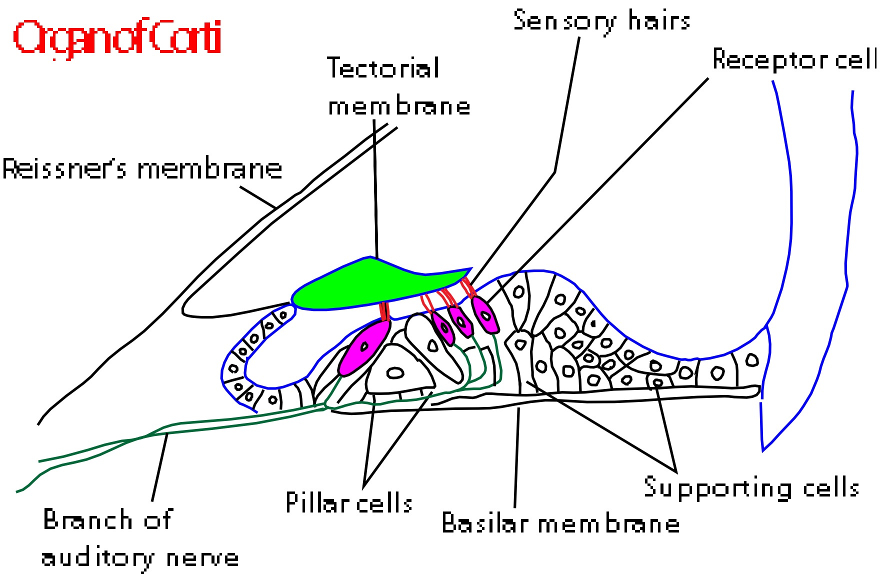
## The cochlea

Consists of a coiled tube, which is divided longitudinally into three parallel canals: **vestibular** (connecting with the oval window). Membranes separate the three canals from each other: **Reissner's membrane** between the vestibular and tympanic canals, and the Basilar membrane between the middle and tympanic canals. All the three canals are filled with fluid: endolymph in the middle canal and perilymph in the other two canals.

The relationship between the canals and membranes is shown in the cross section below:




The cross section also show the receptor cells that respond to sound. Into the middle canal projects a shelf, the **tectorial membrane**, which runs parallel with the basilar membrane for full length of the cochlea. Receptor cells span the gap between the basilar membrane and tectorial membranes. Their bases are rooted in the basilar membrane where they are connected to nerve fibres that join the auditory nerve. At the other end they bear fine hairs which just reach the tectorial membrane. This is the part of the cochlea that actually respond to sound and is called **Organ of Corti**




Hearing

a) Sound waves impinge on tympanic membrane that vibrate accordingly.
b) The movement of the tympanic membrane are transmitted by the three ossicles to the oval window
c) This causes displacement of fluid in the vestibular canal which;
d) in turn causes movement of Reissner's membrane.
e) Vibration of Reissner's membrane displaces fluid in the middle canal which move the basilar membrane, thereby displacing fluid in tympanic canal
f) Displacement of the fluid in the tympanic canal is taken up by stretching of the membrane covering the round window.
g) The vibration of basilar membrane distorts the sensory cells of Organ of Corti, which fire impulses to the brain.
h) The **pitch** of sound is determined by the frequency of vibration of the basilar membrane determine by the frequency of sound
i) The **intensity or loudness** of sound is determined by the amplitude of the vibration of basilar membrane in turn determined by amplitude of sound.

