



Inner ear role in balance

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Posture & Equilibrium

- Reflexes maintain body position at rest & movement

- Receptors of postural reflexes are :-

1- proprioceptors

2- Visual(retinal) receptors

3- non auditory membranous labyrinth



- Labyrinth is :-

- 1- Membranous labyrinth :-

- a- auditory (cochlea for **hearing**)

- b- non- auditory for **equilibrium**

-

IT IS **Vestibular apparatus** = sacule & utricle & 3 semicircular canals.

- 2- Bony labyrinyth (bony cochlea & 3 bony semicircular canals), which enclose the membranous labyrinth **for protection.**

- Fluids in the ear :-

- 1- **perilymph** between bony & membranous labyrinth

- 2- **endolymph** inside membranous labyrinth.

Vestibular apparatus:-

- 1- utricle & saccule has a sense organ called macula (otolith organ)
- 2- SCC has ampulla.

membranous labyrinth

Bony labyrinth

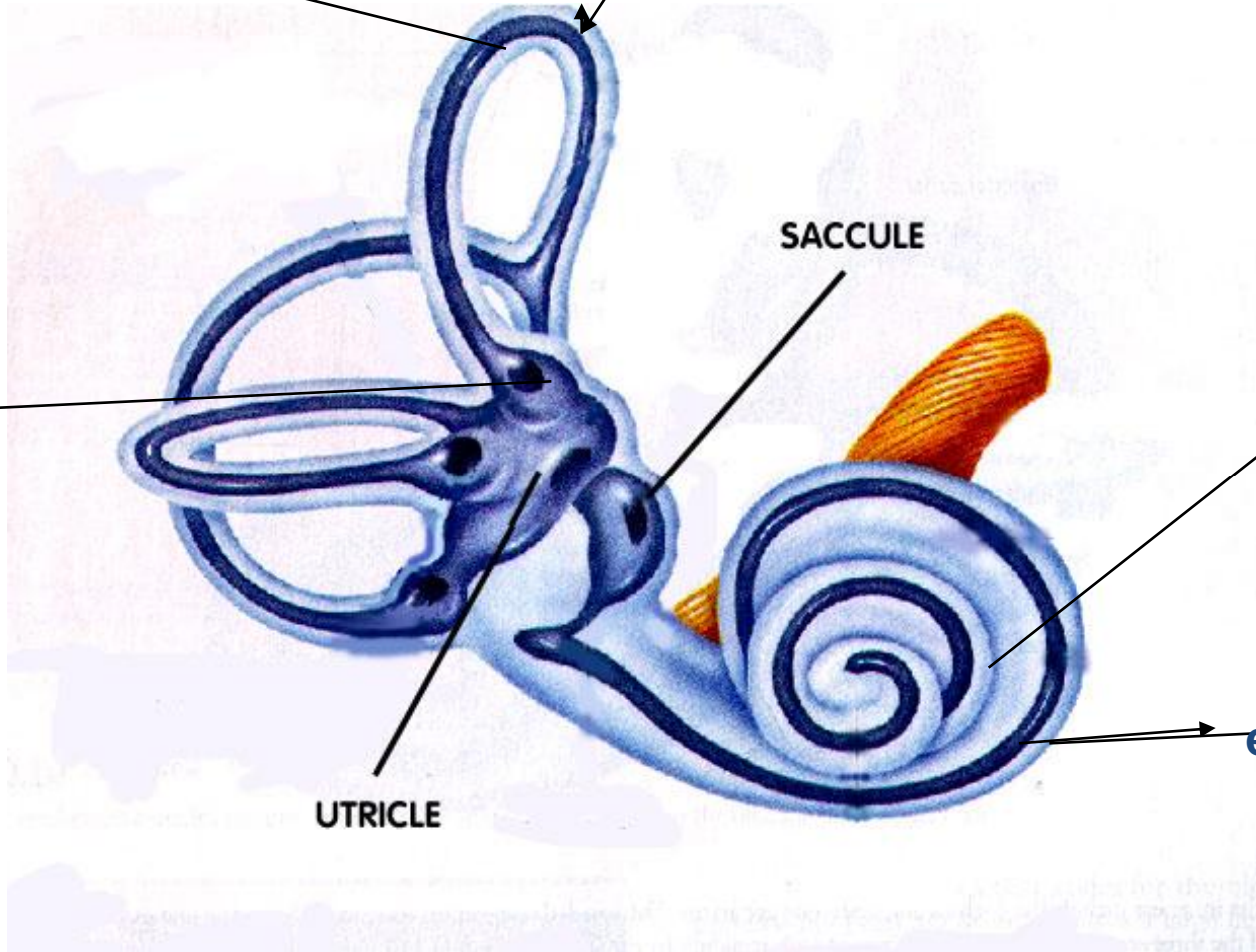
SACCULE

perilymph

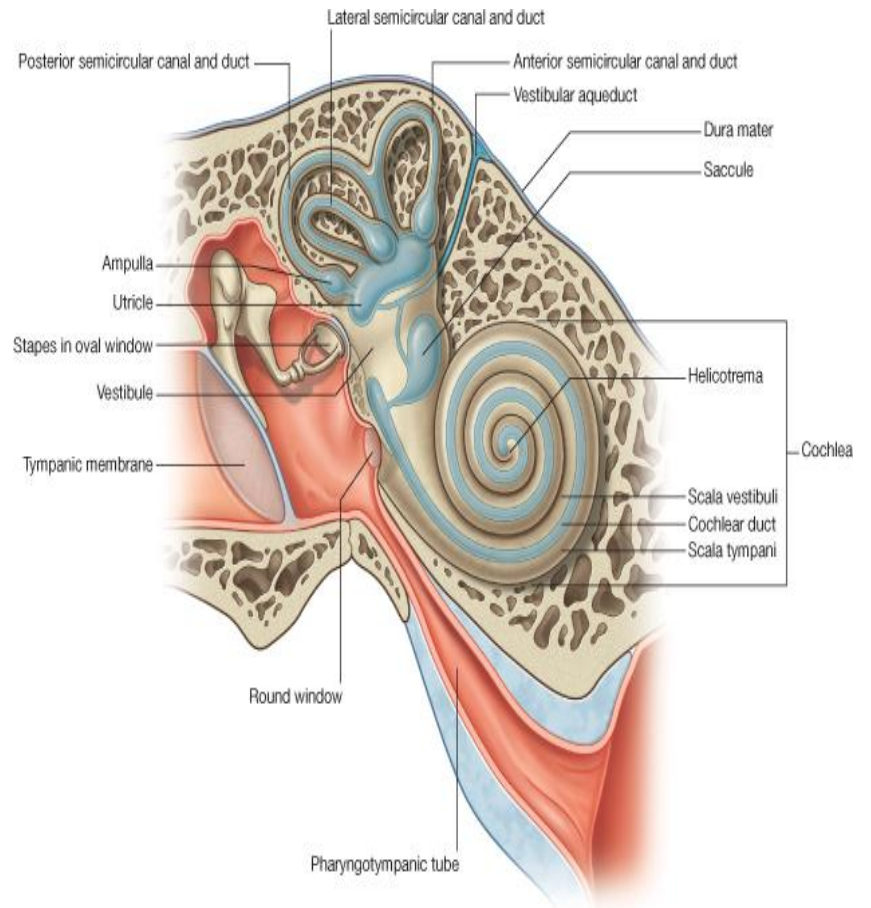
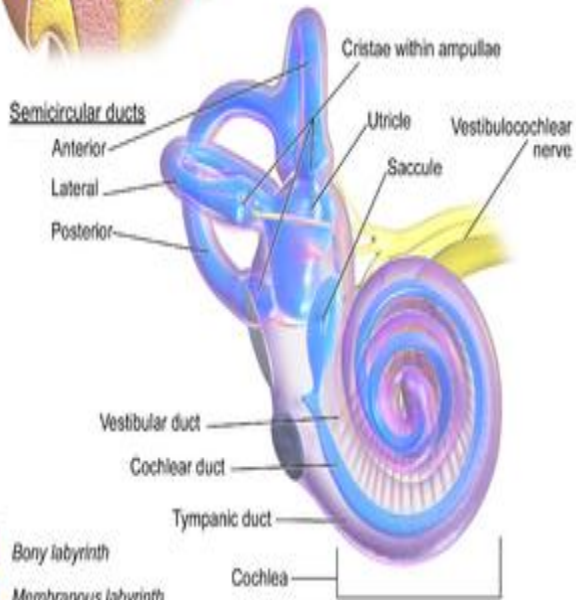
endolymph

UTRICLE

ampulla



The Internal Ear



- **Macula (otolith organs) of utricle and saccule:-**

- 1-thousands of hair cells (receptor) between a ridge of columnar epithelial cells.

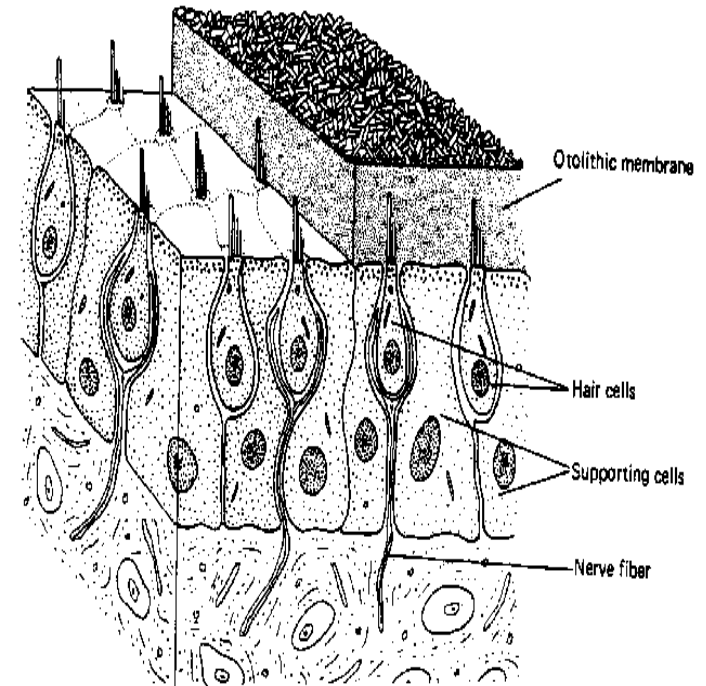
- -hair cell synapse with endings of the vestibular nerve.

- --Each hair cell has 30-150 varying size cilia called stereocilia & one large cilium called kinocilium, arranged, from shortest to tallest (towards kinocilium)

