Lectures on Medical Biophysics

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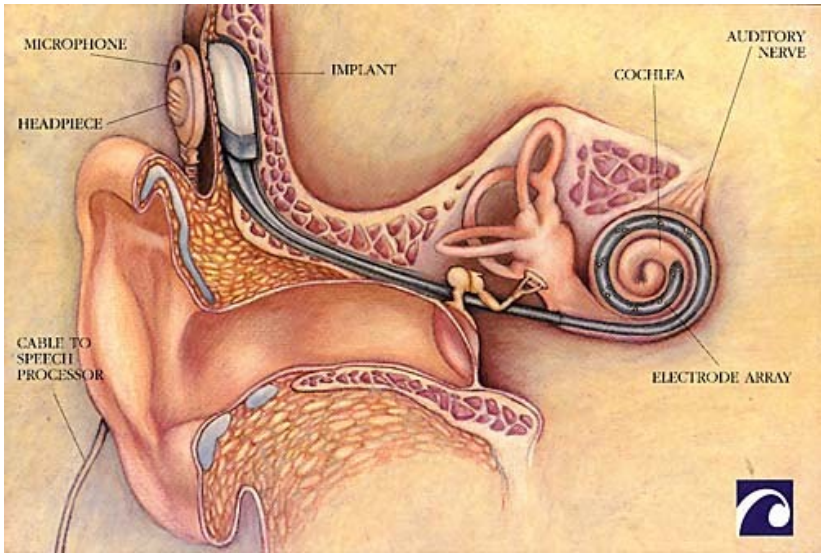


Sensory perception examination and aids

Lecture outline

- Visual acuity
- Ametropia - errors of the optical system of the eye
  - Spherical ametropia: Nearsightedness and farsightedness
  - Aspherical ametropia (astigmatism)
- Examination of vision
- Electroretinography (ERG)
- Retinal implant
- Audiometry – assessment of hearing impairment
- Hearing aids for correction of hearing impairment
- Cochlear implants

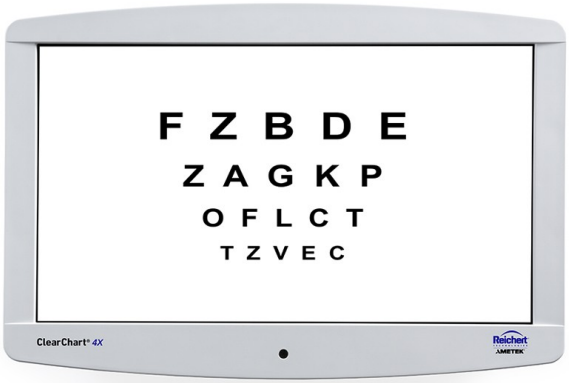
Visual acuity

Definition: clarity and sharpness of vision (Latin “acuitas” = sharpness)

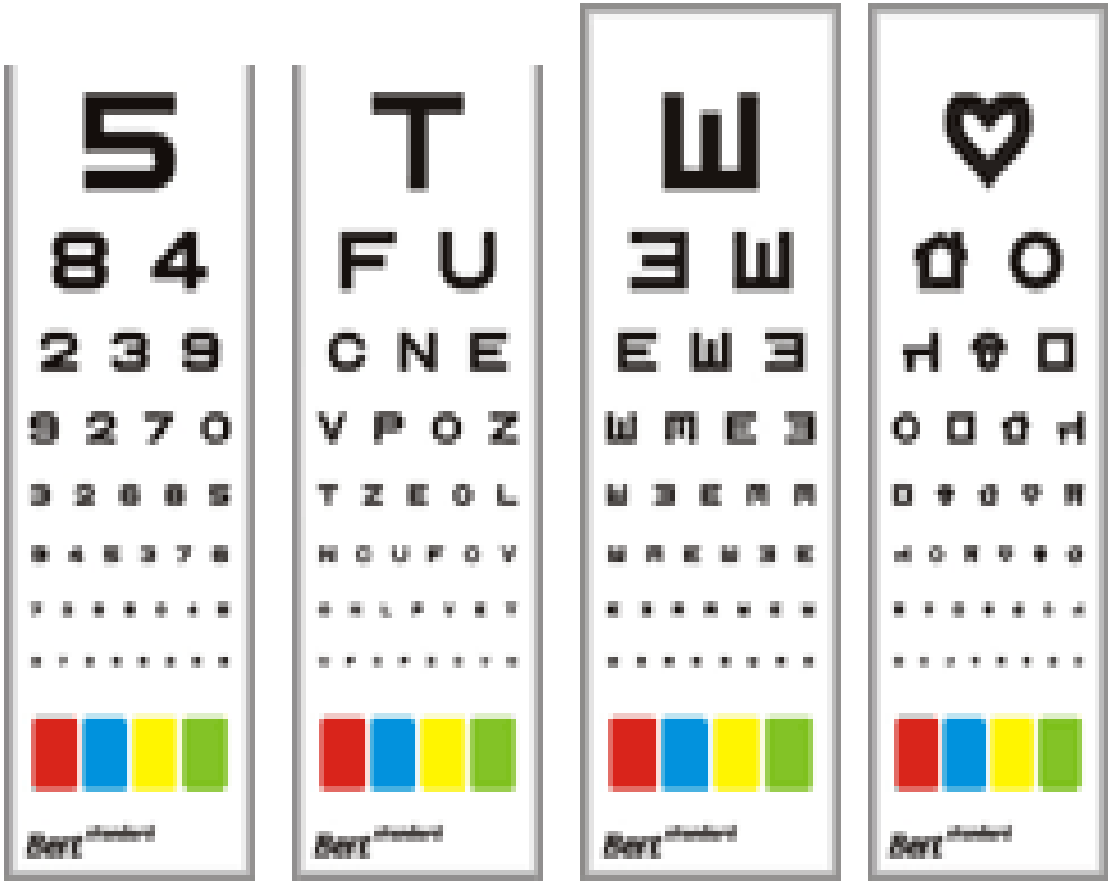
Often referred to as “Snellen” acuity. The **Snellen charts** used in its assessment are named after a 19th-century Dutch ophthalmologist Hermann Snellen (1834–1908) who created them as a test of visual acuity in case of myopia.