**The analysis of sound frequencies by the basilar membrane.**

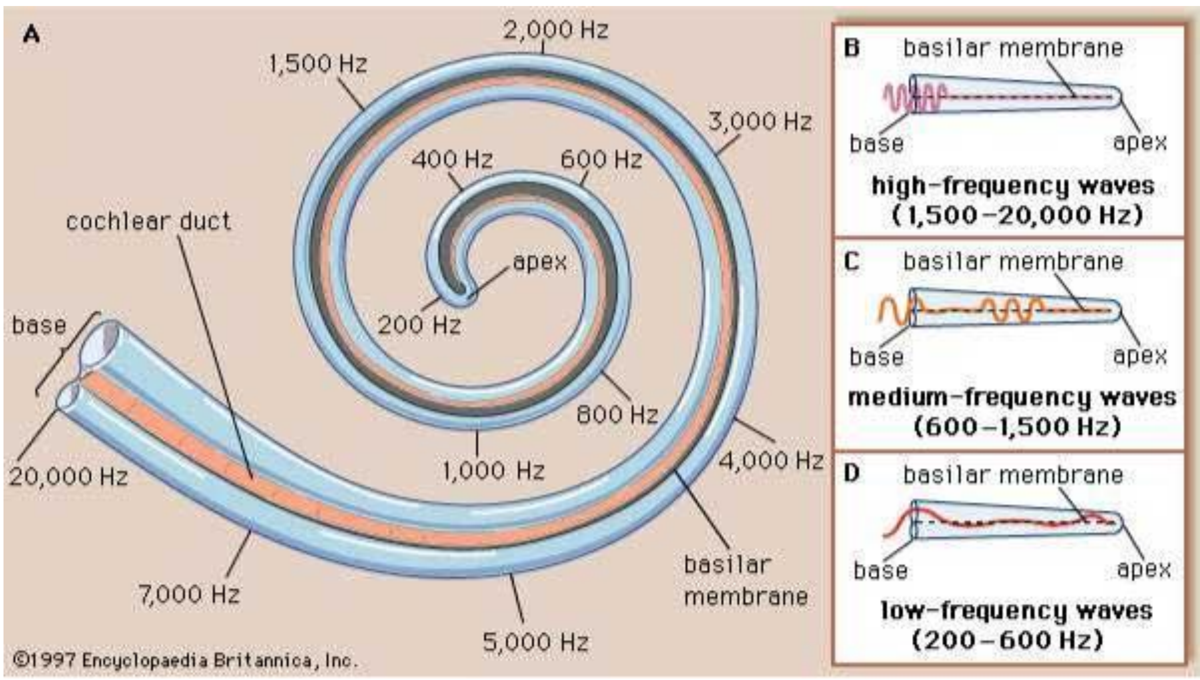
The fibres of the basilar membrane become progressively wider and more flexible from the base of the cochlea to the apex. As a result, each area of the basilar membrane vibrates preferentially to a particular sound frequency.

The higher the frequency of the sound imposed, the shorter the distance the waves travel.

Thus, a tone of a given frequency causes stimulation to reach a peak at a certain place on the basilar membrane. The region that vibrates most vigorously stimulates the greatest number of hair cells in that area of the organ of Corti, and these hair cells send the most nerve impulses to the auditory nerve and the brain. The brain recognizes the place on the basilar membrane, and thus the pitch of the tone, by the particular group of nerve fibres activated.

(i) High-frequency sound waves cause maximum vibration of the area of the basilar membrane nearest to the base of the cochlea;
(ii) medium-frequency waves affect the centre of the membrane;
(iii) low-frequency waves preferentially stimulate the apex of the basilar membrane.

The locations of cochlear frequencies along the basilar membrane shown are a composite drawn from different sources. below

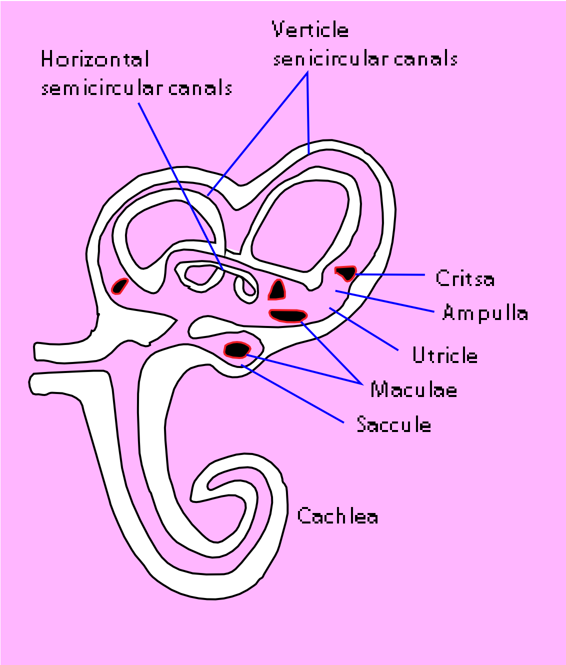


# The vestibular apparatus

The vestibular apparatus responsible for the sense movements in body and maintenance of dynamic equilibrium, consists of three semicircular canals in planes at right angles to each other.

