

الله
قال الله
الله
٤٢

THE SPECIAL SENSES

VESTIBULAR FUNCTION



DR SYED SHAHID HABIB
MBBS DSDM PGDCR FCPS
Professor
Dept. of Physiology
College of Medicine & KKHU

OBJECTIVES

At the end of this lecture you should be able to describe:

- ▶ 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 Reflexes



Overview of Proprioception & Balance

Equilibrium

Static Equilibrium
Utricle & Saccule

Linear Acceleration
Horizontal (Utricle)

Linear Acceleration
Horizontal (Saccule)

Angular Acceleration
(SCCs)

Predictive Functions
(SCCs)

Proprioception

Static
position sense (Ia)

Dynamic
position sense (II)

Neck
Proprioceptors

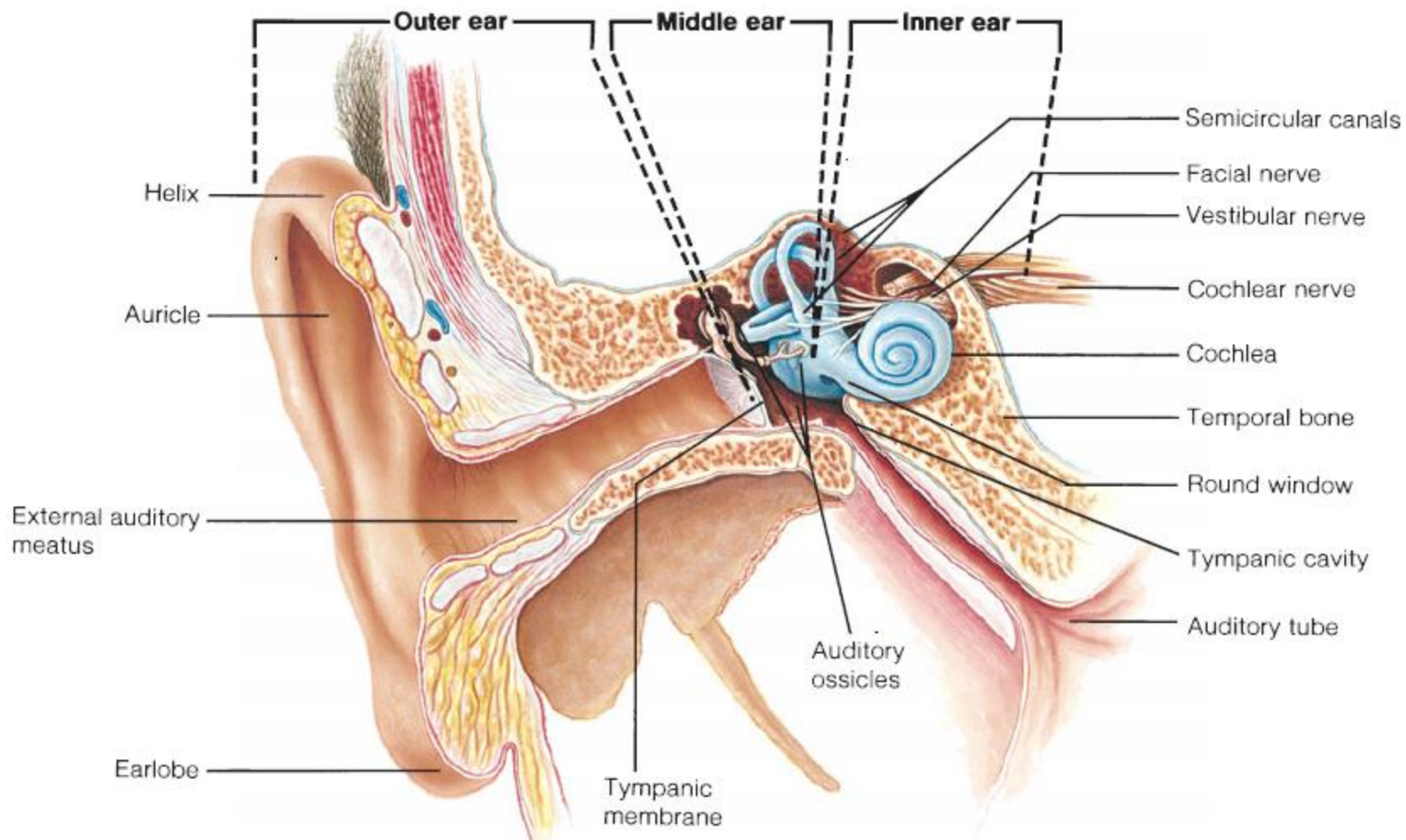
Visual Information
(vestibulo Ocular)

Vestibular Apparatus

Chest Wall
Proprioceptors

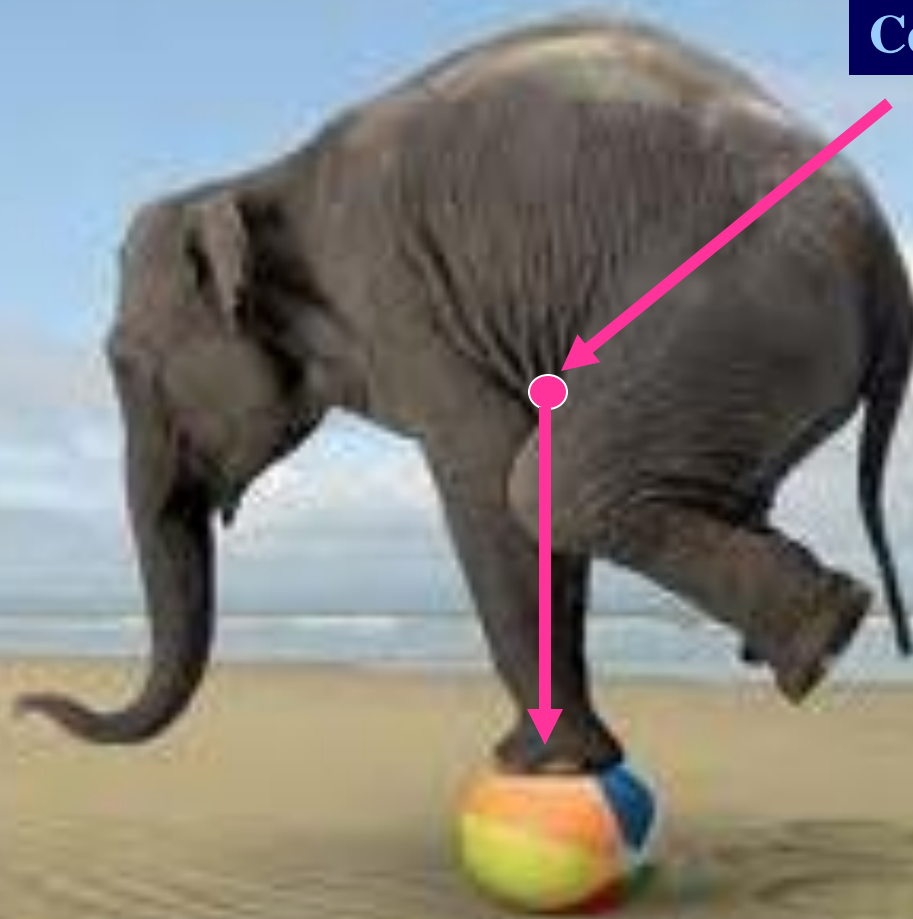
air pressure against
body

Footpads pressure



To balance the centre of gravity must be above the support point.

Centre of gravity



Balance is the Key to Life

Physiology Of Body Balance



Balance & Equilibrium

Balance is the ability to maintain the equilibrium of the body

- Foot position affects standing balance

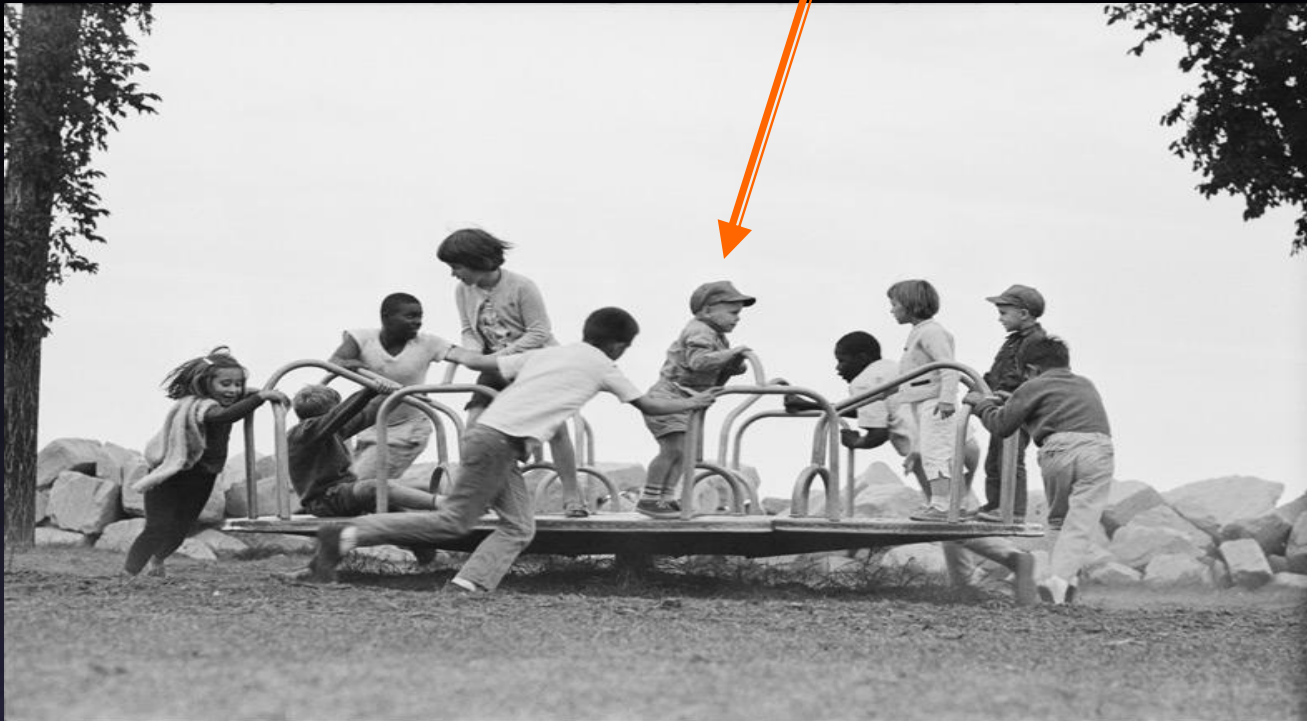
Equilibrium is the state of a body or physical system at rest or in un accelerated motion in which the resultant of all forces acting on it is zero and the sum of all torques about any axis is zero.

