Audiological System (E.N.T)

Mechanism of Hearing

Speech and hearing are the most important means by which we communicate with each other. Through hearing we receive speech sounds from others and also listen to ourselves. In some ways it is more of a handicap to be born 'stone deaf' than to be born blind. Any child who cannot hear the sounds from his own vocal cords cannot learn to talk without special training. In earlier times a child deaf from birth was also mute, or dumb and since so much of our learning takes place through hearing, he often was not educated. The sense of hearing is in some ways more remarkable than the sense of vision. We hear a range of sound intensities of over a million million (10^{12}), or 100 times greater than the range of light intensities the eye can handle (Fig. 1). The ear can hear frequencies that vary by a factor of 1000, while the frequencies of light that eye can detect vary by only a factor of 2.

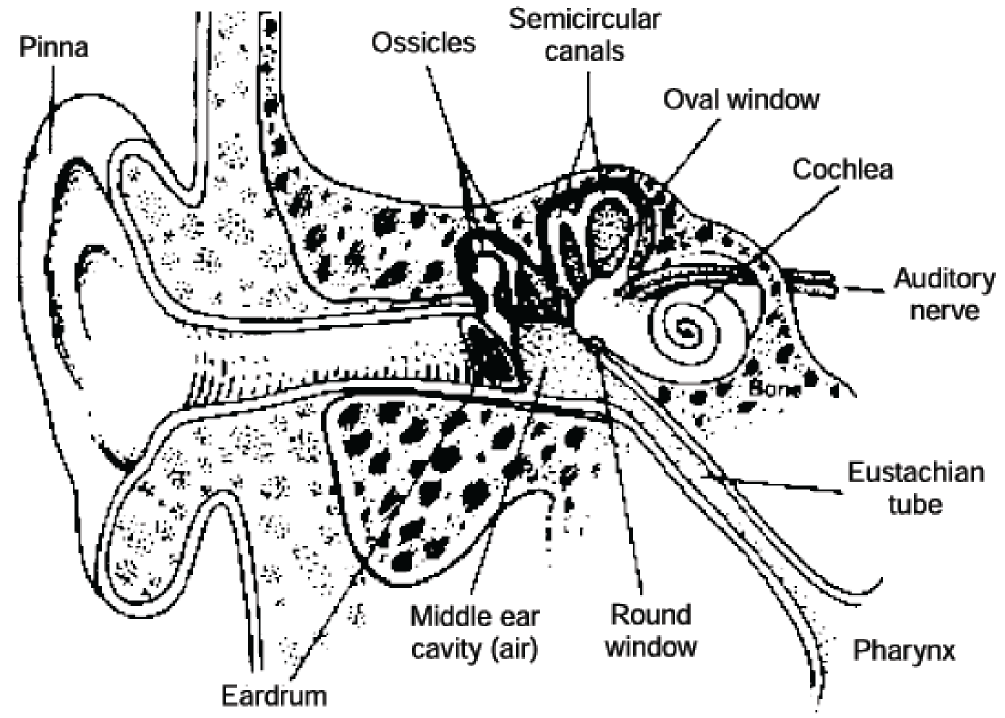

Figure 1. The cross sectional view of human ear showing parts.

The sense of hearing involves

1. the mechanical system that stimulates the hair cells in the cochlea;
2. the sensors that produce the action potentials in the auditory nerves;
3. the auditory cortex, the part of the brain that decodes and interprets the signals from the auditory nerves.

Deafness or hearing loss results if any of these parts malfunctions. The ear is a cleverly designed converter of very weak mechanical waves in air into electrical pulses in the auditory nerve. Fig.1 shows most of the structures of the ear involved with hearing. The ear is usually thought of as divided into three areas; The outer ear consists of the ear canal, which terminates at the eardrum (tympanic membrane). The middle ear includes the three small bones (ossicles) and an opening to the mouth (Eustachian tube). The inner ear consists of the fluid filled spiral shaped cochlea containing the organ of Corti. Hair cells in the organ of Corti convert vibrations of sound waves hitting the ear - drum into coded nerve pulses that inform the brain of these sounds. Fig. 1. Shows the cross section of the Ear. (note that the connection to the middle ear to the pharynx).

