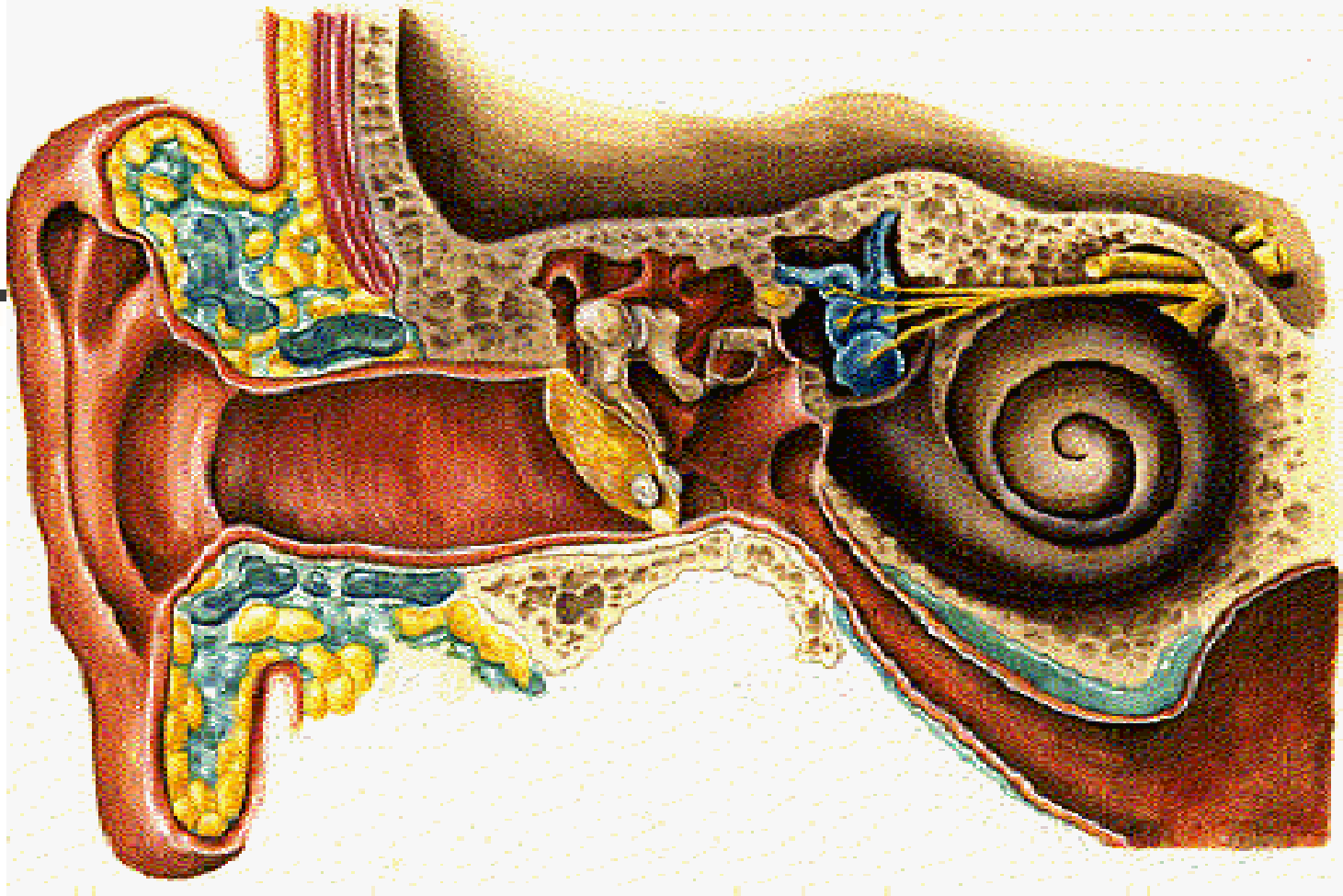
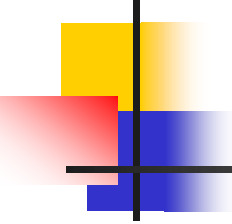


The Inner Ear



Ear Anatomy, Middle and Inner

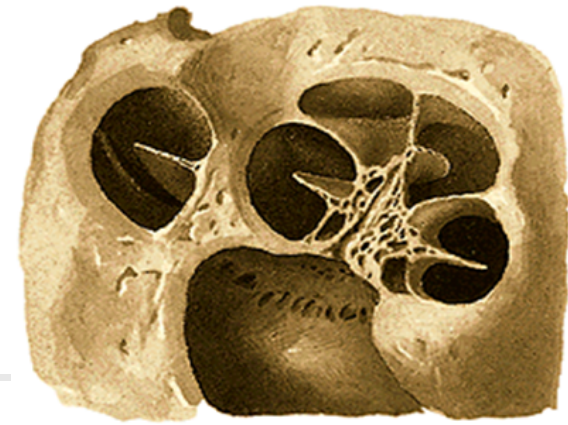




The Inner Ear

- A complex structure that place deep within the a very dense portion of the skull known as the **petrous portion** of the temporal bone.
- Because of its complexity it is also known as the a **labyrinth**
- The inner ear consists of a bony outer called, the **osseous labyrinth** and within in the bony structure is the **membranous labyrinth**

