Unit 1: Sound and hearing

1.0 Objectives

After studying this unit, you will be able to

- Define and describe sound
- Describe physical and psychological characteristics of the sound
- Discuss the functions of ear and hearing

1.1 Introduction

You all know that ear is one of the most important sense organs of human beings. Every day we hear so many sounds. Hearing different types of sounds is very useful to us. For example, sound can alert of some dangers, sounds of speech helps us in communication, sound of music can relax us. Do you know how a sound is produced? If there is a sound in a room, do you think everybody in the room will hear it in the same way? No, they will not, because it depends on the hearing ability of the individual. A majority of the individuals you have seen around you may be having normal hearing. However, there are a few individuals who do not hear as well as others. Now let us find out more about the ear, hearing and hearing loss.

1.2 Sound

1.2.1 Definition of sound, its generation and transmission

We hear sounds all around us. If you are on the road, you may hear sounds of vehicles, people speaking or shouting. When you are inside your house, you may hear sound of footsteps, music from radio or television, water running from the tap. Early morning you may hear birds chirping.

Some of the sounds we hear are pleasant but some are unpleasant. Have you ever thought how this sound is produced? A sound is created when some force sets an object into vibration. Vibration refers to back-and-forth movement of an object. The best way to understand about sound production is to watch a musician playing a stringed instrument such as a Veena or Sitar/Guitar. You will observe that the musician will vibrate the string and when he vibrates the strings a sound is produced. The vibrating string will move the air particles and this is called as a sound wave. Sound is a form of vibration. We hear a sound when these sound waves reach our ear. Sound waves can travel through any medium, air, solid or liquid but it cannot travel if there is no medium. That is sound does not exist in a vacuum. Sound travels in all directions from the sound source, in the same way a water pond carries waves when a stone is dropped into the pond. Therefore, sound has been defined as a **vibration that is capable of being heard**. More specifically it has been defined as vibrations transmitted through a solid or a liquid or gas. If these vibrations are between 20 to 20,000 Hertz, it produces sensation of hearing in humans.

1.2.2 Physical and psychological attributes of sound

You all have heard different kinds of sounds. You know that the sound of a bell is different from that of a drum. Why are they different? They are different because they produce **sounds of different frequency**. You must have noticed that some of the sounds can be heard from a long distance e.g., bus horn, railway engine but some of the sounds can be heard only when you are close to it e.g., sound produced by a mosquito. That means some sounds are loud whereas some sounds are soft or feeble. So sounds can be

of **different intensities**. Yes, basically two important measures or parameters are used to describe a sound. They are frequency and intensity.

1) **Frequency**: You learnt earlier that a sound is produced when an object vibrates. Now, the number of times the object vibrates in a given time may vary. If you observe again a musician playing a stringed instrument, you will observe that sometimes the string vibrates fast, sometimes it moves slowly. And if you listen carefully, the sound you hear will be different, depending on whether the strings are moving fast or slow. Yes, the number of times an object vibrates in a second determines its frequency. The frequency of a sound refers to the number of vibrations per second. It is measured in Hertz (Hz) or cycles per second. More the number of vibrations in a second, higher is the frequency. That means if the object vibrates slowly, it produces low frequency signal, if it vibrates fast, it produces high frequency sounds. If a string vibrates 1000 times in a second, the frequency of the signal it produces is 1000 Hz. A high frequency sound is perceived as a high pitch sound and a low frequency sound is perceived as a low pitch sound. The sound of a drum is a typical example of a low pitch or low frequency sound and the sound of a pooja bell is an example of high frequency or high pitch sound. Human speech also has sounds of different frequencies.

2) **Intensity**: Intensity refers to the amount of movement or displacement of air particles that occurs when a sound is created. The intensity of a sound depends on the force applied to create that sound. Greater the

force applied, greater is the amount of displacement and more intense or louder is the sound produced. Intensity is measured in decibels (dB). The unit used for assessment of hearing is either dB SPL (Sound Pressure Level) or dB HL (Hearing Level). Intensity is psychologically perceived as loudness. The sound of a bird chirping is very soft or of very low intensity but the sound of a fighter jet is very loud or of high intensity. The intensity of a sound heard also depends on the distance between the source of the sound and the person or the receiver. You can experience this yourself. Turn on a radio or a television at a fixed volume. First stand very close to it and then keep moving away from it. You will feel that the loudness of the sound goes on reducing as you move away from the radio or the television.

The other parameters of the sound include duration of the signal, timbre or quality of the signal. Also, a sound may be of a single frequency or may be a complex signal like our speech consisting of many frequencies.

1.2.3 Range of human hearing

The human ear responds to a wide range of frequencies and intensities. We hear very low pitch sound of 20 Hz as well as very high pitch sound of 20,000 Hz. We hear sounds of very low intensities as well as very high intensities. The softest signal or the lowest intensity an average adult can hear is 0 dB HL. Sounds of intensities above 120 dB HL cause discomfort and may be painful to individuals with normal hearing. That means the range of human hearing is 0 dB HL to 120 dB HL and 20 Hz to 20,000 Hz.

The range of human hearing is sufficient for the hearing and understanding of all the speech sounds. The lowest frequency which occur in speech is about 200 Hz while the highest frequency which occur in speech is about 8,000 Hz. Whispered speech has an intensity level of about 30 dB SPL. Conversational speech has an average intensity of between 55 and 65 dB SPL.

1.2.4 Development of auditory behaviour

Have you observed how children of different age respond to their name and other sounds around them? If you observe carefully, you will notice that a one year baby with normal hearing will turn his head when you call his name but a newborn baby will only show a startle response to a loud sound. The responses that can be observed in a child with normal hearing at different ages are listed here in Table 1.

Table 1: Responses observed in children with normal hearing at different ages

Infant's Age in months	Response
At birth	Arousal from sleep for 90 dB SPL
3-4	Rudimentary head turn for normal conversation (50-60 dB SPL)
4-7	Head turn to side for soft sounds (40-50 dB SPL)
7-9	Head turn to side and indirectly below for a loud whisper (30-40 dB SPL)
9-13	Head turn to side and below to a loud whisper (30-40 dB SPL)
13-16	Head turn to side, below and indirectly above to soft sounds
16-21	Head turn directly to the side, below and above to a whisper
21-24	Locate directly even a soft sound from any angle

As the age of the infant increases, infant starts responding for lower intensity signals. The type of response you see in a child will also vary depending on the age of the child. A head turn in response to a sound is seen only after 4 months of age. Responses that can be observed in a child before 4 months of age include startle response, searching response, widening of eyeballs, awakening from light sleep.

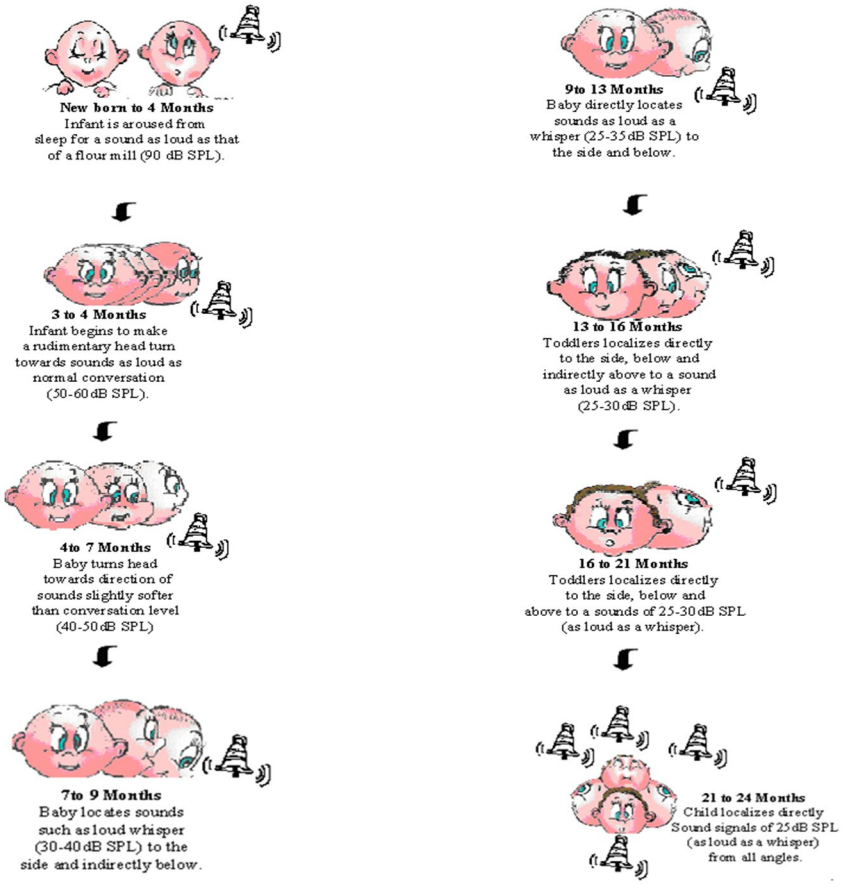

Figure 2: Development of auditory responses in children (adapted from Northern and Downs (2002)

You will get a better understanding of the development of hearing from Figure 2 given above. The bell in the picture indicates the location from where the sound is produced. By the time children are 2 years of age they would be able to respond to sounds from all directions even if they are soft.

1.2.5 Functions of hearing

Hearing is one of the five important senses of human beings. Some of the important functions of hearing are listed below:

- Hearing alerts us when there is a danger. For example if you hear a bus honking from behind, you know that you have to move away from the road. So one of the functions of hearing is warning regarding danger.
- Hearing is used for recreation. We all listen to music or watch cinema or drama and enjoy.
- One of the most important functions of hearing is in communication. You know that the most efficient form of communication is through speech. To communicate through speech, one has to listen and understand what is being said. So hearing is important for communication through speech.
- Hearing is important to learn speech. A child learns to speak as he/she keeps listening to people around talking. You must have noticed that a child speaks the same way as his/her parents or relatives/friends around him speak. That is because a child learns to talk by listening to and imitating people around him.
- Hearing is useful for learning/education. We learn about world around us mainly through hearing. You also know that the most effective

means for providing education is through lectures which require that the student/participant to listen and understand what is being said.

