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Can You Hear Me Now?

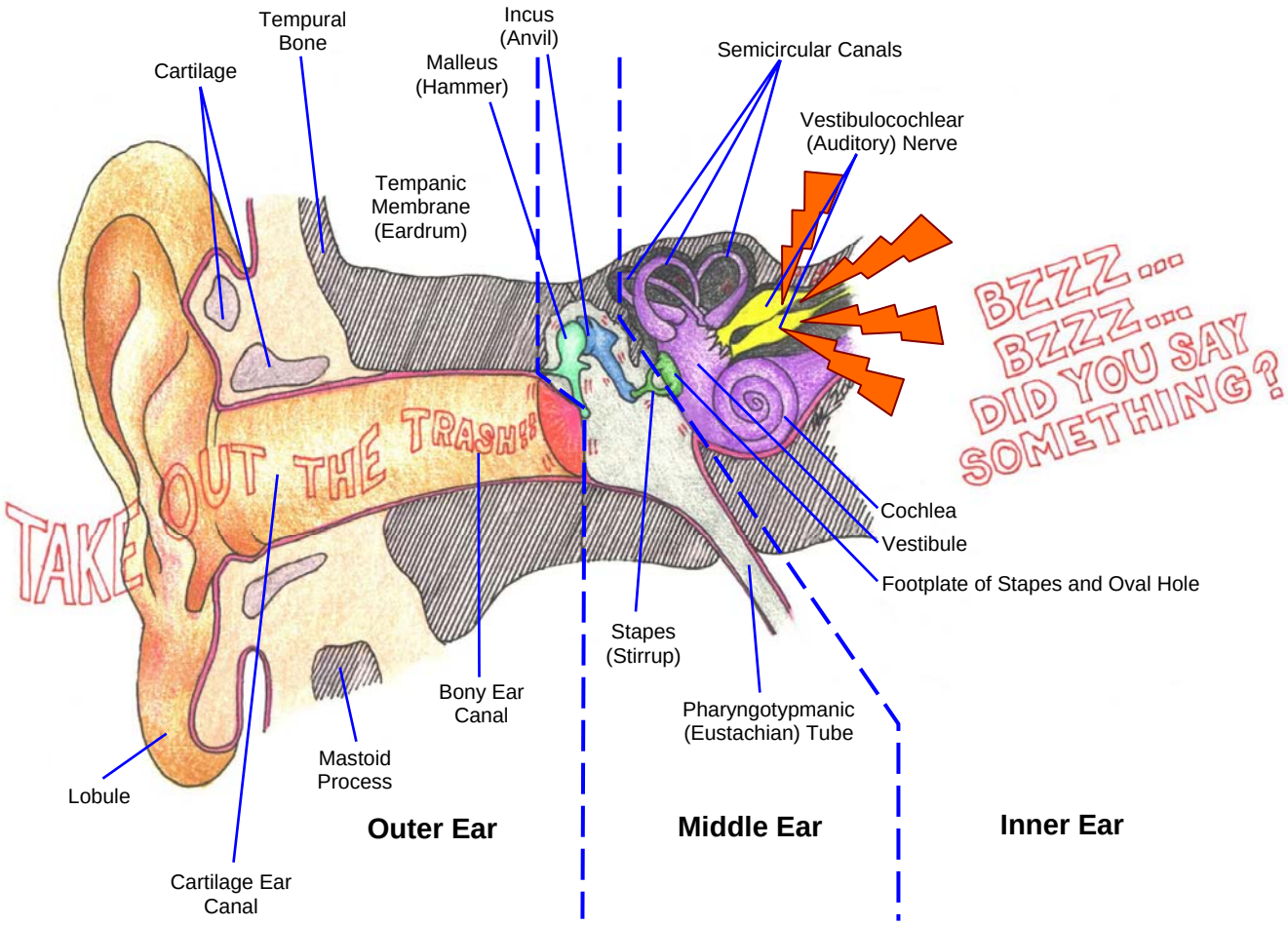


Figure 1: Anatomy of the Human Ear

Hearing (not to be confused with *listening*) is a physiological function. The ear is a remarkable and quite complex sensory organ that serves two primary functions: transferring sound waves into vibrations and then into nervous impulses for the brain to interpret (hearing), and providing bearings (spacial information) for the brain to interpet, so we know in which direction our head is situated. The brain uses this information to balance the body (otherwise

we would simply fall over and be unable to function). The ear is essentially divided into three parts: outer, middle, and inner ear (see Figure 1).

