UNIT 10 SPECIAL SENSES

Structure

10.1 INTRODUCTION

We live in an information age. We are flooded with information, a lot of which is not relevant to our needs. There are a few organs in the body, which collect information of special significance to us from the external environment and are therefore called the *'organs of special senses'*. Special senses include vision, hearing, taste and smell. The range of these sense organs is limited. For example, the eyes are sensitive to only a limited range of spectrum – the rainbow (VIBGYOR) and hearing to frequencies 20 Hz - 20 KHz and that too only if the intensity of the sound is above a certain threshold. Thus the information perceived by our sense organs is only a fraction of what reality is.

Special senses include the senses for vision, hearing, smell and taste. Organs for special senses are the eyes, ears, nose and tongue. In this unit, we shall focus on the physiology and the mechanism of functioning of these organs.

Objectives

After going through this unit, you will be able to:

- describe the structure of eye and mechanism of vision,
- discuss the physiology and mechanism of taste perception,
- enumerate the factors affecting and inhibiting taste perception,
- explain how sound is transmitted and perceived, and
- discuss the mechanism of sense of smell.

Let us begin our discussion with the vision as a special sense, which helps us to see and perceive the world around us.

10.2 VISION

The eyes are the sense organs for vision. They contain receptors that are called *photoreceptors* e.g. cones and rods. These cells are responsible for converting the specific light energy into action potentials of nerve fibers. Thus, these act as solar cells converting light into electrical energy. The sun gives us light, the eye perceives this light and the brain interprets it. Let us now study the structure of the eye.

10.2.1 Structure of the Eye

The eyes are located in bony orbital cavities and are cushioned in a fatty connective tissue. The wall of each eyeball is made of three coverings. See Figure 10.1 and try to locate these. The first covering is the tough protective coat that is fibro-elastic in nature is the *sclera* (white of the eye). This layer is opaque and does not allow the light to pass through. It forms the posterior five-sixths of the eyeball. The thin transparent layer called *cornea* forms the anterior one-sixth of the outer layer of the eyeball. The middle layer, consists of the vascular choroid which forms ciliary body and iris anteriorly. The iris has a small adjustable circular gap in the front called pupil. The third, innermost layer is light-sensitive retina. Its central portion is maculalutea.

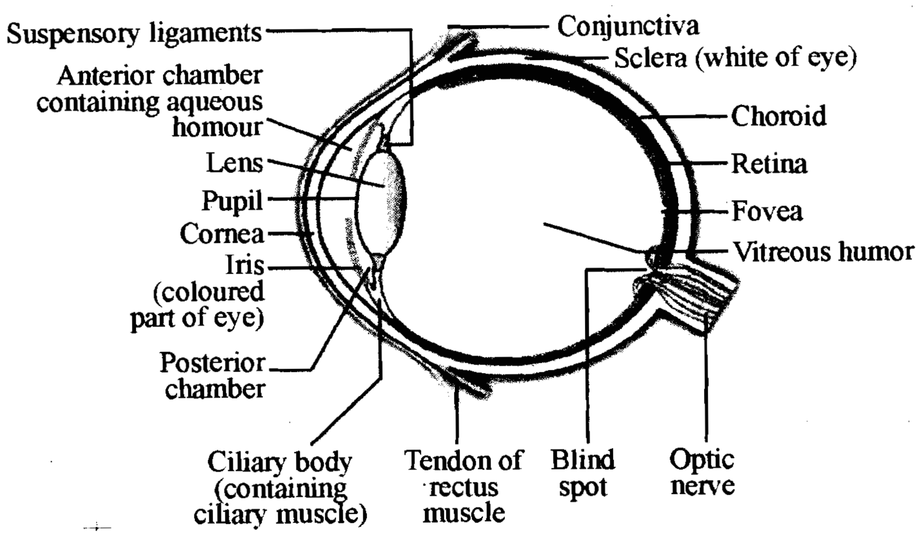


Figure 10.1: The structure of the eye

The eyeball is like a ball that has reins of muscles attached to it. These help move the eyes in all directions – up, below, left, right, clockwise and anticlockwise. These are supplied by the cranial nerves. That may be remembered by the chemical formulae of an imaginary compound LR_6SO_4 $REST_3$: Lateral Rectus: 6^{th} nerve, Superior Oblique: 4^{th} nerve and the 3^{rd} nerve supply the rest of the muscles. The sclera provides a surface for attachment of these muscle strings. What will happen if these muscles become weak? In case of paralysis or weakness of these muscle strings, the condition which results is of *squint.* What is this condition and how does it occurs? The muscle of one eye pulls in one direction and that of the other in a different direction and this result in the squint. The person would see two instead of one object for example, two moons instead of one! This condition is termed as *diplopia,* meaning di or double vision.

The cornea acts as a convex lens, bending light reflected from the object. This helps in focusing an object on the innermost sensitive curtain of the eye called the *retina.* The retina is made up of cells and nerve fibers. See Figure 10.2 for the microscopic structure of retina.

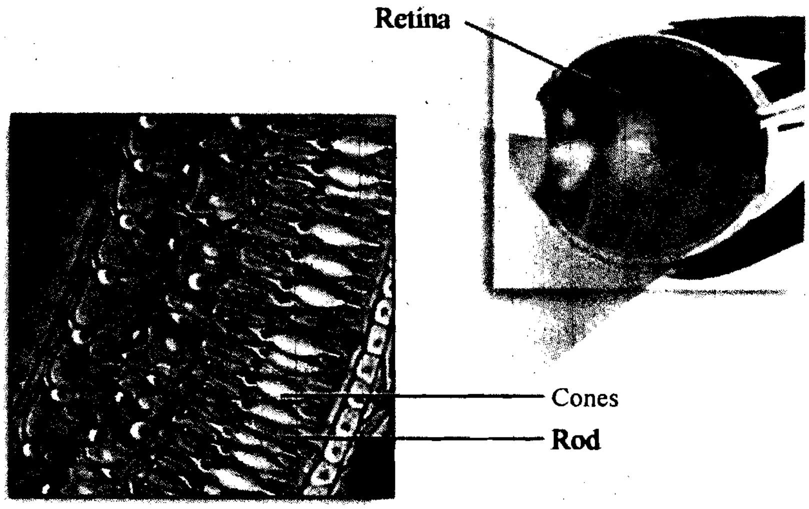


Figure 10.2: Structure of retina

The retina nerve cells are the *rods* and *cones* as highlighted in Figure 10.2. The distribution of rods and cones are not equal in the retina, like the stars, which are not uniformly distributed in the universe. The *cones* are concentrated toward the center of the retina and are responsible for *colour vision*. The *rods* are responsible for *black-and-white* vision in dim lighting. Let us get to know the rods and cones better.

The rods are most sensitive to light and dark changes, shape and movement and contain only one type of light-sensitive pigment. Rods, therefore, are not good for colour vision. In a dim room, however, we use mainly our rods, but we are "colour blind." Rods are more numerous than cones in the periphery of the retina. Next time you want to see a dim star at night, try to look at it with your peripheral vision and use your *rod vision* to see the dim star. There are about 100 million rods in the human retina.

The cones are not as sensitive to light as the rods. However, cones are most sensitive to one of three different colours – green, red or blue. Signals from the cones are sent to the brain which then translates these messages into the perception of colour. Cones, however, work only in bright light. That's why you cannot see colour very well in dark places. So, the cones are used for colour vision and are better suited for detecting fine details. There are about 3-6 million cones in the human retina. Some people cannot tell some colours from others – these people are *colour blind*. Someone who is colour blind does not have a particular type of cone in the retina or one type of cone may be weak. We shall learn about colour blindness in a little while from now. The properties of rods and cones are highlighted in Table 10.1.

Table 10.1: Properties of Rods and Cones

Rods	Cones
100 million/retina	3 million/retina
Vision in shades of grey	Colour vision
High sensitivity	Low sensitivity
Low activity	High activity
Night vision (Scotopic)	Day vision (Photopic)
More numerous in periphery	Concentrated in fovea

Rods have a pigment that is sensitive in even dim light. This pigment is purple coloured and is called *rhodopsin*. This pigment is formed by a series of reversible reactions as indicated in photochemical reactions shown in Figure 10.3.

Rhodopsin

Light ↓↑ dark

Opsin

+

11-Cis-retinal

⇕

All-trans-retinal

⇕

All-trans-retinol

(Vitamin A)

Figure 10.3: Photochemical reactions in light and dark

Many nocturnal animals like the owls have only rods. This enables them to see even in the dark. A deficiency causes night blindness in man because rods cannot function if rhodopsin is not synthesized from vitamin A. The person cannot see in dim light and bumps into things in dim light. Vitamin A helps to restore the sight.

The *blind spot* (refer to Figure 10.1) is an area where there are no cones and rods. This area is devoid of the ability of vision. The blind spot marks the point of convergence of neurons that form the optic nerve.

Lateral to the blind spot, there is a depressed area of retina called *fovea,* which contains only cones and no rods. Ability for vision is highest in the fovea and the light falls directly on retina here. This may be responsible for love at first sight! Since the light is converted and transmitted at a faster rate here than other areas of the retina. The other peculiarity of the fovea is that it is backed by only four neurons with one to one representation from the cones. These are *the bipolar cells, the amacrine cells, the horizontal cells and the ganglion cells, and the neuronal cells* of the retina as shown in Figure 10.4. These neurons are responsible for appreciating the shape, contrast, directional orientation of light and Colour properties of the vision. The details on these topics are out of the scope of this unit, hence we shall not take this up any further.

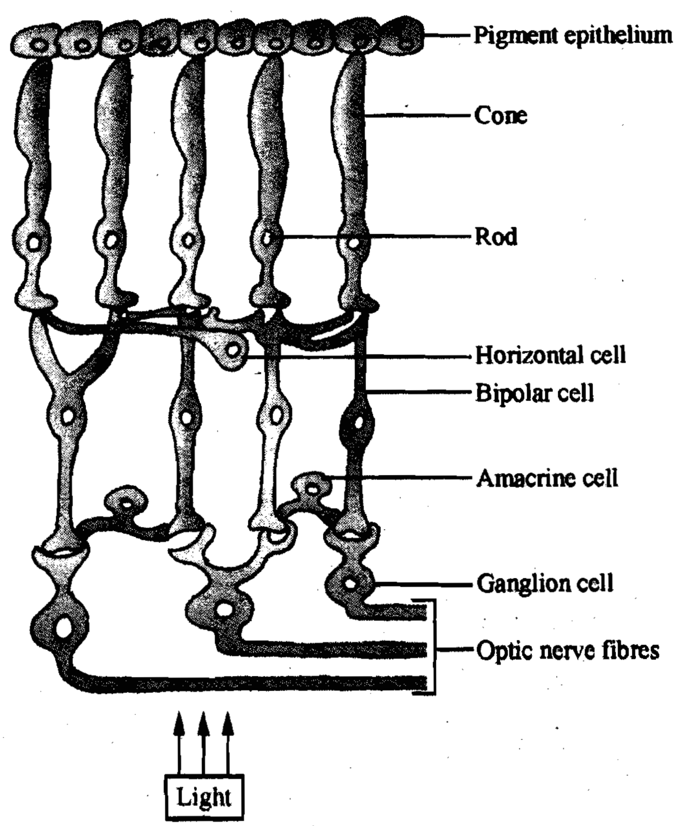


Figure 10.4: Retinal cells

We shall move to the middle layer of the eye now.

