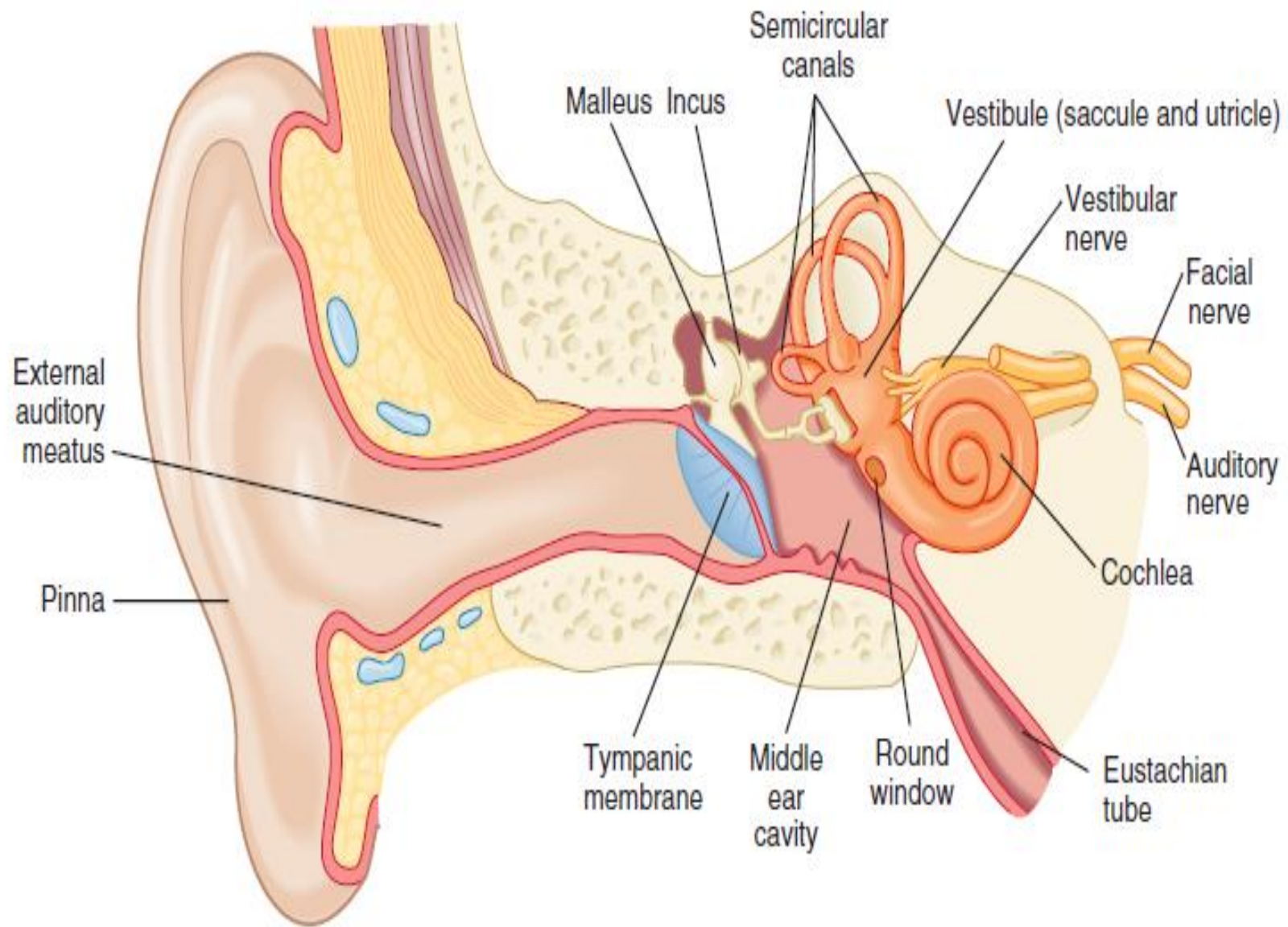
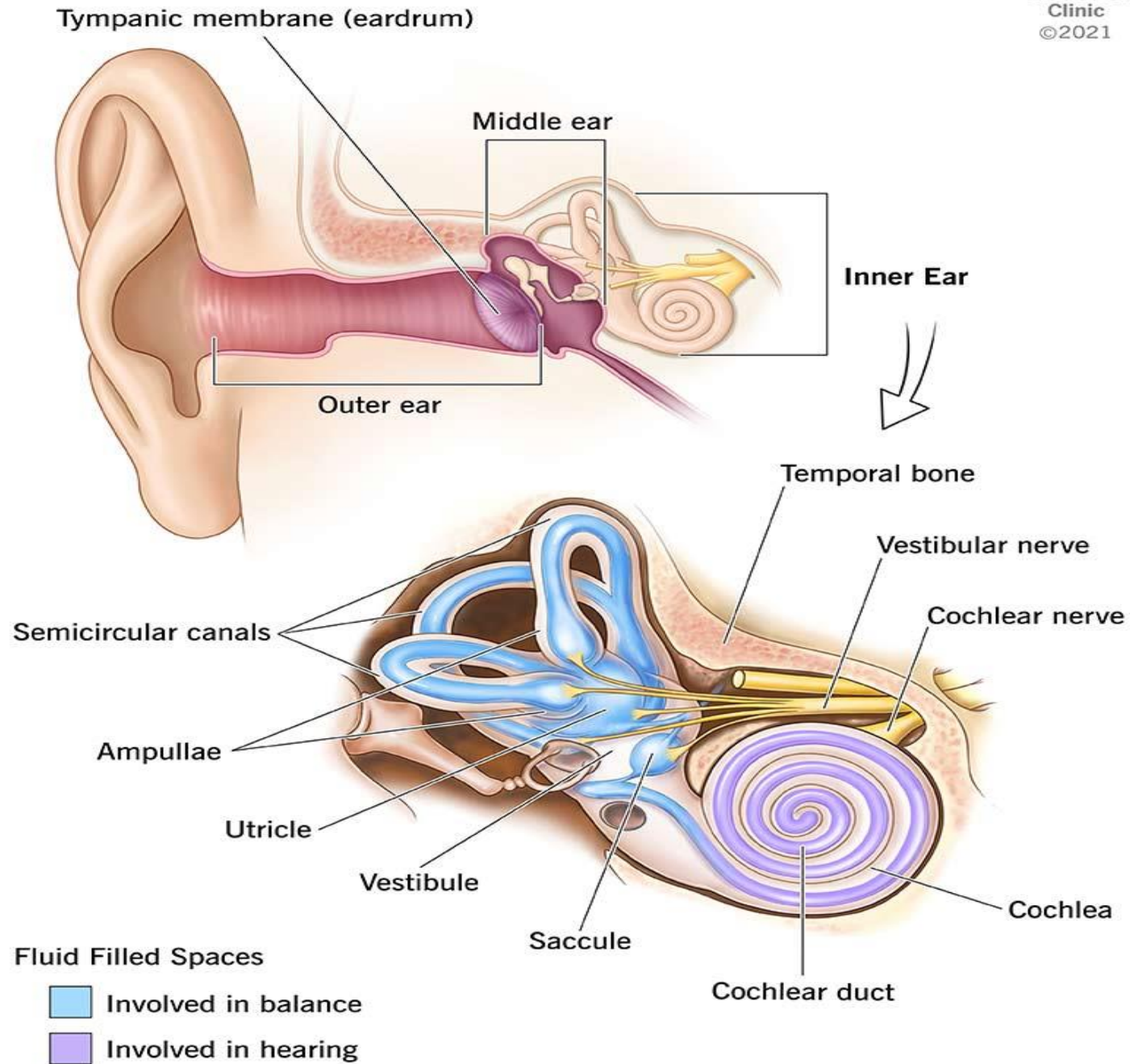


