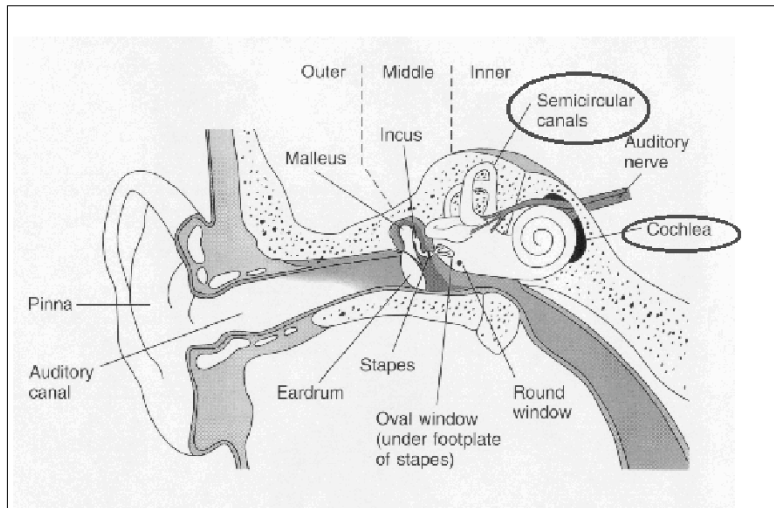


# Anatomy of the Inner Ear

## Auditory transduction takes place in the inner ear

Transduction refers to the transformation of energy from one form to another. In the case of the ear, acoustic (mechanical) energy is transformed to electrochemical energy

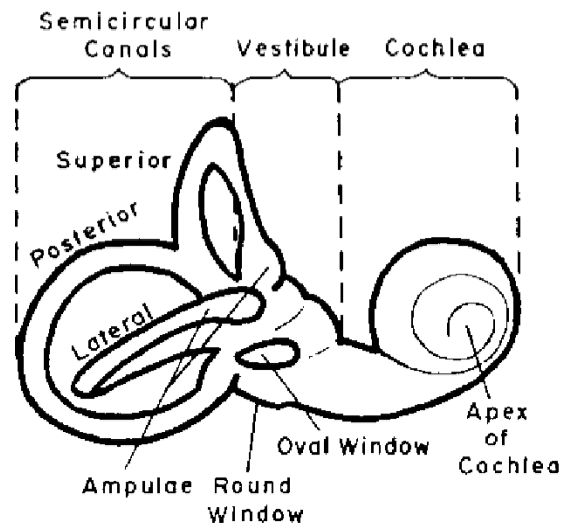
## The Inner Ear



From [www.unc.edu/courses/psyc21/3-26-99/sld008.htm](http://www.unc.edu/courses/psyc21/3-26-99/sld008.htm)

The inner ear consists of a membranous “labyrinth” encased in an osseous labyrinth.

## Parts of the inner ear

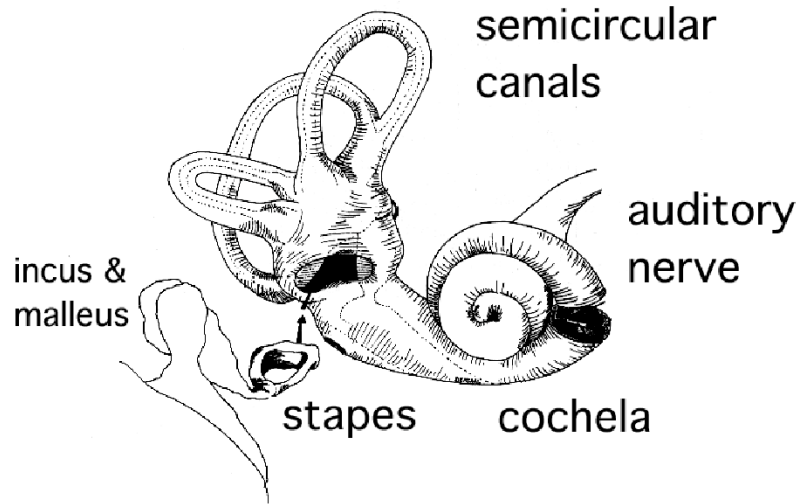


**Figure 2.11** The osseous (bony) labyrinth.

From Gelfand (1998)

The vestibule and semicircular canals are concerned with vestibular function (balance); the cochlea is concerned with hearing. The cochlea is a coiled tube. Notice that the oval window and round window open into the vestibule, at the base of the cochlea.

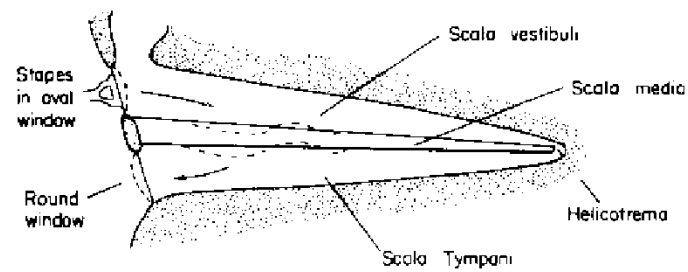
## The cochlea



[http://depts.washington.edu/otoweb/inner\\_ear.html](http://depts.washington.edu/otoweb/inner_ear.html)

The cochlear coil extends “up” from its base. It is coiled around the modiolus.