The middle layer consists of the *choroid, the ciliary body* and *the iris.* The vascular structure – *the choroid* is pigmented and separates two layers of the eye. Could you guess by seeing the diagram in Figure 10.1 what the two layers are? Yes, these are the *outermost sclera* and the *innermost cornea.*

The choroid is connected in front to a thick muscular structure – the *ciliary body.* The muscles are smooth involuntary muscles and are called as the *ciliary muscles.* These suspend thread-like ligaments that attach to the edges of the lens. The *lens* is a transparent structure and has elongated cells. It is an elastic structure that can be bent like the contact lens in your fingers. This helps in accommodating near objects for example, during reading or inserting a thread in a needle.

Have you ever seen some people have beautiful green eyes or blue eyes or even jet-black or light brown? Ever wondered what gives this wonderful tinge to make each of us different? The answer lies in the genes that we inherit from our parents and which code for this wonderful pigment that gives us the colour. The coloured diaphragm in Figure 10.5 is the *iris.*

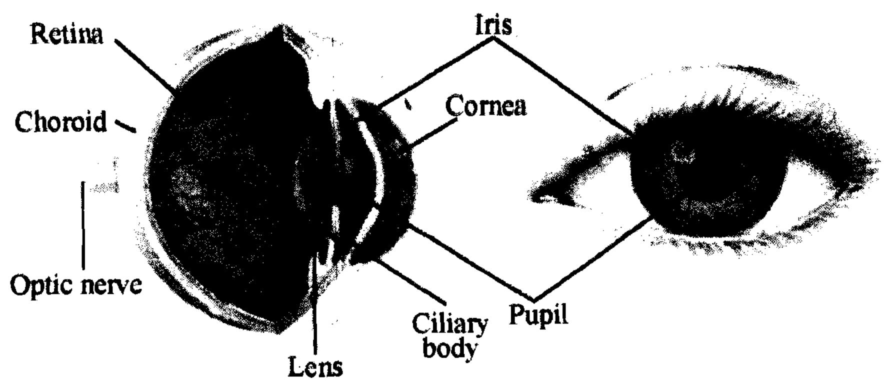


Figure 10.5: The iris

Take a torch and shine it in a dark room in the mirror. Observe the eye dilating and constricting. This is because of the sphincter and dilator papillae located in the iris, as shown in Figure 10.6. These radial and circular iris muscles allow the light to pass through the pupil to the lens. In Figures 10.5 and 10.6, you would notice a central black hole. This is called as *the pupil* of the eye. The lens then focuses the light to form a sharp image on the retina.

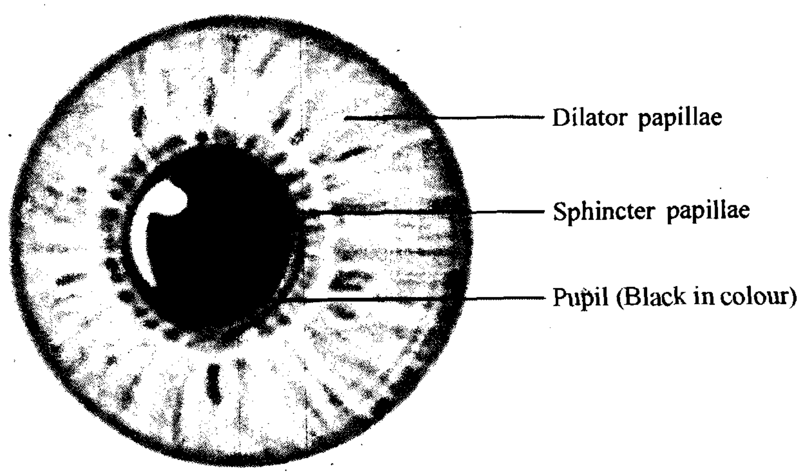


Figure 10.6: Muscle of iris

The cavity inside the eyeball is divided by the lens, ciliary body and suspensory ligaments into an anterior compartment and a posterior compartment. The anterior compartment is filled with a fluid called *aqueous humor*. Close your eyes. Remove your spectacles, if wearing. On the left eyeball, press the eyeball with your right index finger. Do you feel the eyeball displace? This may be better appreciated by feeling the eyeball with the left index finger. This displacement is of the aqueous humor. The aqueous humor is the fluid, which is responsible for providing nutrition to the lens and cornea and by its pressure, it maintains shape of the eyeball and supports the lens. The posterior compartment is filled with a transparent gelatinous material called *vitreous body* that supports the lens and the retina.

Glaucoma is a condition in which the eyeball bulges due to an increase in intraocular tension either due to an excessive production of aqueous humor because it cannot be drained through a narrow opening called the *Canal of Schlemm*. This fluid exerts a tension in the eyeball as does water when filled in a water balloon. The normal intraocular tension is 12 to 20 mm Hg. The intraocular pressure (IOP) is considered to be high if it is above 20 mm Hg (2.66 kPa) on repeated measurements. In an attack of acute glaucoma, it can exceed 60 mm Hg (8 kPa).

We have just read about the IOP. Have you wondered what makes us appreciate colour? Cones contain a violet-coloured photosensitive pigment called *iodopsin*. Sparrows that are active only during the daytime have only cones and are not active at night. Let us get to know about the mechanism of colour perception, next.

10.2.2 Mechanism of Colour Perception

How do we perceive colour? Let us, in this section try to understand the mechanism of colour perception and the factors that influence it. We start with the pre-requisites of colour perception.

Pre-requisites of Colour Perception

To be able to perceive colour, there must be a light source, an object and of course, the organ of perception. The brain, which plays an important role, in colour perception, cannot be forgotten. Let us look at each of these pre-requisites.

1) *Light source:* No colour may be detected by the eyes or by an instrument in the dark i.e. in the absence of a light source emitting radiant energy in the visible range of the spectrum. Wrong results will be obtained if the light source is not emitting sufficient radiant energy at the critical wavelength. To avoid this, three standard illuminants i.e. light sources have been established by the *International Commission of Illumination*. These are:
   - Illuminant A i.e. incandescent lamp (2844°K)
   - Illuminant B i.e. noon sunlight (4000°K)
   - Illuminant C i.e. cloudy daylight (6800°K)
2) *Object:*
   - Metameric pair – shows different colours at different wavelengths.
   - Non-Metameric pair – shows same colour at all wavelengths.
3) *Organ of perception:* These are the receptors. Receptors, as you may already know, are the rods and cones cells present in the retina of eyes. They are able to receive the light and transmit the signal to the brain via the nerve fibres.
4) *Brain or detector:* The fibre identification of colour takes place in the brain.

If any of these four pre-requisites are not present, the perception will not take place. In case of colour perception, the reaction time is very fast. The perception is the result of the interaction of light source, object, receiver and detector. The receiver is eye and the detector is brain. When light falls on an object, there is an imbalance of radiant energy and a number of phenomena may occur due to this imbalance, which include reflection, absorption and transmission. The colour perceived is dependent on the reflected light. Reflected ray is received by the retina of the eye, which gets stimulated, the impulse is transferred to the nerve fibres via optic nerve and finally, it goes to the brain. There are special centers in the brain where colour is identified.

To conclude, colour is the stimulus that results from the detection of light, after it has interacted with an object. Three factors are involved: *a light source, an object* and *a receiver-detector.* The light may be reflected, transmitted, absorbed or refracted by an illuminated object.

Next, let us study the factors which influence colour perception.

Factors affecting colour perception

The two most important factors which influence colour perception include:

- Temperature, and
- Humidity

How do these factors influence colour perception? Both these factors affect the dullness or brightness of the colour. Colour appears to be brighter at a higher temperature, as the glossiness is increased at higher temperatures. Under humid conditions, reflected rays are more diffused so the object appears dull in colour.

Earlier, we learnt that the cones are not as sensitive to light as the rods, but are most sensitive to one of three different colours – green, red or blue. So, the cones are used for colour vision. Some people cannot tell some colours from others – these people are "colour blind." Let us now try to understand what is meant by the term *colour blindness* and what its types are.

Colour Blindness: Normal individuals possess three cone pigments viz. red, green and blue which are referred to as *tri-chromates*. Colour blindness refers to the partial i.e. reduced levels or complete absence of one or more of the cone pigments. Colour blindness can be classified into:

- *Dichromates or mild colour blindness:* A dichromate individual possesses only two cone pigments. Lack of the red pigment, called *protanopia,* makes distinguishing of the red and green colours impossible and the visual system is insensitive to deep red colours. Similarly, the lack of the green pigment, called *deuteranopia* also makes the differentiation of red and green colours impossible but the visual system is nevertheless sensitive to light in the range normally served by green pigment because responsiveness of red and blue pigments overlaps into this range. *Dalton* was red green blind. Just imagine him driving a car at a traffic light signal! Lack of the blue pigment, called *tritanopes* makes the discrimination of blue and green colours impossible.

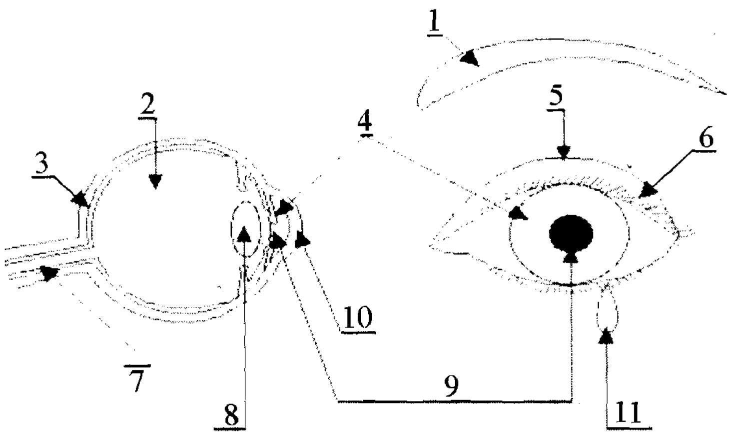
- *Monochromates or total colour blindness*: The monochromate individuals lack all cone pigments and cannot distinguish colours at all. They find bright light very unpleasant. They perforce have to use the *scotopic* system for seeing both in bright and dim light.

Colour blindness is often assessed using *Ishihara's charts*. If ever you visited an eye specialist, you too must have seen this chart. In this, the numbers are inscribed amongst different dotted coloured background. The degree of dotted coloured background is enhanced progressively thereby making it more and more difficult to discern numbers. *Trichromates* i.e. normal individuals can distinguish these numbers easily, while colour blind individuals cannot see or they recognize a wrong number.

The next section focuses on the process of vision and disorders related to proper image. But before we move to the section, let us recaptitulate what we have learnt so far.

Check Your Progress Exercise 1

1) Label the different parts of the eye shown in the diagram below:



2) Which type of photoreceptor is most sensitive to bright light and colour? Give the properties of this photoreceptor.

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3) What is normal intraocular tension? Name an acute condition in which tension is raised.

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4) Briefly discuss the factors affecting the colour perception.

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5) How would you classify colour blindness and diagnose a case?

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10.2.3 Optics of Vision

The overview of the vision process is presented first, in this section, followed by the vision process in the normal, disordered and corrected eye.

For proper vision, light rays from a visual object must be focused on the retina. In the resting state, the ciliary muscles remain relaxed, keeping the suspensory ligaments stoutly stretched. The stretch by the suspensory ligaments flattens the elastic lens to reduce its curvature. The lens in the resting state focuses parallel rays from distant objects, like the tree in the far end of the park, on the retina.

