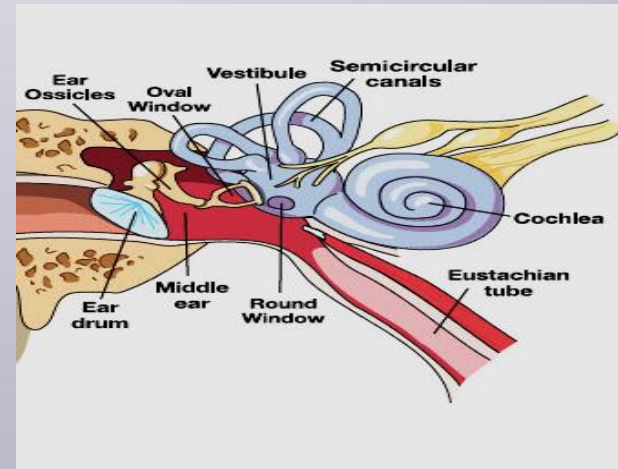




# 6. EQUILIBRIUM

## PNS MODULE



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2024

# The vestibular apparatus

- It is the organ that detects the sensation of equilibrium and present in the petrous temporal bone of the skull
- It is composed of:
  - Bony part** (bony labyrinth) which consisted of 3 bones semicircular canals & vestibule.
  - Membranous part** (non-auditory labyrinth) which consisted of 3 semicircular canals, the utricle and saccule.
  - Between the bony and membranous labyrinth, there is a fluid called **perilymph** (CSF) and inside the membranous labyrinth there is another fluid (endolymph).

The non -auditory labyrinth in each side is composed of :-

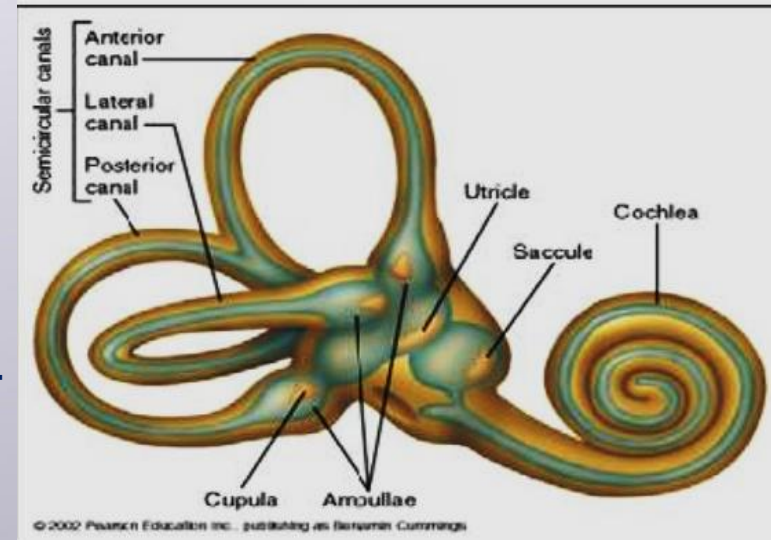
(A) The utricle and saccule:

\* Structure: 2 sacs inside the bony vestibule.

-Contain sensory organ called the Macula or otolith organ.

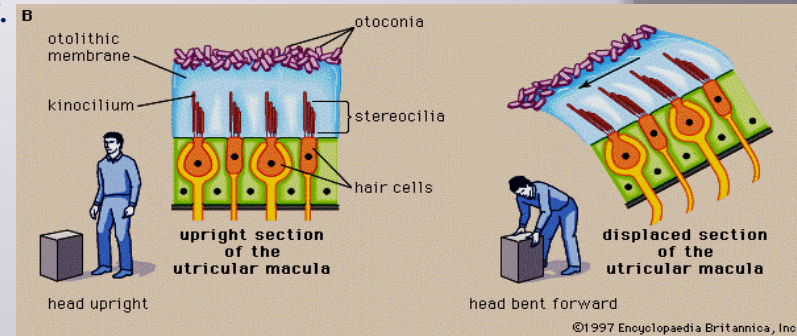
- The macula is formed of a ridge of columnar epithelium with hair cells having 50-70 small cilia called stereocilia and one large kinocilium on one side with filamentous attachments between tips of the cilia. These cilia covered with gelatinous material, embedded on its top small particles of calcium carbonate called Otoliths or otoconia.

