Vestibular apparatus

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Introduction

- The vestibular apparatus is the sensory organ for detecting sensations of equilibrium.
- It is encased in a system of bony tubes and chambers located in the petrous portion of the temporal bone, called the *bony labyrinth.*
- Within this system are membranous tubes and chambers called the *membranous labyrinth.*
- **The membranous labyrinth is the functional part of the vestibular apparatus.**

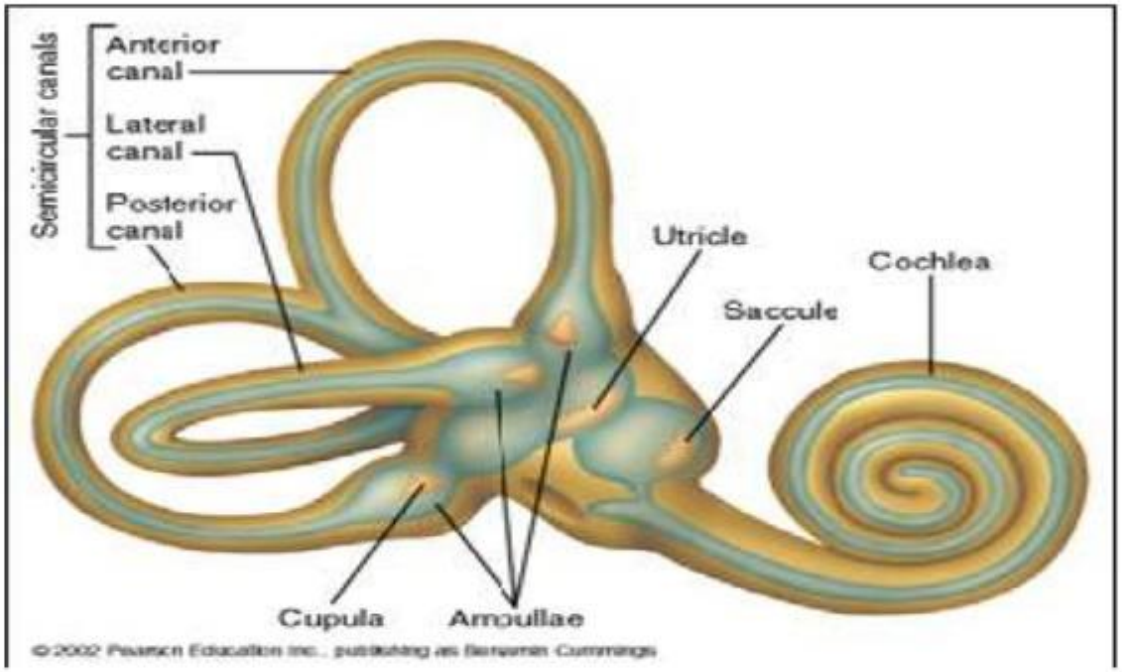
Vestibular Apparatus(Labyrinth) - Sense of equilibrium

- 2 in number - One vestibular apparatus on each side in inner ear

It consists of:

- Otolith organs
  - Utricle
  - Saccule
- 3 semicircular canals (*right angles to each other)*
  - Anterior/Superior
  - Posterior/Inferior
  - Lateral/Horizontal/External

Vestibular Apparatus



Vestibular Apparatus(Labyrinth) - Sense of equilibrium

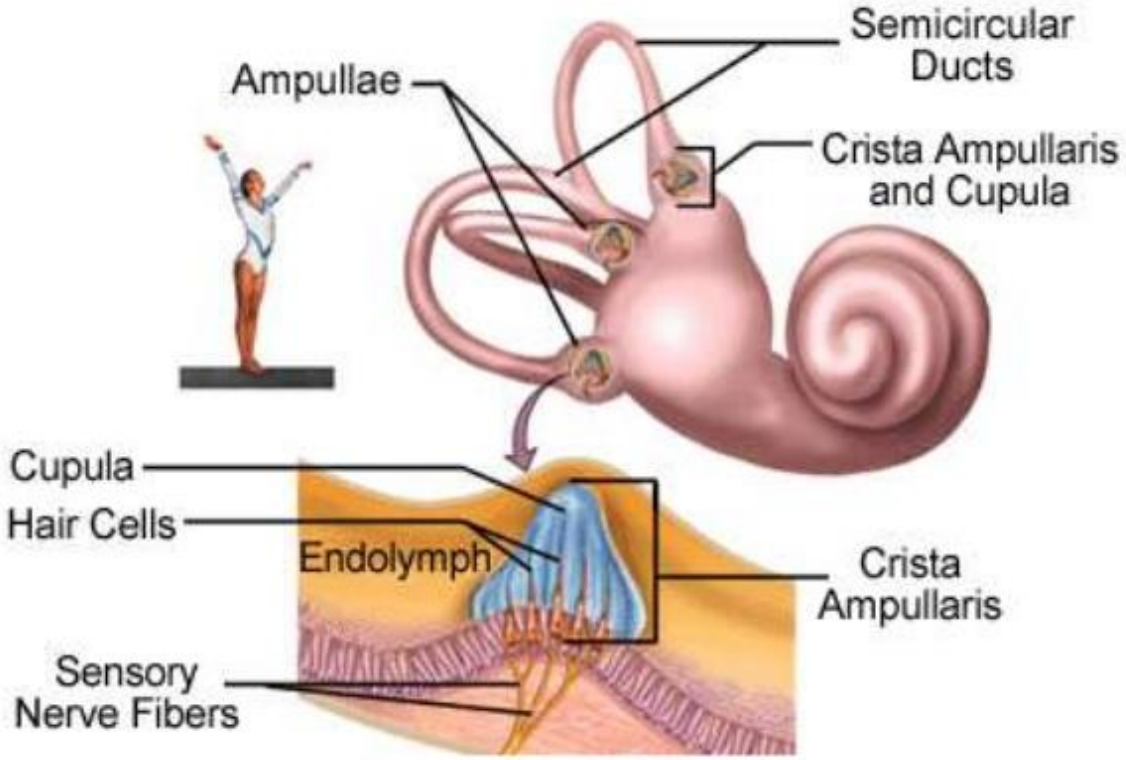
- Receptor - hair cell - Each hair cell has kinocilium & stereocilia
- Utricle & saccule – has macula – senses **linear acceleration**
- Each semicircular canal has an ampulla which has crista ampullaris (cupula – gelatinous mass of hair from the hair cell)– senses **angular acceleration**

