Inner ear in balance and equilibrium

Control of Equilibrium

Equilibrium: Reflexes maintain body position at rest & movement .

Sensory inputs from:

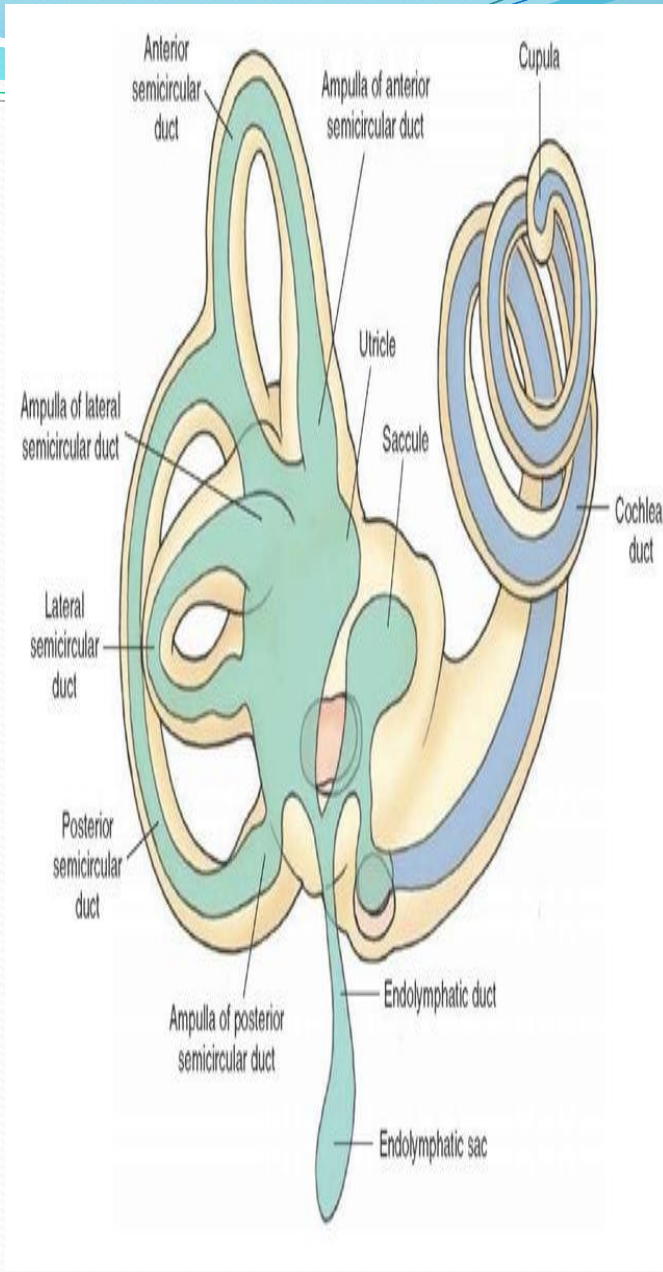
1. Vestibular system
2. Visual system
3. Proprioceptive system
4. Cutaneous sensations

- **Labyrinth:-**

1- Bony labyrinth
(bony cochlea , vestibule and 3 bony semicircular canals)
Enclose the membranous labyrinth.

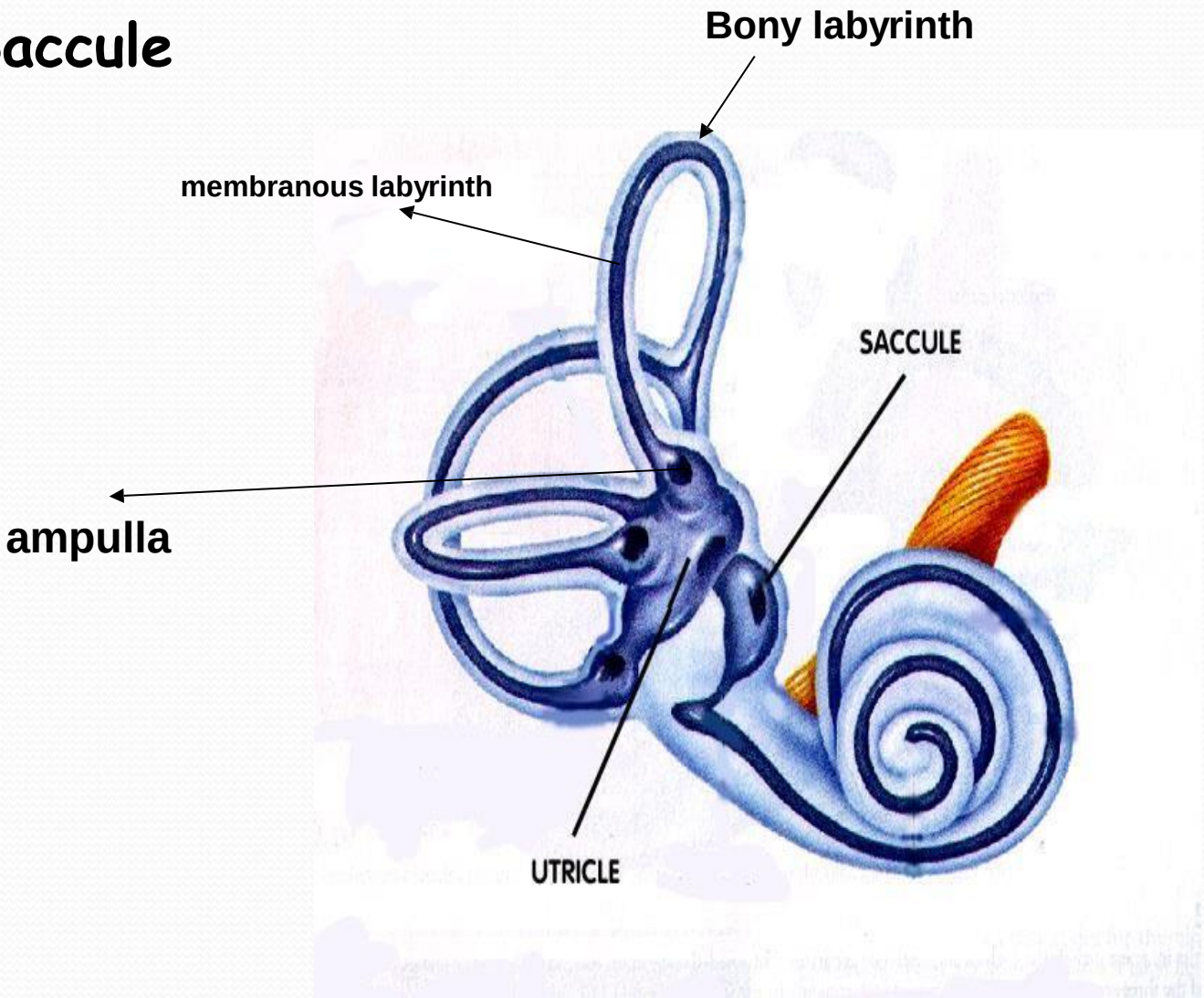
2. Membranous labyrinth :-

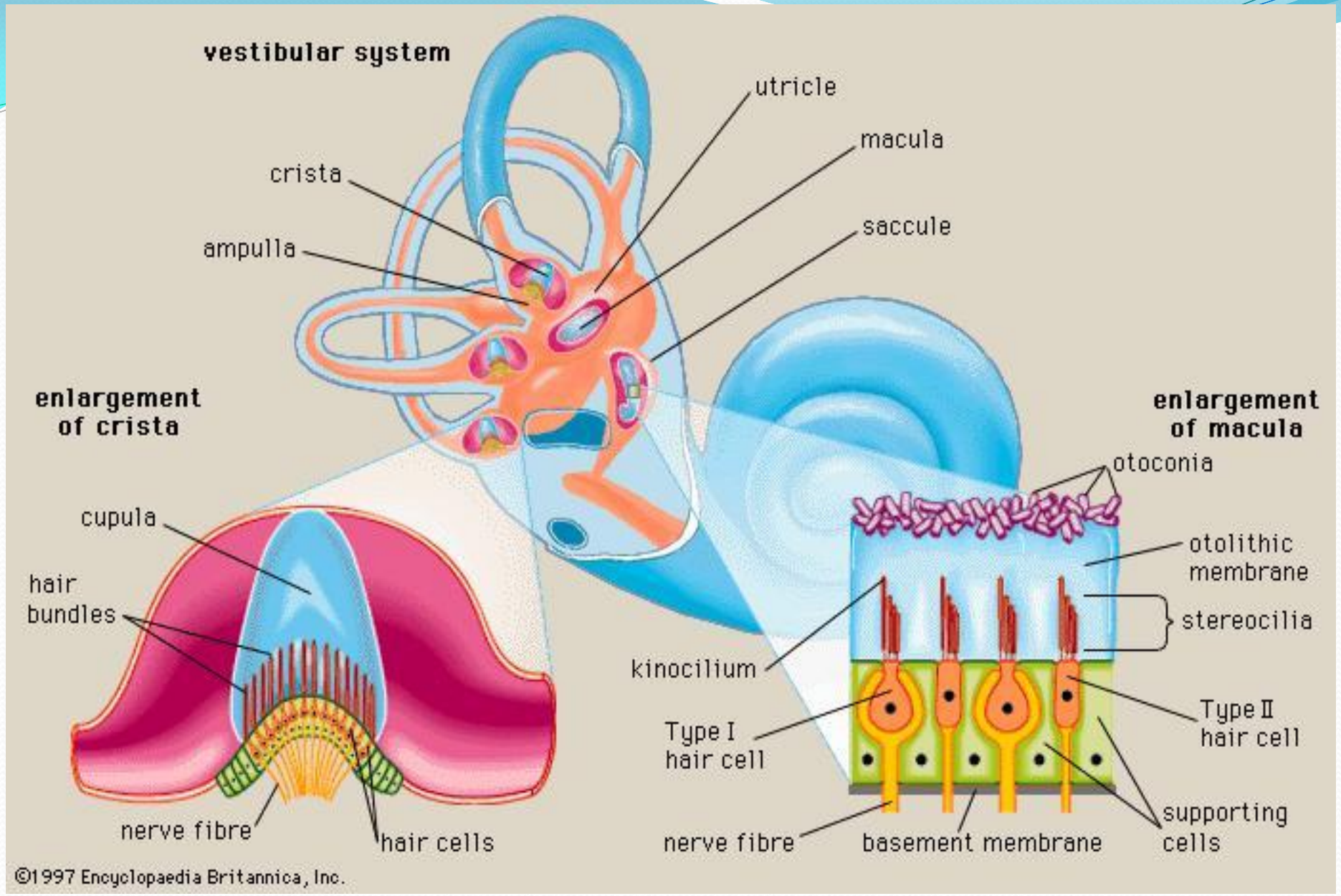
a- Auditory (cochlea for hearing)
b- Non- auditory for equilibrium
(Vestibular apparatus)