VESTIBULAR APPARATUS

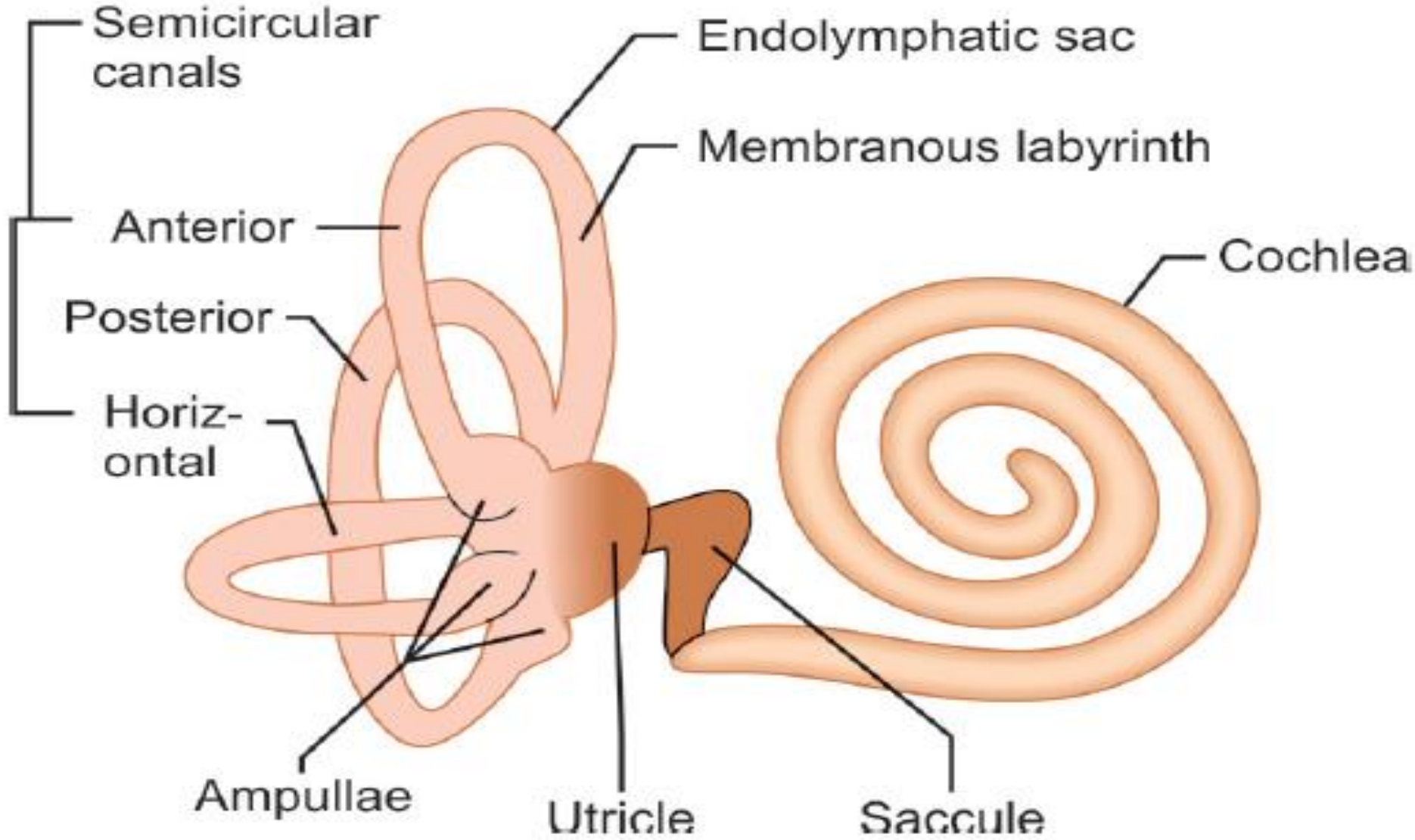


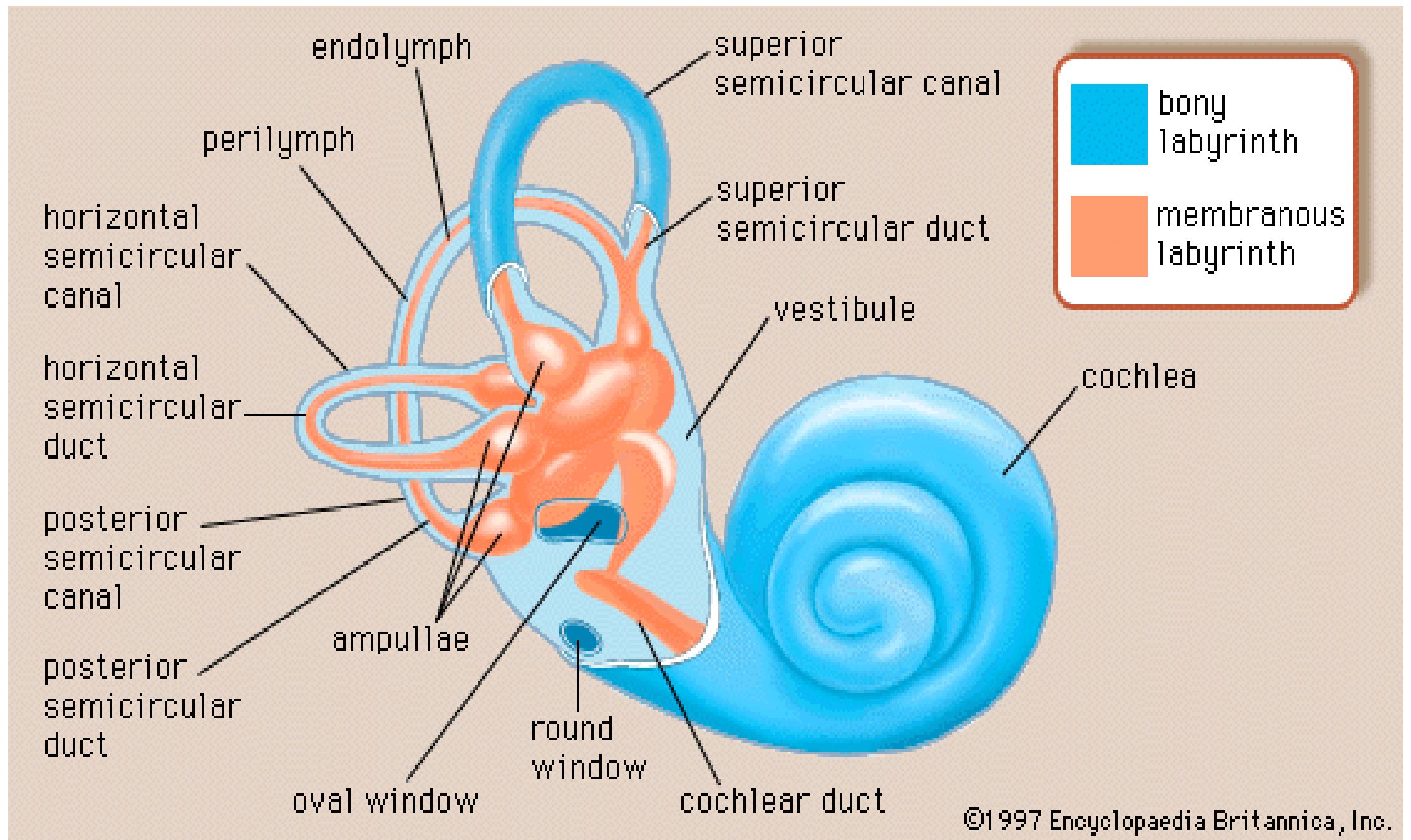
Inner Ear



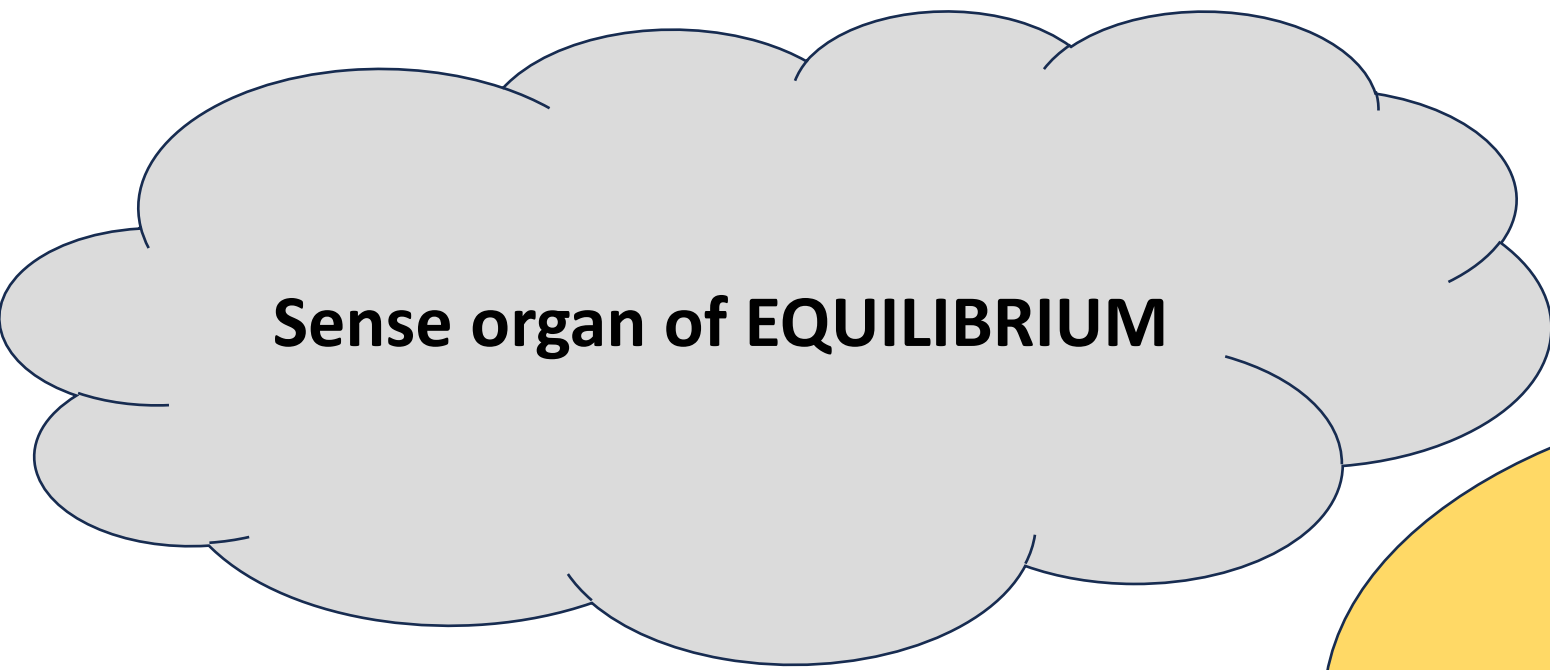
INNER EAR/ LABYRINTH

- Location → *PETROUS PART OF TEMPORAL BONE*
- **BONY LABYRINTH**
 - VESTIBULE
 - SEMICIRCULAR CANALS
 - COCHLEA
- **MEMBRANEOUS LABYRINTH**
 - VESTIBULAR APPARATUS
 - DUCT OF COCHLEA

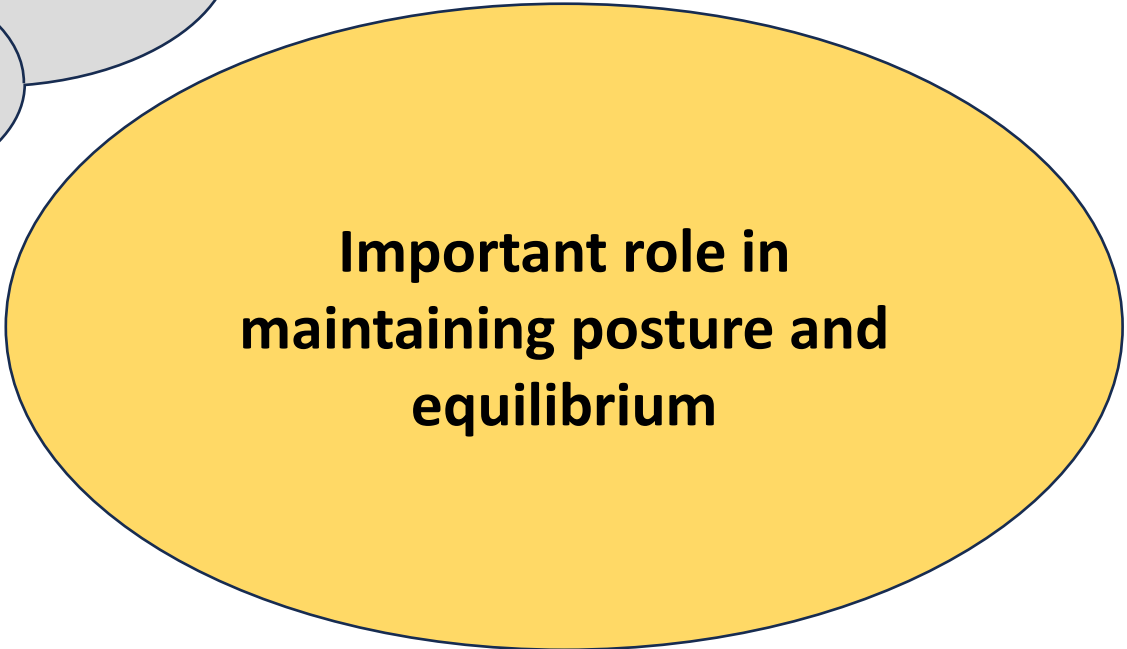




VESTIBULAR APPARATUS



Sense organ of EQUILIBRIUM



**Important role in
maintaining posture and
equilibrium**

Membranous labyrinth contains
ENDOLYMPH → rich in **K⁺**

Space between bony and membranous
labyrinth → **PERILYMPH**

VESTIBULAR APPARATUS

```
graph TD; A[VESTIBULAR APPARATUS] --> B[OTOLITH ORGANS]; A --> C[SEMICIRCULAR CANALS]; B --> D[UTRICLE]; B --> E[SACCCULE]; C --> F[ANTERIOR]; C --> G[POSTERIOR]; C --> H[HORIZONTAL];
```

OTOLITH
ORGANS

UTRICLE

SACCCULE

SEMICIRCULAR
CANALS

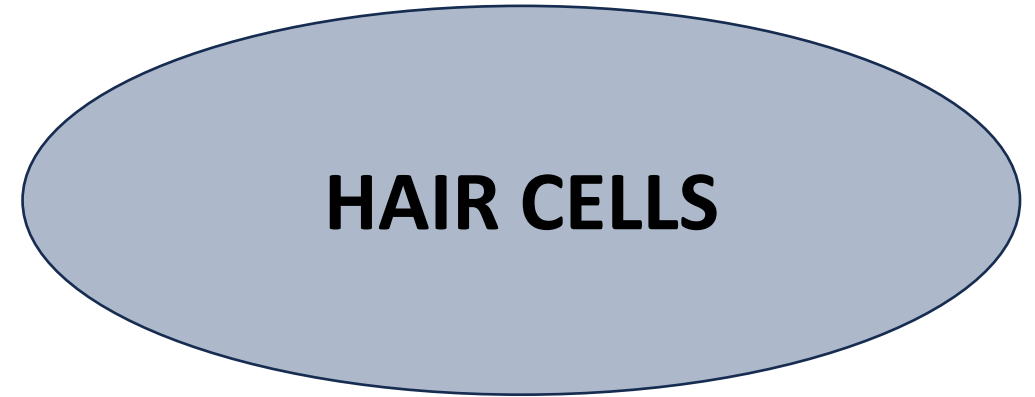
ANTERIOR

POSTERIOR

HORIZONTAL

SENSORY RECEPTORS IN THE EAR

- *Mechanoreceptors*



- Organ of Corti → Hearing
- Utricle → Horizontal Linear Acceleration
- Saccule → Vertical Linear Acceleration
- Semicircular canals → Rotational Acceleration