- With the head in the erect position, the macula of the utricle is in the horizontal plane while that of the saccule is vertical.



## - Mechanism of action of Macula:

- Bending the cilia of hair cells to side of Kinocilium → depolarization of hair cells and increase its discharge in the vestibular nerve.
- Bending the cilia to the opposite side causes hyperpolarization of hair cells and inhibition of afferent impulses.
- As the hair is stimulated when otoconia pull on them, each group of hair is oriented in a different direction so, each position of head detected by a particular group of hair.



## \* Function of the otolith organs (Maculae):

### (1) Orientation of the head in space (static equilibrium)

- Impulses from Rt. & Lt. utricles are in balance when head in the normal erect position.
- Tilting the head to Rt. → the otoliths of Rt. side displaced by gravity and bending the hair cells → ↑ rate of discharge from Rt. utricle and ↓ discharge from Lt. utricle → sensation of tilting of head to right.

### (2) Receptors for linear acceleration:

When the body is suddenly forward accelerated, the otoconia (which have greater inertia than surrounding fluid) displaced backwards → bending of cilia → stimulation of hair cells → false sensation of falling backwards → automatic leaning the body forwards for proper equilibrium.

### (3) Maculae are the receptors for some postural reflexes:

- Labyrinthine statotonic reflexes.
- Labyrinthine righting reflexes.

(4) Maculae are receptors for orientation during swimming under deep water. Since visual and proprioceptive impulses are absent in this condition because water pressure is equal in all the body (by equal pressure). So, any one with inner ear disease must avoid swimming because if he closes his eyes he will immediately sink down.

## (B) Semicircular canals: (SCC)

### \*Position:

- SCC are 3 on each side and lie in 3 planes in space,
- at right angles to each other.

When the head is bent forward 30 degrees

- the horizontal canal is nearly horizontal.
- So, anterior canal in one side is parallel to posterior canal in other side

### \*Structure:

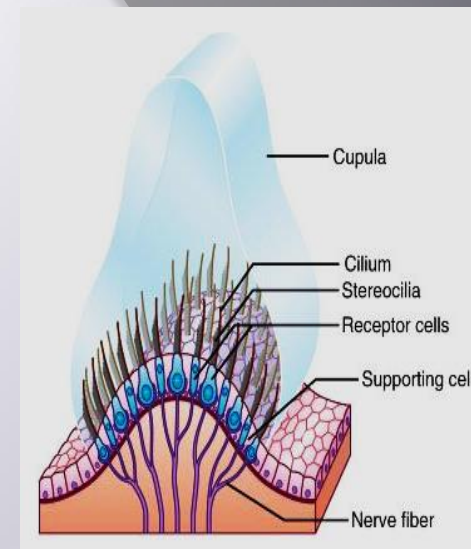
- Each SCC has a dilated end called the ampulla opening into the utricle by 5 openings only, as ant. & post. canals have a common opening at their non ampullary end.
- The **ampulla** contain sensory organ called **Crista Ampullaris**
- The crista composed of ridge of columnar hair cells. The hair is embedded in gelatinous material called cupula, and each cell contains 40-70 stereocilia and one large kinocilium.

### \*Stimulus:

- The hair cells are stimulated (depolarized) when the stereocilia are bent towards the kinocilium but hyperpolarized with the reverse side.
- In the horizontal canals the kinocilia is present towards the utricle. So, crista is stimulated when it bends towards the utricle.
- In the vertical canals the opposite occur.

### \*Function:

The function of SCC is to detect angular acceleration (rotation) and the effective stimulus to each crista is the rotation of the head in the plane of its canal.