For viewing near objects, the lens curvature changes to accommodate the light rays on the retina. Figure 10.7 illustrates thè relaxed and accommodated position of the lens. The 3rd nerve is activated from the cortex during reading to cause contraction of the suspensory ligaments and this reduces the stretching action of the lens.

The lens consequently increases its curvature due to its elasticity and its power is enhanced. It can now focus the divergent rays on the retina. This reflex is called as the *accomodation reflex*. The accommodation reflex is described as the constriction of the pupil as the eye fixates on near objects.

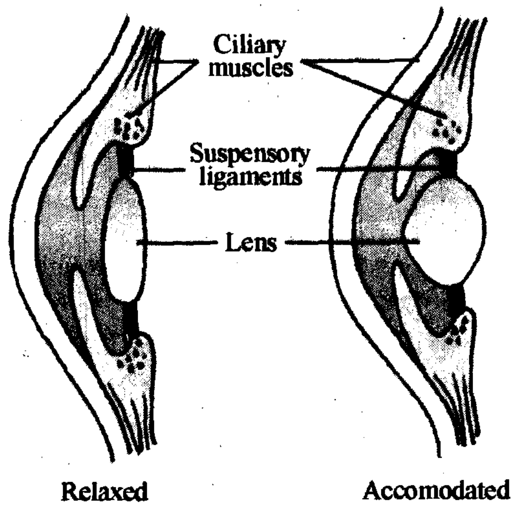

Figure 10.7: Accomodation reflex

Having understood the vision process, let us move on to study the disorders of the eye, and how it affects the vision process.

An eye whose far and near points are normal is called *emmetropic eye*. However, it is a common knowledge that eyes cannot see objects at infinity or as near as 10 cm. Accordingly, three common errors have been defined – myopia, hypermetropia and presbyopia. Figure 10.8 explains the image formation in a normal eye, disordered eye and the corrected eye.

Disorders of image formation and its correction can be discussed as follows:

- *Myopia:* The lens and cornea of a normal eye will focus a distant object on the retina. However, in some individuals, the eyeball is too long or too short, relative to the power of the lens and cornea. If the eyeball is too long or the cornea and lens are too powerful, it causes the focal point to be too near to the lens. The image is formed in front of retina as you can see in the Figure 10.8b. This is called *myopia* or *short-sightedness*. In myopic condition, the individual cannot see the far objects distinctly. It is corrected by placing a divergent or concave lens in front of the myopic eye as illustrated in Figure 10.8d.

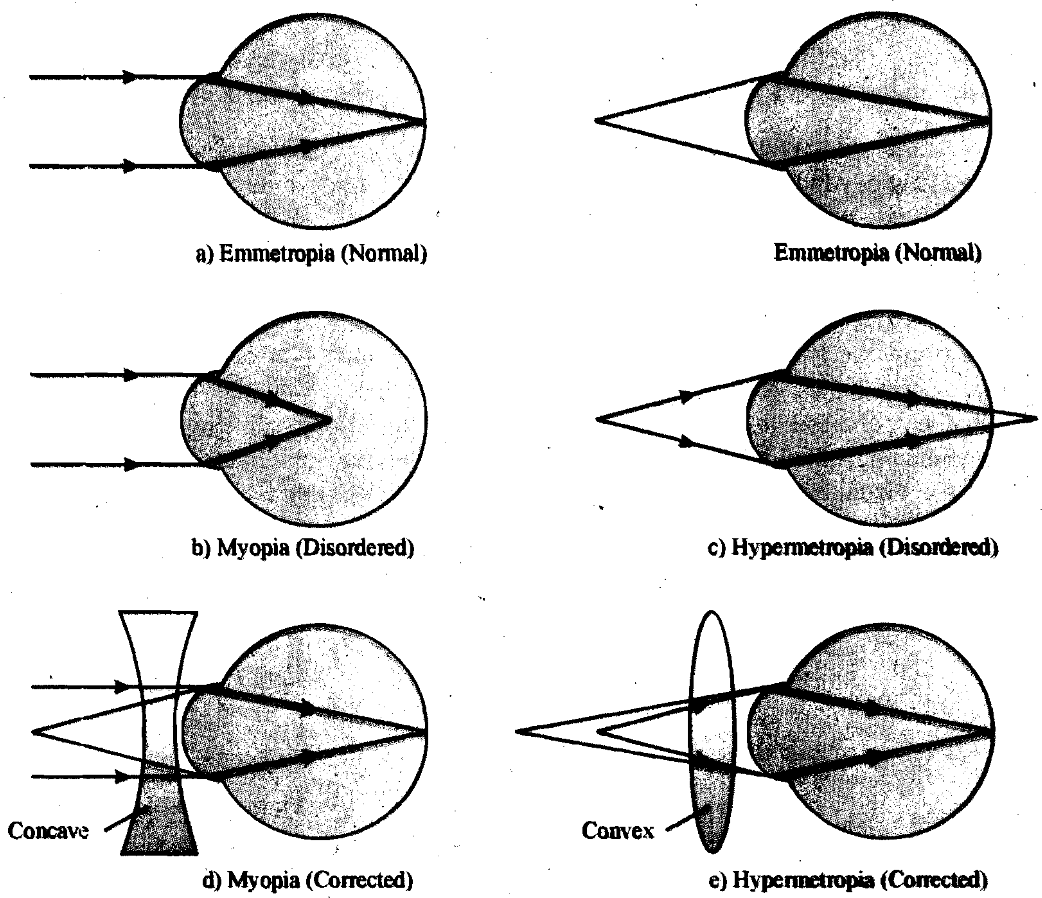

Figure 10.8: Disorders of image formation

- *Hypermetropia:* On the other hand, if the cornea and lens are too weak or the eyeball is too short, it is called *hypermetropia* or *far-sightedness*. Have a look at the Figure 10.8c. In such condition, the image is formed behind the retina. It is corrected by placing a convex (convergent) lens in front of the hypermetropic eye as illustrated in Figure 10.8e.

- *Presbyopia:* In older individuals, the lenses on the eyes loose some of the elasticity. Consequently, it becomes difficult to focus on the near objects. This condition is called *presbyopia* or *restriction of accommodation.*

Regardless of the age factor, the deformities in the lens and cornea of the eyes have been discussed above. But there are certain age-related debilitating changes that have been noticed in the eye lens. Let us study about these.

The lens during aging: The most apparent change that occurs as a consequence of aging is that the yellow tint or gloss of the lens gets intensified. In addition, as the years pass by, the lens becomes gradually more rigid, rendering it progressively harder for the ciliary muscles to change its shape i.e. to make it more spherical, as during accommodation. A person's ability to focus on close images deteriorates along with it. A young child can focus on the objects held within a distance of an inch from the eyeball, a young adult can only do that if the objects are placed at about 8 inches from the eyeball. By the time one reaches the age of 40 years, the lens has become stiffer and not able to focus objects placed nearby or two or three feet away. By the age of 40 years, the lens becomes as rigid, that it is almost impossible to adjust it very much either to distant or close objects. This condition is known as *presbyopia*. That is why bifocal or sometimes trifocal glasses are prescribed. Such lenses are designed to concede the inflexibility of the lens and to provide two or three other zones of focus artificially. The top of the bifocal length is usually slightly convex to concentrate on the things that are some distance away, while the semicircle along the bottom of the glasses is concave to permit focusing on the objects nearby.

The lens also looses its water with age. This results in an opaque lens called *cataract.* Modern treatment is replacing the lens with an artificial intraocular lens (IOL).

With our discussion above, we end our study on the optics of vision. Next, what happens beyond the eye? How our eye focuses on a particular object and its image is perceived by us? Let's find out.

10.2.4 Beyond the Eye

Just now we have seen how our eye focuses on a particular object and its image is perceived by us. But how does this actually happens? Well, the answer to this lies in the '*columnar organization of the primary visual cortex*', the details of which are shown in the Figure 10.9. See in Figure 10.9 how optic nerve transmits the signal to the visual cortex by means of optic tract and radiation.

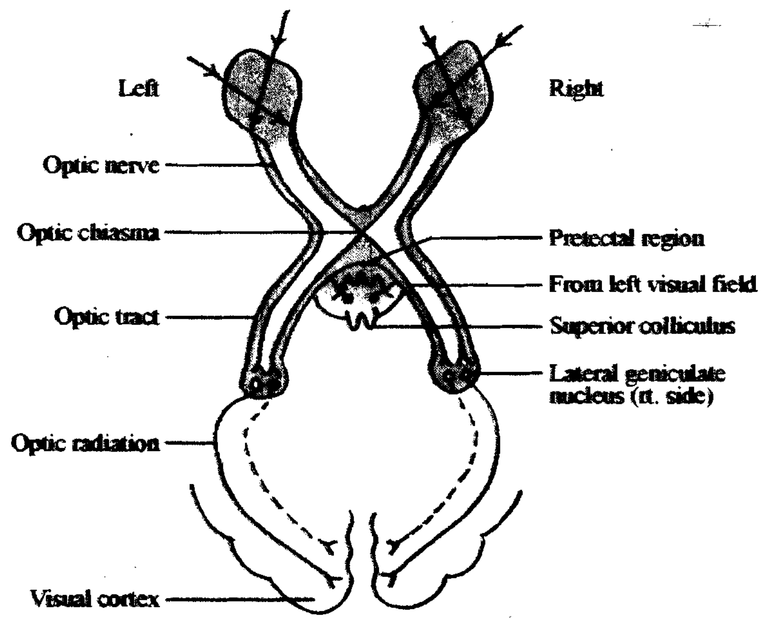

Figure 10.9: Principal visual pathway

Vision is generated by photoreceptors in the *retina*, a layer of cells at the back of the eye. The information leaves the eye by the way of optic nerve, and there is a partial crossing of axons at the optic chiasma as can be seen in Figure 10.9. After the chiasma, the axons are called the *optic tract.* The optic tract wraps around the midbrain to get to the *lateral geniculate nucleus* (LGN), where all the axons must synapse. From there, the LGN axons fan out through the deep white matter of the brain as the optic radiations, which will ultimately travel to primary visual cortex in the occipital lobe at the back of the brain.

Let us now understand what is this 'visual cortex' and its constituent cells, which have a major role to play in the mechanism of vision. This information is supplementary. Do not get bogged down by the details. It is only for your information.

The visual cortex consists of *macro-columns*, each macro-column measuring about 1 mm^2 of the cortical surface. Cells in the various layers of a macro-column have receptive fields within the area of the visual fields. Macro-columns consist of 'orientation micro-columns', each of which contains simple, complex and hyper-complex cells. They all respond maximally to a single orientation. Each macro-column has a band of 'micro-columns', dominated by inputs from the left eye and a band dominated by inputs from the right eye. Each cortical macro-column seems to contain all of the circuitry needed to analyze the small portion of visual world. Details of various cells playing their role in the primary visual cortex are as follows:

- *Simple cells:* They are most sensitive to lines oriented in a particular angle to the vertical. Simple cells probably receive a convergence of inputs from lateral geniculate cells whose receptive fields partly overlap.
- *Complex cells:* They are sensitive to both orientation and movement. For example, a line or edge with a particular tilt might stimulate a complex cell only if it was also moving in the right direction.
- *Hyper complex cells:* They require not only the line or edge to be moving but it should also possess a certain length with a corner.