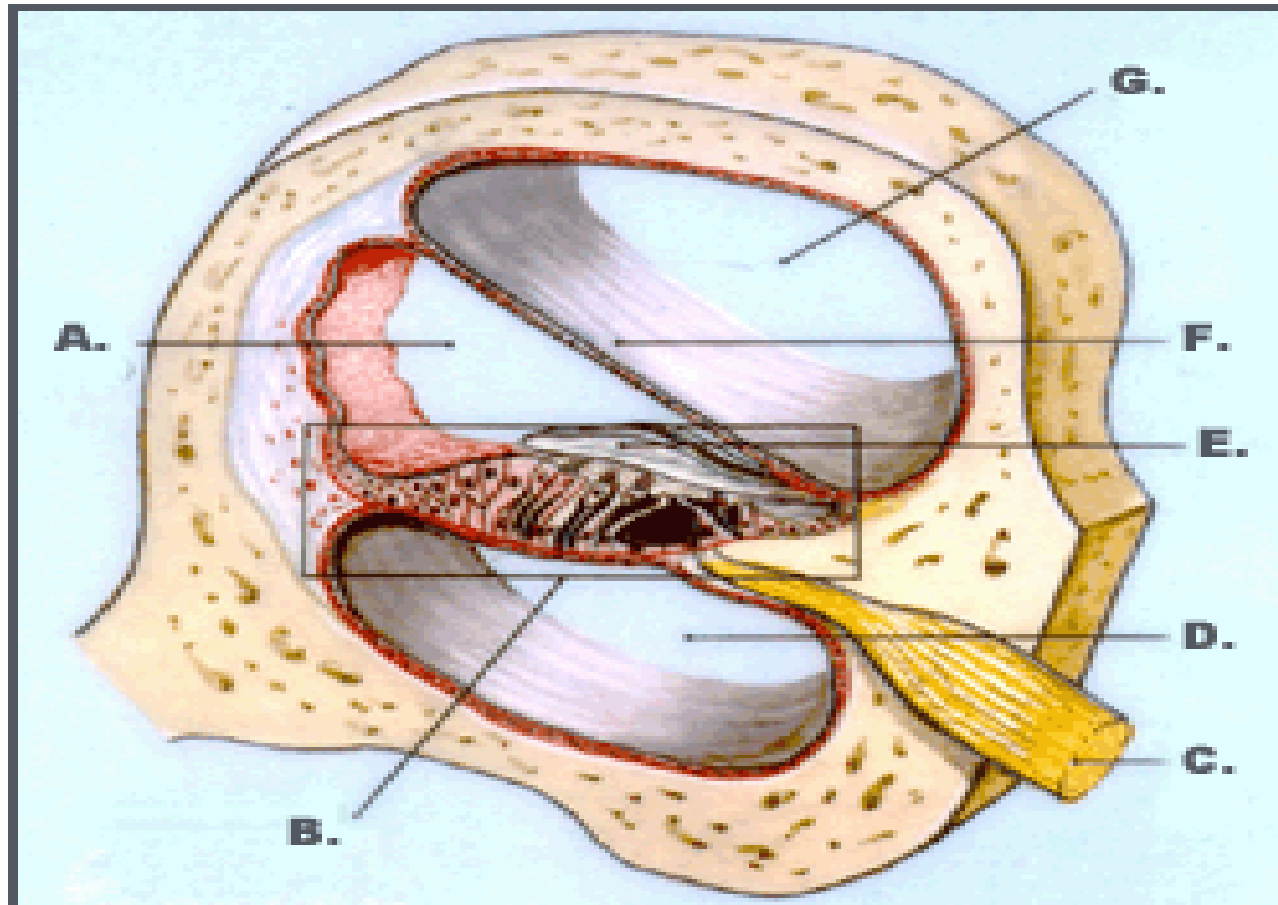
Osseous labyrinth



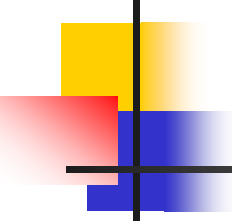
- Can be divided into 3 major sections:
 - The semicircular canals (superior, lateral, posterior)
 - The vestibule (mid portion)
 - The cochlea (snail shaped)
- The **semicircular canals and vestibule** assists in maintaining balance and posture, not hearing.
- The **cochlea** contains the sensory organ for hearing. It functions in hearing, by changing fluid energy into neural energy

The cochlea

- 
- Contains sensory organ for hearing.
 - snail-shaped cochlea has approx. $2\frac{3}{4}$ turns in the human ear.
 - Largest turn = basal turn
 - Smallest turn = apical turn (located at the top of cochlea)
 - 2 additional landmarks of the inner ear
 - Oval window (where footplate of the stapes attaches)
 - Round window



- A. SCALA MEDIA (COCHLEAR DUCT)
- B. ORGAN OF CORTI
- C. COCHLEAR NERVE
- D. SCALA TYMPANI
- E. TECTORIAL MEMBRANE
- F. VESTIBULAR MEMBRANE
- G. SCALA VESTIBULI



Membranous labyrinth

The compartment “sandwiched” between the coiled cochlea that runs throughout the osseous labyrinth. ■

Further subdivided into 3 compartments ■

All 3 are fluid filled ■

1. Scala media (middle compartment) filled with ■
endolymph

Basilar membrane ■

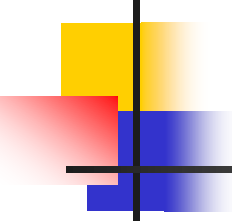
Reissner's membrane- opposite partition ■

2. Scala Vestibule ■

3. Scala tympani ■

These two contain a different type of fluid called ■

Perilymph

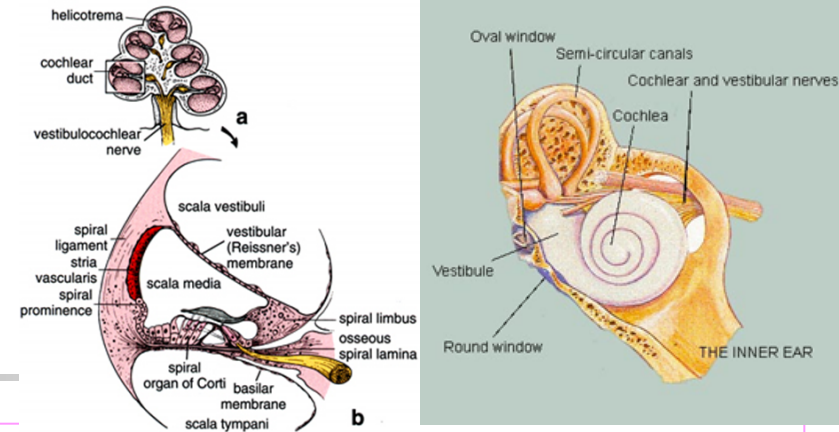


The cochlea

Reissner's membrane extends upward and diagonally from the osseous spiral lamina to a region of the outer wall slightly above the basilar membrane-thus there is a completely sealed “sac” in the middle of the cochlea called the cochlear duct, which runs the length of the cochlea, except for a small portion at the apex. ■