Thus, hearing is very vital to human beings.

1.2.6 Role of hearing in learning

Normally, in order to be able to speak, we need to hear. A baby learns to communicate using speech by listening to the speech of others. Babies learn to associate what is heard with objects and actions around them. This association leads to the development of language. This happens naturally without any effort as long as the baby is able to hear. It is through listening and imitating the speech sounds heard that babies eventually learn to speak.

Throughout our lives it is essential that we continue to hear sounds around us in order to learn new things. We imitate the various speech sounds or words that we hear others produce and thereby continue to learn new things.

We also need to hear ourselves in order to be able to monitor what we say. If we could not hear the speech produced by ourselves, we would not know whether we have produced the speech sounds correctly or not.

Thus, hearing is important for the development of speech and language and to learn new things. It is also important for the maintenance of speech and language once we have developed these abilities.

Check your progress

You have now learnt about production of sound and its properties. Try answering these questions to check whether you have understood the concept.

a) How is sound produced?
b) What is the intensity and frequency range humans can hear?
c) At what age does a baby turn his/her head directly to the side, below and above to a whisper?
d) How does hearing help in our day-to-day life?

1.4 Lets sum up

Now we will summarize what we learnt in this unit. We learnt that vibration of an object produces sound. The sound waves travel through air, solid or liquid medium. Two important parameters of sound are frequency and intensity. Psychological correlate of frequency is pitch and intensity is loudness. You also learnt about different types of responses seen in infants to sound. Furthermore, we studied the importance of hearing in daily life and role that hearing plays in learning language.

1.5 Answers to check you progress exercises

Check your progress I

a) refer 1.2.1
b) refer 1.2.3
c) refer 1.2.4
d) refer 1.2.5

1.6 Questions for self study

1) Explain the parameters of sound
2) Describe the development of auditory behaviour
3) Discuss the functions of hearing

1.7 Suggested readings

Martin, P. N., & Clark, G. J. (2000*). Introduction to audiology*. Boston: Allyn and Bacon.

Newby, H. A. (1964). *Audiology*. New York: Appleton Century Crofts.

Rangasayee, R. (Ed.). (2006). *Fundamentals of hearing, hearing impairment and audiology management.* Jaipur: Advance Books.

Villchur, E. (2000). *Acoustics for audiologists*. California: Singular Publishing Group.

Unit 2 – Anatomy and Physiology of ear

2.0 Objective

After studying this unit, you will be able to

- Explain the parts of the ear
- Describe how we hear
- Explain the anatomy of vestibular system

2.1 Introduction

You know that we have two ears, one on either side of the face. Do you know that what we see outside is only one part of the ear? Look at Figure 1. You will understand that the ear or the auditory system can be divided into three main parts, the outer or external ear, the middle ear and the inner ear. The auditory nerve which is connected to the inner ear links the ear with the auditory nervous system.

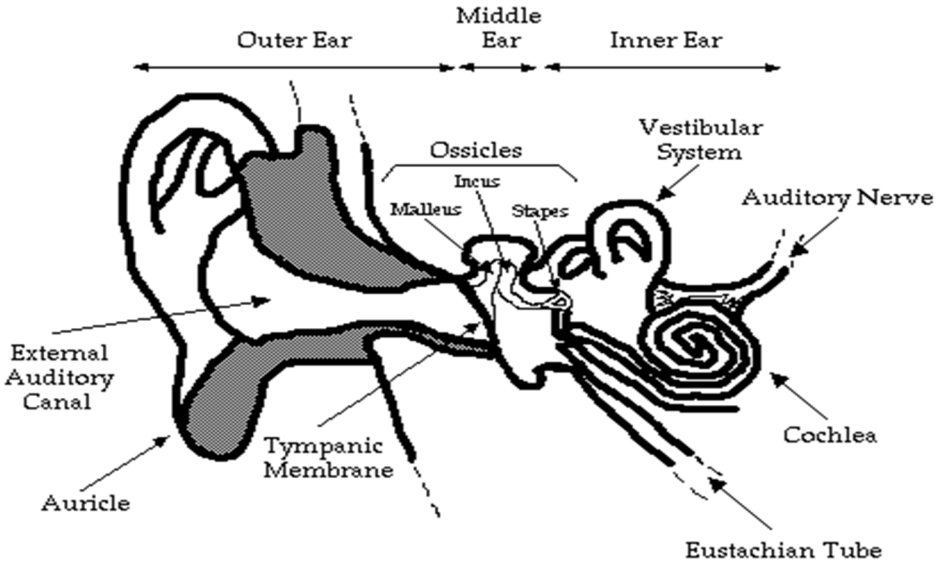

Figure 1. Different parts of the ear

2.2 Anatomy

External ear

The outer ear: The outer or the external ear consists of **pinna or auricle** and the **ear canal**. Auricle or pinna is the visible, flap like part of the ear that is fastened to the side of the head at an angle of about 30 degrees. It is a funnel like structure and it gathers and directs the sound wave through external auditory meatus to the tympanic membrane or ear drum. Pinna is a Latin word for wing. Surfaces of the pinna are uneven and filled with pits, grooves and depressions. Deepest of these depressions is called concha. Rim like peripheral structure is called helix, which descends in to concha anteriorly. This part of the helix divides the helix in to cymba superiorly and cavem inferiorly. Second rim like structure anterior and parallel to helix is called antihelix. Depression between helix and antihelix is known as scaphoid fossa. At the level of ear canal anteriorly opposite to concha there is flap like structure which partially occludes ear canal called tragus. Flap like structure opposite to tragus is known as antitragus The tragus and antitragus is separated by a notch called intertragul notch. The inferior extremity of ear is lobule or ear lobe.

The communication between middle and inner ear and external environment is provided by the external auditory meatus. External auditory meatus is a curved and irregular shaped tube, about 25 mm in length and about 8 mm in diameter. The diameter is largest at the auricular orifice, and becomes increasingly small towards isthmus, which is the junction between cartilaginous and bony portions of the ear canal. Diameter expands again and then decreases before the meatus terminates medially at tympanic

membrane. Lateral one-third to one half is cartilaginous and medial two-third is bony. Bony portion is fixed in diameter while cartilaginous portion is variable in diameter and is dependent on such things as movement of jaws. At birth there is no bony portion and it does not develop completely up to three years.

The Middle ear

External auditory meatus leads to tympanic membrane or ear drum. Middle ear cavity resembles the army drum and hence it got the name of 'tympanum'. The middle ear cavity is composed of the tympanic membrane, the air filled middle ear cavity and its contents such as ossicles and muscles and the highly vascular mucous membrane that coves the middle ear cavity.

Tympanic membrane reaches its full size during fetal life. It is placed obliquely. Tympanic membrane is cone shaped, like a miniature loud speaker and is displaced inwards by about 2 mm at its centre. It is very thin (0.1mm). Tympanic membrane forms the lateral wall of the middle ear. Middle ear is a air filled cavity and has six walls namely lateral wall (tympanic membrane), medial wall (towards cochlea), anterior wall, posterior wall, roof and floor. Middle ear houses three small bones which are important for sound conduction. These bones are Malleus, Incus and Stapes. These bones conduct the sound to cochlea.

Eustachian tube is 35-38 mm in length and establishes the communication between nasopharynx and middle ear. The primary functions of the Eustachian tube are (1) to equalize the pressure between middle and

external auditory canal (i.e both the sides of the tympanic membrane) and (2) to drain the middle ear secretions from middle ear to nasopaharnx. Tympanic membrane can efficiently conduct the sound pressure when the pressure on both the sides of the membrane is equal. When we go in to a high altitude or deep, there is a rapid increase or decrease in the outside pressure with respect to middle ear pressure. Due to this tympanic membrane will become very stiff and will not conduct the sound efficiently. This results in blocking sensation in the ear. During this, opening of the eustachian tube will allow the air pressure to become equalized. Eustachian tube opens when we shout, yawn, chew, and swallow. If there is dys-function of the tube due to any reasons, and if the pressure is not equalized between middle ear and atmosphere for a long time, it may result in middle ear effusion and infection.

Inner ear and vestibular system

The inner ear is housed in the temporal bone, which is a part of the skull and consists of fluid filled tubes. The bony tubes, called as **bony labyrinth**, are filled with fluid called **perilymph**. Within this bony labyrinth, a **membranous labyrinth** consisting of delicate cellular tubes are present. The membranous labyrinth is filled with fluid called **endolymph**. The membranous labyrinth contains the actual hearing cells, **the hair cells of the organ of corti.** Figure 2. Depicts the organ of corti.

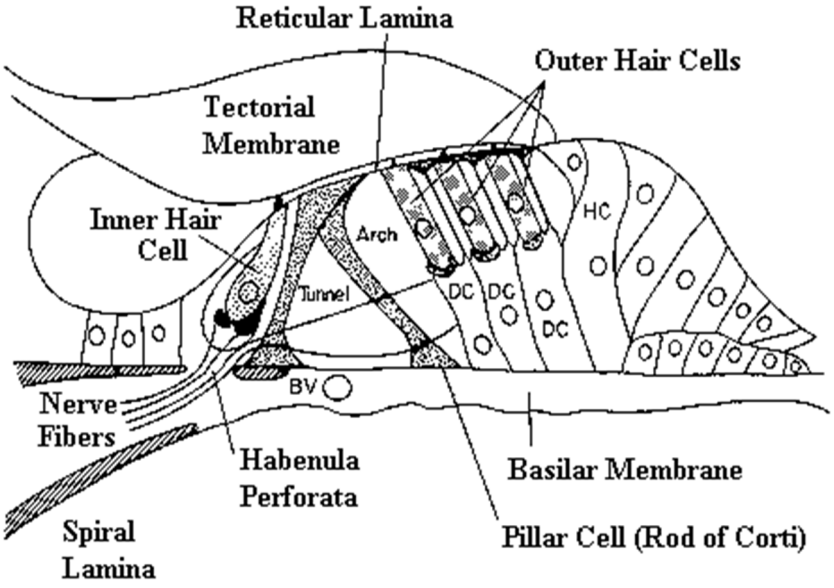

Figure 2. Organ of Corti

The bony labyrinth consists of the following three main parts:

- The front portion is the snail-shaped **cochlea**, which is the organ of hearing.
- The rear part, the **semicircular canals**, which helps maintaining balance.
- **Vestibule**, which interconnects the cochlea and the semicircular canals. It contains the sense organs responsible for balance, the **utricle and saccule**. Figure 3 depicts different parts of the vestibular system.