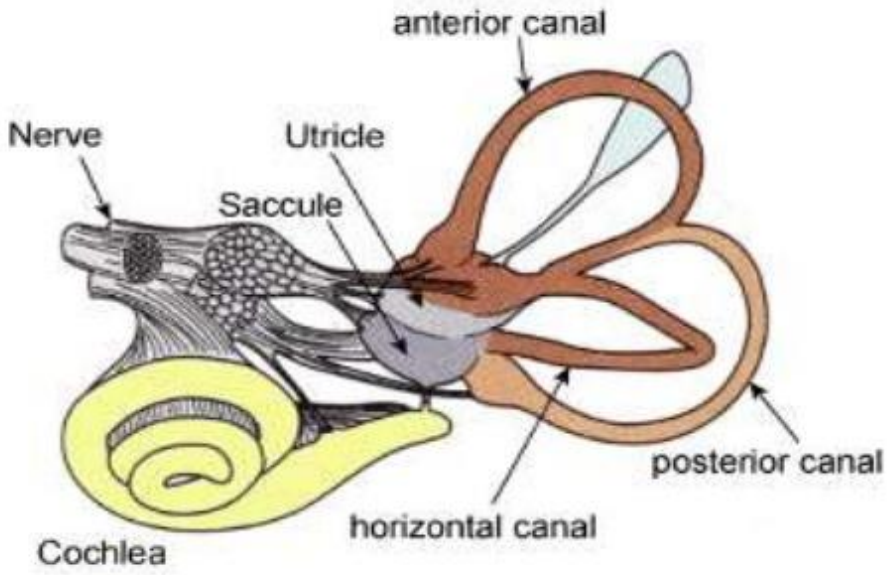
Organ	Receptor - location of hair cell	Function
Semicircular canal (Anterior/superior, Posterior/inferior, Lateral/horizontal)	Crista ampullaris (situated in the ampulla)	Posture and equilibrium during **rotational /angular acceleration**
Utricle	Macula (otolith organ)	Posture and equilibrium during **linear acceleration** in horizontal direction
Saccule	Macula (otolith organ)	Posture and equilibrium during **linear acceleration** in vertical direction

- Hair cells of utricle also stimulated during dorsiflexion or ventroflexion of head (as in signifying “yes”)

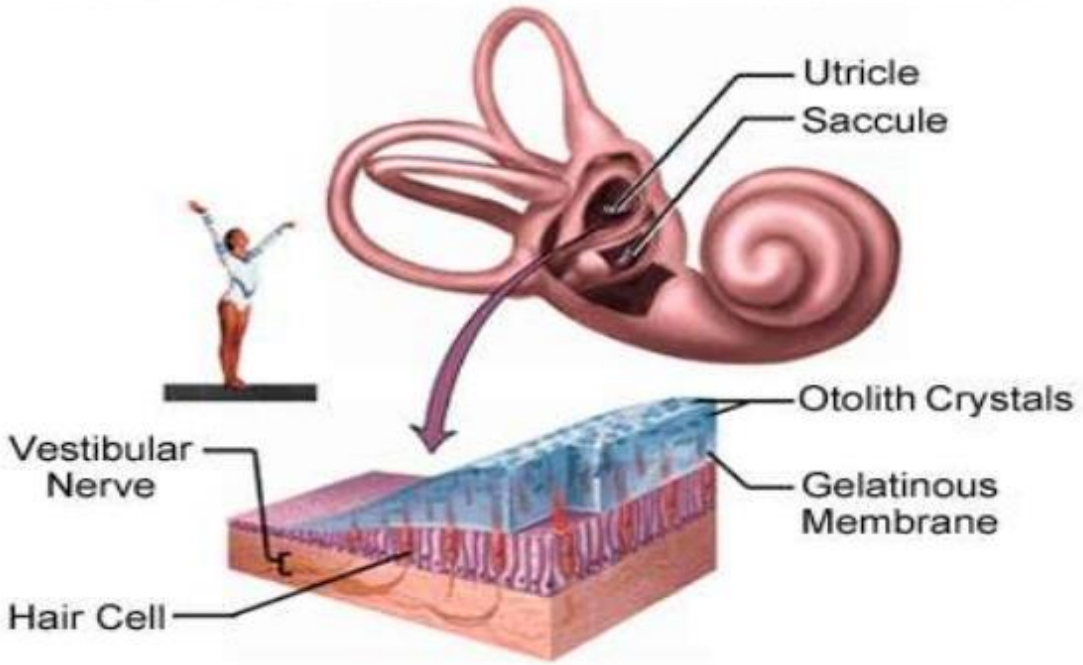
- Hair cells of saccule also stimulated when the head is tilted sideways

Semicircular Canals




anterior canal
Nerve
Utricle
Saccule
posterior canal
horizontal canal
Cochlea

Macula Sacculi and Macula Utriculi

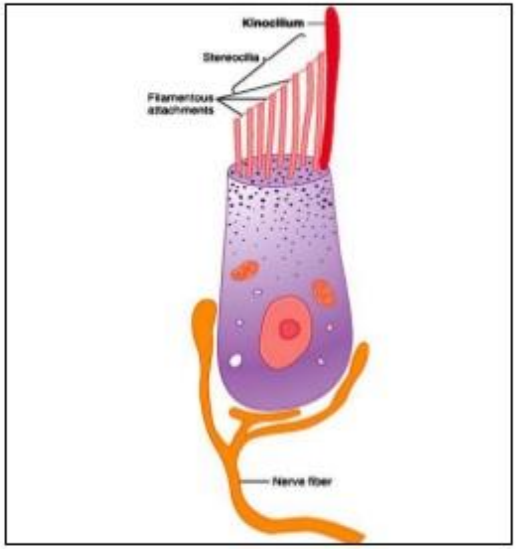


- A gelatinous material covers the macula which contains small dust-like particles made up of calcium carbonate crystals called otoconia. Hence, the macula is also known as otolith organ.

