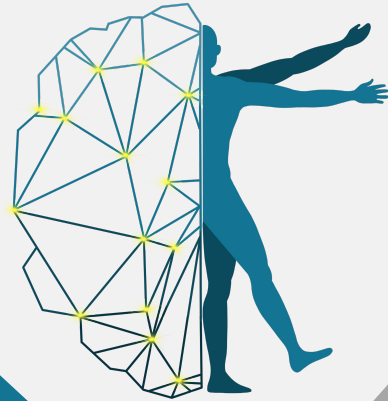


Revised & Approved



Physiology of Inner Ear in Balance

Objectives:

- ❖ Functional anatomy of Vestibular apparatus.
- ❖ Dynamic and static equilibrium.
- ❖ Role of utricle and saccule in linear acceleration.
- ❖ Role of semicircular canals in angular motions.
- ❖ Vestibular Disorders.

Important: These pages from the reference books were sent by the males doctor. Please read them well. Good luck!

Utricle & Saccule



Semicircular canals



Color index:

- ❖ Important.
- ❖ Girls slide only.
- ❖ Boys slide only.
- ❖ Dr's note.
- ❖ Extra information.



Editing File

Anatomy of The Inner Ear

L16

Bony labyrinth *

Bony cochlea & 3 Semicircular canals. Enclose the membranous labyrinth.

Membranous labyrinth: Cochlea (auditory)

Organ of Corti containing receptors for hearing.*

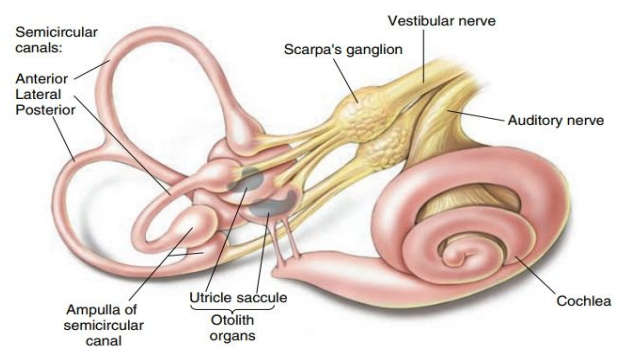
Membranous labyrinth: Utricle & saccule

Macula contain otolith organs and receptors that respond to gravity and head tilt.*

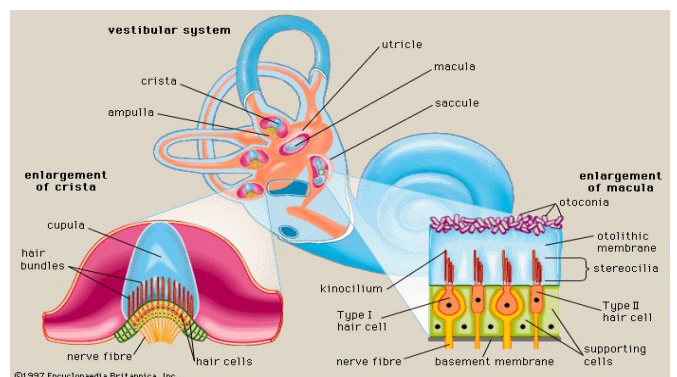
SemiCircular Canals

1-Anterior (sense the forward & backward movement)
2-Posterior (sense the up & down movement)
3-Horizontal/lateral (sense the left & right movement)
Crista ampullaris containing receptors that respond to head rotation.

- Vestibular apparatus (Non- auditory for equilibrium): utricle, saccule, 3 semicircular canals, vestibular nerve and nuclei.
- posterior canal shares plane with contralateral anterior canal.
- horizontal canals share plane.



Macula presents inside utricle and saccule and responsible for the sensation of our direction. It consists of type 1 & 2 hair cells and in between supporting cells, these hair cells have nerve fiber and stereocilia which is covered by gelatinous material (otolith membrane) and on the top of that there are calcium carbonate particles (otoconia). The function of the otolith membrane and otoconia is to sense and transmit any movement that the body does.