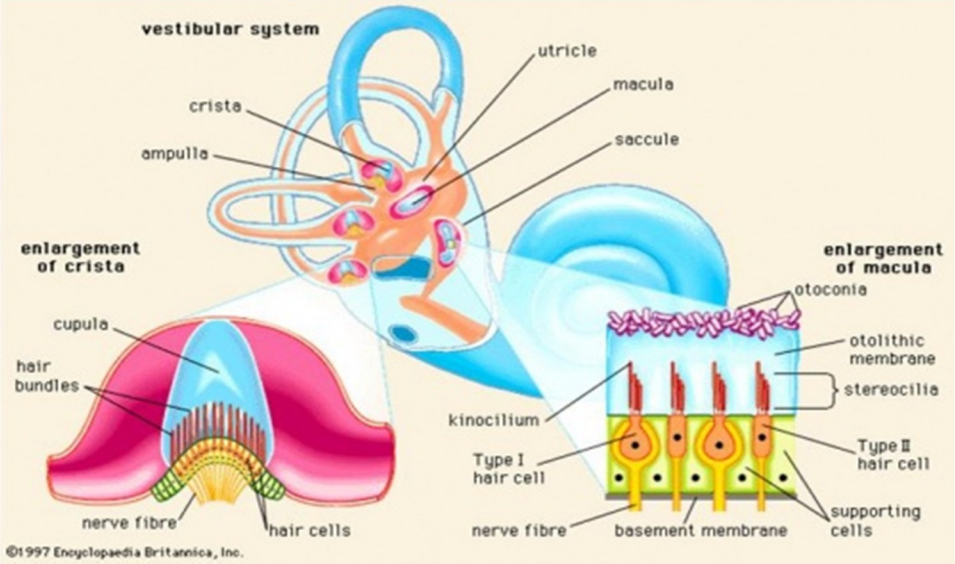

Figure 3. Different parts of the vestibular system

The inner ear has two membrane-covered windows into the air-filled middle ear - the **oval window** and the **round window**. The oval window is immediately behind the stapes, the third middle ear bone. The organ of hearing in the inner ear is cochlea. Cochlear has two types of sensory cells called inner hair cells and outer hair cells which are important for hearing. These hair cells are located on a membrane called basilar membrane. These sensory cells are connected to auditory nerve or 8th cranial nerve. Auditory nerve carries the information from cochlea to higher centres in the nervous system for further processing and understanding of heard sound. Some of the important neuronal junctions in the auditory pathway are cochlear nucleus, superior olivary complex, and inferior colliculus. The part of the brain responsible for hearing sound is auditory cortex. Auditory cortex is located in temporal lobe of the brain.

Auditory nervous system

Auditory nerve is 8th cranial nerve. Cell bodies of auditory nerve are present in spiral ganglion and dendrites innervate the sensory cells in the organ of Corti. Axons of the auditory nerve enter the brainstem at the level of pons and synapses with the cochlear nucleus. Other major nuclei in the auditory nervous system are superiory olivary complex, lateral laminiscus, inferior colliculus, medial geniculate body. Finally, after passing through these nuclei auditory information reaches auditory cortex where sound is analyzed for meaning and content.

Check your progress

Now it is time to check your progress. Try answering the following questions:

a) Name the three bones in middle ear
b) Describe the structure of pinna.
c) What are the parts of inner ear?

2.3 Physiology of the ear

External ear

Ear canal and pinna both channelizes the sound towards tympanic membrane. While conducting the sound both have certain acoustic properties that enhance amplitudes of frequencies which are essential for understanding speech. Pinna also helps in locating the direction of sound source. In addition, both pinna and ear canal have certain non auditory functions. This includes the protection of the tympanic membrane and deeper structures from

injury and the maintenance of a clear and disease free passage through which sound can be conducted to the tympanic membrane.

Middle ear

Middle ear ossicles and tympanic membrane helps in the conduction of the sound to inner ear. When the sound travels from one medium to another medium most of the energy is reflected back. This is because of the differences in the impedances between two mediums. When the sound waves enter into the ear it is in air medium. Sensor cells of the hearing which are in inner ear are in liquid medium. Hence, more than 99% will get reflected back. Middle ear acts like a transformer and helps in preventing the loss of energy.

Inner ear

Vibration of the foot plate of the stapes causes the cochlear fluids to be displaced. This results in the motion of the sensory cells within the organ of corti. Once the sensory cells are activated, electrical energy is passed on to auditory nerve, which then passes on the information to higher centers in the nervous system for processing of sound.

2.4 Lets Sum up

In this unit you studied about different parts of the ear. Ear can be divided into external ear, middle ear and inner ear. External ear comprises of pinna and ear canal, middle ear has tympanic membrane and ossicles and inner ear has cochlea, vestibular system and auditory nerve. You also learnt about how these structure help in hearning.

2.5 Answers to check your progress

a) , b) and c) refer 2.0

2.6 Questions for self study

1) Explain the physiology of ear

2) What are the functions of Eustachian tube?

3) Name the sensory cells in the inner ear.

2.7 Suggested reading

Martin, P. N., & Clark, G. J. (2000). *Introduction to audiology*. Boston: Allyn and Bacon.

Newby, H. A. (1964). *Audiology*. New York: Appleton Century Crofts.

Unit 3 – Hearing loss

3.0 Objectives

After studying this unit, you will be able to

- List the causes of hearing loss
- Know the effects of hearing loss
- Be familiar with the signs and symptoms of hearing loss
- Discuss how to prevent hearing loss
- Understand the importance of early identification of hearing loss
- Understand what associated problems refer to.

3.1.1 Introduction

You have learnt that a hearing loss can occur due to a defect in any part of the ear or auditory system and there are many causes of hearing loss. Now do you think all those who have a hearing problem have similar problems? If you carefully observe different individuals with a hearing loss, you will realize that nature of hearing loss varies and the problems that occur due to a hearing loss are not same in all the individuals. Now, in this unit, you will learn about different types of hearing loss, effects of hearing loss and the need to identify hearing loss early.

3.2 Hearing Loss

3.2.1 Nature of hearing loss

The mother of Rina, a nine months old baby, noticed that Rina did not turn around when her name was called. Even if there was a loud sound in the room, she did not show any response. Shekar observed that his father did

not give appropriate answers to his questions, since the last six months. If somebody knocked on the door or rang the door bell, his father did not open the door. Now what to do you think is the problem with this child Rina and Shekar's father, an old gentleman? Yes, they both have a hearing loss. You also must have come across some individuals who do not show appropriate responses when you call them. The inability of a person to hear sounds properly is called hearing loss. A hearing loss can occur due to defects in any part of the ear. The nature and the severity of the hearing problem will vary depending on the part/s of the auditory system that is/are affected. You may have seen children and adults with a hearing loss. Yes, hearing loss can occur in children or adults. The problem in hearing can be congenital, i.e., hearing loss can be present from birth or it can be acquired any time in life. In some individuals, it starts suddenly whereas in others it occurs gradually. The hearing loss may become worse and worse day by day (progressive) or it can remain the same. In some individuals it fluctuates from time to time.

You must have seen that some people have an abnormality but yet they are able function normally whereas functioning is also is affected in a few individuals. That is, everybody who has impairment may not have a disability. World Health Organisation (WHO, 1980) has given definitions to differentiate impairment, disability and handicap. **Impairment** is defined as an abnormality of a structure or function (e.g., an abnormality of the ear or auditory system). **Disability** is the functional consequence of impairment (e.g., inability to hear certain sounds or Inability to speak clearly). **Handicap** is the social consequence of impairment (e.g., isolation, loss of job, or having to make career changes as a result of communication

difficulties). By applying the WHO definitions, distinctions are made that apply to how one function as a result of impairment. Not all impairments result in disabilities and not all individuals with a disability are handicapped.

From the above information you can understand that hearing loss can be defined as the full or partial decrease in the ability to detect or understand sounds.

3.2.2 Causes of hearing loss

Have you seen children with discharging ears? Have you noticed people who do not have pinna, the external part of the ear? Such problems can lead to a hearing loss. A number of causes can lead to hearing loss. Some of the causes of hearing loss are observable but some of the causes cannot be seen. Any problem in the external, the middle or the inner ear or the auditory nerve can lead to hearing loss. Now become familiar with some of the causes of hearing loss. The causes of hearing have been divided into causes of external ear problems, middle ear problems and inner ear problems.

Causes of external ear problems

a) Congenital malformations – These are abnormalities present since birth. The common abnormalities seen are:
   - Deformity of the pinna
   - Closure of the ear canal

b) Blockage of the ear canal due to

- Impacted wax
- Foreign bodies
- Tumours/growths

c) Infections of the external ear

Causes of middle ear problems

a) Rupture or perforation of the eardrum

b) Infections of the middle ear

c) Ossicular abnormalities:

- Congenital absence of one or more ossicles
- Accidental fracture of one of the three ossicles
- Improper connection among the ossicles themselves
- Fixation of one of the ossicles
- Fluid or any growth in the middle ear which disrupts the movement of the ossicles

Causes of inner ear and the auditory nerve

a) Congenital malformation of the inner ear and/or auditory nerve

b) Destruction of the hair cells of the cochlea due to:

- Aging
- Trauma/injury
- Noise
- Drugs
- Viral and bacterial infections

c) Changes in the pressure of inner ear fluids

d) Abnormalities in the blood supply to the cochlea

e) Destruction of the nerve cells

The cause for these abnormalities in an individual could be **genetic or nongenetic**. If the cause of hearing loss is genetic, i.e., related to abnormalities in the genes or chromosomes, they can be passed on from one generation to the other. Such individuals will generally report of a family history of hearing loss. A genetic counsellor can predict the chances that an individual with a family history of hearing loss will have hearing loss. Non genetic factors that lead to hearing loss may occur before the birth of a child (**prenatal causes**), during the birth of the child (**perinatal or natal causes**) or after a child is born (**postnatal causes**).