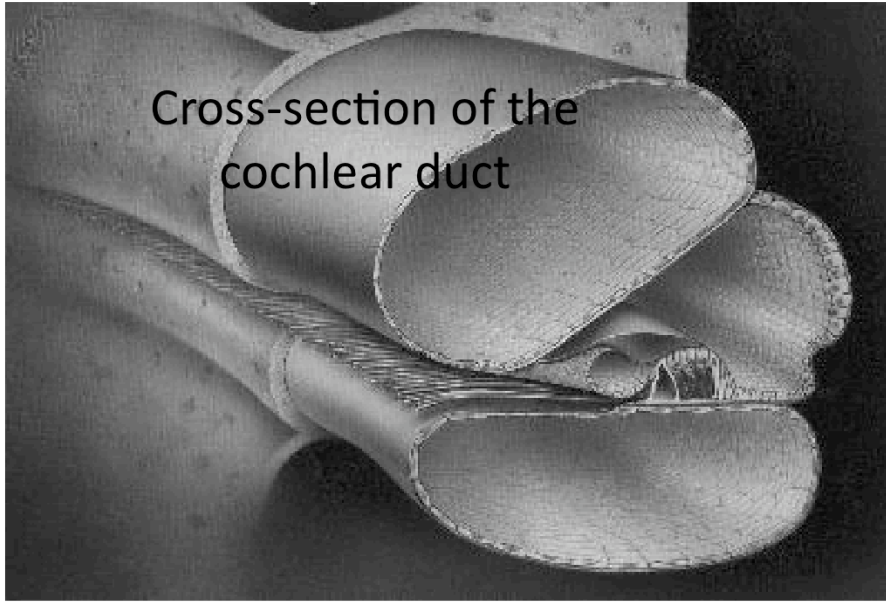
## The cochlea uncoiled



From Pickles (1992)

Reissner's membrane and the basilar membrane divide the the cochlea longitudinally into three scalae. Movement of the the basilar membrane by pressure changes induced by stapes footplate motion at the oval window is a critical step in the transduction process

## Cross-section of the cochlear duct



<http://btrrh.boystown.org/cel/inside.htm/>

If you cut the cochlear tube cross sectionally, you'd see something like this. Scala vestibuli on top, scala tympani on the bottom. Scala media is a triangular duct in the middle. The process of transduction occurs in the structures within scala media, sitting on the basilar membrane -- these structures comprise the organ of Corti. The side of the duct where the nerve fibers exit (left in this picture) is the "inner" or "modiolar" side of the duct. The opposite side is the "outer" side.

## the organ of Corti

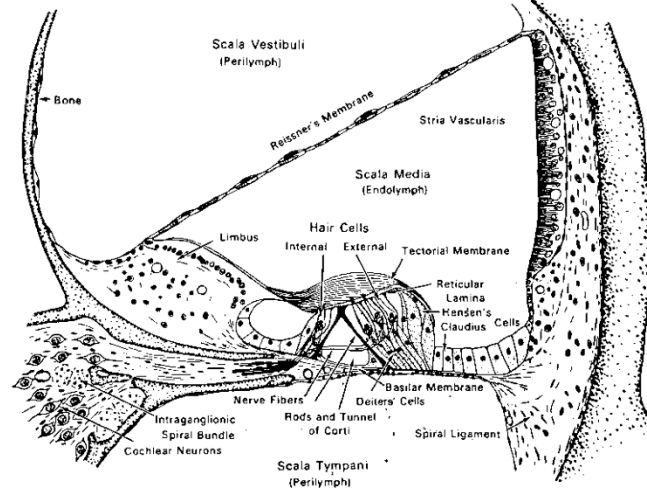


Figure 2.17 Cross-section of the organ of Corti. From Davis (1962), with permission.

From Gelfand (1998)

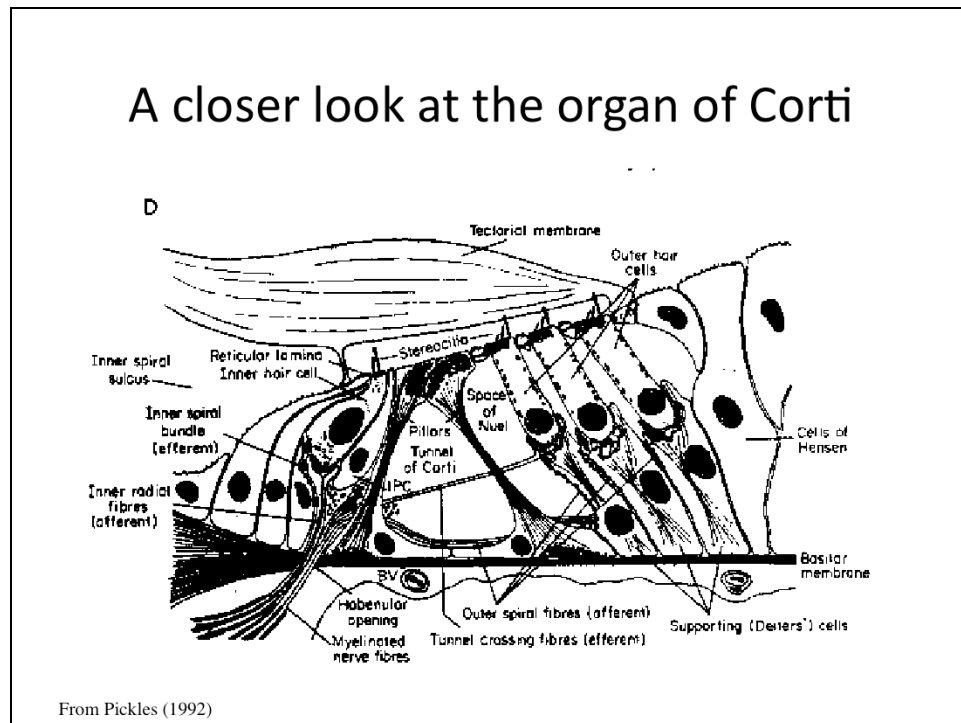
Notice that scala media is more or less triangular, formed by Reissner's membrane, basilar membrane and the structure called the stria vascularis.