The optotypes are made for a viewing distance of 4, 5 and 6 m. Visual acuity is expressed by means of a fraction where the numerator is the viewing distance in m and the denominator the number of the row of correctly distinguishable symbols (e.g. acuity of 6/18 indicates visual acuity reduced to a third).

Someone with **6/6 vision** is just able to distinguish a symbol that subtends a visual angle of *5 minutes of arc* (written *5′*) at the eye.

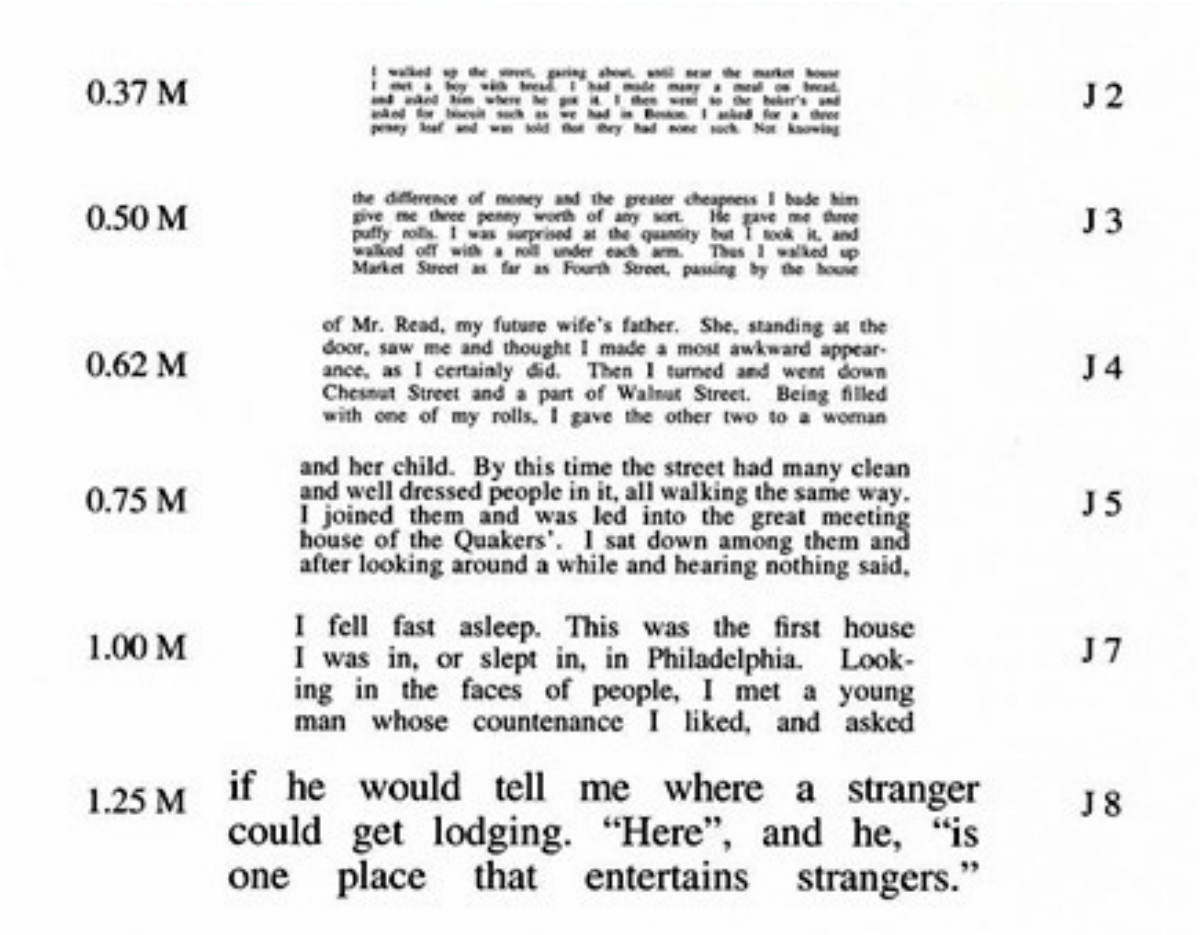


Snellen charts



https://is.muni.cz/do/rect/el/estud/lf/js16/refrakcni_vady/web/pages/03-naturalni-zrakova-ostrost.html

Jaeger test card for examination of hyperopia



0.37 M	I walked up the street, gazing about, until near the market house I met a boy with bread. I had made many a meal on bread, and asked him where he got it. I then went to the baker's and asked for biscuit such as we had in Boston. I asked for a three penny loaf and was told that they had none such. Not knowing	J 2
0.50 M	the difference of money and the greater cheapness I bade him give me three penny worth of any sort. He gave me three puffy rolls. I was surprised at the quantity but I took it, and walked off with a roll under each arm. Thus I walked up Market Street as far as Fourth Street, passing by the house	J 3
0.62 M	of Mr. Read, my future wife's father. She, standing at the door, saw me and thought I made a most awkward appearance, as I certainly did. Then I turned and went down Chesnut Street and a part of Walnut Street. Being filled with one of my rolls, I gave the other two to a woman	J 4
0.75 M	and her child. By this time the street had many clean and well dressed people in it, all walking the same way. I joined them and was led into the great meeting house of the Quakers'. I sat down among them and after looking around a while and hearing nothing said,	J 5
1.00 M	I fell fast asleep. This was the first house I was in, or slept in, in Philadelphia. Looking in the faces of people, I met a young man whose countenance I liked, and asked	J 7
1.25 M	if he would tell me where a stranger could get lodging. "Here", and he, "is one place that entertains strangers."	J 8

Ametropia - errors of eye optical system

Emmetropia: the normal (“emmetropic”) eye images in points and images are focused (projected) on the retina.