You all must have listened to grandmothers telling pregnant women that they need to be very careful about their health and take nutritious food as it can affect the baby to be born. Listening to the advice of grandmothers can avoid hearing loss in the baby to be born by preventing the prenatal causes of hearing loss. Especially during the first three months of pregnancy, an expecting mother should avoid getting infections. One of the most common prenatal causes of hearing loss is maternal rubella or German measles in the expectant mother. But infectious agents such as toxoplasmosis, syphilis, herpes and cytomegalovirus can also lead to hearing loss. Other prenatal causes of hearing loss include exposure to X-rays or radiations, and side effects of certain medicines.

A common cause that can affect hearing during the birth of a baby is lack of oxygen to the brain or the ear. Lack of oxygen may occur if the child does not cry immediately after birth. Damage to the ears can occur if proper medical care is not taken at the time of delivery of the baby. Low birth weight also indicates that the baby is at risk for hearing loss. Other risk

factors include the baby spending more than 10 days on a mechanical ventilator after birth, neonatal jaundice (jaundice especially during the first 10 days after birth). Causes of hearing loss in older children and adults include measles, mumps, meningitis (brain infection), ear infection, adverse side effects of certain medications, head injury, exposure to loud sounds.

Check your progress I

Can you answer these questions?

- Define impairment, Disability and Handicap
- What is congenital hearing loss?
- List the prenatal causes of hearing loss.

3.2.3 Different types of hearing loss

You have learnt in the previous unit that the ear can be divided into different parts. Depending on which part of the ear is affected, the hearing loss can be classified into three main types. They are as follows:

a) Conductive hearing loss: Hearing loss because of a problem in the external ear and/or the middle ear
b) Sensorineural hearing loss: Hearing loss because of a problem in the inner ear
c) Mixed hearing loss: Hearing loss because of a problem in the external ear and/or the middle ear as well as the inner ear

Another type of problem that is less commonly observed is auditory processing disorder. You must have observed that some individuals may respond when you speak loudly whereas others may not respond even to

loud sounds. That is, the extent of hearing loss varies in different individuals. Depending on the extent, the hearing loss is categorized into different degrees. The communication problems faced by the individuals with different degrees of hearing loss are described in Table 2.

Table 2: Communication problems of individuals with hearing impairment

Degree of hearing loss	**Probable communication problems**
Mild	Has difficulty hearing faint or distant speech
Moderate	Understands conversational speech only from a distance of 3-5 feet
Moderately severe	Conversation must be loud to be understood. There is great difficulty in group conversation
Severe	May hear a loud voice about one foot from the ear, may identify environmental noises; may distinguish vowels but not consonants
Profound	May hear loud sounds; does not rely on hearing as a primary channel for communication

Hearing loss in an individual can be progressive or of sudden onset. Progressive hearing loss is a hearing loss that becomes increasingly worse over time. A sudden hearing loss is one that has a rapid onset and occurs quickly. Some hearing losses fluctuate i.e., hearing losses change over time. It sometimes gets better and sometimes gets worse. Such a hearing loss is called as fluctuating hearing loss. Rehabilitation or line of treatment advised for an individual with hearing impairment depends on the nature and the extent of hearing problem.

Check your progress II

- What is a sensori-neural hearing loss?
- When will you say that an individual has moderate degree of hearing loss?

3.2.4 Effects of hearing loss

Hearing loss is an invisible problem. That is, in a majority of the individuals, the physical appearance will not give any indication that the individual has a hearing loss. But the effects or consequence of hearing loss are obvious. Hearing loss is challenging at any age but the problems due to hearing loss are more in infants and children. Now let us understand various problems faced by an individual with hearing loss. As mentioned earlier, the problems that occur due to a hearing loss are not same in all the individuals with hearing loss. A number of factors including the type of hearing loss, degree of hearing loss, age at which hearing loss occurred, age at which rehabilitation was started determine the problems faced by an individual with a hearing loss.

Effects of hearing loss in children

If you observe children with hearing loss, you will notice that a majority of the children with hearing loss since birth have speech and language problems, unless they are identified and treated early in life. That is because, if children cannot hear others speaking, they cannot learn to speak. The development of speech and language is affected in a child with hearing loss since birth. The effect of hearing loss may vary depending on the

degree of haring loss. Those with severe to profound hearing loss will fail to acquire speech or verbal language unless they are rehabilitated at an early age. Children with lesser degree of hearing loss may learn to speak but they may have limited vocabulary and may find it difficult to learn grammar. Children with speech, language and hearing problems will have difficulty in academic achievement (especially reading and mathematics). That means their performance in school will be poor. The career opportunities will be limited to those with poor educational background.

Hearing loss can also lead to psychological problems. It can lead to problems such as depression and anxiety. The psychological problem in a child with hearing loss may lead to behavioral problems such as hyperactivity, aggression on one extreme or isolation on the other extreme. That means a hearing loss in children can affect their quality of life. The impact of hearing loss on a developing child is quite different from the effects of hearing loss that occurs in adulthood.

Thus you now realize that there are four major ways in which hearing loss can affect children:

- It causes delay in the development of receptive and expressive communication skills (speech and language).
- As the communication problem, learning becomes difficult and this can result in reduced academic achievement.
- The communication difficulties often lead to social isolation and psychological problems.
- Later in life it could affect their vocational abilities.

Effects of hearing loss in adults

The effects of hearing loss are less severe if it is acquired in adults and geriatrics. As the hearing ability reduces, the ability to effectively communicate also reduces. People who fail to understand what is being said may withdraw from social situations. Failure to understand what is being said can lead to feelings of frustration, discouragement and embarrassment. Hearing loss may affect the quality of life. It may lead to isolation which may have an impact on both personal and professional life of an individual. Communication problems that occur due to a hearing loss can have an effect on their performance at work. It can lead to loss of productivity and work-related accidents. You must have noticed that some of the individuals with hearing loss speak very softly whereas others talk very loudly. That is because individuals with hearing loss have difficulty in monitoring their own voice. Generally individuals with conductive hearing loss hear their own voice louder than others and hence speak very softly. Those with sensorineural hearing loss have difficulty in hearing their own voice and hence speak very loudly. Many times, adults and geriatrics with hearing loss may not realize how much hearing they have lost. Rather, family and friends will often notice changes in behaviour of someone with hearing loss.

The ways a hearing loss can affect an adult can be summarized in the following ways:

- The individual with a hearing loss would find it difficult to follow what is said by others. This would lead to a communication break-down.
- As the person would find it difficult to monitor his own speech production, there may be deterioration in the speech of the person.
- Not being able to communicate can lead to psychological stress.
- Their social and family life may get adversely affected.
- Decrease in the ability to communicate effectively can also affect their vocation.

3.2.5 Signs and symptoms of hearing loss

There are several signs and symptoms of hearing loss. A few of the common ones are listed below. The individual may:

- Ask for frequent repetition of message being spoken
- Ask for the message to be spoken louder
- Not respond when spoken to from the back
- Come closer, bending his/her head towards the speaker
- Cup his/her ear to hear well
- Have difficulty in following a conversation between two or three people, when they talk simultaneously
- Not understand speech well in a noisy situation
- Relies more on speech reading (lip reading)
- Give incorrect responses to a question
- Unclear speech
- Avoid participating in a conversation
- Increase the volume of a TV or radio to hear well

- The person may have problems in answering a telephone
- May have poor academic performance, if he/she is a child
- May be distracted, carrying out other activities while the classes are being conducted, if he/she is a child

Some other signs and symptoms that may occur are:

- Ringing sound in one or both the ears (tinnitus)
- Blocking sensation in the ear/ears
- Ear discharge
- Ear pain
- Giddiness
- Frequent attacks of cold

You should remember that several of the above signs and symptoms could occur in individuals having conditions other than a hearing loss. Hence, do not conclude that a person has a hearing loss only based on the signs and symptoms. This information would only enable you to suspect that the individual may have a hearing loss so that you can refer them for further audiological evaluation.

3.2.6 Associated problems with a hearing loss

You have so far learnt about the impact or consequences of hearing loss in children and adults. You have learnt that a child with hearing loss may have communication problem and/or psychological problems as a result of hearing loss. You have also learnt that there are a few signs and symptoms associated with hearing loss. Signs and symptoms of hearing loss include

ringing sound in the ear (tinnitus) and giddiness/dizziness. Most often the factor which causes hearing loss also leads to tinnitus but the exact cause of tinnitus is not known. You have learnt in the first unit that the inner ear houses the organ for hearing and balancing. So many a times, factors that lead to a hearing loss will also cause balancing problem or giddiness. However, you have to remember that giddiness is not always associated with a disorder of the vestibular system (organ for balancing in the ear). It is a symptom which can be caused due to disorder other than those of the vestibular system.

Sometimes hearing loss may co-exist with other abnormalities. The cause for the co-existing abnormalities may be same as seen in a client with a syndrome (Syndrome refers to a group of symptoms that collectively indicate or characterize a disease, psychological disorder, or other abnormal condition) or may be different. Some of the associated problems an individual with hearing loss may have include low vision or blindness, mental retardation, cerebral palsy, learning disorder. The consequences of hearing loss vary depending on the associated problem/s of the individual. The method used for testing and rehabilitation also varies depending on the associated problems of the individual.

3.3 Lets sum up

In this unit you learnt that there are different types and degree of hearing loss and an audiogram gives information regarding this. Hearing loss can affect the life of an individual and the impact of hearing loss is different in children and adults. It is essential that hearing loss be identified as early as possible especially in children so that appropriate measures can be taken for

rehabilitation. You also learnt about the problems that may be associated with hearing loss.