There are 2 types of **Equilibrium**

- » Static -
- » Dynamic –

Static Equilibrium

keep the body in a desired position



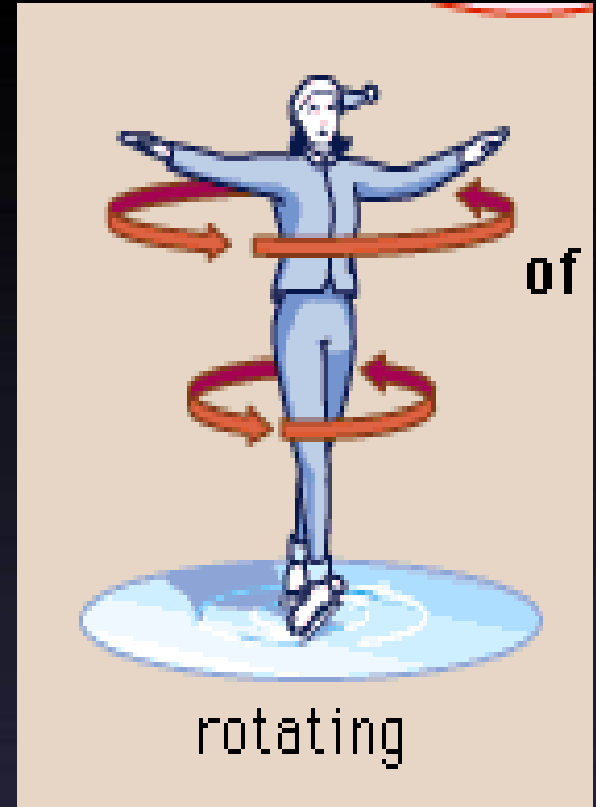
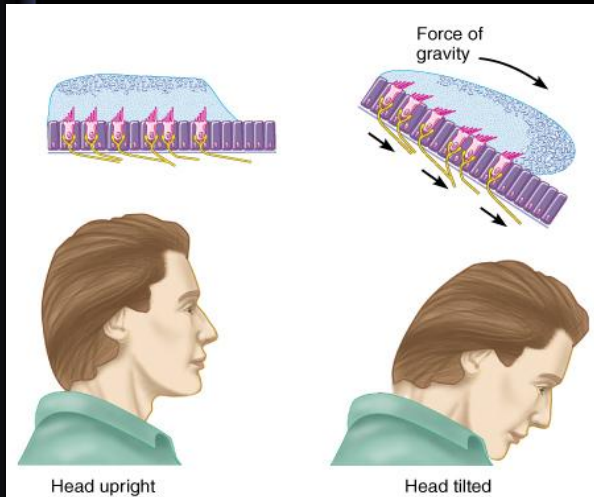
Static equilibrium –The equilibrium is maintained in a **FIXED POSITION**, usually while stood on one foot or maintenance of body posture relative to gravity while the body is still.

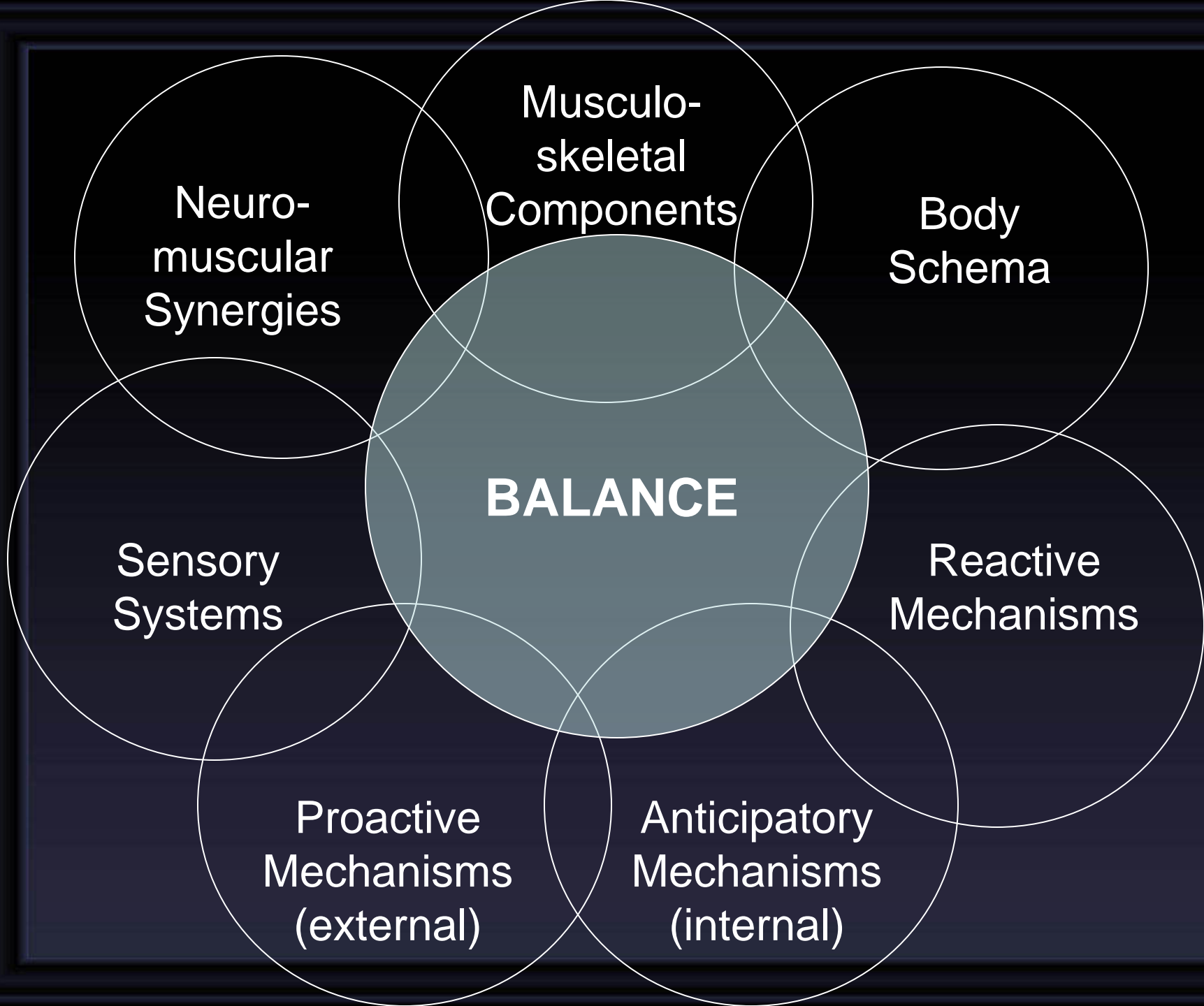
Dynamic Equilibrium to move the body in a controlled way



Dynamic equilibrium 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.

Acceleration Linear & Angular (Rotational)





Neuro-
muscular
Synergies

Musculo-
skeletal
Components

Body
Schema

BALANCE

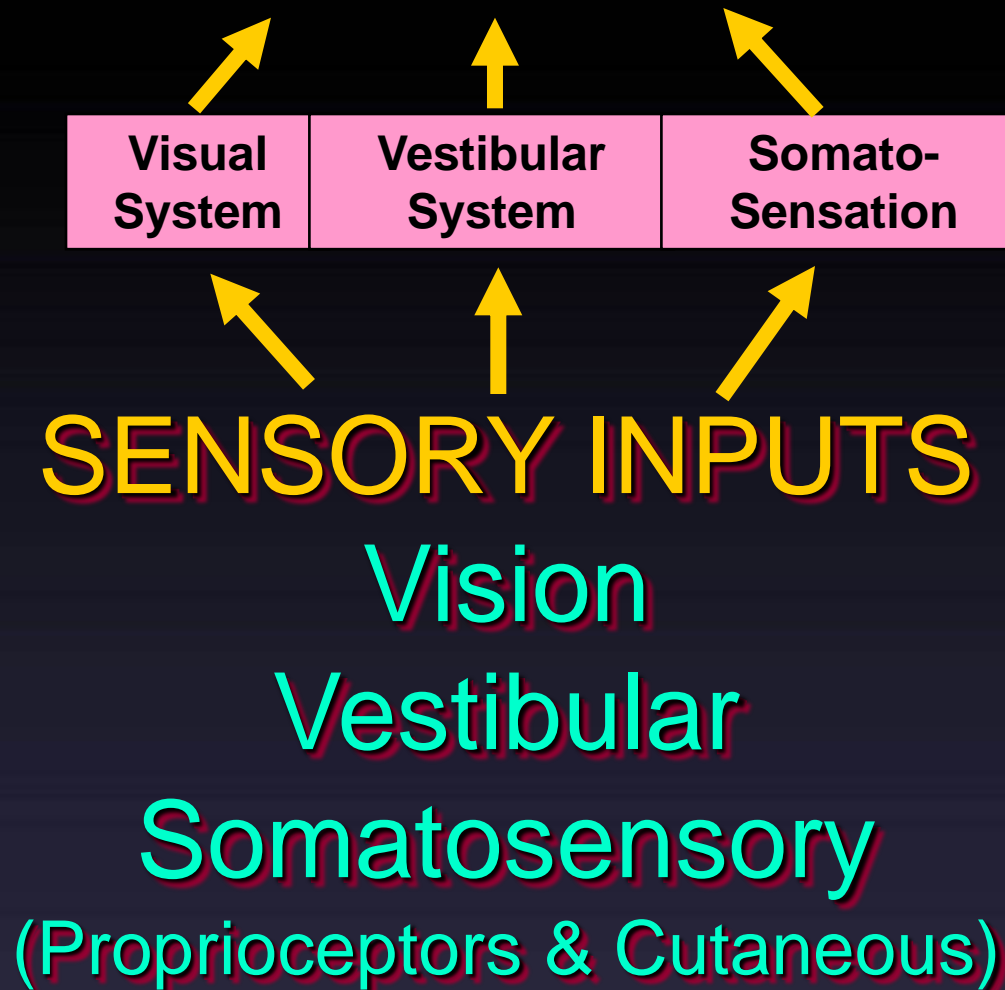
Sensory
Systems

Reactive
Mechanisms

Proactive
Mechanisms
(external)