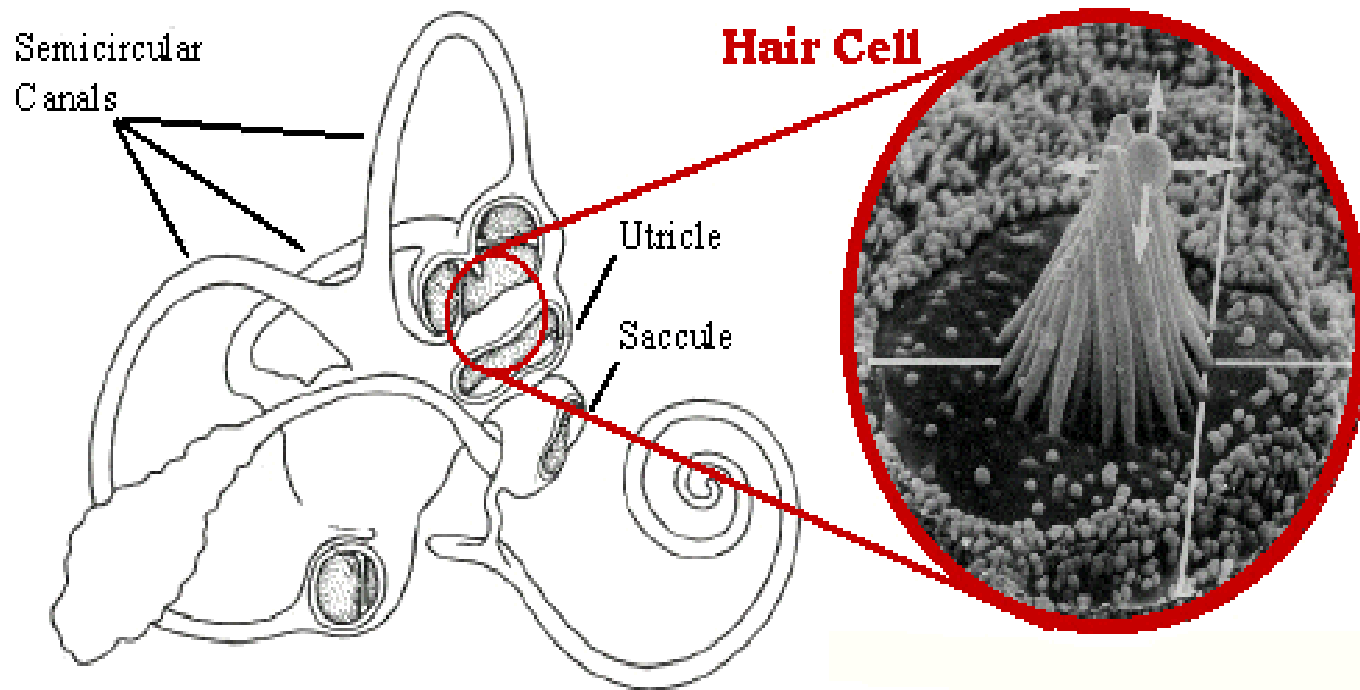
- - kinocilium connected to stereocilia , thin filamentous attachments

- -Each cilium membrane has channels for positive potassium ions.




- - stereocilia has otolithes (statoconia) of calcium carbonate subended in gelatinous material.

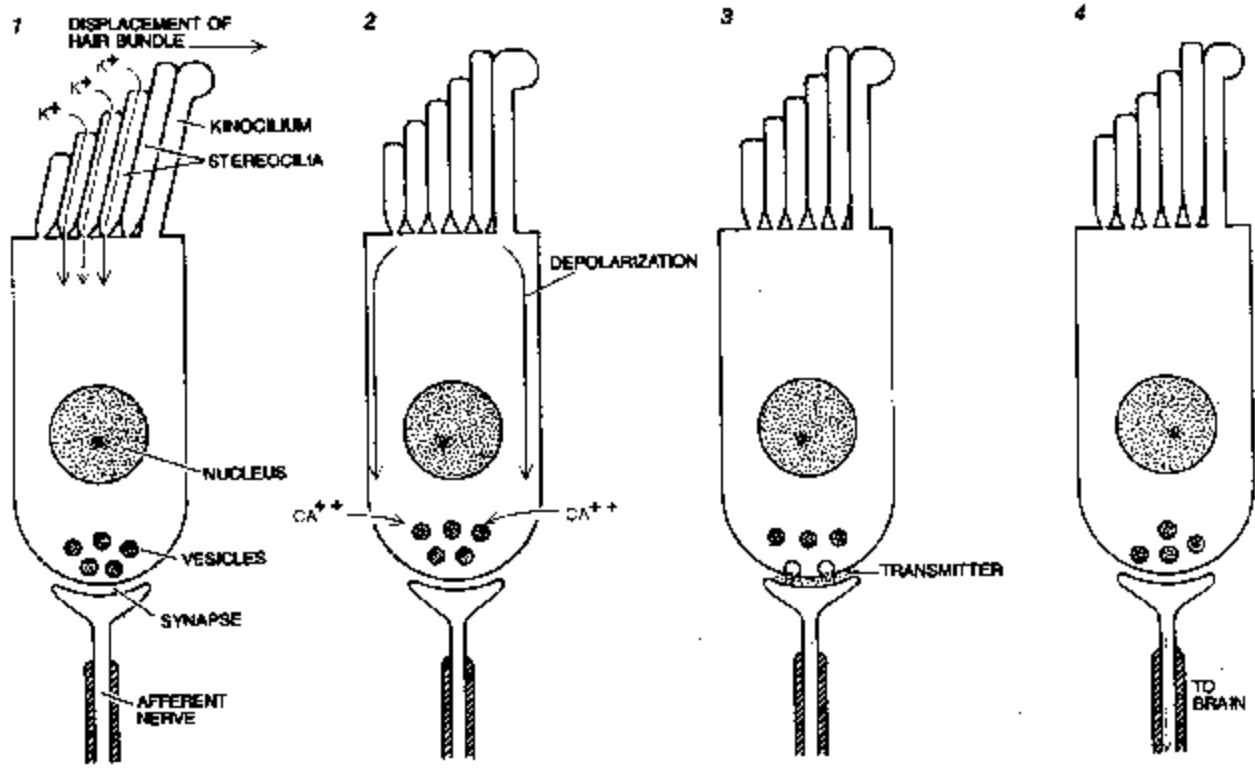


- - macula of utricle is IN horizontal plane if the head is vertical, so cilia point upwards
- - stimulated when the head bends forward & backward & laterally



- Mechanism of action:-
- 1- basal resting tonic discharge from nerve fibers of hair cells **AT REST** (increased or decreased by bending the head).
- 2- bending of stereocilia **towards** kinocilium>>>>>.open potassium channels >>>>>> **depolarization** & Ca entry & neurotransmitter release >>>>>>>>- **increase** rate of impulses to 8th nerve fibers .
- 3- bending of stereocilia **away** from kinocilium >>>>>>>-- **close** potassium channels>>>>>>**hyperpolarization**>>>>>>>**decrease rate** of impulses to 8th nerve fibers.