The outer ear is comprised of a cartilage structure (auricle) and lobule, the ear canal (part cartilage and part bony), and ends at the tempanic membrane (commonly known as the eardrum). It helps to think of the outer ear as a sort of funnel into which sound waves are received. The shape of the canal and the fact that it is both cartilage and bone facilitate concentrating sound waves towards the tempanic membrane, which then vibrates at related frequencies as it is struck by the waves. Cells within the canal excrete cerumen (ear wax), a sticky substance with the purpose of trapping foreign objects to prevent intrusion into the ear and subsequent infection or damage to the eardrum.[1]

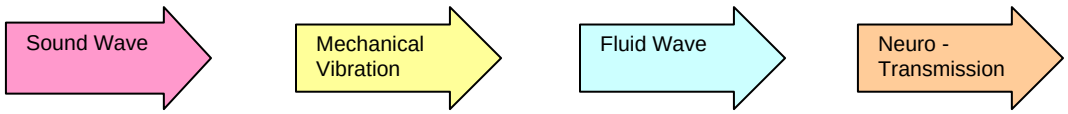
The middle ear is comprised of three very tiny, delicate bones (Malleus, Incus, and Stapes, or more commonly the Hammer, Anvil, and Stirrup) within an air-filled chamber, and the eustachian tube (which opens into the nasopharynx). This delicate assembly (known as the auditory ossicles) serves to magnify and transfer the vibrations of the membrane to the vestibule of the cochlea through the footplate of the stapes. Pressure is equalized between the outer ear and the middle ear chamber by the eustachian tube, so the tempanic membrane is free to move back and forth in response to the sound waves in the ear canal.

The inner ear (labrynth) is comprised of the vestibule (containing the oval and round windows), the cochlea, the semi-circular canals, and the auditory nerves – these are the organs of hearing and balance. The cochlea receives sound vibrations from the middle ear via the stapes footplate, which rocks back and forth across the oval window, causing fluid motions at specific frequencies and intensities (amplitude – how loud or soft the sound is) within the cochlea. Amazingly, these waves travel through the cochlea where they are picked up by

[1] The secondary purpose of cerumen appears to be that of prompting your mother to insist there are potatoes growing in your ears.

specifically shaped hair-like nerve cells that are essentially 'tuned' to excitability by certain frequencies (in other words, they are discriminatory). The nerves then respond by transmitting impulses to the brain. These signals are received into the brain (the "hearing area" of the cerebrum) and are thus interpreted as sounds (either familiar or unfamiliar ones). Residual waves leave the cochlea via the round window and are dissipated into the middle ear.

The auditory function of the ear, then, is to receive a sound wave through the air, convert it into a mechanical vibration, amplify it and transmit it into fluid where the waves will then stimulate specific nerve cells[2], and transmit these signals to the brain for interpretation. We are able to fix the direction sound comes from because we have two ears—both ears will receive the sound waves, but because of the way our ears face away from one another and where they are in relation to the sound, there will be very subtle differences in the waves being received. These differences eventually permit the brain to determine from which approximate direction and distance the sound comes.



To hear our friend's voice across a room and pick it out of all the other voices, our brains will interpret the subtle impulses from the auditory nerves into an understanding that the sound is familiar, associate the frequency and pitch of the voice with our friend, and establish the basic

[2] Stimulation of the cells is based upon *frequency*—this is known as the "place principle", and is similar to striking a specific key on a piano. You might imagine a miniature piano along the cochlear basil membrane that contains somewhere in the neighborhood of 24,000 keys!

direction in which we may find him or her—thus putting invisible sound waves into very rich context for us.[3]

Last but by no means least, the remaining structures within the inner ear that have to do with balance: the semicircular canals are fluid-filled and highly sensitive to motion, but they have no function in hearing. These tiny canals situated along the planes of three dimension (X, Y, and Z axes) literally aid the brain in determining "which end is up." Full function in *both* ears' semi-circular canals is required in order for the brain to interpret the body's position in the context of three dimensions (X, Y, and Z axis). These impulses are coupled with sensory input from the eyes and muscles/joints of the body, and the brain uses all of this information to process body position, posture, and the ability to fix the eyes in one spot regardless of the body's position or movement.[4]

[3] When we "hear" the sound (receive the waves and transfer them through the ear to the auditory nerve and to the brain), the process may also trigger other responses because our brains may associate the specific sound with a particular mental or emotional state of being. The sound of the friend's voice stimulates an association:

This frequency/pitch = friendly, familiar person (friend, Reggie) = warm, fuzzy feeling.

Conversely, we can have the same type of association when hearing the voice of someone we dislike:

That frequency/pitch = unfriendly, disliked person (boss or ex-boyfriend) = anxious feeling = need to escape.

[4] When these signals are interrupted or misinterpreted, violent dizziness can occur. A test to determine whether degradation to the semicircular canals exists is accomplished by flushing a patient's ear (only one of them) with warm water, which ultimately changes the temperature of the inner ear. Electrodes record the patient's eye movements to determine the degree of resulting dizziness (the eyes are unable to remain fixed, and the room seems to be spinning). The test is repeated with cold water, and both ears are tested. The eye movement results are then analyzed against a norm to make a determination regarding potential inner ear damage. The test is not much fun!

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