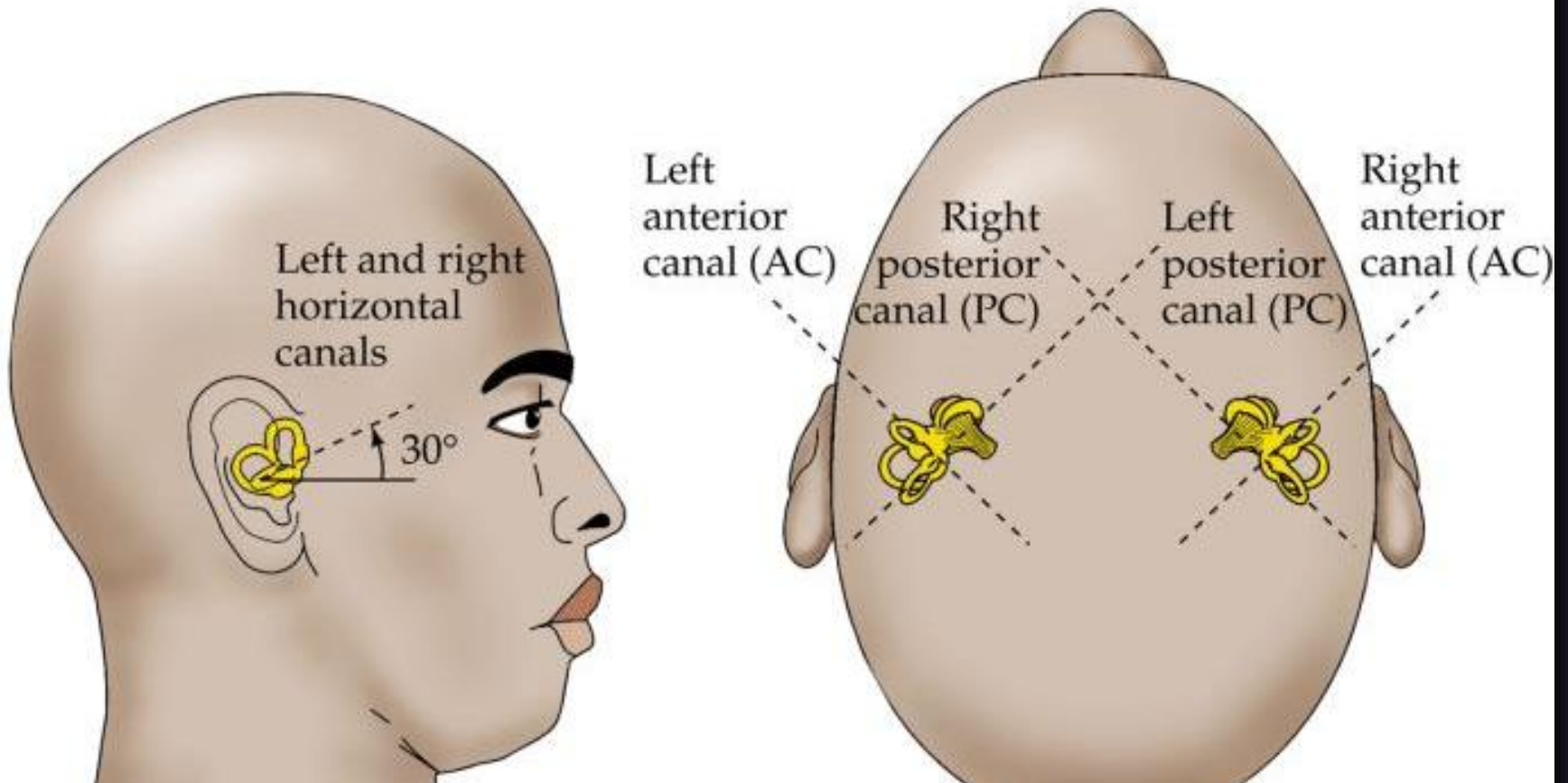
Anticipatory
Mechanisms
(internal)

Compare, Select & Combine Senses



The vestibular labyrinth

(C)

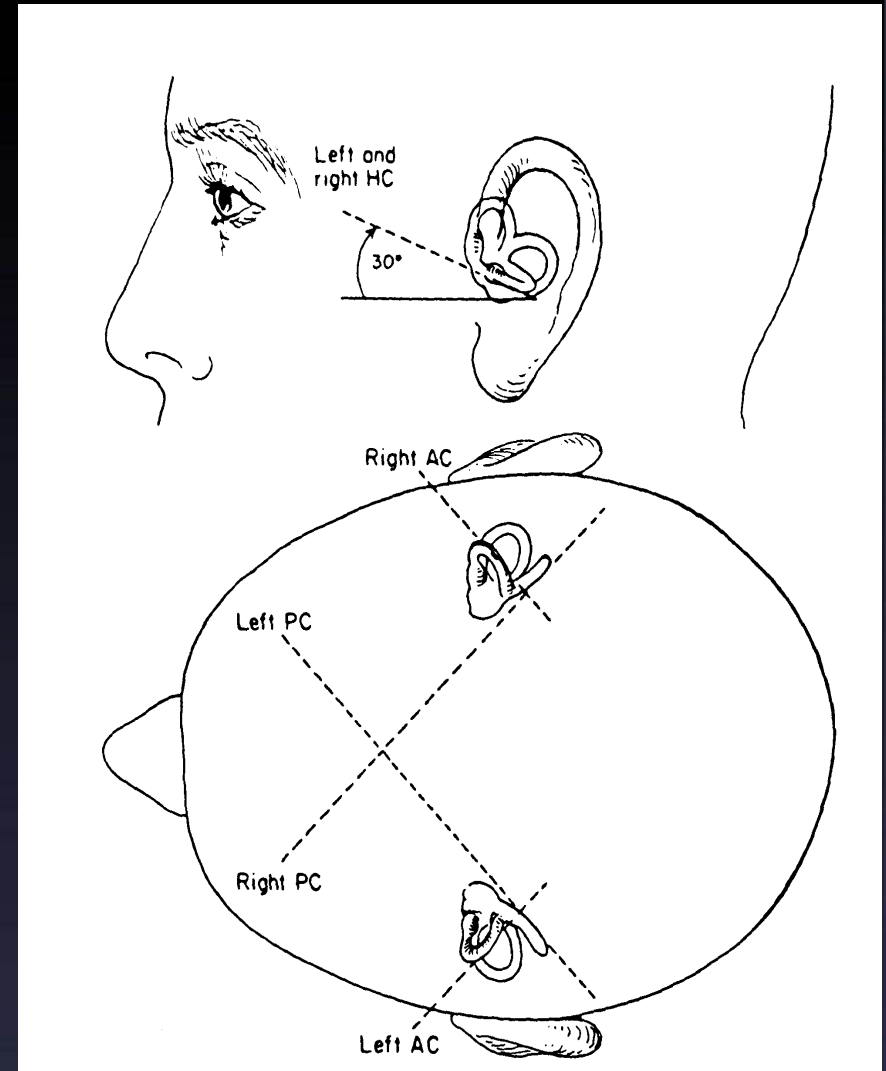


- posterior canal shares plane with contralateral anterior canal.
- horizontal canals share plane.

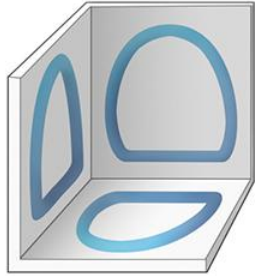
The Vestibular Apparatus

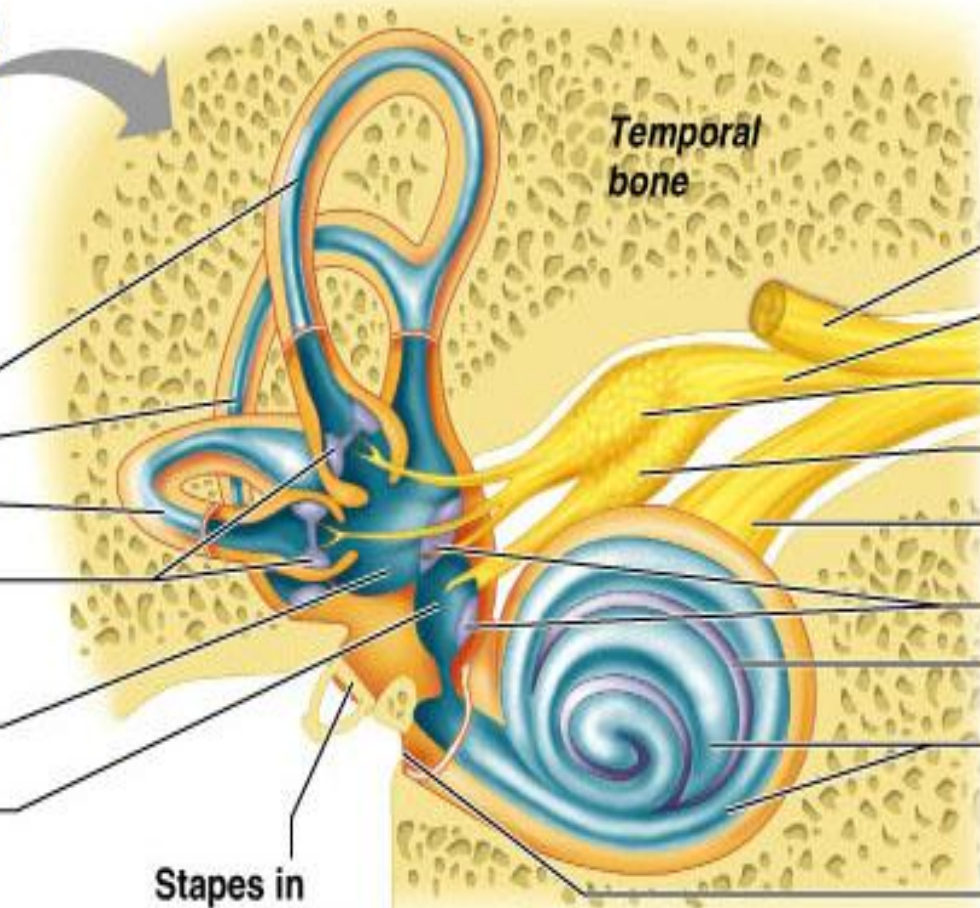
Components

- Three SCCs
 - Anterior
 - Posterior
 - Lateral
- a. Vestibule (Utricle and Saccule)
- b. Vestibular nerve and nuclei



Lateral S
Posterior





Semicircular ducts in semicircular canals:

- Anterior
- Posterior
- Lateral

Cristae ampullares in the ampullae

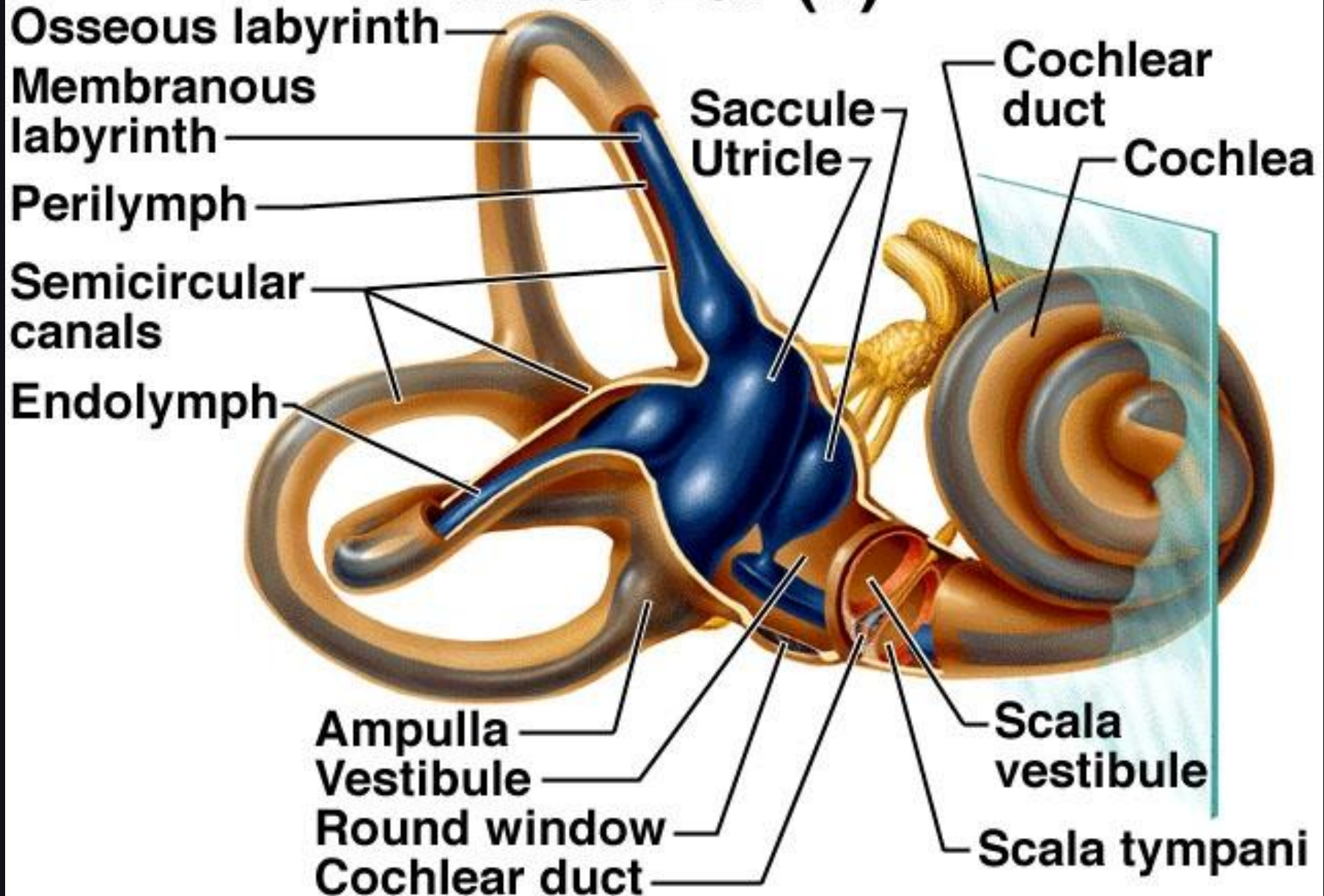
Utricle in vestibule
Saccule in vestibule

