17 Physiology of inner ear

CNS

Slide resources :

- Male slide
- Female slide

Objective :

- Functional anatomy of Vestibular apparatus
- Dynamic and static equilibrium
- Role of utricle and sacculein linear acceleration
- Role of semicircular canals in angular motions
- Vestibular Reflexes

Slide resources :

- Male slide
- Female slide

Posture & Equilibrium

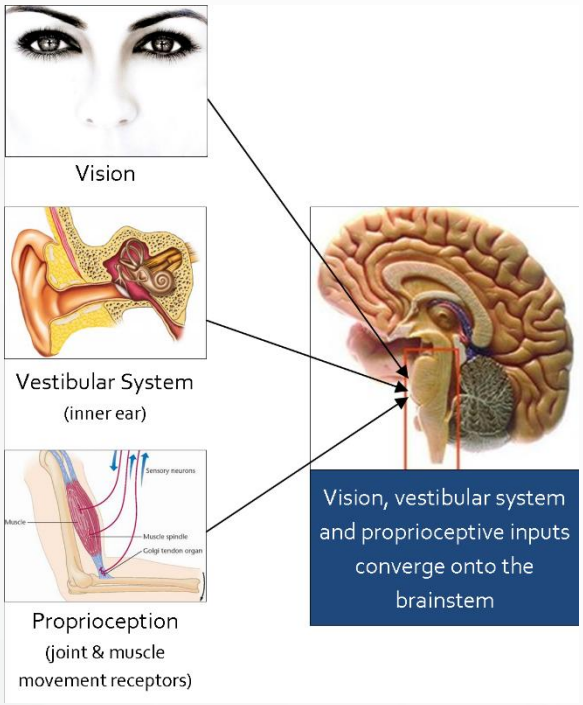
Reflexes maintain body position at rest & movement

Types of equilibrium :

- **static :** the equilibrium maintained in a fixed position.
- **Dynamic :** the equilibrium maintained while performing a movement.

Receptors of postural reflexes are :

1- proprioceptors
2-Visual (retinal) receptors "Rods and cones"
3- non-auditory membranous labyrinth



Labyrinth (inner ear) components are is :-

1- Membranous labyrinth:

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

b- non- auditory (vestibular apparatus **for equilibrium**)

Vestibular apparatus = saacule, utricle & 3 semicircular canals.

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

3- Fluids in the inner ear:

A- perilymph between bony & membranous labyrinth

B- endolymph inside membranous labyrinth.

Vestibular apparatus:

Utricle & Saccule

Receptor: Macula
Function: Linear acceleration & Orientation
Movement by: statoconia (calcium carbonate)

Cilia of hair cells embedded in **Gelatinous material of otolithes** (calcium carbonate crystals)