The fluid that fills scala tympani and scala vestibuli is called perilymph; the fluid that fills scala media is called endolymph.

The organ of Corti rests on the basilar membrane within scala media.



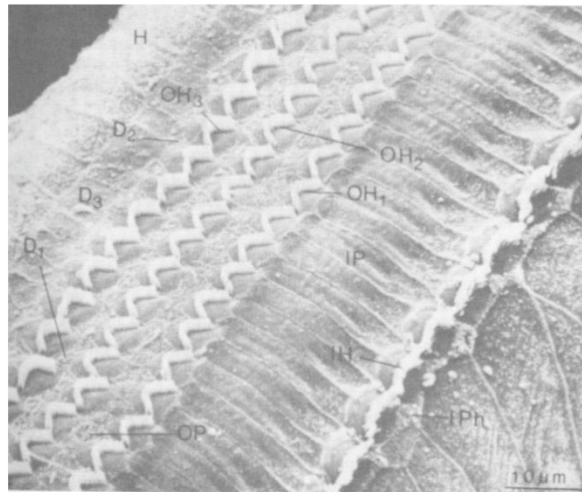
## A closer look at the organ of Corti



Two types of cells in the organ of Corti are support cells and hair cells. The hair cells are the “receptor” cells-- the ones that transduce sound. Support cells such as the Deiter’s cells support hair cells. The tops of the hair cells and pillar cells form the reticular lamina, which isolates the hair cells’ stereocilia from their cell bodies. The tectorial membrane is loosely coupled to the reticular lamina. Endolymph & perilymph.

There are 4 rows of hair cells, one on the inner (modiolar) side of the tunnel formed by the pillar cells-- these are the inner hair cells; and 3 one the outer side of the Tunnel of Corti, these are the outer hair cells. Notice that the Deiter’s cells support the Outer hair cells at their base, but that the outer hair cell walls are surrounded by fluid. The inner hair cell is surrounded by support cells.

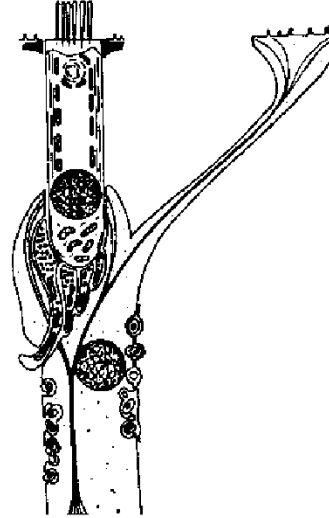
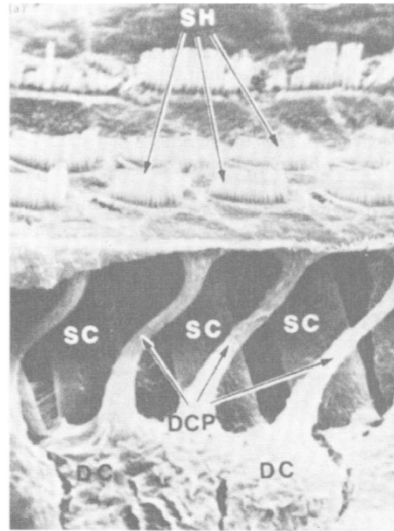
## Reticular lamina



From Gelfand (1998), Lim (1986)

The reticular lamina is a solid surface at the tops of the hair cells, so the tops of the hair cells are in endolymph and the bottom of the hair cells are in perilymph.

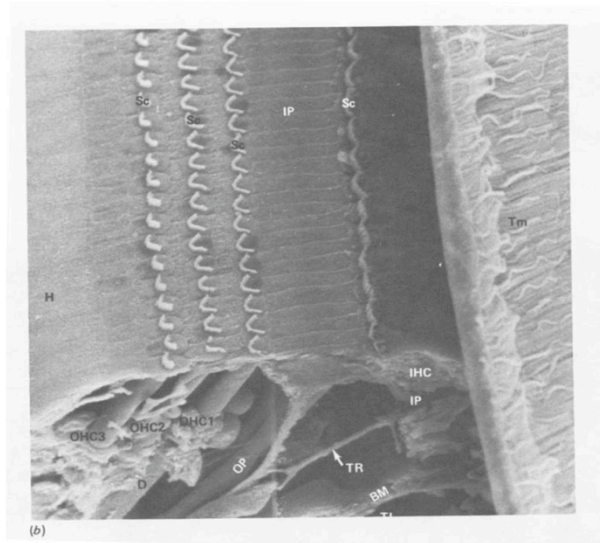
## Deiter's cells



From Gelfand (1998)

Deiter's cell processes "fill in the gaps" between the tops of the outer hair cells to form the reticular lamina.