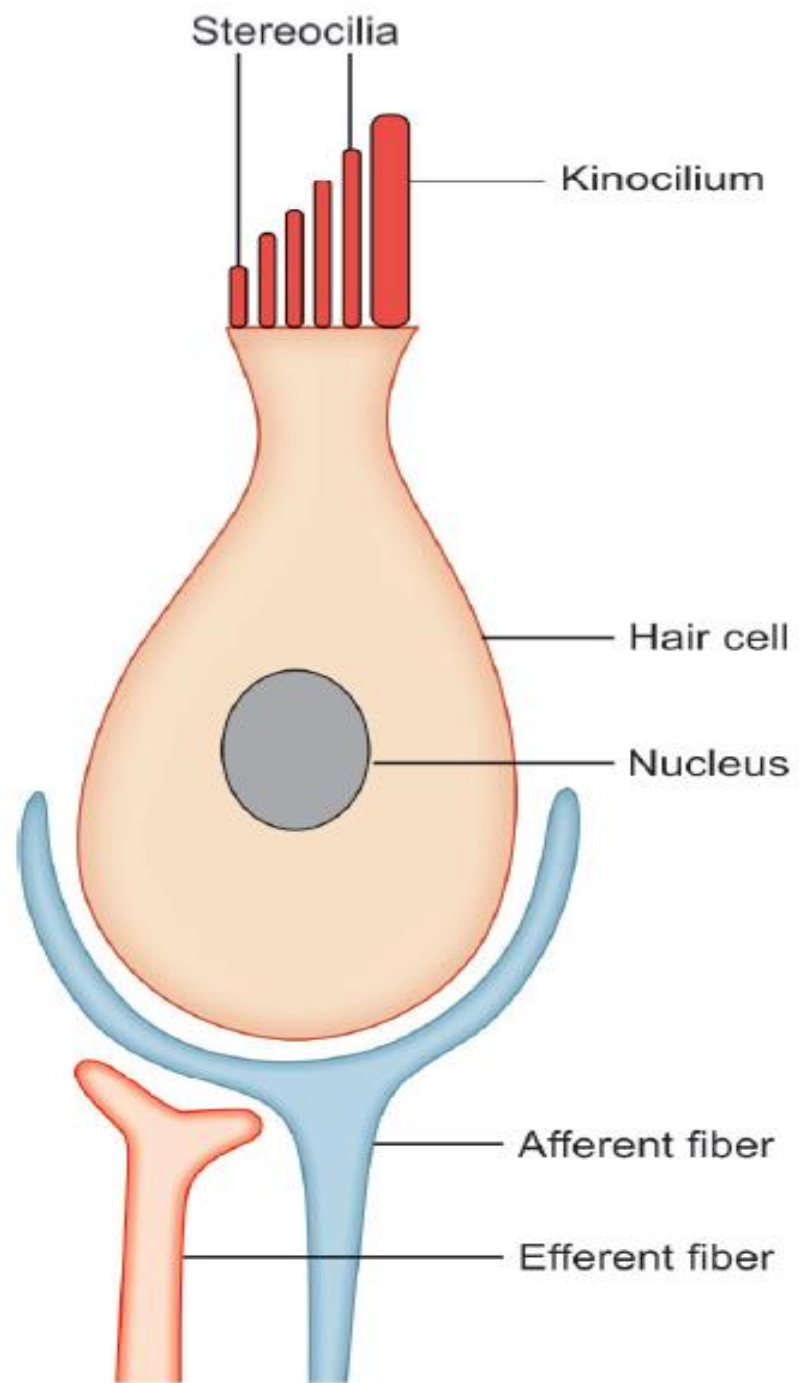
STRUCTURE OF HAIR CELL

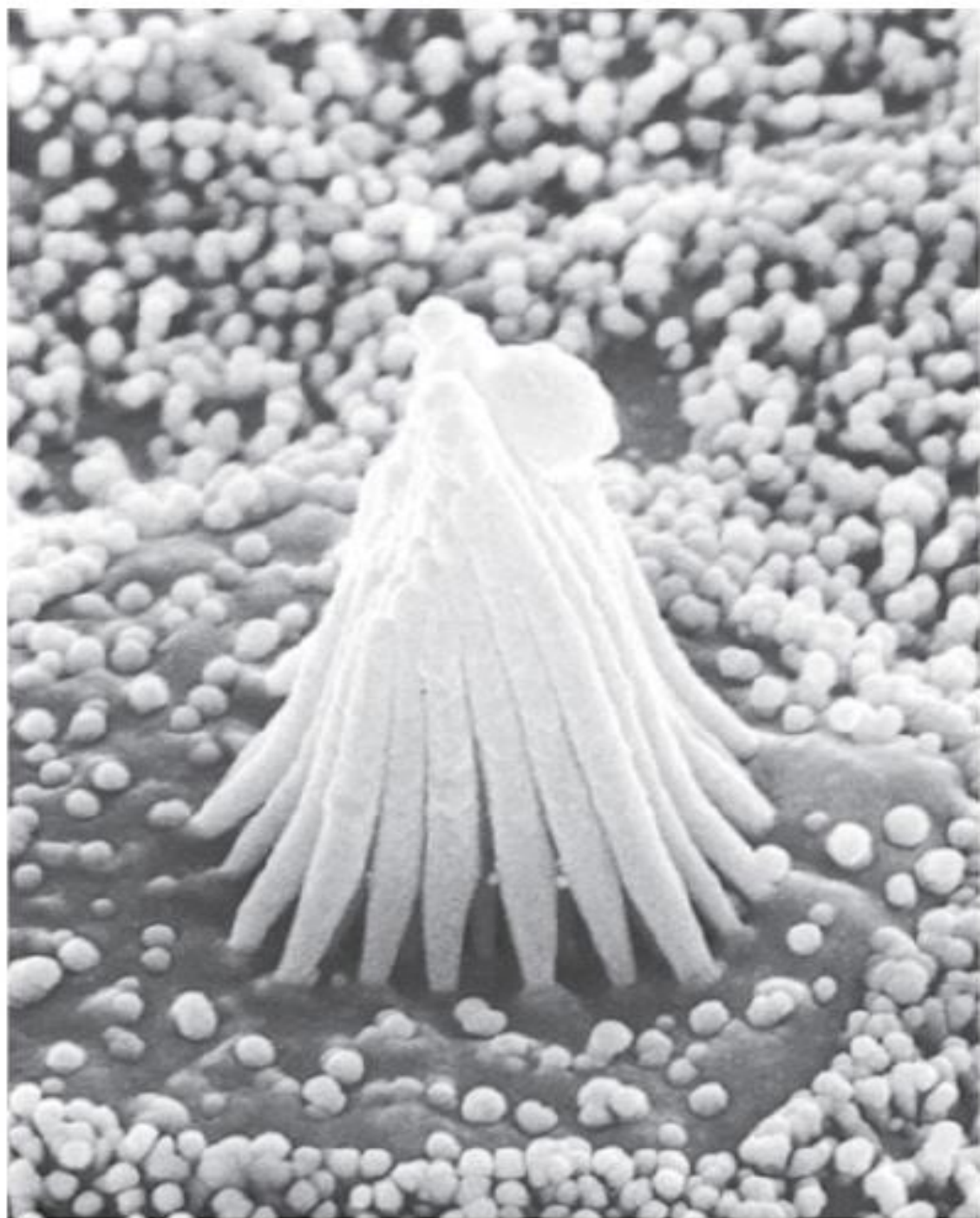
- Each hair cell → embedded in an epithelium made up of SUPPORTING CELLS
- **Apical end** → 30 – 150 rod-shaped processes or **HAIRS**
- **Basal end** → in close contact with **AFFERENT NEURONS**

RMP of hair cell = -60 mV

HAIRS

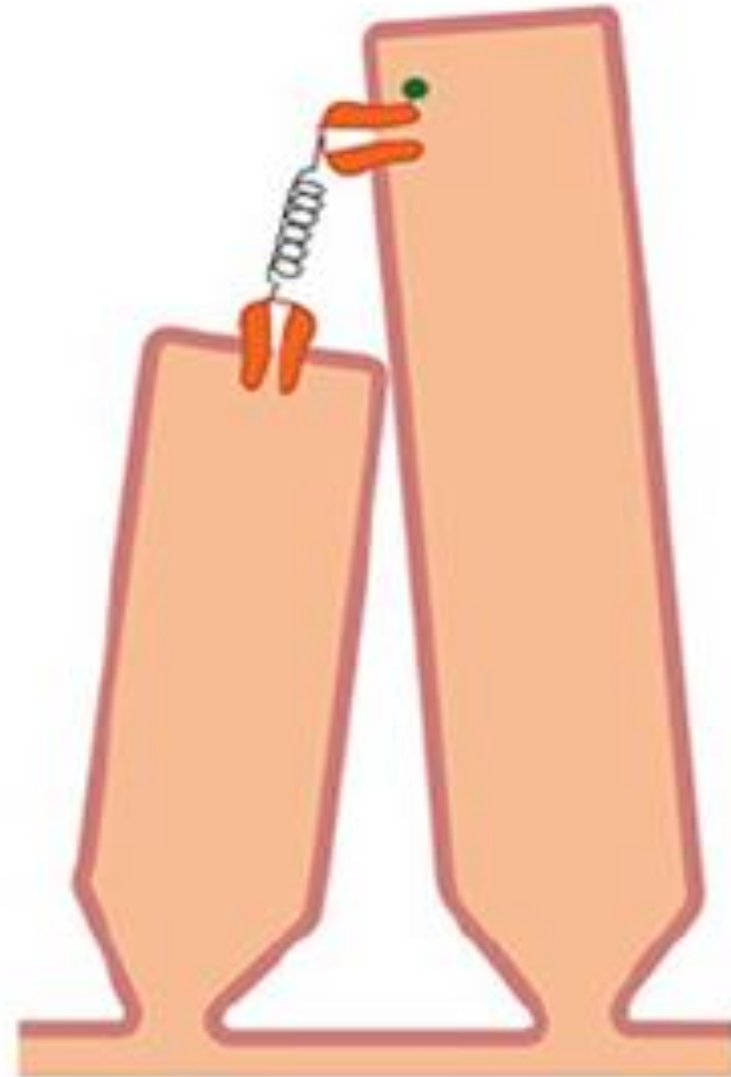
- One of these – **KINOCILIUM**
- True cilium
- Non-motile
- 9 pairs of microtubules around its circumference and a central pair of microtubules
- *Absent in the cochlea*
- The rest – **STEREOCILIA**
- Present in all hair cells
- Progressively increase in height along the axis of Kinocilium
- Core – **ACTIN**
- Coated with **MYOSIN**





TIP LINKS

- Very fine processes
- Tie the tip of each stereocilium to the side of its higher neighbour
- At the junction of attachment of tip links on the taller process →
MECHANICALLY – SENSITIVE CATION CHANNELS



MECHANISM

Shorter stereocilia are pushed toward the taller ones lead to stretching of tip links



Opening of mechanically – sensitive cation channels in taller process



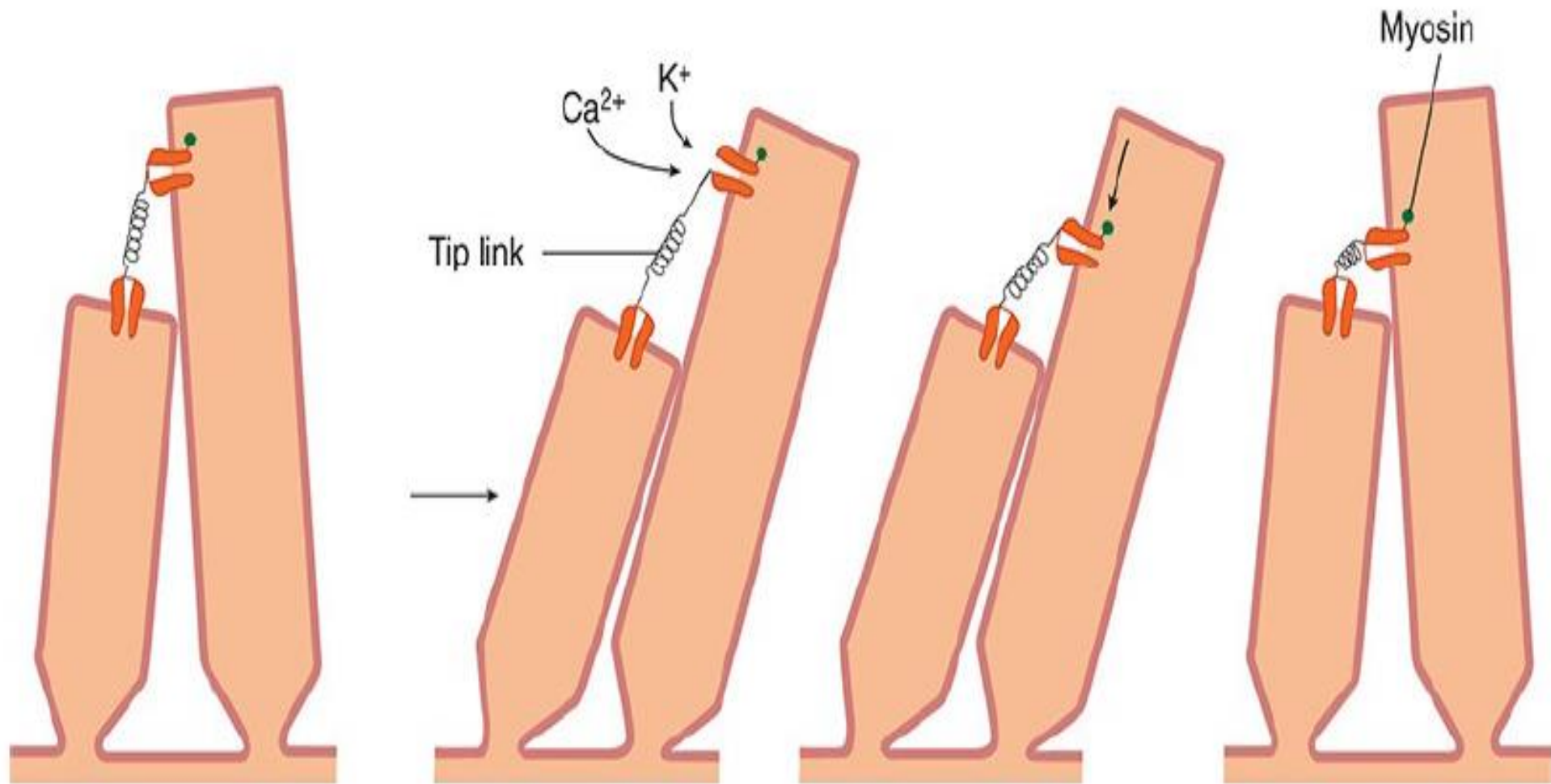
K^+ and Ca^{2+} enter through these channels and produce **DEPOLARIZATION**