Vestibular apparatus:-

1- Utricle & Saccule
2- SCC




vestibular system
utricle
macula
crista
saccule
ampulla
enlargement of crista
enlargement of macula
cupula
otoconia
hair bundles
otolithic membrane
stereocilia
kinocilium
Type I hair cell
Type II hair cell
nerve fibre
hair cells
nerve fibre
basement membrane
supporting cells
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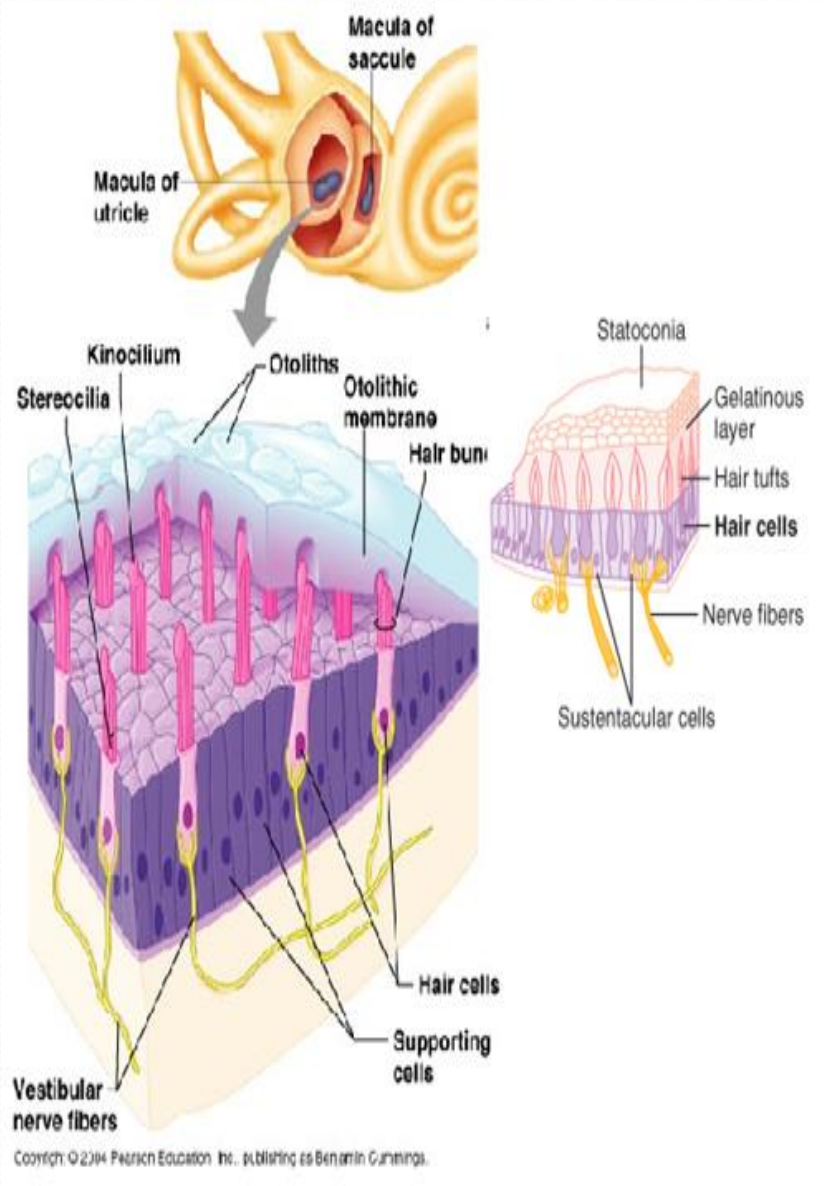
Macula (otolith organs) of utricle and saccule:-

- -hair cell synapse with endings of the vestibular nerve.
- -Hair cell has 30-150 (stereocilia)

&

- one large cilium called (kinocilium)
- Both connectdd with thin filamnetous attachments
- -All cilium membrane has positive potassium channels
- -Otolithes (statoconia) of calcium carbonate suspended in gelatinous material.
- - macula of utricle is IN horizontal plane if the head is vertical , so cilia point upwards
- - stimulated when the head bends forward & backward & laterally



- **Hair cells in utricle**

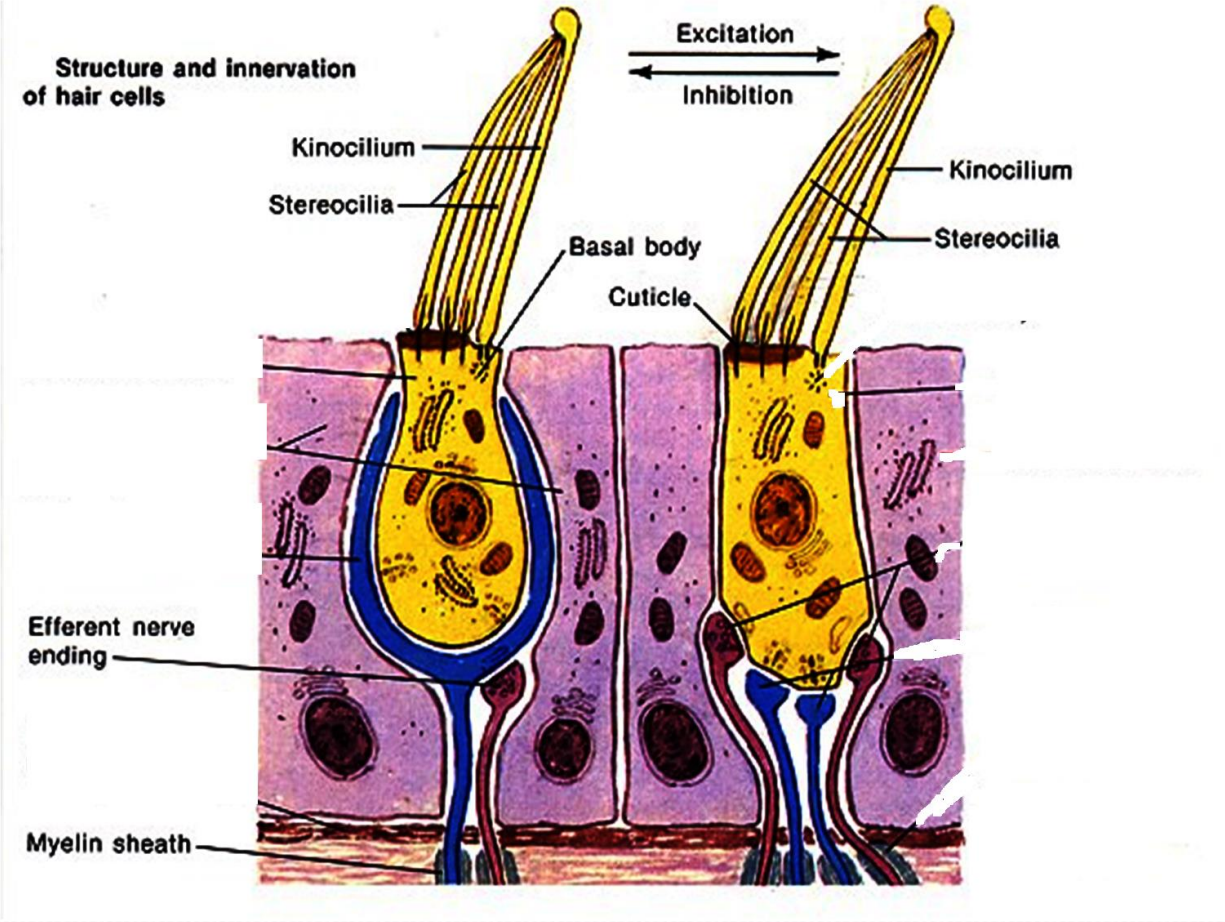
Person in upright position: (Head vertical)