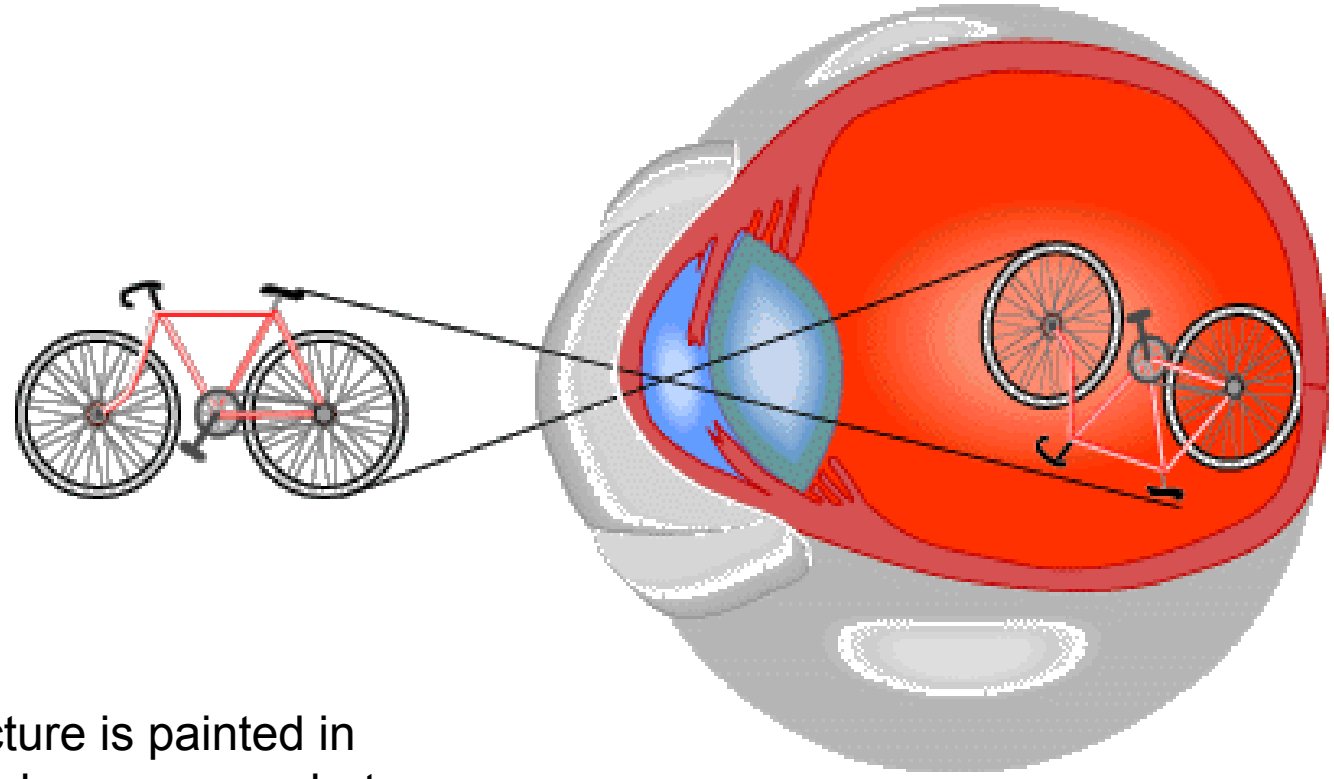
Ametropia: If the image focus is not situated on the retina or the eye does not image in points (the eye is “ametropic”).

we can distinguish two main ametropias:

- spherical (nearsightedness and farsightedness)
- aspherical (astigmatism)

Normal eye

Normally, our eye can project an image exactly on the retina:



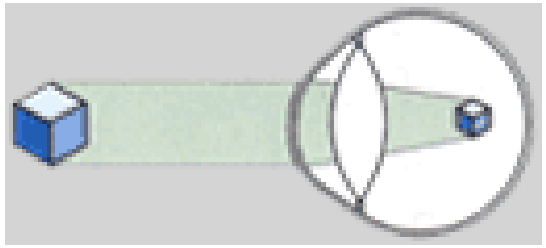
(this picture is painted in absolutely wrong way but otherwise it is nice)

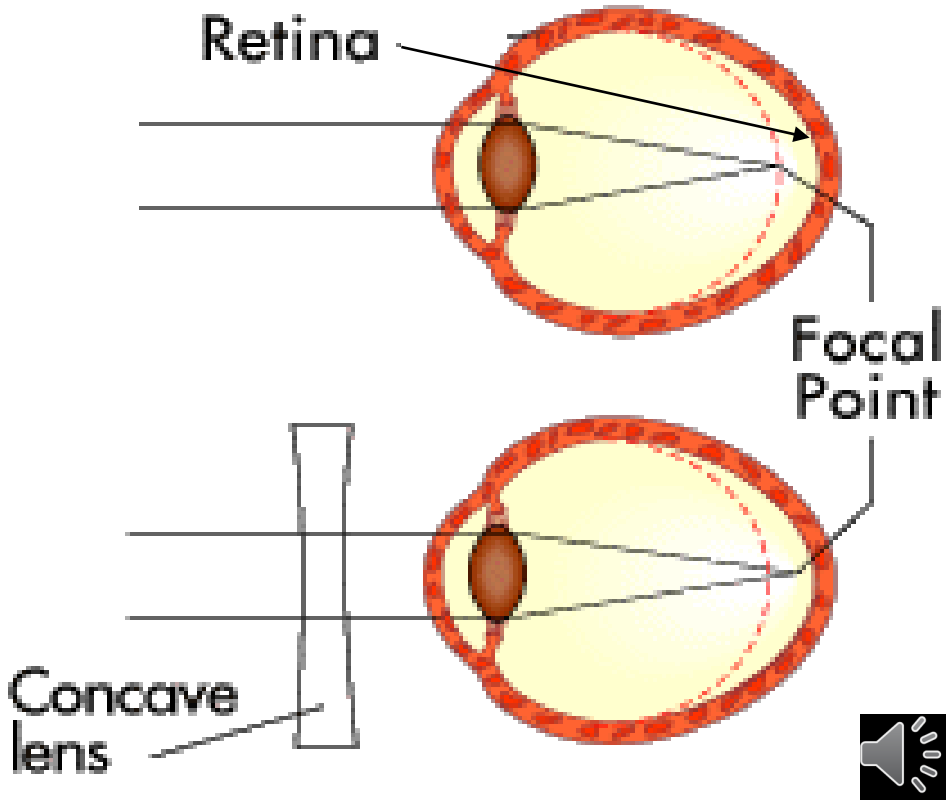
Spherical ametropia: Nearsightedness and farsightedness

Nearsightedness (myopia): see near objects well, and difficulty seeing faraway. Light rays coming from far distance are focused in front of the retina. This is caused by an eyeball that is too long, or a lens system that has too high dioptric power. Corrected with a **concave (diverging)** lens**.** This lens causes the light to diverge slightly before it reaches the eye.