POSITION OF CILIA	NEUTRAL	TOWARD KINOCILIUM	AWAY FROM KINOCILIUM
<p data-bbox="479 388 680 468">KINOCILIUM (1)</p> <p data-bbox="409 502 633 582">STEREOCILIA (60 - 100)</p> <p data-bbox="494 616 680 645">HAIR CELL</p> <p data-bbox="316 682 776 753">VESTIBULAR AFFERENT NERVE ENDING</p> <p data-bbox="363 796 730 825">ACTION POTENTIALS</p> <p data-bbox="305 862 768 933">VESTIBULAR EFFERENT NERVE ENDING</p>			
<p data-bbox="413 1008 668 1079">POLARIZATION OF HAIR CELL</p>	<p data-bbox="880 1031 1031 1059">NORMAL</p>	<p data-bbox="1124 1031 1360 1059">DEPOLARIZED</p>	<p data-bbox="1414 1031 1715 1059">HYPERPOLARIZED</p>
<p data-bbox="367 1133 734 1205">FREQUENCY OF ACTION POTENTIALS</p>	<p data-bbox="884 1148 1039 1176">RESTING</p>	<p data-bbox="1178 1148 1309 1176">HIGHER</p>	<p data-bbox="1518 1148 1649 1176">LOWER</p>



- 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 mal-equilibrium.
 - b- bending the head to one side :- statoconia crystals of hair cells fall to that side by their weight>>>>>pull stereocilia to move towards kinocilium>>>>>depolarization (stimulation)
 - -stereocilia of the other side moves away from kinocilium-----hyper-polarization (inhibition) .
 - Tilting to right , stimulate right utricle & inhibit left utricle >>>>> sense of imbalance, sensation of tilting to the stimulated side(RIGHT).

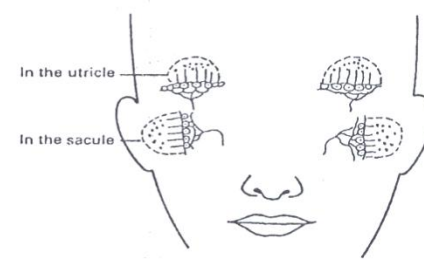


Fig. (23):
Orientation of the maculae in the utricle and saccule.

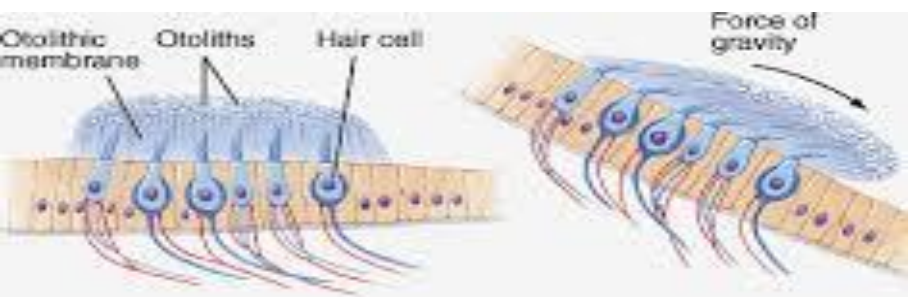
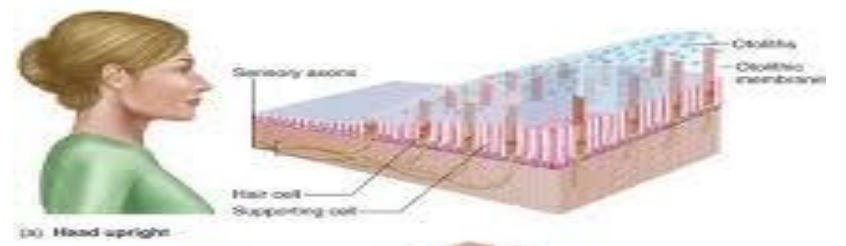
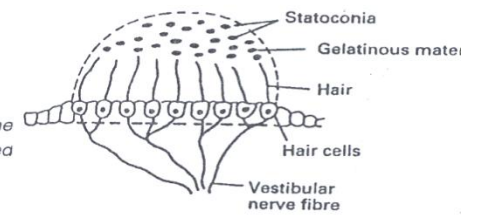
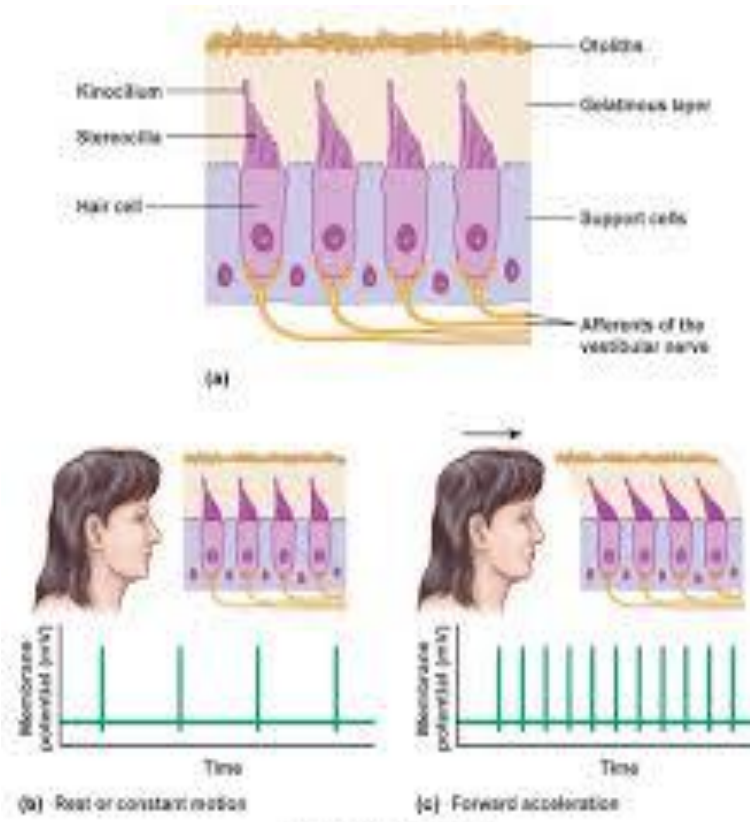
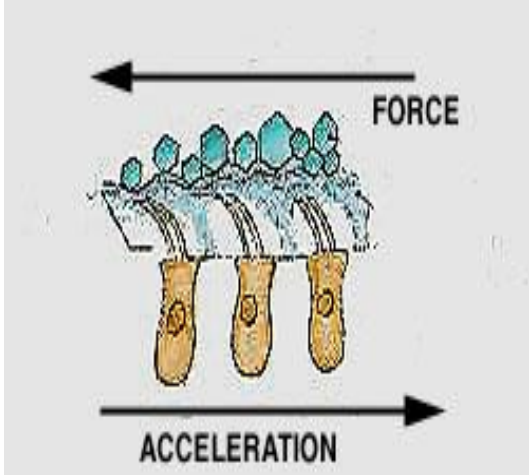