- Macula in horizontal plane
- Hairs pointing upwards
- Hair cells signal head movements in any direction >> >> inform the brain of orientation of head in space

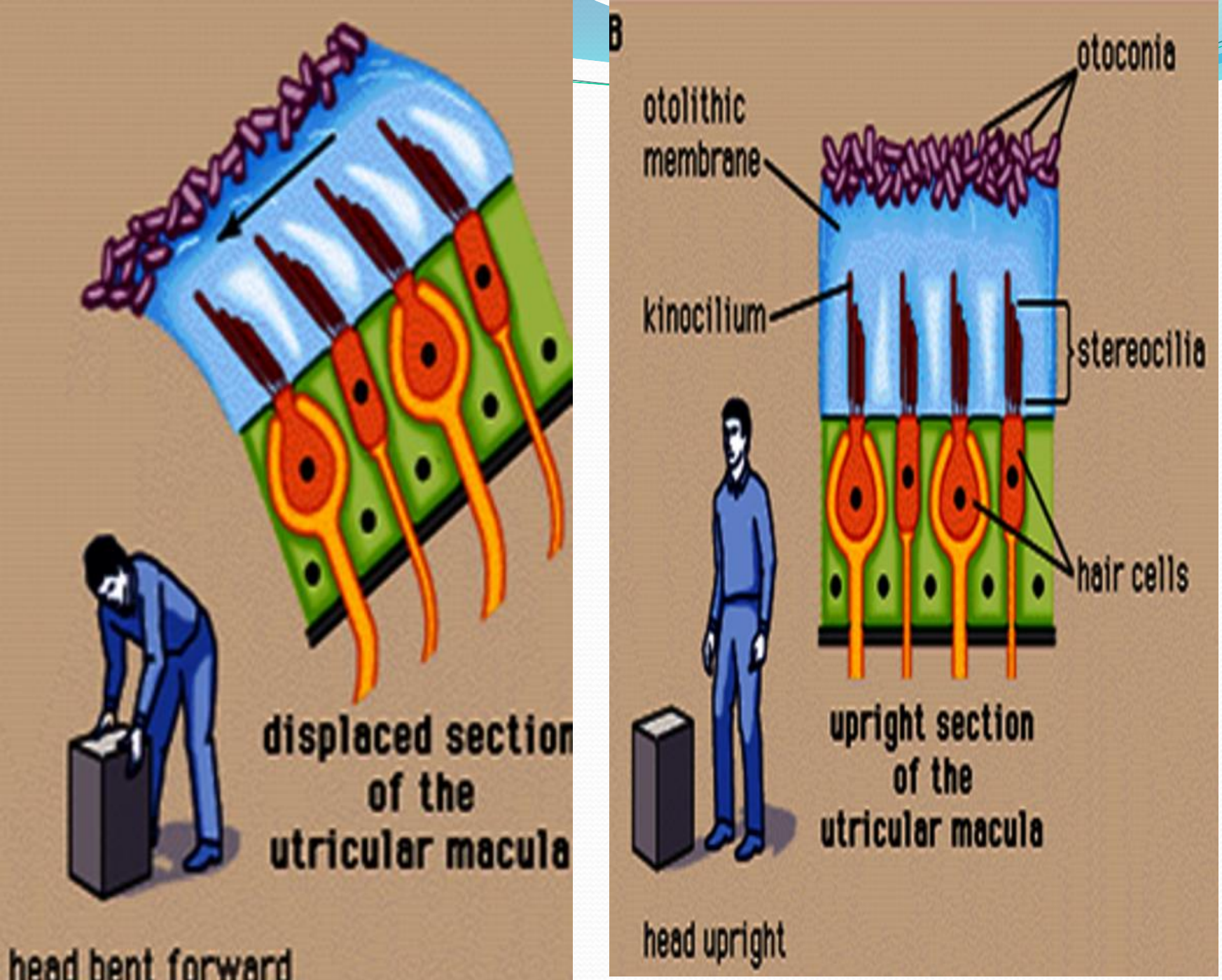
Hair cells in Saccule

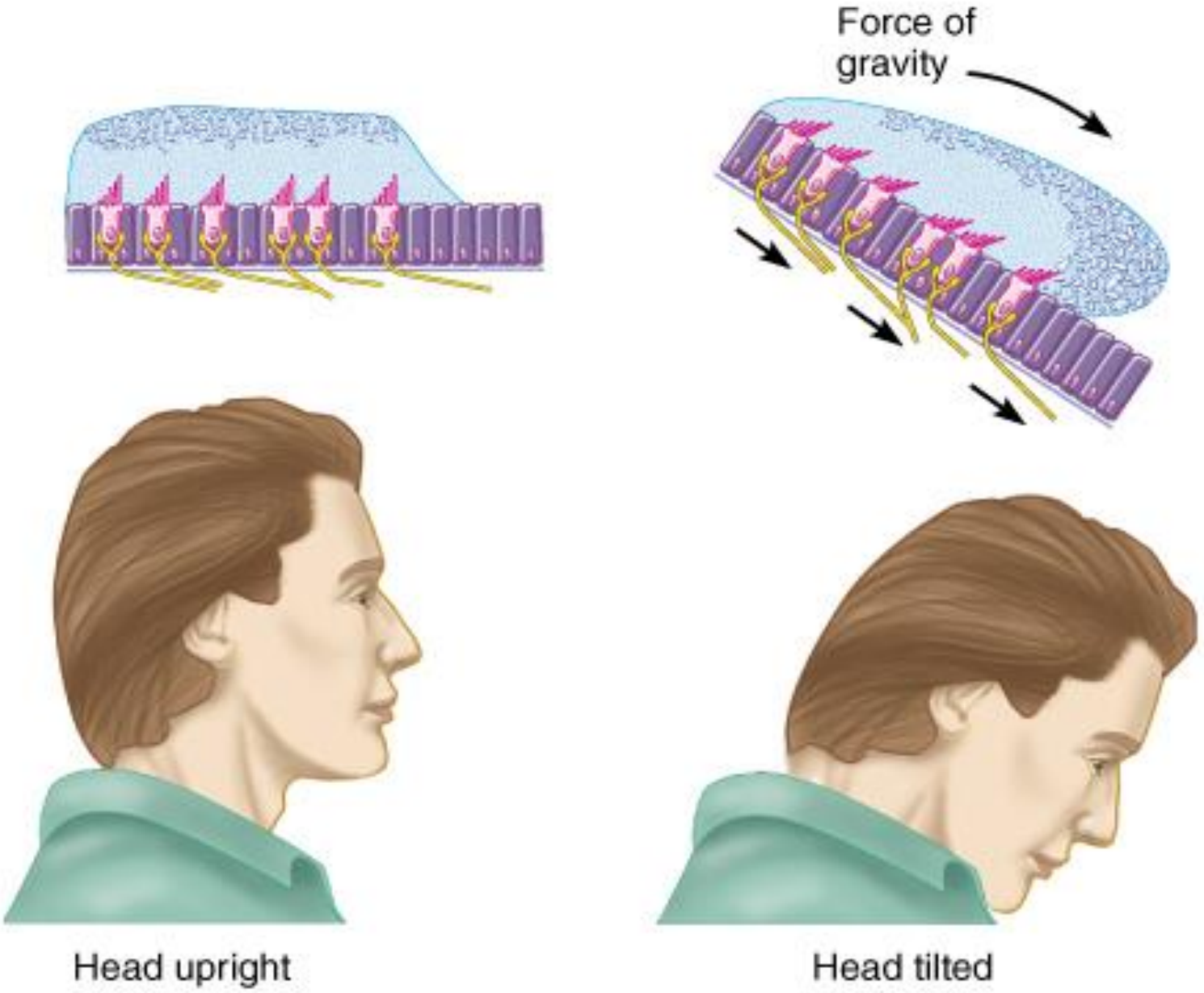
Person in upright position: (Head vertical)

- Macula in vertical plane
- Hairs pointing laterally
- Hair cells operate when one is lying down

