ENYONG, RUTH KINGSLEY

17/MHS01/119

MEDICINE AND SURGERY

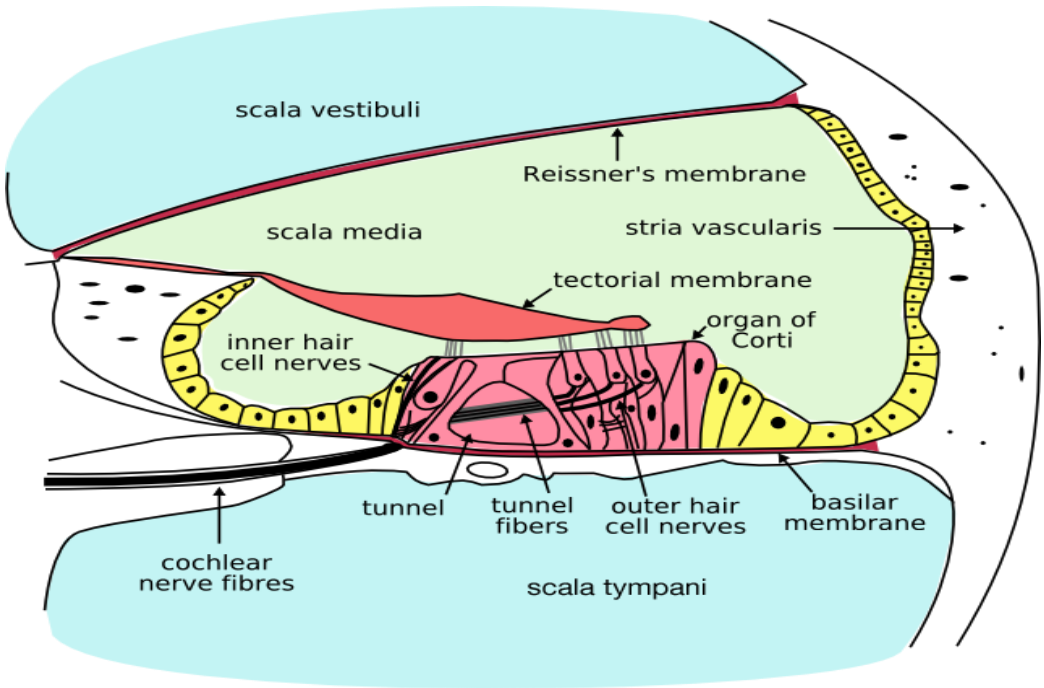
HISTOLOGY OF SPECIAL SENSES AND NEUROHISTOLOGY (ANA 305)

HISTOLOGY OF EAR ASSIGNMENT

WITH THE AID OF A DIAGRAM, WRITE AN ESSAY ON THE HISTOLOGY OF THE ORGAN OF CORTI.

THE ORGAN OF CORTI

The organ of Corti or spiral organ is the receptor organ for hearing and is located in the mammalian cochlea. This highly varied strip of epithelial cells allows for transduction of auditory signals into nerve impulses' action potential. Transduction occurs through vibrations of structures in the inner ear causing displacement of cochlear fluid and movement of hair cells at the organ of Corti to produce electrochemical signals.



A CROSS SECTION OF THE COCHLEA ILLUSTRATING THE ORGAN OF CORTI

The organ of Corti is located in the scala media of the cochlea of the inner ear between the vestibular duct (scala vestibuli) and the tympanic duct (scala tympani) which exist in a low potassium fluid called perilymph and is composed of mechanosensory cells, known as hair cells. Projecting from the tops of the hair cells are tiny finger like projections called stereocilia, which are arranged in a graduated fashion with the shortest stereocilia on the outer row and the longest in the center. This gradation is thought to be the most important anatomic feature of the organ of Corti because this allows the sensory cells superior tuning capability. The fibrous tectorial membrane rests on top of the stereocilia or the outer hair cells. Mutations in an alpha-tectorin, which encodes a protein specific to the tectorial membrane, cause deafness. The organ of Corti, surrounded in potassium rich fluid called endolymph. Endolymph fills the scala media and it 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" or "pump-leak" balance that determines endocochlear potential, endolymph composition and ultimately the sensivity and stability of hair cells and hearing over a lifetime. The hair cells are strategically positioned on the basilar membrane of the organ of Corti. There are different types of hair cells namely: the inner hair cells, the outer hair cells and the supporting cells.