## Mode of action of SCC in angular acceleration:

- During rest these is equal impulses are discharged from SCC of both sides.
- During rotation to **right** the following occurs:

### (1) At the beginning of rotation:

- The endolymph by its inertia rotates to **Lt** (opposite to side of rotation) → bending both cristae to left.
- The **Rt.** crista bends towards the utricle so it is stimulated (depolarized) → ↑ impulse frequency.
- The **Lt.** crista bends away from the utricle so it is inhibited (hyperpolarized) → ↓ impulse frequency.
- This unbalanced discharge gives the CNS the sensation of rotation to the Rt.

### (2) After 20-30 seconds of rotation:

As the rotation continues the inertia is overcome and the endolymph moves at the same rates as its bony canal so the **capula** return to their normal position by their elasticity → the sensation of rotation disappear.

### (3) At the stoppage of rotation:

The endolymph due to its momentum (force keeping it moving) continue to move to the Rt. after stoppage of rotation → bending the cristae to right → stimulation of left crista → false sensation of rotation to left (**vertigo**).

### (4) After 20-30 seconds of stoppage:

The movements of endolymph stop and **cupula** return to its resting position due to their elasticity → sense of rotation stops.

- Thus the SCC are stimulated at the beginning of rotation, end of rotation and change in rate of rotation, but at **constant** rate of rotation these is no stimulation (we don't perceive the rotation of earth).
- SCC have a predictive function of mal-equilibrium for correction before fall down.

## \*Methods of stimulation of the S.C.C, utricle and saccule:-

- 1) Angular or linear acceleration (rotation).
- 2) Electrical stimulation on mastoid process..
- 3) Thermal method: by warming endolymph which leads to its movement and displacement of cristae ampullaris. This occurs during ear wash when the fluid used in wash is either too hot or too cold.

## \*Results of stimulation of S.C.C:

- 1) Vertigo.
- 2) Nystagmus.
- 3) Autonomic reaction.
- 4) Past pointing test of Barany's.
- 5-muscle tone changes.

### 1) Vertigo:

•Definition: It is a false sensation of counter rotation felt on stoppage of rotation □ disturbance in equilibrium.

#### •Pathway of vertigo:

Crista of SCC → vestibular nerve → vestibular ganglion → vestibular nucleus → inferior cerebellar peduncle → folliculo-nodular lobe of cerebellum → dentate nucleus → superior cerebellar peduncle → reticular formation (may receive direct impulses from vestibular nucleus) → thalamus of opposite side → superior temporal gyrus (center of vertigo).

#### •Causes of vertigo (Dizziness or Giddiness):

- 1) Stoppage of angular rotation the endolymph due to its momentum continue to move after stoppage of rotation → bending the cristae → false sensation of rotation to opposite direction (vertigo).
- 2) Eye strain (blurring of vision).
- 3) Alcohol toxicity and overdose of streptomycin.
- 4) Motion sickness: result of excessive labyrinthine stimulation due to motion of a vehicle (car, ship or plane).
- 5) Menier's disease
- 6) Liver failure.
- 7) Drug toxicity
- 8) Fever.

## 2) Nystagmus:

• Definition: It is a rhythmic oscillatory movement of the eye (horizontal or vertical) according to direction of rotation.

It has 2 components:

**1-Slow component:** in the direction opposite to rotation (impulses from SCC).

**2-Rapid component:** in same direction of rotation (impulses from brain stem reticular formation).

• Aim: to fix objects in the field of vision for long period.

• Pathway: **For slow component:**

Stimulate of crista in SCC → vestibular nerve → vestibular ganglion → vestibular nucleus → medial longitudinal bundle → 3,4,6 cranial nerves → extra-ocular ms. → movements of eye ball.

**For rapid component:** Impulses from reticular formation of brain stem → the same pathway

• **Causes:** 1) Rotation and post rotation. 2) Optokinetic nystagmus when looking from a window of a train. 3) Defective vision or searching nystagmus due to central corneal opacity (scotoma).

4) Neocerebellar syndrome.

5) Menier's disease.

6) Hysterical nystagmus.