Stapes in oval window

Temporal bone

- Facial nerve
- Vestibular nerve
- Superior vestibular ganglion
- Inferior vestibular ganglion
- Cochlear nerve
- Maculae
- Spiral organ of Corti
- Cochlear duct in cochlea
- Round window

Inner Ear (1)



Equilibrium

Semi-circular canals

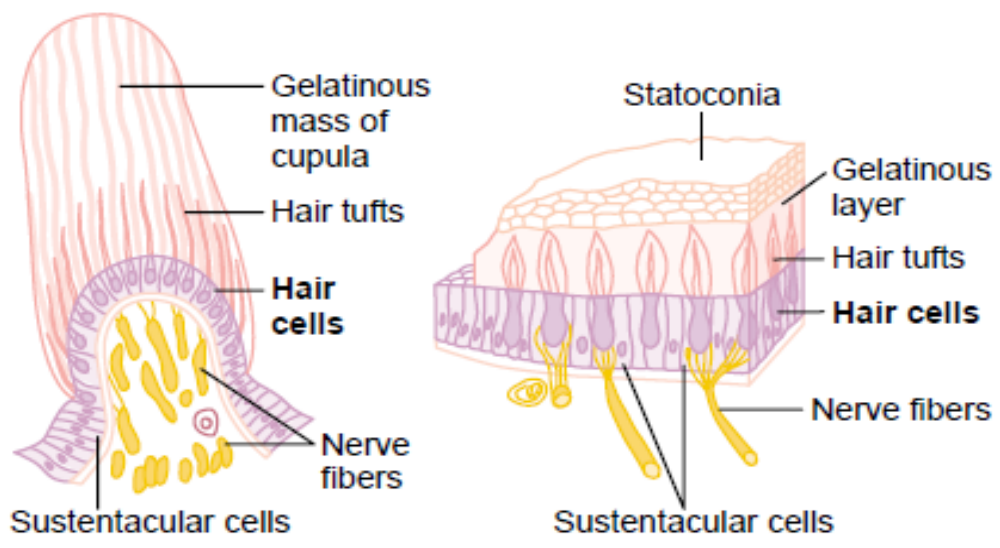
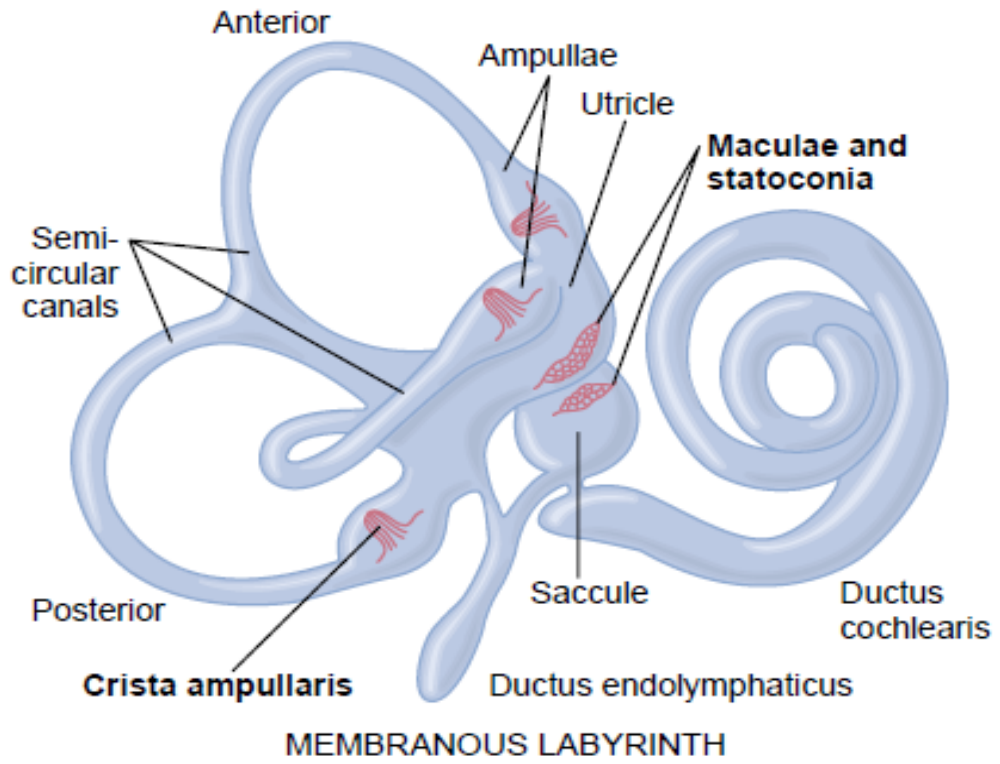
(Ant,Post,Lat)

- **Crista ampullaris**
- **Hair cells in each crista are oriented in the same direction**
- **Rotational motion**

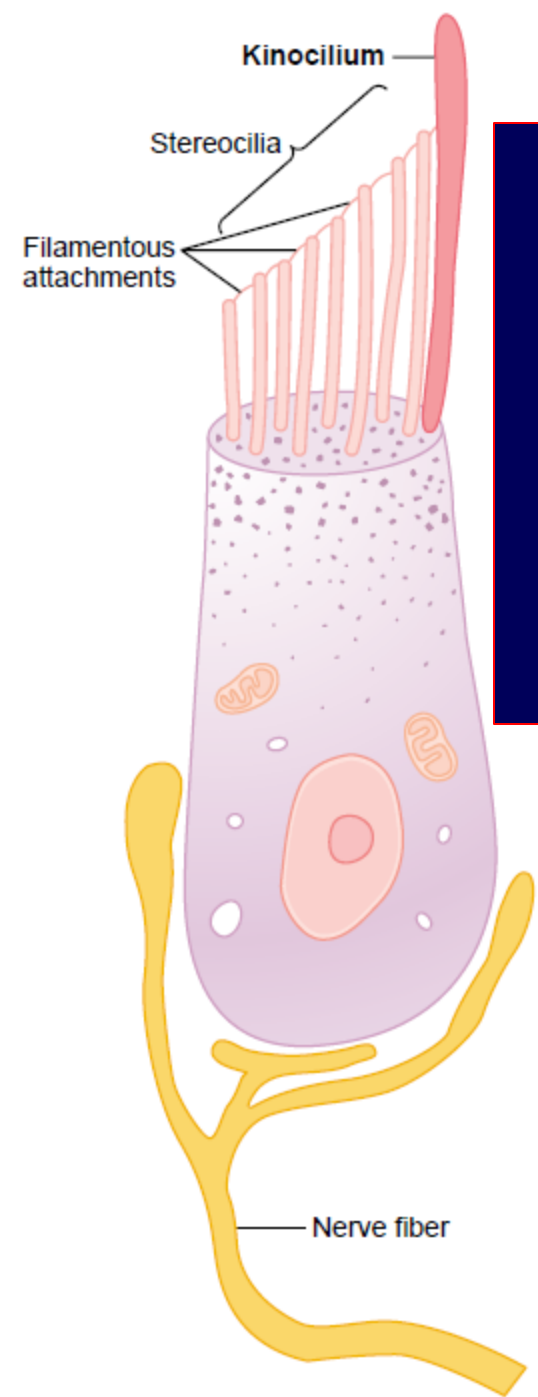
Vestibule

(saccule and utricle)

- **Maculae**
- **Hair cells in each macula are oriented in all direction**
- **Otoliths** (calcium carbonate crystals)
- **Static equilibrium**