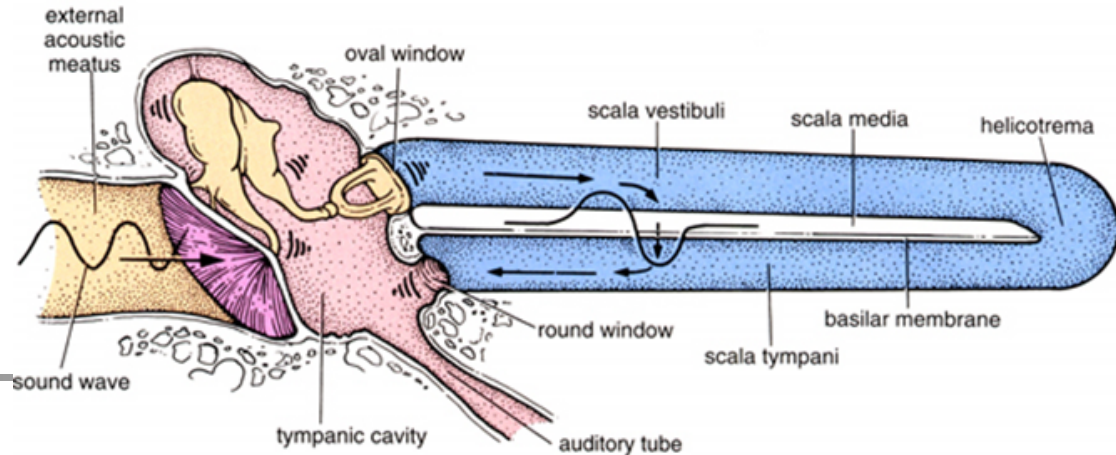
The outer wall of the scala media is covered by the stria vascularis, which has a dense layer of blood capillaries and specialized cells-it provides the basic metabolic control for the cochlea. ■

Inner ear

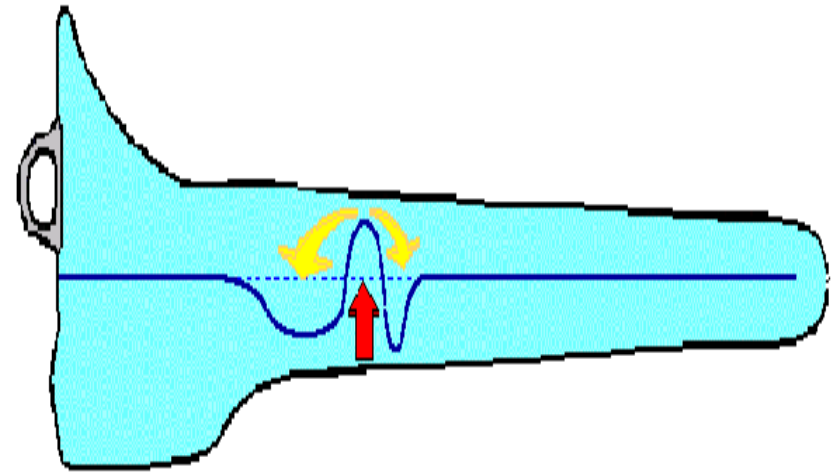


- At the apex of the cochlea is a small hole called the **helicotrema**, which connects the perilymph filled compartments (scala tympani & scala vestibuli)
- The **oval window** forms an interface btw the ossicular chain and the fluid filled scala vestibuli
- When the oval window vibrates as a consequence of vibration of the ossicular chain, **a wave is established within the scala vestibuli**
- Must be outward displacement to match the OW inward displacement and this happens at the **round window**, which communicates directly with the scala tympani

Cochlea



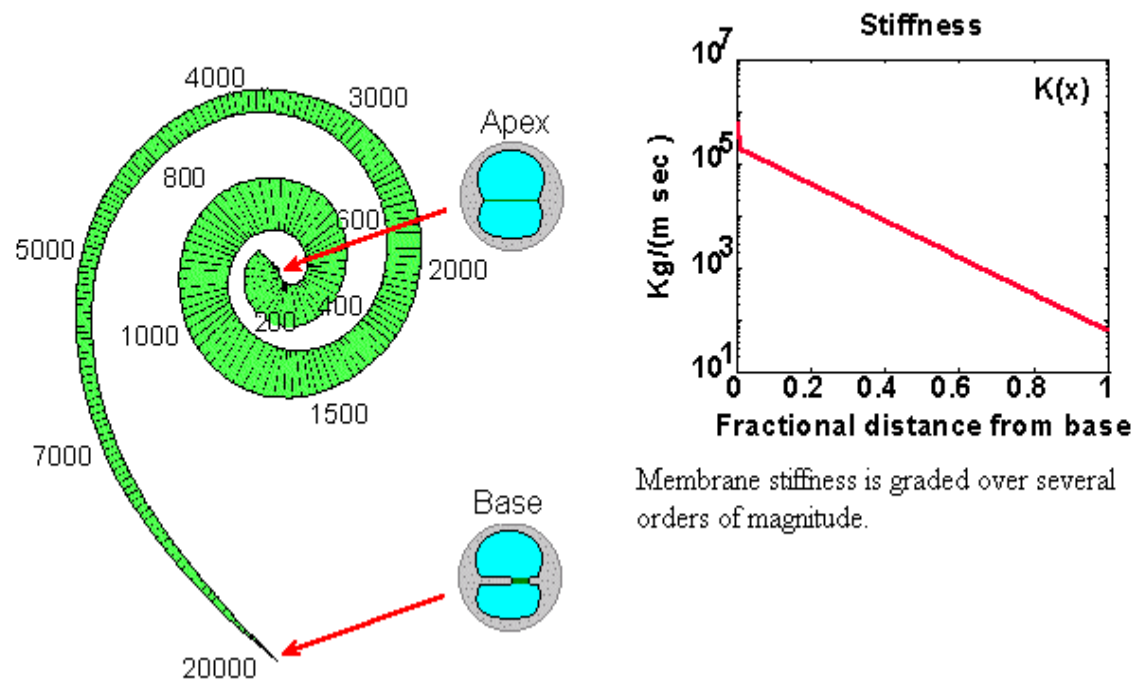
- This wave displaces the scala media in a “wave-like manner.”
- The displacement pattern is simplified by the basilar membrane as well as the Reissner’s membrane

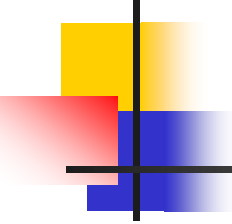


Longitudinal section of the “uncoiled” cochlear duct. Stiffness gradient combines with hydrodynamics to shrink the wave-length.