Stethoscope

Perhaps no symbol is more associated with the physician than the stethoscope hanging his neck or protruding from the pocket. This simple ‘hearing aid’ permits a physician or nurse to listen to sounds made inside the body.

Audiometer

Generally employed transducers in audiometer are the following:

1. Earphone
2. Microphone
3. Bone-vibrator
4. Loud speakers

Earphones

Earphones are usually of the moving coil type and gives reasonably flat frequency response up to 6KHz after which their sensitivity decreases rapidly. They are specially designed for audiometric applications rather than for communication purposes.

Microphones

These are used to translate wave motion in space into electrical signal. Two types which are carbon button changes resistance with the pressure. The second one is the electrodynamic type in which the voltage is induced in a coil by its motion relative to a magnet. The third one is the condensor in which the capacitance of a condensor is varied by vibration of one of the condensor plates. High quality microphones of diameter 12.5, 6.25 and 3.15 mm are currently used depending on the frequency to be measured. For special purposes, microphones can be fitted to the earpiece used in reciprocal arrangment to transmit sound to the ear.

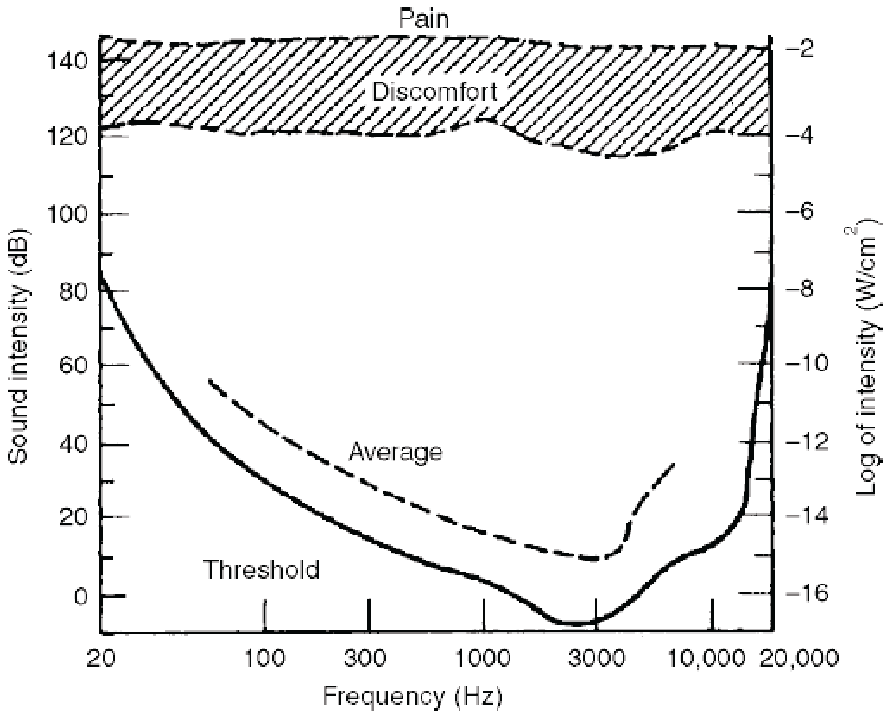

Figure 2. showing the sensitivity of the Ear.

Basic Audiometer

An Audiometer is a machine, which is used to determine the hearing loss in an individual, see Fig.3. The audiometer must be capable of making all measurements quickly, precisely, with no discomfort to the patient. Pure Tone Audiometer works on the principle of presenting specific pure tone signals to the subject and determining the intensity at which they can barely hear these signals. Coming from India, where more than seventy percent of the population is rural, and the doctors attending to these masses have to often travel large distances on their two wheelers, it warrants that the Audiometer be extremely portable and rugged.