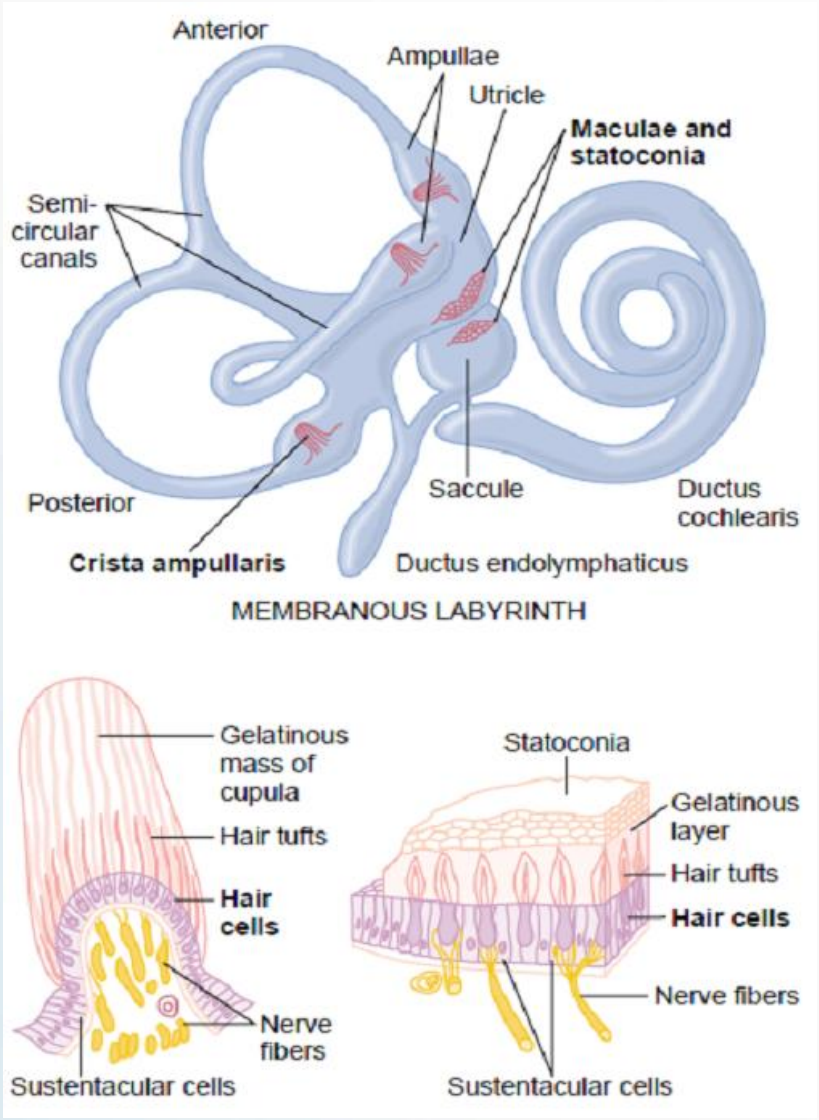
Semicircular canals

Receptor: Crista ampularis
Function: Angular acceleration **(rotation)**
Movement by: Endolymph

Cilia of hair cells embedded in **Gelatinous material of Cupula**

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)
- stereocilia & a large kinocilium directed to the **utricle** in which the ampulla open.



Hair Cells:

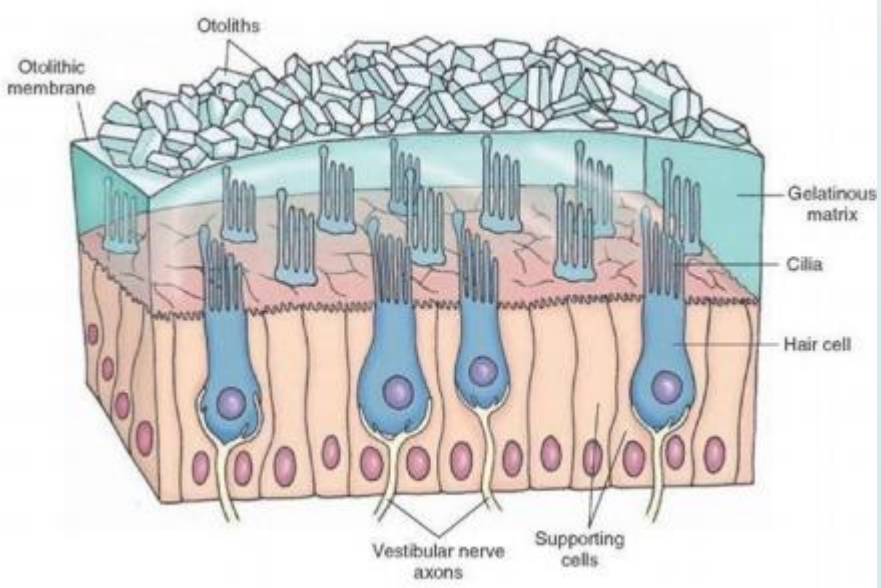
thousands of hair cells (receptor) between a **ridge of columnar epithelial cells.**