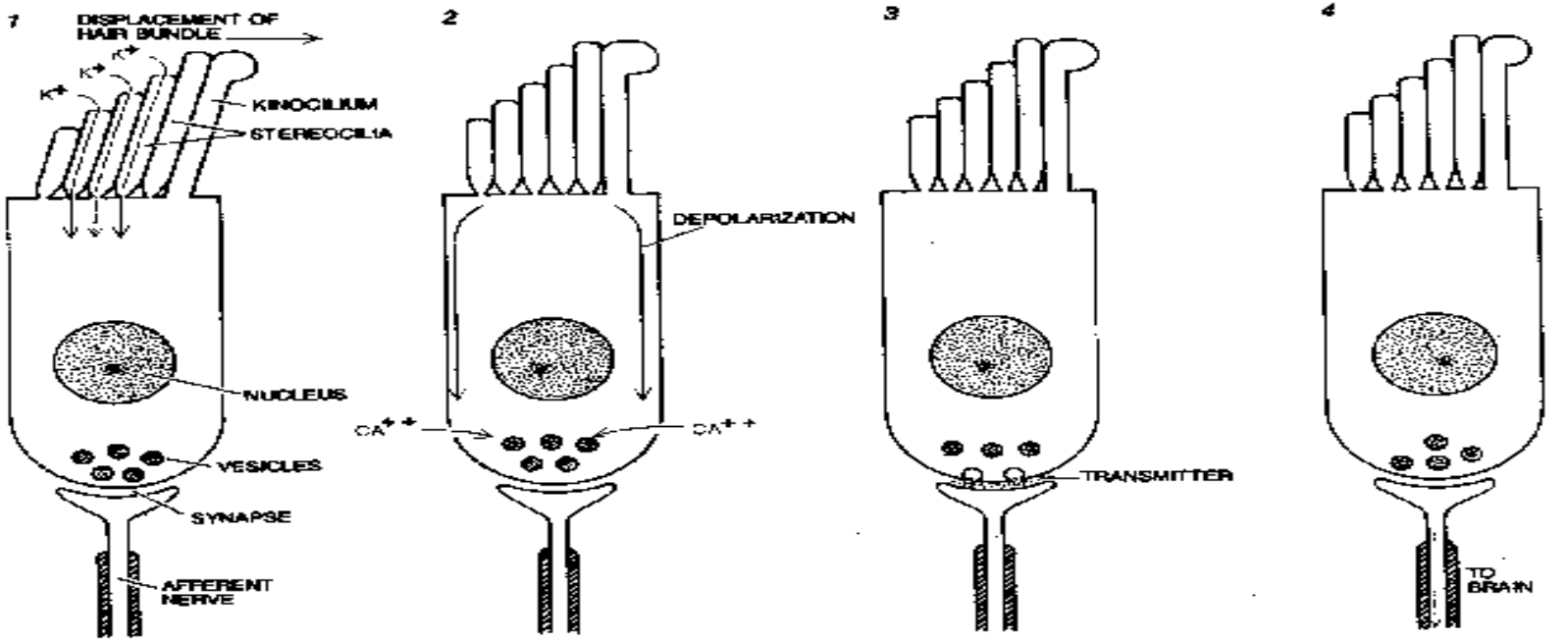

Structure and innervation of hair cells
Excitation
Inhibition
Kinocilium
Stereocilia
Basal body
Cuticle
Kinocilium
Stereocilia
Efferent nerve ending
Myelin sheath

POSITION OF CILIA	NEUTRAL	TOWARD KINOCILIUM	AWAY FROM KINOCILIUM
KINOCILIUM (1) STEREOCILIA (60 - 100) HAIR CELL VESTIBULAR AFFERENT NERVE ENDING ACTION POTENTIALS VESTIBULAR EFFERENT NERVE ENDING			
POLARIZATION OF HAIR CELL	NORMAL	DEPOLARIZED	HYPERPOLARIZED
FREQUENCY OF ACTION POTENTIALS	RESTING	HIGHER	LOWER


B
otoconia
otolithic membrane
kinocilium
stereocilia
hair cells
displaced section of the utricular macula
upright section of the utricular macula
head bent forward
head upright



(c)



- **Mechanism of action:-**
- 1- bending of stereocilia towards kinocilium>>>>> depolarization >>>>>>- increase rate of impulses to 8th nerve fibers

- 2- bending of stereocilia away from kinocilium
- >>>>-- hyperpolarization>>>>decrease rate of impulses to 8th nerve fibers

Functions of macula (mainly utricle):-

- **1- orientation of head in space & maintenance of static equilibrium:-**

- a-in erect upright position (vertical position) :
- RT & LT utricle impulses balance each other
- No sensation of male-equilibrium

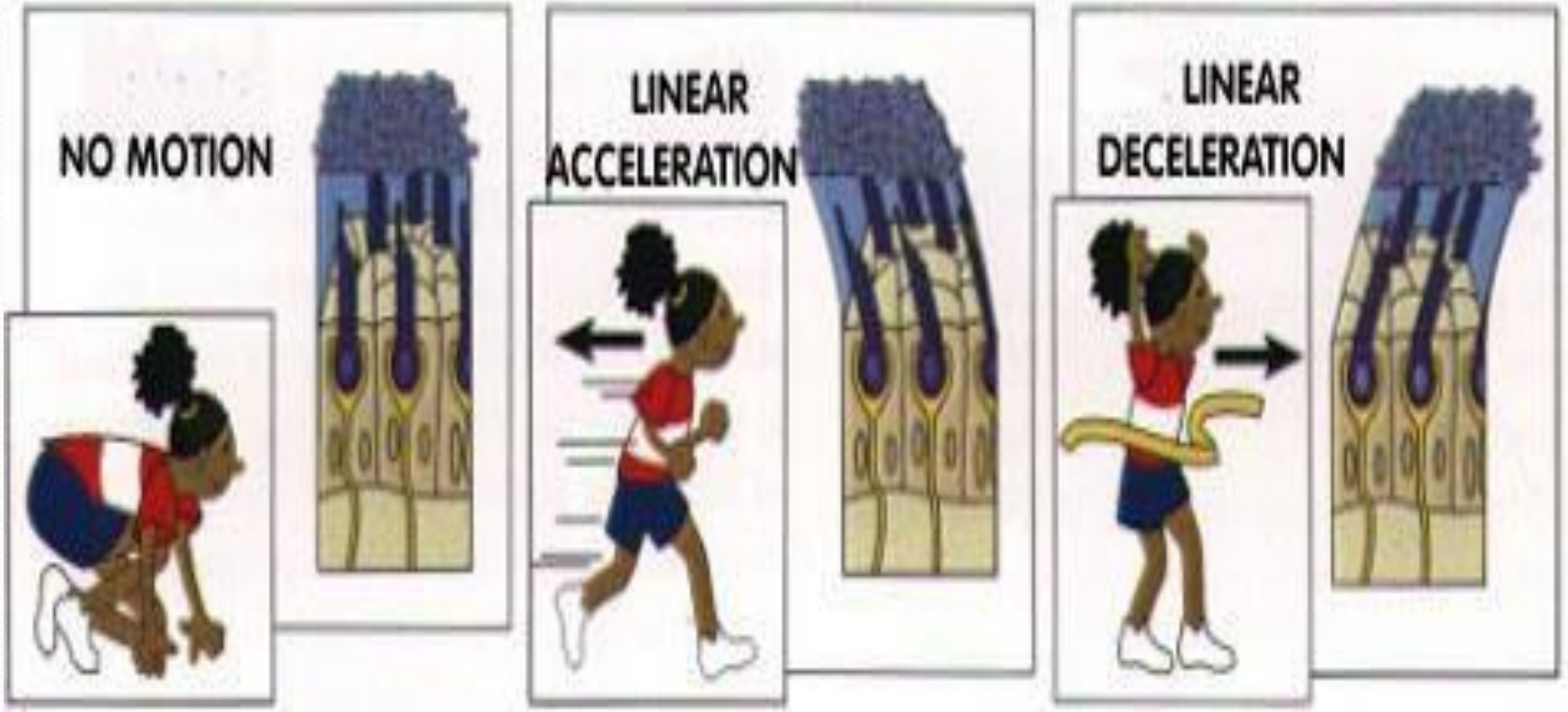
- b- bending the head to one side ;
- - statoconia crystals of hair cells fall to that side by their weight>>>>>>pull steriocilia to move towards kinocilium>>>>>depolarization (stimulation)
- -steriocilia of the other side moves away from kinocilium-------hyper-polarization (inhibition)

- **2- Detection of linear acceleration :-**

- - linear acceleration:- as at running & standing in a bus .

- - at beginning of movement statoconia lag behind movement by its inertia >>>>> fall backwards
- >>>>cilia moves backward >>>>> person feels he is falling backwards
- >>>> try to correct this by leaning forwards to shift statoconia & cillia anteriorly

- - at deceleration (runner try to stop) >>>>>
- statoconia move forwards by its momentum
- >>>> person feels falling anteriorly