Basilar membrane

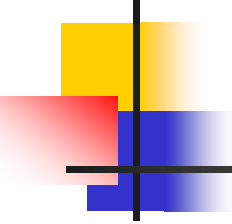
Basilar membrane





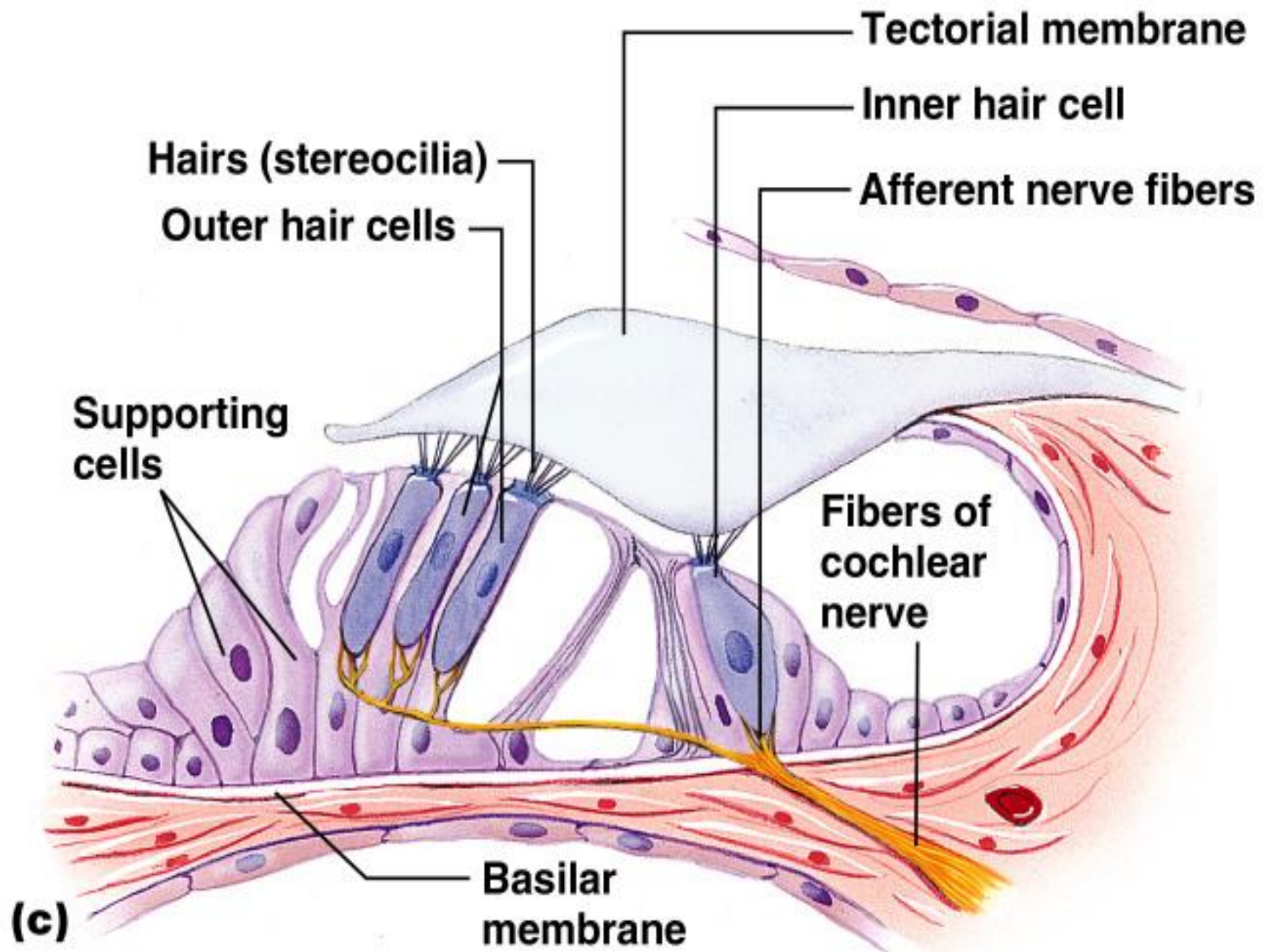
BM

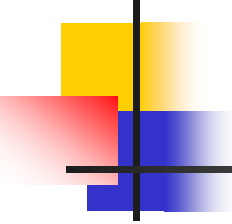
- The primary physical feature of the inner ear responsible for the direction in which the traveling wave progresses is the **stiffness gradient of the basilar membrane.**
- The BM is stiffer at the base and the stiffness decreases as you move toward the apex. **Stiffness has greatest opposition to displacement of low frequencies.**
- That opposition forces low frequency waves to travel up the cochlea to the apex where there **is less stiffness and less opposition to low frequency vibration.**



Organ of Corti

- Sensory organ of hearing
- Rest on top of the basilar membrane and below the tectorial membrane
- Contains several thousand sensory receptor cells called **hair cells**
- Each hair has several tiny hairs protruding from the top of the cell called **cilia**





Organ of Corti

Two types of hair cells ■

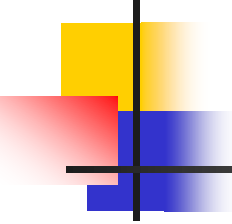
1. **inner hair cells**- make up a single row of ■
receptors located closest to the bony core of
cochlea (modiolus)

Free standing, meaning they don't make contact ■
with any other structures

Approx 90-95% of the auditory nerve fibers that ■
carry information to the brain make contact with
the inner hair cells

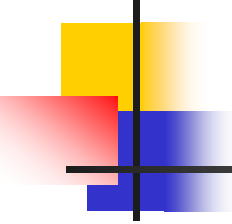
2. **outer hair cells**- much greater in number and ■
organized in 3 rows.