With our discussion on visual cortex and its constituent cells, we come to an end of our study on how our eyes perceives an object.

Check Your Progress Exercise 2

1) What are the disorders of image formation? How are they corrected?

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2) How do the roles of the cornea and the lens in image formation differ from one another?

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3) What is accommodation in the eye? How it is brought about?

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4) What are the changes in the lens during aging?

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In the previous section, we have read about vision, the structure of the eye and the refractive errors and their correction. We shall now get to know about yet another special sense i.e. hearing in the next section.

10.3 HEARING

The ears, as we all know, are sense organs for hearing. The ear consists of an *external ear, a middle ear* and *an internal ear*. It houses receptors for both hearing and body equilibrium. The air conducts sound to the ear, which perceives it and the brain understands it. Let us get to know the physiology of the ear and the mechanism involved in the hearing process. But, first, we shall acquaint ourselves to the nature of sound.

10.3.1 The Nature of Sound

This section is a recapitulation of what you have learnt in school. You would recall that sound waves consist of the longitudinal waves of alternate compression and rarefaction. Areas of compression have a higher pressure and density of air molecules than the area of rarefaction. The waveform propagates itself for long distance because of the influence, which the areas of compression or rarefaction have on the neighbouring areas.

Thus, it is only the waveform that is transmitted and not the air molecules. The velocity of sound depends on the medium through which it is transmitted. In air, the velocity is about 340 m/sec. The loudness of a sound is related to the amplitude of pressure waves and the pitch to their frequency. Let us understand what we mean by the term 'amplitude'.

In simpler terms, amplitude is *the amount or relative value of a signal.* Amplitude is measured in units of pressure e.g. Newtons/sq. m. But what is physiologically more relevant is power, i.e. $(\text{amplitude})^2$. The faintest whisper that the ear can hear is much weaker than the loudest sounds that the ear can tolerate without getting damaged. Therefore, if the entire range of intensity of audible sound were to be expressed directly, we would be dealing with very inconvenient figures. Hence, we use a *logarithmic scale* to measure the intensity of sound. A logarithmic scale, as you know, is a highly condensed scale.The logarithm of 1 is 0, and log 10^{12} is 12, therefore the range from $1\text{-}10^{12}$ gets condensed to 0-12 on the logarithmic scale.

Bel, the unit of measurement of sound, is named after *Alexander Graham Bell. Bell* was the inventor of the telephone, but for some curious reason, is spelt with a single 'l'. Bel is too large a unit. Hence a unit, one – tenth as high, called *'decibel'* (dB) is more commonly used. Thus the range of human hearing extends from 0-120 dB. Besides intensity, the other important characteristic of sound is *frequency*, which is the major determinant of *pitch.* Pitch is expressed in cycles per sec or Hertz (Hz), named after an eminent German physicist of nineteenth century.

What is the range of frequency of sound which we can hear comfortably? Well, the range is really long. The human ear can detect sounds between 20 and 20,000 Hz (20 kHz). But most of the common sounds fall between only 200 and 4,500 Hz. Frequencies above 16 KHz are called *'ultrasound'* and those lower than 20 Hz *'infrasound'*. The audible range of man thus extends from 20 Hz to 16 KHz and from 4 to 130 phon (dB). This is the audible area or range. In the middle of this are the frequencies and intensities produced in speaking. This area or range in which the speech falls, is called as the *speech area* (250 Hz to 4 KHz, 40 to 75 db). For speech to be adequately understandable, transmission systems (e.g. telephone) must transmit frequencies at least in the range 300 Hz - 3.5 KHz. In older people, sensitivity to high frequencies regularly declines, a phenomenon known as *presbycusis.*

Let us now have a look at Table 10.2, where the various sources of sound, their level of loudness and its comparison to the faintest audible sound are given.

Table 10.2: Sources of sound and their level of loudness

S. No.	Sound source	Loudness (db)	Comparison to faintest audible sound (Threshold)
1.	Rustle of leaves	10	10 times more
2.	Ticking of watch	20	10 times more
3.	Normal conversation	60	1 million more
4.	Shouting	80	1 billion more
4.	Loud rock concert	120	1 billion
6.	Take off Jet plane	140	1 quadrillion

Having understood the nature of sound, let us get to know the structure which enables us to hear these sounds i.e. our ears.

10.3.2 The Ear – The Organ of Hearing

The human ear consists of three sections: *the outer ear, the middle ear,* and *the inner ear* as illustrated in Figure 10.10. The outer ear includes the auricle (pinna), the visible part of the ear that is attached to the side of the head, and the waxy, dirt-trapping auditory canal. The tympanic membrane (eardrum) separates the external ear from the middle ear, an air-filled cavity.

The part of the ear, which we can see, is only a small and rather unimportant part of the ear, and is called the *external ear* or the *pinna*. The visible part, or the pinna, is a small appendage on our face, as can be seen in Figure 10.10. It is commonly thought to collect the sound waves and funnel them.

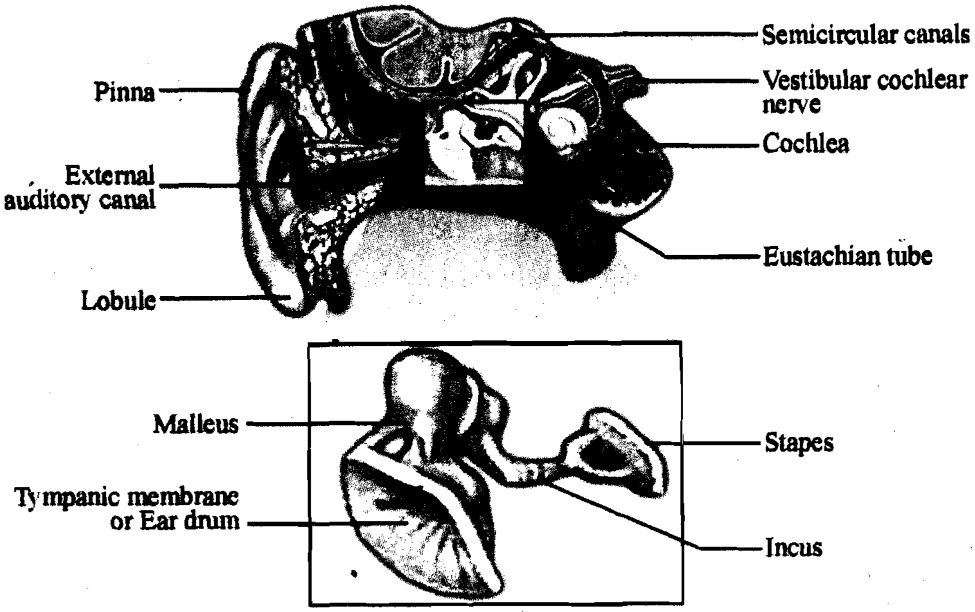


Figure 10.10: The external, internal and middle ear

But at least in human beings where the pinna is rather small, it is unlikely that this function is significant. Experiments have been conducted in which the various depressions of the external ear have been filled with a plasticine-like material to obliterate them. It has been found that doing so, makes no difference to the efficiency of hearing. Even in animals with large pinnae, a far more important function of these structures is to help in the localization of sound. By moving the ears, such experiments can accentuate the difference in the intensity of the sound reaching the two ears, and thereby localize sound more accurately. Since human beings cannot move their ears, they cannot use the pinnae very efficiently for this purpose. For accentuating the difference in the intensity of sound reaching the two ears, they turn the whole head instead of turning just the ears. The direction from which a sound is coming is judged from the difference in the time at which the sound arrives at the two ears, and the difference in the intensity of the sound at the two ears.

The other part of the outer ear is the *ear canal.* The ear canal, which conveys the sound to the eardrum, is a rather tortuous canal. It is lined with skin, which secretes wax from ceruminous glands and oil from the sebaceous glands. The wax and oils help in keeping the ear canal clear by trapping cellular debris and dust particles. The ear canal is about 2.3 cm long in an adult, and is open at one end but closed at the other end.

Next let us explore the middle part of the ear.

The air-filled middle ear – a box-like structure – contains the tympanic membrane, the ossicles (malleus, incus, and stapes), their associated muscles and ligaments, and the opening of the auditory tube, which provides communication with the pharynx and equalizes pressure on both sides.

The middle ear contains three small bones, which are the tiniest bones in the body. Try and identify these in the Figure 10.10. These bones i.e. *malleus, incus* and *stapes* are interconnected to form a lever system, which conveys the vibrations of the sound from the external ear to the inner ear. We shall learn about the inner ear in the next sub-section. But, here we must emphasize that the inner ear is safely enclosed within the skull and contains the receptors for detecting sound. These receptors detect sound and transduct this mechanical stimulus into an electrical stimulus, which, in turn, is conveyed by the auditory nerve to the brain, where it is perceived as sound.

We have seen in Figure 10.10 that middle ear consists of three small bones or ossicles namely, the malleus, the incus, and the stapes. Let's get to know these and their functions. These bones mechanically relay vibrations from the tympanic membrane to the 3 mm^2 membrane of the oval window. These bones also form a lever system, which produces a mechanical advantage and thus amplifies sounds by about a factor of two.

There are certain factors which contribute to an approximately eighty-fold increase in sound wave pressure through middle ear. These are:

- Tympanic resonance (the tendency of the membrane to vibrate best over a particular range of frequencies).
- Ossicle mechanical advantage, which amplifies sound twice.
- Concentration of sound at small oval window. The difference in area between the tympanic membrane and the smaller oval window concentrates the sound energy by a factor of about 20.

These factors constitute an impedence matching system that increases the wave pressure so that it is effectively transmitted from the low resistance medium of air into the higher resistance medium of the fluid in the inner ear.

One of the major functions of the middle ear is to protect the ear from loud sounds. Let us see how this is done.

Protection from Loud Sounds

Sometimes, it might happen that we are accidentally or deliberately exposed to loud sounds. In such cases, how is our ear protected against the loud sounds? Well, the two muscles, the *tensor tympani* and *stapedius*, attached to the stapes, control the effectiveness of sound transmission through the ossicles. Loud sounds initiate a reflex that activates these muscles, stiffening the chain of ossicles and decreasing sound transmission. Besides impedance matching, the middle ear also has some other functions. The tensor tympani and stapedius muscles possibly play a role in protecting the ear from the damaging effects of very loud sounds, and in protecting our mind from disturbing effects of our own voice. Stimulation of the ear by intense sounds produces contraction of the stapedius and tensor tympani muscles, this is known as the 'acoustic reflex'.

Stapedius pulls the stapes medially while the tensor tympani pull the malleus anteriomedially. The overall effect of the actions of these muscles is to press the ossicles against one another, thereby increasing the rigidity of the ossicular lever system. This is the system which is more stable while at the same time, it reduces the efficiency with which the sound signal would be transmitted to the inner ear. In human beings, acoustic reflex is absent in diseases affecting the stapedius muscle but not when disease afflicts the tensor tympani.

This suggests that only contraction of the stapedius is of functional importance in the human acoustic reflex. The protective effect of the acoustic reflex is itself doubtful. The reflex is too slow to be useful in protecting the ear from damage due to loud sounds. Further, the ear is rarely exposed to sounds enough to evoke the reflex.