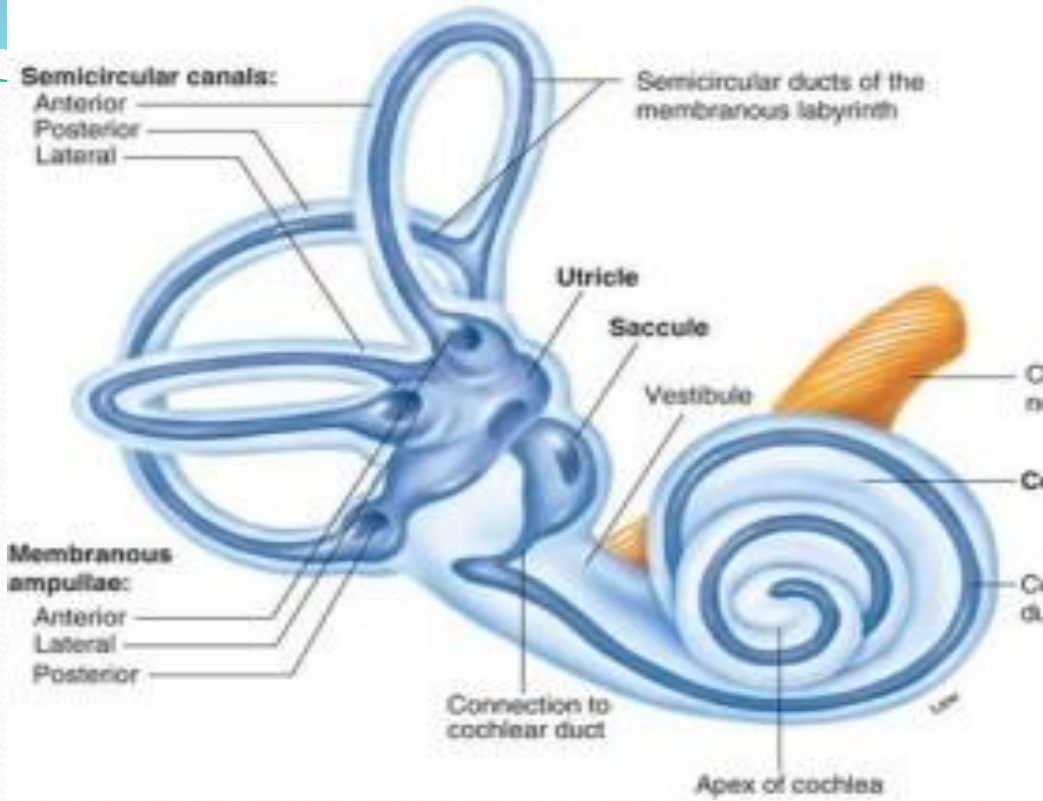

NO MOTION
LINEAR ACCELERATION
LINEAR DECELERATION

Semicelrcula canals

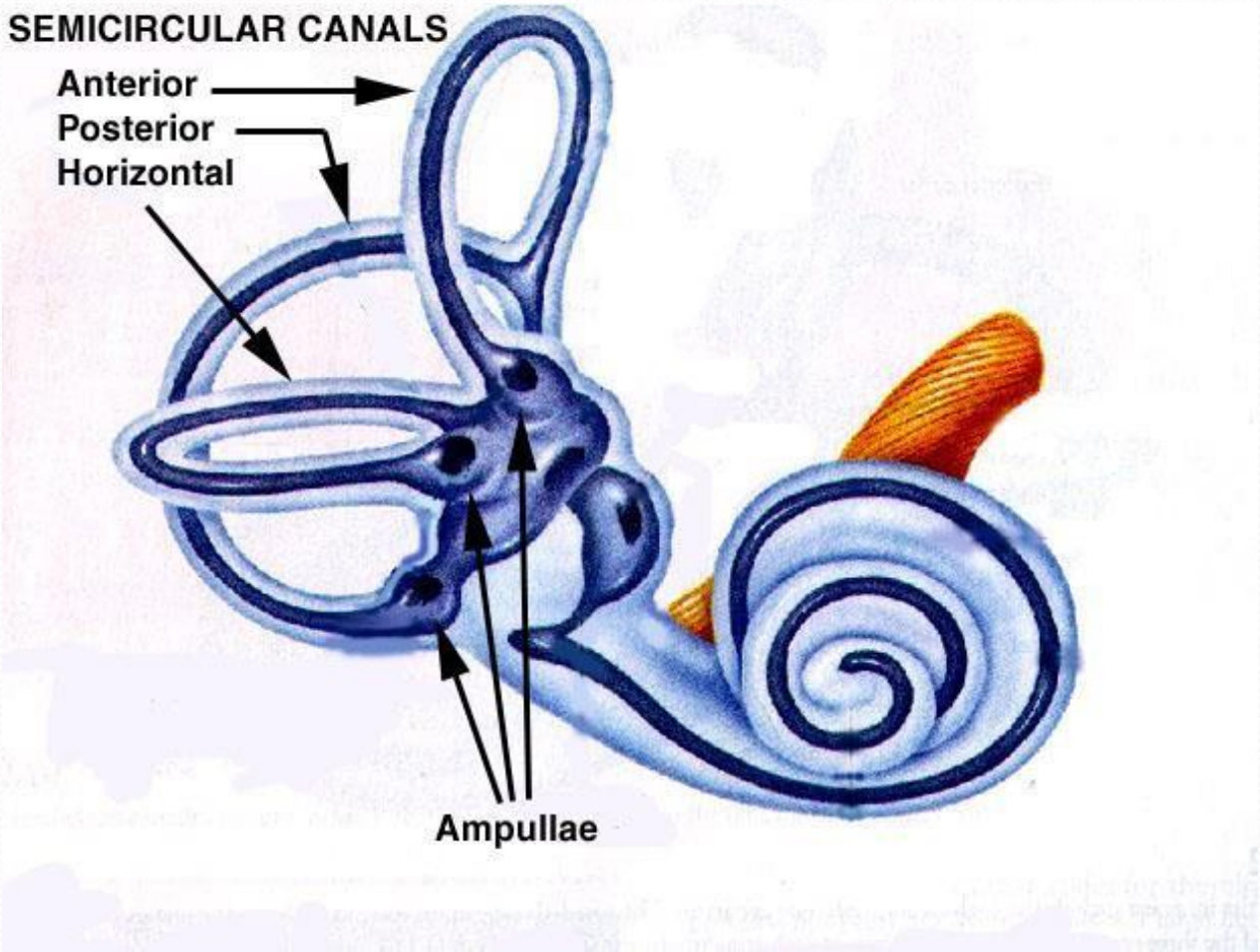
Horizontal

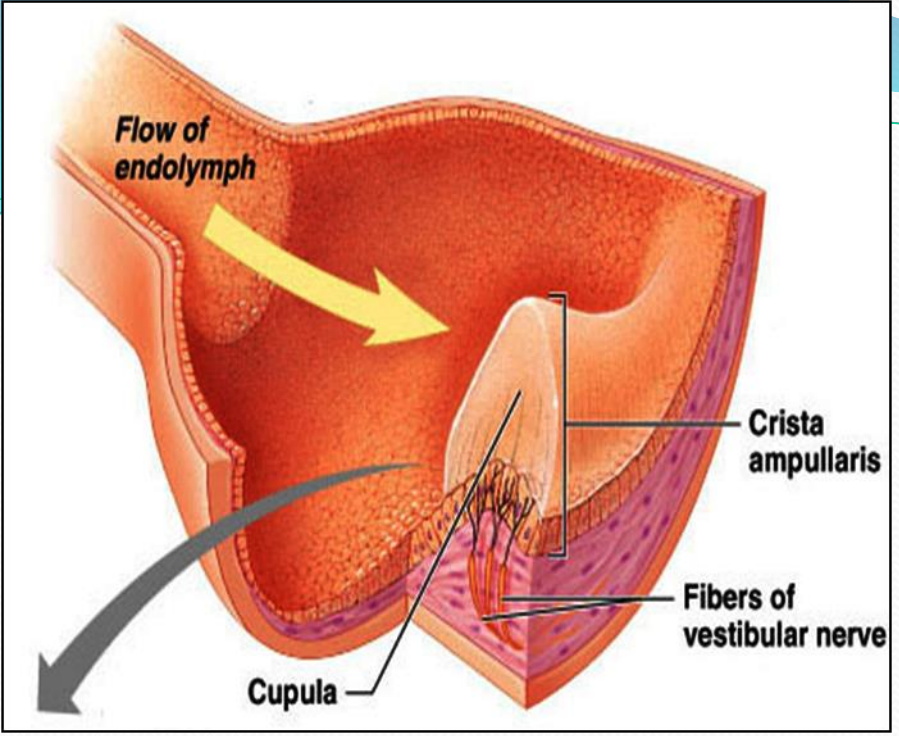
Anterior

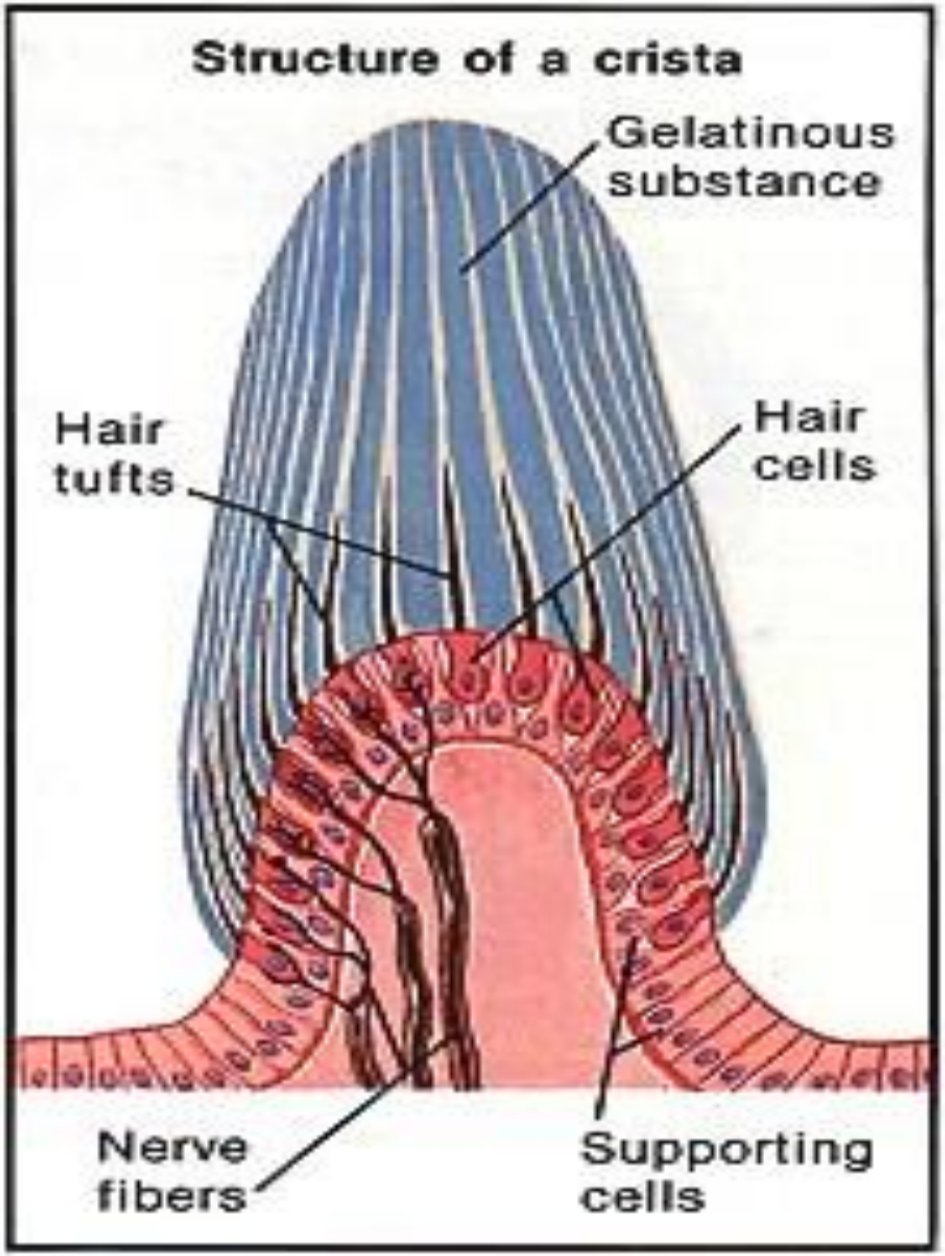