Structure of the receptor

- A Large non-motile cilium-*Kinocilium* is present at one end of the hair cells
- Remaining hair cells - *stereocilia* progressively increase in height towards *Kinocilium*

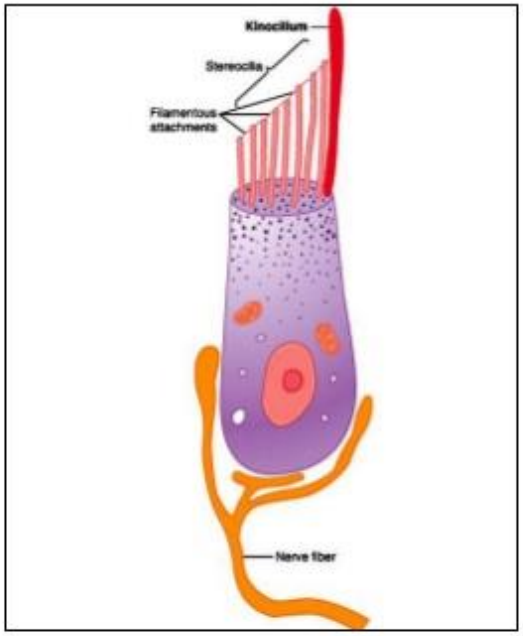
Directional Sensitivity of the Hair Cells- Kinocilium



- Hair cell of the equilibrium apparatus and its synapses with the vestibular nerve

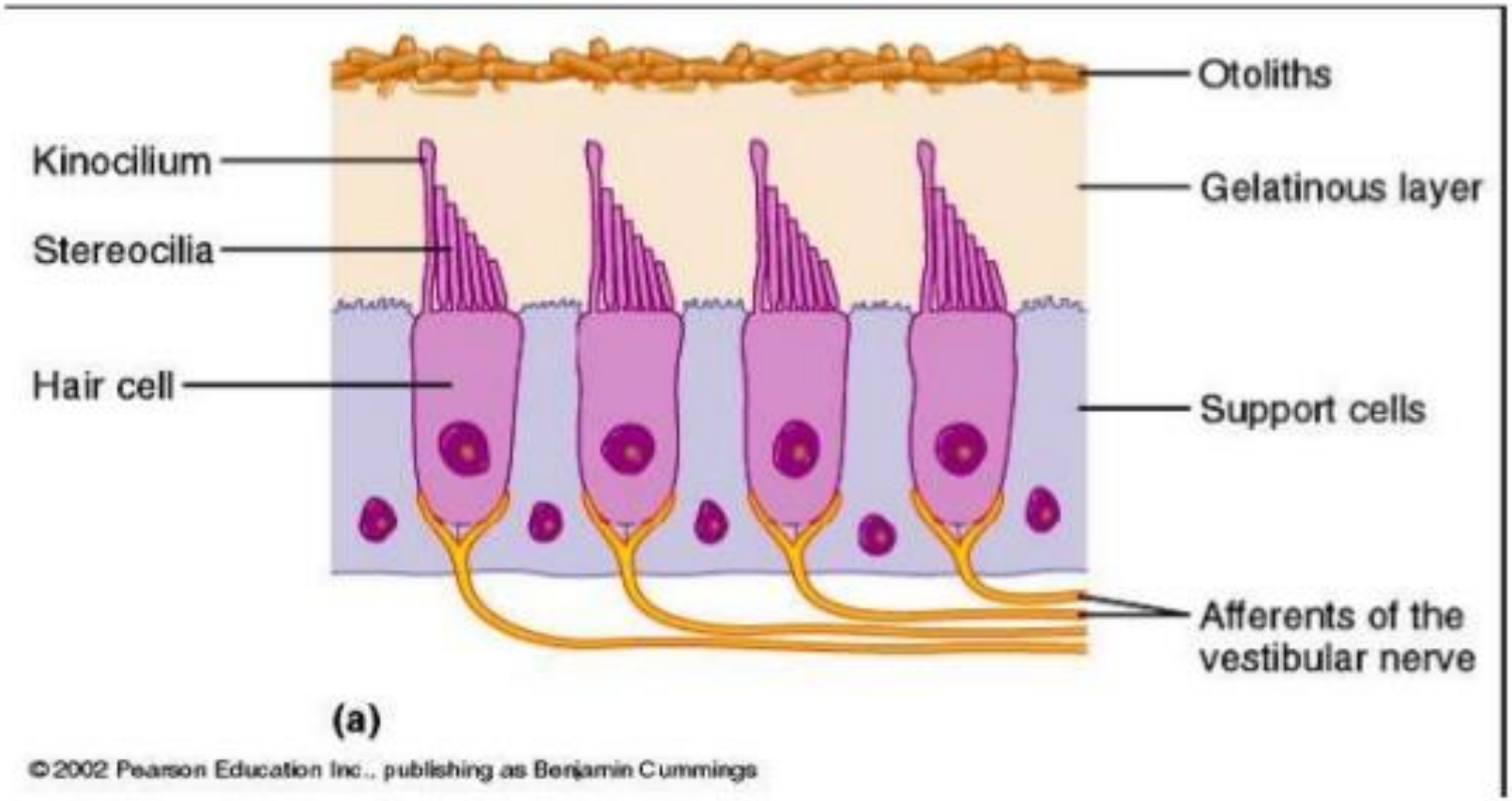
Electrical responses

- Membrane potential of hair cell -60mv
- Stereocilia pushed towards kinocilium, MP falls to -50mv, Depolarisation, release of NT, glutamine – opening of ion channel – entry of Ca^{2+} & K^{+}

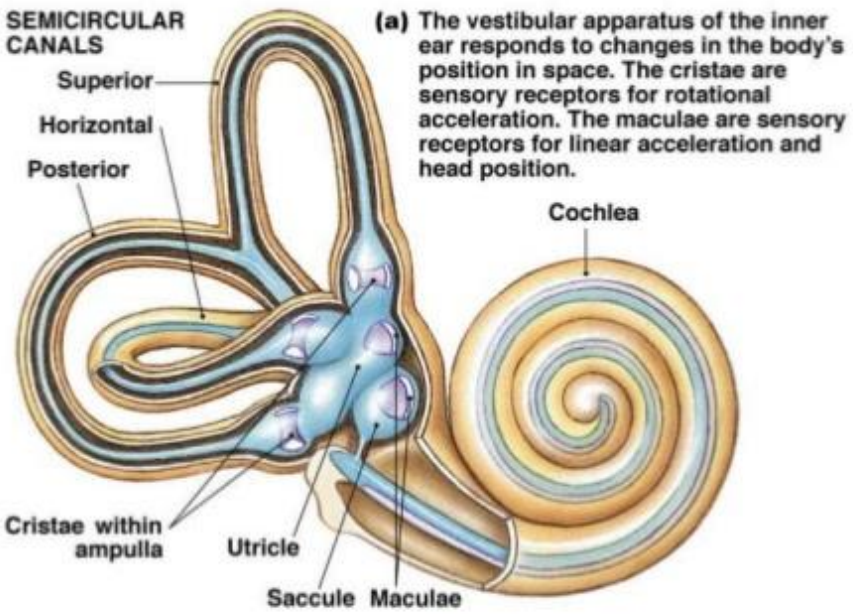


- When bundle of processes is pushed in the opposite direction, cell is hyperpolarized