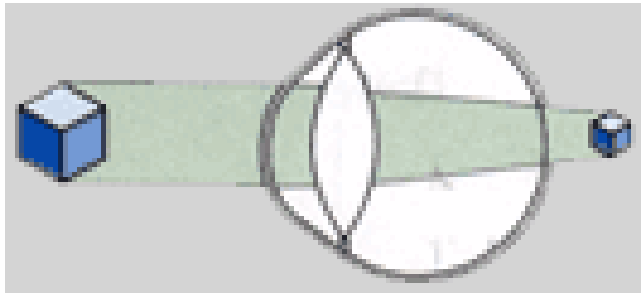
When **farsightedness (hyperopia):** see distant objects well but not near objects. Light rays are focused behind the retina. This is caused by an eyeball that is too short, or by a lens system that has too little dioptric power. Corrected with a **convex (converging)** lens.

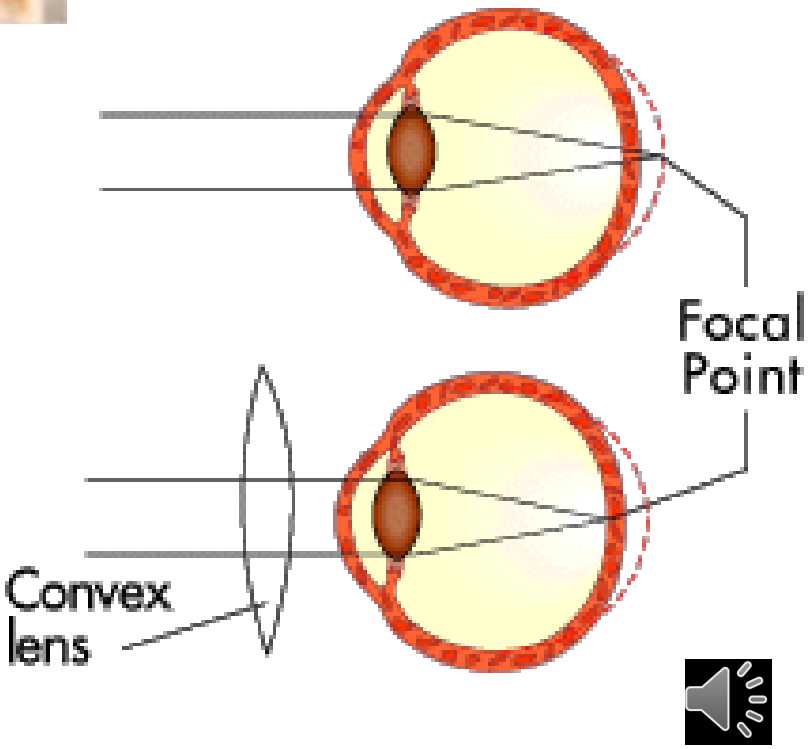
Nearsightedness (myopia)





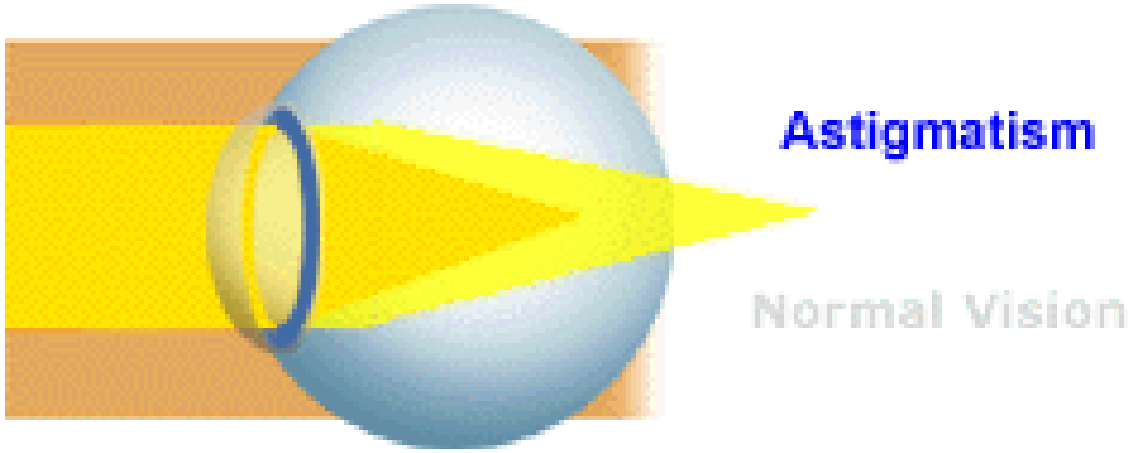
Farsightedness (hyperopia)