3.4 Answers to check your progress exercises

Check your progress I

Refer 3.2.1, 3.2.2

Check your progress II

Refer 3.2.3

3.5 Questions for self study

1) Name some causes of external ear problems and mention the type of hearing loss it would cause.
2) List some of the associated problems seen along with a hearing loss.
3) What are different types of hearing loss?

3.6 Suggested readings

English, K. M. (2002). *Counselling children with hearing impairment and their families.* Boston: Allyn and Bacon.

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Unit 4- Evaluation of hearing

4.0 Objectives:

After studying this unit, you will be able to:

- List the different methods used for testing hearing
- Identify the parts of an audiometer
- Describe the procedure for pure tone audiometry
- Describe different types of audiometer
- Understand the factors affecting audiometry

4.1 Introduction

In the previous units, you learnt about ear, hearing and hearing loss. You know that the hearing abilities of all the individuals are not same. Hearing ability needs to be assessed to identify individuals with hearing loss. Different methods are used to test the hearing ability of an individual. Some are formal while others are informal methods. Some tests help in only identifying if an individual has a hearing problem whereas others will identify which part of the ear is not functioning normally and indicate the possible line of treatment. Now in this unit you will learn about hearing testing.

4.2 Hearing testing

By testing the hearing of individuals we get an idea about the actual hearing abilities of the person. A few of the things we get to know from hearing tests are the type and degree of hearing loss. Some of the tests also give us an idea about how much of speech the person would be able to perceive.

4.3 Methods of testing hearing

A number of methods are available for testing hearing. The tests used for testing hearing can be broadly classified as screening tests and diagnostic tests. A screening test will only tell us if an individual has a hearing loss or not but it will not give information regarding the type and degree of hearing loss. Diagnostic tests are performed by an audiologist to find out the extent and type of hearing loss.

For both screening and diagnostic purpose, either behavioural or physiologic tests can be used. Behavioural tests are those tests where the subject has to give an intended response to a test sound. These tests are also called as subjective tests. Physiological tests are those tests where an intentional response from the subject is not required. These tests are also called as objective tests.

Generally an audiologist administers a group of tests to diagnose hearing loss. The tests chosen depend on a number of factors which include age, complaints, and associated problems of the individual and the purpose of the evaluation. Based on the results of the tests administered, the audiologist will diagnose the problem of the client and make appropriate referrals. You have learnt in the previous unit that an individual may have a problem in any part of the auditory system. If the problem is in the external ear or middle ear, the individual is referred to an ENT doctor for treatment. If an individual has sensorineural hearing loss, i.e., a problem in the inner ear, the individual is advised to try a hearing aid after an ENT clearance. The individual is referred to a neurologist, if the audiologist suspects a

problem in the auditory nerve or the auditory nervous system. Some of the tests commonly used for hearing assessment are listed below:

- Tuning fork tests
- Pure-tone audiometry
- Speech audiometry
- Immittance evaluation
- Auditory brainstem response (ABR/BERA)
- Otoacoustic emissions

Before administering any of these tests, a detailed case history has to be taken to record the complaints of the client.

4.3.1 Tuning fork

Tuning fork tests are very simple tests that give a rough idea about the type of hearing loss a person has. A 512Hz vibrating tuning fork is used to test the hearing of the individual. To get the tuning fork vibrating it should be struck against one's elbow or knee. There are different types of tuning fork tests. Two of the commonly used tuning folk tests are:

- Rinne test
- Weber test

In the **Rinne test** the vibrating tuning fork is first held near the external auditory meatus. This will measure the sound being heard through air conduction. Then the tuning fork is pressed firmly against the skull behind the pinna. This will measure the signal being sent directly to the cochlea through bone conduction. The patient's ability to hear a tone conducted via

air and bone conduction is compared. The patient is asked whether the sound is louder when the tuning fork is kept near the external ear or when it is kept on the skull. The responses would be different depending on the type of hearing loss.

- In individuals with **normal hearing** the tone will be more audible near the **external ear**.
- In individuals with **sensorineural hearing loss** the tone is audible at the **external ear**. This is called **Rinne-positive.**
- In individuals with **conductive hearing loss** the tone is audible through **bone conduction**. This is called **Rinne-negative.**

The Weber's test was developed to detect unilateral hearing loss. It compares bone conduction in both ears. A vibrating 512Hz tuning fork is placed on the centre of the patient's forehead. The patient is asked whether the sound is heard in the middle or to one side.

- If the sound is louder on the side in which the hearing loss is present then the person may have a conductive hearing loss.
- If the sound is not louder on the side in which the hearing loss is present then the person may have a sensorineural hearing loss.

Other lesser known tuning fork tests are:

- Bing test
- Schwabach test

You should remember that tuning fork tests are not usually recommended to be used as they give unreliable results. It is always better to use an audiometer to check a person's hearing ability.

4.3.2 Audiometery and parts of an audiometer

An audiometer is the most basic instrument used for testing hearing. Both portable and desk type audiometers are available in the market. Audiometers are classified into different types based on the facilities available for testing. The minimum facility available in an audiometer is pure-tone testing through air conduction mode. A majority of the audiometers have facility for air and bone conduction testing. Figure 5 shows picture of an audiometer with a headset and a bone vibrator. For air conduction testing, generally, a headset with earphones is placed over the ears. However, insert earphones may also be used. Insert earphones are fitted to the ear canal with the help of an ear tip. For bone conduction testing, a bone vibrator is placed over the mastoid bone behind the pinna. Other facilities that may be available in an audiometer include speech audiometry, masking, special tests such as Tone decay test (TDT), Alternate Binaural Loudness Balance tests (ABLB), Short Increment Sensitivity Index (SISI). These special tests are used by the audiologists for a detailed evaluation of hearing. Audiometers work on alternating current (AC) power supply. Some of the screening audiometers can also work on power supply through battery.

A pure-tone audiometer has a signal generator which produces a pure-tone. A pure-tone is a signal which has energy at a single frequency. The

intensity and frequency of this pure-tone signal can be varied. A conventional audiometer will have facility to vary the frequency from 250 Hz to 8000 Hz at octave or mid octave intervals for air conduction testing.

Figure 5: An audiometer with a headset and bone vibrator

For bone conduction testing, octave or mid octave frequencies from 250 Hz to 4000 Hz will be available. The testable frequencies will be 250 Hz, 500 Hz, 750 Hz, 1000 Hz, 1500 Hz, 2000 Hz, 3000 Hz, 40000 Hz, 6000 Hz and 8000 Hz for air conduction testing and it will be up to 4000 Hz for bone conduction testing. The intensity range for air conduction testing will be from -10 dB HL to 120 dB HL at frequencies between 500 Hz to 6000 Hz, with slightly lower maxima at 250 Hz, and 8000 Hz. The range of intensities available for bone conduction testing is limited. The maximum

limit for bone conduction testing generally does not exceed 50 dB HL at 250 Hz and 70dB HL at other frequencies.

Some of the basic controls available in an audiometer are as follows:

- A frequency dial to vary the frequency of the signal generated
- An intensity dial to vary the intensity of the signal generated
- An interrupter switch to present the signal
- An output selector for selection of transducer (supra aural earphones, insert earphones, loud speakers or bone vibrator) and ear to be tested

4.3.3 Audiogram

The results of audiometry are plotted on a graph called audiogram. An audiogram is a chart of a person's hearing ability. You can see from Figure 6, that in an audiogram frequency (pitch) is represented across the horizontal axis or X-axis and intensity (loudness) is represented on the vertical axis or the Y-axis. Frequency is measured in Hz and intensity is measured in dB HL.

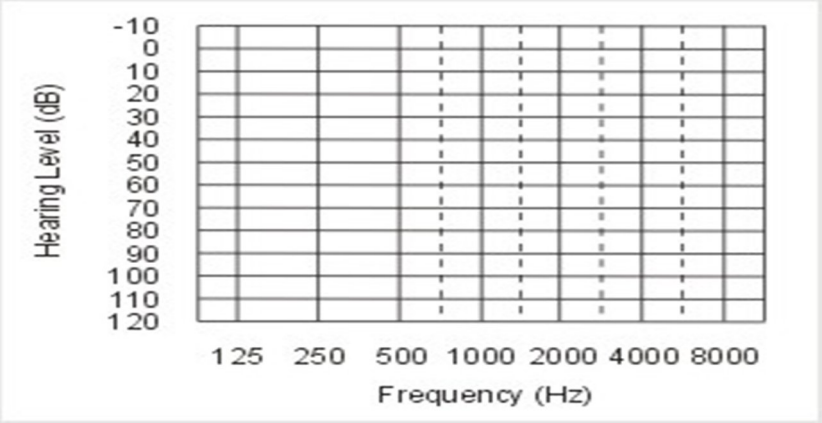

Figure 6: Audiogram format

The frequencies are low on the left side (125 or 250 Hz), and then gradually increase to higher frequencies on the right side (8000 Hz). The intensity scale goes from very low intensities (soft sounds) at the top (-10 or 0 dB HL) to very high intensities (loud sounds) at the bottom (110 dB HL). The scale used for intensity is not absolute. That is 0 dB HL does not mean that there is no sound at all. It is the softest sound that a person with normal hearing ability would be able to detect the sound at least 50% of the time. Different symbols are used to plot the results of air conduction and bone conduction testing. Results of right and left ear are also plotted using different symbols. "X" = left ear AC, "O" = right ear AC, ">" = left ear BC, and "<" right ear BC. It is also recommended that the results of the right ear are marked in red colour and those of the left ear are marked in blue colour. The results of the two ears can be plotted on two different graphs or on a single graph.

Check your progress I

- List the tests used for hearing assessment
- What are the different types of transducers used for hearing evaluation?

