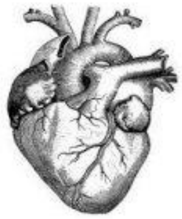
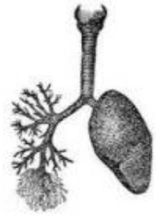
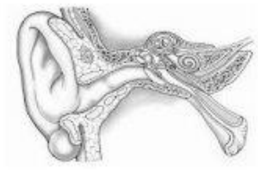
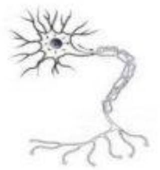
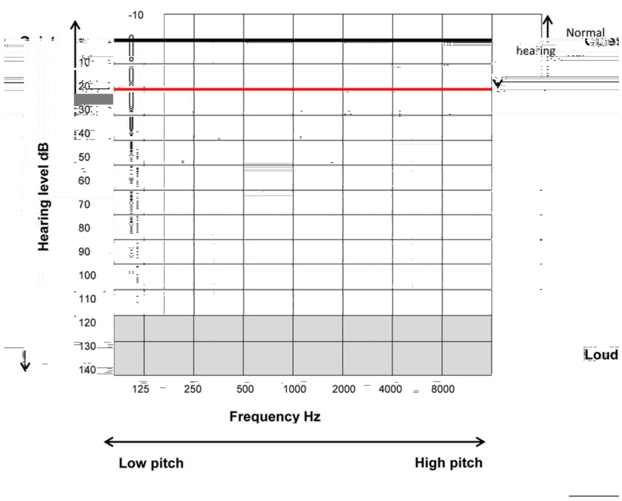
    