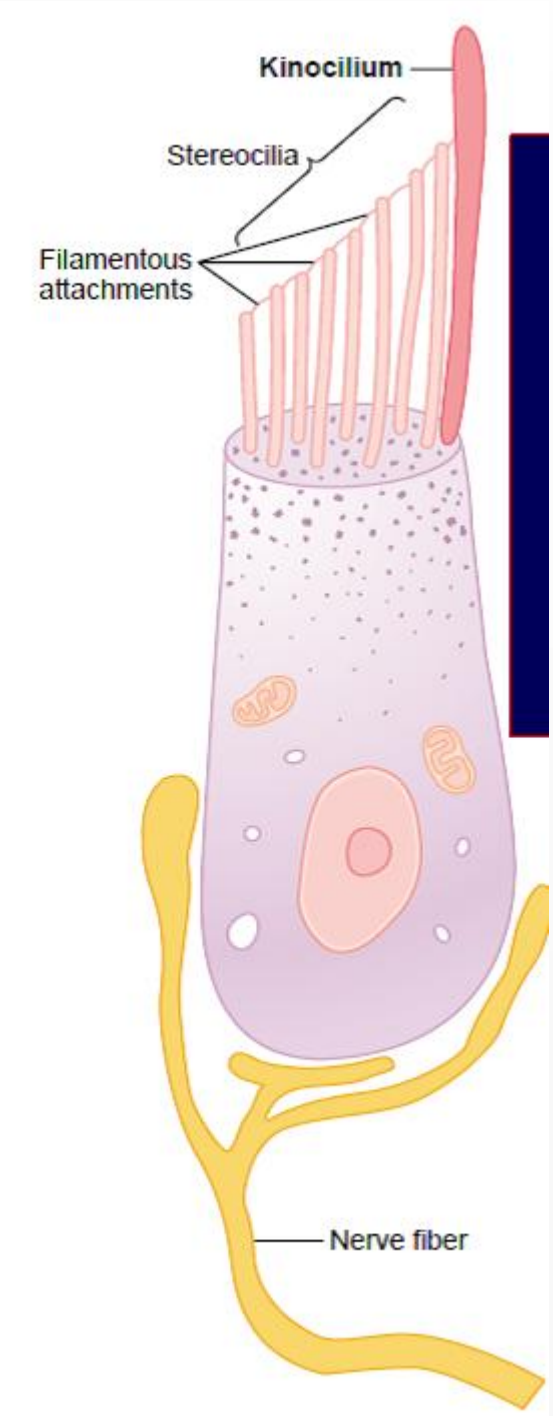
- **hair cell synapse with:** endings of **the vestibular nerve.**

- **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 by:** thin filamentous attachments

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





Mechanism of actions of macula in utricle:

1- Orientation of head in space & maintenance of static equilibrium

Macula of utricle is in horizontal plane if the head is vertical , so cilia point upwards.
(movement of hair cells by **calcium carbonate crystals of hair cells** by their weight)

At rest (Vertical position):

basal resting tonic discharge from nerve fibers of hair cells from both ear.
(Right & Left utricle impulses balance each other , So no sensation of mal-equilibrium)
Bending of head increased or decreased the impulses and lead to:

At the same side of bending:

bending of stereocilia **towards kinocilium** → open potassium channels → **depolarization** → Ca entry → neurotransmitter release → **increase rate of impulses** to 8th nerve fibers .

In the opposite side of bending:

bending of stereocilia **away from kinocilium** → close potassium Channels → **hyperpolarization** → **decrease rate of impulses** to 8th nerve fibers.

For example: Tilting to right , stimulate right utricle & inhibit left utricle
→ sense of imbalance, sensation of tilting to the stimulated side(RIGHT).

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

Mechanism of actions of macula in utricle:

2- Detection of linear acceleration

When someone is running in straight line or standing in a bus

At the beginning of Acceleration:
statoconia lag backward by its **inertia** (القصور الذاتي) → statoconia fall backwards →
cilia moves backward → person feels he is falling backwards

Try to correct this feeling by:
correct this by **leaning forwards** to shift statoconia & cilia **anteriorly**

At deceleration (Try to stop):
statoconia move forwards by its **momentum** (عزم أو دفع) → statoconia fall forward →
cilia moves forward → person feels he is falling forward

Try to correct this feeling by:
correct this by **leaning backwards** to shift statoconia & cilia **posteriorly**

Mechanism of actions of crista ampularis in SCC:

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

they are stimulated at beginning & at end by changing direction or rate of rotation
(not stimulated by maintained constant rotation as earth rotation)
مثلاً دوران الأرض ما يحفزها لأنه ثابت ، وإلا فقدنا التوازن بسبب دوران الأرض بسرعات عالية

At rest :
basal resting tonic discharge about 200 impulses/sec from both ear.

We have to know that:

Bending cupula **towards utricle** (bending kinocilium towards utricle) → **stimulate hair cells**

Bending cupula **away from the utricle** (bending kinocilium away from utricle) → **inhibit hair cells**.

Example:- rotation from left to right in horizontal plane

A. At the beginning of rotation:

Endolymph from **right to left (opposite direction by inertia)** → the cilia of **right side** bent by endolymph towards the kinocilium → towards the utricle → **depolarization** → impulses from right side increase → impulses from left side decrease as cilia bent away from utricle → 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 moments after stop of rotation:

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

Nervous connections to Vestibular apparatus:

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

1- cerebellum: floculonodular 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 and nystagmus)

Effects of stimulation of S.C.C by rotation or caloric test:

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**

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CNS Block