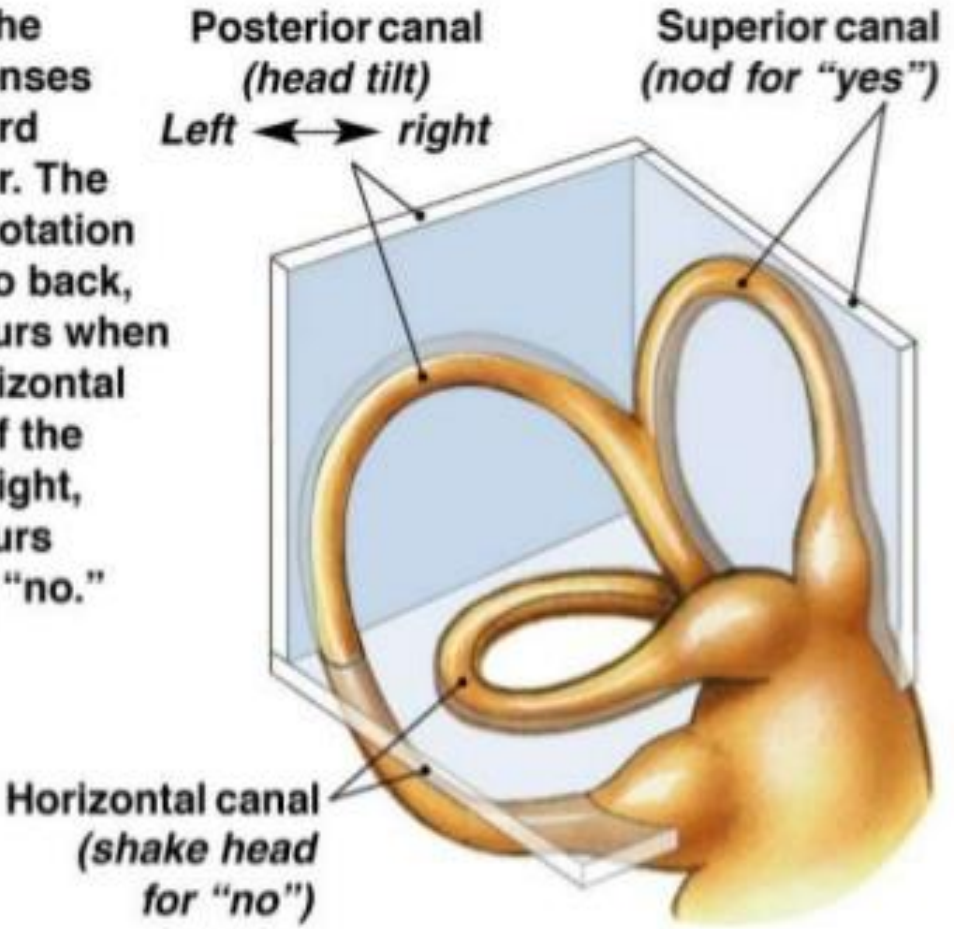
- Displacing the processes in a direction perpendicular to this axis provides no change in membrane potential

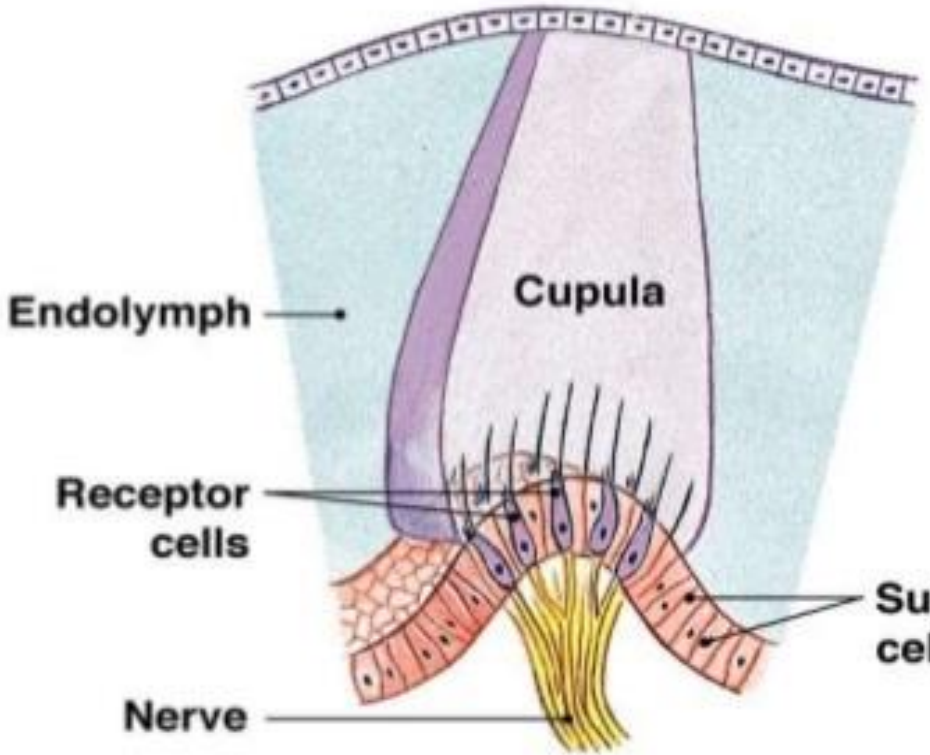


Vestibular apparatus provides information about movement and position in space



(b) The posterior canal of the vestibular apparatus senses the tilt of the head toward the right or left shoulder. The superior canal senses rotation of the head from front to back, such as that which occurs when nodding "yes." The horizontal canal senses rotation of the head as it turns left or right, such as that which occurs when shaking the head "no."