Posterior

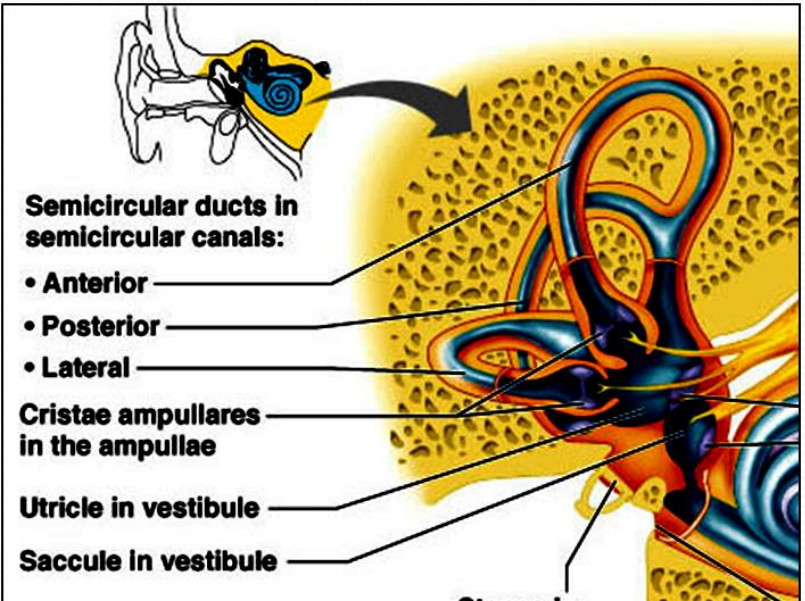


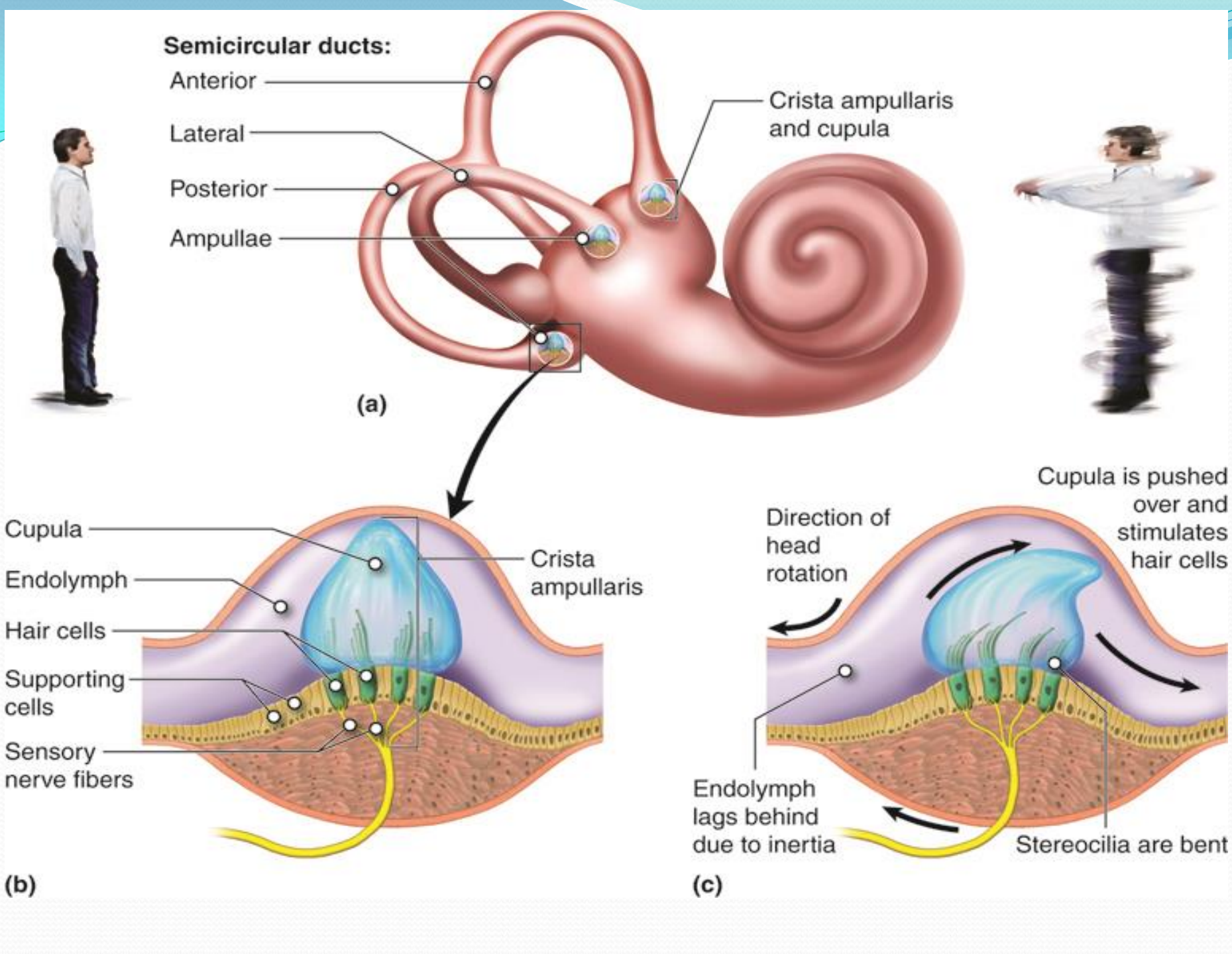
Perpendicular to each other
Filled with endolymph
Dilated end called ampulla
crista ampularis (as macula)
cilia embedded in a gelatinous mass called cupula).