Balance and Equilibrium

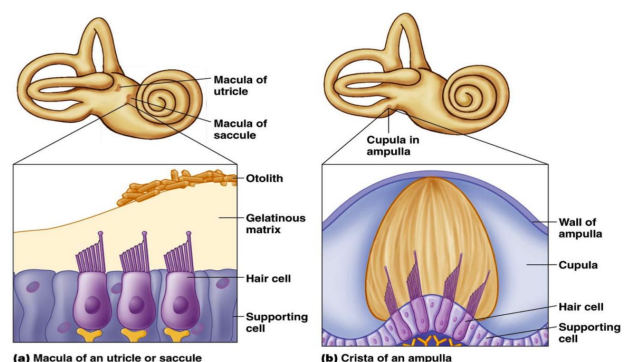
Males slides only

- ❖ **Center of gravity:** the point at which weight is evenly dispersed and all sides are in balance. To balance the centre of gravity must be above the support point at which the weight is evenly dispersed. **the higher the center of gravity -> less stability**
- ❖ **Balance:** the **ability** to maintain the equilibrium of the body.
Foot position affects standing balance.
- ❖ **Equilibrium:** the **state** of a body or physical system at rest or in unaccelerated motion in which the resultant of all forces acting on it is zero and the sum of all torques about any axis is zero.
 - **Static:** The equilibrium is maintained in **FIXED POSITION**, usually while standing on one foot or maintenance of body posture relative to gravity while the **body is still**.
Sense the position of the head, maintain stability and posture.
 - **Dynamic:** The equilibrium must be maintained **while performing a task** which involves **MOVEMENT** e.g. Walking the beam – maintenance of the body posture (mainly the head) in response to sudden movements. Tracking a moving object.
Balance the head during sudden movement.

Maintaining equilibrium (impt for MCQ but only males' slides)

SemiCircular Canals	Saccule and utricle (vestibule)
Crista ampullaris	Macula
Hair cells in each crista are oriented in the same direction	Hair cells in each macula are oriented in all direction
No Otoliths	Otoliths (calcium carbonate crystals)
Dynamic Equilibrium and angular motion	Static equilibrium and Linear Acceleration
Predictive function	No predictive function

Equilibrium: Reflexes maintain body position at rest & movement
Through receptors of postural reflexes:
1-Proprioceptors
2-Visual(retinal) receptors
3-Non-auditory membranous labyrinth



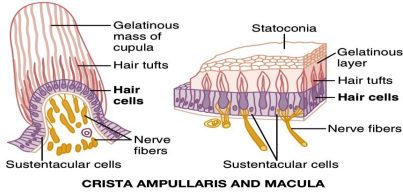
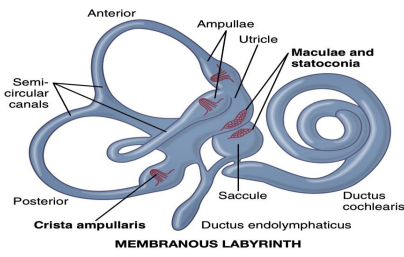
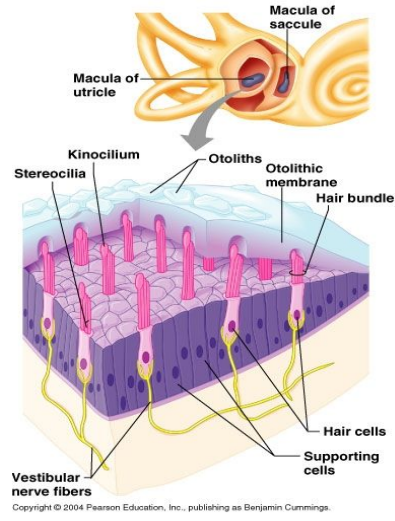
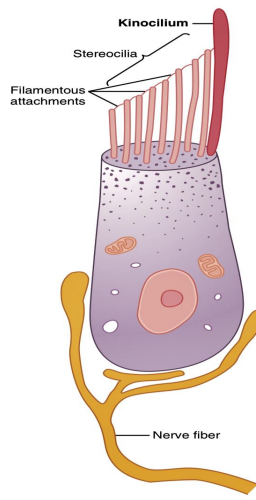


Figure 56-9. Membranous labyrinth and organization of the crista ampullaris and the macula.