A more likely benefit of the reflexes is attenuation of internal sounds, and most of the internal sounds have low frequencies. Attenuation of internal sounds would reduce their masking effect, thereby improving the sensibility of the ear to external sounds, which needs to be heard.

Having learnt about the functions of the middle ear, we move on to the eustachian tube.

Look at Figure 10.10. Can you locate the eustachian tube in the ear? Eustachian tube joins the middle ear to the nasopharynx. It is about 4 cm long. Its diameter is three times larger at its middle ear opening than at its nasopharyngeal opening. In fact, the nasopharyngeal end of the tube is normally closed and opens only during swallowing, yawning, sneezing or shouting. The opening up of the tube, particularly during swallowing serves to keep the middle ear pressure equal to the pressure in the nasopharynx, which in turn, is equal to the atmospheric pressure.

The pressure in the external ear is also quite obviously equal to the atmospheric pressure. Thus, the eustachian tube keeps the pressure on the two sides of the tympanic membrane equal. This is important to prevent the tympanic membrane from bulging on either side. Bulging would impair its function, and bulging beyond a certain limit could damage the tympanic membrane.

Another function of the eustachian tube is to prevent any fluid from collecting in the middle ear. It drains the fluid into the nasopharynx. If this drainage mechanism was absent, any fluid collecting as a result of inflammation or extravasations would tear through the tympanic membrane.

Every coin has two sides. The eustachian tube is not an unmixed blessing. In an upper respiratory infection, it may convey the infection from the nasopharynx to the middle ear. While conveying the infection, the tube itself also gets inflamed.

Just now we saw how our ears are protected and which internal parts help us to do so. Let us now move on to the understanding of the structure and functions of the internal ear.

10.3.3 Structure and Function of the Internal Ear

We shall start with understanding the structure of the inner ear.

The inner ear, a labyrinth, consists of two parts – one concerned with equilibrium is referred to as the *vestibule*, and the one concerned with hearing is termed as the *cochlea* as can be seen in Figure 10.10. The cross section of the cochlea is shown here in Figure 10.11.

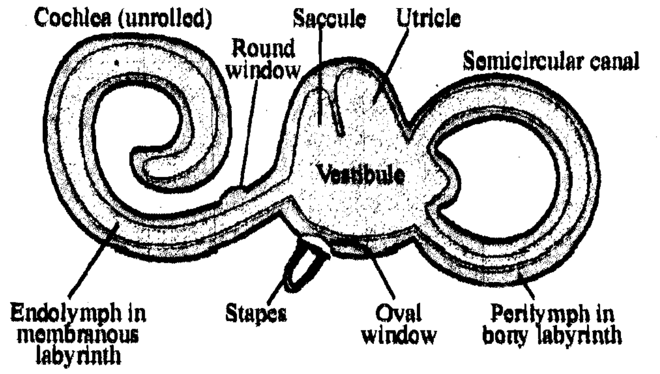


Figure 10.11: The cochlea and the vestibular labyrinth

Cochlea is the snail shaped structure you see in the inner ear which is the sensory organ of hearing. The cochlea, a coiled structure enclosing three fluid-filled chambers, is encased in the temporal bone with two membranous surfaces exposed at its base: the oval window and the round window as can be seen in Figure 10.11. The foot plate of the stapes, the third middle ear bone, adheres to the oval window, transmitting sound vibrations into the cochlea.

The vestibular labyrinth comprises of the *saccule* and *utricle* (refer to Figure 10.11), the sense organs of balance which inform our brain about our linear position in space. They are stimulated by pull of gravity. The internal ear is made up of a bony labyrinth and membranous labyrinth. The bony labyrinth has three pairs of semicircular canals. The horizontal, anterior and posterior semicircular canals are also part of our vestibular labyrinth, and inform our brain about rotational movement in space i.e. angular acceleration and deceleration of rotational movements.

What are the functions of the inner ear?

The inner ear plays an important function in the detection of sound.

In the last section, we left middle ear function at the point where the sound stimulus results in movement of the stapes. The footplate of the stapes is adjacent to the oval window of the inner ear as you learnt above. The stapes footplate moves in and out like a piston in response to sound stimuli. Since the footplate is adjacent to the oval window of the inner ear, its movements produce pressure variations in cochlear fluids. These variations result in movement of the basilar membrane (BM) found in the inner ear. Movements of the BM result in movements of hair cells. Hair cell movement displaces their steriocillia, which in turn, enhances or depresses hair cell excitability. Afferent nerve fibers to the centre nervous system convey altered excitability of hair cells. In short, the inner ear transducts vibratory stimulus to electrical signals to be transmitted to the central nervous system.

But the inner ear is more than a transducer. It also performs a preliminary analysis of the sound stimulus in terms of its frequency and amplitude characteristics. The BM plays an important role in this analysis.

With over a million essential moving parts, the auditory receptor organ or cochlea is the most complex mechanical apparatus in the human body. Surely you would agree, having looked at the structure and the physiological role of this organ now. Next, let us see what happens beyond the ear. How does the central nervous system sense the sound?

10.3.4 Beyond the Ear

The ear is a wonderful and compact organ, which can receive, transduct and analyze an acoustic stimulus. But unless the electrical impulses that it generates in the auditory nerve are conducted to the central nervous system, it would be impossible to hear anything. Listening needs involvement of even high faculties of the central nervous system in auditory function, which is generally studied in terms of auditory pathway from the cochlea to the cortex. Let us learn about this pathway.

There exists a fairly distinct chain of neurons from the hair cells of the cochlea to the cerebral cortex. The path taken by this chain is the *ascending auditory pathway*. The fact that the path exists, does not, however mean that the whole of it is actually used every time we receive a sound stimulus. The stimulus may merely evoke a reflex response involving only the brainstem.

There exists also a descending pathway through which the central nervous system can influence ear function. An ascending auditory pathway is represented in the Figure 10.12.

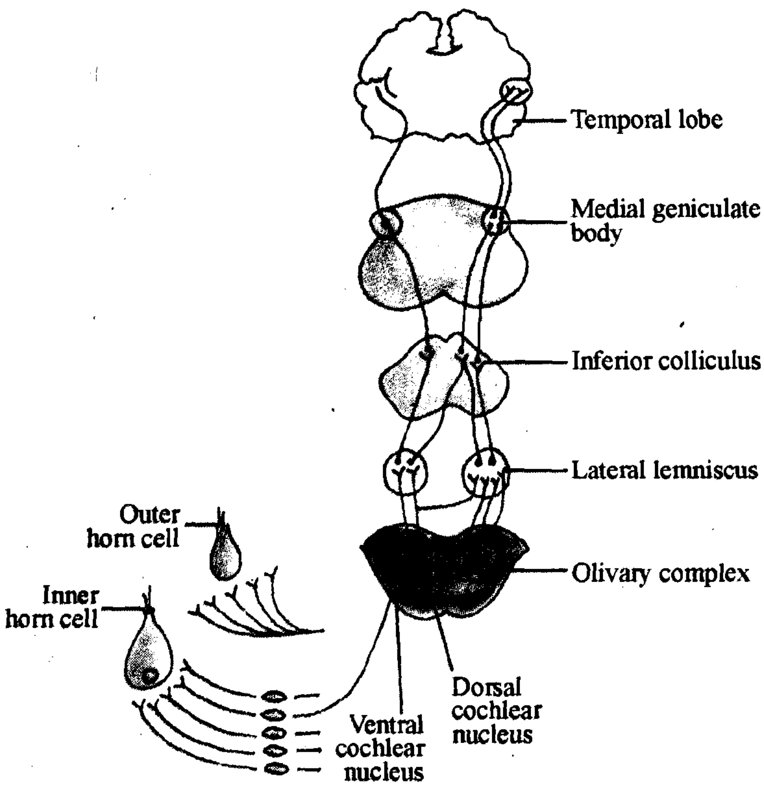


Figure 10.12: Ascending auditory pathways

You would realize that the auditory nerve fibers innervating the hair cells have their cell bodies located in the spinal ganglion. The axons of the neurons relay in the dorsal and ventral cochlear nuclei of the medulla oblongata. The fibers originating in the ventral cochlear nucleus project to the olivary complexes. The olivary complexes also project to the nuclei of the lateral lemniscus. From the nuclei of the lateral lemniscus, the auditory tract relays to the inferior colliculus, medial geniculate body of the thalamus and finally the auditory cortex. The primary auditory cortex is located in Brodmann's areas 41 and 42 in the superior temporal gyrus. Surrounding the primary auditory cortex are the auditory association areas, which receive inputs from the primary auditory cortex, as well as, the thalamus.

Information from either ear is projected to the auditory cortex on both sides but the projection is heavier on the contralateral side. The main auditory pathway described above gives collaterals along its route by which it interacts with the pathways conveying other sensory inputs to the brain.

Let us now deal with the defects of hearing in the following section.

10.3.5 Applied Auditory Physiology

Many common disorders of hearing, their evaluation and treatment can be understood better in light of auditory physiology. These topics will receive only sketchy treatment here. Let us start by getting to know about the hearing defects.

Types of Hearing Defects: From a physiological point of view, impairment of hearing, or deafness, is of two types – *conduction* and *sensorineural*. See Figure 10.13. Let us discuss about them briefly and try to understand what is meant by these.

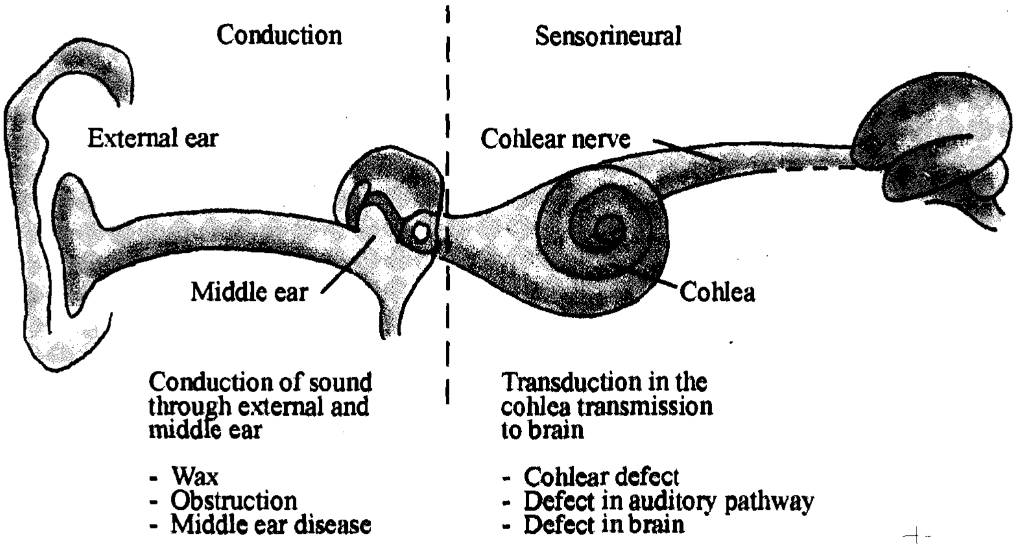


Figure 10.13: Deafness

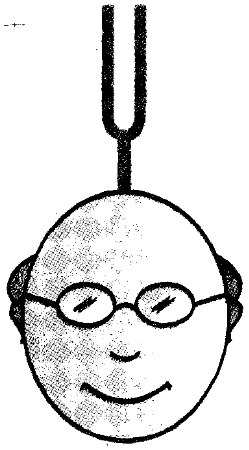
1) *Conduction deafness*

In conduction deafness, sound cannot be conducted to the cochlear receptors (hair cells) efficiently. Although it could be due to a defect either in the external or the middle ear, conduction deafness is commonly understood to mean only middle ear deafness. Common causes of conduction deafness are wax in the ear canal, perforation of the tympanic membrane, inflammatory disease of the middle ear (otitis media), or immobility of ossicles (otosclerosis).