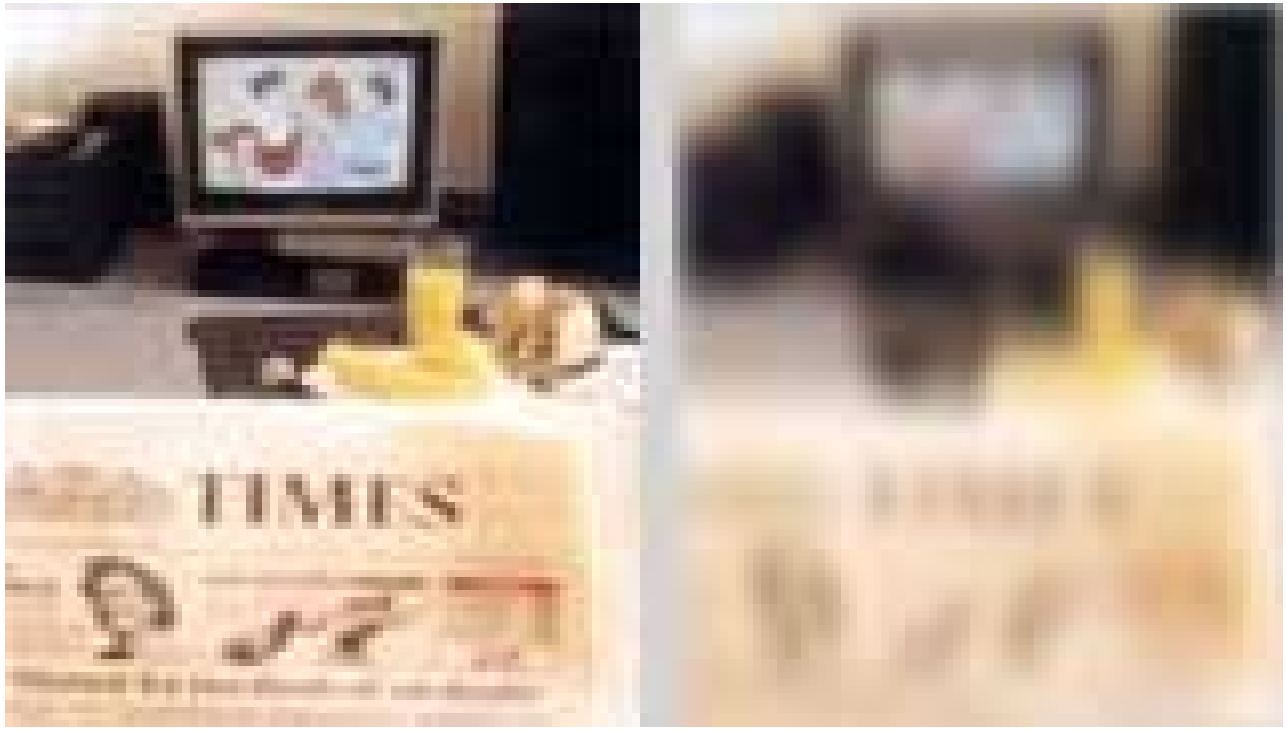


Aspherical ametropia (astigmatism)

Astigmatism occurs when the cornea or the lens, have a different curvature in different planes. This irregular shape prevents light from focusing properly on the retina. As a result, vision may be blurred at all distances.



Astigmatism

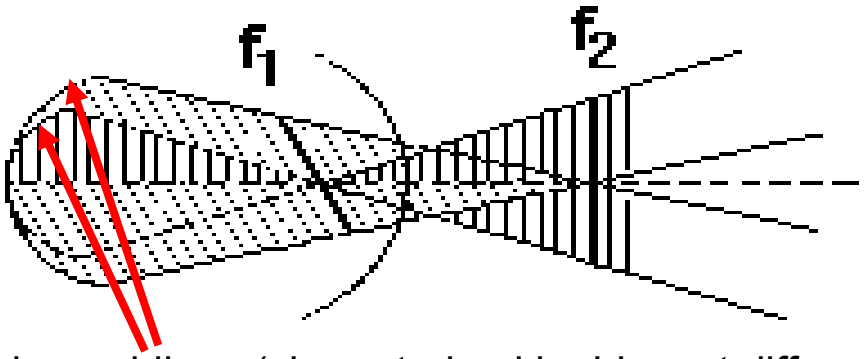


Astigmatism

Simple astigmatism: One of the focal lines does not lie on retina

Mixed astigmatism: Both focal lines are not on the retina – one in front, one behind.

Compound astigmatism: means the eye has characteristics of both astigmatism and nearsightedness / farsightedness. Both focal lines are in front or behind the retina.



Main meridians (characterised by biggest difference in curvature) of the eye can be seen – case of mixed astigmatism.

How to correct astigmatism

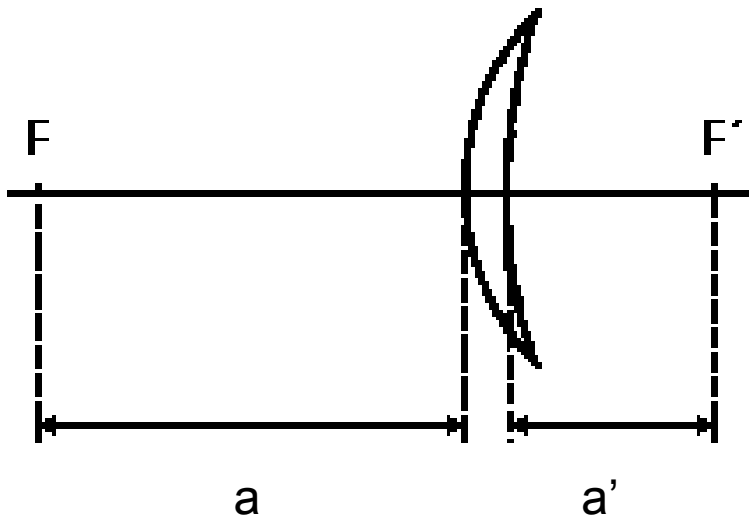
Simple astigmatism is corrected by a **cylindrical lens**, or *refractive surgery*.

Compound and mixed astigmatism are corrected by **toric lenses** (a toric refraction surface originates by a combination of cylindrical and spherical surfaces, i.e. has different radii of curvature in different planes).

Eyeglass lenses - back vertex power

- As opposed to other optical systems which are characterized by power, eyeglass lenses are characterised by their ‘back vertex’ power

  $A' = 1 / a'$



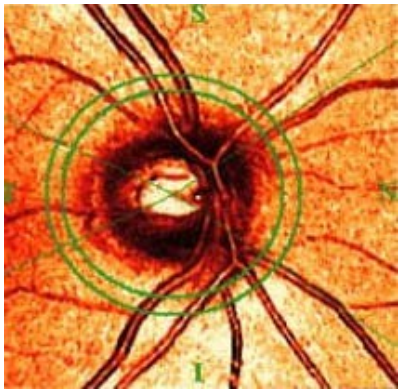
Contact lens

Contact lens made of hydrophilic gel (weak – Otto Wichterle invention) or hard contact lenses (RGP – Rigid Gas-Permeable)

Refractometer – objective examination of vision

Further devices for examination of vision

Perimetry the investigative method to assess the extent of visual field. Its essence is the ability of the eye to distinguish two stimuli in the field of vision. One stimulus is a light mark and the second the background surrounding the light mark. It is performed at the suspected loss of visual field, called scotoma.