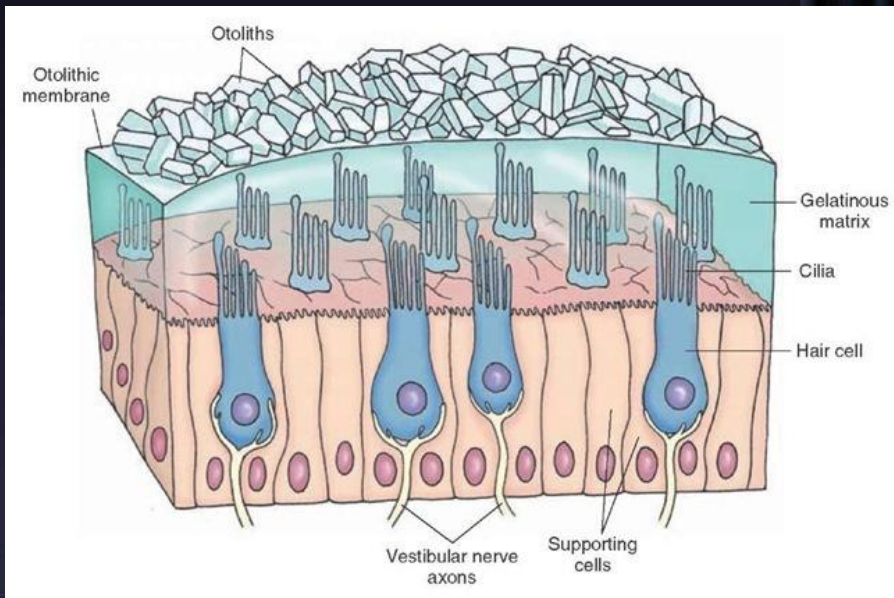
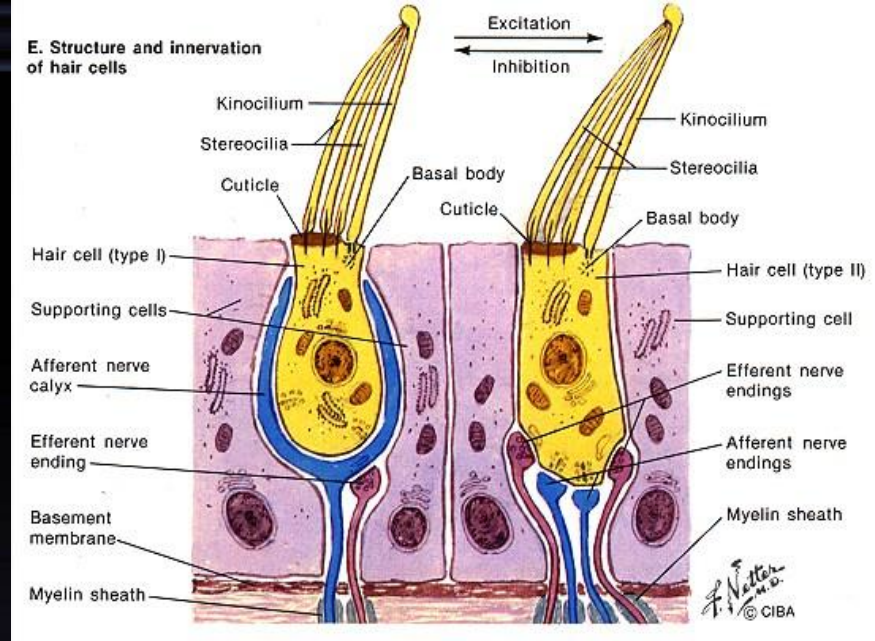
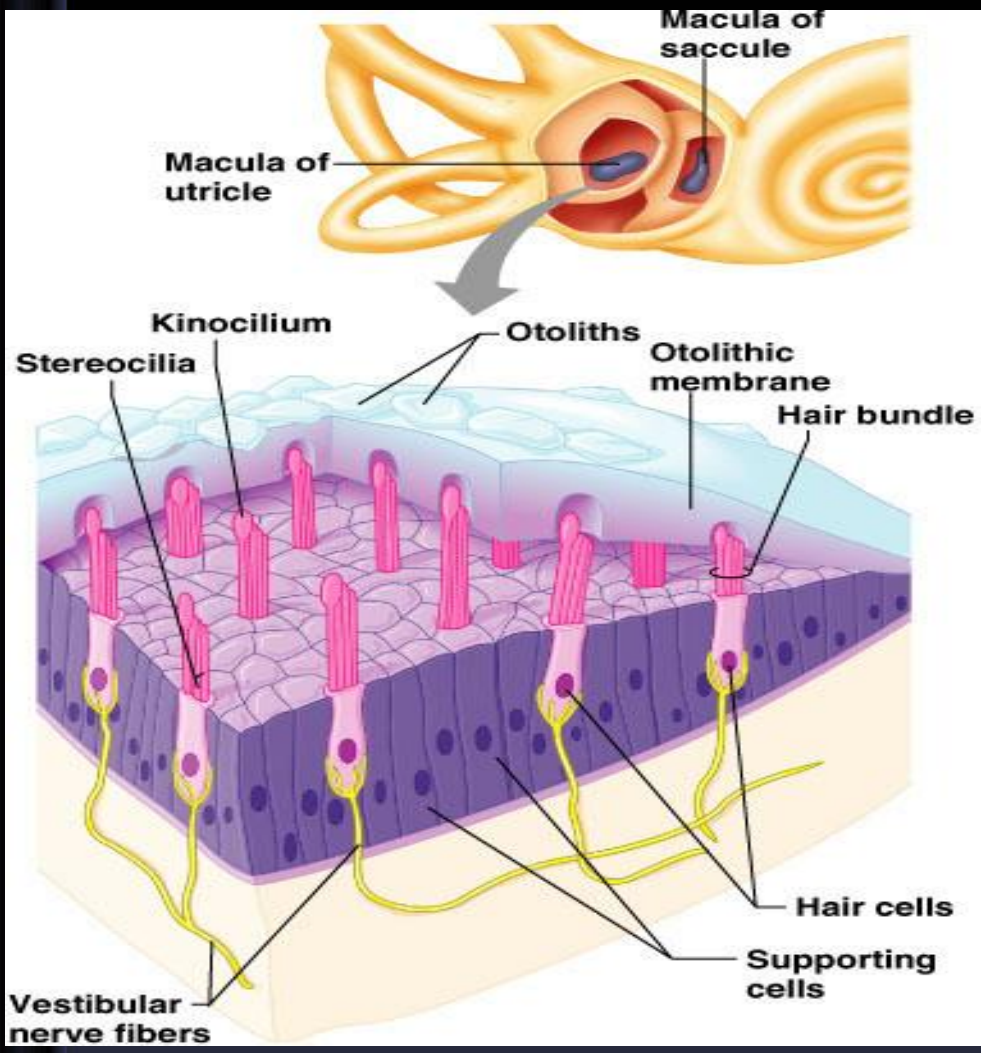


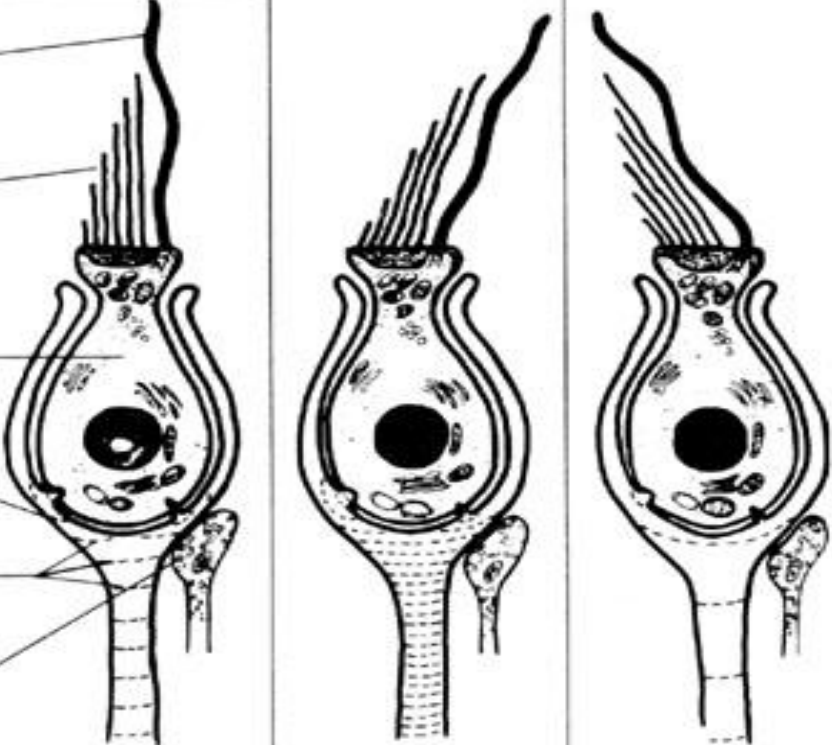



CRISTA AMPULLARIS AND MACULA



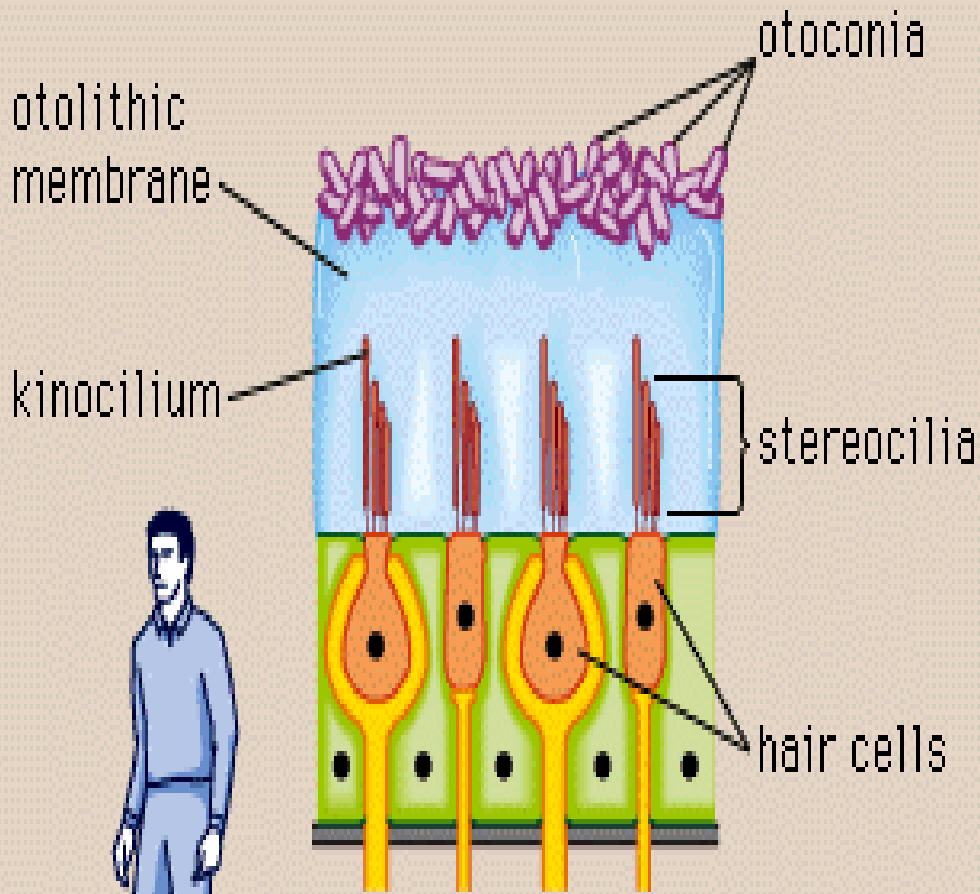
**One (large) kinocilium
30 to 150 (small) stereocilia
Cilia connected by fine filaments (tip links)**

Maculae



| POSITION OF CILIA | NEUTRAL | TOWARD KINOCILIUM | AWAY FROM KINOCILIUM |
|--|---|--|--|
| <p data-bbox="446 329 658 368">KINOCILIUM (1)</p> <p data-bbox="378 472 610 565">STEREOCILIA (60 - 100)</p> <p data-bbox="465 615 658 654">HAIR CELL</p> <p data-bbox="282 694 755 779">VESTIBULAR AFFERENT NERVE ENDING</p> <p data-bbox="330 836 707 875">ACTION POTENTIALS</p> <p data-bbox="272 922 745 1008">VESTIBULAR EFFERENT NERVE ENDING</p>  |  |  |  |
| <p data-bbox="378 1100 649 1179">POLARIZATION OF HAIR CELL</p> | <p data-bbox="871 1122 1016 1160">NORMAL</p> | <p data-bbox="1122 1122 1363 1160">DEPOLARIZED</p> | <p data-bbox="1412 1122 1731 1160">HYPERPOLARIZED</p> |
| <p data-bbox="330 1250 716 1329">FREQUENCY OF ACTION POTENTIALS</p> | <p data-bbox="871 1269 1035 1308">RESTING</p> | <p data-bbox="1170 1269 1315 1308">HIGHER</p> | <p data-bbox="1518 1269 1663 1308">LOWER</p> |