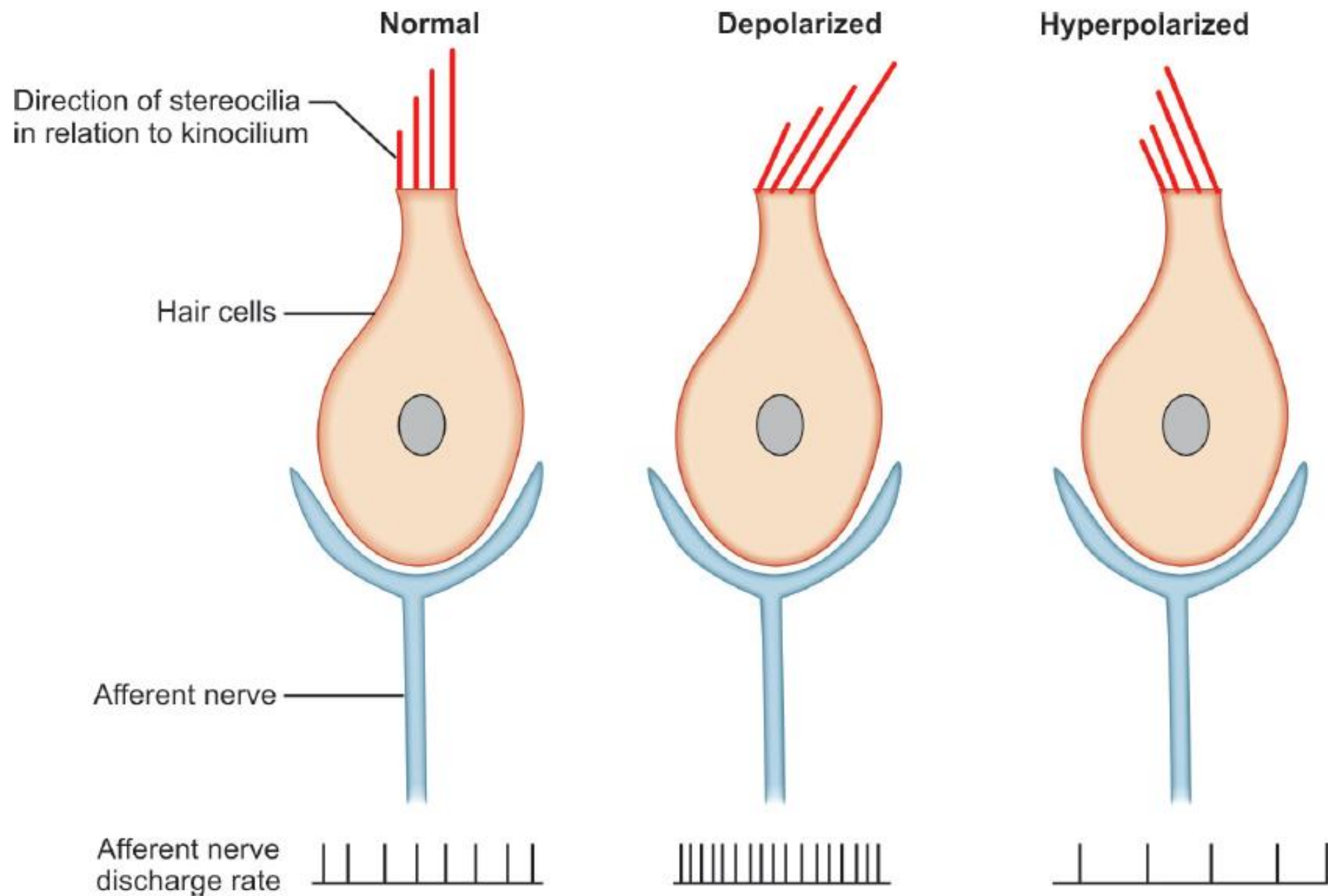


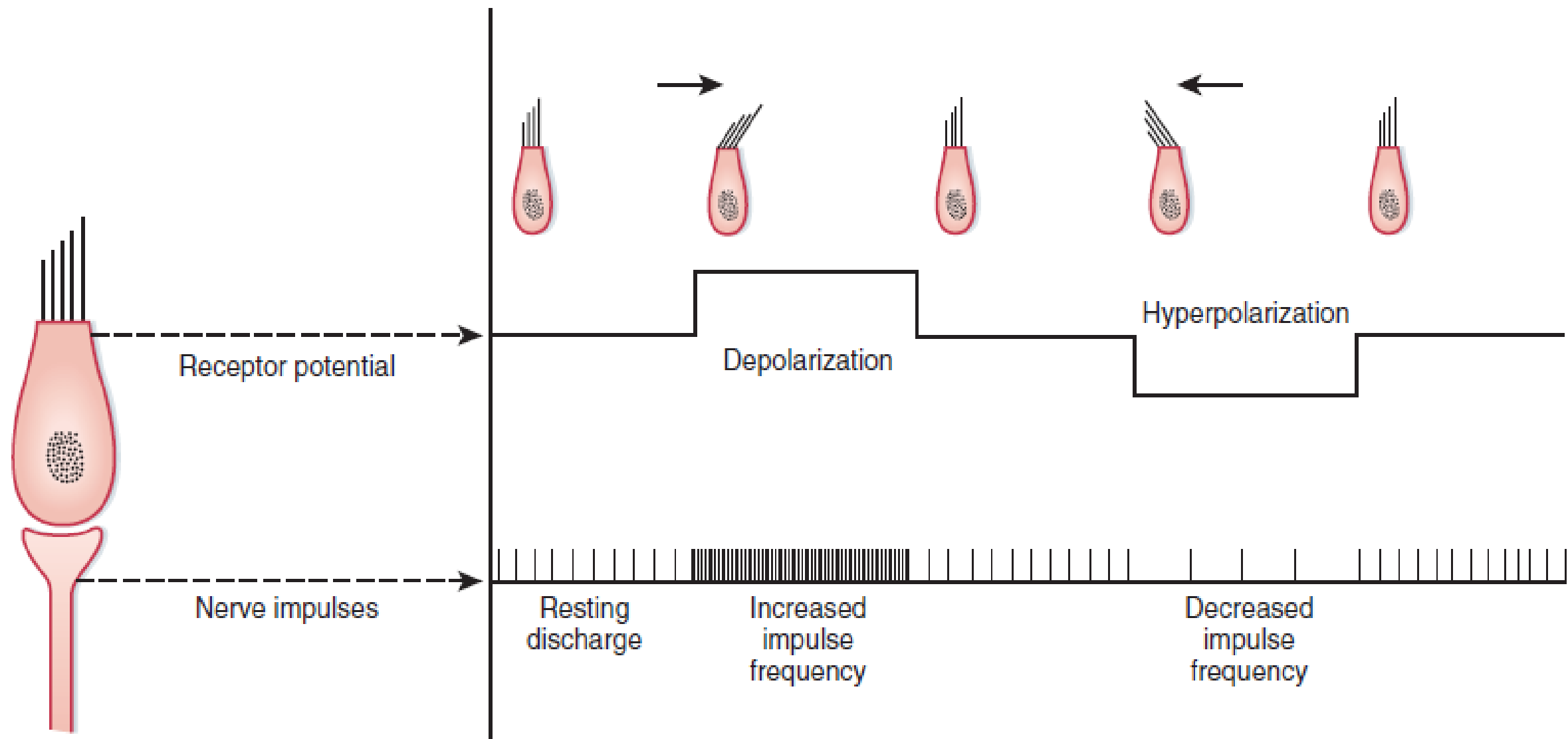
Releases neurotransmitter **GLUTAMATE**



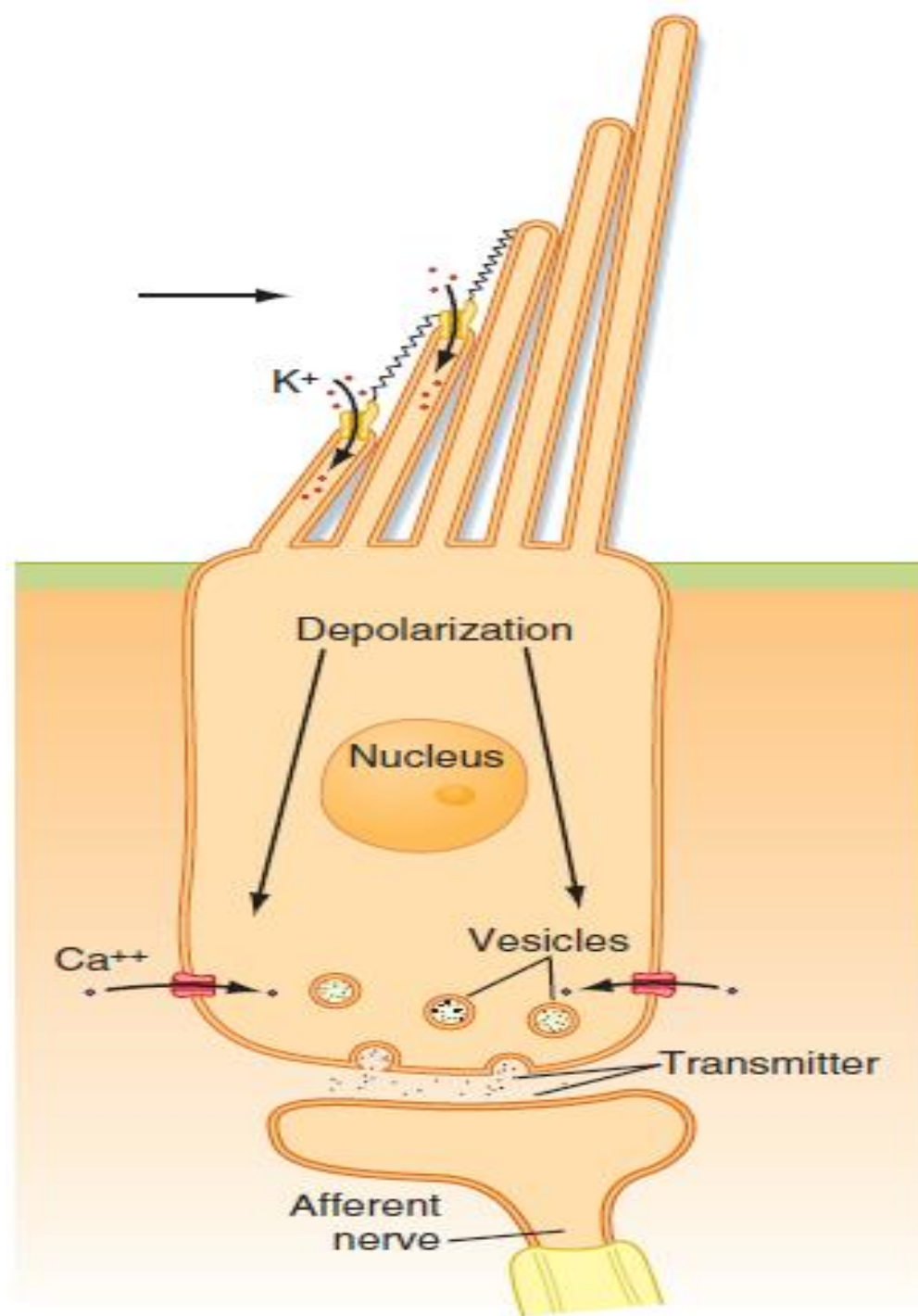
Initiates **DEPOLARIZATION** in the afferent neurons

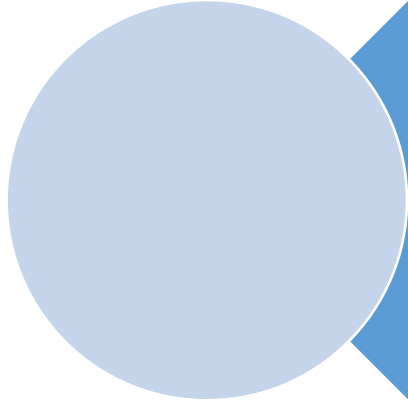




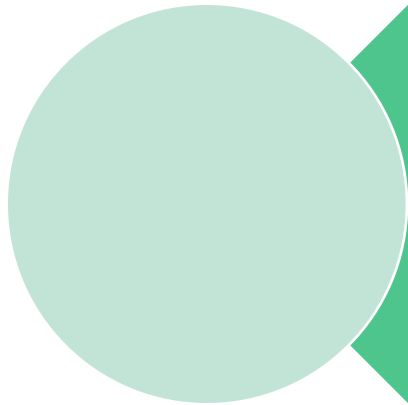


• **Fig. 8.26** Functional Polarization of Vestibular Hair Cells. When the stereocilia are bent toward the kinocilium, the hair cell is depolarized, and the afferent fiber is excited. When the stereocilia are bent away from the kinocilium, the hair cell is hyperpolarized, and the afferent discharge slows or stops. (Redrawn from Kandel ER, Schwartz JH. *Principles of Neural Science*. New York: Elsevier; 1981.)