AUDIOMETRY SCREENING COURSE

BY

LEE BOSWELL



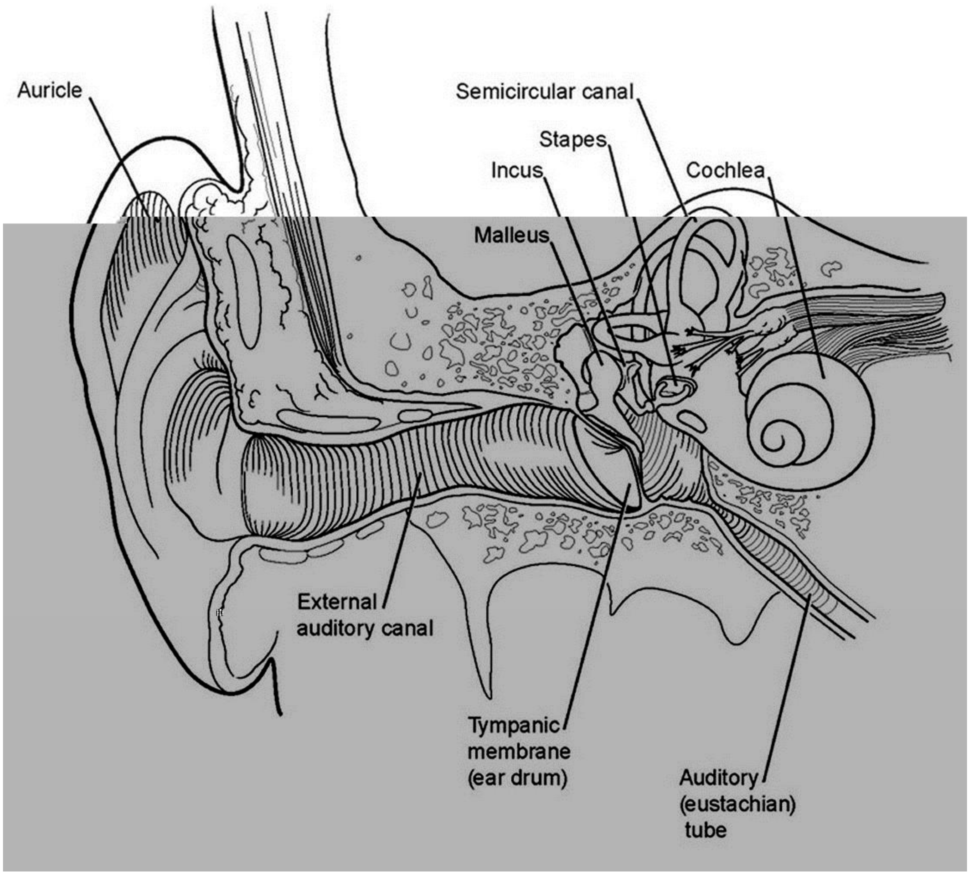
ANATOMY AND PHYSIOLOGY OF THE EAR

The anatomy of the ear is divided into three separate parts. The outer ear consists of the pinna, external auditory canal and the outer surface of the tympanic membrane. The middle ear, consisting of the middle ear cleft itself, the ossicles, the Eustachian tube and the inner layers of the tympanic membrane. The inner ear consists of the cochlea, utricle, saccule and the semicircular canals; behind is the VIIIth auditory nerve passing through the internal auditory meatus.

1. The Outer Ear

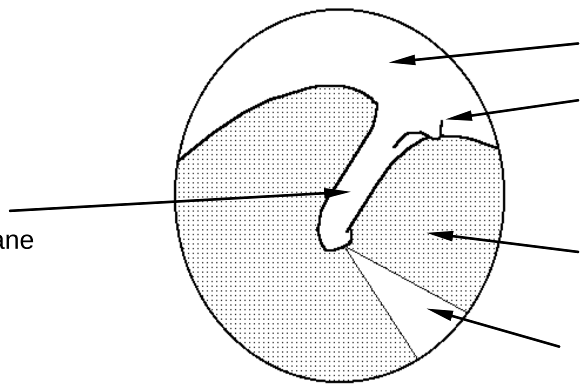
a. The pinna, or auricle, has little function, apart from a slight funnelling effect for sound waves. In animals, particularly dogs, this function is more noticeable they have muscular control of the pinna pointing them towards the sound source. The human ear consists of a cartilaginous framework, apart from the soft lobule, tightly covered with skin.

b. The external auditory canal is the only skin lined cul de sac in the body. It is about 3cm long in the adult and is slightly ‘S’ shaped. It is part cartilaginous, and part bony. The outer one third, cartilaginous, runs inwards, upward and backwards. The inner two thirds runs inward, downward and forwards. The skin is continuous with that of the pinna and covers the tympanic membrane, this skin ‘migrates’ slowly, about the same as the growth of a finger nail, from the centre of the tympanic membrane to the periphery and out along the meatal wall. Situated in the outer cartilaginous part are hairs, pilosebaceous and ceruminous glands whose combined secretions form wax, a sticky protective barrier preventing dirt entering the ear and keeping the skin of the drum and canal moist.



2. The Middle Ear

a. The tympanic membrane, eardrum, is about 1cm in diameter and consists of three different layers, an outer epithelial layer, a middle fibrous layer, absent in the area known as the pars flaccida and an inner mucosal layer. It lies obliquely across the meatus and appears as a shallow oval cone. Viewed from the outside it is a pearly white colour. Its principle function is to absorb airborne sound waves and to convert them into mechanical vibrations.