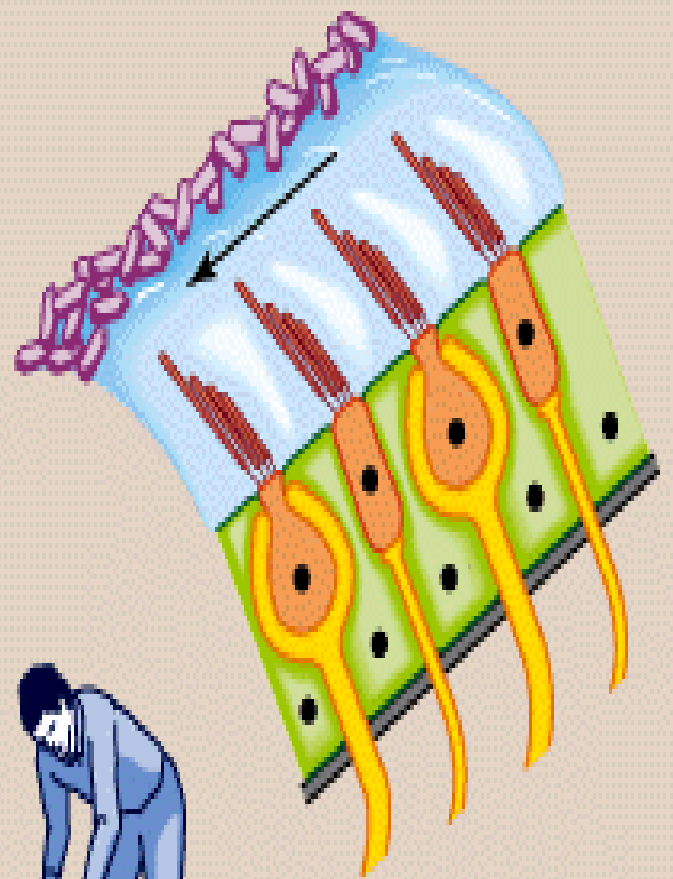
B



upright section of the utricular macula



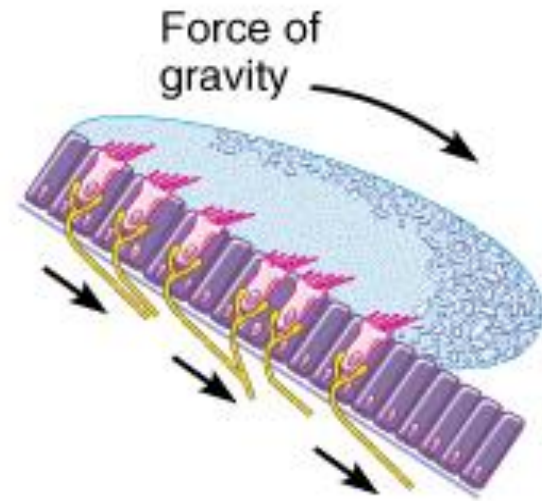
head upright



displaced section of the utricular macula



head bent forward



Head upright

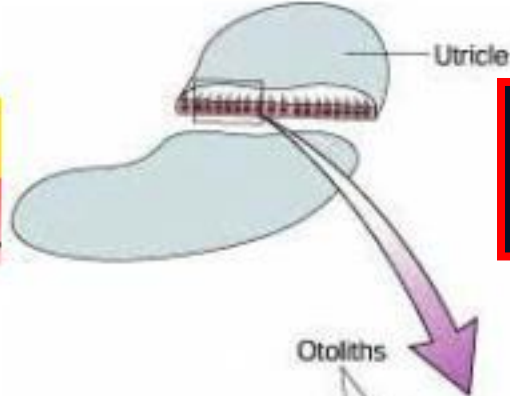


Head tilted

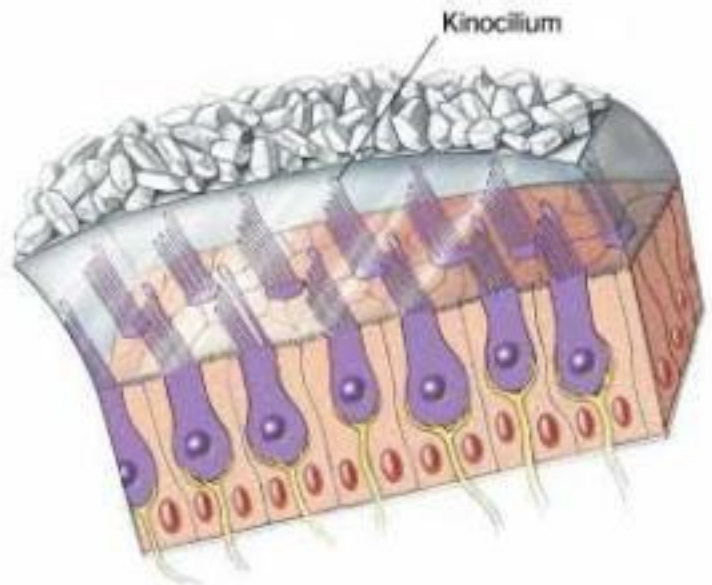
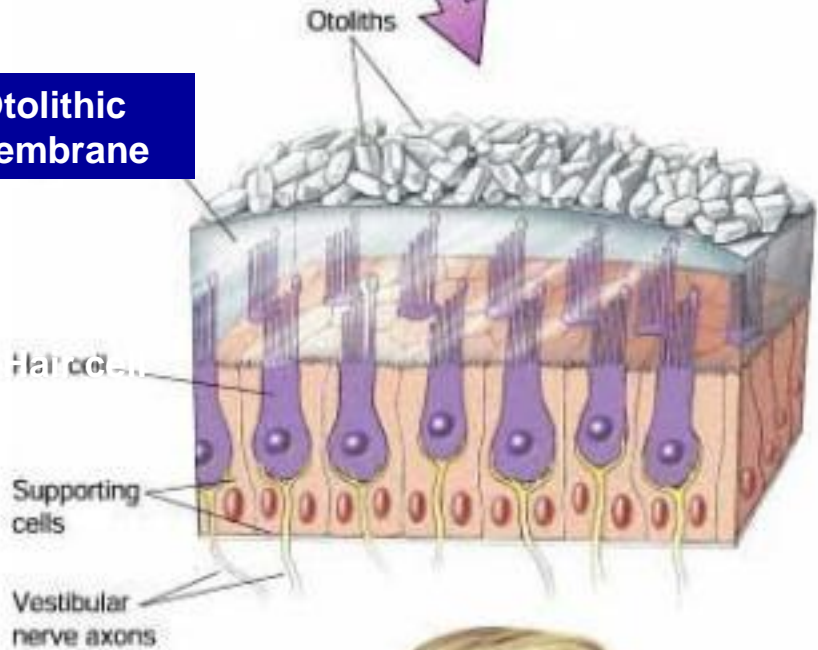
In macula: hair cells are oriented in different direction and tilt Of Head In Any Direction is Signaled

Anatomy: Maculae of Utricle or Sacculle

Physiology: Linear acceleration of head



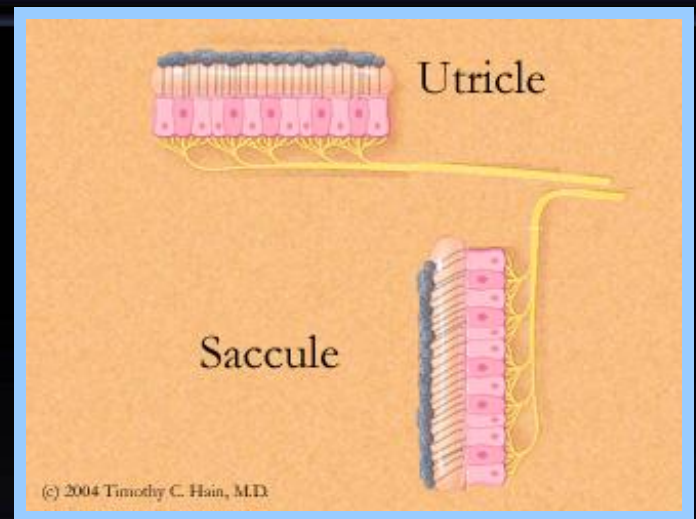
Otolithic membrane



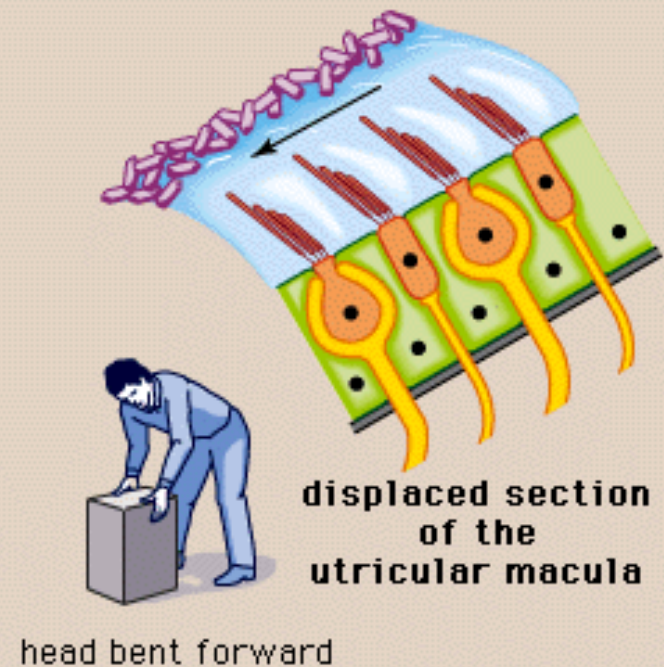
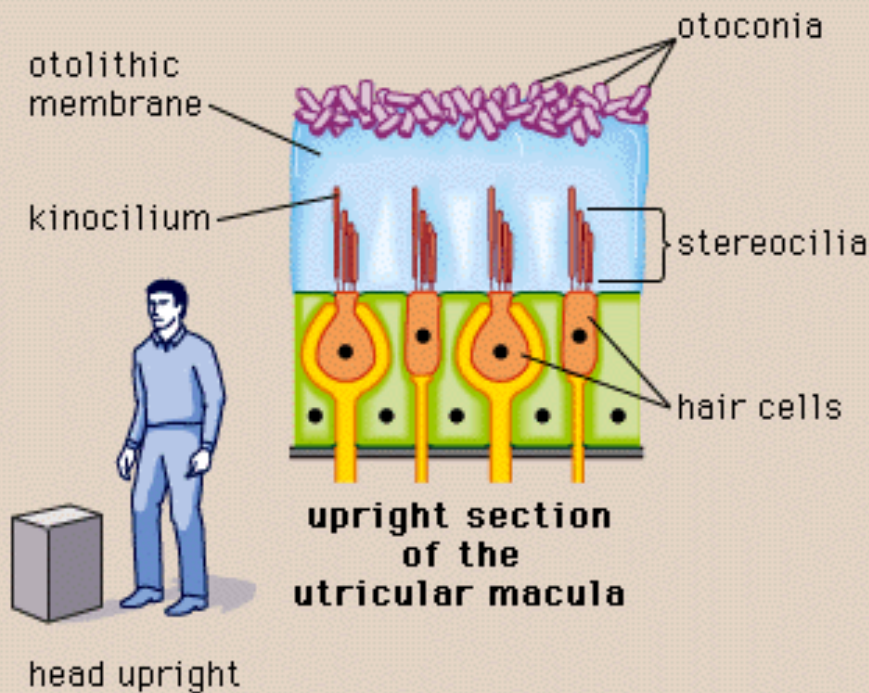
“ear rocks”



The two maculae, the utricle and saccule, are oriented in the horizontal and vertical planes and tell us how we are aligned relative to gravity.