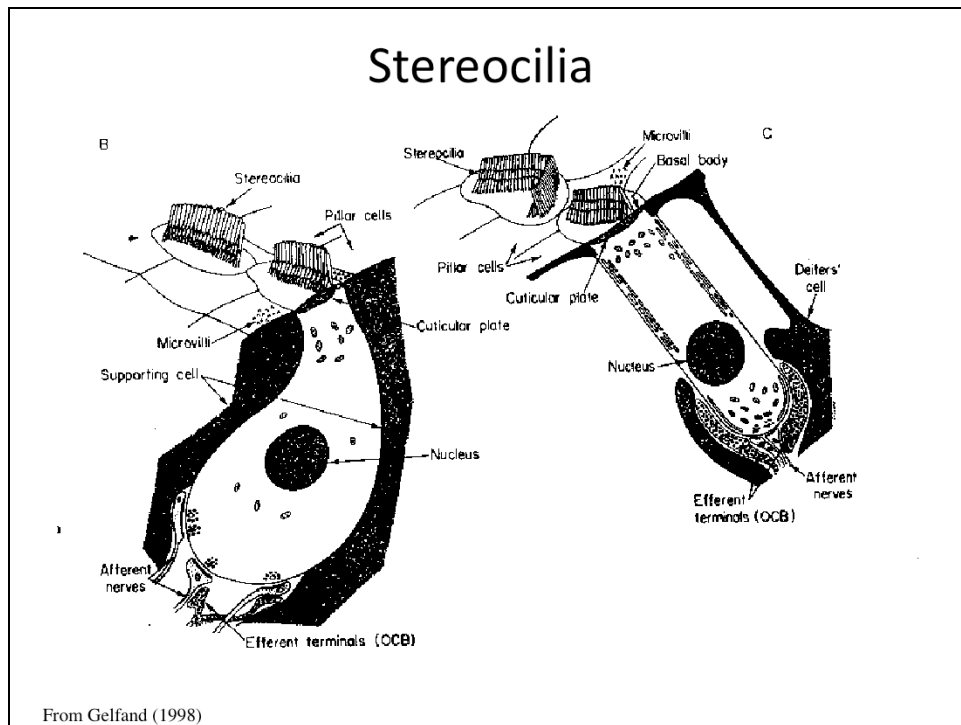
## Arrangement of hair cells



From Yost (1993), Courtesy of Dr. Ivan Hunter-Duvar, Hospital for Sick Children, Toronto

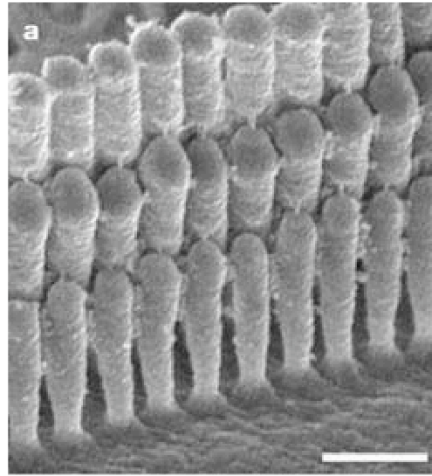
Outer hair cells, supported by Deiter's cells, form “columns” between the basilar membrane and the reticular lamina.

## Stereocilia



Stereocilia on inner (left) and outer (right) hair cells. Stereocilia are arranged in curved or v-shaped rows that face toward the modiolus.

## Arrangement of stereocilia



From Schneider et al. (2002)

Each row of stereocilia is taller than the next. The tip of each stereocilium is linked to the side of the stereocilium behind it by a tip link.

## Another view...

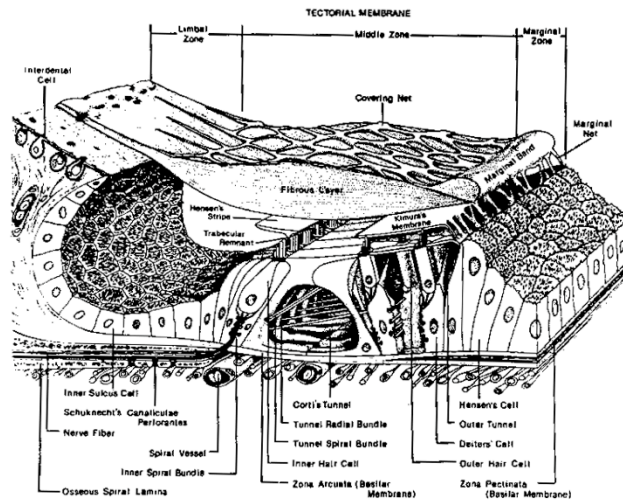
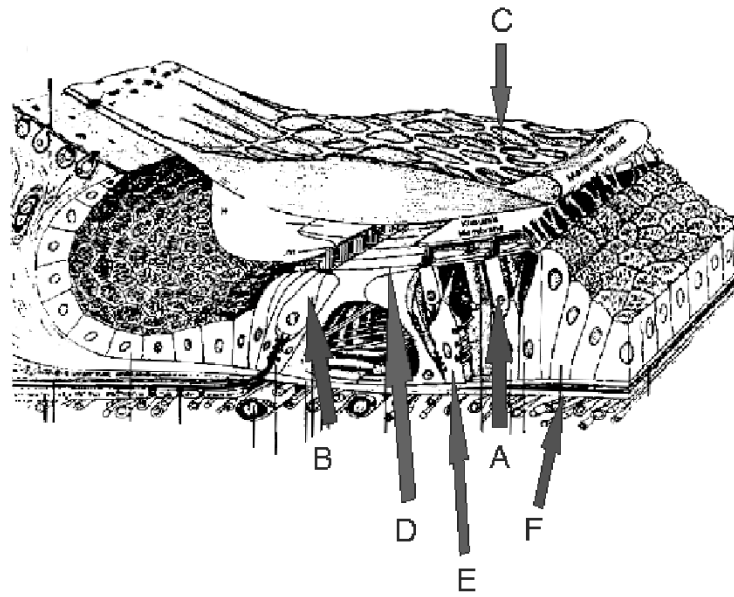