The cilia of the outer hair cells are embedded within ■
a gelatinous structure – **tectorial membrane**, which
overhangs the organ of corti



Inner hair cells

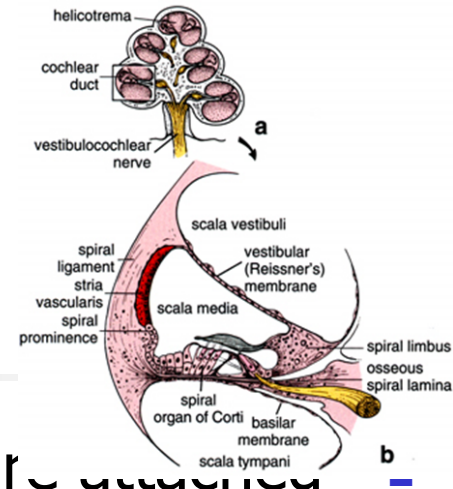
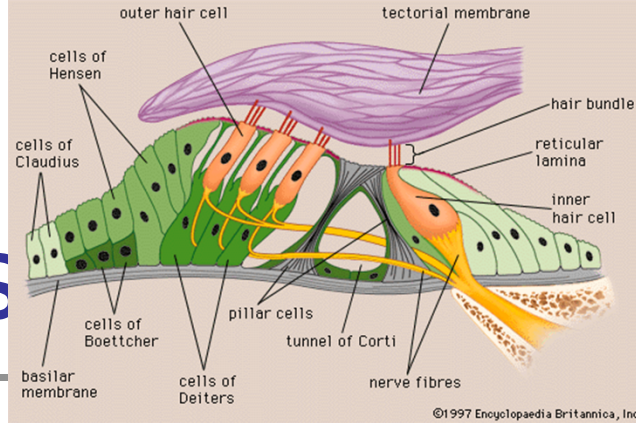
- The tips of the hair cells are called stereocilia, these structures fire an electrochemical signal every time they are bent or displaced by the movement (shearing force) of the basilar membrane and the contact made by the tectorial membrane which rest above the Organ of Corti
- Kinocilium is an extremely long cilium



Outer Hair cells

The outer hair cells as well as  changing the energies of the wave, also help in changing the response of the cochlea. The outer cells can do this because they have more movement due to their covering which works like muscle fibers this flexibility and motion gets more energy to the basilar membrane which makes sound more fine tuned.

Hair Cells

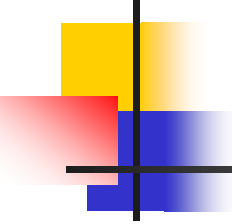


Tect. Memb is a soft ribbon like structure attached along one edge to the **spiral limbus**

When the basilar membrane is displaced in an upward direction (toward scala vestibuli) the cilia of OHC undergo a shearing force in a radial direction (horizontal direction)

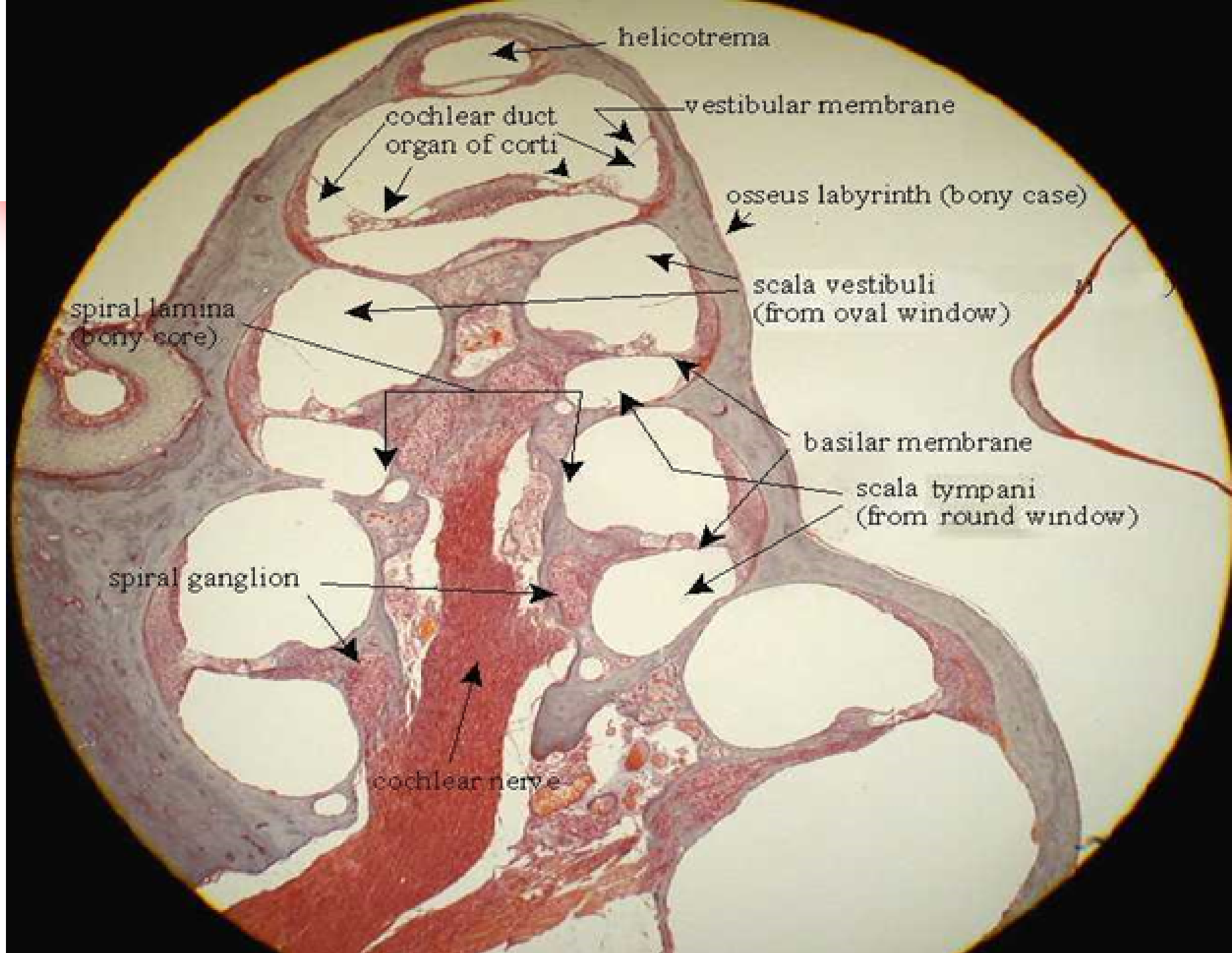
Displacement in a downward direction develops a radial shearing force in opposite direction.