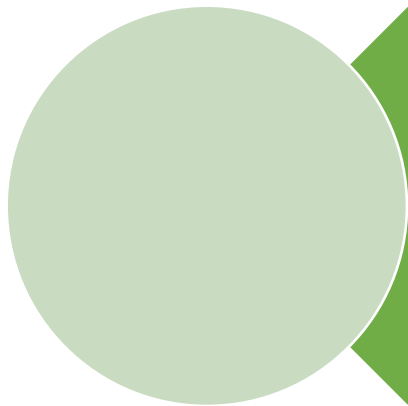




MYOSIN- BASED MOLECULAR MOTOR in the taller process move the channel toward the base

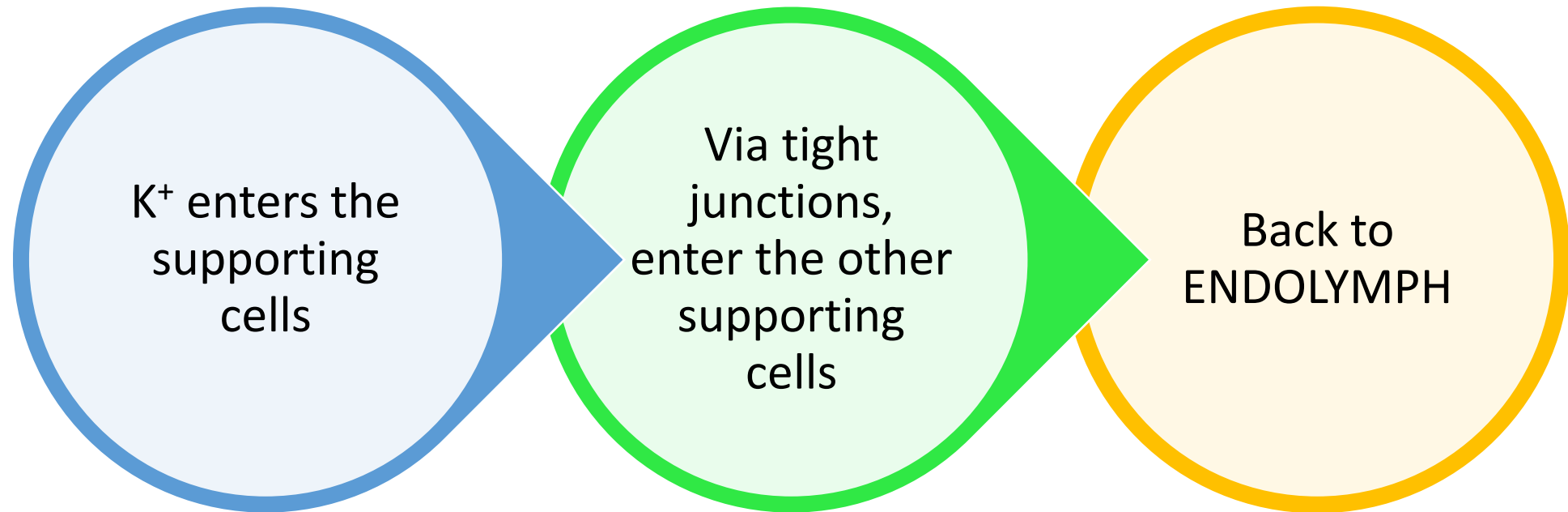


Releases tension in the tip link



Channels close and permits restoration of resting state

RECYCLING OF POTASSIUM IONS



VESTIBULAR APPARATUS

```
graph TD; A[VESTIBULAR APPARATUS] --> B[OTOLITH ORGANS]; A --> C[SEMICIRCULAR CANALS]; B --> D[UTRICLE]; B --> E[SACCCULE]; C --> F[ANTERIOR]; C --> G[POSTERIOR]; C --> H[HORIZONTAL];
```

OTOLITH
ORGANS

UTRICLE

SACCCULE

SEMICIRCULAR
CANALS

ANTERIOR

POSTERIOR

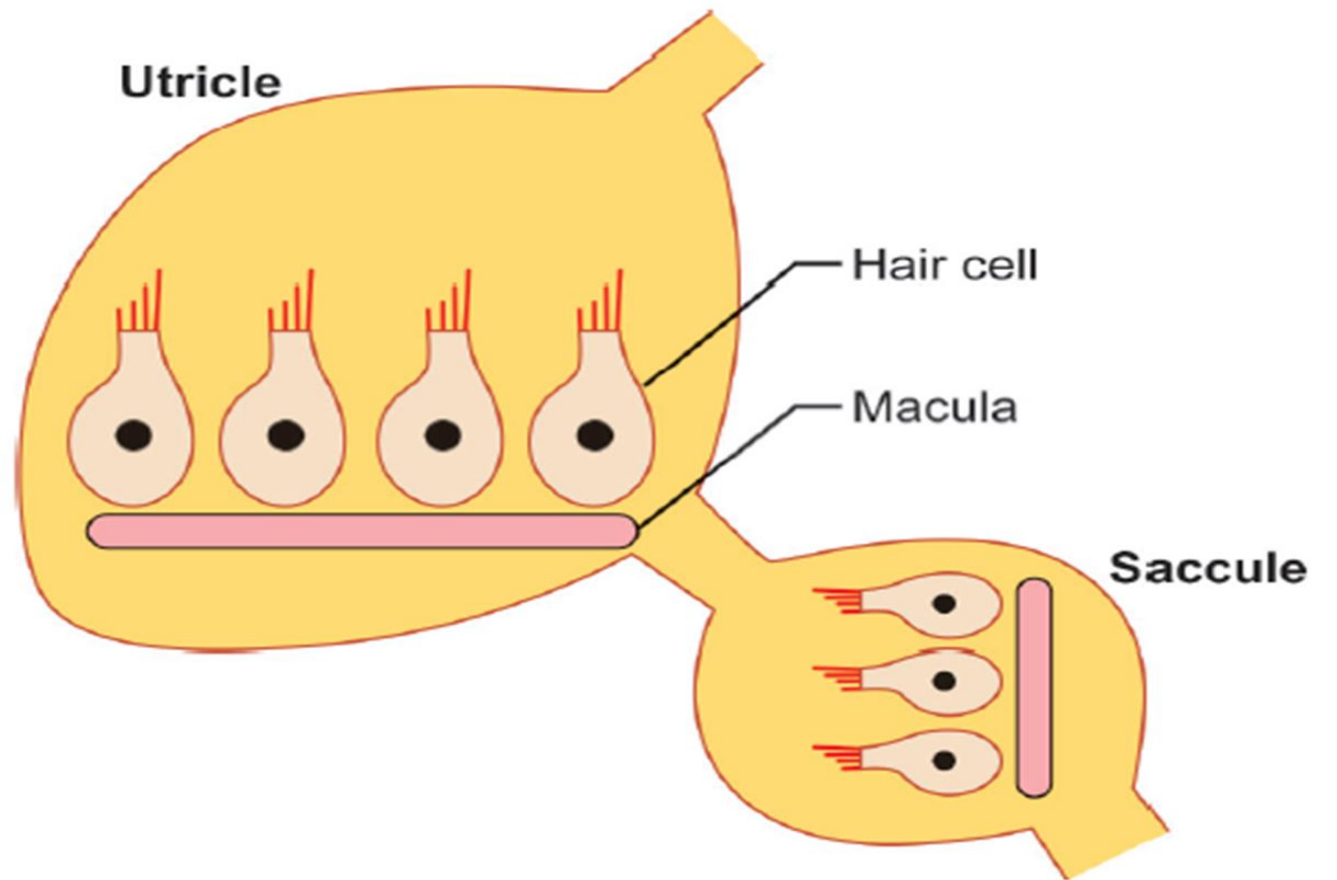
HORIZONTAL

OTOLITH ORGANS

- UTRICLE
- SACCULE

- Hair cells → located in th

- **Utricle** → macula oriented *HORIZONTALLY*
- **Saccule** → macula oriented *VERTICALLY*



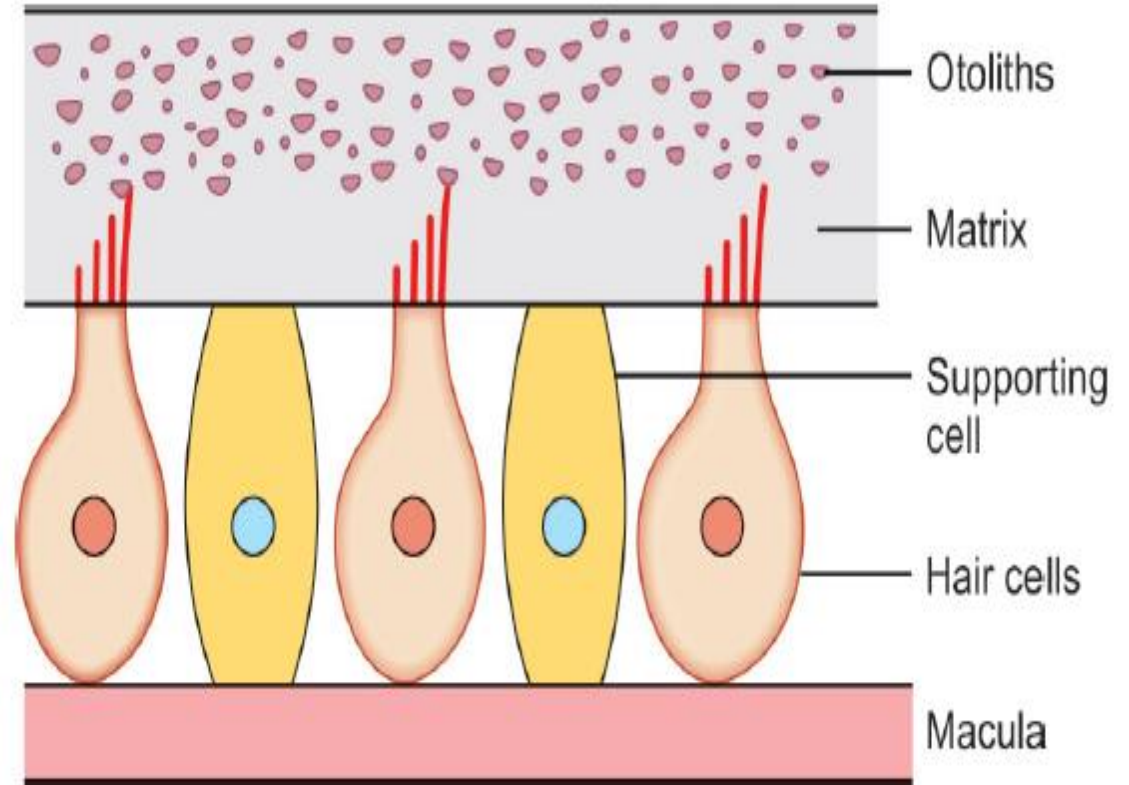
Hair cells of otolith organs → stimulated by **linear acceleration**