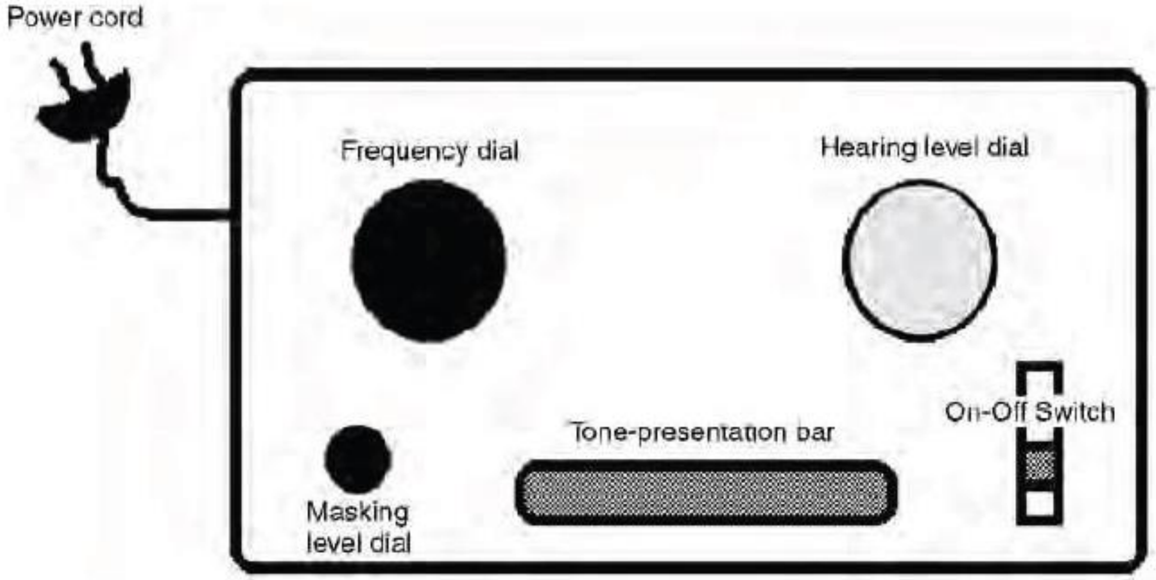

Figure 3. A simple Audiometer.

An audiometer will essentially have an oscillator along with a pair of head phones. Usually, this is calibrated in terms of frequency and acoustic output. Both frequency and output are adjustable over the entire audio range.

Pure tone audiometers and speech audiometers are two main groups of audiometers and are grouped according to the basis of the stimulus they provide to elicit audio response.

In conventional pure- tone audiometry, head phones are worn by the subject and a set of response is obtained. A bone conductor vibrator can then be attached to the head at the center forehead position to see whether the hearing threshold improves. If it is so, then the disorder is most likely wholly or partly conductive in origin. To avoid stimulation of the ear with the vibrator not tested, it can be temporarily made deaf by introducing a suitable masking noise in the non-test ear via an earphone. A narrow-band noise centered on the pure-tone test frequency or a wide band white noise is used for this purpose. The problem of how to recognize the need for masking and then the correct intensity is a source of considerable difficulty.

The intensity range of most audiometers starts from approximately 15 dB above normal to 95 below normal over a frequency range from approximately 500 to 4000 Hz, see Fig.4. The intensity range is somewhat less for frequencies less than 500 Hz and above 4000 Hz. This is partly because of certain instrumental limitations imposed by the earphone or vibrator and partly due to the desirability of avoiding the threshold of feeling from stimulation at the lower frequency levels. The threshold of feeling is the sensation of pain or tickle in the ear which results from the sound pressures and limits the maximal sound intensity level at which the threshold of feeling is stimulated and varies with the frequencies. For example, the threshold of feeling is stimulated at the intensity level approximately 120 dB above the normal threshold of audibility from about 500 to 4000 Hz, but at 64 Hz the threshold of feeling is stimulated at sound pressures approximately 65 dB above the normal threshold value.