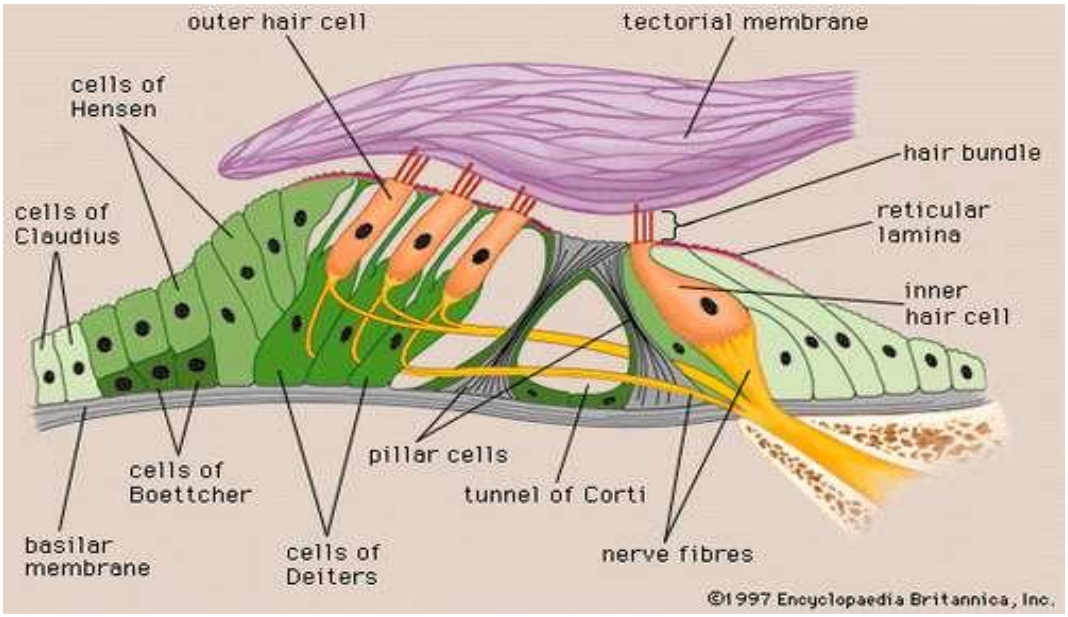
The inner hair cells are specialized in the mechanoelectrical transduction. There are almost 3500 cells disposed in one line along all the basilar membrane. They are connected to type I neuron peripheral fibers of spiral ganglion, these connection are very divergent. The luminal part of the cell is immerged in endolymph, the basal one is immerged in normal extracellular fluid. The luminal portion is formed by bundles of stereocilia (inner ear), whose tips are connected by filamentous structures called tip-links. They are supported and enclosed by the inner phalangeal cells, which rest on the thin outer portion, called the tympanic lip, of the spiral limbus. On the inner side of the inner hair cells and the cells that support them is a curved furrow called the inner sulcus. This is lined with more or less undifferentiated cuboidal cells. There is a row of pear-shaped inner hair cells present.