At one end of each semicircular canal is a swelling (**ampulla**) which contains a receptor called a **crista.**

Each semicircular canal connects to two sacs called **saccules** and **utricle** often called Otolith organs.

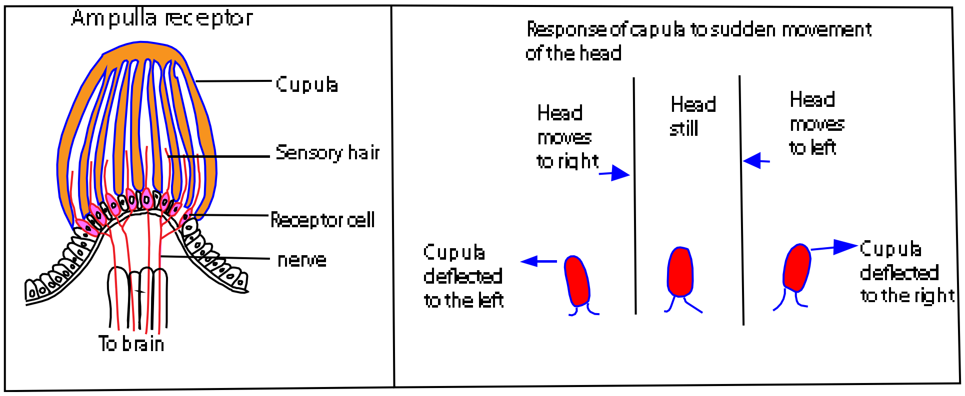



**The ampulla**

The ampulla contains of a group of receptor cells with hairs embedded in in a dome shaped gelatinous cap, the **Cupula** sensitive to movements of the head.

The fact that, the three canals are in different planes ensures sensitivity to movement in any plane.

Because of inertia of the fluid in the semicircular canals, movement of the head deflects the ampulla in an opposite direction as shown by the figure below.



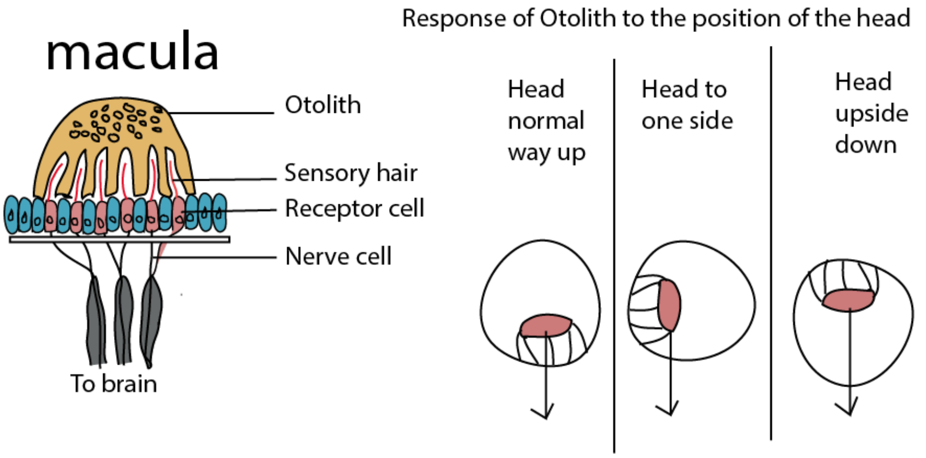

The deflection of the cupula puts mechanical strain on receptor cells, causing them to fire impulses to the brain

**The utricle and saccule**

The utricle and saccule contain specialized group of cells called **macula** that give information on the position of the head.

Macula consists of  a group of receptor cells, the free ends of which are embedded in a gelatinous substance containing a high concentration of dense particles of calcium carbonate called **otolith**. The role of otolith is to increase inertia.

According to the position of the head, the pull of gravity on the Otolith vary as shown in the diagram below.




The differential distortion of the receptor cells resulting from the head being held in difference position determines the pattern of impulses discharged by the nerve fibre to the brain.

Because of the way they are situated within the vestibular apparatus, the saccule is more sensitive to vertical acceleration (like riding in an elevator) and the utricle is more sensitive to horizontal acceleration (riding in a car).