This shearing force is believed to be the trigger that initiates a series of **electrical and chemical processes within the hair cells**



Hair cells

In turn, this leads to the activation of ■
the auditory nerve fibers that are in
contact with the base of the hair cell



Anatomy of vestibular labyrinth

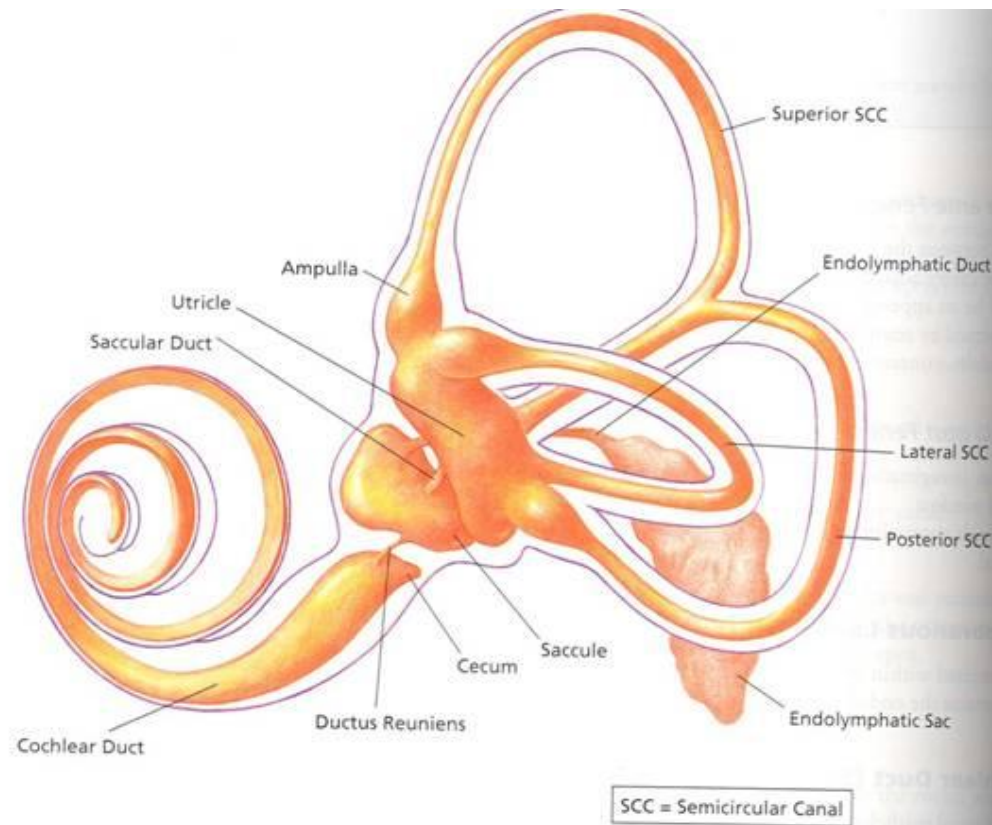
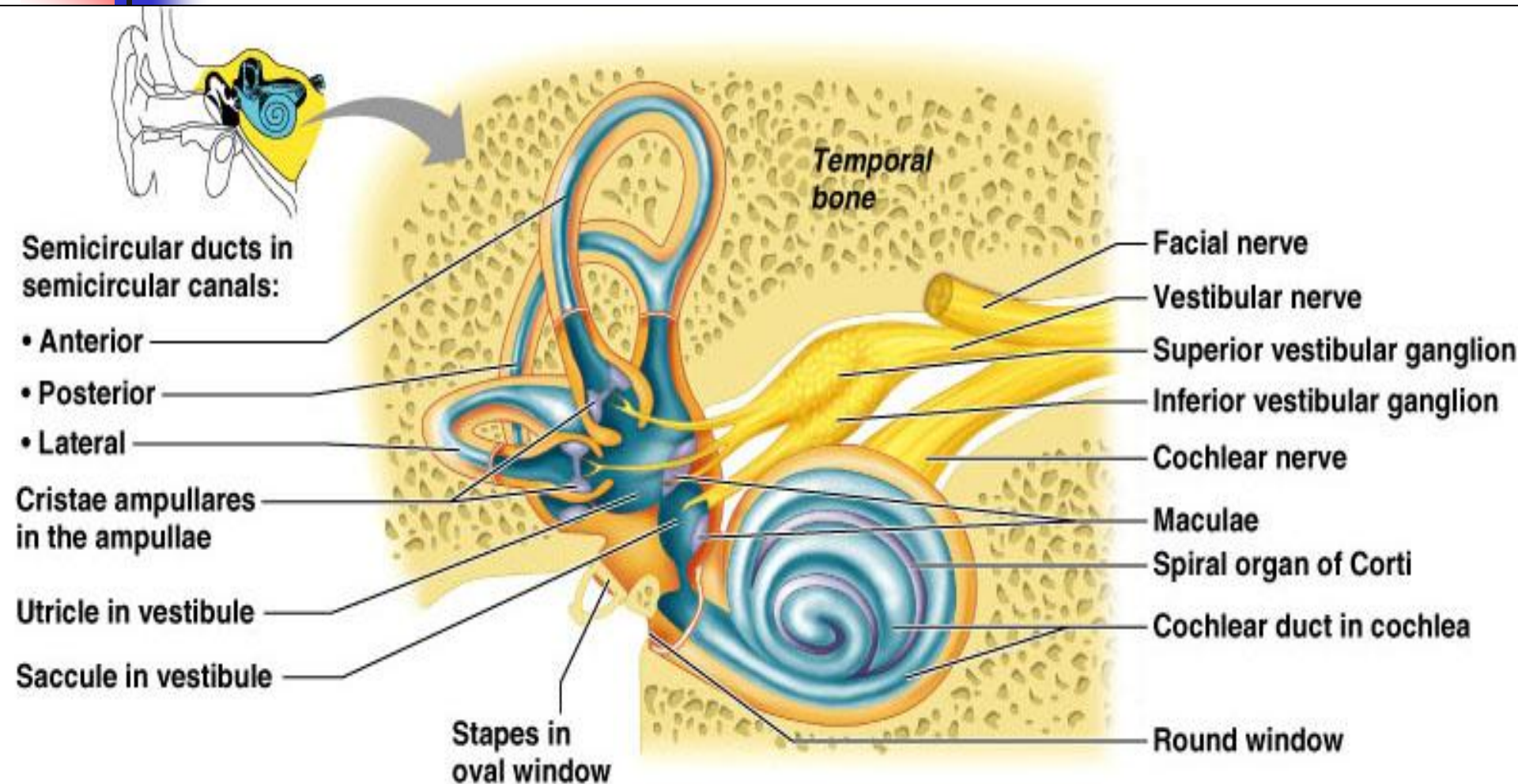