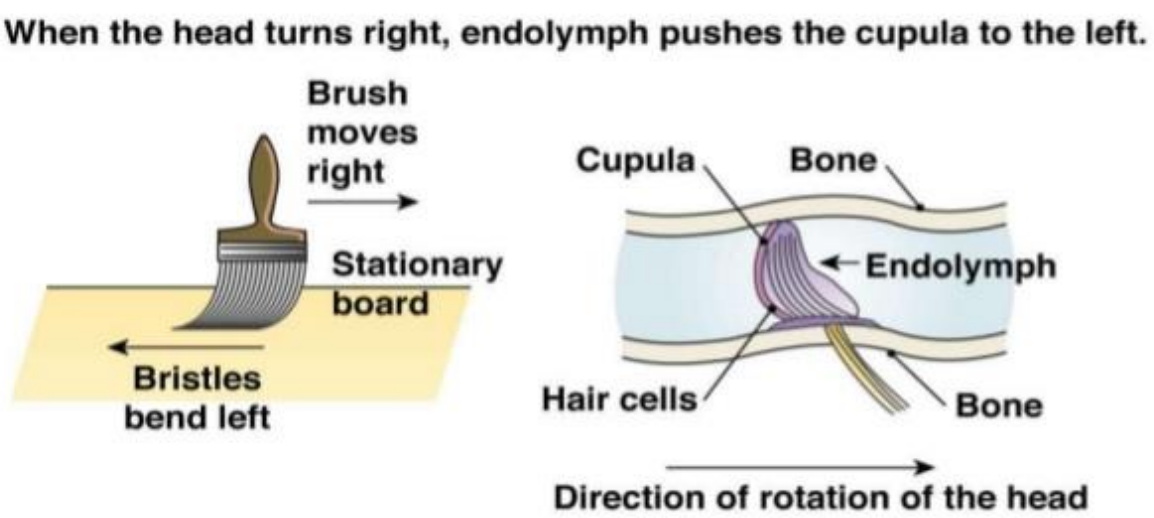




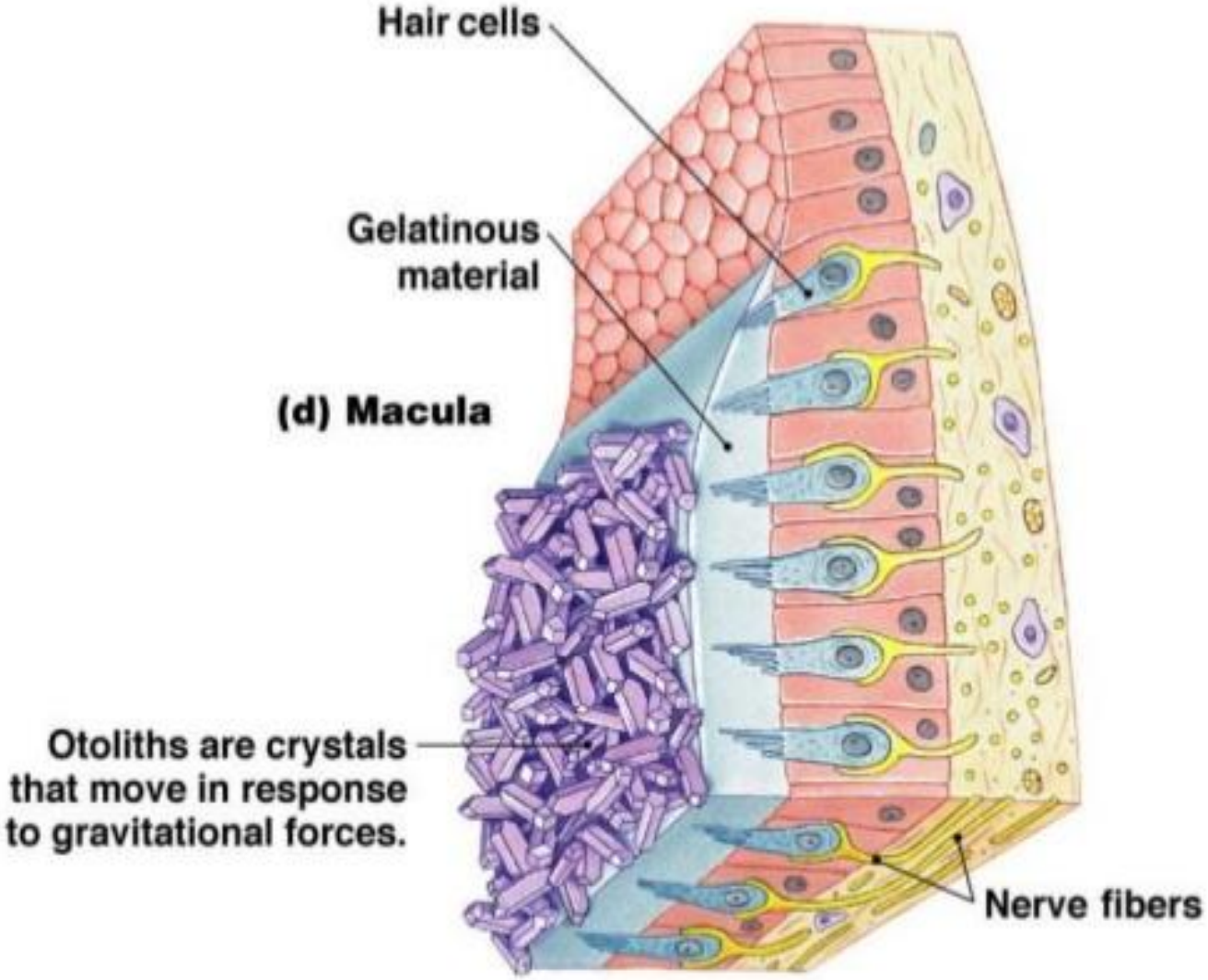
(c) Movement of the endolymph pushes on the gelatinous cupula and activates the receptor cells.

Rotational Forces in the Cristae

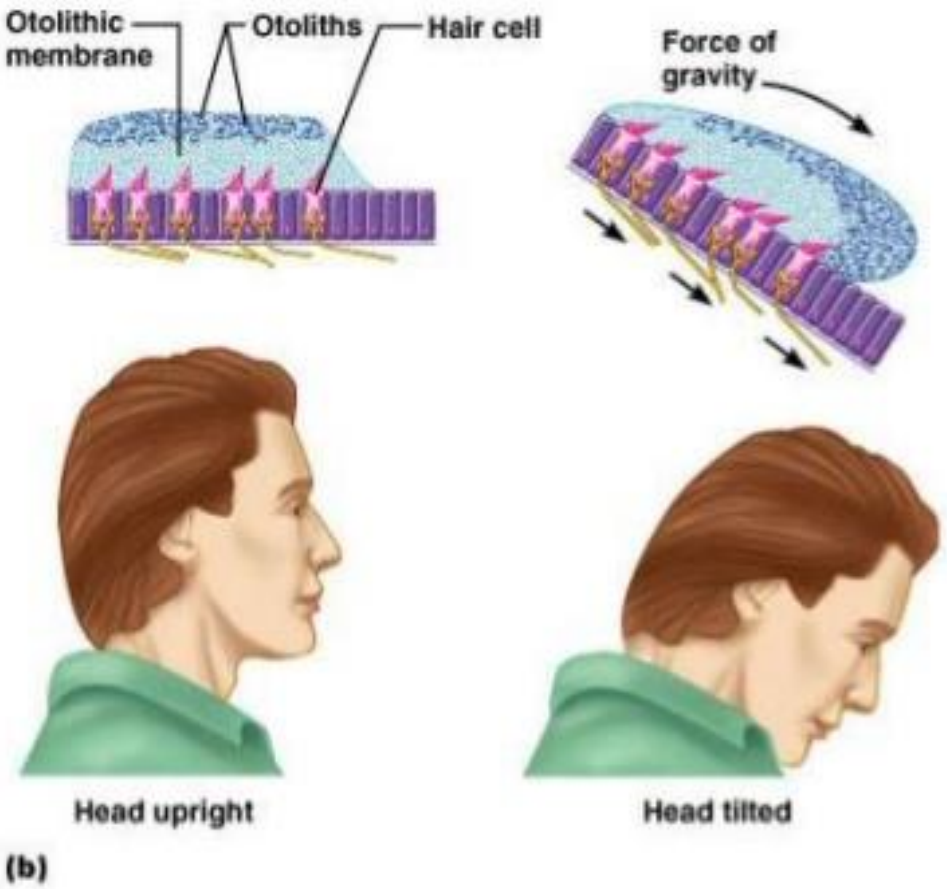
- The semicircular canals sense rotational acceleration