The analyzer of nerve fibres layer - GDX (Glaucoma Diagnostics). Thickness of the layer of nerve fibres of the retina is measured using a laser scanning polarimetry. This technique uses birefringence of nerve fibres. Phase shift between ordinary and extraordinary beam after passing through a layer of retinal nerve fibre will be used to measure the thickness of peripapilar area. The device is equipped with a scanning unit with a light-emitting diode (wavelength 780 nm), which is associated with the computer transferring the degree of polarization in each image point to the thickness of nerve fibres using Fourier analysis.

Electroretinography (ERG)

Electroretinography

is a test to measure the electrical response of the eye's light-sensitive cells (rods and cones). Electrodes are placed on the cornea and the skin near the eye (monitored by unipolar leads), 100 – 400 μV.

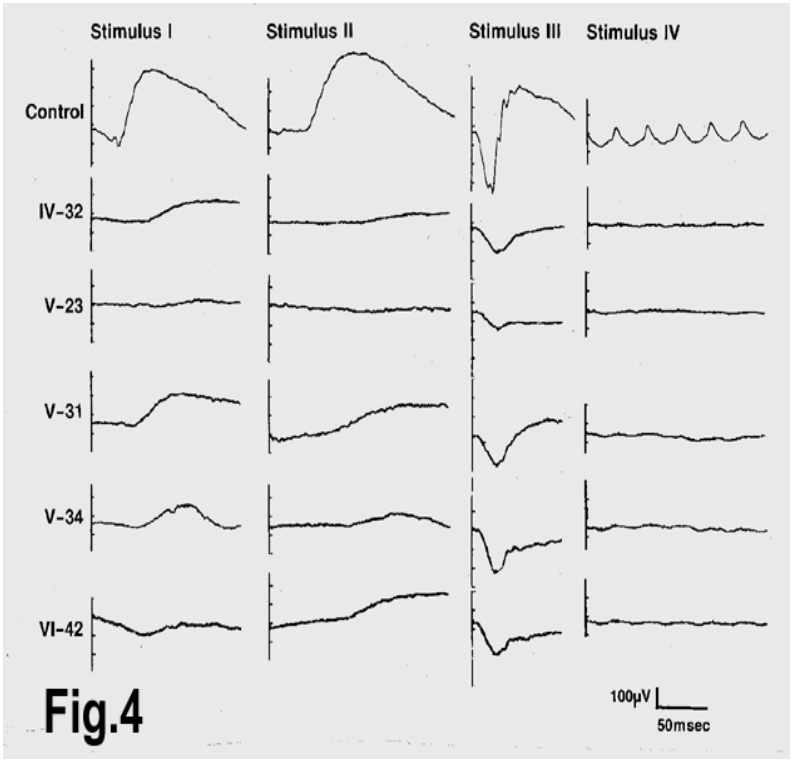
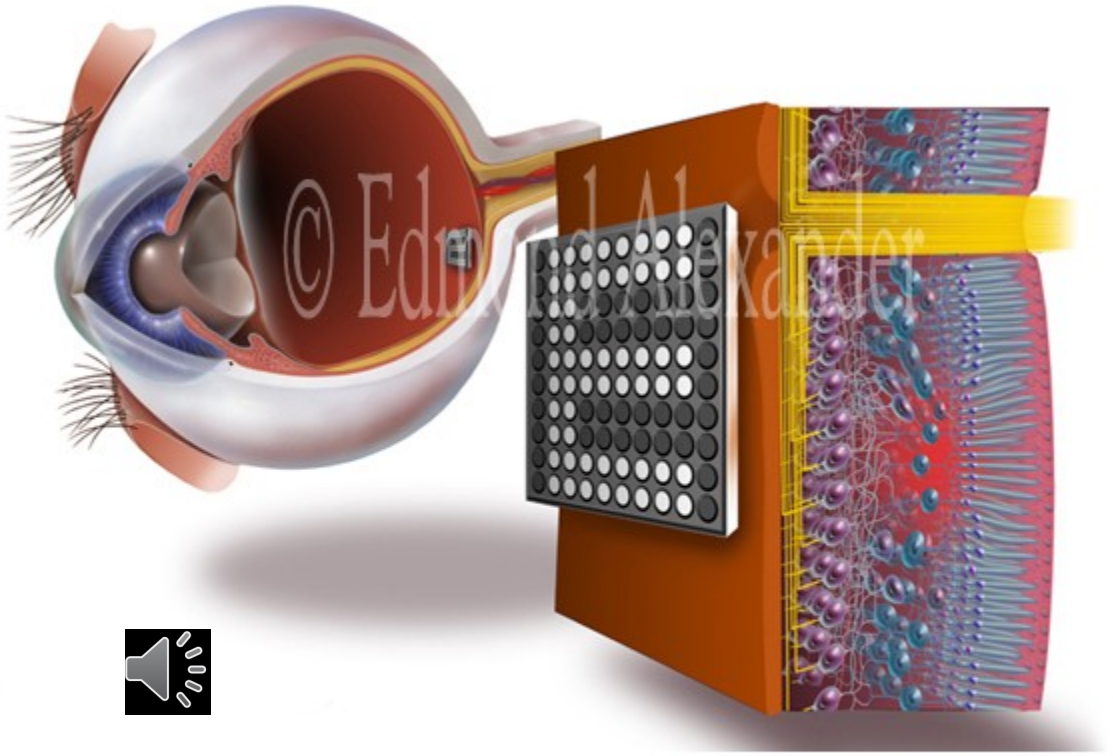
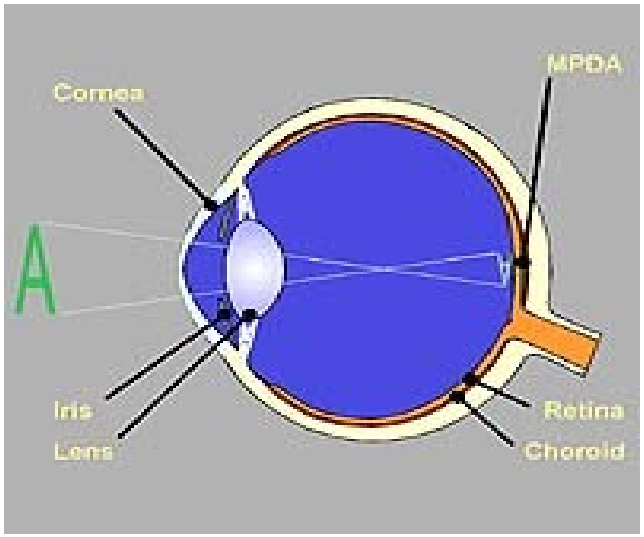


