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COURSE: HISTOLOGY OF THE SPECIAL SENSES.

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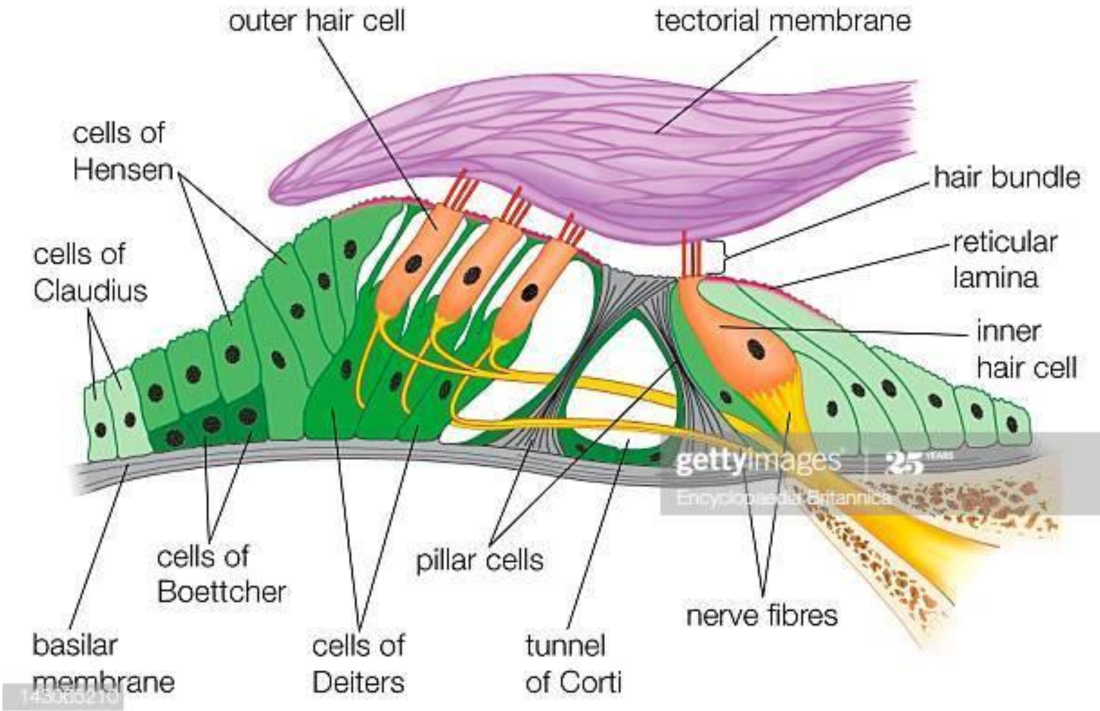
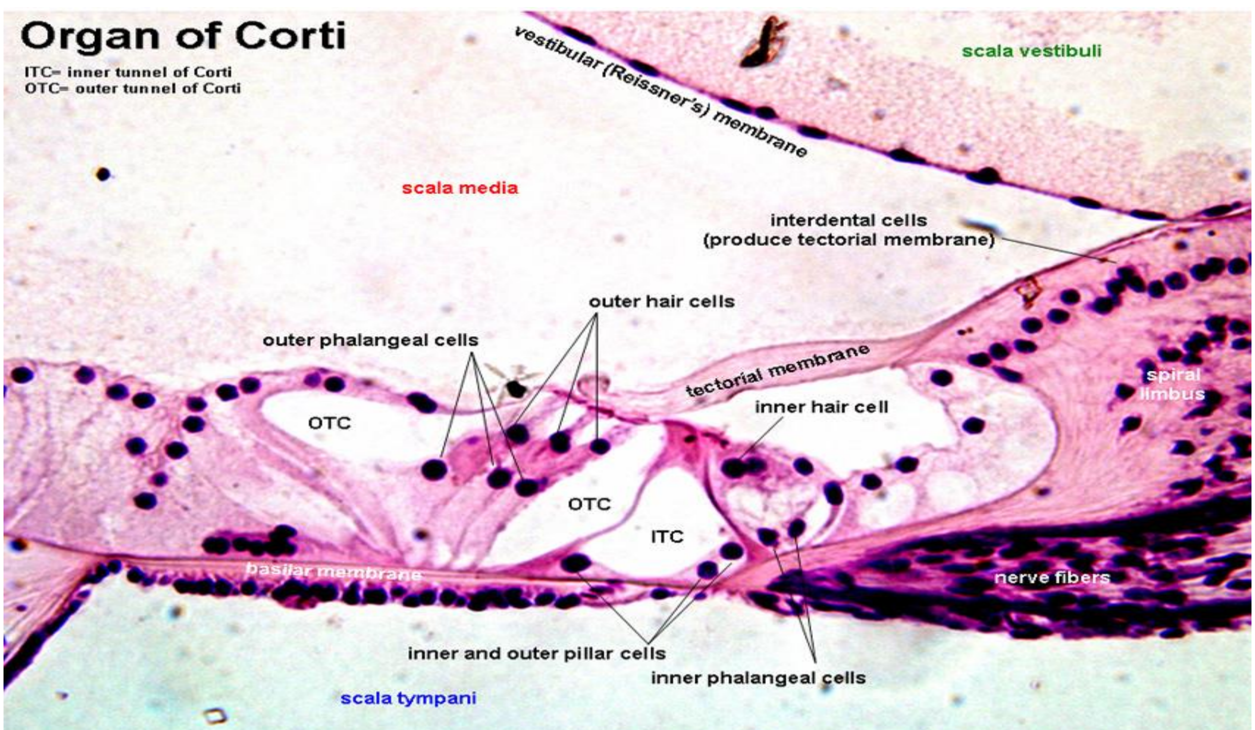
ASSIGNMENT