Fig. (24):
The macula of the saccule and utricle (stimulated by the pull of gravity).



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 & cilia anteriorly



- - at deceleration (runner try to stop) >>>>>
statoconia move forwards by its momentum **عزم- دفع**
>>>> person feels falling **anteriorly** >>>>>> try to
correct this by leaning backwards to shift statoconia
& cilia posteriorly,

-

NO MOTION



LINEAR ACCELERATION

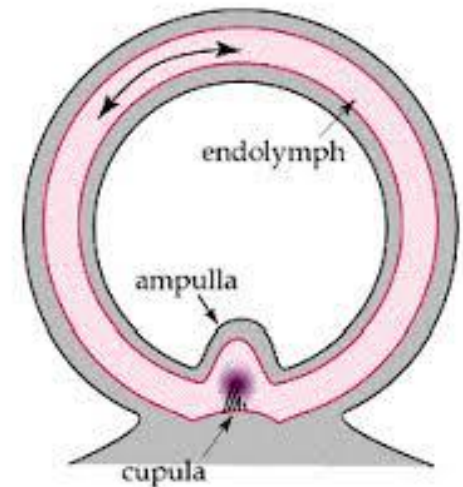


LINEAR DECELERATION



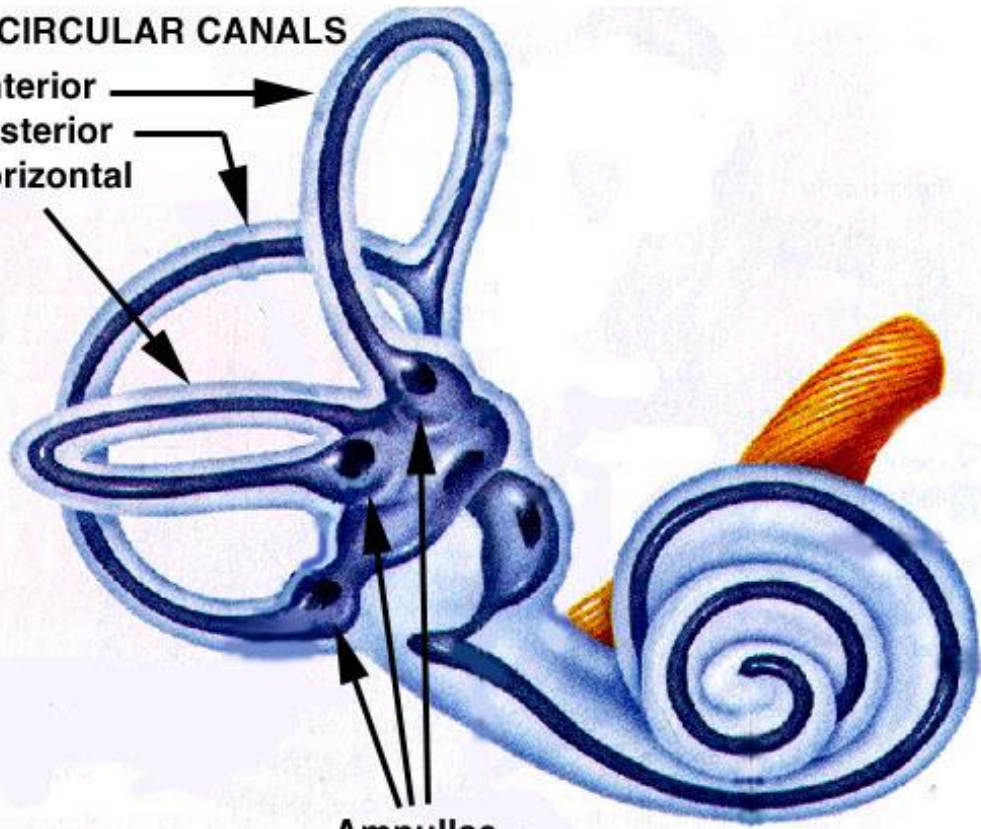
SEMICIRCULAR CANALS (SCC)

- There are 3 SCC on each side:-
- 1- Horizontal 2- anterior
3- posterior
- -All are perpendicular to each other, filled with endolymph, each has a dilated end called ampulla
- Ampulla: has crista ampularis (as macula)
- -with cilia (stereocilia & a large kinocilium directed to the **utricle** in which the ampulla open). (cilia bending towards utricle by movement of endolymph)
- - cilia embedded in a gelatinous mass called cupula).