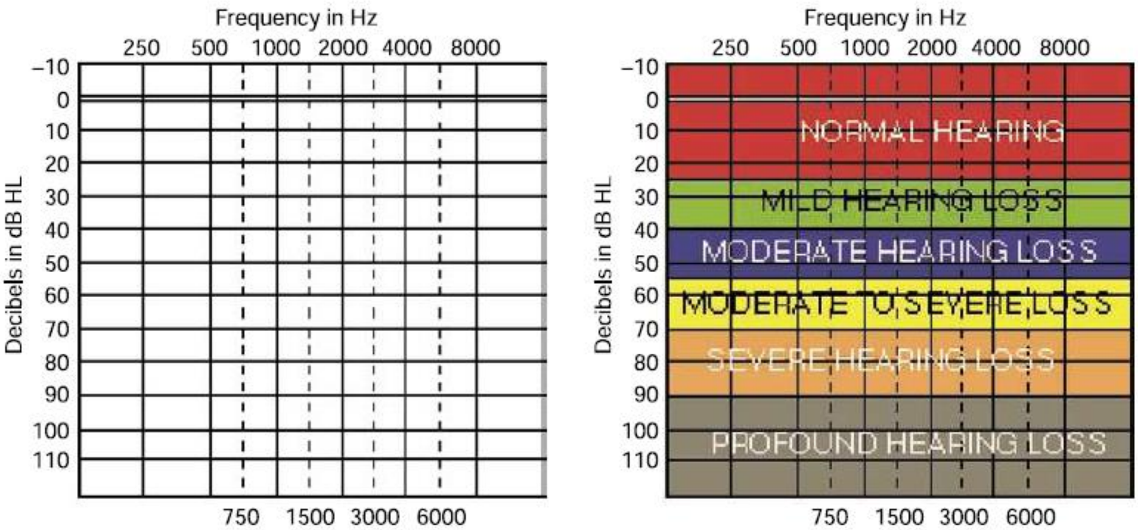

Figure 4. Showing the audiometer scale and thresholds of hearing levels.

The stimulation dials on the audiometer provide variable intensity or volume controls, see Fig.5. They are calibrated in decibels usually in discrete steps which differ by 5 dB in frequencies from step to step. Auditory acuity for each frequency is thus measured in dB above or below the normal hearing - zero dB reference level for that frequency. This level is the minimal intensity at which each given frequency can be perceived by the normal ear in a noise free environment and is experimentally determined by averaging the results of measurement on a larger number of normal individuals between 18 and 25 years of age.