2) *Sensorineural deafness or Nerve deafness*

The auditory nerve pathways may get destroyed with age or with disease. As you can see in Figure 10.13, the defect lies in the inner ear.

These defects can be detected by conducting tests namely, *Weber's test*, *Rinne's test* and *Schwabach's test*. These are illustrated in the Figures 10.14, 10.15 and 10.16 respectively.



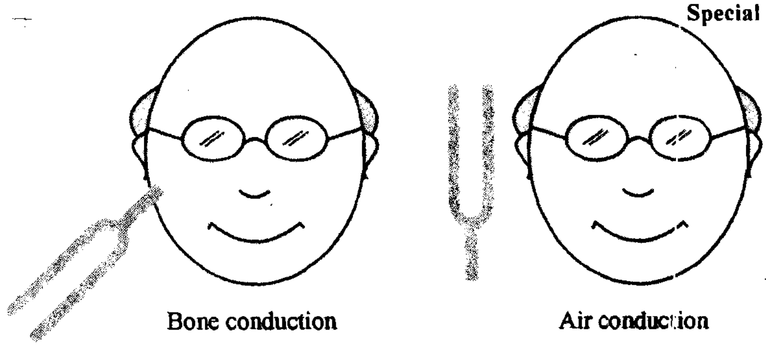
Normal	Right ear	=	Left ear
Conduction deafness	Diseased	>	Normal
Nerve deafness	Normal	>	Diseased

> Implies heard better or longer

Figure 10.14: Weber's test

In *Weber's test,* the stem of a vibrating tuning fork is placed on the midline of the head, and the patient indicates in which ear the tone is heard louder. A patient with a unilateral conductive hearing loss (deafness) hears the tone louder in the ear with the conductive hearing loss. In contrast, a patient with a unilateral sensorineural hearing loss hears the tone louder in the normal ear because the tuning fork stimulates both inner ears equally and the patient perceives the stimulus with the more sensitive, unaffected end organ and nerve.

Rinne's test compares the patient's ability to hear a tone conducted via air and bone – the mastoid process. A vibrating 512 Hz tuning fork is first placed on the mastoid process and then held in line with the external auditory meatus as shown in Figure 10.5.The patient is asked whether the sound is louder behind or in front – referring to bone and air conduction respectively. Normally air conduction of the sound of a tuning fork is longer than transmission of bone – if altered, there is an abnormality of conduction, not perception.

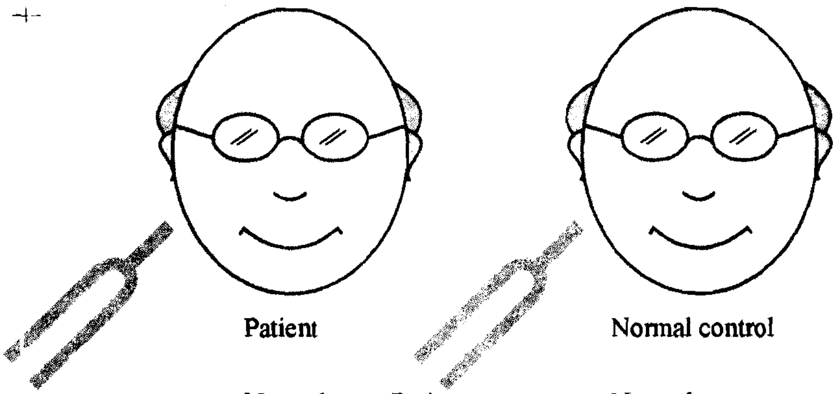


Normal	Air	>	Bone	(+ ve)
Conduction deafness	Bone	>	Air	(- ve)
Nerve deafness	Air	>	Bone	(+ ve)

> Imples heard better or longer

Figure 10.15: Rinne's test

Schwabach's test is a hearing test performed with the opposite ear masked, with tuning forks of 256, 512, 1024, and 2048 Hz, alternately placing the stem of the vibrating fork on the mastoid process of the patient and that of the control (whose hearing should be normal) until it is no longer heard by one of them. The result is expressed as "Schwabach prolonged" if heard longer by the patient (indicative of conduction deafness), as "Schwabach shortened or diminished" if heard longer by the examiner (indicative of sensorineural deafness), and as "Schwabach normal" if heard for the same time by both.



Normal	Patient	=	Normal
Conduction deafness	Patient	>	Normal
Nerve deafness	Normal	>	Patient

> Implies heard longer

Figure 10.16: Schwabach's test

Besides these hearing tests, hearing in patients can also be assessed by:

- Puretone audiometry (subjective test to assess specific loss of frequency)
- Brain stem audiometry (to assess functional integrity of auditory pathways) – very useful in newborn and children (objective testing).

Now, before moving on to the next section on taste, let us quickly review what we have learnt so far.

Check Your Progress Exercise 3

1) What is the audible range of human ear? Which is the speech region in this region?

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2) What are the middle ear ossicles and their functions?

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3) What are the main factors causing increase in sound pressure through middle ear?

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4) How is our ear protected from damaging effects of intense sound?

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5) Explain the mechanism of hearing.

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10.4 A SENSE OF TASTE – GUSTATION

Modern man/woman uses the sense of taste mainly to derive pleasure. He/she peruses food that tastes good, and often takes unwanted and even undesirable foods if they are tasty. Besides guiding us to pleasing foods and helping us avoid unpleasant foods, taste also helps us to recognize desired foods, accept and select the required foods. The fact that taste is an indicator of the needs of the body may not be completely true. For example, there is no evidence to suggest that a liking for fried foods indicates a need for fats and calories, or that a craving for pickles during pregnancy is due to a need for any nutrient that only pickles can provide.

In course of evolution, the most useful role of taste possibly was to warn animals against poisonous foods. Poisonous plants are frequently bitter or unpleasant to taste, which would in turn help the animals to avoid the same food later. Taste involves harmony, especially by fitness, critical capacity or quality in general. It has been noted many times that among human senses, taste might be called the "poor relation". Perhaps it is because taste contributes so few important qualities to the sum of human experience when compared to vision or audition. What is taste, then? How is it sensed?

Well, taste is *a combination of sensation conveyed by the tongue, and smell, temperature and even texture of the food.* The sensation involves the detection of a stimuli dissolved in water, oil or saliva, by the taste buds which are located primarily on the mucosa of the palate and areas of the throat. The sensation is conveyed to the receptors present on the tongue and smell by the chemical molecules and thus is called *chemical sense*.

Let us get to know about the organs involved in taste perception.

10.4.1 Organs Involved in Taste Perception

The tongue is a strong muscle in the mouth that is covered with papillae (small bumps on the tongue) and taste buds (that sense bitter, salty, sweet and sour tastes) as illustrated in Figure 10.17. The taste buds are clustered along the sides of the tongue. Papillae are the visible specialized structures on the tongue and are called *organs of taste*.

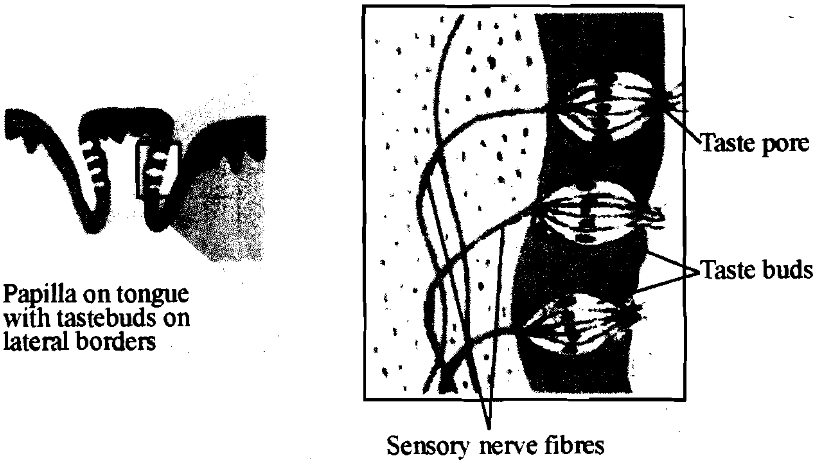

Figure 10.17: Taste buds

Taste is initiated by contact of an aqueous solution of a chemical with the taste buds on the surface of the tongue and the adjacent region of the mouth and throat. In this, taste differs from smell, which reacts primarily to the chemicals in gases.

The receptors for taste are located on the surface of sensory cells, which are grouped into bud shaped clusters of about 40 each. Each of these clusters is called a *taste bud* as illustrated in Figure 10.17. They are grouped in structures called *papillae* (*Papilla,* nipple). The number of taste buds per papillae in the human varies from 33-508 and averaging about 250.The taste buds are also called "taste beakers" or "taste onions" – refers to the spindled shaped cells as shown in Figure 10.17, bulging out at the root and coming together at the taste pore, very much like the petals of a bud. Each bud contains a number of taste cells 5 to 18, together with the other cells which may be immature taste cells. Human taste buds are about 0.07 mm wide at their widest diameter.

Within the taste buds are the *sustentacular cells* and *gustatory cells*, arranged to enclose a small chamber i.e. grouped together into a bundle-like structure. Each receptor cell contains numerous microvilli which extend into the taste pore. These microvilli facilitate the rapid absorption of the taste substance.

In 1803, *Charles Bell* demonstrated that the tongue was insensitive to taste in regions where there were no papillae, gustatory sensibility was confined mainly to the tip and edges. Four kinds of papillae are found in the human tongue: fungiform, foliate, circumvallate and filiform as can be seen in Figure 10.18.

Let us get to know about these papillae:

a) *Fungiform papillae*, as the name suggests, resemble a fungus to be more specific, a mushroom. They are distributed almost the entire surface of the tongue.

b) *Foliate papillae* are so called because they are shape like foliage of a leaf, and are continued to the back of the tongue.

c) *Circumvallate papillae* or *vallate papillae* resemble a well or a moat and are present at the base of the tongue. Stick out your tongue in front of a mirror and the large papillae you see at the back are the circumvallate papillae.

d) *Filiform* (*finger-shaped*) *papillae* but these have no taste buds. Their secretions possibly keep the surface of the tongue moist, wash away particulate matter from the tongue and also dilute the chemical substance which stimulates the taste receptors. The dilution may be of protective value in case of bitter and irritant substances.