***Characteristics of Hair cells:**

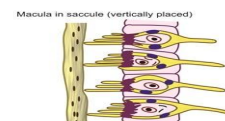
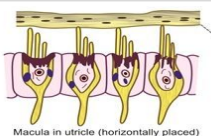
imp for saq

1. Directional sensitivity
2. Slow adaptation
3. Highly sensitive to mechanical stimulation

Macula

- Vestibule (between cochlea and semi-circular canals) contains static equilibrium receptors called macula.
- Hair cell synapse with endings of the vestibular nerve.
- Hair cells are oriented in different direction and tilt of head In any direction is signaled.
- Hair cell has: *stereocilia* (30-150) & *kinocilium* (one large cilium) connected by fine filamentous attachments (tip links)
- All cilium membrane has positive potassium channels .
- *Otolithes* (statoconia) of calcium carbonate suspended in gelatinous material.

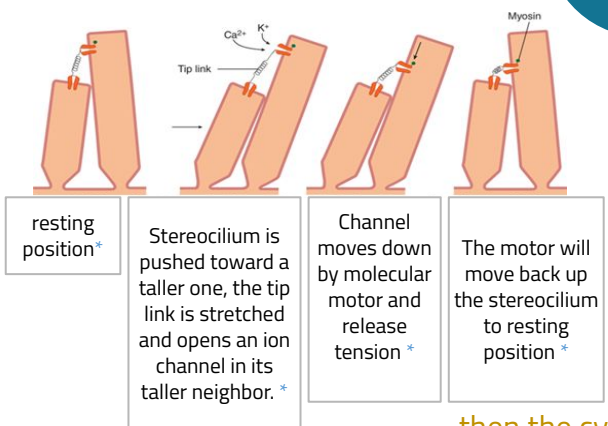
Hair cells in Utricule	Hair cells in Saccule
in upright position (head vertical):	
hair (cilia) pointing <i>upwards</i>	hair pointing <i>laterally</i> *
Hair cells signal head movements in any direction*	Hair cells operate when one is lying down *
Macula in <i>horizontal plane</i>	Macula in <i>vertical plane</i> *
Macula detect linear acceleration of head	
macula detect: <i>horizontal acceleration</i> balance in <i>horizontal direction</i>	macula detect: <i>vertical acceleration</i> balance in <i>horizontal and vertical direction</i>
-stimulated when the head bends forward & backward & laterally * (Linear acceleration) -Inform the brain of orientation of head in space *	



Hair Cells Mechanism of Action

1- bending of stereocilia **towards** kinocilium
 ⇒ **depolarization**, Ca entry & neurotransmitter release ⇒ **increase** rate of impulses to 8th nerve fibers.

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



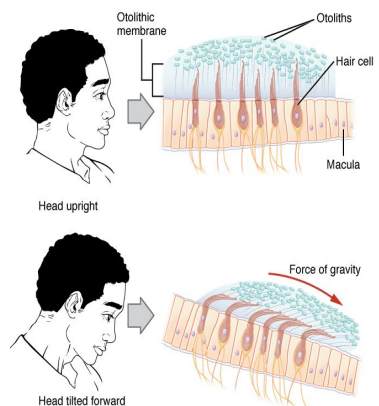
then the cycle begins again

1

Linear acceleration (detection of static tilt)

Detection of static tilt

- Upright vertical position: Impulses from both utricle maculae balance each other.
- Body tilts to one side: Two maculae send signals informing brain of new position of
 - **head in space.**
 - **Sensation of imbalance.**



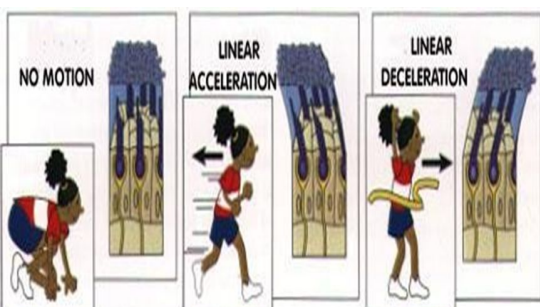
Detection of linear acceleration

Sudden acceleration* ⇒ at beginning of movement statoconia lag behind movement by its inertia* ⇒ Falling backwards* ⇒ Otoliths falls back on hairs* ⇒ cilia moves backward* ⇒ sensation of mal-equilibrium (falling backwards)* ⇒ Correction by leaning forward to shift statoconia & cilia anteriorly.

at deceleration (runner try to stop) ⇒ statoconia move forwards by its momentum ⇒ person feels falling anteriorly.*

Girls doctor explanation:

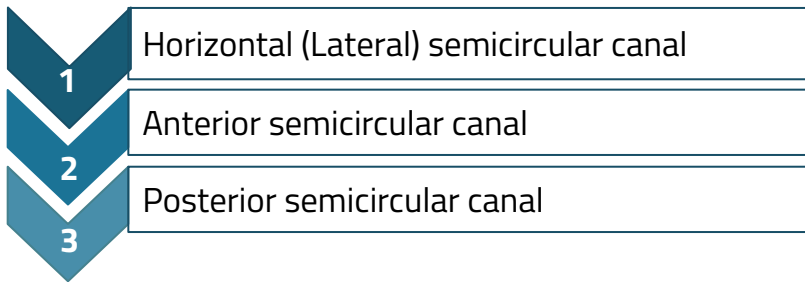
- At rest, the otoconia exert similar pressure on all surface of the macula.
- If we are standing on a bus and it suddenly moves forward the gelatinous material will move backward and otoconia move backward further, then hair cells present in the back on the macula will give action potential in the nerve fiber due to the pressure of the gelatinous material & otoconia. This gives us the sensation of falling backward, so we will try to correct our position by moving forward a little bit.
- When the bus stop the gelatinous material & otoconia will move forward pressing the hair cells in the front of the macula. This gives the sensation of falling forward and then backward reflex movement occurs.



Plane of rotation determines the canal to be stimulated

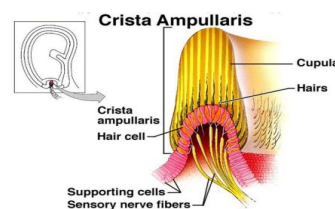
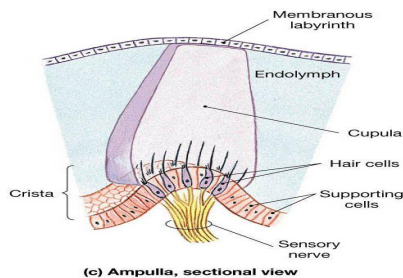
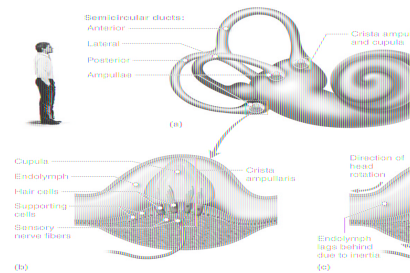
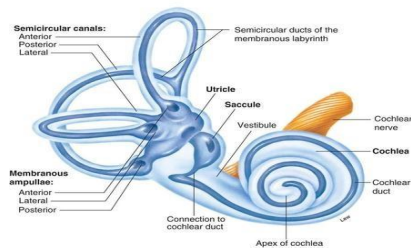
1. Rotation of head on vertical axis → Horizontal semicircular canal
2. Lateral movement of head (AP axis) (approximate head to shoulder) → posterior semicircular canal
3. Anterolateral or posterolateral head movement (Oblique axis) → Superior semicircular canal

Semicircular canals



- ❖ They are perpendicular to each other.
- ❖ Filled with **endolymph**
- ❖ Dilated end of each canal is called Ampulla or Crista ampullaris (as macula), cilia is embedded in a gelatinous mass called Cupula.
- ❖ **Sensory organ:** Crista ampullaris
- ❖ **Detects** angular changes
- ❖ **Hair cells:** oriented in same direction unlike macula

Female slides only



STUDY BREAK!!!!