SEMICIRCULAR CANALS
Anterior
Posterior
Horizontal
Ampullae


Flow of endolymph
Crista ampullaris
Fibers of vestibular nerve
Cupula

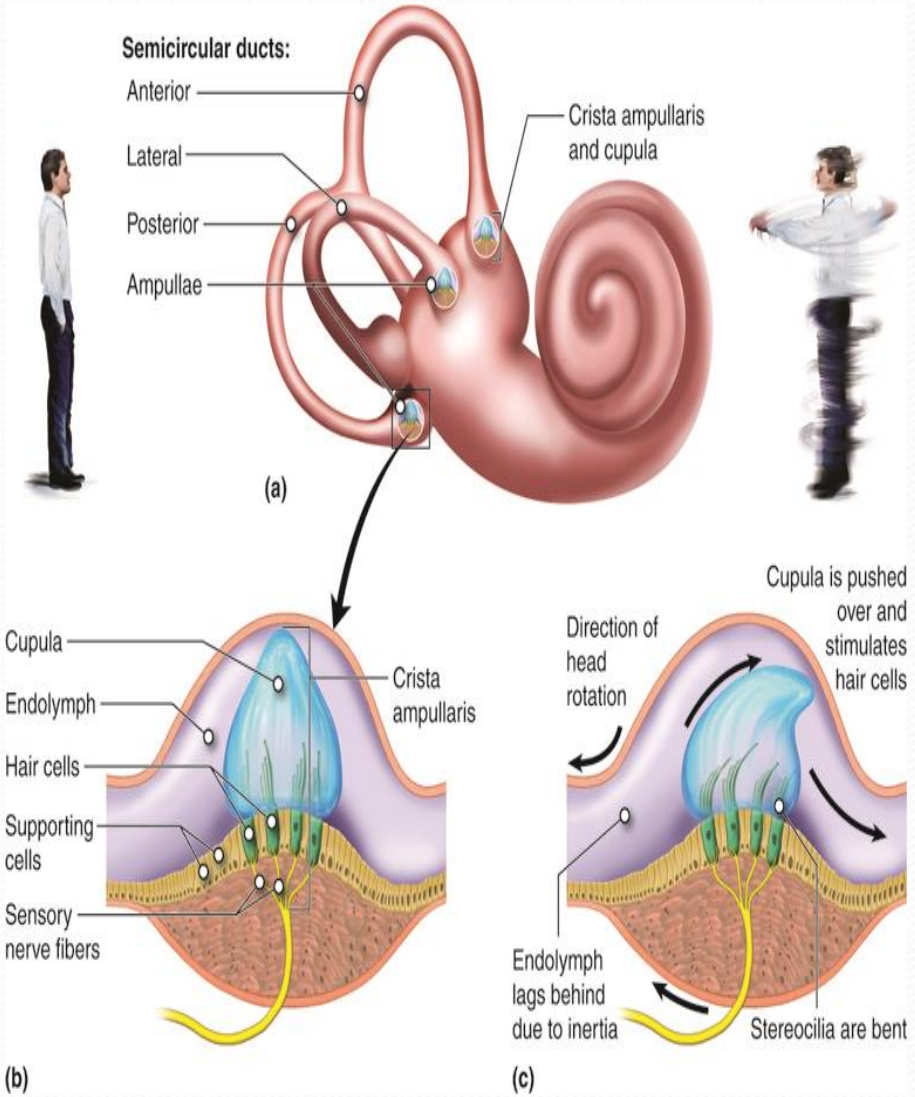

Structure of a crista
Gelatinous substance
Hair tufts
Hair cells
Nerve fibers
Supporting cells


Semicircular ducts in semicircular canals:
• Anterior
• Posterior
• Lateral
Cristae ampullares in the ampullae
Utricle in vestibule
Saccule in vestibule


Semicircular ducts:
Anterior
Lateral
Posterior
Ampullae
Crista ampullaris and cupula
(a)
Cupula
Endolymph
Hair cells
Supporting cells
Sensory nerve fibers
Crista ampullaris
(b)
Direction of head rotation
Cupula is pushed over and stimulates hair cells
Endolymph lags behind due to inertia
Stereocilia are bent
(c)

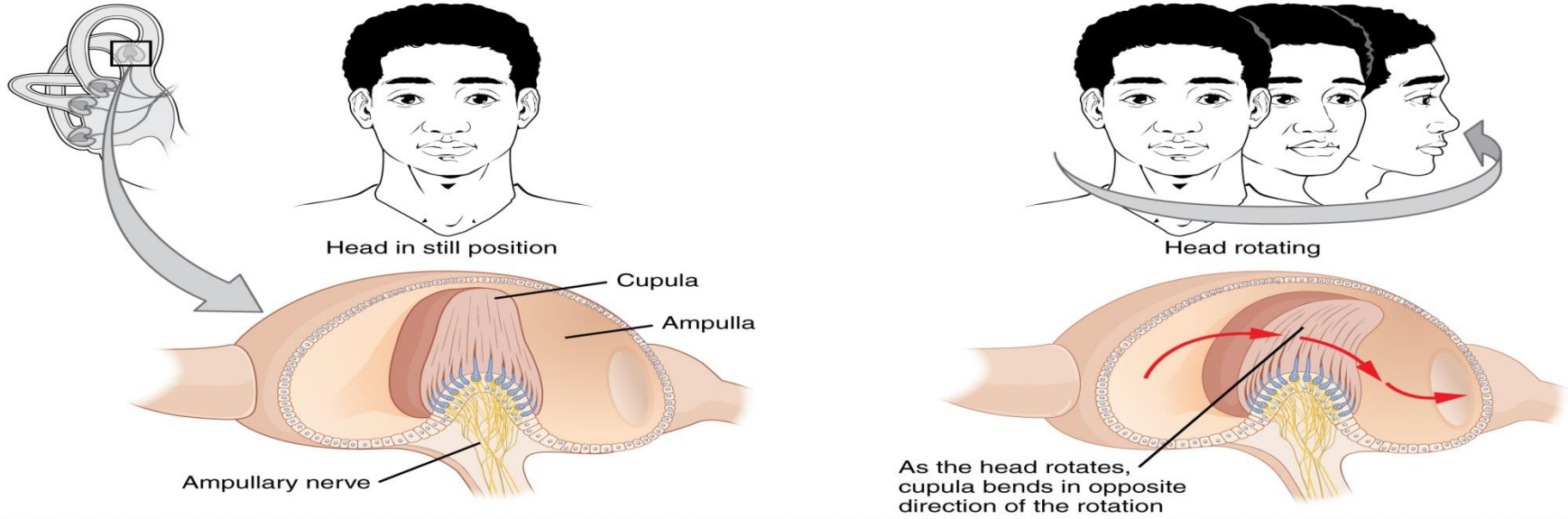
Mode of action & functions

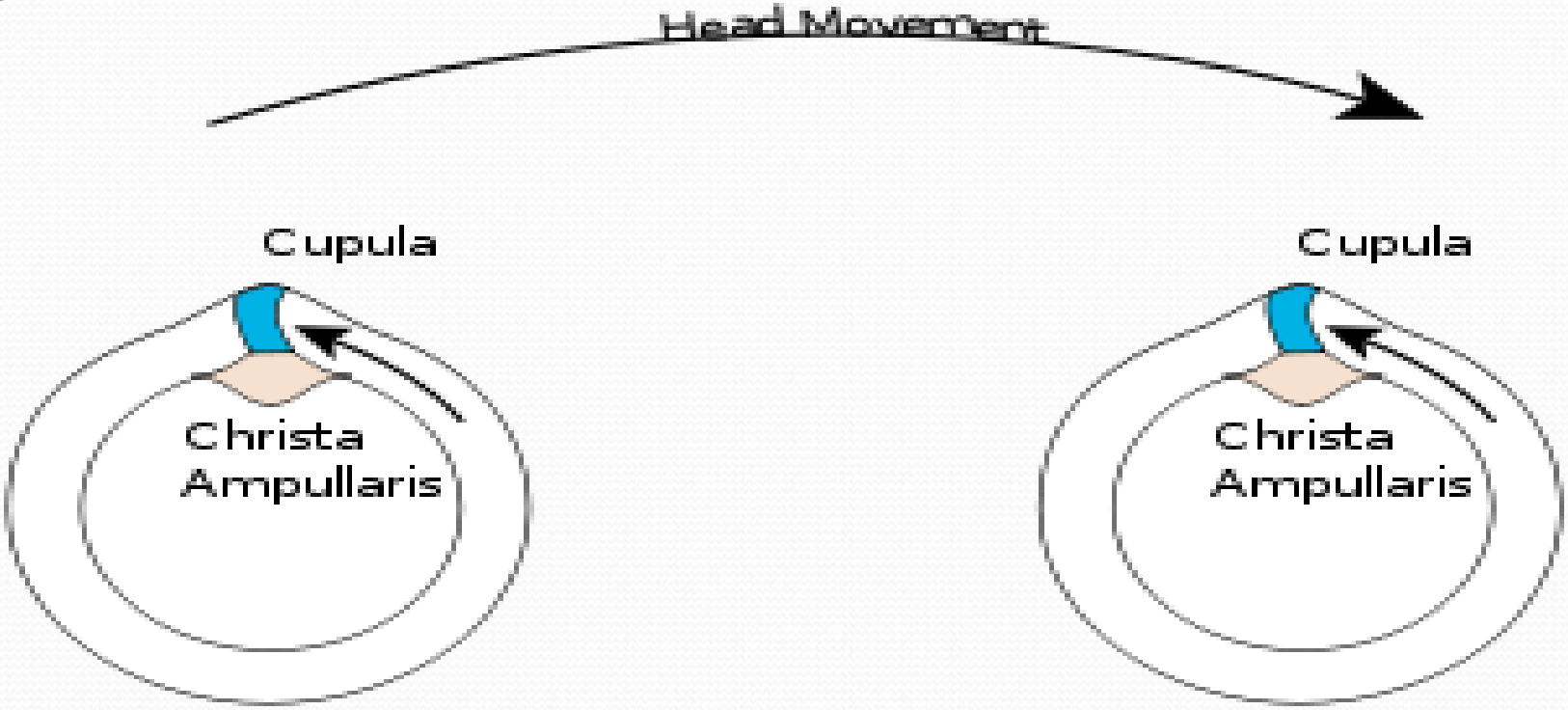
- 1- during rest : equal discharge from SCC on both
- 2- Detect & maintain posture during head rotation in any direction
- (angular acceleration) rotation



Rotation from left to right in horizontal plane:-

- Endolymph -->>>opposite direction by
- inertia --from right to left,
- -> the cilia of right side bent by endolymph towards the kinocilium >towards the utricle--
- depolarizationà--impulses from right side increase.
- --impulses fom left side decrease as cilia bent away from kinocilium.>>>>>
- - sensation of rotation to right.