4.4 Pure tone audiometry

4.4.1 Case history

The first step in hearing assessment is obtaining a detailed case history. The client and/or the informant of the client are interviewed to obtain

information regarding the nature of the problem and the associated problems. The case history should include the following information:

- Demographic information such as name , age and gender of the client
- Education and occupation
- Age of onset of hearing problem
- Whether the problem is in one ear or both ears
- Whether the problem started suddenly or gradually
- Whether the problem is increasing day by day
- Whether the client has a complaint of
  - Ear pain
  - Ear discharge
  - Ringing sound in the ear (Tinnitus)
  - Giddiness/dizziness/vertigo/balancing problem
  - Headache
  - Speech, language problems
- History of any illness or injury that could be associated with hearing loss, medication taken for illness
- Whether the client is/was exposed to loud sounds
- In case of children, any illness/injury that could lead to hearing loss when the mother was pregnant or during the birth of the child (prenatal and natal history)
- Associated problems
- Family history of hearing problem
- Reports of previous evaluation and treatment

Information collected from case history is helpful for the tester to decide the type and procedure of tests that needs to be carried out for the client. Case history also gives valuable information while diagnosing and making appropriate referrals for the client.

4.4.2 Procedure for pure tone audiometry

Pure-tone audiometry has to be performed in a room which is free from environmental noises. Even feeble or soft sounds can affect the results of the test. The rooms should be acoustically treated to ensure that the noise inside the room is not loud enough to interfere with the testing. National and international norms/standards are available for this purpose. It is preferred that the testing is carried out in a two-room set-up. Figure 5 shows a picture of audiometry being carried out in a two-room set-up. If a two-room set-up is not available then the testing is carried out in a single room set-up.

Figure 5: Audiometry being carried out in a two- room set up.

Pure-tone audiometry assesses the hearing ability of each ear separately at different frequencies. That is, we find out the lowest intensity of the signal

an individual can hear at octave frequencies for the right and left ear separately. This minimum level an individual can hear 50% of the time is called as hearing threshold. Conventional pure-tone audiometry includes obtaining thresholds for air conduction and bone conduction hearing. For air conduction testing, signals are presented through supra aural or circum-aural earphones. Sometimes insert earphones or loudspeakers may be used for air conduction testing. To obtain bone conduction thresholds, a bone vibrator is used.

The procedure for obtaining pure-tone thresholds includes the following steps:

- Seat the client or the subject on a comfortable chair.
- Take a detailed case history to get information regarding the present and past complaints related to hearing
- Examine the client's ear to ensure that the ear canal is free from wax, foreign body or debris. If not, refer the client to an ENT doctor.
- Give the following instruction to the client:

  "A sound will be presented to your ears. If you hear a sound, raise your finger/hand. When you stop hearing the sound put down your finger/hand. The loudness of the sound may vary. Even if you hear a soft sound, raise your finger/hand".

- If a client is a young child who cannot follow instructions or the client does not have sufficient speech and language to follow instructions, play audiometry is carried out. In play audiometry, blocks, marbles or any item which the child likes are used for training the child. The child is trained to carry out a play activity

such as putting down a block or rolling a marble every time he/she hears a sound. If a child cannot be trained for play audiometry also, then other alternate tests such as behavioral observation audiometry and other physiological tests such as auditory brainstem responses, otoacoutic emissions are carried out.

Air conduction testing

- Place earphones over the ears. Note that the headset generally has a blue mark on one earphone and a red mark on the other. Place the headset in such a way that the blue earphone is placed over the left ear and the red earphone is placed over the right ear.
- First test the better ear (as reported by the client). If you do not know which the better ear is, test the right ear first.
- Choose 1000 Hz on the frequency dial and 40 dB HL on the intensity dial. Press the interrupter to present the signal.
- If the client raises his finger/hand, decrease the intensity by 10 dB. If the client does not respond, increase the intensity by 5 dB. Present the signal.
- Repeat this procedure until you find out the lowest intensity that can be heard by the client. The lowest intensity at which the client responds at least 50 % of the time is plotted as his/her threshold at that frequency.
- Change the frequency to 2000 Hz and repeat this procedure.
- Repeat the procedure to obtain threshold at 4000 Hz and 8000 Hz.
- Recheck threshold at 1000 Hz. Then obtain threshold at 500 Hz and 250 Hz.

- Repeat the entire procedure to obtain thresholds for the other ear at 1000 Hz, 2000 Hz, 4000 Hz, 8000 Hz, 500 Hz and 250 Hz.

Bone conduction testing

- Place the bone vibrator on mastoid bone behind the pinna. Bone vibrator is generally placed on the mastoid of the better ear and the thresholds obtained are called as common bone conduction threshold. If air conduction thresholds of both the ears are similar, then place the vibrator on the right ear.
- Obtain bone conduction thresholds from 250 Hz to 4000 Hz using the same steps used for air conduction testing.

4.4.3 Different types of audiograms

A hearing loss is described in terms of the type, degree and configuration of the audiogram. The following information plotted in an audiogram is used for explaining the type, degree and configuration of hearing loss:

- The average amount of hearing loss by air conduction and the amount of hearing loss by air conduction at different frequencies
- The amount of hearing loss by bone conduction and the difference between air conduction threshold and bone conduction thresholds

Type of hearing loss: The difference between air conduction and bone conduction thresholds, the air-bone gap, gives information about type of hearing loss. Following guidelines are used to classify the hearing loss into different types.

Conductive hearing loss: An individual is said to have conductive hearing loss if his/her bone conduction thresholds are normal but air conduction thresholds are affected. Figure 8 shows an example of conductive hearing loss.

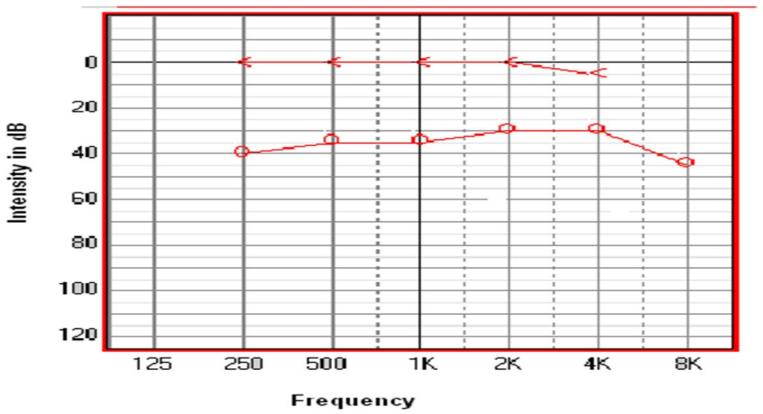

Figure 6: Audiogram showing mild conductive hearing loss in the right ear

Sensorineural hearing loss: An individual is said to have sensori-neural hearing loss if both air and bone conduction thresholds are affected to the same extent.

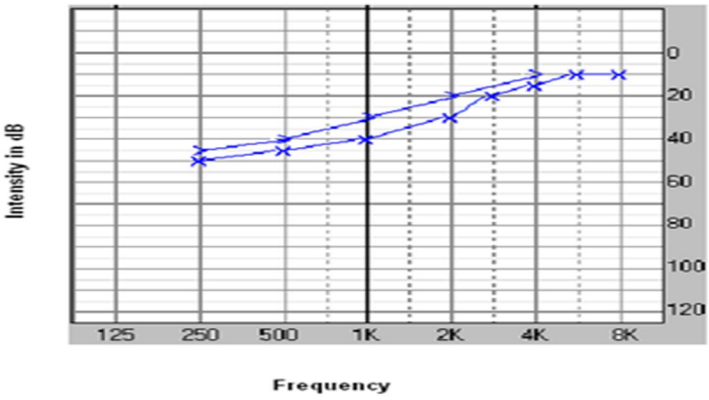

Figure 9: An audiogram showing mild sensorineural hearing loss in the left ear

That means hearing thresholds for both air and bone conduction are abnormal and the air-bone gap is less than 10 dB. An example of sensori-neural hearing loss is shown in Figure 9.

Mixed hearing loss: An individual is said to have mixed hearing loss if both air and bone conduction thresholds are affected but the amount of loss by air conduction is more than that by bone conduction. That means the air-bone gap is more than 10 dB in individuals with mixed hearing loss. Figure 10 shows an example of mixed hearing loss.

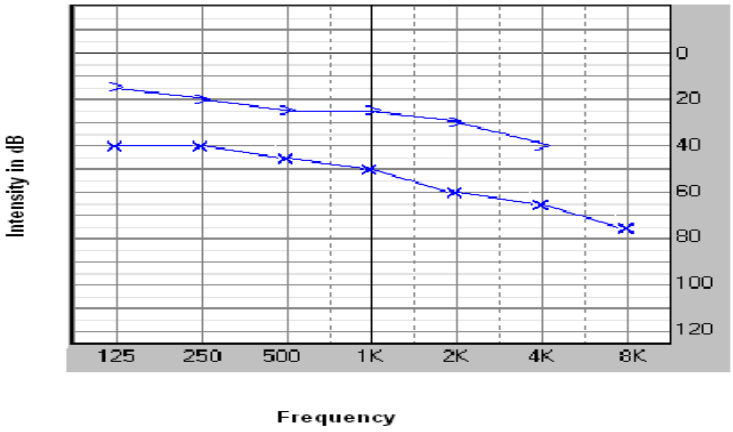

Figure 10: Audiogram showing moderate mixed hearing loss in left ear

Degree of hearing loss: Amount of hearing loss by air conduction is used to describe the degree of hearing loss. Hearing loss is classified into different degree based on pure-tone average for air conduction thresholds. The pure-tone average (PTA) refers to the average of air conduction thresholds at 500 Hz, 1000 Hz and 2000 Hz. One of the commonly used classifications of degree of hearing loss is that given by Clark (1981). The guidelines for the classification given by Clark (1981) are as follows:

PTA Less than 15 dB HL	Normal hearing
PTA of 16 to 25 dB HL	Minimal hearing loss
PTA of 26 to 40 dB HL	Mild hearing loss
PTA of 41 to 55 dB HL	Moderate hearing loss
PTA of 56 to 70 dB HL	Moderately severe hearing loss
PTA of 71 to 90 dB HL	Severe hearing loss
PTA > 90 dB HL	Profound hearing loss

Configuration of hearing loss: The amount of hearing at different frequencies tells us about the shape or configuration of the audiogram. You can see in the audiograms shown in Figures 8, 9 and 10, the amount of hearing loss or the hearing thresholds are not same at all the frequencies. A hearing loss that only affects the high frequencies would be described as a high-frequency loss. Its configuration would show good hearing in the low frequencies and poor hearing in the high frequencies and the audiometric configuration is described as sloping hearing loss (refer Figure 10). On the other hand, if only the low frequencies are affected, the configuration would show poorer hearing for low tones and better hearing for high tones. This would be referred to as raising configuration (refer Figure 9). Some hearing loss configurations are flat, indicating the same amount of hearing loss for low and high tones (refer Figure 8).