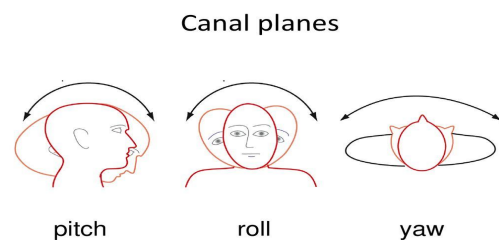
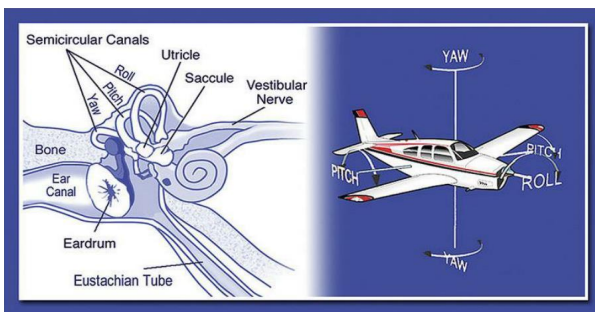
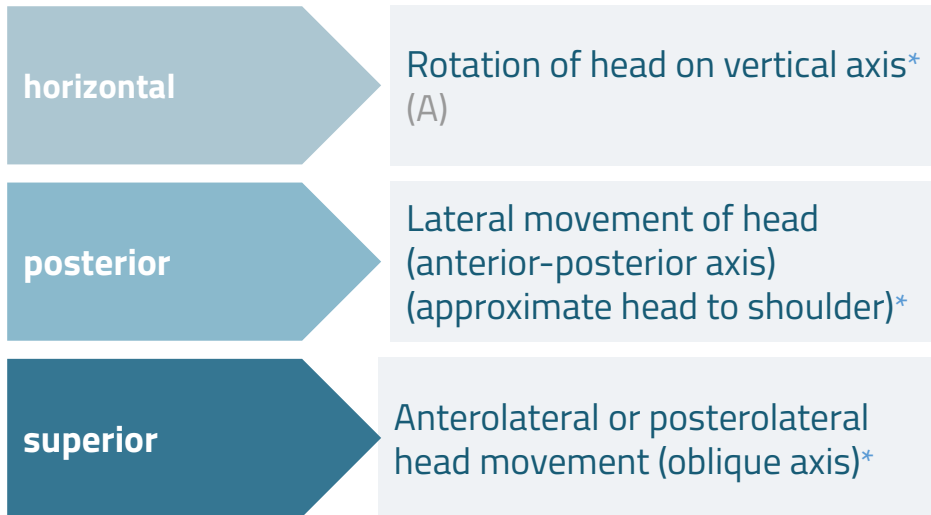
You've been working hard. Take a moment to appreciate yourself! and since we are here, what is your favourite chocolate bar?? (You will be judged based on your choice!)



Click me

Semicircular canals

Plane of rotation determines the canal to be stimulated (again)



Pitch: Superior + Posterior

Roll: Posterior + Superior

Yaw: Lateral

Function of the Semicircular Duct System in the Maintenance of Equilibrium

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

SCCs detect ANGULAR ACCELERATION:

- ❖ the beginning of rotation
- ❖ End of rotation
- ❖ Changes in rate of rotation (e.g. Joy riding)

SCCs Predictive Function:

Predict ahead of time that mal-equilibrium is going to occur → Send impulses to CNS for corrective measures before the start of the fall.*

The maculae of the utricle and saccule can't detect that the person is off balance in angular acceleration until after the loss of balance has occurred.*

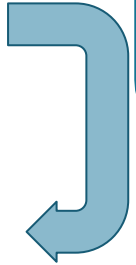
Movement of endolymph in SCC



Bending of hairs (Opposite on two sides)



Opposite discharge from two sides



As rotation continues endolymph will soon rotate in the same direction (& speed) as the SCC



Sensation of rotation in CNS

Cupula being elastic returns to resting position



Discharge from both sides returns to resting level

Toward = depolarization = increase.
Away = hyperpolarization = decrease

* No sensation of rotation as long as eyes are closed. *

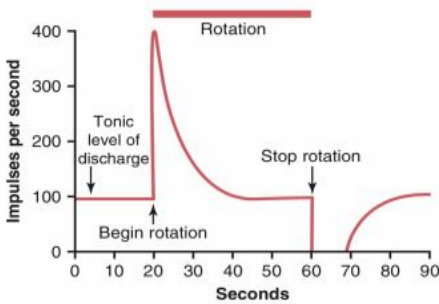
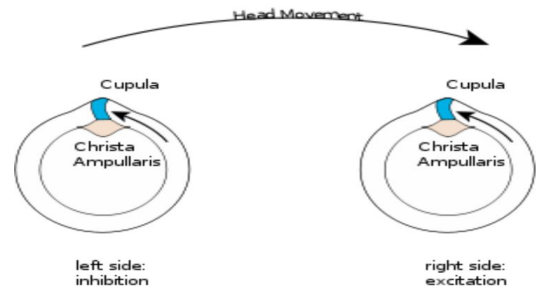
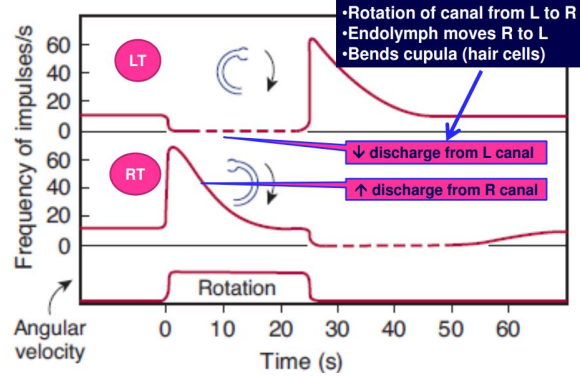
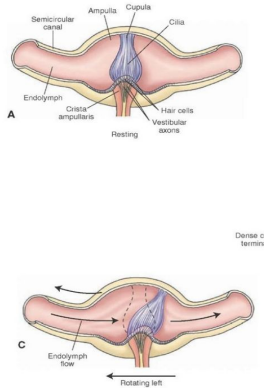