- Continuous rotation – endolymph moves in the same direction


Hair cells
Gelatinous material
(d) Macula
Otoliths are crystals that move in response to gravitational forces.
Nerve fibers

Function of the Maculae



Structure of the receptor

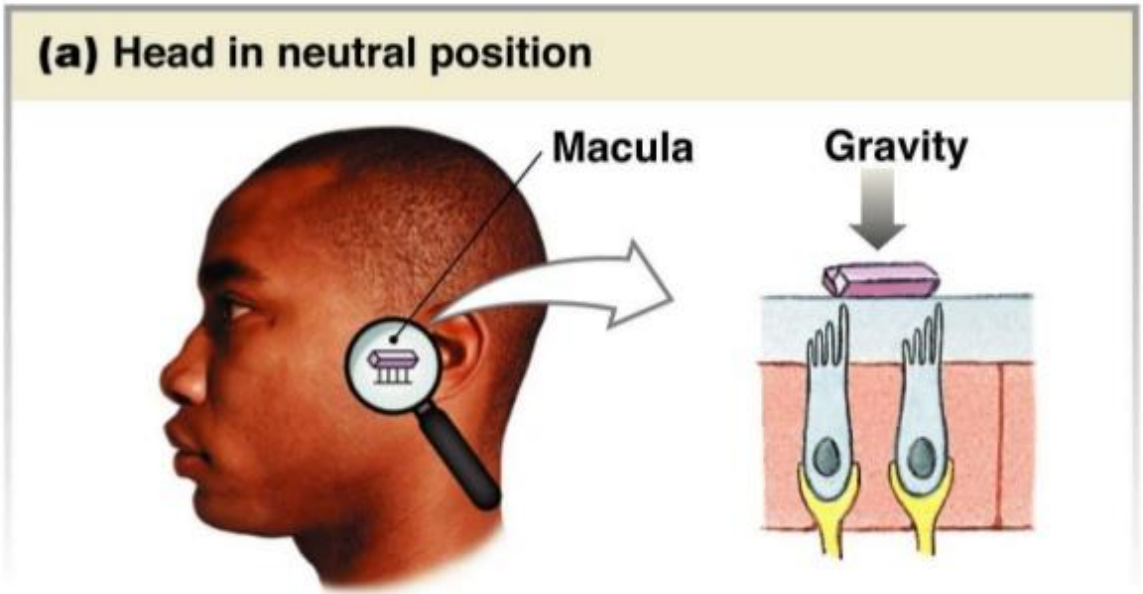
When head is erect;

- Macula of utricle is in a horizontal plane & hair cells are vertical

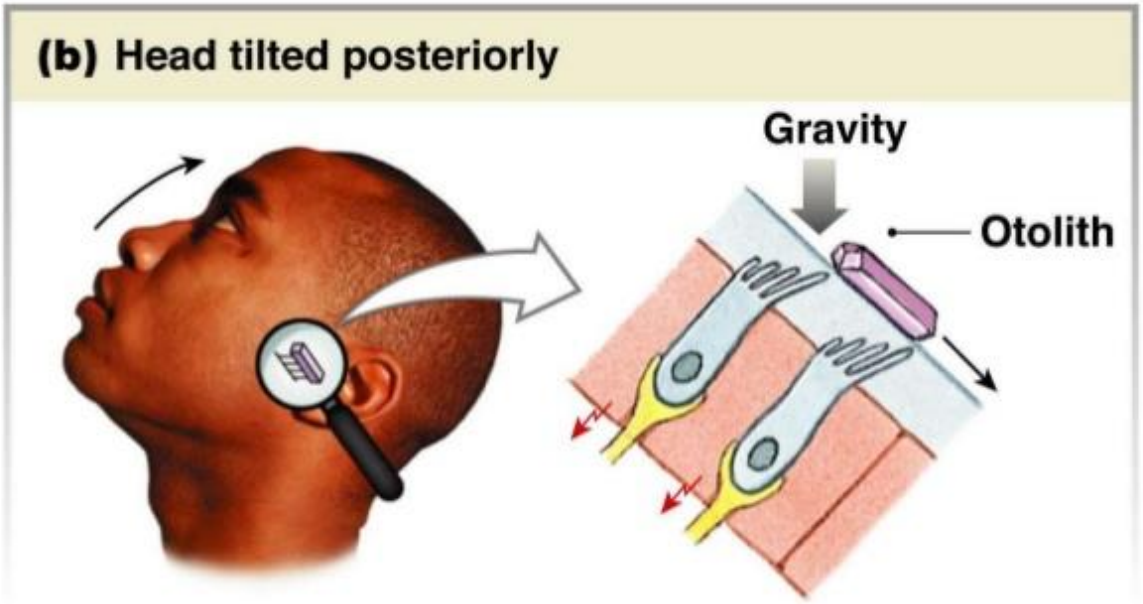
- Macula of saccule is in a vertical plane & hair cells are horizontal

Otolith Organs

The otolith organs sense linear acceleration and head position



Otolith Organs



Otolith organs

- Gravitational pull causes the otoconia to settle down and press on the hair cells leading to bending of the hair.

- Linear acceleration – bending of cilia of hair cells; no initial movement of otolithic membrane. The greater relative mass of the otolithic membrane causes it to lag behind the macula temporarily, leading to transient displacement of the hair bundle.