T

**Revision questions**

1. cones have better visual acuity than rods because cones
   A. have little retinal convergence
   B. are more sensitive to light
   C. connect with a single optic fibre
   D. are more concentrated at the fovea
2. Which one of the following is true of what occurs at the excitatory synapse when impulse arrives?
   A. chloride channels close
   B. receptor site close
   C. post synaptic membrane becomes impermeable to calcium ions
   D. Sodium ion channels open
3. In the mammalian eye, rods have a poorer visual acuity than cones because they are
   A. fewer in number
   B. smaller in size
   C. connected to more than one optic nerve
   D. less sensitive to light
4. Staying in a dark room for a long tine increases the sensitivity of the eye to light because photochemical pigment are
   A. Not broken down
   B. Formed faster than they are broken down
   C. Destroyed
   D. Not synthesized
5. Which one of the following is the correct state of the structures in the mammalian eye during accommodation for far objects?

| | Ciliary muscle | Suspensory ligament | Curvature of the lens |
|---|---|---|---|
| A. | Relaxed | Taut | Decreased |
| B. | Contracted | Taut | Increased |
| C | Relaxed | Relaxed | Decreased |
| D. | Contracted | Relaxed | Increased |

6. Which of the vestibular apparatus responds to vertical movement of the head?
   A. Vestibular canal
   B. Saccule
   C. Utricle
   D. Semi-circular canal
7. Arthropods have a lower visual acuity compared to vertebrate because

A. The ommatidia are less sensitive to light than rods and cones
B. Compound eyes contain fewer rods and cones
C. The ommatidia are big and only few are packed in an equal area
D. Ommatidia contain photochemical pigments which are less readily bleached.

8. Which of the following does not contribute to the short reaction time in insects?

A. Large size of ommatidia?
B. High flicker fusion frequencies
C. Rapid transmission of impulses
D. Large coverage of the head by compound eye

9. Loud and low-pitched sound is caused by sound waves of
A. Large amplitude and high frequency
B. Low frequency and large amplitude
C. high frequency and small amplitude
D. small amplitude and low frequency

10. Which of the following applies to the cones of the retina? They
    A. show visual acuity
    B. perceive dim light
    C. show much retinal coverage
    D. contain rhodopsin pigment

11. Excellence in detection of movement at the lateral edges of the visual field is attributed to
    A. rods and cones
    B. rods only
    C. cones only
    D. compound eyes

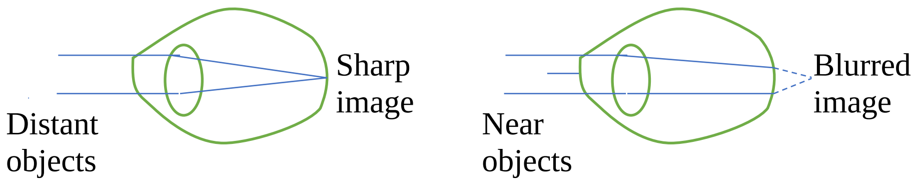
12. Which one of the following types of sound waves travel farthest along the basilar membrane? The sound waves with
    A. high frequency and high amplitude
    B. low frequency and high amplitude
    C. high frequency and low amplitude
    D. low frequency and low amplitude

13. An individual with vocal cords that have lost elasticity is likely to produce sound that is
    A. high pitched
    B. loud
    C. low pitched
    D. shaky
14. Which of the following describes the pigment within the rod cells?
    A. Breaks down easily on illumination
    B. Requires high light intensity to be activated
    C. Is not readily resynthesized after breakdown
    D. Is capable of color reception.
15. Mutual inhibition in the compound eye of insect is to
    A. Increase color vision
    B. Increase brightness of light in the eye
    C. Increase the contrast in light intensities between adjacent ommatidia
    D. Reduce the intensities of light into the eye
16. Inability to see clearly immediately one enters a dark room from bright light could be due to