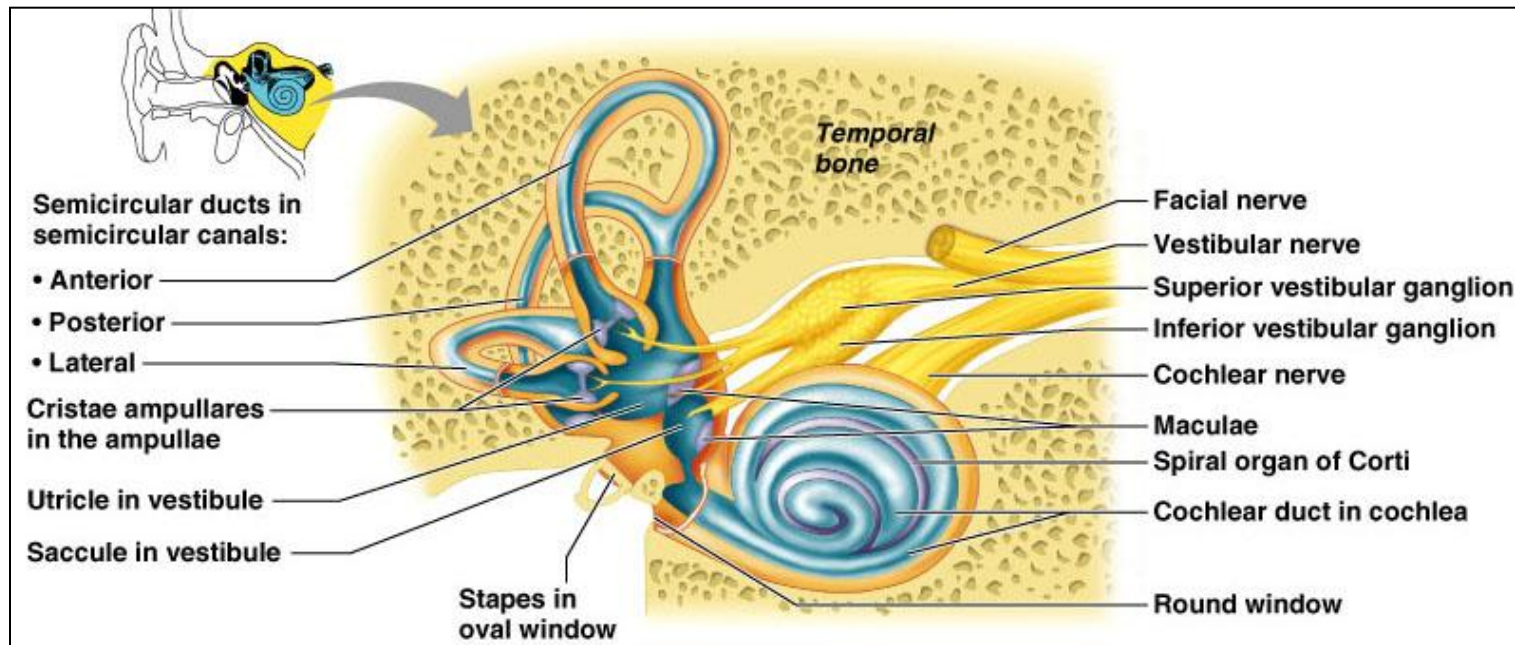
FIG. 9.22. Membranous labyrinth.

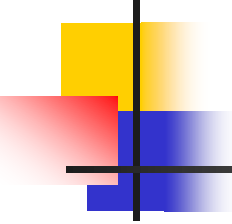
The Vestibule central cavity of the bony labyrinth with two suspended sacs: the saccule and utricle. The saccule is continuous with the cochlea
The utricle is continuous with the semicircular canals
Both sacs contain equilibrium receptors called maculae that respond to gravity and changes in the position of the head



The Semicircular Canals – Angular Movement

3 canals lying in the three planes of space - membranous semicircular ducts line each canal and communicate with the utricle - the ampulla is the expanded end of each canal and houses equilibrium receptors in a region called the crista ampullaris -these receptors respond to angular movements of the head