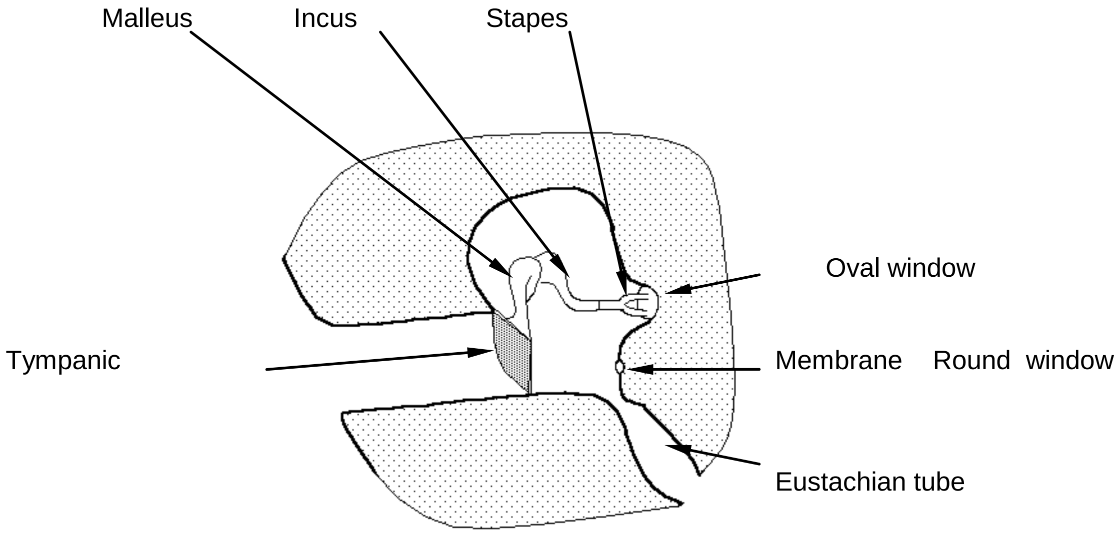


b. The middle ear cleft is the space in the temporal bone behind the drum. It is about $1^1/_2$ cm across and only 2mm wide at its narrowest part. The upper part is called the attic and communicates with the mastoid air cells via a small passage called the aditus ad antrum. The surface is lined with mucous membrane continuous with that of the mastoid air cells, the Eustachian tube and that of the nasopharynx and respiratory tract. The promontory is the bulge outward from the inner wall with the oval window of the cochlea above and behind it and the round window below and behind. The facial nerve runs through the middle ear just above the oval window.

c. The ossicles are three small bones that bridge the middle ear from the drum to the oval window in the cochlea. These are called the malleus (hammer), the incus (anvil) and the stapes (stirrup) and they are connected together by small joints. Parts of the malleus, the handle, lie in the fibrous layer of the tympanic membrane and can usually be seen through the drum. The smallest of the ossicles, the stapes, fits into the oval window by its footplate. Between the two is the incus. These three bones together form the ossicular chain whose function is to transmit the sound vibrations from the tympanic membrane to the cochlea. In doing this sound is, to a small extent, amplified by a slightly advantageous lever effect and by the hydraulic of transferring the sound from the relatively large area of the tympanic membrane to the smaller area of the oval window.

d. The tensor tympani and stapedius are two very small muscles in the middle ear. The tensor tympani is enervated by the Vth nerve (trigeminal) and is connected by its ligament to the neck of the malleus. The stapedius is enervated by the VIIth nerve (facial) and has its origin in the posterior wall of the cavity being connected to the neck of the stapes by its tendon. The function of these muscles is to apply tension to the ossicular chain and tympanic membrane in order to keep them in a compliant state. The stapedius also has another function that of a safety mechanism. When the ear is exposed to unusually loud sound it contracts stiffening the chain and increasing the impedance of the system and preventing harmfully large vibrations reaching the cochlea. The stapedius also contracts when we speak.

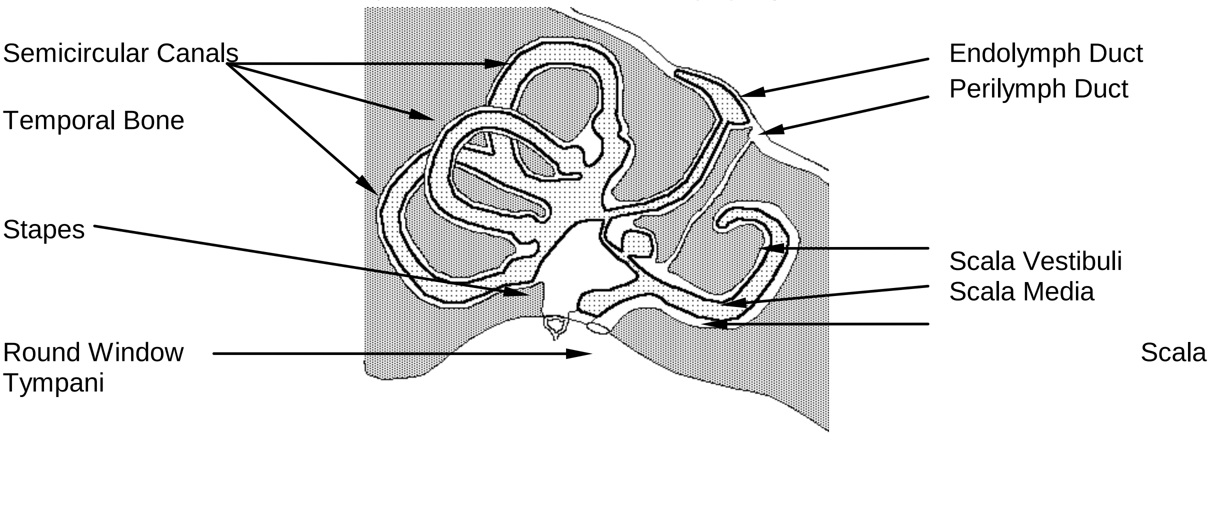
e. The Eustachian tube is about 3-4cm long connecting the nasopharynx with the middle ear. It has a bony upper one third and a cartilaginous lower two thirds. The tube is normally collapsed at rest and can be opened by yawning or swallowing to allow air to enter the middle ear. In doing this it serves as a ventilation shaft, its principle function being to maintain the air in the middle ear at the same pressure as the surrounding atmosphere. It also acts as a drain for the mucous secretions of the middle ear.