Utricle → linear acceleration in **horizontal** direction

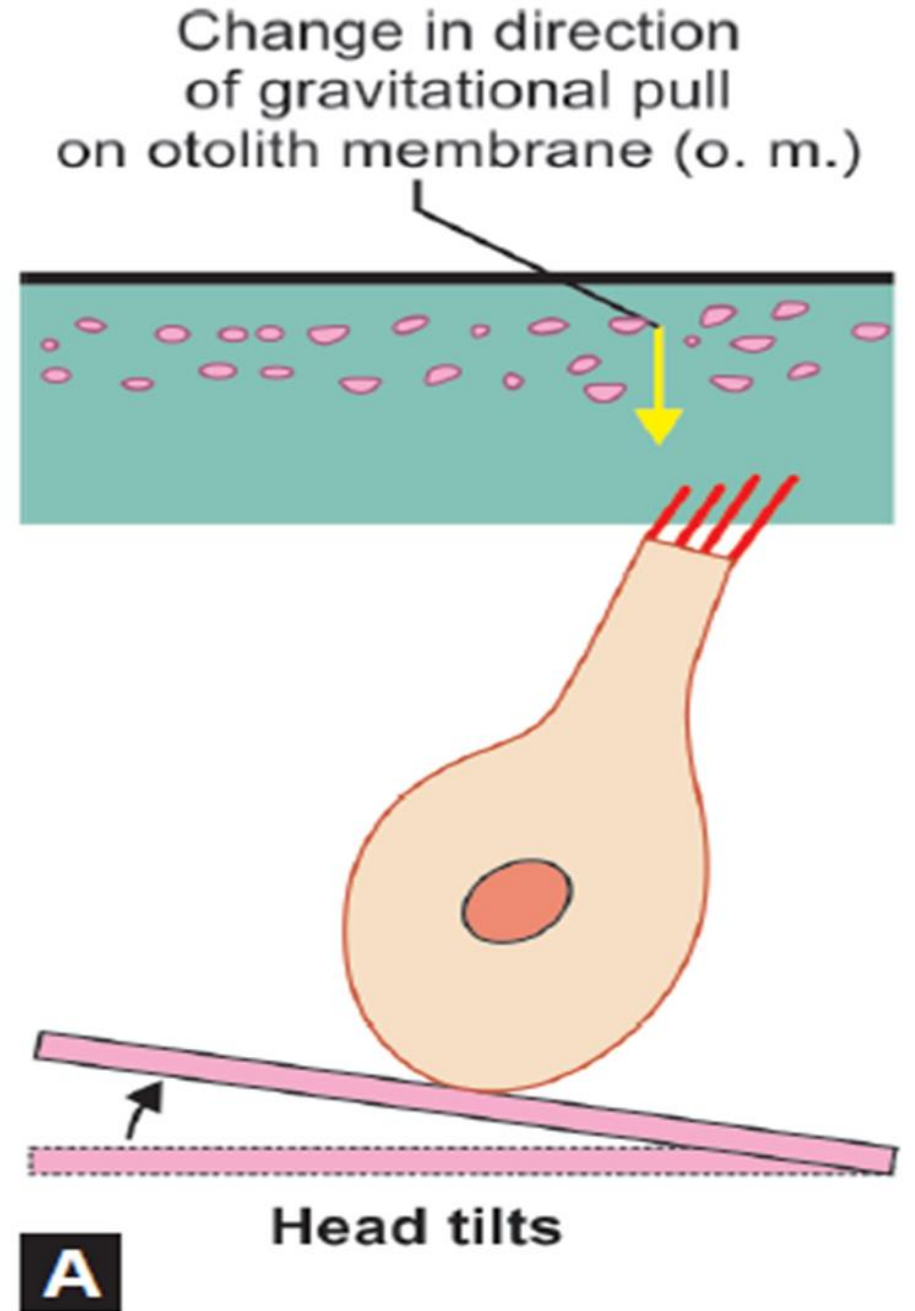
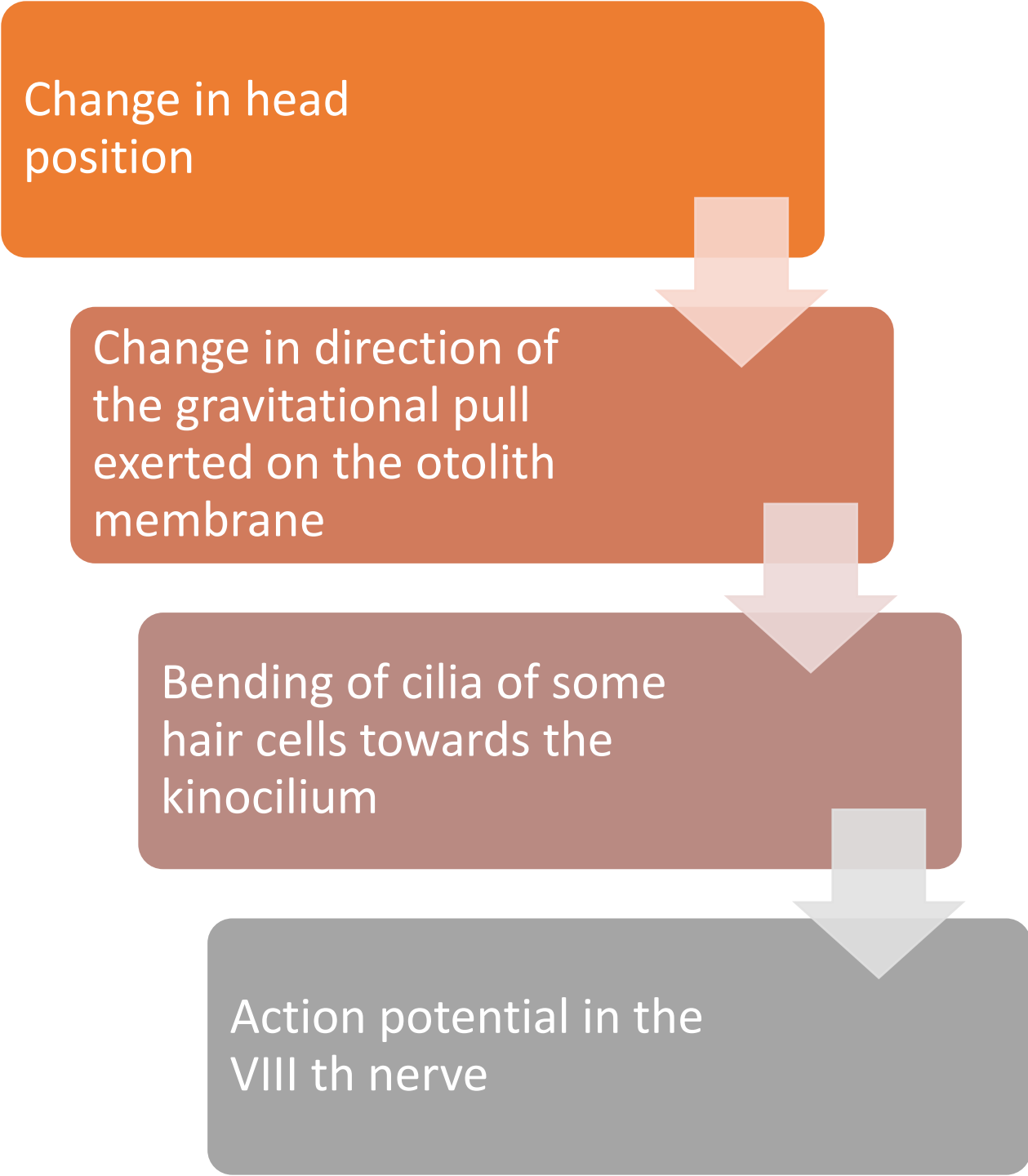
Saccul → linear acceleration in **vertical** direction

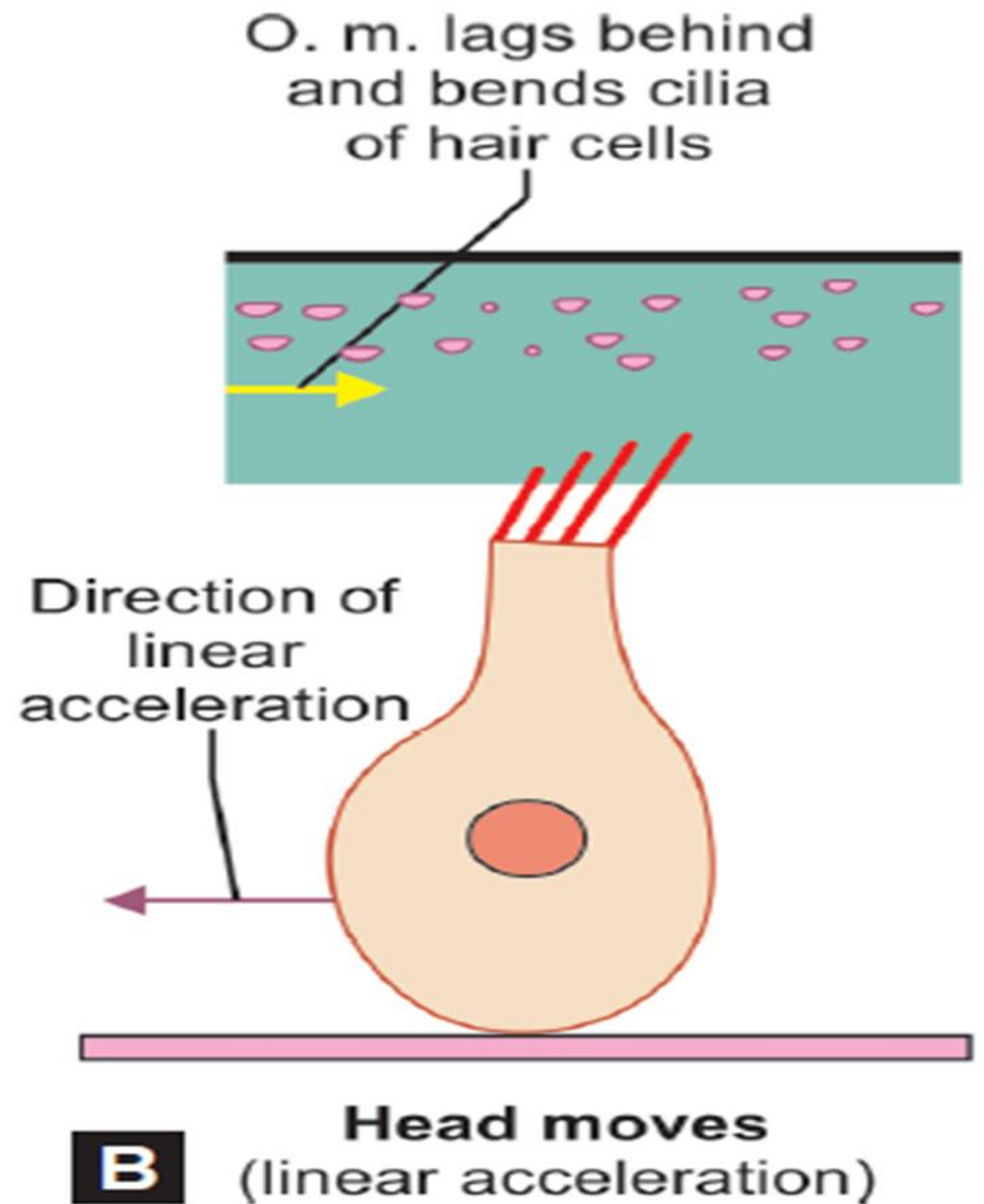
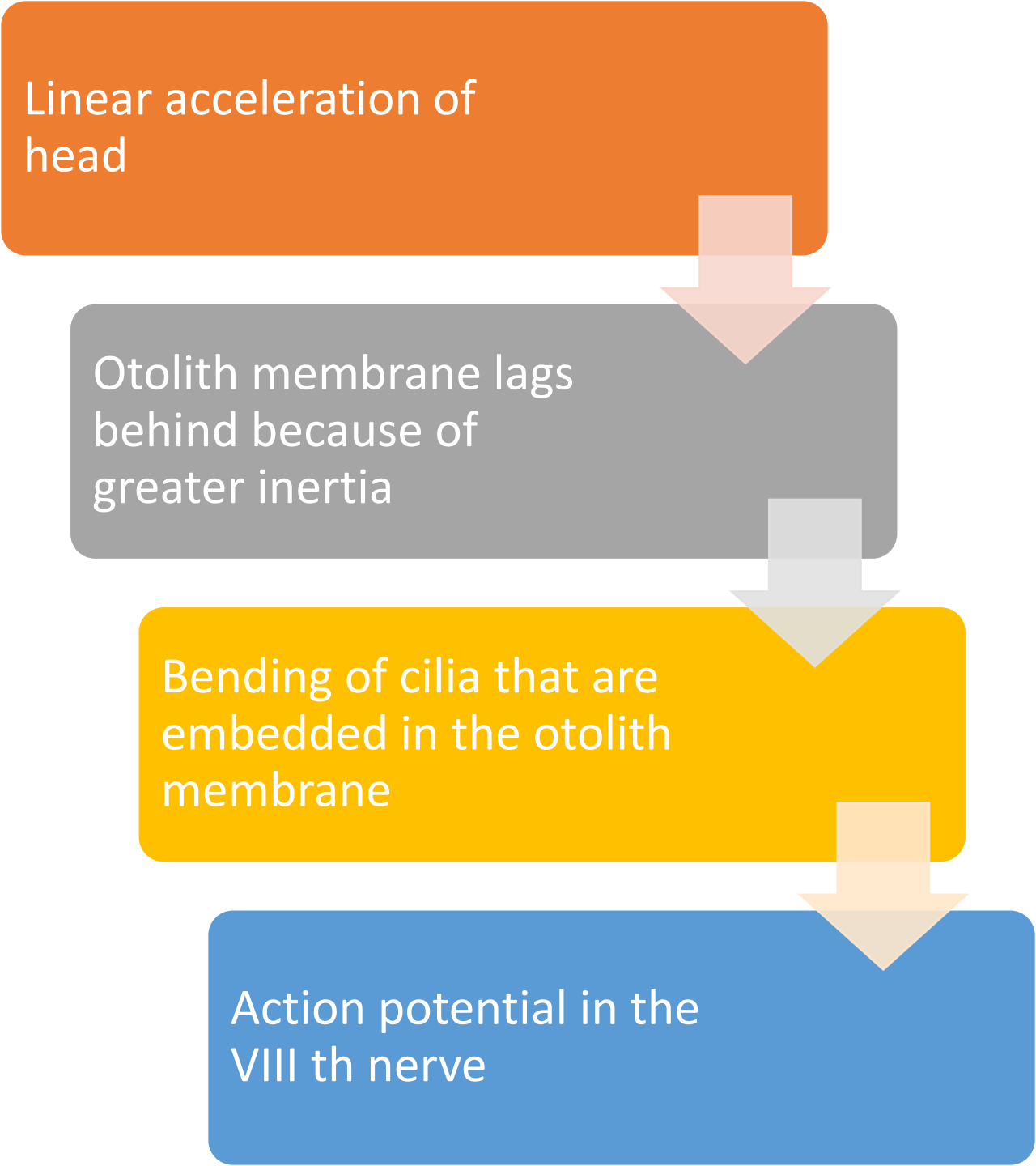
Also detect **CHANGE IN HEAD POSITION** like tilting or bending of head

- Macular hair cells → covered with an **OTOLITH MEMBRANE** → cilia of hair cells project into this
- Gelatinous mass
- Contains crystals of **CALCIUM CARBONATE** → **OTOLITHS/OTOCONIA/ST ATOCONIA/EAR DUST**



- Otoliths → heavier than endolymph
- Change in direction of the gravitational pull exerted on the otolith membrane → bends the cilia of hair cells
- **Change in head position**
- **Linear acceleration**