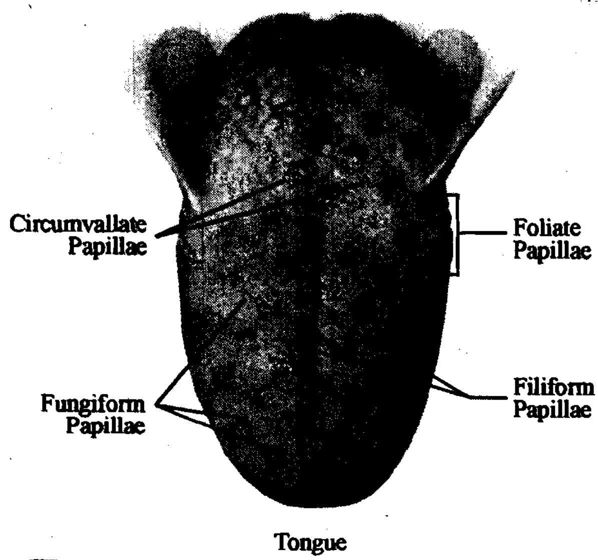

Figure 10.18: Types of papillae

The sensitivity of the papillae to different stimuli varies. Have a look at the Figure 10.19. Here you would notice the different stimuli and the corresponding area of sensation on the tongue. For example, the tip of the tongue is most sensitive to sweet, edges to sour and the back is most sensitive to bitter. That is why when we have to swallow a bitter pill, we avoid letting it touch the back of the tongue. Salty and sour tastes are not clearly differentiated but that of sweet and bitter are differentiated not only from each other but also from saline and sour. This research proves that there are only four basic tastes, but these four appear to be different for each other. The number of distinct tastes is very large but many believe that there are combinations of four basic tastes.

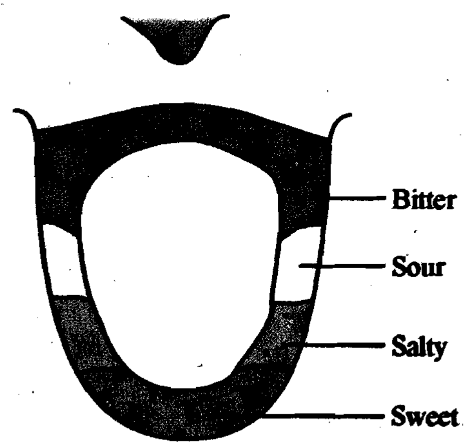

Figure 10.19: Four taste receptors

Sweet taste is perceived more intensely on the tongue than on the hard palate. Bitter taste will be perceived on the palate, while the salty taste is sensed more intensely on the tip of the tongue. Sour taste is perceived more intensely on the hard palate.

Similar to the sense of vision and hearing, the sense of gustation too declines with age. What happens in this case, let's read and find out.

With age, the number of papillae varies, becoming less in number and more restricted in distribution. In adults, the taste buds containing the receptors are located mainly in depressions or moats of the papillae, except for the fungiform type, but in children, they may also be found in the cheeks. A few are found on the larynx and pharynx. Besides the taste buds in the papillae, there are a few in the mucosa of the left palate, and in children, on the sides and even on the roof of the mouth.

The taste stimulus is apparently carried down into the grooves by the convection forces exerted by the contraction and expansion of the grooves due to dynamics of the musculature of the tongue. We shall learn about the mechanism of taste perception next.

10.4.2 Mechanism of Taste Perception

Salivary glands play a very important role in perceiving the taste. They are found in and around our mouth and throat. There are 3 pairs of salivary glands: parotid, sublingual and submaxillary, as can be seen in the Figure 10.20. They all secrete saliva into our mouth. The secretion of the parotid gland is watery and rich in enzymes mainly amylase. Sublingual and submaxillary secretion is viscous, having a protein *mucin*. These secretions are very important to have the dissociation of tasteful substances. Saliva also buffers acids and helps to control temperature by means of the relatively high specific heat content of the water component.

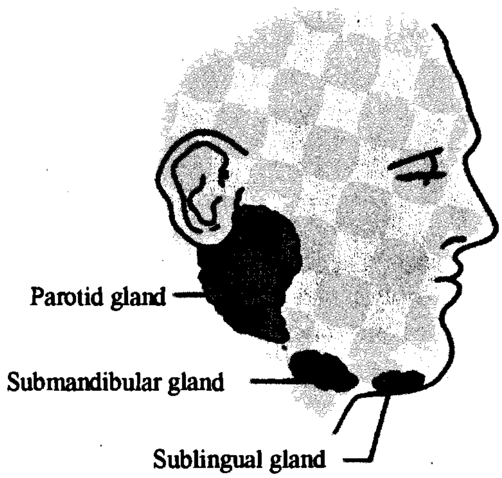

Figure 10.20: Salivary glands

Chewing stimulates salivary secretion, as do stimuli brought about by the thought, sight or odour of food. Let us next see how the four basic tastes are perceived. The mechanism of taste perception involves 4 steps:

Initiation – Perception – Transmission – Identification.

Let us get to know each of these.

1) *Initiation:* If food is a solid, it is first converted to semisolid form by the combined action of the chewing and secretion of salivary glands. If it is in liquid form, it directly enters into the taste buds and comes in contact with it.

2) *Perception:* It is due to the combination of saliva, taste buds and the tongue movements. Saliva contains various ions such as potassium (K) and thiocyanate. The concentration of these 2 ions differs among various individuals. Therefore, different individuals have got different sensitivity for various tastes. K influences the sensitivity for salty and bitter taste in the mouth. During the chewing action, food is uniformly distributed on the various parts of the tongue due to the tongue movement. As a result, there is a gradient created for different tastes or different taste components cannot perceive the taste. The muscular movements constantly disrupt the concentration.

3) *Transmission:* In this step, the taste is actually perceived by the taste cells. Through the taste cells, the signal is transmitted to the brain via the nerve cell.

4) *Identification:* In the final stage of identification, which takes place in the brain, special receptors present in the brain will identify different tastes.

A major taste pathway is indicated in the Figure 10.21. The pathway involves – taste buds→ solitary tract nucleus→ thalamus→ cortex – as illustrated in Figure 10.21.

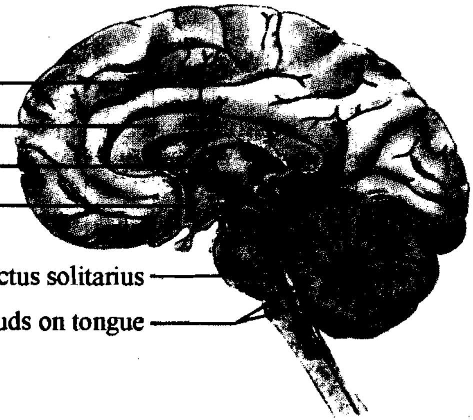

Figure 10.21: Major taste pathway

So we have seen that the perception of taste is a complex mechanism extending from the tongue to the brain. Have you heard of taste in mind? If not, then read the next section and find out.

Taste in the Mind

In the brain, there is a pathway terminating in the cortex, and another in the limbic system. The former is possibly concerned with conscious perception while the latter is responsible for the emotional reaction to taste. When *Mahatma Gandhi* was in England, his commitment to vegetarianism and simplicity made him to turn to foods like boiled spinach (without condiments and spices). But his conviction was so strong that he relished even such insipid dishes. While quoting these details in his autobiography, he wrote, "Many such experiments taught me that the real seat of taste was not the tongue but the mind".

What are the factors which affect taste perception?

The factors affecting taste perception include:

1) *Effect of certain diseases.* Temporary alterations in taste sensation take place due to certain metabolic disorders or it may be due to the consumption of various drugs or antibiotics. In jaundice, the bitter taste is perceived faster even after the convalescence period is over.

2) *Defects in adrenal glands.* Hormones of adrenals change the sensitivity of different taste receptors.

3) *Irradiation of the tongue* decreases the sensitivity for different taste except for sour and it takes two months to recover.

4) *Taking too hot products* causes injury to the taste buds and taste is not perceived for sometime.

5) *Tobacco, pan parag or betel nut* bring about certain changes in the taste receptors resulting in poor perception.

6) *In case of diabetes,* sensitivity for sweet taste increases because of certain physiological changes in the people suffering from the disease.

7) *Consumption of lots of antibiotics* cause the continuous perception of bitter taste.

In addition, there are certain other observations related to taste perception. These are highlighted next.

Certain other observations related to taste perception

A few interesting observations have been made with respect to taste perception. You might be aware of a few of these. What are these? Let us have a look.

1) Lack of sleep for 72 hours did not affect the threshold value for salty and sweet taste but lack of sleep for 48-72 hours decreases the sensitivity for sour taste.

2) Sensitivity for 4 basic tastes decreases during hunger. There is a slight decrease in sensitivity for about 1 hour after meal followed by increases in next 3-4 hours.

3) Depletion of body salts increases the sensitivity for salty taste.

4) Women have higher sensitivity for sweet and salty taste but less for sour and there is no difference for bitter taste.

5) New born has little differentiation for initial 4-40 days.

6) Smoking could also affect taste preferences.

7) Various vitamins are also known to affect sensitivity like vitamin A. For studying the effects, vitamin A deficiency experiment was done on rats. They were given the diet depleted in vitamin A and it was seen after a long time they start rejecting bitter compounds which indicates greater sensitivity for bitter taste and sometimes after, salty substances were also rejected which indicates that even the vitamins have some role to play in the taste sensation.

Our study of the sense of taste shall not be complete without a look at the disorders linked with perception of taste. Lets us get to know them.

Certain Disorders Linked with Perception of Taste

1) *Ageusia:* this is a permanent or a temporary loss of taste sensation. The person is not able to perceive the taste.

2) *Hypogeusia:* the taste sensation is reduced.

3) *Parageusia:* there is a wrong perception of taste which may be due to certain defects in the brain.

Check Your Progress Exercise 4

1) What are the different organs involved in taste perception?

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2) Explain the mechanism of taste perception.

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3) What are the factors affecting taste perception?

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4) Name certain disorders related to taste perception.

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The last part of the unit focuses on the sense of smell.

10.5 A SENSE OF SMELL – OLFACTION

The sense of smell is amazingly sharp in some animals. It is said that a dog can discriminate even the smells of individual human beings. Humans are not so gifted! They vary in their olfactory ability. At one extreme are the 'olfactory types', whose abilities are exceptional and may be made use of perfume industry. At the other extreme are those with partial or total anosmia (*a,* not; *osme*, smell). Humans can distinguish between 2000 and 4000 different odours.

Let us get to know about the primary odours.

The Primary odours

The Primary odours, if any, are not known with certainty. One of the better-accepted schemes proposes seven primary odours: camphoraceous, musky, floral, peppermint, ethereal, pungent and putrid.

Next, let us get to know about the olfactory receptors.

Olfactory receptors

In the section on taste receptors earlier, we learnt that there is a regional distribution of taste buds for the primary taste sensations like sweet, salt, sour and bitter, whereas olfactory neurons are not specialized to detect single fundamental odours. Same receptors may respond vigorously to some stimulus molecules, weakly to several others and not at all to others.

Consequently, the olfactory system can mediate a large number of different odour sensations. For stimulation of olfactory receptors, molecules must dissolve in the mucus before causing stimulation, whereas, there is a direct interaction between taste receptors and molecules. Afferent information from the taste buds is relayed directly to specific location near the mouth region of somatosensory cortex by way of the brainstem and thalamus whereas the central afferents of olfaction split into two. The first one involves limbic system, which influences sex, emotion, feeding and visceral homeostasis. It is possible that olfactory signals process along this route, influence moods and behaviour without entering conscious awareness. The second route leads to olfactory cortex. Connection between the olfactory cortex and other sensory regions of the cortex allow integration of olfactory sensations with those arising from other sensory modalities. Signals that are processed along this route are more likely to lead to conscious sensation.