1. With the aid of a diagram, write an essay on the Organ of Corti.

HISTOLOGY OF THE ORGAN OF CORTI.





ORGAN OF CORTI

The **organ of Corti** is a specialized sensory epithelium that allows for the **transduction of sound vibrations into neural signals.** The organ of Corti is named after Italian anatomist **Alfonso Corti,** who first described it in **1851**. 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.

STRUCTURE

The organ of Corti is located in the **scala media** of the cochlea of the inner ear **between the vestibular duct and the tympanic duct** and is composed of **mechanosensory cells,** known as **hair cells.** Strategically positioned on the basilar membrane of the organ of Corti are three rows of **outer hair cells** (OHCs) and one row of **inner hair cells (**IHCs). Separating these hair cells are supporting cells**: Deiters cells**, also called **phalangeal cells,** which separate and support both the OHCs and the IHCs.

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 rows 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.

Viewed in cross section, the most striking feature of the organ of Corti is the arch, or **tunnel of Corti**, formed by two rows of **pillar cells, or rods.** The pillar cells furnish the major support of this structure. They separate a single row of larger, pear-shaped **inner hair cells** from three or more rows of smaller, cylindrical **outer hair cells.** The inner hair cells 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.

Each outer hair cell is supported by a phalangeal cell of **Deiters, or 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. Beyond the hair cells and the Deiters' cells are three other types of epithelial cells, usually called the **cells of Hensen, Claudius, and Boettcher,** after the 19th-century anatomists who first described them. They are assumed to help in maintaining the composition of the endolymph by ion transport and absorptive activity.

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 (hairlike) 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.

The total number of **outer hair cells** in the cochlea has been estimated at **12,000** and the number of **inner hair cells** at **3,500**. Although there are about **30,000 fibres** in the **cochlear nerve**, there is considerable overlap in the innervation of the outer hair cells.

Viewed from above, the organ of Corti with its covering, the reticular lamina, forms a well-defined mosaic pattern. In humans the arrangement of the outer hair cells in the basal turn of the cochlea is quite regular, with three distinct and orderly rows; but in the higher turns of the cochlea the arrangement becomes slightly irregular, as scattered cells form fourth or fifth rows. The spaces between the outer hair cells are filled by oddly shaped extensions (phalangeal plates) of the supporting cells. The double row of head plates of the inner and outer pillar cells cover the tunnel and separate the inner from the outer hair cells. The reticular lamina extends from the inner border cells near the inner sulcus to the Hensen cells but does not include either of these cell groups. When a hair cell degenerates and disappears as a result of aging, disease, or noise-induced injury, its place is quickly covered by the adjacent phalangeal plates, which expand to form an easily recognized "**scar.**"

LOCATION

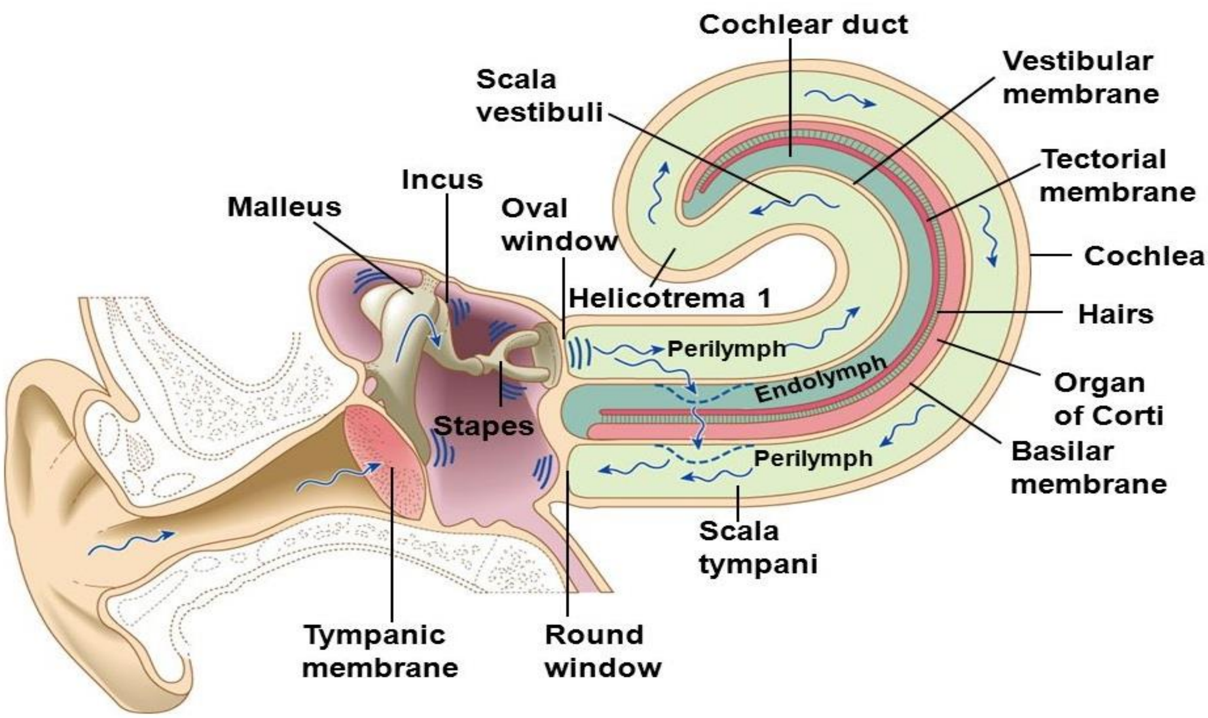
The organ of Corti is located in the **scala media** of the cochlea of the inner ear **between the vestibular duct and the tympanic duct.** The scala media also known as the **cochlear duct** and it is an **endolymph filled cavity** inside the cochlea, located between the **tympanic duct** and the **vestibular duct**, separated by the **basilar membrane** and **Reissner's membrane (the vestibular membrane)** respectively.