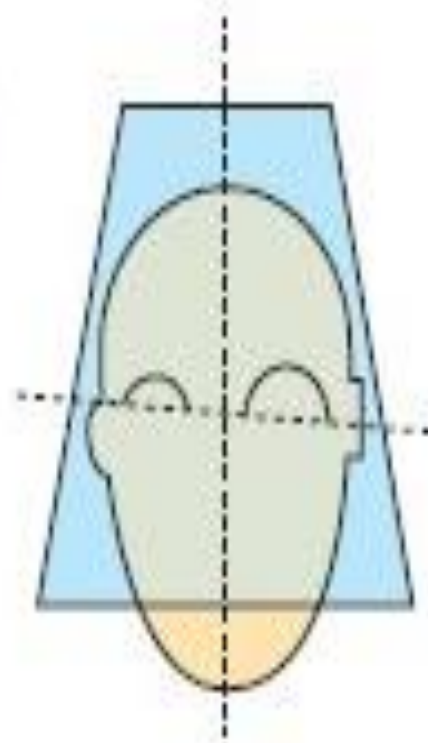




Hair cells of utricle → horizontal linear acceleration
Hair cells of saccule → vertical linear acceleration

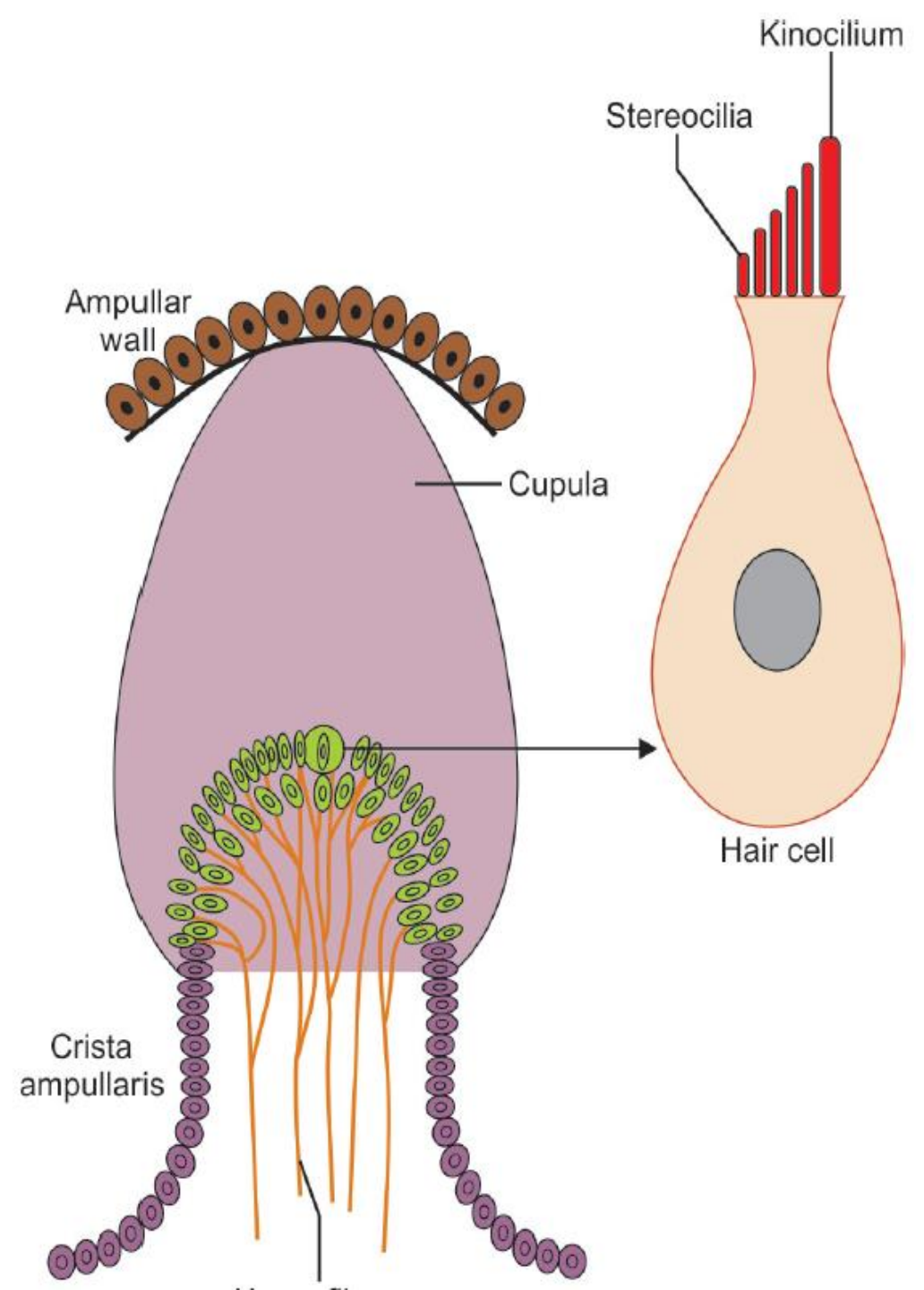
SEMICIRCULAR CANALS

- Arranged in three mutually perpendicular planes
- HORIZONTAL CANAL
- ANTERIOR CANAL
- POSTERIOR CANAL
- Hair cells → located in the AMPULLA from the distal end of each canal



CRISTA TERMINALIS

- Contain hair cells and supporting cells
- Cilia of ampullary hair cells → embedded in a gelatinous mass → **CUPULA**
- No otoliths
- Specific gravity of cupular fluid is same as endolymph



Hair cells of semicircular canals → ROTATIONAL
ACCELERATION

Head rotation to
one side



Canals
automatically
rotate to that side



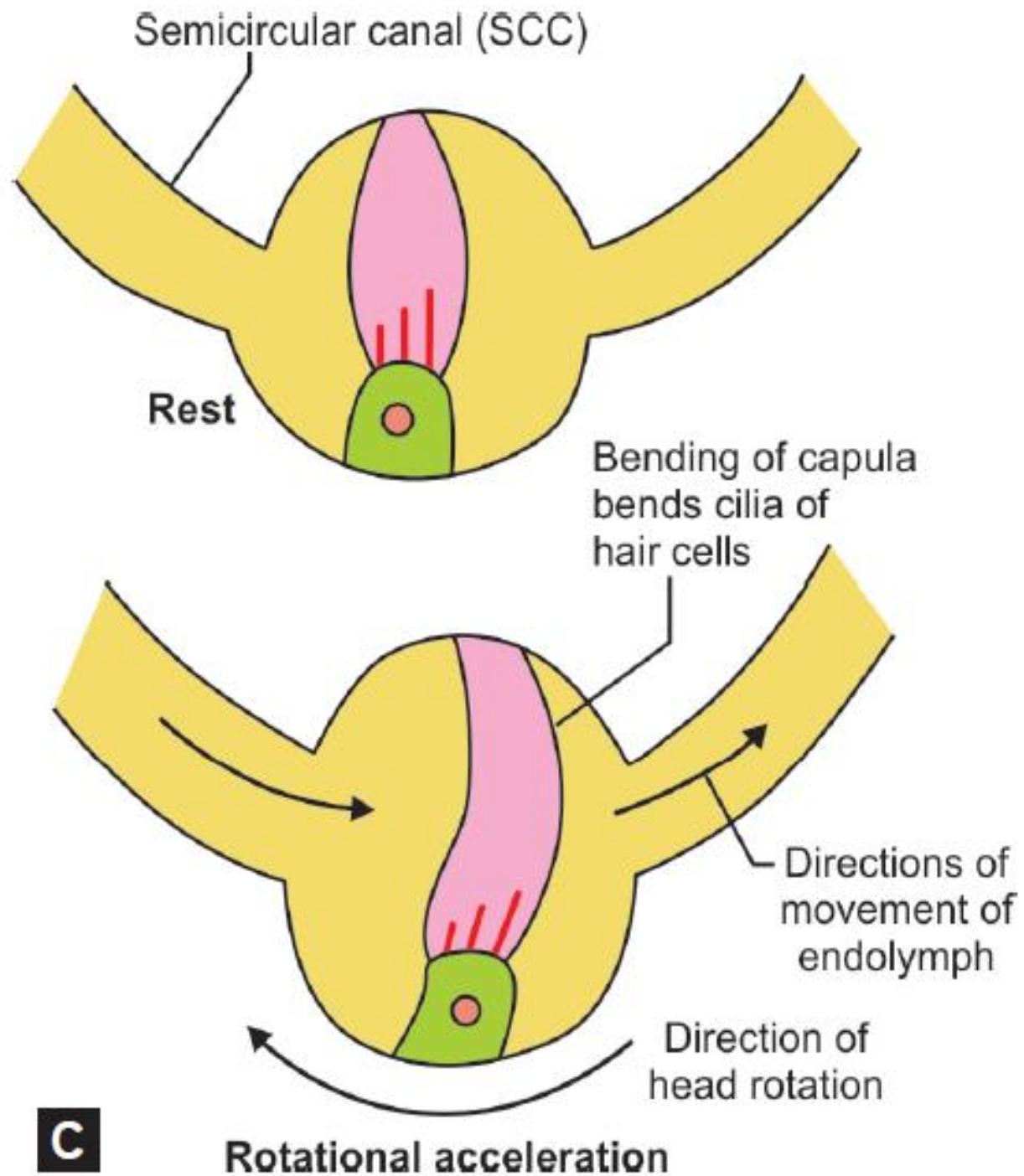
But endolymph in
the canals does not
move immediately
for about 20
seconds due to
inertia



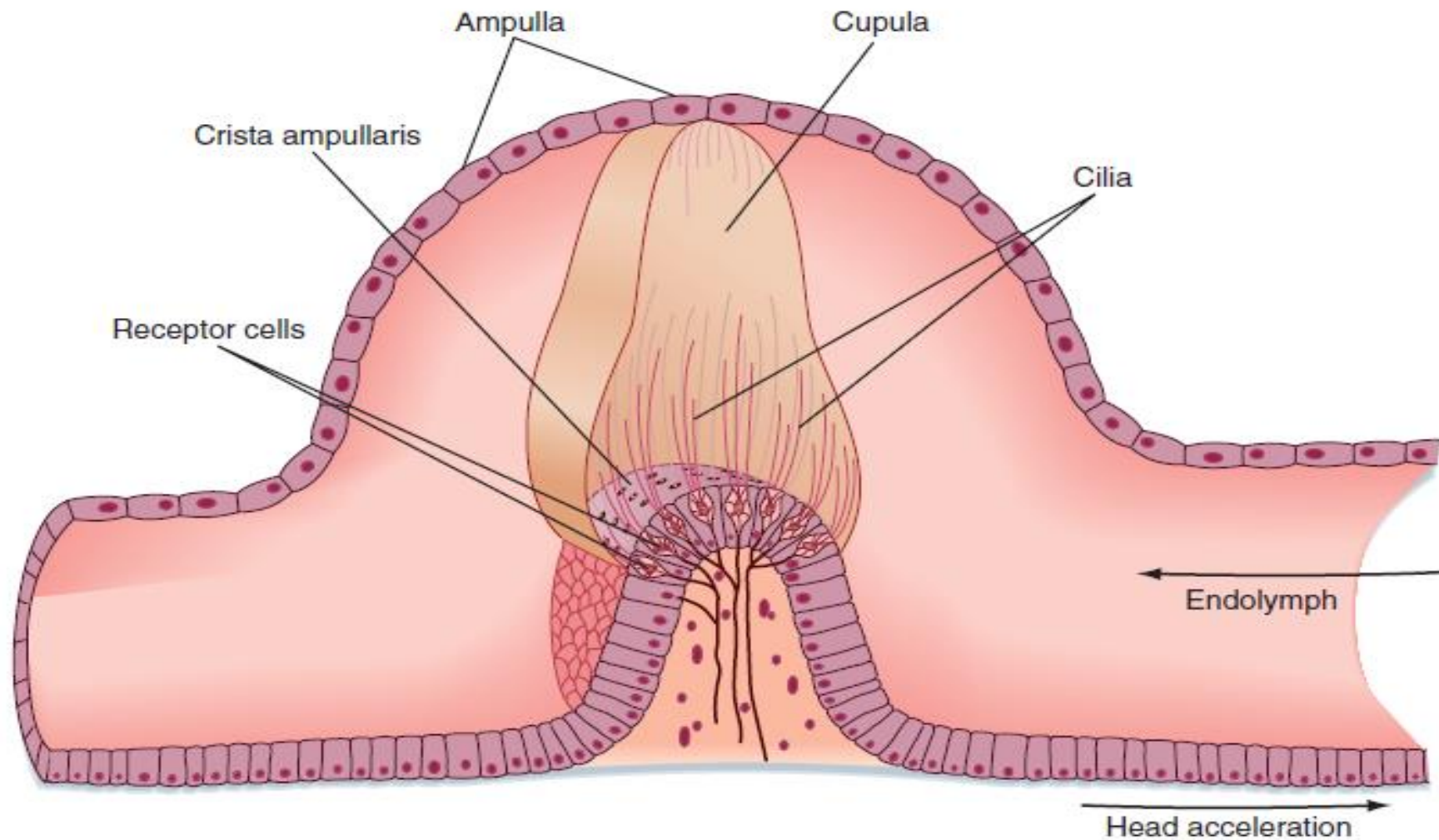
Displacement of
cupula towards
utricle bends cilia
towards kinocilium
and stimulates hair
cells