A. Denatured rod
B. Denature cones
C. Rhodopsin being resynthesized
D. ATP molecules being resynthesized

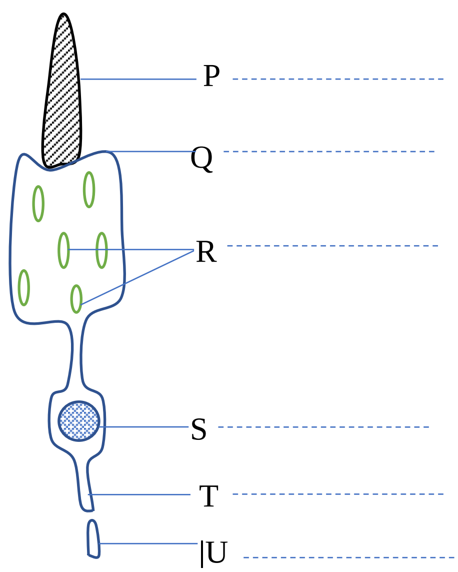
17. Which one of the following features make cones to have better visual acuity than rods?
    A. Each cone is connected to a single optic nerve fiber
    B. Cones are more sensitive to light
    C. Cones are connected to more than one optic nerve fiber
    D. Cones have high retinal convergence

18.




The diagrams in the figure show a defect of the eye. What is it and what does it cause?
    A. Eyeball is too short for the lens, causing short sightedness
    B. Lens is too thick, causing short sight
    C. Eyeball is too short for the lens, causing long sighted
    D. Eyeball is too large for the lens, causing astigmatism

19. The figure below is a drawing of a rod cell from the retina of the cell




(a) Name the points P, Q, R, S T and U.
    (b) (i) Indicate by the means of an arrow the flow of impulse built up in the cell on stimulation
    (ii) Mark with an X, the part which contains the light sensitive pigment.
    (c) Give the name of the light sensitive pigment.

(d) Briefly outline the process which lead to the building up of an impulse in the sensitive cell.

(e) How is the rod cell specially adapted to increase efficiency in its functions?

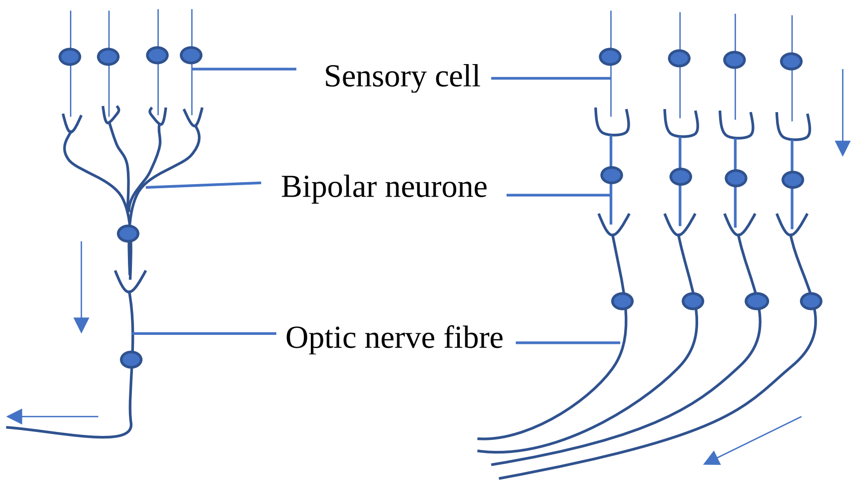
20. Explain why

(i) Rods show high sensitivity to light (04marks)

(ii) Cones show high visual acuity (4matks)

(iii) It is difficult to catch a fly (2marks)

21. The figure shows two types of arrangement, A and B, of sensory cells in the mammalian eye.




(a) What is the effect of each arrangement on the response of the eye?

(i) Arrangement A (1mark)
(ii) Arrangement B (1mark)

(b) Explain how the effect of each arrangement is brought about
(i) Effect of arrangement A (3marks)
(ii) Effect of arrangement B (3marks)

(c) Under which light conditions is each arrangement most effective and why

(i) Arrangement A (01marks)
(ii) Arrangement B (01mark)

22. (a) Outline the various ways in which the efficiency of receptors is ensured (07marks)
(c) Explain the differences in acuity and sensitivity of light by different parts of the retina. (13marks)

23. (a) Describe the characteristic of receptor cells. (06marks)
(b) Describe the role played by each of the following in maintenance of balance in a human body.
(i) Semi-circular canal (07marks)
(ii) Utriculus and saccules (7marks

24. (a) What is the correct order of structures through which light passes before striking the retina in a mammalian eye?
(b) Explain why;
(i) retinal convergence increases the sensitivity of the eye.
(ii) While trying to see an object clearly at night, it is best not to look directly at it, but rather slightly to one side.