3. The Inner Ear

The inner ear or labyrinth, as it is sometimes called, is made up of two parts, the cochlea and the semicircular canals. This bony labyrinth is a series of channels in the petrous portion of the temporal bone. Inside these channels, surrounded by a fluid called perilymph is a soft membranous labyrinth filled with a fluid called endolymph.

a. The cochlea resembles a snail shell and is a coiled tube about 35mm long and $1^1/_2$ mm in diameter that makes $2^1/_2$ turns. Throughout its length the basilar and Reissner's membranes divide it into three chambers (or scalae). The upper scala vestibula and the lower scala tympani contain perilymph and communicate with each other at the apex through a small opening called the heliocotrema. At the base of the cochlea the scala vestibula is closed by the stapes footplate and the scala tympani is closed by the round window. The round window is a hole in the medial wall of the middle ear that is closed by the flexible secondary tympanic membrane.



b. The semicircular canals make up the other part of the inner ear and consist of three circular canals in the three different planes filled with endolymph. The semicircular canals are concerned with balance, motion and spatial awareness.

4. Sound Transmission

The function of the ear is to convert airborne sound waves into action potentials in the auditory nerves for onward transmission to the cortex. The tympanic membrane responds to the sound pressure waves by moving in and out, thus acting as a resonator reproducing the vibrations of the sound source. When the sound stops the drum almost stops immediately being very critically damped. The movement of the drum is transmitted to the malleus, which rocks on its axis and transmits the movement through its short process to the incus. Movement of the incus is transmitted to the head of the stapes in such a way that the stapes footplate moves to and fro, like a door, hinged at the posterior edge of the oval window. The ossicles thus act as a lever system, converting the resonant vibrations of the drum into movements of the stapes footplate against the perilymph fluid in the cochlea.

This system increases the sound pressure that arrives at the oval window in two ways. Firstly there is a slight leverage advantage, due to the arrangement of the ossicles that increases the force 1.3 times. Secondly the area of the tympanic membrane is much greater than that of the oval window. These combined effects produce a transformation ratio of 22:1.

In Summary:

a. Sound waves impinge on the drum causing it to vibrate.
b. Ossicles vibrate as a unit.
c. Stapes moves in and out of the oval window.
d. Sound waves are transmitted along scala vestibula in the perilymph.
e. Short waves (high frequencies) act at the base of the cochlea.
f. Long waves (low frequencies) act at the apex of the cochlea.
g. The wave is transmitted across scala media to scala tympani.
h. Waves travel along scala tympani.
i. Effect of wave on round window causes it to bulge outwards.
j. Wave motion distorts Reissner’s membrane and basilar membrane thus stimulating the organ of hearing (Organ of Corti)
k. Impulses from hair cells are then transmitted along the cochlea nerve.

PURE TONE AUDIOMETRY

1. Pure Tone Audiometry

In its simplest form the pure tone audiometer consists of:

a. An oscillator producing pure tones of a frequency that can be varied, usually from 125 - 8000 Hz in one half-octave steps.
b. An attenuator, which alters the intensity of the sound, delivered usually in 5dB steps.
c. A receiver that delivers the sounds to the ear.

Normally other controls will include, an interrupter, which is a noiseless switch that allows the sound to be presented, and a selector switch to deliver the sound in either the left earphone or right earphone. These are the basic controls of the simplest audiometer and are only adequate for screening purposes.

In the clinical situation added refinements are essential if a more sophisticated testing is to be undertaken. One of these includes masking or broad-spectrum noise that can be delivered to the ear not under test in order to prevent it from receiving loud signals intended for the test ear. Usually masking is available as wide band where the sound consists of all frequencies and is always used in speech audiometry, or narrow band where the noise frequencies are filtered to include only those frequencies around the test frequency. This latter type of masking is usually used in pure tone testing where the frequency of the noise automatically alters with the frequency of the test signal. A masking attenuator similar to a pure tone attenuator and graduated in the same way governs the masking output.