Other descriptors associated with hearing loss include the following:

Bilateral versus unilateral: Bilateral hearing loss means both ears are affected. Unilateral hearing loss means only one ear is affected.

Symmetrical versus asymmetrical: Symmetrical hearing loss means that the degree and configuration of hearing loss are similar in both the ears. An asymmetrical hearing loss is one in which the degree and/or configuration of the loss is different for each ear. In clients with unilateral or asymmetrical hearing loss, special procedure called masking is required during pure-tone audiometry. Masking is used to prevent the participation of better ear while testing the poorer ear.

4.4.4 Factors that affect hearing testing

A number of factors related to the subject/client, test environment, instrument and test procedure used for testing could affect the results of pure-tone audiometry. Some of the factors that can affect the test results are listed here:

- Client's ability to understand instructions for the test
- Co-operation of the client
- Motivation of the client
- Attention of the client
- Noise levels in the test room
- Reverberation (Reverberation refers to the amount of signal that is reflected from the walls of the room) and temperature inside the test room
- Calibration of the instrument (Calibration checks whether the signals presented through the instrument are same as what it is supposed to be)
- Procedure used for testing

Check your progress II

- Define threshold of hearing
- List the subject related factors affecting hearing testing

4.5 Speech audiometry

Speech audiometry assesses a patient's ability to understand words, which are much more representative of everyday listening experience than pure tones. It gives the clinician a clearer picture of the patient's functional hearing ability and is extremely valuable to predict a patient's success with hearing aids. Speech audiometry is carried out using an audiometer. The tests that are routinely done as a part of speech audiometry are Speech Detection threshold, Speech Recognition Threshold and Speech Identification Scores.

4.6 Lets sum up

To summarize, you learnt from this unit that different tests are available for hearing testing. In some of the tests, the client has to give a response during testing whereas in others no voluntary response is required from the client. Most basic and common test used for hearing testing is pure-tone audiometry. You learnt how to obtain air conduction and bone conduction hearing thresholds of a client. However a diagnosis cannot be made only based on pure-tone audiometry. The results of pure-tone audiometry have to be crosschecked with results of other tests such as speech audiometry, immittance evaluation, auditory brainstem response and otoacoustic emissions before arriving at a diagnosis.

Remember to check the working of audiological equipment and take care of them properly. Use the daily checklist to make sure that the instruments are functioning well. Also, maintain a record of the instruments in your centre.

4.7 Answers to check your progress exercises

Check your progress I

Refer 4.3 and 4.3.2

Check your progress II

Refer 4.4.2 and 4.4.4

4.8 Questions for self study

- Describe the procedure for pure-tone audiometry
- Write a note on speech audimetry

4.9 Suggested readings

DeBonis, D. A. & Donohue, C. L. (2004). *Survey of Audiology. Fundamentals for audiologists and health care professions*. Boston: Allyn and Bacon.

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Unit 5 – Early Identification and prevention

5.0 Objectives

After studying this unit, you will

- Appreciate the importance of early identification
- Understand the strategies used in early identification
- Have the knowledge of hearing screening in different set-ups
- Know the importance of prevention

5.1 Introduction

It is important to identify the hearing disorder early and start the rehabilitation process. During early period of life, specifically during infancy, learning language is much easy compared to later in life. Infants learn language quiet effortlessly and passively. However, you may have observed that if adults, for example if you want to learn new language it is quite difficulty and requires lot of effort. It is essential that an individual with hearing loss be identified as early as possible so that appropriate measures can be taken to rehabilitate the individual. Hearing loss should be identified early in both children and adults. The effects of hearing loss are more severe in a developing child and hence it is more important that the hearing loss is identified early in infants and children. Earlier the hearing loss is identified and the individual is rehabilitated, better is the outcome of rehabilitation. Early identification and rehabilitation reduces the gap between an individual with hearing impairment and an individual with normal hearing. It also reduces the cost of rehabilitation. It is recommended that every baby born in the country be screened for hearing impairment.

5.2 Early identification and prevention

5.2.1 Importance of early identification

It is very important to identify hearing loss early and start the rehabilitation process. In fancy there is rapid development in the brain cells and is most sensitive to learning. Therefore, sensory stimulation during this period is very important for language learning. In biology, there are many instances of learning for which there is a critical period. During this period, typically early in life, there is a (heightened) sensitivity to stimuli that are necessary for the development of the ability concerned. After this period, there is a decline in sensitivity. If the relevant stimuli are not present during this critical period, the ability concerned will no longer (fully) develop under normal circumstances. Most popular example of critical period is imprinting in ducklings. When they are born they follow the first moving object they see, but only during first few days. There are many scientific evidence that language can be best learnt before 3 years of age. There are lot of scientific studies which have shown that late learners perform significantly poorly than early learners. The primary justification for early identification of hearing impairment in infants relates to the impact of hearing impairment on speech and language acquisition, academic achievement, and social/emotional development. The first 3 years of life are the most important for speech and language acquisition. Consequently, if a child has hearing loss since birth or experiences hearing loss in infancy or early childhood, it is likely that child will not receive adequate stimulation required for speech and language learning, social and emotional

development. The goal of early identification and intervention is to minimize or prevent these adverse effects.

If hearing loss is identified early, it will enable early rehabilitation, during the critical age for speech and language development. Early rehabilitation will include fitting of an appropriate hearing aid and providing speech and language therapy. Late identification of hearing loss increases the gap between normal and hearing impaired. Also, the psychological problems will be less if rehabilitation starts early. Children with better speech and language skills usually succeed in a normal school and it is easier to find appropriate job placements later in life. It is important to identify hearing loss early in an individual who has acquired hearing loss since hearing is required for monitoring of speech.

5.2.2 Prevention of hearing loss

There is an old proverb which says "Prevention is better than cure". This is true with respect to hearing loss also. Prevention of hearing loss will not only help an individual but it will also lessen the burden on the society. Unfortunately, not all the causes of hearing loss can be prevented. Therefore, prevention of hearing loss is discussed under three main categories namely **primary prevention** of hearing loss, **secondary prevention** of hearing loss and **tertiary prevention** of hearing loss. Primary prevention of hearing loss refers to the steps taken to eliminate or inhibit the onset and/or development of the causes of hearing loss. Secondary prevention of hearing loss refers to preventing the problem from becoming a disability. It includes early identification of hearing loss so that

appropriate measures can be taken to prevent it from becoming a disability. Tertiary prevention of hearing loss refers to preventing a problem from becoming a handicap. It involves early rehabilitation of the individual so that the individual learns to cope with the problem. For primary prevention of hearing loss, you need to know the causes of hearing loss that are preventable. Some of the preventable causes of hearing loss and approaches to prevent them as listed by WHO (2006) is described here.

Prevention of prenatal causes

***Genetic counselling*:** Genetic causes of hearing loss can be transmitted from one generation to generation. Therefore, if there is a family history of hearing loss, counselling the parents-to-be regarding the chances of having a child with hearing loss can help in preventing transmission of genetic causes from one generation to another.

Immunization: Occurrence of Rubella in a pregnant woman may lead to hearing loss in the child to be born. Vaccinating adolescent girls will help in prevention of hearing loss in their children to be born.

Proper health care: Pregnant women should be screened for diseases such as syphilis and toxoplasmosis and appropriate treatment should be given, if necessary. Women should also be educated regarding occurrence and effects of such diseases.

Avoiding ototoxic medicines: Pregnant women should be educated regarding side effects of medicine and should be advised to take medication only on recommendation by a medical doctor.

Prevention of natal causes

Nutrition: Nutrition taken by a pregnant woman has an effect on the birth weight of the baby. So care should be taken to ensure that the appropriate nutrition is provided to pregnant women.

Improved birth practice: Chances of birth trauma and delayed birth cry is more if delivery is not carried out under appropriate medical care and supervision.

Prevention of postnatal causes

Immunization: Children should also be immunized against diseases such as measles, mumps, rubella, meningitis as hearing loss may occur as a result of these diseases.

Avoiding ototoxic medicines: Public should be educated regarding side effects of medicine and should be advised to take medication only on recommendation by a medical doctor.

Proper health care: Appropriate health care and personal cleanliness can prevent occurrence of ear infection. Public should also be educated regarding proper management of cold and cough, especially in children, as it can lead to ear infection.

Avoid exposure to loud noise: Public should be educated regarding harmful effects of noise and should be advised to wear ear protective devices when exposed to loud noise. Laws which limit the exposure to loud sounds should be enforced.

Use of helmets and seat belts: Public should be educated and encouraged to use helmets and seat belts to avoid head injury during road accidents.

5.2.3 Hearing Screening

Definition of hearing screening

Screening tests helps us in identifying if an individual has a hearing problem or not. Tests used for screening do not require much time and hence it is possible to screen a large number of individuals in a short time. The results of screening tests are classified as pass or refer. "Pass" indicates that the individual does not have a hearing loss. "Refer" suggests that the individual probably has hearing loss and needs to be referred for a detailed hearing evaluation. Hearing screening can be carried out by audiologists or allied professionals.

5.2.4 Hearing screening methods

Either formal or informal methods can be used for hearing screening. Formal methods use standard tests which have been developed and tested for its efficacy. Most often they require some instruments to carry out screening. Some of the formal methods used for hearing screening by audiologists are:

- High risk register
- Behavioral Observation Audiometry
- Auditory brainstem response
- Otoacoustic emissions
- Immittance screening
- Pure-tone screening

High Risk Register / Checklists

One of the least expensive and simplest test for hearing screening is the use of check lists. The check list used for hearing screening varies depending on the age of the individual to be screened. For screening new born babies, infants and children, high risk checklists are used. A high risk check list includes a list of factors that are likely to cause a hearing problem in a child. You have learnt in the previous unit that hearing loss may be caused by a number of factors. A high risk register includes factors that can lead to hearing loss in a child before the baby is born (prenatal causes), during the birth of the child (natal causes) and after the child is born (postnatal causes). Therefore, it identifies congenital hearing loss as well as hearing loss acquired early in childhood.