Figure 56-12. Response of a hair cell when a semicircular canal is stimulated first by the onset of head rotation and then by stopping rotation



438:

• When you move your head rightward, the cristae on right side will be stimulated “depolarized”, it means the stereocilia are bending towards the kinocilium. While the cristae on the left semicircular canal is hyperpolarized.

• Whenever in space your head is having Angular movement, the rate of movement of fluid within the semicircular duct alters. This changes the bending of the cristae which alters the electrical signals that are transmitted to the brain

Girls doctor explanation:

The stereocilia are arranged to be lateral to the kinocilium. If we move our heads to the right, the fluid inside the **RIGHT** semicircular canal will move to the opposite direction and that will move the stereocilia toward the kinocilium (depolarization/excitation **of the right CN 8**), and on the **LEFT semicircular canal**, the stereocilia will move away from the kinocilium (hyperpolarization/inhibition **of the left CN 8**). By this the brain know the head movement as well the speed.

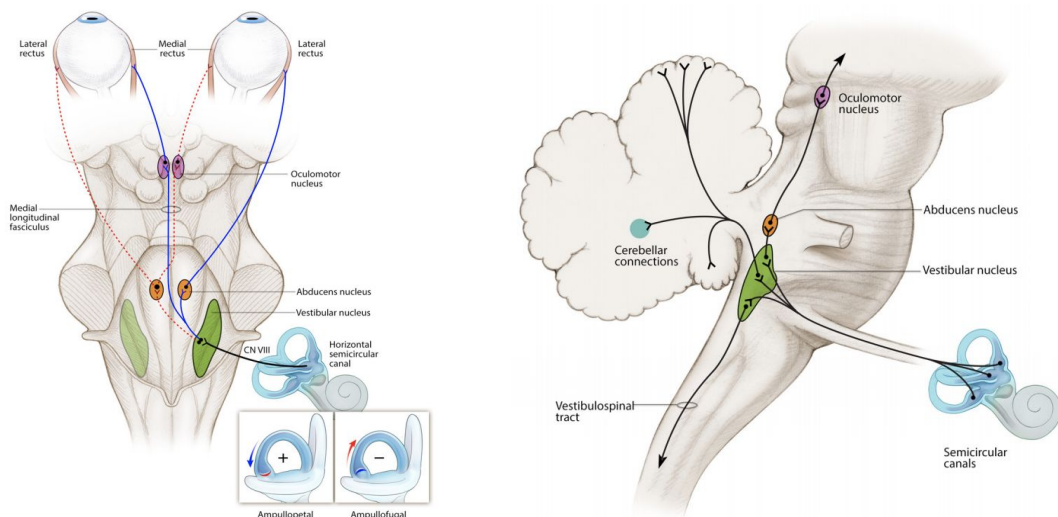
Vestibular pathway

Neural Connections:

• Nerve fibers from maculae & cristae ampullaris → Vestibular nerve → ipsilateral vestibular nuclei on either sides of the brainstem send signal to:

1. Cerebellum (Flocculonodular lobe)
2. Motor nuclei of CNs 3,4 & 6 (to lateral & medial rectus)
3. Reticular formation (**Spinal cord**)
4. Spinal cord (Vestibulo-spinal tract)

* Impulses (from 3,4) maintain equilibrium i.e. facilitate or inhibit the stretch reflex (regulate muscle tone) *



*Compare, Select & Combine Senses:

1-Visual System

2-Vestibular System

3-Somato-Sensation

Effects of stimulation of semicircular canals (rotation)

Female slides only

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

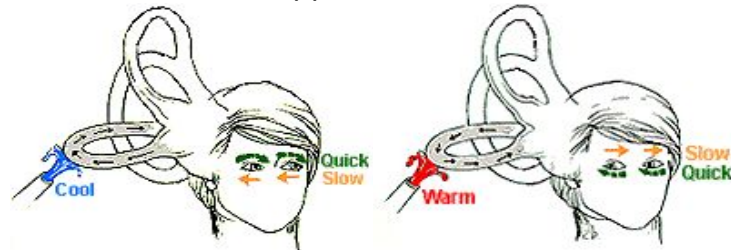
Testing Vestibular system

1. Calorie test:

- The semicircular canals are stimulated by instilling warm (40°C) or cold (30°C) water into the external auditory meatus
- The temperature difference sets up convection currents in the endolymph, with consequent motion of the cupula.
- In healthy subjects, warm water causes nystagmus that bears toward the stimulus, whereas cold water includes nystagmus that bears toward the opposite ear.

★ Mnemonic **COWS** (Cold water nystagmus is Opposite sides, Warm water nystagmus is Same side).

- In the case of unilateral lesion in the vestibular pathway, nystagmus is reduced or absent on the side of lesion.



IMPORTANT NOTE: Nystagmus direction is not the direction of the eye!. Nystagmus is more like a tremor of the eye. [here](#) is an example with cold water (try to guess which ear without cheating from the description)

2-Rotation:

To avoid nystagmus, vertigo, and nausea when irrigating the ear canals in the treatment of ear infections, it is important to be sure that the fluid used is at body temperature.

Vestibular disorders

Name	Description	Treatment
Benign paroxysmal positional vertigo (BPPV)	otoconia from the utricle separate from the otolith membrane and become lodged in the canal or cupula of the semicircular canal	Canalith repositioning
Meniere disease	an abnormality of the inner ear causing vertigo or severe dizziness, <u>tinnitus</u> , fluctuating hearing loss, and the sensation of pressure or pain in the affected ear lasting several hours.	Labyrinthine Sedatives (Meclizine)
motion sickness	produced by excessive vestibular stimulation	antiemetics
Space motion sickness	(in astronauts) develops when they are first exposed to microgravity and often wears off after a few days of space flight. Due to mismatches in neural input from vestibular apparatus and other gravity sensors	Antihistamines or scopolamine, a cholinergic muscarinic receptor antagonist.

MCQ & SAQ:

L16

Q1: which of the following is NOT part of the vestibular apparatus?

- A. cochlea
- B. vestibule
- C. cochlear nerve
- D. vestibular nerve

Q3: which of the following is a feature of semi-circular canals?

- A. Otolith
- B. Crista ampularis
- C. static equilibrium
- D. hair cells oriented in all direction

Q5: Which one of the following is an effect of the semicircular canal in rotation?

- A. Decrease muscle tone in the same side of the rotation.
- B. Hypertension
- C. Tachycardia
- D. Vertigo

Q2: "the ability to maintain the equilibrium of the body" is

- A. equilibrium
- B. balance
- C. center of gravity
- D. static equilibrium

Q4: .Which one of the following structure detect rotation of the lateral movement of the head "anterior-posterior axis"?

- A. Utricle
- B. Anterior semicircular canal
- C. Posterior semicircular canal
- D. Horizontal semicircular canal

Q6: .Which one of the following disorder is produced by excessive vestibular stimulation?

- A. Meniere disease
- B. Motion sickness
- C. Ataxia
- D. Deafness

6: B
5: D
4: C
3: B
2: B
1: C&A
key:
answer

- 1- Compare between hair cells in the utricle and saccule in the vertical position**
- 2- Mention the parts of membranous labyrinth and the receptive structure in each**
- 3- Mention 3 vestibular pathway?**
- 4- Mention 3 of vestibular disorders ?**

A1: refer back to table in slide 5

A2: refer back to the first slide

A3: 1. Cerebellum / 2. Motor nuclei of CNs 3,4 & 6 / 3. Spinal cord (Vestibulo-spinal tract)

A4: 1. Benign paroxysmal positional vertigo (BPPV) / 2. Meniere disease / 3. Motion sickness

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