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**HISTOLOGY OF THE EAR**

**Question**

With the aid of a diagram, write an essay on the histology of an organ of Corti.

**Answer**



The organ of Corti, or spiral organ, where sound vibrations of different frequencies are detected, consists of hair cells and other epithelial structures supported by the basilar membrane. Here the sensory hair cells have precisely arranged V-shaped bundles of rigid stereocilia; each loses its single larger kinocilium during development. Two major types of hair cells are present:

* Outer hair cells, about 12,000 in total, occur in three rows near the saccule, increasing to five rows near the apex of the cochlea. Each columnar outer hair cell bears a V-shaped bundle of stereocilia.
* Inner hair cells are shorter and form a single row of about 3500 cells, each with a single more linear array of shorter stereocilia.

Both outer and inner hair cells have synaptic connections with afferent and efferent nerve endings, with the inner row of cells more heavily innervated. The cell bodies of the afferent bipolar neurons constitute the spiral ganglion located in the bony core of the modiolus. Two major types of columnar supporting cells are attached to the basilar membrane in the organ of Corti:

* Inner and outer phalangeal cells extend apical processes that intimately surround and support the basolateral parts of both inner and outer hair cells and the synaptic nerve endings. The apical ends of phalangeal cells are joined to those of the hair cells by tight zonulae occludens, forming an apical plate across the spiral organ through which the stereocilia bundles project into endolymph.
* Pillar cells are stiffened by heavy bundles of keratin and outline a triangular space, the inner tunnel, between the outer and inner complexes of hair cells and phalangeal cells. The stiff inner tunnel also plays a role in sound transmission. On the outer hair cells the tips of the tallest stereocilia are embedded in the gel-like tectorial membrane, an acellular layer that extends over the organ of Corti from the connective tissue around the modiolus. The tectorial membrane consists of fine bundles of collagen (types II, V, IX, and XI) associated with proteoglycans and forms during the embryonic period from secretions of cells lining this region.

The bony and membranous labyrinths in the ear contain two different fluids, these fluids are:

* Perilymph fills all regions of the bony labyrinth and has an ionic composition similar to that of cerebrospinal fluid and the extracellular fluid of other tissues, but it contains little protein. Perilymph emerges from the microvasculature of the periosteum and drains via a perilymphatic duct into the adjoining subarachnoid space. Perilymph suspends and supports the closed membranous labyrinth, protecting it from the hard wall of the bony labyrinth.
* Endolymph fills the membranous labyrinth and is produced by stria vascularis. Potassium secreted into the endolymph by the stria vascularis enters the hair cells through apical mechanosensitive channels. It is recycled back to the stria vascularis through supporting cells and fibrocytes of the spiral ligament for another round of secretion. Hair cells and stria vascularis are tied together in a “push-pull” balance that determines endocochlear potential (EP +85mV), endolymph composition and ultimately the sensitivity and stability of hair cells and hearing over a lifetime. It is characterized by a high-K+ (150 mM) and low-Na+ (16 mM).

By detecting minute movements of the stereocilia, hair cells in the spiral organ of Corti act as mechanoelectrical transducers very much like those of the vestibular maculae described previously and mediate the sense of hearing.



As shown in the figure above, sound waves collected by the external ear cause the tympanic membrane to vibrate; this moves the chain of middle ear ossicles and the oval window. The large size of the tympanic membrane compared to the oval window and the mechanical properties of the ossicle chain amplify the movements and allow optimal transfer of energy between air and perilymph, from sound waves to vibrations of the tissues and fluid-filled chambers.

Pressure waves within the perilymph begin at the oval window and move along the scala vestibuli. Each pressure wave causes momentary displacement of the vestibular and/or basilar membranes and the endolymph surrounding the organ of Corti. The width, rigidity, thickness, and other physical properties of the basilar membrane and its organ of Corti all vary in precise gradients along its length. This allows the region of maximal displacement to vary with the sound waves’ frequency, that is, the number of waves moving past a point per unit of time (measured in hertz). High-frequency sounds displace the basilar membrane maximally near the oval window. Sounds of progressively lower frequency produce pressure waves that move farther along the scala vestibuli and displace the spiral organ at points farther from the oval window. The sounds of the lowest frequency that can be detected produce movement of the basilar membrane at the apex or helicotrema of the cochlea. After crossing the cochlear duct (scala media) and organ of Corti, pressure waves are transferred to the scala tympani and exit the inner ear at the round window.

The main mechanoreceptors for the sense of hearing are the more heavily innervated inner hair cells in the organ of Corti. The outer hair cells, with their stereocilia tips embedded in the tectorial membrane, are depolarized when stereocilia are deformed, as described previously, for vestibular hair cells. In the organ of Corti, however, hair cell activities are more complex, allowing greater control on sensory reception.

Depolarization of the outer hair cells causes these columnar cells to shorten very rapidly, an effect mediated by an unusual 80-kD transmembrane protein called Prestin (Italian. presto, very fast) abundant in the lateral cell membranes. Prestin undergoes a voltage-dependent conformational change that affects the cytoskeleton, rapidly shortening the cells when the membrane is depolarized and elongating them again with membrane hyperpolarization. Piston-like movements of the outer hair cells pull down the tectorial membrane against the stereocilia of the inner hair cells, causing depolarization of these cells which then send the signals to the brain for processing as sounds. This sequential role for outer and inner hair cells produces further cochlear amplification of the sound waves.

Some types of sensorineural deafness can be treated by a cochlear implant. A small cable with a series of electrodes is threaded into the scala tympani, with the electrodes along the wall containing branches of the cochlear nerve. A device containing a microphone, a speech processor to filter extraneous sounds, and a transmitter is worn behind the external ear.

Sounds of various frequencies transmit signals to a receiver implanted in a bone of the skull and attached to the array of electrodes that stimulate nerve branches appropriate for those frequencies. The neural impulses are interpreted in the brain as sounds. Cochlear implants do not restore normal hearing but can provide a range of sounds that allows understanding of speech.

**Clinical Anatomy**

Sensorineural deafness can be congenital or acquired and due to defects in any structure or cell from the cochlea to the auditory centers of the brain, but it commonly involves loss of hair cells or nerve degeneration. This type of hearing loss often results from exposure to either loud sounds or ototoxic drugs (These drugs are K+ channel blockers; they block the ability of inner and outer hair cells to depolarize e.g. Aminoglycoside antibiotics). Exposure to loud noises causes the vibrational shift between the tectorial and basilar membranes to increase. This shift can damage the sterocilia of the outer hair cells. When damage occurs to the outer hair cells, the stiffness of the organ of corti decreases which in turn increases vibrational forces on the inner hair cells. Damage to the outer hair cells decreases the protection of inner hair cells and causes them to be more sensitive. Over time, the inner hair cells will also become damaged and audition affected.

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