Figure 2.21 The tectorial membrane in relation to the other structures of the organ of Corti. From Lim (1980) with permission of *J. Acoust. Soc. Am.*

From Gelfand (1998)

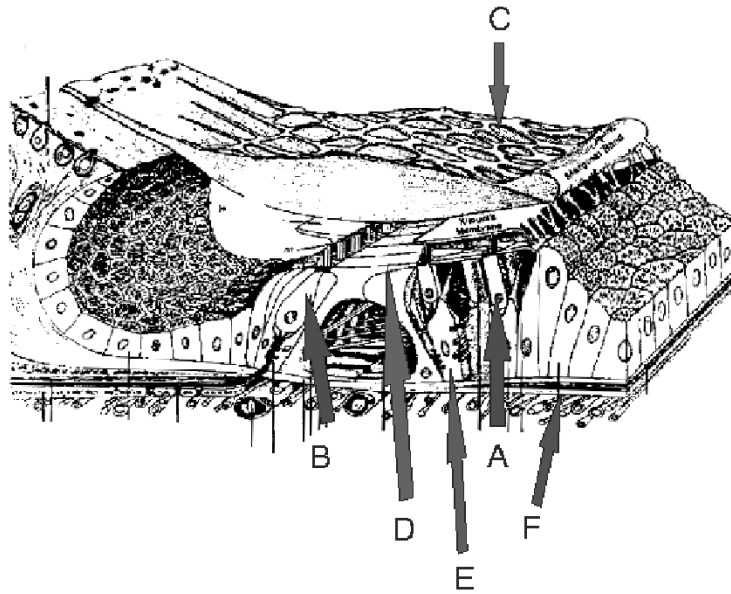
Outer hair cell?



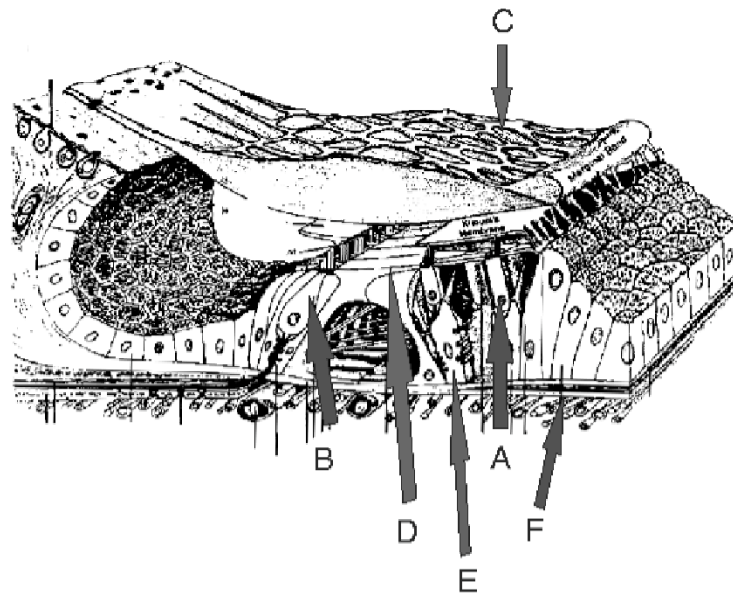




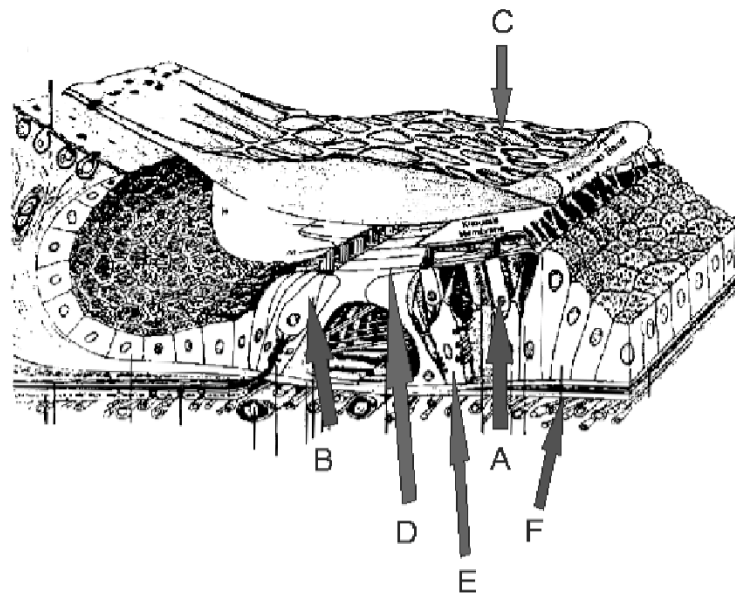
Tectorial membrane?