A high risk register developed and modified for Indian population is given in Appendix I. It has two lists. The High Risk Register for Neonates is used for children in the age range of 0 to 28 days. The High Risk Register for Older Babies is used for children in the age range of 29 days to 3 years. You should interview the mother or a family member of the child to check if the child had any of the high risk factors listed in the register. If the answer to any of the questions is "yes", then the child being screened is at risk for hearing loss and should be referred for a detailed hearing evaluation.

A self-assessment scale can be used to screen for hearing loss in adults. An individual with hearing loss will have difficulty in communication and the communication difficulties of an individual vary depending on the degree

of hearing loss. A self-assessment scale is a questionnaire which checks the communication difficulties of an individual. It assesses the problem an individual has in hearing sounds, understanding speech and also the psychological effects of hearing loss. One of the self-assessment scales developed in India is given in Appendix II. If an individual gets a score of more than three, then he/she should be referred for a detailed hearing evaluation.

Development of Auditory Behaviour

You have learnt in the previous unit how children with normal hearing respond to different sounds. You learnt that at different ages the responses to sounds differ. This was referred to as the development of the auditory behaviour. You can check with the mother or the informant whether this normal development of auditory behaviour has been observed in the child. If the answer is no, the child may be at risk for hearing loss. You should however make sure that the child does not have any other problem such as mental retardation or cerebral palsy.

Behavioural observation

During behavioral test, sounds of different frequencies and intensities are presented in free field in an audiometric room and the responses of the child to these sounds are observed.

Material required: Noise makers – choose one which makes high frequency sound (e.g. pooja bell, jingles), one which makes low frequency

sound (a rattle). For checking mid frequencies, speech sounds such as /a/ or word "Aha!" can be used.

Procedure for testing: It is preferred that the testing is carried out in a quiet room. You require two testers, one for presenting stimuli and another for observing the responses. The mother holds the baby in such a way that the baby is facing the front when the testing is being carried out. One of the testers presents a sound from behind preferably from a distance of one foot. Another tester standing in front of the child, observes the child's response. The child may search for the sound or may turn towards sound source. Remember that the response of the child varies depending on the age of the child. The observer distracts the child and gets the child's attention away from the sound source when the sound is not being presented. The tester again presents a sound, from a different direction and watches for the child's response. This procedure is repeated to observe responses to different sounds. Make sure that the same sound is not presented repeatedly. Otherwise the child gets bored or adapted and stops responding. If age appropriate responses are not observed in the child, then hearing loss is suspected and the child is referred to an audiologist for a detailed evaluation.

Ling's six sound test

You have learnt in the previous unit that our speech contains a wide range of frequencies. It has been observed that the six speech sounds namely, /a/, /i/, /u/. /s/. /ʃ/ and /m/ represent sounds of different frequencies. A normal hearing child will be able to hear and identify all these sounds even when it

is presented from the back. So you can present these six sounds to the child from the back and check.

- Whether the child is aware of the sounds
- Whether the child can identify these sounds

If the child does not hear or is not able to identify these sounds, then the child needs to be referred for detailed audiological evaluation.

Otoacoustic emissions

Otoacoustic emissions are sound emitted by the inner ear in response to stimulation. This sound can be recorded by placing a small microphone in the inner ear. Presence of otoacoustic emissions is a hallmark of normal hearing. It is very efficient screening tool to detect the presence of hearing loss. This test takes very short duration and can be performed by a person with minimal training. Therefore, it is widely used for new born hearing screening in hospital set up. Modern day otoacoustic emission analysers are hand held and battery operated. After the testing results would be displayed as pass (normal hearing) or refer (suspected hearing loss). If the results are refer test may be repeated after two weeks and if still same results persists, child should be referred for detailed audiological evaluation

5.2.5 Hearing screening in different set-ups

You have learnt various screening tools that are available. Depending on the population and set-ups you may have to use one or more screening tools. For example, i) in hospital set-up if you are screening new born babies you may use high risk registers, behavioural observation and

otoacoustic emissions; ii) in school, you may depend on signs and symptoms of hearing loss, Ling's six sound test and pure tone audiometry; iii) in camps or rural set-ups you may use pure tone audiometry for children above 3 years old and behavioural observation test for children below 3 years old.

Advantages and limitations of screening

Some of the advantages of informal testing are as follows:

- It is not time consuming. A large number of babies can be tested in less time.
- It is cost effective. Does not require expensive instruments to carry out these tests.
- It is easy to train personnel to carry out these tests.
- It can be carried out anywhere

However, the results of informal screening have to be interpreted with caution. Both false 'referrals' and false 'pass' will be high when informal tests are used for hearing screening. That means individuals without hearing loss may be referred for a detailed hearing loss (false 'referrals') and those with hearing loss may not be referred for a detailed evaluation (false 'Pass'). Also, the test procedures are not standardized i.e., the procedure used for testing is not uniform across the country and hence it is difficult to compare results obtained by different testers.

Check your progress

You have learnt about importance of early identification and prevention, methods to screen for hearing loss. Try answering following questions to check if you have understood the concept

a) What is the importance of early identification of hearing loss?

b) List three types of prevention

c) What is Ling's six sound test?

5.3 Care and maintenance of audiological equipment

You will now learn about some simple things that should be kept in mind while handling an audiometer or any other audiological instrument.

- Do not keep the audiometer in places with extreme temperature. Store in a cool, dry place.
- Do not drop the instrument or transducer. Make sure it is kept in a place where it is not in danger of falling.
- Keep the instrument covered when not in use to avoid dust collecting on it.
- Avoid dropping water or any other liquid on the instrument.
- Wipe the instrument with a clean dry, soft cloth.
- Make sure that there is no vibration transmitted to the instruments. This precaution should be taken especially when transporting the instruments for outreach programs.
- Do not apply force on the switches or dials of the instrument. The controls should move freely.

- Do not twist the cords of the instruments when storing them. Make sure that they are kept untangled when in use. Never bend or twist the cords where they enter the transducers.
- Always keep a stock of extra cords, which are stored properly, since they are likely to go out of order more frequently when compared to other parts.
- Place the transducer on a hanger or hook when not in use. Do not hang the transducer using the cords, rather they should be hung from the headband.
- Do not stretch the headband as it will loose its tension.
- The audiological instruments should be electroacoustically calibrated to meet the standards at least once in six months. This should be done by qualified professionals.
- While using instruments which work on AC power supply ensure that it works on 220 volts, 50 Hz stable power supply.
- While using instruments which work on DC power supply, check the voltages of the battery before using the instrument.
- Ensure that there is no internal hum from the audiometer

Daily before using any audiological equipment, a visual inspection of the instrument is required. Following this, a listening test needs to be carried out. Given below is a list of things that need to be done in order to check an audiometer.

Checklist to be maintained before using audiological equipment

- Check to see if all cords are correctly connected
- Check if the cords are cracked or worn out
- Check the audiometer to see if the dials move properly
- Check that the earphones are properly attached to the headset (headband)
- Check the instrument for any crack or damage, especially the transducers
- Check if the power supply is present
- Make sure that the audiometer is switched on
- After putting on the headsets, present tones through each of the head phones and make sure it comes through the correct earphone
- Turn the attenuator dial from minimum to maximum levels and listen for increases and decreases in loudness.
- Check if the signals are clear even at high intensity levels
- Check that when the frequency is changed, there is a change in the pitch of the signal. This should be done with the intensity set at a comfortable loudness
- Check the thresholds of someone who has normal hearing and whose thresholds are known and see if they match. This should be done for both air conduction and bone conduction.
- Check if the signals are heard continuously even if the headphone cords are moved or twisted gently.
- Check if no additional sounds are present through the transducer other than the signal that is being presented.

The above information should be checked and recorded daily. The form in which you record this information is called the 'Daily Listening Check form'.

List of equipment, specification for the same

Audiologists should be consulted before buying any audiological equipment. They would give you a list of instruments which should be bought for an audiological set-up. They would also provide the specifications for each of the audiological equipment that should be procured. The specifications of any instrument are a detailed set of parameters / features that the instruments should have. The specification for each audiological instrument would vary depending on the type of instrument being procured. (e.g. audiometers or immittance audiometer) and the purpose for which the instruments are being got (e.g. screening or diagnostic).

Once your audiological centre has got the necessary equipment it is important that you maintain a record of the instruments that you have got. Open a register and maintain the following information in the format given:

Name of instrument (Model name)	Accessories got with the instrument	Serial number	Date of purchase; Company from which purchased; Invoice no; Cost	Present location of the instrument	Name and signature of staff in-charge of the instrument

The above information should be maintained separately for each category of instrument. For example, this should be done separately for each of the following: screening audiometer; diagnostic audiometer; screening immittance audiometer; diagnostic immittance audiometer.

5.4 Lets sum up

To summarize, from this unit you learnt importance of early identification, consequences of late identification and different strategies to prevent hearing loss. You also learnt that to test a large number of subjects in a short time, hearing screening can be carried out. Either formal or informal tests can be used for hearing screening. Those, who do not pass hearing screening need to be referred for a detailed hearing evaluation. Remember to check the working of audiological equipment and take care of them properly. Use the daily checklist to make sure that the instruments are functioning well. Also, maintain of a record of the instruments in your centre.

5.5 Answers to check your progress exercises

a) refer 5.2.1

b) refer 5.2.2

c) refer 5.2.4

5.6 Questions for self study

1) How do you take care of audiological equipment?

2) What is critical period and write its relevance?

5.7 Suggested readings

Martin, P. N., & Clark, G. J. (2000*). Introduction to audiology*. Boston: Allyn and Bacon.

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