- Angular acceleration – head movement – effect of gravity – movement of otolithic membrane

Vestibular Pathways

- Nerve endings from crista & macula have their cell body in bipolar cells of vestibular ganglia (FIRST ORDER NEURON), central axons of vestibular Nerve enter medulla ventral to inferior Cerebellar peduncle

- Axons divide into ascending & descending branches which end in four-part vestibular nuclei(SECOND ORDER NEURON) on same side:***Medial Nuclei, Lateral Nuclei, Inferior Nuclei, Superior Nuclei***

- In addition to the main afferents from vestibular apparatus, the vestibular nuclei also receive inhibitory fibres from cerebrum & cerebellum

Vestibular Pathways

Efferent fibres from Vestibular nuclei pass to:

i) both sides of cerebellum

ii) red nucleus & reticular formation

iii) III, IV, VI Cranial N via medial longitudinal fasciculus

iv) Opposite thalamus & temporal lobe via medial lemniscus

v) Ventral horn cells of spinal cord via vestibulo-spinal tracts

Concerned with

1. Postural adjustment
2. Eye movements

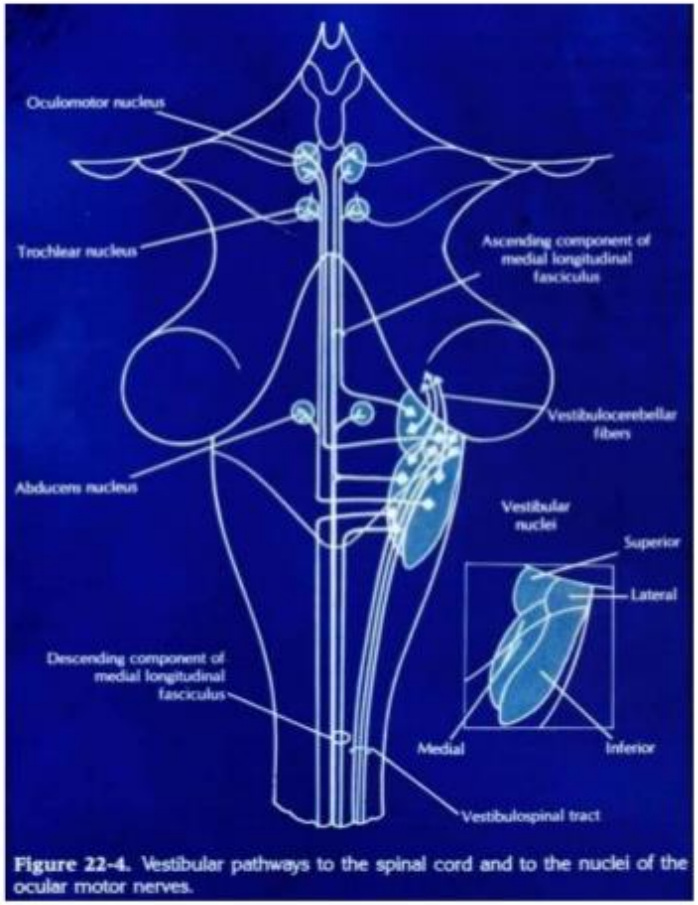
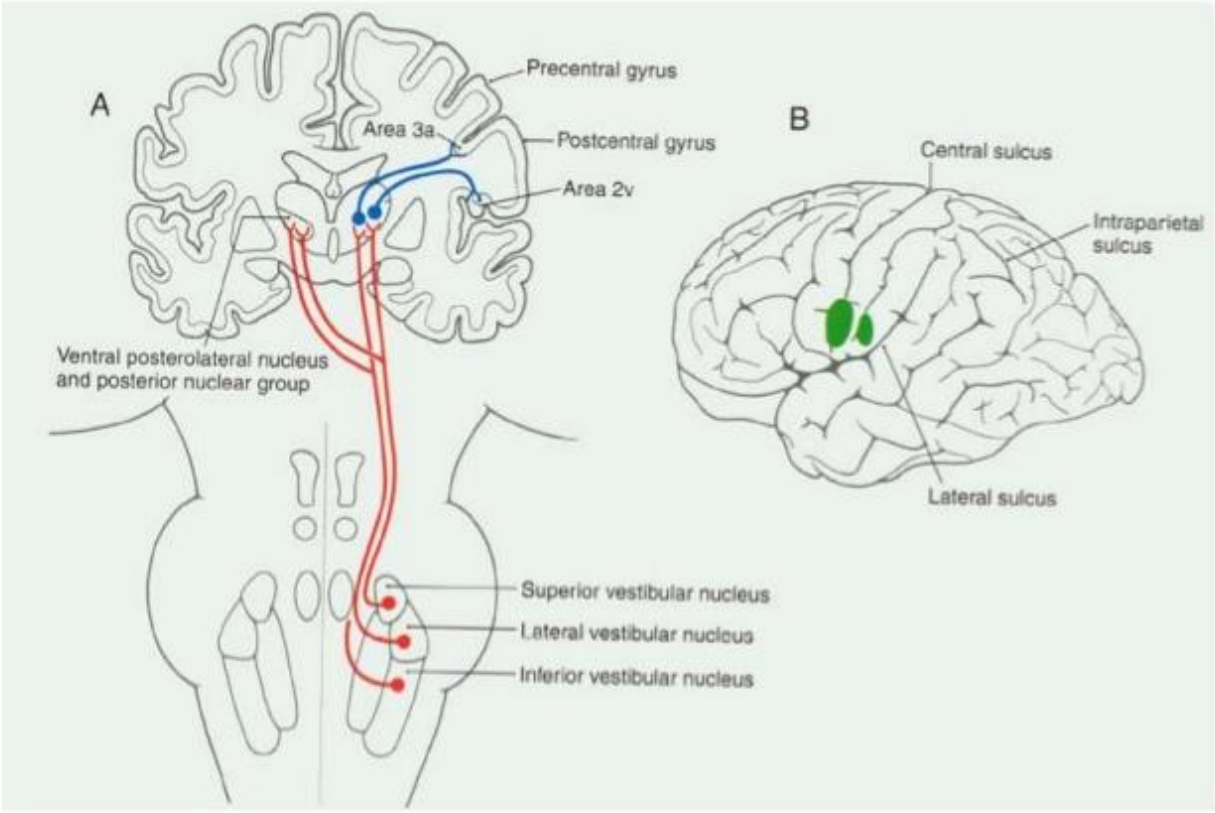


Figure 22-4. Vestibular pathways to the spinal cord and to the nuclei of the ocular motor nerves.


A
Precentral gyrus
Area 3a
Postcentral gyrus
Area 2v
Ventral posterolateral nucleus
and posterior nuclear group
Superior vestibular nucleus
Lateral vestibular nucleus
Inferior vestibular nucleus
B
Central sulcus
Intraparietal
sulcus
Lateral sulcus

Functions of Vestibular apparatus

- Otolith organs are stimulated by gravity, linear acceleration & deceleration- Utricle- Horizontal; Saccule- vertical acceleration
- Semicircular canals are stimulated by rotational acceleration & deceleration
- Both play an important role in postural activity

Functions of Vestibular apparatus

- Afferent impulses from VA adapt the position of the trunk & limbs to that of the head, thus enabling erect posture of head & normal posture of body to be maintained.