A Bone conductor is essential if cochlea function is to be assessed. This consists of a vibrator on a headband that can be placed on the mastoid bone. Pure tones are directed through it the same as through the earphone and normally the same attenuator is used. Masking for bone conduction is usually through an insert earphone and again narrow band noise is used.

2. Pure Tone Testing

The purpose of pure tone testing is to determine the quietest possible sound that the patient can hear at a variety of frequencies. With this in mind the test technique merely achieves this end in the quickest and most accurate way. Most patients tested can be done so in a set pattern and valid results will be obtained, however no two individuals are alike or will respond in the same way to a method of testing, this particularly applies to children, elderly patients and malingerers. For this reason the test technique below is purely as a guide that can be adapted to suit a particular situation.

a. Method: Instruct the patient as to what is required of him. Explain that he will hear a series of sounds, each and every time that he hears the sound he is to signal that he has heard it. Sometimes the sounds will be loud and sometimes very faint but every time he hears the sound he is to indicate. One ear will be tested at a time, the better ear first. With children the above method may have to be repeated more than once, it is no use beginning the test until the subject knows what is expected. Fit the headphones over the ears ensuring that the pinna is closed completely with the red earphone over the right ear. If the subject wears spectacles remove them.

b. Technique: The tones are first presented at an intensity that the patient can hear well in order to give a little practice in the technique. The intensity is then reduced in 10dB steps until the subject ceases to signal that he can hear the sound. We can assume at this stage that the hearing threshold has been passed. The sound intensity is then increased in 5dB steps until the subject again signals that he has heard it. Again the sound is decreased in 10dB steps and increased in 5dB steps. This procedure is repeated until the subject consistently responds to one intensity and nothing at a lower intensity. This value can then be recorded as the hearing threshold for that one particular frequency. The next frequency is then tested in the same way, although it is not now necessary to give too loud a starting signal, as the subject should now be aware of what is happening. If the subject fails to hear this starting frequency increase the intensity by 20dB.

c. Protocol: Normally testing starts at 1000Hz and progresses to the highest frequency then drops to 500Hz and progress down to the lowest frequency. The better ear is always tested first, if neither is better as a matter of course the right ear is tested first. Tone presentation should never be at regular intervals, even the most honest subject finds it difficult to resist the temptation to signal when he thinks a tone is due if the tester has been presenting the tones at regular intervals.

As pointed out earlier the individual patient will dictate the method of testing, for instance a very young child will rapidly get bored listening to hundreds of sounds. It is far better to get reliable results of three frequencies on each ear than a complete audiogram that is hopelessly inaccurate at all frequencies. So a better method would be to test one ear at 1000Hz then change ears, then test 3000Hz in both ears and so on. Elderly patients are usually tested easily when a slower sequence of presentations is used. Their responses are not as quick as younger patients and rapid tone presentations should be avoided. They usually like to be quite sure that they have heard the tone before signalling so it may be necessary to repeat the tone a couple of times at the same intensity.

Psychogenic hearing losses (non-organic or hysterical) can sometimes be very difficult to detect but usually the tester should get some idea that all is not as it should be in the normal routine test. Again as in testing children it is no use recording threshold levels that are untrue without making some comment on the bottom of the audiogram. Some of the signs that all is not well include inconsistent responses or responding to the initial tone and using this as their threshold and not responding to any lower intensity. Certain types of patient seem to be prone to psychogenic losses particularly adolescent girls, unhappy servicemen (usually junior ranks) and service personnel due to leave the Forces. Another group is children but particularly those who have been subjected to a lot of audiometric testing and seem to thrive on the extra attention that a hearing loss brings. Often there is no apparent reason for psychogenic loss. Sometimes the patient will produce illogical responses because he does not know what is expected of him.

H GRADING FOR PULHEEMS

Grading	Sum of Frequencies; 500, 1000 & 2000Hz	Sum of Frequencies; 3000, 4000 & 6000
H1	≤ 45	≤ 45
H2	≤ 84	≤ 123
H3	≤ 150	≤ 210
H4	> 150	> 210

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