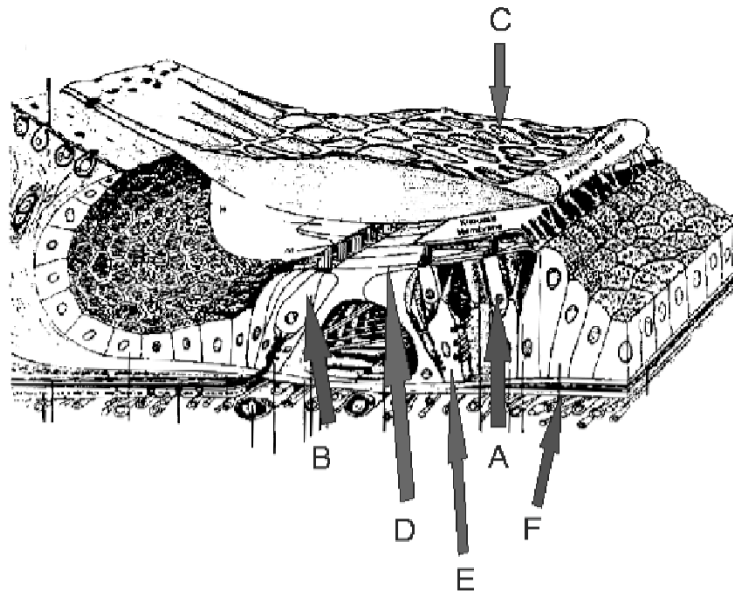
Reticular lamina?



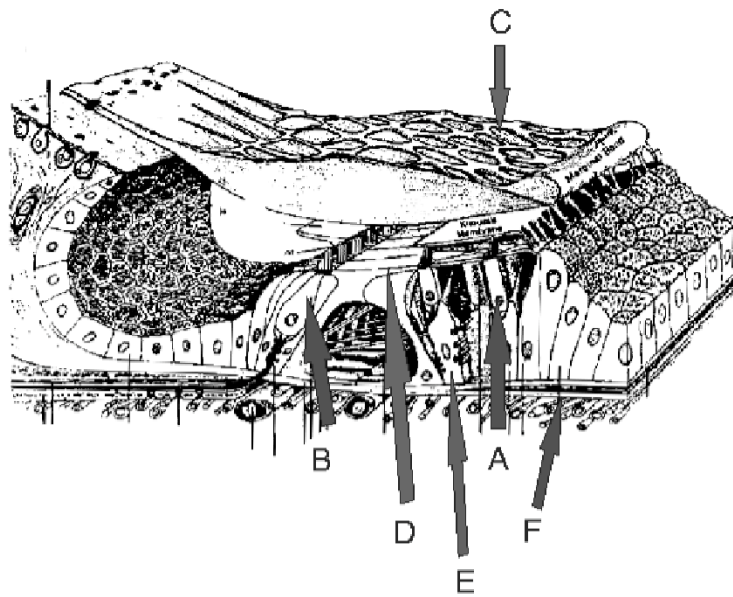
Basilar membrane?



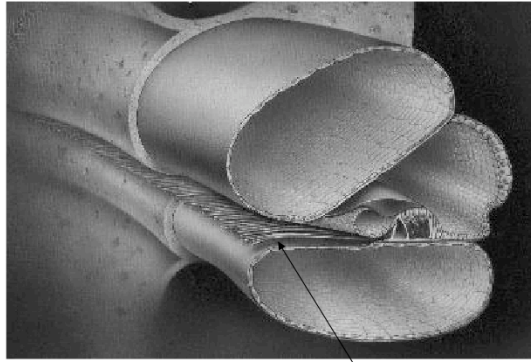
Deiters cell?



Inner hair cell?



## Innervation of the organ of Corti

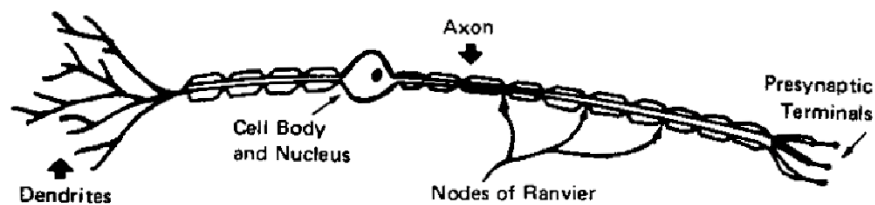


Nerve fibers

<http://btrh.boystown.org/cel/inside.htm/>

Nerve fibers exit the organ of Corti on the modiolar side.

## Neuron review



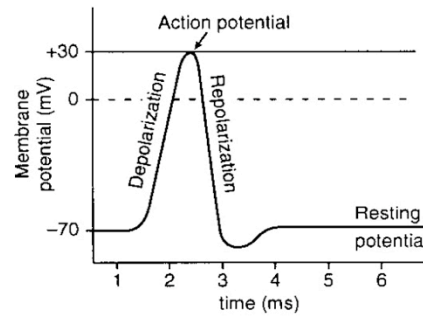
**Figure 2.32** Schematic drawing of a typical bipolar sensory neuron.