The mechanism of smell perception is simple. Odourants are inhaled through the nose, where they contact the olfactory epithelium. Olfactory receptor neurons in the olfactory epithelium transduce molecular features of the odourant into electric signals which then travel along the olfactory nerve into the olfactory bulb as can be seen in Figure 10.22. Axons from the olfactory sensory neurons converge in the olfactory bulb to form tangles called *glomeruli*. Inside the glomerulus, the axon contacts the dendrite (branched projection of the nerve cell) of mitral cells. Mitral cells send their axons to a number of brain area, including the piriform cortex. The function of piriform cortex relates to olfaction.

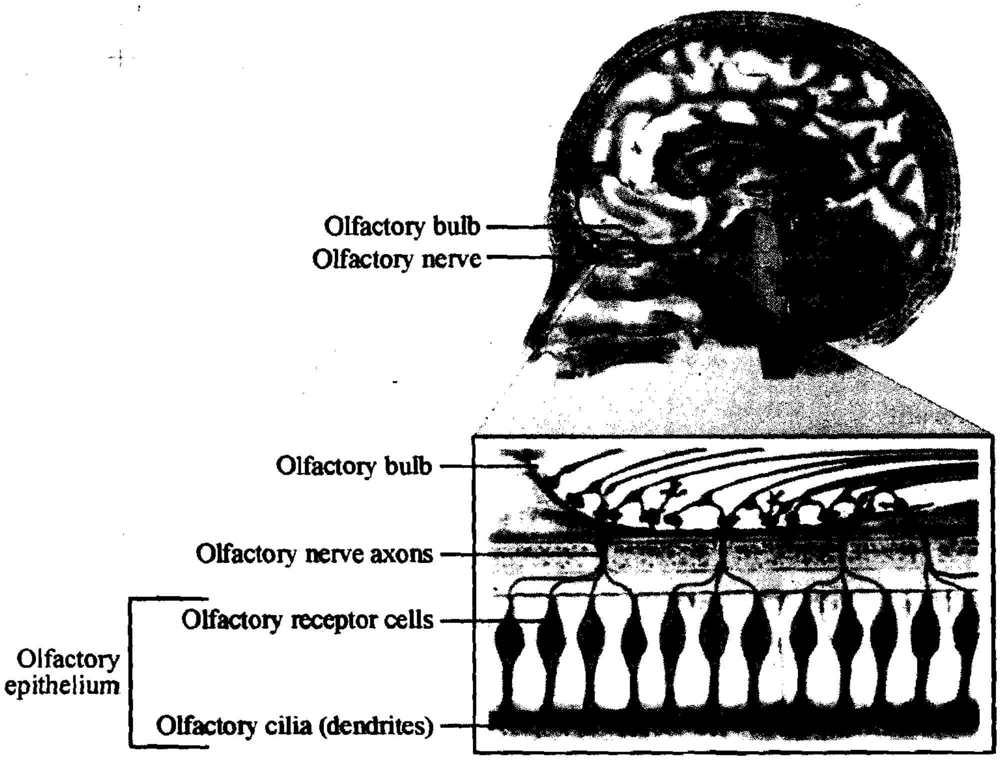

Figure 10.22: Perception of smell

With this, we come to an end on our discussion on special senses.

Check Your Progress Exercise 5

1) What is the difference between taste and olfactory receptors?

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2) Explain the mechanism involved in the process of olfaction?

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3) List the seven primary odours.

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10.6 LET US SUM UP

In this unit, we have learnt about our special senses that include vision, hearing, taste and smell. The organs for special senses are the eyes, ears, nose and tongue. The information perceived by our sense organs provides us with knowledge of the outside world.

10.7 GLOSSARY

Acoustic reflex : contraction of the stapedius and tensor tympani muscles produced by the stimulation of the ear by intense sounds.

Blind spot : an area where there are no cones and rods. It marks the point of convergence of neurons that form the optic nerve.

Cataract : the loss of water with age resulting in an opaque lens.

Choroid : a highly vascular structure that is pigmented and separates other two layers of the eye.

Ciliary body : a thick muscular structure having smooth involuntary muscles to which the choroid is connected.

Ciliary muscles : smooth involuntary muscles of the choroid which suspend thread – like ligaments that attach to the edges of the lens.

Complex cells : cells that are sensitive to both orientation and movement.

Fovea : a depressed area of retina lateral to the blind spot, which contains only cones and no rods.

Glaucoma : a condition in which the eyeball bulges due to increase in intraocular tension either due to excessive production of aqueous humor because it cannot be drained through a narrow opening called the Canal of Schlemm.

Hyper complex cells : cells that require not only the line or edge to be moving but also possess a certain length with a corner.

Iodopsin : a violet-coloured photosensitive pigment, present in the cones.

Neuronal cells of retina : bipolar cells, the Amacrine cells, Horizontal cells and Ganglion cells. These neurons are responsible for appreciating the shape, contrast, directional orientation of light and colour properties of vision.

Pupil : the central black hole of the iris.

Rhodopsin : a purple coloured pigment that is sensitive in even dim light.

Sclera : an opaque layer which does not allow light to pass through. It forms the posterior five-sixths of the eyeball and provides surface for attachment of muscle strings.

Squint : in paralysis or weakness of ocular muscles, the muscle of one eye pulls in one direction and that of the other in a different direction.

Tympanic resonance : the tendency of the membrane to vibrate best over a particular range of frequencies.

Vitreous body : the posterior compartment is filled with this transparent gelatinous material that supports the lens and the retina.

10.8 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1) 1-Eyebrow, 2-Vitreous humor, 3-Choroid, 4-Iris, 5-Eyelid, 6-Eye lashes, 7-Optic nerve, 8-Lens, 9-Cornea, 10-Pupil, 11-Tear.

2) Cones are most sensitive to bright light and colour. Its properties can be enlisted as: 3 million/retina, colour vision, low sensitivity, high activity, day vision (Photopic) and concentrated in fovea.

3) The normal intraocular tension is 12 to 20 mmHg. In an attack of acute glaucoma, it can exceed 60mm Hg (8kPa).

4) The two most important factors which influence colour perception are temperature and humidity. Both these factors affect the dullness or brightness of the colour. colour appears to be brighter at a higher-temperature, as the glossiness is increased at higher temperatures. Under humid conditions, reflected rays are more diffused so the object appears dull in colour.

5) Normal individuals with three cone pigments are referred to as trichromates. colour blindness refers to the absence of one or more of the cone pigments. It may be complete, involving the total absence of a particular pigment or partial, with reduced levels of a pigment. A case of colour blindness can be diagnosed using Ishihara's charts, in which normal individuals can see one number among different dotted coloured background while a colour blind individual cannot see or identify the number.

Check Your Progress Exercise 2

1) The disorders of image formation are myopia, hypermetropia and presbyopia. Myopia is corrected by placing divergent or concave lens in front of the myopic eye. Hypermetropia is corrected by placing a convex (convergent) lens in the front of the hypermetropic eye. In presbyopia, the lens losses its elasticity and it becomes difficult to focus on object close to the eye. It is corrected by bifocal lenses.

2) Cornea and lens are both involved in refraction of light and thus image formation on retina. However, the cornea bends light more than the lens because of the difference between the lens and cornea. While the cornea is optically stronger than the lens, adjustment of its curvature is not very significant for focusing, whereas the curvature of the lens (hence its diopteric power or accommodation) depends on fibres that attach to it and the activity of small ciliary muscles.

3) For viewing near objects, the lens curvature changes to accommodate the light rays on the retina. The 3rd nerve is activated from the cortex during reading to cause contraction of the suspensory ligaments and this reduces the stretching action of the lens. The lens consequently increases its curvature due to its

elasticity and its power is enhanced. It can now focus the divergent rays on the retina. This reflex is called as the accomodation reflex. The accommodation reflex is described as the constriction of the pupil as the eye fixates on near objects.

4) Aging leads to changes in the lens. The yellow tint or gloss of the lens gets intensified and as the years pass, the lens becomes gradually more rigid. A person's ability to focus on close images deteriorates along with it and the person is not able to focus objects placed on nearby as two or three feet away. By the age of 40, the lens become as rigid, that it is almost impossible to adjust it very much either to distant or close objects. This condition is known as presbyopia.

Check Your Progress Exercise 3

1) The audible area or range of human ear is frequencies from 20 Hz to 16,000 Hz (16 KHz). In the middle of this are the frequencies and intensities produced in speaking. This area or range in which speech falls, is called as speech area (250 Hz to 5 KHz, 40 to 75 db).

2) The middle ear ossicles are the malleus the incus and the stapes. These bones mechanically relay vibrations from the tympanic membrane to the membrane of the oval window. These bones also form a lever system which produces a mechanical advantage and thus amplifies sounds by about a factor of two.

3) The main factors causing an increase in sound wave pressure through middle ear are:

   - Tympanic resonance.
   - Ossicle mechanical advantage, which amplifies sound twice.
   - Concentration of sound at small oval window. The difference in area between the tympanic membrane and the smaller oval window concentrates the sound energy by a factor of about 20.

4) Two muscles, the tensor tympani and stapedius attached to the stapes protect the ear from the damaging effects of very loud sounds and from disturbing effects of our own voice.

5) The outer ear, starting with the pinna, channels sound to the eardrum (tympanum). Vibrations of the eardrum are amplified by the 3 small bones (ossicles) of the middle ear. The ossicles transfer these amplified vibrations to the oval window of the cochlea, which contains the receptor cells for sound (the hair cells). The hair cells are attached to the basilar membrane, which separates the two fluid-filled tubes of the cochlea. When sound waves traverse the cochlea to the round window, they vibrate the basilar membrane, causing the hair cells to generate action potentials. These travel down the auditory nerve to the brain.

Check Your Progress Exercise 4

1) Tongue, papillae and taste buds are the organs involved in taste perception.

2) The mechanism of taste perception involves four steps. These include initiation, in which the solid food is first converted to semi-solid form by the combined action of the chewing and secretion of salivary glands. While in liquid form, it directly enters into the taste buds and comes in contact with it. The next step is perception which occurs due to the combination of saliva, taste buds and tongue movements. Transmission is the next step in which the taste is actually perceived by the taste cells through the signal is transmitted to the brain via the nerve cell. The last step is identification, which takes place in the brain where special receptors identify different tastes.

3) The factors affecting taste perception include certain diseases, defects in adrenal gland, irradiation of tongue, consuming hot products, tobacco etc.

4) Disorders related to taste perception are ageusia, hypogeusia and parageusia.

Check Your Progress Exercise 5

1) The primary receptors cells for the taste are modified epithelial cells whereas olfactory receptors are numerous themselves. There is regional distribution of taste buds for primary taste sensations like sweet, salt, sour and bitter, whereas olfactory neurons are not specialized to detect single fundamental odours. Same receptors may respond vigorously to some stimulus molecules, weakly to several others and not at all to others. Consequently the olfactory system can mediate a large number of different odour sensations. For stimulation of olfactory receptors, molecules must dissolve in the mucus before causing stimulation whereas there is direct interaction between taste receptors and molecules.

2) The mechanism involved in the process of olfaction can be described as follows. The odorants are inhaled through the nose where they contact olfactory epithelium and receptor neurons. These neurons transduce molecular features of the odorant into electrical signals which travel into olfactory bulb into the glomeruli. From here, these are passed to the brain area called piriform cortex, through mitral cells which relates to olfaction.

3) The seven primary odours are camphoraceous, musky, floral, peppermint, ethereal, pungent and putrid.