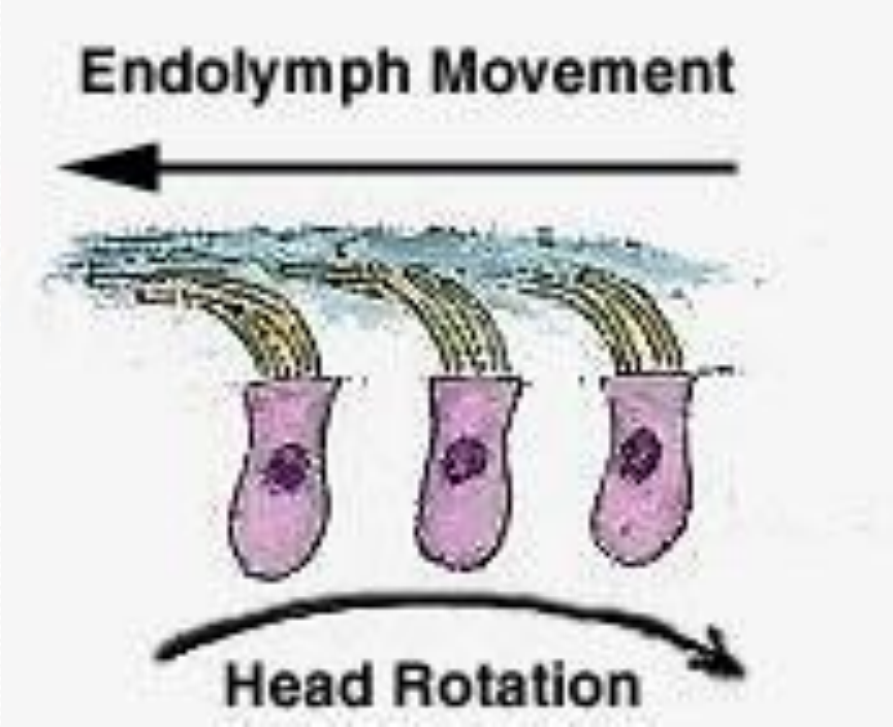




left side:
inhibition

right side:
excitation

Copula in head rotation

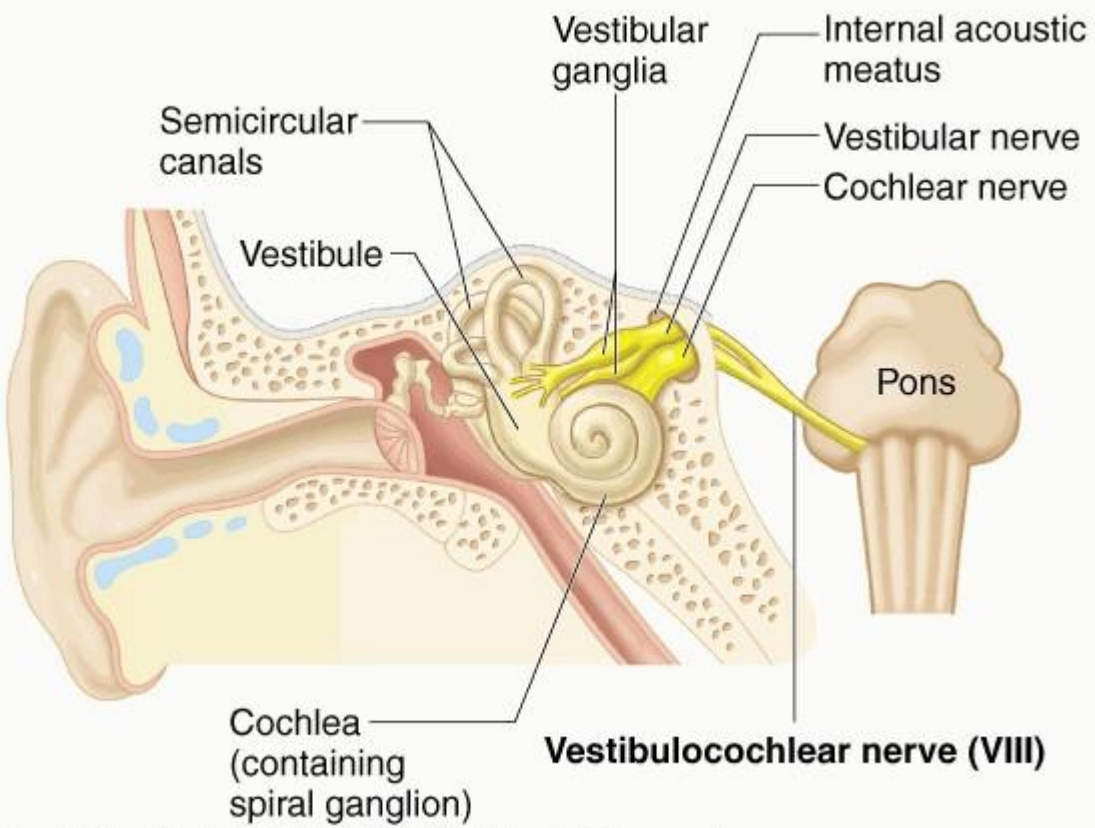


VESTIBULAR FUNCTION

Predictive function of SCC in the maintenance of equilibrium

i.e. Predict ahead of time that mal-equilibrium is going to occur

Send impulses to CNS for corrective measures before the start of the fall



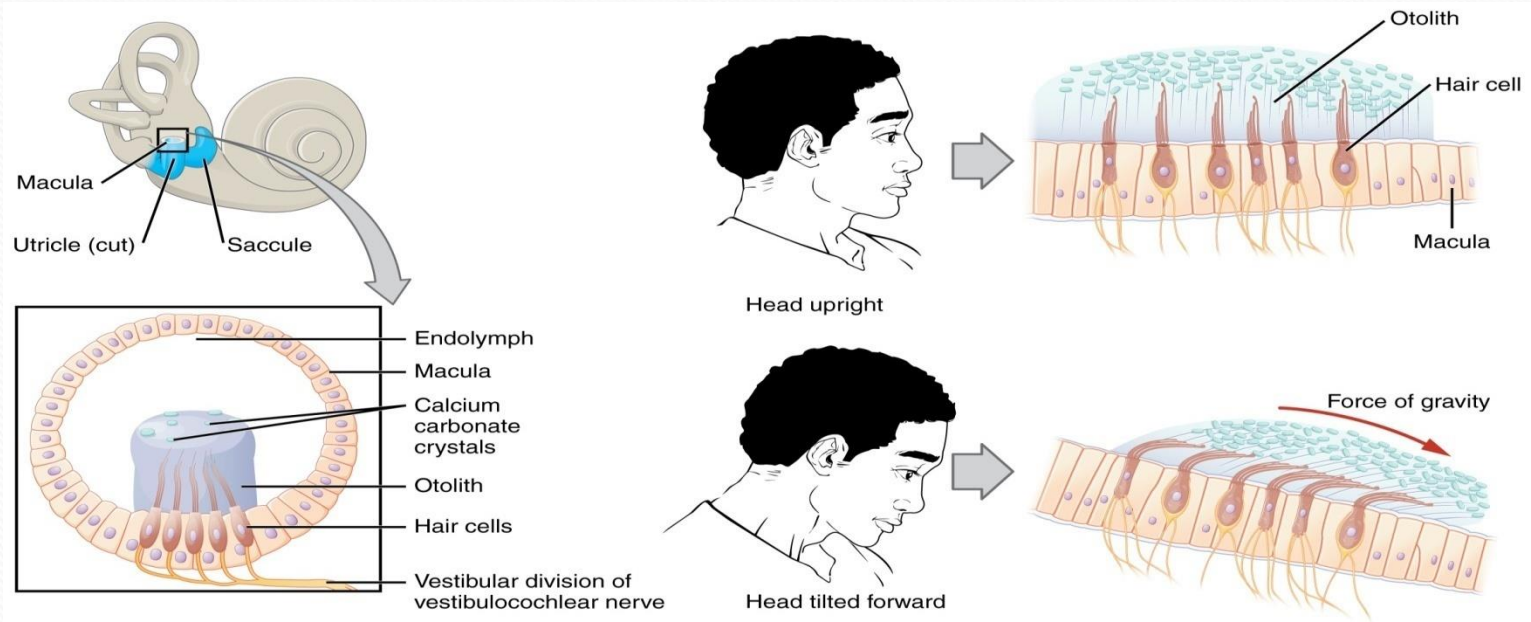
VESTIBULAR PATHWAY

Neural Connections:

- The vestibular nuclei on either sides of the brain stem send signal to:
- Cerebellum.
- Nuclei of cranial nerves III, IV, and VI
- Reticular formation
- Spinal cord (vestibulospinal tracts)
- Thalamus

Effects of stimulation of S.C.C (rotation)

- Vertigo: this false sensation of counter-rotation at end of rotation
- Nystagmus
- Bradycardia & hypotension
- Increased muscle tone on same side of rotation to support the body & decreased muscle tone on the opposite side


Macula
Utricle (cut)
Saccule
Endolymph
Macula
Calcium carbonate crystals
Otolith
Hair cells
Vestibular division of vestibulocochlear nerve
Head upright
Otolith
Hair cell
Macula
Head tilted forward
Force of gravity

Head Rotation