The outer hair cells are acoustical pre-amplifiers. They are almost 12000, disposed in three parallel lines. These cells are connected to type II amyelinic neurons, the connections are very convergent. They have also an afference from superior olivary nucleus. They have contractile activity. Each outer hair cell is supported by a phalangeal cell of Deiters, a supporting cell, which holds the base of the hair cell in a cup-shaped depression. From each Deiters' cell a projection extends upward to the stiff membrane, the reticular lamina that covers the organ of Corti. The top of the hair cell is firmly held by the lamina, but the body is suspended in fluid that fills the space of Nuel and the tunnel of Corti. Although this fluid is sometimes referred to as cortilymph, its composition is thought to be similar, if not identical, to that of the perilymph. There are three rows of cylindrical outer hair cells.

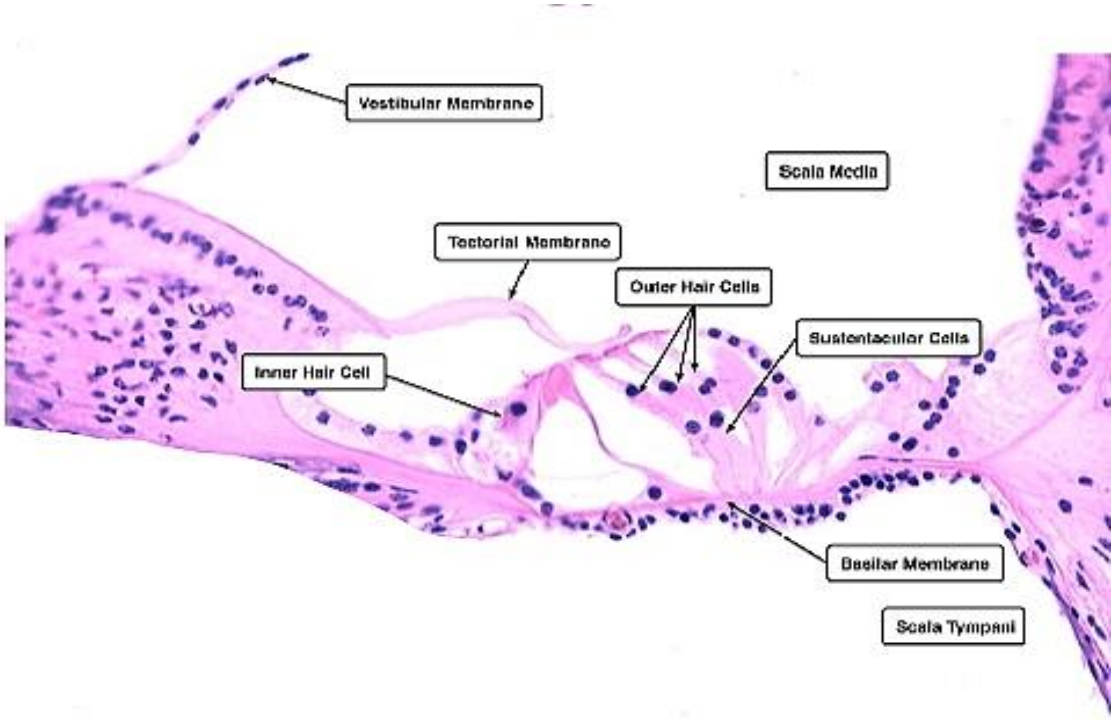
The supporting cells are of four different types: Cortipillars, Hensen cells, Deiters cells and Claudius cells. They separate the inner and outer hair cells.

Each hair cell has a cytoskeleton composed of filaments of the protein actin, which imparts stiffness to structures in which it is found. The hair cell is capped by a dense cuticular plate,