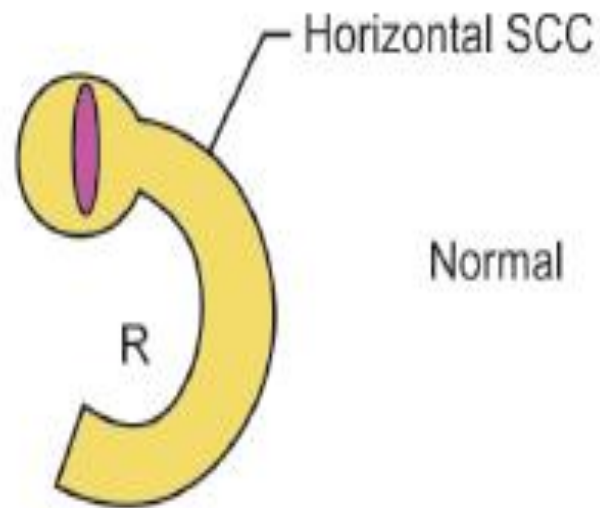
Cupular fluid also
moves similar to
endolymph



- Head rotation is detected in the first 20 seconds
- After initial lag period → movement of endolymph and canal equalizes → ***ROTATION NOT DETECTED AFTER THE INITIAL PHASE***

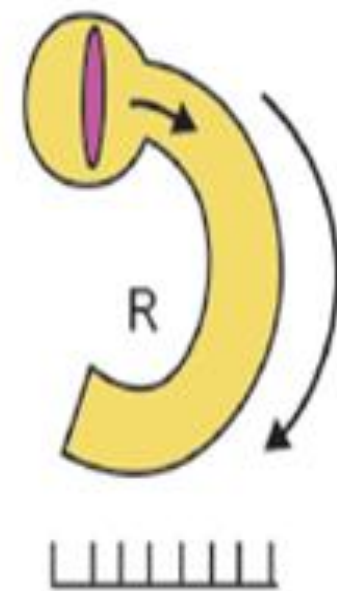


• **Fig. 8.24** Drawing of an Ampullary Crest Inside an Ampulla. The stereocilia and the kinocilium of each hair cell extend into the cupula, which extends across the entire cross-section of the ampulla. Head movement (acceleration) to the right would result in endolymph pressure to the left and deflection of the cupula to the left.

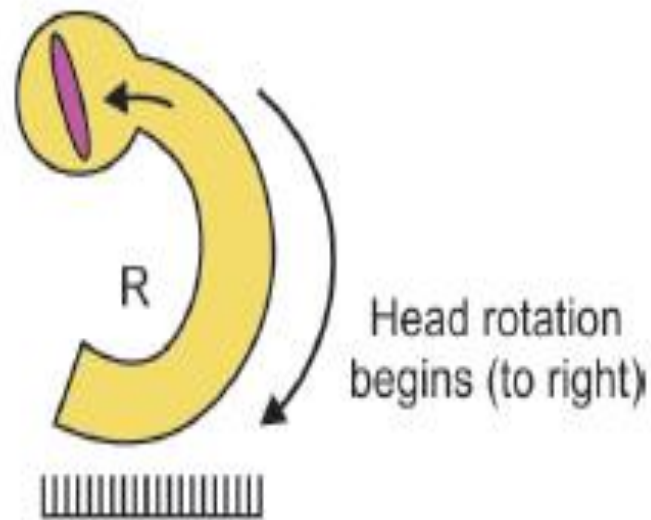


Normal

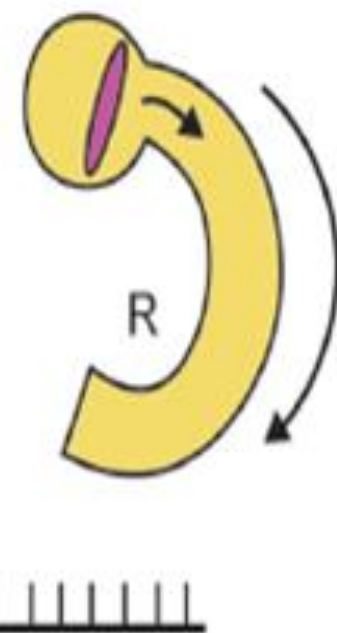
(impulses in afferent nerve)



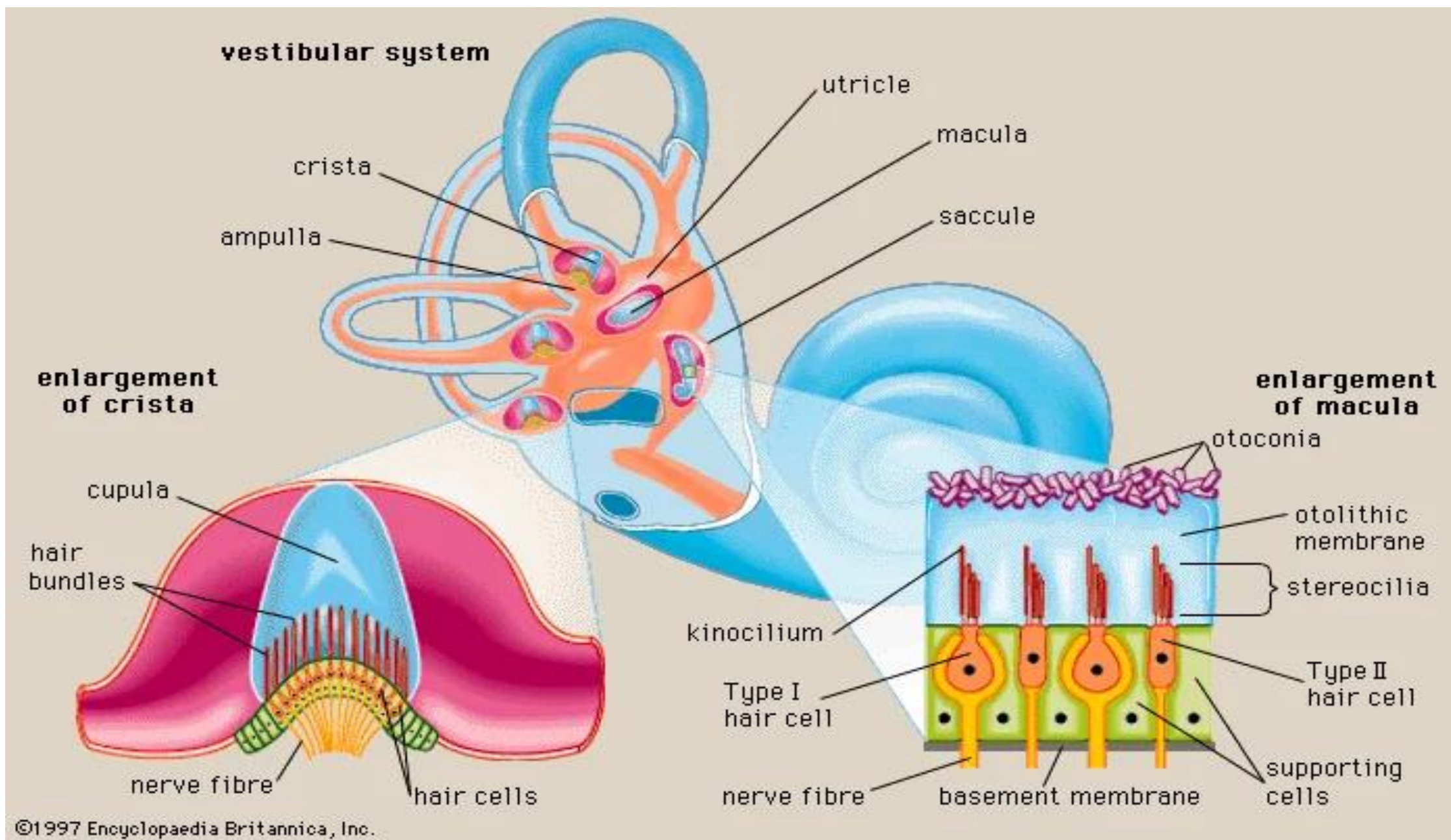
Rotation continues (>30s)



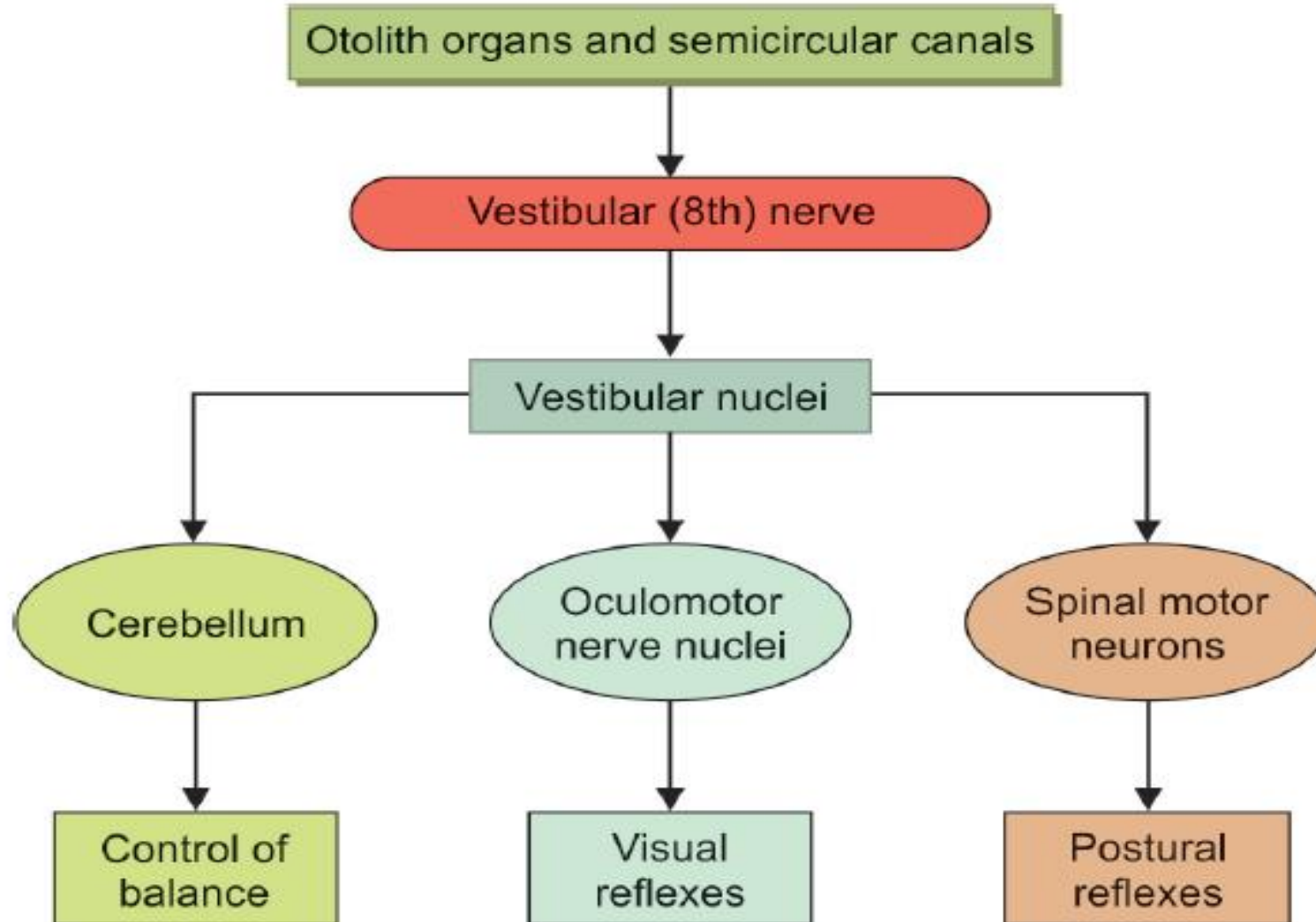
Head rotation begins (to right)



Rotation ends



VESTIBULAR PATHWAYS



APPLIED ASPECTS

VESTIBULAR DISORDERS

VERTIGO
NYSTAGMUS
TINNITUS

BENIGN PAROXYSMAL POSITIONAL **VERTIGO/BPPV**

- Most common vestibular disorder
- Episodes of vertigo with particular changes in body position
- Otoconia from utricle separate from otolith membrane and become lodged in the canal or cupula

MOTION SICKNESS

- Nausea
- BP changes
- Sweating
- Pallor
- Vomiting
- Due to excessive vestibular stimulation

SPACE MOTION SICKNESS

- Due to microgravity

MENIERE'S DISEASE

- Vertigo
- Tinnitus
- Fluctuating hearing loss

VESTIBULAR FUNCTION TESTS

- *Rotational stimulation/ post-rotatory nystagmus*
- *Caloric stimulation*
- *Electronystagmography*