<u>COCHLEAR DUCT</u>

The cochlear duct is a cavity filled with endolymph and is a component of the membranous labyrinth of the ear. It is held in position by the lamina of the **modiolus** . The cochlear duct **starts** at the **saccule** and **ends** blindly at the **apex of the cochlea**. The cochlear duct subdivides the bony labyrinth into two perilymph chambers, namely the **scala vestibuli anteriorly** (opens into the vestibule) and the **scala tympani posteriorly** (ends at the round window)

The cochlear duct is described as being triangular in shape and has:

- **outer wall:** consists of thickened periosteum, known as the spiral ligament
- **roof (vestibular membrane):** separates the cochlear duct from the scala vestibuli
- **floor:** separates the cochlear duct from the scala tympani. It also consists of the lamina modiolus and basilar membrane, which supports the organ of Corti



FUNCTIONS OF THE ORGAN OF CORTI

The function of the organ of Corti is to change (transduce) auditory signals and minimise 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.

Auditory transduction

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 (or BC) hearing, as complementary to the first one described, which is instead called Air Conduction (or AC) hearing. Both AC and BC stimulate the basilar membrane in the same way. The basilar membrane on the tympanic duct presses against the hair cells of the organ as perilymphatic pressure waves pass. The stereocilia atop the IHCs move with this fluid displacement and in response their cation, or positive ion selective, channels are pulled open by cadherin structures called tip links that connect adjacent stereocilia. The organ of Corti, surrounded in potassium rich fluid endolymph, lies on the basilar membrane at the base of the scala media. Under the organ of Corti is the scala tympani and above it, the scala vestibuli. Both structures exist in a low potassium fluid called perilymph. Because those stereocilia are in the midst of a high concentration of potassium, once their cation channels are pulled open, potassium ions as well as calcium ions flow into the top of the hair cell. With this influx of positive ions the IHC becomes depolarized, opening voltage-gated calcium channels at the basolateral region of the hair cells and triggering the release of the neurotransmitter glutamate. An electrical signal is then sent through the auditory nerve and into the auditory cortex of the brain as a neural message.

Inner hair cells function primarily as the sensory organs for audition. They provide input to 95% of the auditory nerve fibers that project to the brain. The stiffness and size of the hair cell arrangement throughout the cochlea enable hair cells to respond to a variety of frequencies from low to high. Cells at the apex to respond to lower frequencies while hair cells at the base of the cochlea (near the oval window) respond to higher frequencies, which creates a tonotopic gradient throughout the cochlea.

While inner hair cells are the output center of the cochlea, the outer hair cells are the input center. They receive descending inputs from the brain to assist with the modulation of inner hair cell function (i.e., modulating tuning and intensity information). Unlike other regions of the brain, the modulation of inner hair cells by outer hair cells is not electrical but mechanical. Activation of outer hair cells changes the stiffness of their cell bodies; this manipulates the resonance of perilymph fluid movement within the scala media and allows for fine-tuning of inner hair cell activation.

CLINICAL SIGNIFICANCE

Hearing loss

The organ of Corti can be damaged by excessive sound levels, leading to noise-induced impairment. The most common kind of hearing impairment, sensorineural hearing loss, includes as one major cause the reduction of function in the organ of Corti. Specifically, the active amplification function of the outer hair cells is very sensitive to damage from exposure to trauma from overly-loud sounds or to certain ototoxic drugs. Once outer hair cells are damaged, they do not regenerate, and the result is a loss of sensitivity and an abnormally large growth of loudness (*recruitment*) in the part of the spectrum that the damaged cells serve.