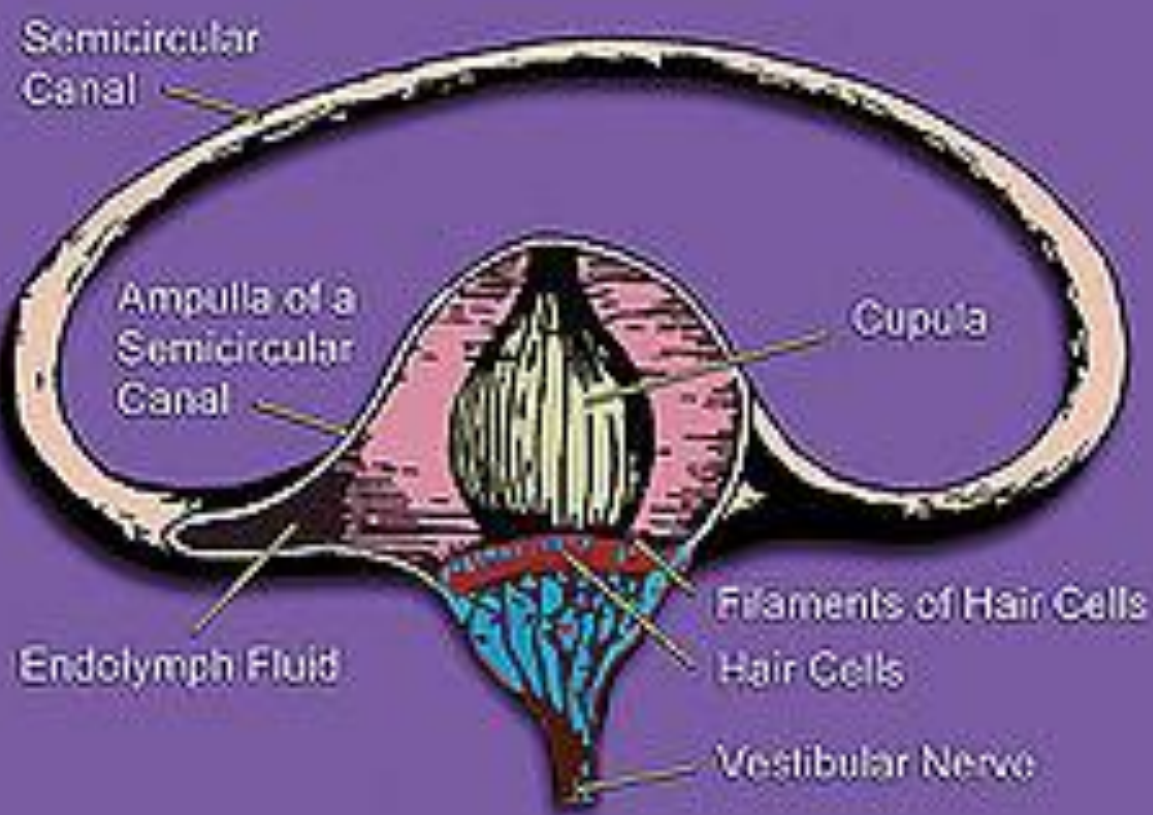


SEMICIRCULAR CANALS

Anterior →
Posterior ↙
Horizontal ↘



Ampullae



Mode of action & functions

1- during rest:- equal discharge from SCC on both sides
-transmit from their cristae about 200 impulses/sec as basal tonic discharge.

2- Detect & maintain posture during head rotation in any direction
(angular acceleration)= rotation

a- they are stimulated **at beginning & at end & by changing direction or rate of rotation**(not stimulated by maintained constant rotation as earth rotation)

-In horizontal SCC:- bending kinocilium towards utricle means cupula towards utricle>>>>>stimulate hair cells

-while bending cupula away from the utricle >>>>>inhibit hair cells.

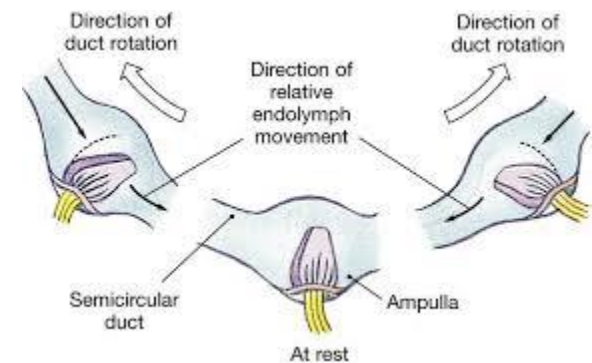
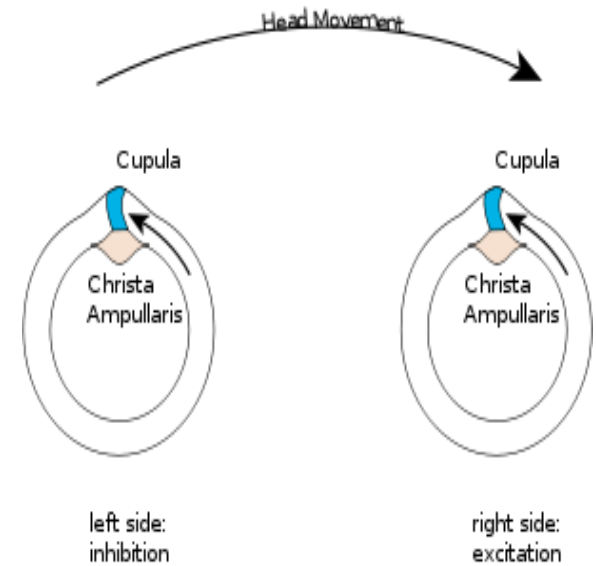
-e.g/- Rotation to RT>>>> the cilia of right side bent by endolymph towards the kinocilium >>>>> cupula moves towards the utricle>>>>>depolarization>>>>>impulses from right side increase.

