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Among the more complex and fascinating examples of biomechanical engineering in the body is featured in the human ear. These intricate sensory organs capture and transmit sound waves and maintain our sense of equilibrium and balance. Unfortunately, many things can go wrong with such finely tuned apparatus. To develop a better understanding of the problems related to hearing loss, dizziness, poor balance, and tinnitus, some basic knowledge of the inner workings of the ear should be applied.

The ear is made up of three distinct parts: The **outer** (external) ear, the **middle** ear, and the **inner** ear or *labyrinth.* (fig 1)

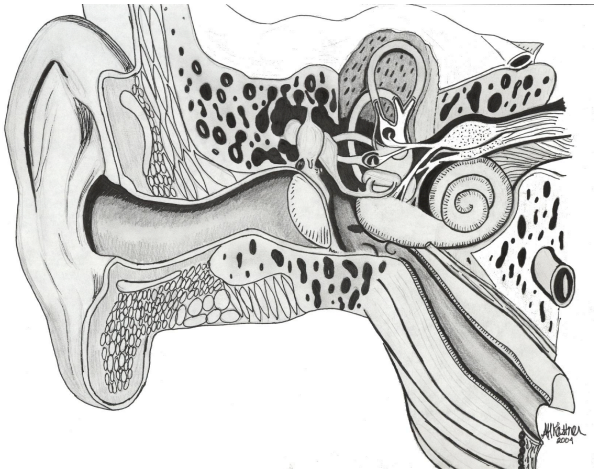

figure 1. The Human ear

Sound waves enter the auricle (the part you can tug on) and are funneled down the ear canal to vibrate the eardrum (tympanic membrane). From here, the three middle ear bones (ossicles) vibrate and pass the sound waves to the inner fluids of the **cochlea**. Up to this point, all of the sound energy is vibratory and is in the form of mechanical energy. Any problem along this part of the pathway, for example, a perforated ear drum, fluid inside the middle ear, or fixation of the ear bones, will reduce transmission of those sound waves and result in what is termed a **Conductive Hearing Loss**.

The cochlea consists of a hollow, sea-shell-like structure with approximately 2 3/4 turns tonographically arranged with low tones located at the point (apex) and high tones at the base. When the fluid inside the cochlea is vibrated, a miracle takes place. The mechanical vibratory energy is converted into nerve impulses (electrical energy) that then travel up to your brain where the sounds are perceived and understood (hopefully). The part of the cochlea that converts vibrations into electricity is the Organ of Corti. (fig 2)

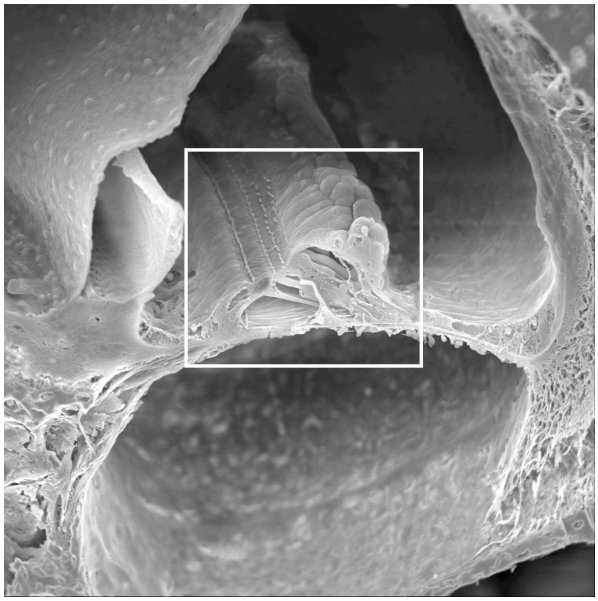

figure 2. Electron microscope (60,000 x) of the Organ of Corti (boxed)

which is comprised of millions of **Hair cells**. (fig 3)

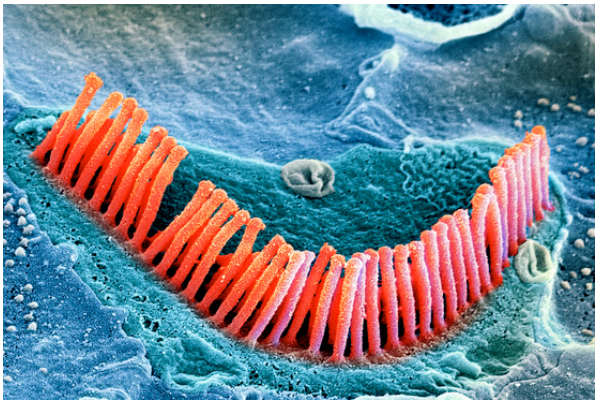

figure 3. Hair cells.

These cells are not made of hair, rather, when viewed under a microscope, they have a “hairy” appearance due to their many cilia. Any problem in this part of the pathway will result in a **Neurosensory Hearing loss**. For example, the hair cells can be damaged by excessive loud noise, toxic drugs, infections, and the effects of growing older. The **acoustic nerve** that connects the cochlea to the brain can also be damaged by a rare tumor (Acoustic Neuroma) or by reduced blood flow (mini-stroke). If the *inner* ear fluid (endolymph) becomes imbalanced, hearing loss, tinnitus, and dizziness can result in a syndrome called **Meniere’s Disease**.

Lastly, any condition that results in a loss of hearing can cause tinnitus, or abnormal sounds in the ears or head. This is usually described as high pitched ringing but it can take on other forms. The exact mechanism for tinnitus is still poorly understood.

Remember, the inner ear is comprised of two parts- the Cochlea for hearing and the **Vestibular** portion for balance and equilibrium.

When the Vestibular apparatus malfunctions, our worlds can be turned upside-down, literally! It turns out that the vestibule also contains hair cells. These hair cells have tiny cilia (hairs) that bend from side to side when the fluid that surrounds them moves. Every time we turn our heads or bend over, the fluid inside the vestibule and semi-circular canals (fig 4) moves opposite to the direction of head movement. The hair cells sense the fluid motion and convert the mechanical energy to electrical (nerve) impulses that transmit to the brain. This way, the brain can instruct the rest of the body (the eyes, neck muscles, trunk and legs) to take corrective action to maintain balance and avoid falling.

figure 4. Crystals within the Semicircular canal.

Dizziness results when the signals from the vestibule to the brain are abnormal or

not symmetrical. A common form of dizziness is termed Benign Paroxysmal Positional Vertigo (**BPPV**). This occurs when tiny salt crystals (fig 4) break loose and start floating around the inner ear whenever the patient lies back or turns their head. These crystals disturb the fluid inside the inner ear and send abnormal signals to the brain- the result is dizziness or vertigo. Viruses can also attack the inner ear and alter the signals transmitted to the brain (labyrinthitis/ vestibular neuritis) and cause dizziness.

Lastly, what's the difference between the terms "vertigo" and "dizziness"? **Vertigo** is a particular kind of dizziness which has a spinning component, usually caused by inner ear problems. Dizziness is less specific and has many causes.

As with most things in nature, form and function are joined. The design of our hearing and balance apparatus represents a supreme evolutionary achievement, but is not without its potential shortcomings or susceptibility to injury.

About the author:

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