Ear

The ear functions for both hearing and balance. It is connected to the brain by the vestibulocochlear (auditory) nerve (CN VIII).

The ear has three regions:

Region 1) Outer ear (auricle or pinna) - Is a large cartilaginous structure. This structure is subdivided into several parts such as the helix (rim), antihelix, tragus, antitragus, and concha. At the bottom of the auricle there is usually a fleshy area known as the lobule.

The external auditory canal is the opening that leads from the auricle into the external auditory meatus of the temporal bone, to the tympanic membrane. It contains many ceruminous glands for the production of cerumen (ear wax). Cerumen functions to keep the tympanic membrane soft and waterproof. The external auditory canal also contains many small hairs. Together the hairs and the cerumen help prevent foreign objects from reaching the tympanic membrane.

The tympanic membrane (ear drum) is the innermost portion of the outer ear. It is a thin double layered membrane that is very sensitive to pain via cranial nerve five (CN V) and cranial nerve ten (CN X). The tympanic membrane transmits vibrations to the malleus in the middle ear.

Region 2) Middle ear (tympanic cavity) - is located in the petrous portion of the temporal bone. It is defined as the area between the tympanic membrane and the oval and round windows. There are 2 openings (entrances/exits) from this cavity:

a) epitympanic recess, which connects the tympanic cavity to the mastoid air cells.
b) pharyngotympanic (eustachian) tube, which connects the tympanic cavity to the nasopharynx. This tube serves for equilibration of air pressure between the tympanic cavity and the external environment.

The middle ear contains three ossicles (bones). These form a tandem connection from the tympanic membrane to the oval window. In order, from the tympanic membrane to the oval window these bones are, the malleus, the incus, and the stapes. These three bones act as levers to intensify the vibrations being passed from the tympanic membrane to the oval window. This force is also magnified by the step-down effect from the large tympanic membrane to the small oval window. Together these two factors increase the vibratory force about 20-fold. To regulate the amount of force transmitted to the oval window there are two regulatory muscles;

a) tensor tympany muscle. - which functions to pull the malleus inward. The tensor tympani muscle is innervated by a branch from the trigeminal nerve (CN V).
b) stapedius muscle. - which functions to pull the stapes outward away from the oval window. The stapedius muscle is innervated by a branch of the facial nerve (CN VII).

Region 3) Inner ear (labyrinth) - contains the functional organs for balance and hearing. It is divided into two portions, the bony labyrinth and the membranous labyrinth.

The bony labyrinth is divided into three areas:

Area 1). The vestibule, one wall of the vestibule contains the oval and round windows. The vestibule also contains the two portions of the membranous labyrinth as two connected sacs. These are the;

a) utricle, is the larger sac of these two sacs.
b) saccule.

Both of these sacs are sensitive to gravity and detect linear movement.

Area 2) semicircular canals - There are three semicircular canals in each ear. one to represent each plane of the body. These are sensitive to angular acceleration/deceleration and rotational movement. They contain semicircular ducts with a membranous ampulla. These connect to the upper part of the utricle.

Area 3) Cochlea - is coiled 2 ½ times to resemble a snail shape. The cochlea is divided into 3 chambers:

a. scala vestibuli - starts at the oval window. It is the uppermost chamber.
b. scala tympani - is the lower chamber. It ends at the round window.
c. cochlear duct - is the middle chamber. Its roof is the vestibular membrane, which forms the septum between the scala vestibuli and the cochlear duct. Its floor is the basilar membrane.

The scala vestibuli and scala tympani contain perilymph, and are connected at the helicotrema.

The cochlear duct contains endolymph and ends at the helicotrema.

The spiral organ or Organ of Corti is inside the cochlear duct. It contains the receptors that transform mechanical vibrations into nerve impulses. These are located in the basilar membrane of the spiral organ thus making it the functional unit of hearing. It consists of support cells situated along the basilar membrane, and hair cells that are supported by the support cells. It also has a tectorial membrane that extends from the vestibular membrane, out over the hair cells.

High intensity waves traveling in the perilymph are transmitted through the vestibular membrane and the basilar membrane, into the endolymph. This causes displacement of the endolymph, which in turn displaces the tectorial membrane, which then displaces the cilia of the hair cells. The hair cells then send an impulse to the spiral ganglion. From here the impulse will travel to the brain via the cochlear portion of the vestibulocochlear nerve (CN VIII).

Equilibrium, or balance is accomplished by the brain interpreting information relayed to it from the semicircular canals and the saccule and utricle.

Recall that the semicircular canals function to detect rotational, or angular, motion. The semicircular canals have an ampulla at their base. Within the ampulla there is an elevated area known as the crista ampullaris. It has many hair cells. These hair cells reach into a dome shaped gelatinous mass called the cupula. The semicircular canals are filled with endolymph. Rotational or angular motion slightly displaces the endolymph. This slight displacement alone is not enough to bend the microvilli on the hair cells. The cupola acts much like the sails on a boat. The large surface area of the sail is able to catch even the slightest breeze, and thus provide the energy needed to move the boat. The cupola catches the slight displacement of the endolymph and is itself displaced. This causes a bending of the "hairs" on the hair cells, which then send impulses to the brain via the vestibular portion of Cranial Nerve eight, the vestibulocochlear nerve, abbreviated CN VIII.

Recall that the utricle and saccule function to detect linear motion. Within these two structures we will find support cells which support hair cells. There is a structure that is found within the saccule, known as the macula. This is a gelatinous mass which contains otoliths. Otoliths are small crystals of calcium carbonate which gives additional mass to the macula. The cilia of the hair cells are embedded in this gelatinous mass, and movement of the mass will bend the cilia. Because of this additional mass, it takes more energy, or movement, to displace the mass. Also, once the mass is moving, it takes more energy to stop the movement. This arrangement ensures that you do not think you are moving just because of very slight vibrations. There has to be actual movement before the nerve impulse will be generated.

The hair cells related to the vestibular system are structurally different from those in the spiral organ. The "hairs" of these cells are actually microvilli, and one larger structure known as a kinocilium. For each hair cell there are roughly 20 - 50 microvilli and 1 kinocilium. Nerve impulses are generated based on the movement of the microvilli related to the kinocilium. In general, if the microvilli deflect toward the kinocilium, a depolarization signal will be generated. If the microvilli deflect away from the kinocilium. a hyperpolarization signal will be generated.