Fig.4

Retinal implant

www.nmi.de/deutsch/
showprj.php3?id=3&typ=1



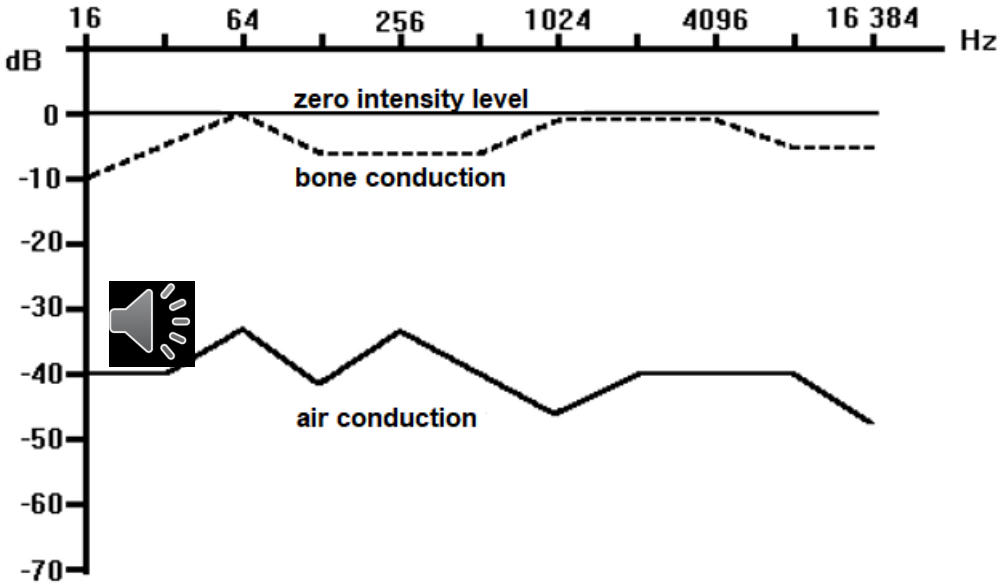


MPDA – micro-photo-diode-array

This device is in clinical testing. It should enable basic spatial orientation of blind people.

Audiometry - hearing disorder examination

- **Audiometry** - see practical exercises. In practice, we obtain a **graph of loudness differences versus frequency** in comparison with normal hearing.
- **Bone conduction** is examined by tuning forks or **special oscillators** laid on *proc. mastoideus*.



finding: bone conduction normal, air conduction impaired

Two types of hearing disorders

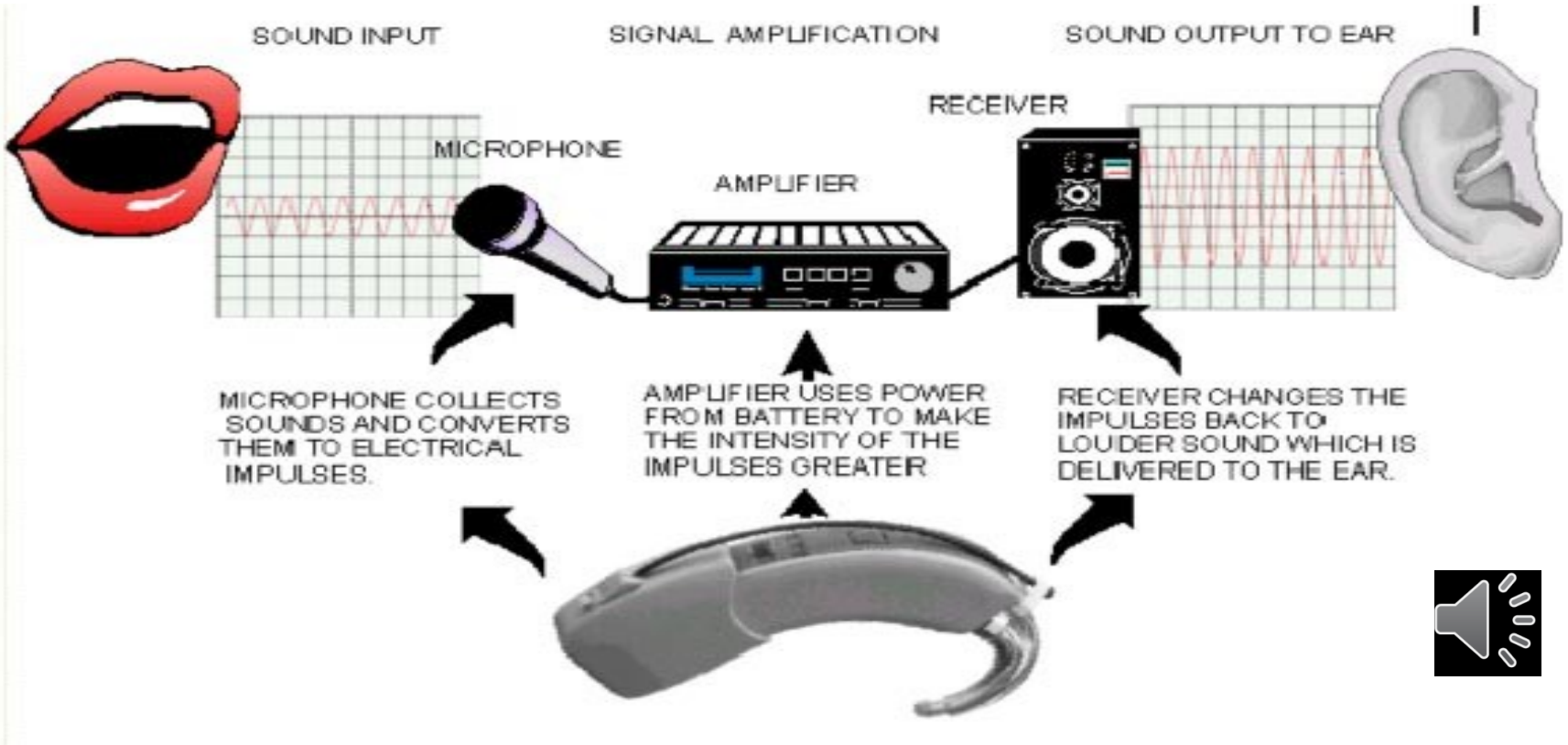
- **1) Sound conduction disorder -** caused by cerumen (ear wax), Exudate or mucus in meatus, rigid drum, lowering of ossicular motility after inflammation. No full hearing loss is caused in this case - sound partly penetrates through bones into inner ear. The audiogram for air conduction is lowered in the whole range of audible frequencies, however the bone conduction is not damaged.