**--impulses fom left side decrease as cilia bent away from kinocilium.
- sensation of rotation to right.**

- Example:- rotation from left to right in horizontal plane:-

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

- B- With constant rotation
- -endolymph rotate to same direction & velocity of rotation-----The cupula by its elasticity return to the resting position----- equal tonic balanced discharge from both sides-
- - no sense of rotation.



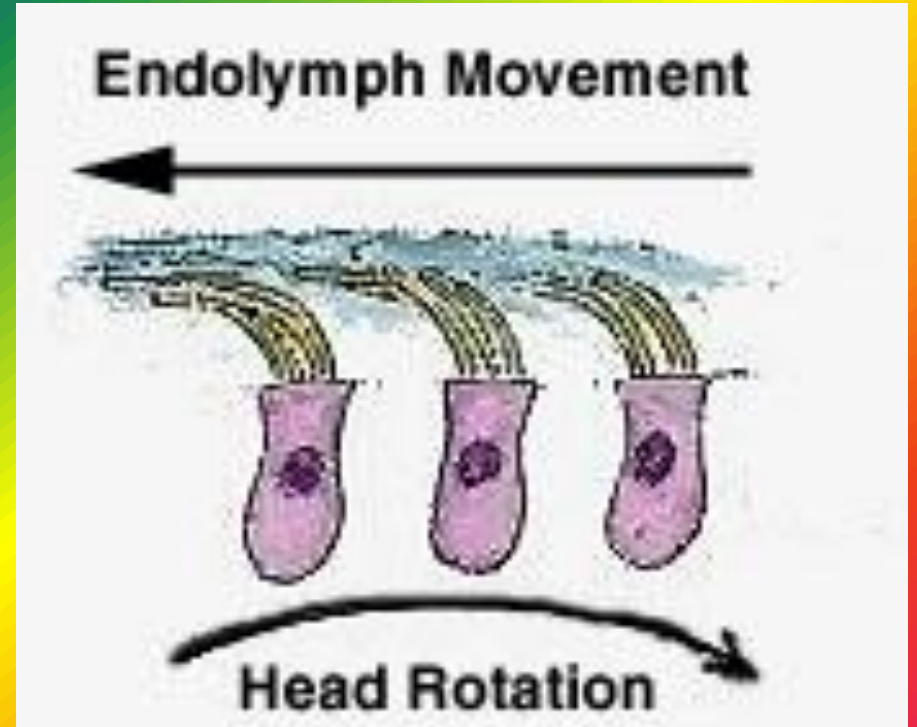
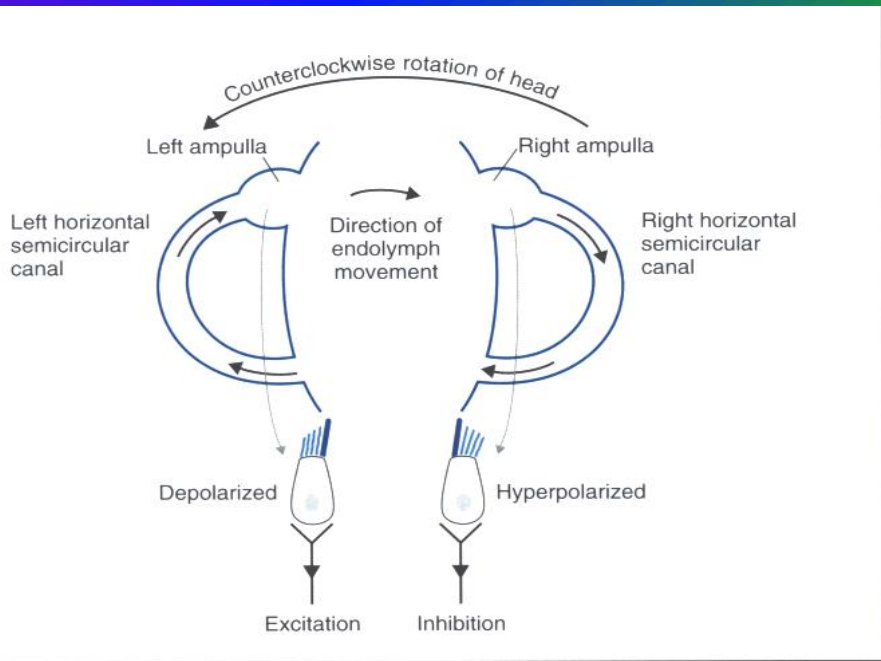
C- At stoppage of rotation

- endolymph continues to rotate from **left to right** by its momentum,
- the cilia of left side bent towards the kinocilium -----towards the utricle--
→>**depolarization**→.impulses from left side increase
- right side cilia bent **away** from kinocilium. & impulses decrease -
- >>>>sensation of rotation to **left,(from right to left)**
- **this false sensation of counter-rotation** is VERTIGO

D-few seconds after stoppage of rotation,

- Endolymph stops to rotate & cupula recoil -----resting position----- basal tonic discharge appear & vertigo disappear

Copula in head rotation



Nervous connections of vestibular apparatus:-

Nerve fibers from maculae & cristae ampularis
>>>>> Vestibular nerve->>>>>>> ipsilateral vestibular nucleus to :-