7) Physiological nystagmus: very fine movements of the eye during exposure to light to avoid adaptation.

**3) Autonomic reactions:** Due to impulses from SCC to autonomic centres in reticular formation causing nausea, vomiting, bradycardia, hypotension, sweating & pallor.

**4) Post-rotatory reaction (past-pointing Barany's test)**

After end of rotation to right the person feels false sensation of rotation to left. So if he is asked to touch a point on the wall (he determined it previously) while closing the eye, he touch to right of the point to compensate false sensation of rotation to left.

**5) Changes in muscle tone:**

Stimulation of SCC causes increase in ms. tone on the **same side** and decrease in **opposite side** to support the body posture.

# "Postural or equilibrium reflexes"

- The receptors of postural reflexes are found in three sites :-

1- In proprioceptors in all the body but specially in antigravity muscles.

2- In the labyrinth which is found in the inner ear.

3- In the retina (visual receptors).

- There is a center of equilibrium which is found in the **temporal lobe** in each side of the two cerebral hemispheres near auditory center. When the body equilibrium starts to be disturbed this leads to unequal impulses to both centers, which stimulate immediately the postural reflexes .

**\*Types of the postural reflexes :** the postural reflexes are classified according to site of its center into:

**[1] Spinal postural reflexes :** it's center lie in the spinal cord they are better studied in spinal animal, lesion below C5, as :- 1- Stretch reflex . 2-Steeping reflexes (direct- Crossed (Phillipson's reflex)-diagonal ) . 3- Positive supporting reaction. 4-Crossed extensor reflex.

**[2] Medullary postural reflexes (statotonic reflexes):**

**(a) Statotonic Neck reflexes:**

1- Ventroflexion of head → flexion of fore limbs and extension in hindlimbs .(like a cat looking underneath a chair)

2-Dorsiflexion (extension of head) → extension of forelimb and flexion of Hind limbs.(like a cat looking above a shelf).

3- Turning the head to one side → extension and rigidity in that side and decrease tone and flexion in other limbs.

**(b) Statotonic Labryinthine reflexes:**

1- Ventroflexion of the head or prone position → flexion of the 4 limbs (minimal tone).

2- Dorsiflexion of the head or supine position → extension of the 4 limbs (maximal tone).



### [3] Midbrain postural reflexes: (Rightening reflexes)

#### A- Two reflexes correct the head position:

##### (1) Labyrinthine rightening reflex on the head:

When the animal is held in air from its pelvis (no proprioceptors) and tilted to one side → the position of head is corrected with eyes lying in horizontal plane (receptors are otoliths).

##### (2) Body rightening reflex on the head:

If a thalamic labyrinth-less animal is put on its side the pressure on that side stimulate the proprioceptors → correction of head position in horizontal plane.

#### B-Two reflexes correct the body position after correction of the head:

(1) **neck rightening reflex on the body:** After correction of the head in thalamic labyrinth-less animal as above, the twisted neck stimulate the proprioceptors to send impulses to correct the body on standing position (correct the anterior limb at first).

(2) **Body rightening reflex on the body:** If thalamic animal (blind) with fixed neck or destroyed neck dorsal root is put on its side, the pressure receptors on this side send impulse to correct the whole body.

**C- Grasp reflex : is one of the rightening reflex:** -If an object is placed in contact with the palm of thalamic animal or with **area 6 lesion**, the fingers will close firmly (grasp) around it & attempt to remove this object from hand causes more grasp.

-This reflex present in before one year due to lack of myelination of the inhibitory descending tracts from cortical area 6 which newbornh inhibit it.

### [4] Cortical postural reflex:

(a) **Optical rightening reflexes:** Visual impulses to the visual cortex can correct the body position.

(b) **Hopping reaction:** If a standing animal is pushed laterally, it hops (jumps) to restore its balance and to support its body weight.

(c) **Placing reaction:** If a blindfold animal suspended in the air from its pelvis and we touch his body with a surface, the animal will place its limbs firmly on the point of contact.

# Thank You