From Gelfand (1998)

In the auditory nerve, the dendrites contact the hair cells. The cell bodies form what is called the spiral ganglion, and the axons form the auditory nerve that connects the ear to the brainstem. The “contact” points between the dendrites and the hair cells or between the axons of one neuron and the dendrites of another are called synapses. Synapses have specialized structures and substances that allow communication between receptors and neurons or between neurons.



# Action potential

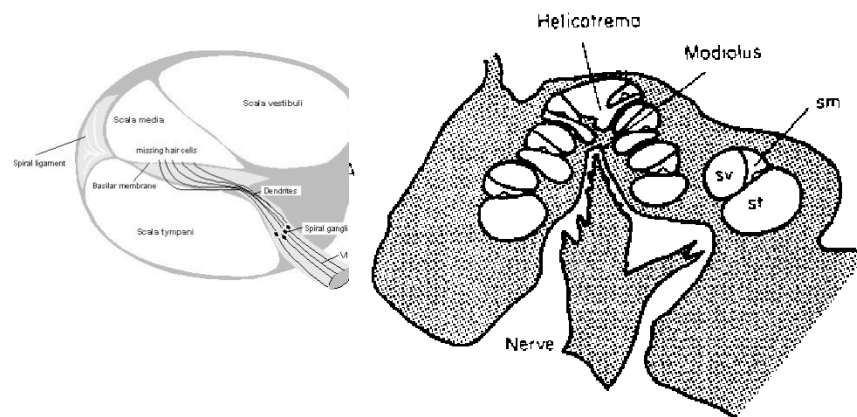


“spike”

From Kandel et al. (1991)

When a neuron's intracellular electrical potential is changed enough by release of neurotransmitter at a synapse (or in some other way), an abrupt change in electrical potential, an “action potential”, occurs. Action potentials are transmitted along the axon to another synapse, where neurotransmitter is released and an action potential may be generated in the neuron on the other side of the synapse (postsynaptic neuron).

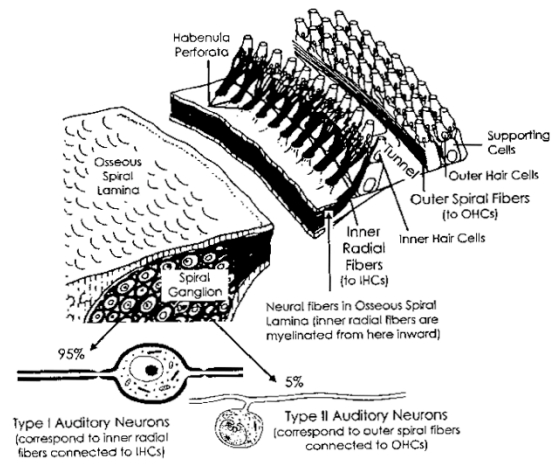
## The spiral ganglion



From Pickles (1992)

The cell bodies of the neurons that form the auditory nerve are located within the cochlear modiolus. The collection of cell bodies is called the spiral ganglion.

## Pattern of afferent innervation



From Gelfand (1998)

Different types of nerve fibers innervate IHCs and OHCs. Type I fibers innervate IHCs; Type II neurons innervate OHCs.

## Pattern of afferent innervation

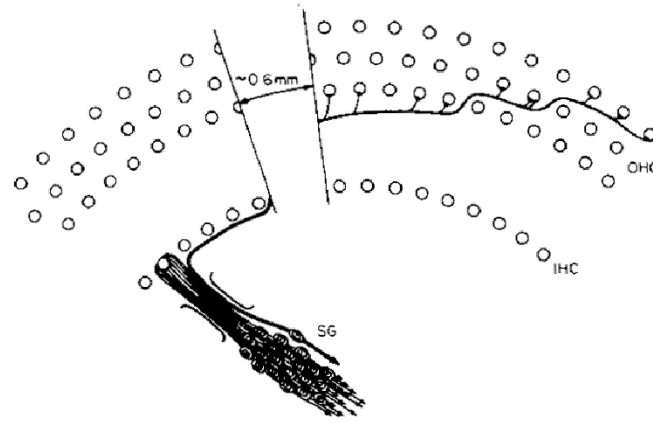


Fig. 3.6 The great majority of auditory nerve fibres (type I fibres) connect with inner hair cells. A few fibres (type II) pass to outer hair cells, after running basally for about 0.6 mm. IHC, Inner hair cells; OHC, Outer hair cells; SG, spiral ganglion. From Spoendlin (1978, Fig 8).

From Pickles (1992)

Nearly all of the nerve fibers that carry messages from the ear to the brain innervate inner hair cells. Notice that the many nerve fibers that contact one inner hair cells do not branch to other inner hair cells. Each IHC has its own “private” set of fibers. The Type II nerve fibers innervate many OHCs, and the OHCs they innervate are basal to the point at which the nerve fiber enters the cochlea.