| | | |
|---|---|---|
| 2 | 2006/1/41 | |
| Assay questions | | |
| 1. | 2011/2/5 | (a) |
| 2. | 2010/2/5 | (iii) ) |
| 3 | 1998/2/6 | (iii) |

Possible answers

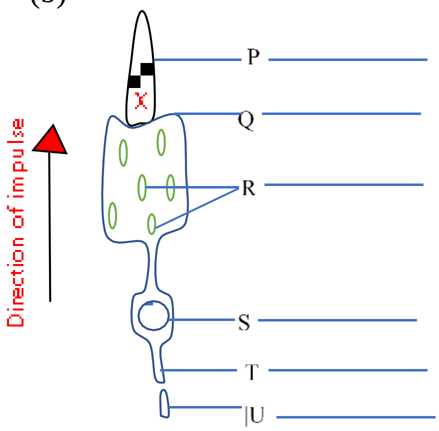
| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | C | 4 | B | 7 | C | 10 | A | 13 | D | 16 | C |
| 2 | D | 5 | A | 8 | A | 11 | B | 14 | A | 17 | A |
| 3 | A | 6 | B | 9 | B | 12 | D | 15 | C | 18 | C |

Structured

19. (a) P – disk
Q- celium
R – mitochondria
S – nucleus
T – axon

U – bipolar neuron

(b)




(c) Rhodopsin

(d) any stimulus that open sodium gate to cause reversal of resting membrane potential elicits and impulse.

(e) Adaptations of rod cells to their functions

- has photosensitive pigment
- has stacked disk to increase room for carriage of photopigment
- contain numerous mitochondria to provide energy for synthesis of bleached photopigment
- has enzymes for synthesis of bleached photopigment.

20. (a) Several rod cells make synaptic, connections with a single neuron, and then connected to the brain via a single optic nerve.

When a small stimulus which would not cause stimulate of rod cell fall on the rod cells depolarization are produced in each rod cell and summate an action potential on the bipolar cell. The action potential is eventually registered by the brain. Thus, the rods show sensitivity to light.

(b) Cones are closely packed into the fovea and each cell has its direct connection to the brain. Light energy from close points on an object on two different cone cells and be separately interpreted the brain. Each cone synapses with one bipolar neuron hence each part of the object is detected by a different cell and, as a result, interpreted differently by the brain.

25. The visual of an insect is so wide it can detect movement over a wider area of its surrounding.

Also the speed of transmission of impulses to the brain is so rapid that reaction time for an insect are much reduced.
Thus, when you try to catch a fly, it will detect the movement of your hand very quickly and react quickly to it by flying away before your hand reaches it .

**21 (a)** (i) Improves sensitivity of eye.

(ii) Improves the visual acuity of the eye.

(b) (i) Sub-threshold stimuli failing on individual sensory cells create depolarization potentials which summate to form an action potential in bipolar neuron.

-The action potential travels to the brain which perceives an image of the area illuminated. The improves sensitivity of the eye.

(ii) Light energy from parts of an object which are close together can fall on separate sensory cells.

- If the light energy is large enough an action potential is built up in each cell which is transmitted individually to the brain .

-Thus, the brain interprets these as two or more separate points on the object.

(c) (i) Din light or light of low intensity.

**Reason:**

Only sub threshold potentials can summate into an action potential in the bipolar neuron. These can be attained by low light intensity.

(i) Bright light
Or light of high intensity

**Reason :**

Each sensory cells conveys its own information and thus, requires enough stimulus to evoke an action potential in it.

22. (a) The efficiency of receptors is ensured in two ways; by their properties and by the synaptic connections of their never supply.

How receptor properties ensure their efficiency;

- Transduction: all receptors are capable of converting a physical stimulus into electrical impulses. This ensures that each stimulus is registered in form of an electrical impulse.
- Sensitivity: receptors can detect even the slightest of a stimulus for which they are meant. In this way, they have a low threshold of stimulation so that even small changes in a stimulus can be registered and transduced into an electrical impulse.
- Precision: receptors are precise in transmission of information. They receive and transmit the exact information about a stimulus without any alteration. This ensures that they send the exact information to the brain about the changes in the environment.
- Inhibition. The transmission of certain impulses in the receptors can be inhibited. This is important because it ensures that the receptors transmit only that information which is of use to the organism it a particular time.
- Adaptation: receptors can adapt and therefore stop firing impulse if a stimulus is maintained over a long time. This is important in protecting the organism against over stimulation and also allows the receptors to record and therefore report only changes in the stimulus.