- Vestibulocerebellar & cerebellovestibular tracts – posture & equlibrium
- Vestibuloocular reflex - VA impulses reach cranial nerve nuclei & cerebral cortex, this helps visual fixation of moving objects
- Vestibulospinal tract – maintain muscle tone
- Labyrinthine righting reflexes

Other factors concerned with equilibrium

- Neck proprioceptors
- Exteroceptive information
- Visual information

Applied Aspects

- Nystagmus
- Vertigo
- Motion sickness
- Meniere's Syndrome

Test for vestibular apparatus

- Test for nystagmus
- Baraney's test

Disorders of Equilibrium: Vertigo

- Sensation of rotation in the absence of actual rotation

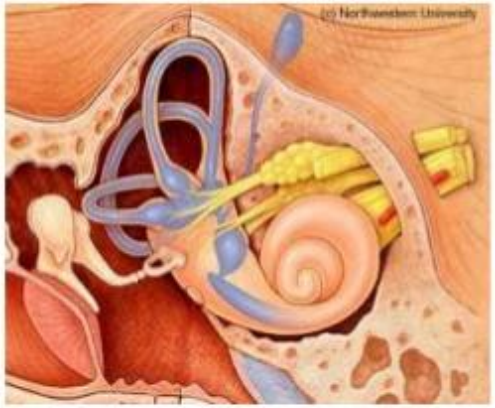
- Benign positional vertigo – elderly
- Physiological vertigo – motion sickness
- Other causes

Disorders of Equilibrium: Motion Sickness

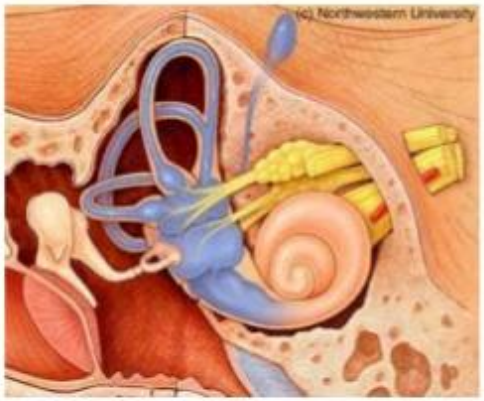
- Motion sickness – car sickness, sea sickness
  - Excessive vestibular stimulation
  - Probably due to reflexes mediated via vestibular connections in brainstem and the flocculonodular lobe of the cerebellum.
  - Nausea,vomiting,dizziness
  - Sweating, palpitation

Disorders of Equilibrium: Meniere's Syndrome

- Meniere's syndrome – equilibrium is greatly disturbed
  - Excessive amounts of endolymph in the membranous labyrinth



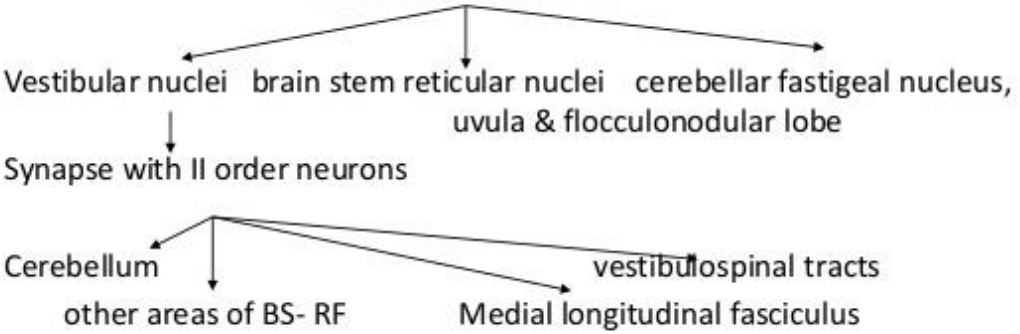
Normal



Meniere's

Neural pathway

- Static/Linear/angular rotation
- Vestibular apparatus
- Vestibular nerves



Vestibular system

- SUMMARY

Labyrinth and semicircular canals

- The vestibular labyrinth is a bony cavity located within the petrous portion of the temporal bone. It consists of the bony framework for the cochlea as well as the three semicircular canals.
- The bony labyrinth houses the three semicircular canals and the two otolithic organs (the utricle and saccule). Moreover, it contains the cochlea which is a part of the hearing apparatus.

- The semicircular canals are the three membranous channels located within the bony semicircular ducts of the labyrinth. They are located in three planes, with each canal making an angle of approximately 90 degrees with the other. Thus, the semicircular canals are the:
- Anterior (superior), located in the sagittal plane
- Lateral (horizontal), located in the transverse plane
- Posterior (inferior), located in the frontal plane

- The terminal part of each canal ends with a dilation called the ampulla, which opens into the vestibule.
- The ampulla of each semicircular canal contains a cluster of mechanoreceptor cells called the crista ampullaris.
- Each crista is composed of the special sensory receptor cells, called the hair cells.
- Given that the semicircular canals are filled with endolymph, the movements of this fluid stimulate the hair cells. In this way, each semicircular canal detects when the head moves during the rotational acceleration along its corresponding plane. In other words, the semicircular canals detect head movements such as nodding up and down, shaking side to side, or tilting left and right.

- The vestibular system is a somatosensory portion of the nervous system that provides us with the awareness of the spatial position of our head and body (proprioception) and self-motion (kinesthesia). It is composed of central and peripheral portions.
- The peripheral portion of the vestibular system consists of the vestibular labyrinth, vestibular ganglion, and vestibulocochlear nerve (CN VIII). The vestibular labyrinth is comprised of proprioceptive components located in the inner ear;
- The semicircular canals, which contain the cells that detect angular acceleration of the head;

- The utricle and saccule, which contain the cells that detect the linear acceleration of the head and position of the head in space (spatial orientation).
- The stimuli from these receptors are conveyed to the vestibular ganglion.
- From here, they travel through the vestibular portion of the vestibulocochlear nerve (CN VIII) into the central portion of the vestibular system; the vestibular nuclei in the brainstem.
- The vestibular nuclei send projections into the cerebellum, spinal cord, thalamus, and nuclei of the oculomotor (III), trochlear (IV) and abducens (VI) nerves.
- Via these connections, the vestibular system contributes to the adjustments of the head and neck movements, as well as the posture and balance of the whole body, vestibulo-ocular reflex and eye movements.

Vestibular Apparatus