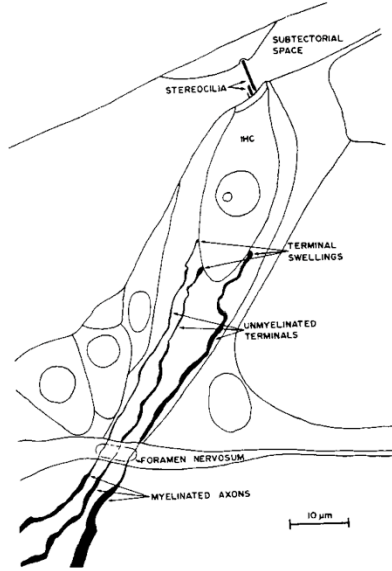


Figure 2.35 The thickest radial fibers attach to the IHC surface facing the OHCs, whereas the thinnest and medium thickness fibers attach on the surface toward the modiolus. From Liberman and Simmons (1985), with permission of *J. Acoust. Soc. Am.*

From Gelfand (1998)

There are  
differences  
among the  
fibers  
innervating  
an inner hair  
cell

Thin fibers attach toward modiolar side, thick fibers toward outer side of IHC.

## Pattern of efferent innervation

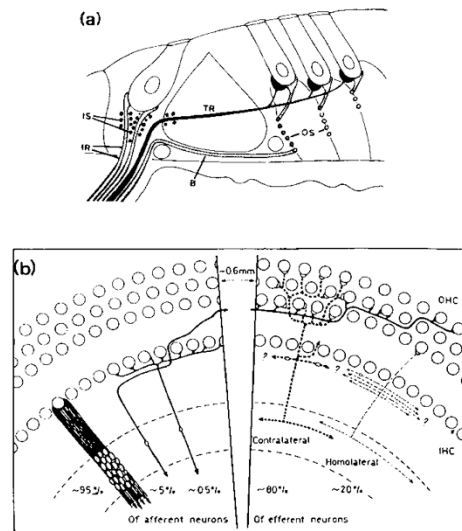
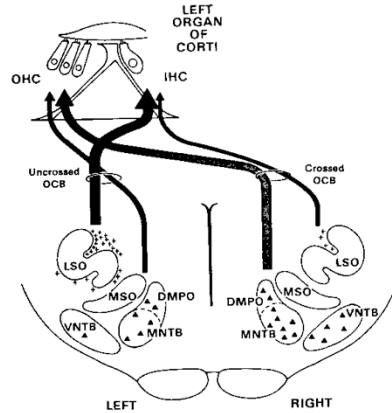


Figure 2.34 (a) Afferent and efferent innervation of the organ of Corti. Afferents gray and efferents black; IS, inner spiral fibers; IR, inner radial fibers; TR, tunnel radial fibers; B, basilar fibers; OS, outer spiral fibers. (b) Arrangement of nerve fibers to the inner and outer hair cells. From Spoendlin (1975) with permission.

From Gelfaqnd (1998)

Neurons from the brainstem also contact hair cells. These neurons carry information from the brain to the ear and are called efferent neurons. The vast majority of efferents innervate OHCs, and the contacts on OHCs differ from those on IHCs. Efferents form large calyx-shaped contacts on the OHC cell body; efferents form small bouton-like contacts on the afferent nerve fibers that contact IHCs.

## Sources of efferent cochlear innervation



**Figure 2.40** Schematic representation of the crossed and uncrossed olivocochlear bundles. As suggested by the wider lines, the crossed OCB goes mainly from the MSO to the contralateral OHCs, and the uncrossed OCB goes mainly from the LSO to the ipsilateral IHCs. OCB, olivocochlear bundle; LSO, lateral superior olive; MSO, medial superior olive; DMPO, dorsal periolivary nucleus; MNTB, medial nucleus of trapezoid body; VNTB, ventral nucleus of trapezoid body; triangles, large OCB neurons; crosses, small OCB neurons. Adapted from Warr (1978), *The Olivocochlear Bundle: Its Origins and Terminations in the cat*, in *Evoked Electrical Activity in the Auditory Nervous System*, R.E. Naunton and C. Fernandex (eds.), Copyright © 1978 by Academic Press.

From Gelfand (1998)

The nuclei shown here are in a part of the brainstem called the superior olivary complex. Fibers from both sides of the brain innervate both IHCs and OHCs, but the fibers innervating the two types of HC originate in different places. One recent study suggests that the SOC receives input from auditory cortex-- so fairly high level processing. The fiber tract containing the efferent fibers is known as the olivocochlear bundle (OCB). The tract from the same side of the brain is called the uncrossed OCB and the tract from the opposite side of the brain is called the crossed OCB.

When the ear talks to the brain, which hair cells are doing most of the talking?

- A. Inner hair cells
- B. Outer hair cells



When the brain talks to the ear, which hair cells is it talking to the most?

- A. Inner hair cells
- B. Outer hair cells

Each inner hair cell is connected to

- A. Many afferent nerve fibers that it shares with its neighbors
- B. One afferent nerve fiber
- C. Many afferent nerve fibers that it does not share with its neighbors
- D. No afferent nerve fibers.

## Conclusions

- The cochlea contains an array of highly specialized cells arranged in a highly specialized manner.
- There are structural differences between IHCs and OHCs that suggest that they differ in function
- The cochlea not only sends a message to the brain, but it may also receive messages from the brain via efferent innervation.

## Text sources

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- Kandel, E.R., Schwartz, J.H., & Jessell, T.M. (1991) Principles of neural science. Norwalk CT: Appleton & Lange.
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