How synaptic connections of receptors ensure their efficiency.

- Convergence and summation.

Many sense cells may be connected to one sensory membrane, a phenomenon called convergence. This provides a high degree of sensitivity to the receptor cells; small subthreshold impulses converge on the sensory neuron and summate into an impulse which can be fired in the neuron.

- Inhibitory synaptic connections with inhibitory neurons. These are important in regulating the frequency of firing of the receptor cells.

(b) Difference in acuity and sensitivity to light by the different parts of the retina depend on the relative distribution of cones and rods in it.

- The cones are concentrated in a small area in the centre of the retina called fovea centralis. Cones are arranged such that each cell synapses with its bipolar cell, which in turn synapses with its own optic neuron. Being closely packed light form two close points on the object can fall on two separate cones so that these can be visualized as separate. Hence, higher visual acuity.

  Rods are scattered in the periphery of the retina.

  With a single bipolar cell, in a phenomenon of convergence. Due to this convergence, rods are more sensitive to light than the cones; low intensity of light which cannot stimulate a single rod or cone is able to stimulate the bipolar neuron connected to the rods as a result of summation.

  As a result, acuity is greatest at the fovea which is normally at the centre of the field of vision and gradually decreases towards the periphery of the retina which forms edges of our field of vision.

  On the other hand, sensitivity is greatest at the periphery of the retina and decreases towards the centre (fovea).

23. Solution

(a) Characteristics of receptor cells include;

- Transduction; receptor cells are capable of changing physical stimuli into an electrical impulse.
- Sensitivity; receptor cells are able to detect the slightest change in their environment (stimulus)
- Adaptation; if a stimulus is maintained, receptor cells are able to adapt to it so that the stimulus no longer causes an impulse, however strong it is.
- Inhibition; receptor cells can be stopped from firing impulses by special synaptic connections. As a result, certain impulses are transmitted only when required.
- Precision; receptors are able to transmit the information precisely without alteration.

(b) (i) semi-circular canals are important in dynamic equilibrium.

The ampulla in the semi-circular canals consists of groups of sensory cells whose hairs are embedded in dome-shaped gelatinous, capulla. The canals are filled with fluid called endolymph. There are three in number, arranged in three planes; vertical canals detect movement in upward direction; horizontal canals detect backward and forward motion while lateral canals detect sideways movements of the head.

When the head moves in any one of these planes, the fluid in the relevant canal also moves, displacing the capulla. Due to inertia, the capulla is deflected in the opposite direction to that of movement of the head.

This puts strain on the sensory cells, causing them to fire impulses in the different nerve fibres to the brain.

The pattern of impulses is interpreted by the brain which detects the direction and speed of movement and sends instructions to relevant organs than maintain dynamic balance.

(ii) The utriculus and sacculus contain maculae which are regions containing receptor cells. These have their hair-like processes attached to otoliths.

By varying the position of the head, the pull of gravity over the hairs on the otoliths tilts them accordingly.

The different influences of the pull of gravity result in a pattern of impulses to the brain. The brain interprets the position of the head in space and accordingly sends instruction to relevant muscles to restore balance.

24 (a) light passes through conjunctiva, cornea, aqueous humor, pupil, lens and vitreous humor to the retina.

(b) (i) Sensitivity is the ability to respond to small amount of stimulus.

Retinal convergence is a situation where many rod cells make synaptic connection with a single with a single bipolar neuron which in turn makes connections with single optic nerve fiber. A small sub threshold stimulus received by rood summate to produce action potential in the bipolar cell though it would not do so if a single rod was stimulated. the action potential is eventually registered by the brain, increasing sensitivity of the eye.

(ii)

- when looking directly at an object, light falls at the fovea, that contain cones only that are less sensitive to light.
- At night, light intensity would be too low to activate the cone.
- looking at object slightly to one side, light fall on the rods that are more sensitive to dim light due to retinal convergence.

Thank you