composed of actin filaments, which bears a tuft of stiffly erect stereocilia, also containing actin, of graded lengths arranged in a staircase pattern. This so- called hair bundle has rootlets anchored firmly in the cuticular plate. On the top of the inner hair cells 40 to 60 stereocilia are arranged in two or more irregularly parallel rows. On the outer hair cells approximately 100 stereocilia form a W pattern. At the notch of the W the plate is incomplete, with only a thin cell membrane taking its place. Beneath the membrane is the basal body of a kinocilium, although no motile ciliary (hair-like) portion is present as is the case on the hair cells of the vestibular system. The stereocilia are about 3 to 5 µm in length. The longest make contact with but do not penetrate the tectorial membrane. This membrane is an acellular gelatinous structure that covers the top of the spiral limbus as a thin fibrillar layer, then becomes thicker as it extends outward over the inner sulcus and the reticular lamina. Its fibrils extend radially and somewhat obliquely to end at its lateral border, just above the junction of the reticular lamina and the cells of Hensen. In the upper turns of the cochlea, the margin of the membrane ends in fingerlike projections that make contact with the stereocilia of the outermost hair cells.



STRUCTURE OF THE ORGAN OF CORTI



HISTOLOGICAL STRUCTURE OF THE ORGAN OF CORTI

The organ of Corti develops after the formation and growth of the cochlear duct. The inner and outer hair cells then differentiate into their appropriate positions and are followed by the organization of the supporting cells. The topology of the supporting cells lends itself to the actual mechanical properties that are needed for the highly specialized sound-induced movements within the organ of Corti. Development and growth of the organ of Corti relies on specific genes, many of which have been identified in previous research (SOX2, GATA3 , EYA1 , FOXG1 , BMP4 , RAC1 and more), to undergo such differentiation. Specifically, the cochlear duct growth and the formation of hair cells within the organ of Corti. Mutations in the genes expressed in or near the organ of Corti before the differentiation of hair cells will result in a disruption in the differentiation, and potential malfunction of, the organ of Corti.

The major function of the organ of Corti is to change (transduce) auditory signals and minimize the hair cells' extraction of sound energy. It is the auricle and middle ear that act as mechanical transformers and amplifiers so that the sound waves end up with amplitudes 22 times greater than when they entered the ear. In normal hearing, the majority of the auditory signals that reach the organ of Corti in the first place come from the outer ear. Sound waves enter through the auditory canal and vibrate the tympanic membrane, also known as the eardrum, which vibrates three small bones called the ossicles. As a result, the attached oval window moves and causes movement of the round window, which leads to displacement of the cochlear fluid. However, the stimulation can happen also via direct vibration of the cochlea from the skull. The latter is referred to as Bone Conduction hearing, as complementary to the first one described which is instead called Air Conduction hearing. Both stimulate the basilar membrane in the same way.

The organ of Corti is also capable of modulating the auditory signal. The outer hair cells

(OHCs) can amplify the signal through a process called electromotility where they increase movement of the basilar and tectorial membranes and therefore increase deflection of stereocilia in the IHCs. A crucial piece to this cochlear amplification is the motor protein prestin, which changes shape based on the voltage potential inside of the hair cell. When the cell is depolarized, prestin shortens, and because it is located on the membrane of OHCs it then pulls on the basilar membrane and increasing how much the membrane is deflected, creating a more intense effect on the inner hair cells (IHCs). When the cell hyperpolarizes prestin lengthens and eases tension on the IHCs, which decreases the neural impulses to the brain. In this way, the hair cell itself is able to modify the auditory signal before it even reaches the brain.

The organ of Corti can be damaged by excessive sound levels, leading to noise-induced impairment. The most common kind of hearing impairment, sensori-neural hearing loss, includes as one major cause the reduction of function in the organ of Corti. Loss of components within the cochlea results in sensori-neural deafness which is more frequency-specific (i.e. the patient will not be able to hear specific pitches depending on the location of the damage in the cochlea). Loss of outer hair cells in a particular region of the cochlea would result in a "threshold shift" whereby sound of a particular frequency could still be detected (because the inner hair cells are still intact), but it would have to be louder to make up for the fact that there are no outer hair cells to help stimulate the inner hair cells. This type of hearing loss can be compensated by a hearing aid. Loss of inner hair cells in a particular region of the cochlea would result in an almost complete inability to detect specific frequencies regardless of how loud they are. In this case, the deafness could only be corrected with a cochlear implant.