- **2) Perception or nerve conduction disorder.** Initially often limited to frequencies around 4000 Hz. It can be caused by long action of strong noise. Patient sound perception is distorted. Audiogram shows lowering of perception at these frequencies, bone conduction lowers as well. It increases with age.

Hearing aid - correction of hearing disorders

Hearing aid: Consists of a microphone, amplifier, energy supply and a reproduction system (loudspeaker). It is an earphone with the end-piece inserted into meatus. For bone conduction, it is better to use a **vibrator** fixed to *proc. mastoideus*.

Purpose of hearing aids: amplification of frequencies at which hearing is lowered. Filtration. Hearing aids can be mounted into side-pieces of glasses.

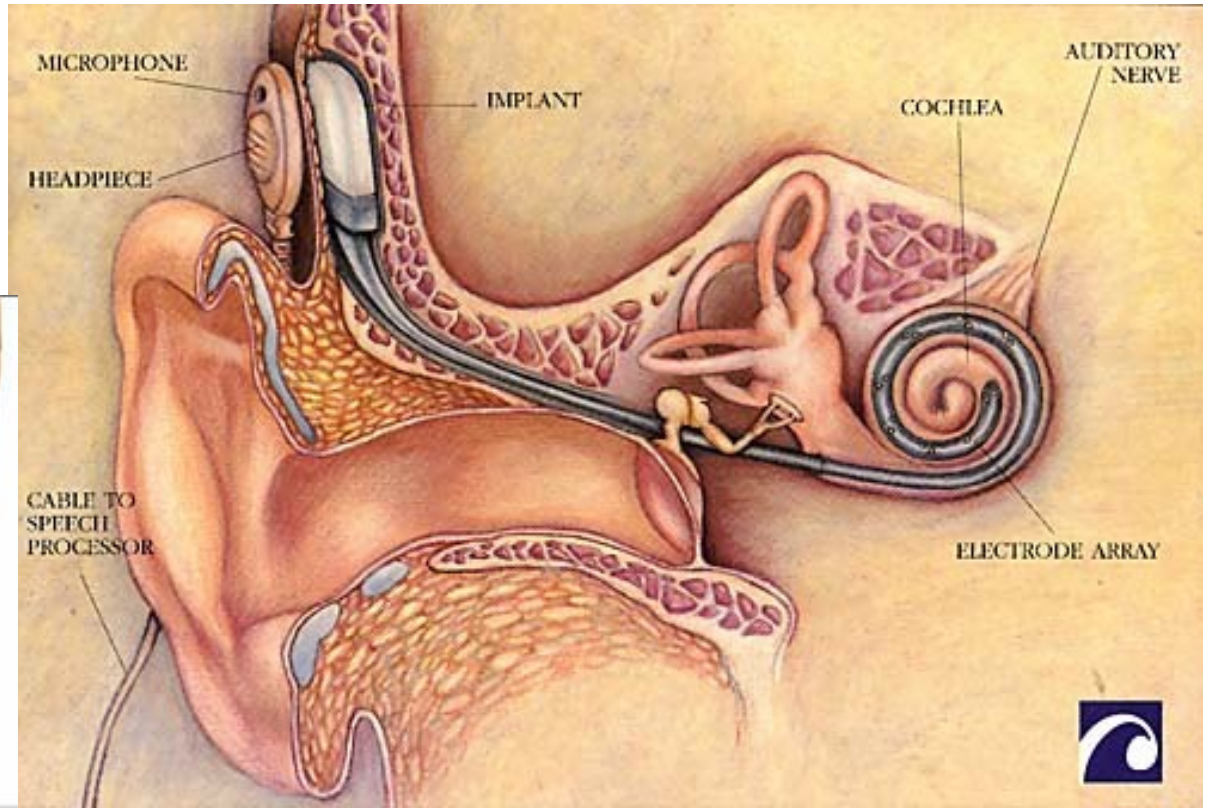


Other methods in audiology

- **Otoacoustic emission** – see the lecture on hearing
- Measurement of **evoked potentials** – objective testing of information transfer between the inner ear and brain 
- **Tympanometry** – testing of acoustic energy transfer into middle ear be means of a reflected 226 Hz tone. In principle, elasticity of the eardrum and ossicle system is tested.

Cochlear implant

•http://www.accessexcellence.org/AB/BA/biochip3.html



- This up to date method utilises the electronic cochlear implants, which can partly replace the Corti's organ, mainly in children which have functioning auditory nerve. It is an electrode system implanted into cochlea, which can stimulate the nerve, by impulses generated by a so-called speech-processor.

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