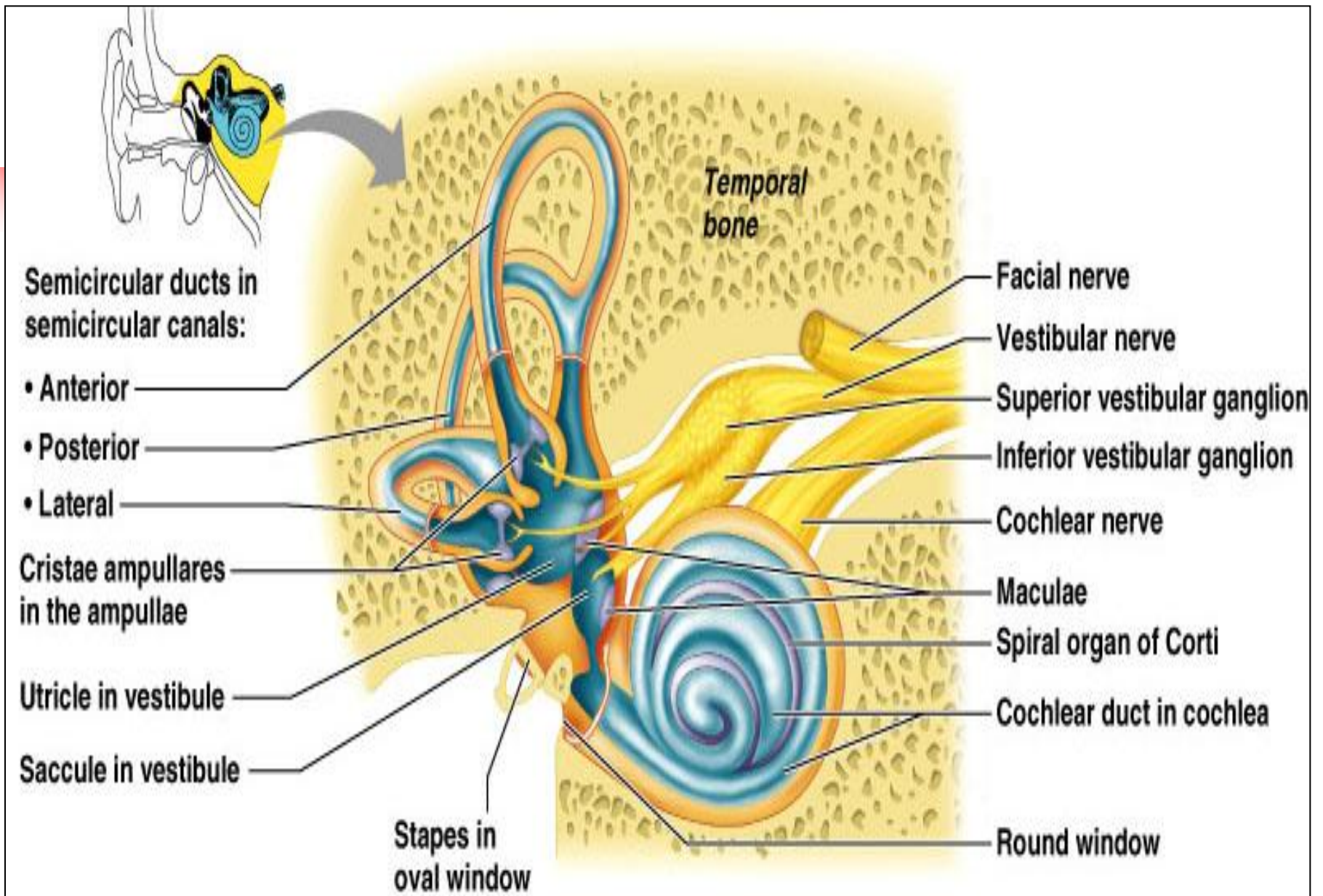




Vestibular receptor organs

Ampulla of the semicircular canals and the utricle of the maculae (otolith organ) ■

Contains sensory neuroepithelium, crista, supporting cells ■



Crista ampullaris is
made up of sensory
hair cells and
supporting cells

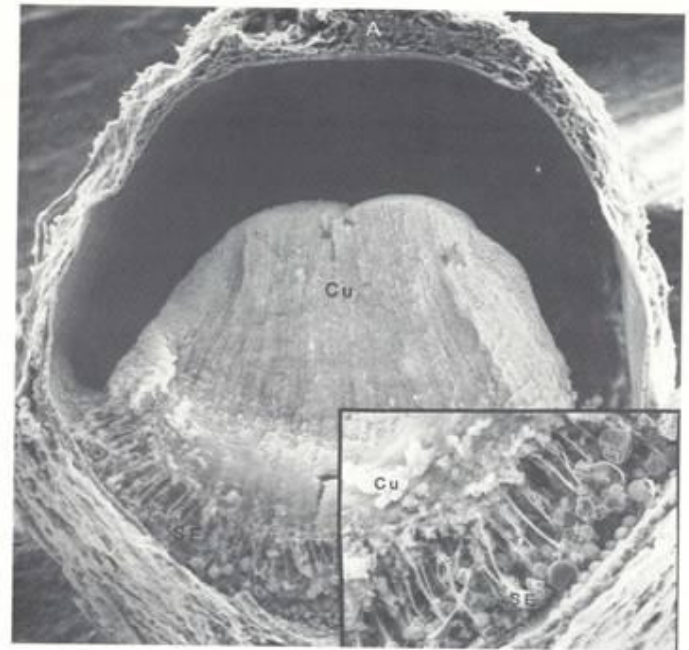


Figure 9.37 Scanning micrograph of the ampulla (A) of a chinchilla showing the cupula (Cu). The cupula is seen to cover the sensory epithelium (SE) of the crista completely. Inset is a higher magnifica-

tion and shows the contact between the cilia of the sensory cells and the cupula (Cu) in the area it covers.

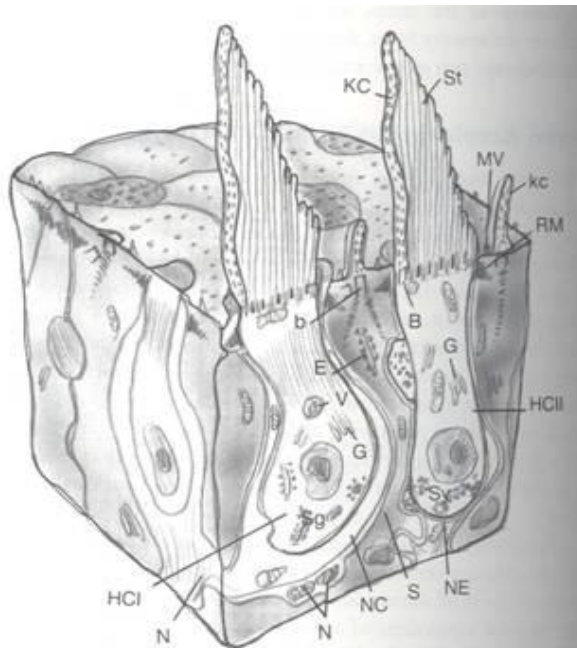


FIGURE 130.5. Vestibular sensory epithelium and its innervation. HCI, HCII, Types of hair cells; St, stereocilia; KC, kinocilia (kc, modified kinocilia and roots [b] of supporting cells, [S]); N, nerve fiber; NC, nerve chalice; NE, nerve endings; Sy, synaptic structures (G, Golgi membranes; RM, multivesicular reticular membrane; E, endoplasmic reticulum; MV, microvilli; V, vesicle). (Modified from Spoendlin HH. The ultrastructure of the vestibular sense organ. In: Wolfson RJ, ed. *The vestibular system and its diseases*. Philadelphia: University of Pennsylvania Press, 1966: 39, with permission.)

- Sensory cells are either Type I or Type II
- Type I cells are flask shaped and have chalice shaped calyx ending
- Type II cells – cylinder shaped, and has no nerve chalice.