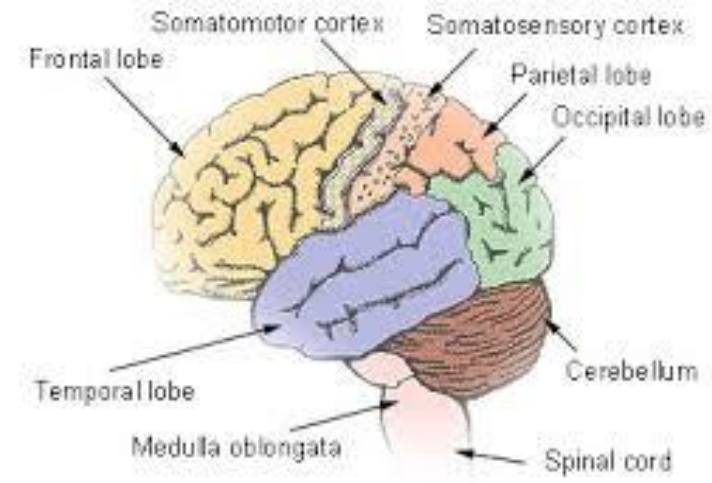
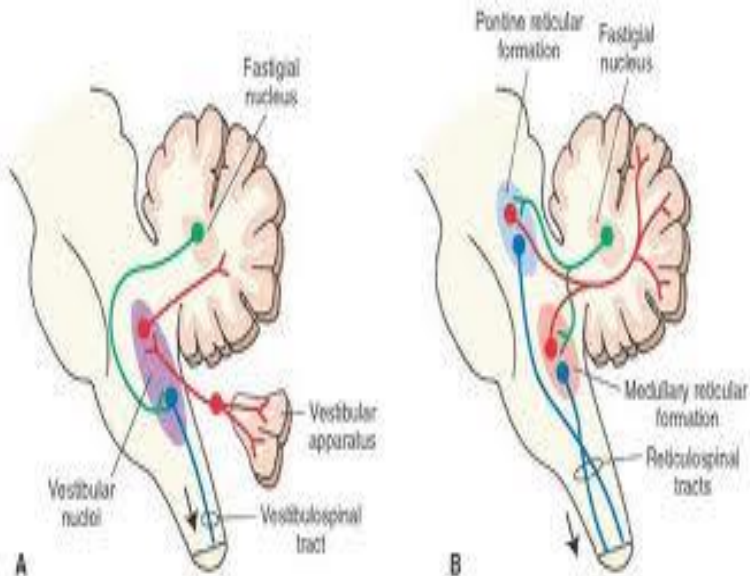
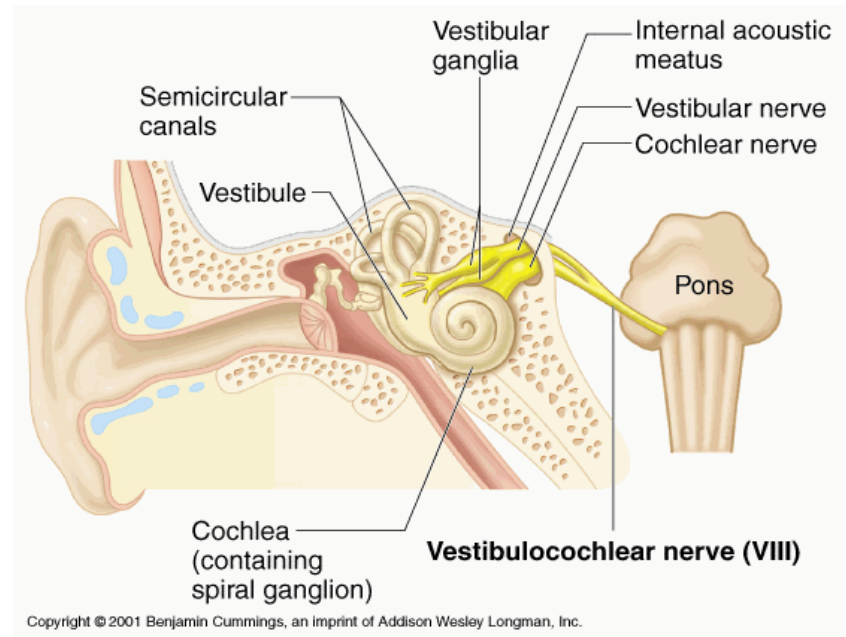
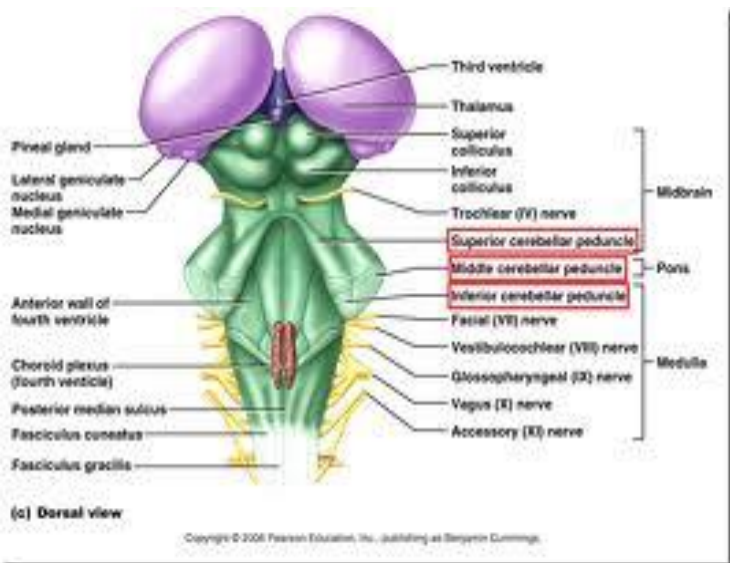
1- cerebellum:- flocculonodular lobe & dentate nucleus>>>>> thalamus of the opposite side>>>>> cortex of the opposite side (motor areas, superior temporal gyrus center for vertigo).

2- spinal cord (vestibulospinal tracts)

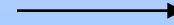
3- Reticular formation

4- Medial longitudinal bundle(for eye movements)(nystagmus)





Lobes of the cerebrum



Effects of stimulation of S.C.C:-

-Stim by rotation or caloric test

(stim of SCC by water hotter or colder than body temp in external auditory canal>>>>convection currents in endolymph>>>>motion of cupula)

1- Vertigo:- - this false sensation of counter-rotation at end of rotation (or angular acceleration)

2- Nystagmus:- jerky eye movements at the beginning & end of rotation to fix objects in the eye field.

- **3- bradycardia & hypotension.**

4- increased muscle tone on same side of rotation to support the body & decreased muscle tone on the opposite side