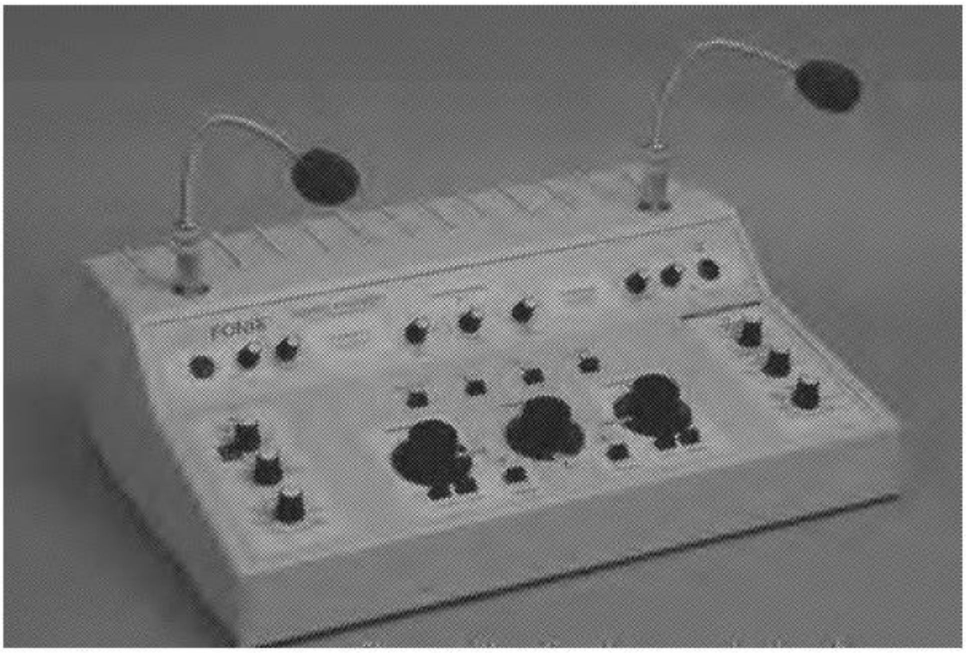

Figure 5. A typical Audiometer.

Audiometers usually have two channels, with a single pure tone generator. First channel has pure tone or speech output while the second channel has nominal masking. The pure tone and speech can be switched to both channels for special tests. Channel two can have either wide or narrow band masking. Each channel has an accurate independent attenuator output and the transducers are switched to each attenuator as required. The specifications for audiometers allow a tolerance of threshold in the other. Masking efficiency depends upon the nature of masking sound as well as intensity. A pure tone can be used to mask other pure tones (Egan and Hake, 1950), but over a range of test frequencies masking efficiency of a pure tone is low compared to a noise composed of many frequencies, as usually provided in commercial audiometers. A restricted frequency bandwidth of white noise is also often used. An excellent complex masking noise can be obtained by using the thermal or random electronic emission from a semiconductor diode. When the tone is just audible against noise background, the total acoustic power of the narrow band is the same as that of the pure tone. This restricted range of frequencies is defined as the critical band. If the difference in air conduction acuity between the two ears is 50 dB or more, it is advisable to place a masking noise over the better hearing ear while determining the threshold in the other.

Pure Tone Audiometers

Pure tone audiometers usually generate test tones in octave steps from 125 to 8000Hz, the signal intensity ranging from - 10 dB to + 100 dB. A pure tone is the simplest type of auditory stimulus. It can be specified accurately in terms of frequency and intensity. These parameters can be controlled with a high degree of precision. Speech audiometry normally allows measurements to be made within the frequency range of 300– 3000Hz. Some patients may have impaired high frequency response due to high intensity level occupational noise at 4000 or 6000 Hz. Pure tone measurements at these frequencies prove a more sensitive indicator of the effect of such noise on the ear than the speech tests. Changes in threshold sensitivity associated with various middle ear surgical procedures can be monitored more accurately with pure tone than speech tests. The attenuators used in these instruments are ladder type, of nominal 10 impedances. The signals are presented acoustically to the ear by an earphone or small loudspeaker.

Speech Audiometer

It is sometimes necessary to carry out tests with spoken voices. These tests are particularly important before prescribing hearing-aids. A double band tape recorder is preferred to interface the two channel audiometer units. Masking noise is supplied by the noise generator. The two channels supply the two head-phones or the two loud speakers of 25 W each. Calibration is effected in terms of the sensitivity relative to a stated threshold. Speech thresholds are not easy to define due to phonetic variations to different languages. Spondee threshold is defined as the level at which 50% of a spondee word list can be recognized and repeated by otologically normal subjects within the age group of 18 to 25 years. The frequency response characteristics of a live voice channel should be such that with the microphone in a free sound field having a constant sound pressure level, the sound pressure level developed by the earphone of the audiometer in the artificial ear at frequencies in the range 250 - 4000 Hz does not differ from that at 1000 Hz by more than +/-10 dB.