B

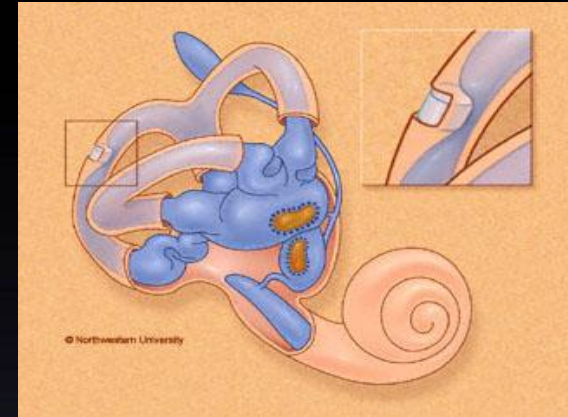


Hair cells in Utricle & Sacculle

In upright position: (Head vertical)

- In utricle:
 - Macula in horizontal plane
 - Hairs pointing upwards
 - Hair cells signal head movements in any direction
- In sacculle:
 - Macula in vertical plane
 - Hairs pointing laterally
 - Hair cells operate when one is lying down

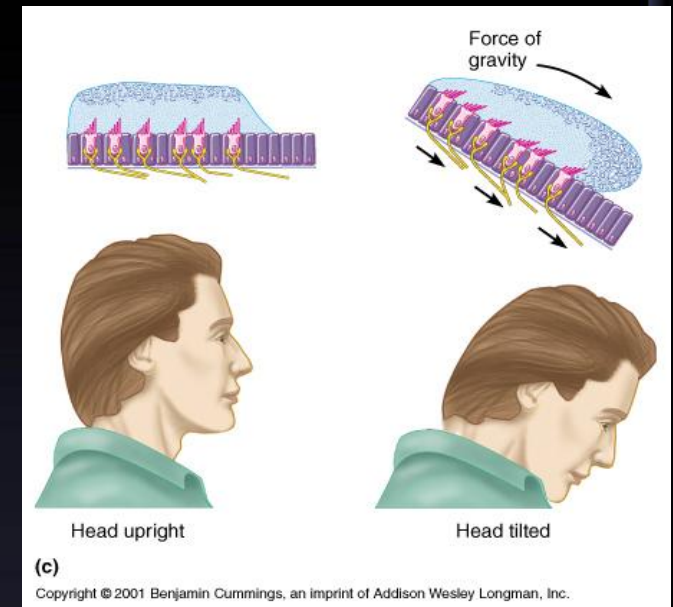
**inform the brain of orientation
of head in space**



Function of utricle and saccule

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
(Response???)



Function of utricle and saccule

2. Detection of linear acceleration:

Sudden acceleration >>>

Falling backwards >>>

Otoliths falls back on hairs >>>

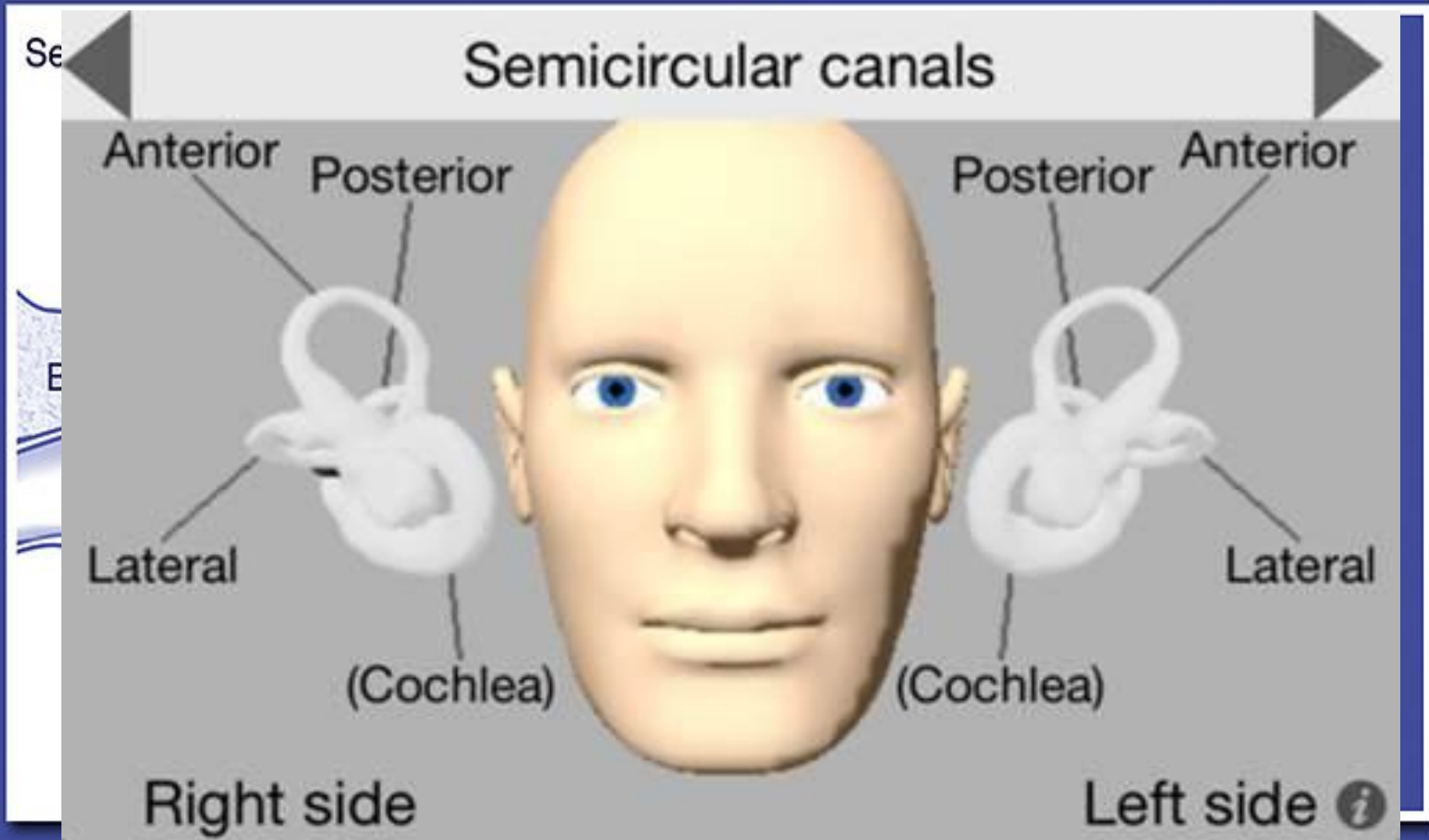
sensation of mal-equilibrium >>

Correction by leaning forward

*Saccular maculae detect vertical acceleration

*Both utricle and saccule horizontal acceleration

Three Semicircular Canals



Three Semicircular Canals

Horizontal (lateral)

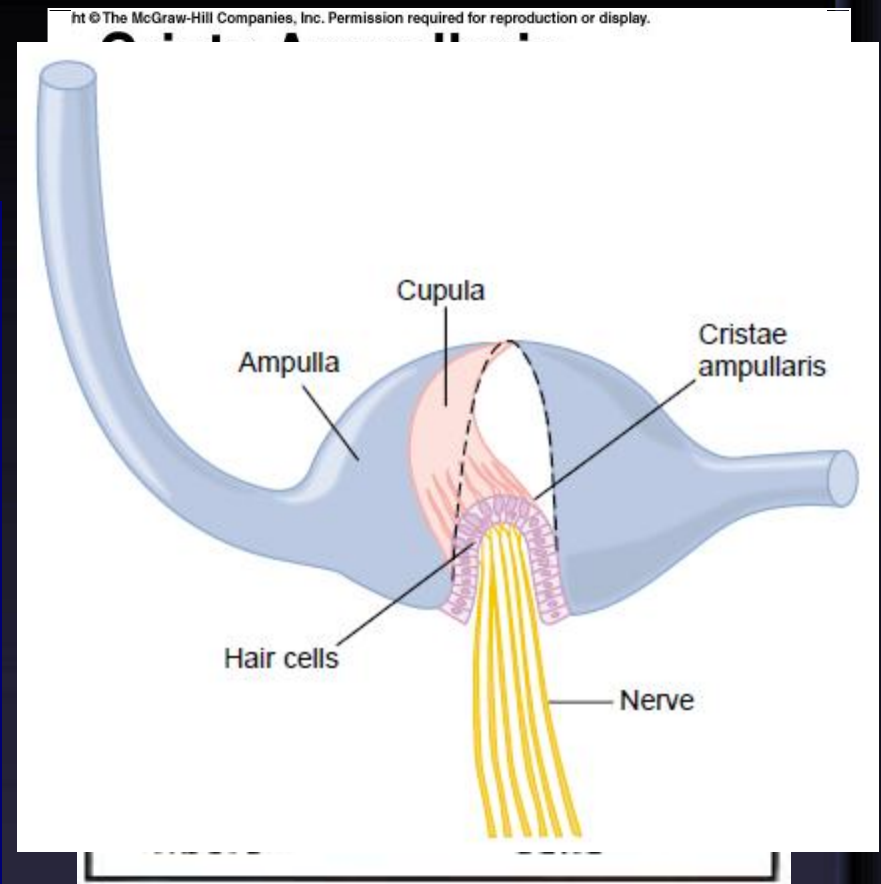
Vertical:

Anterior

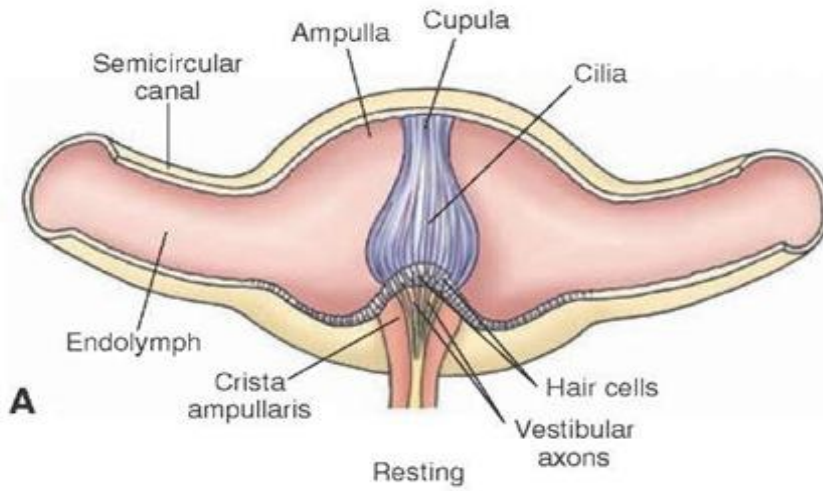
Posterior

SENSORY ORGAN: CRISTA AMPULLARIS

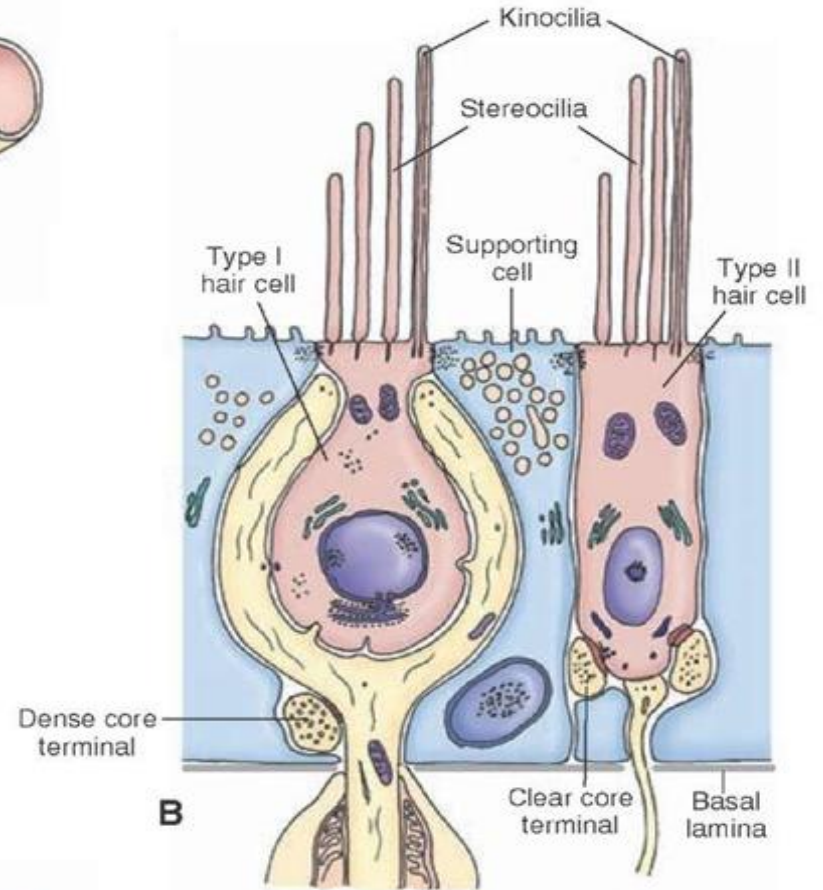
1. Contain Endolymph
2. Each canal has a dilated end = Ampulla
3. The ampulla houses the sensory hair cells (oriented in same direction) which are covered by a gelatinous material (Cupula)



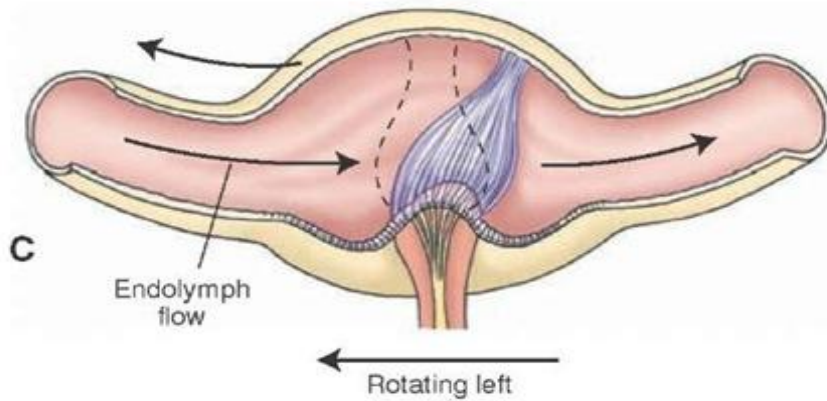
S



A



B



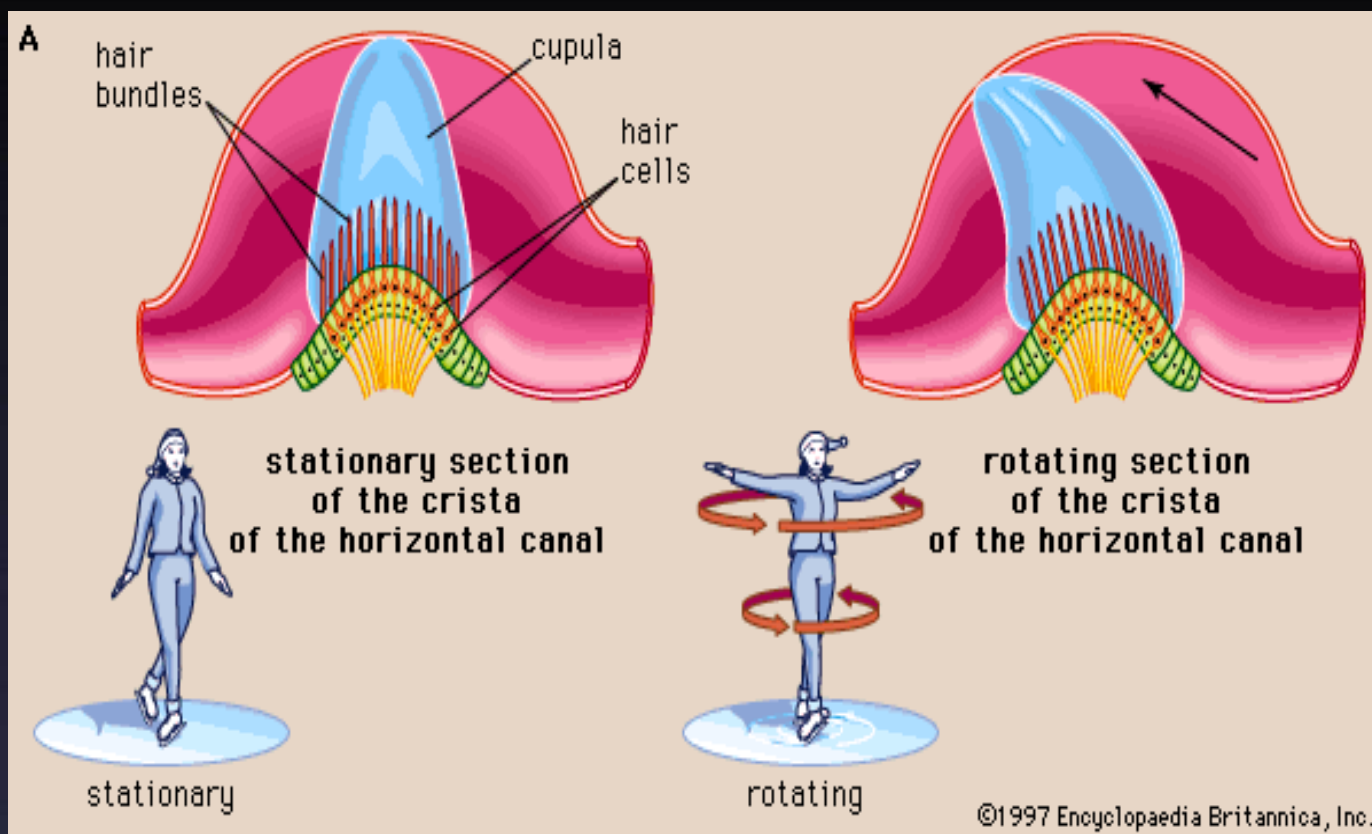
C

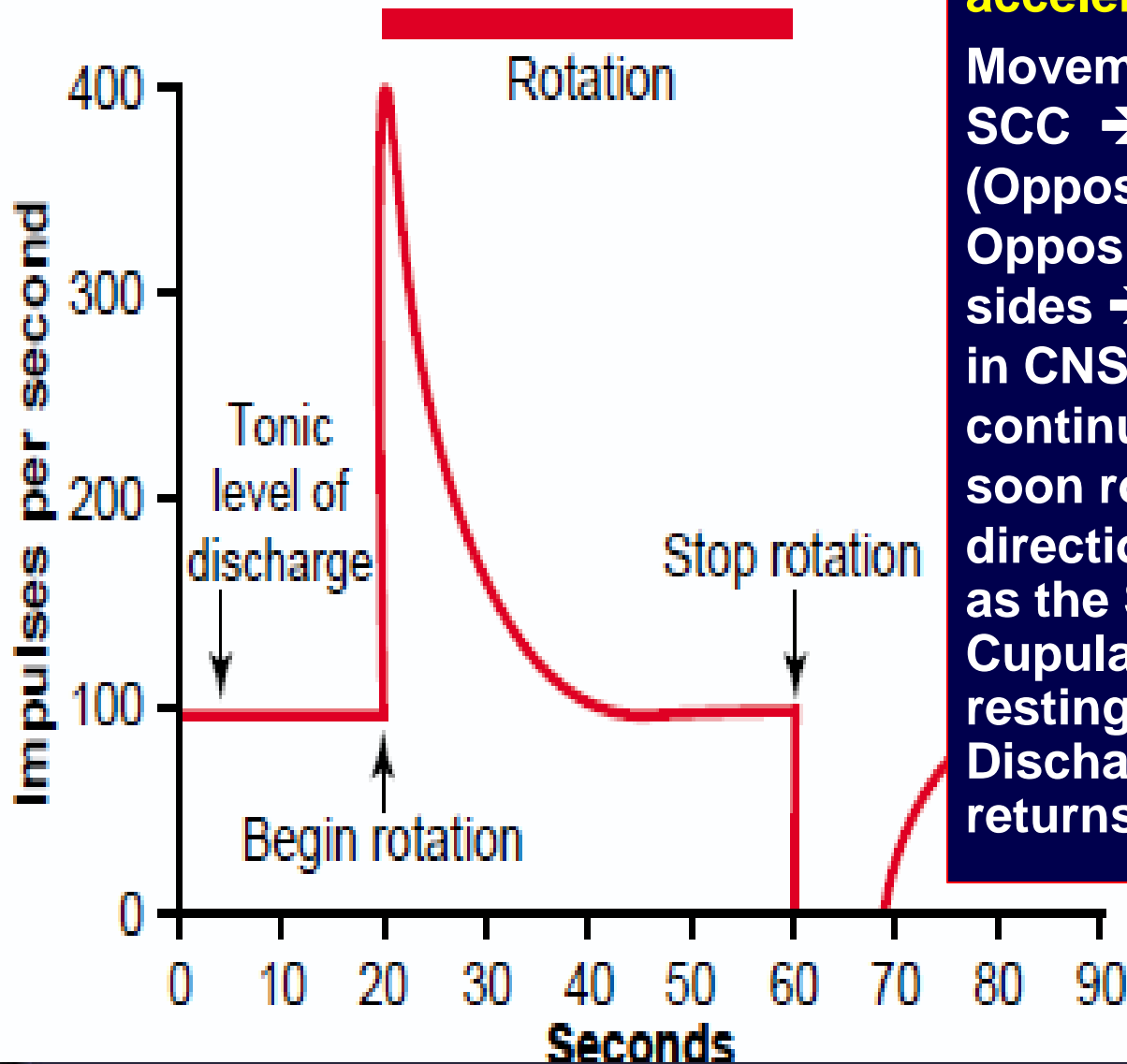


ating

Plane of rotation determines the canal to be stimulated:

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



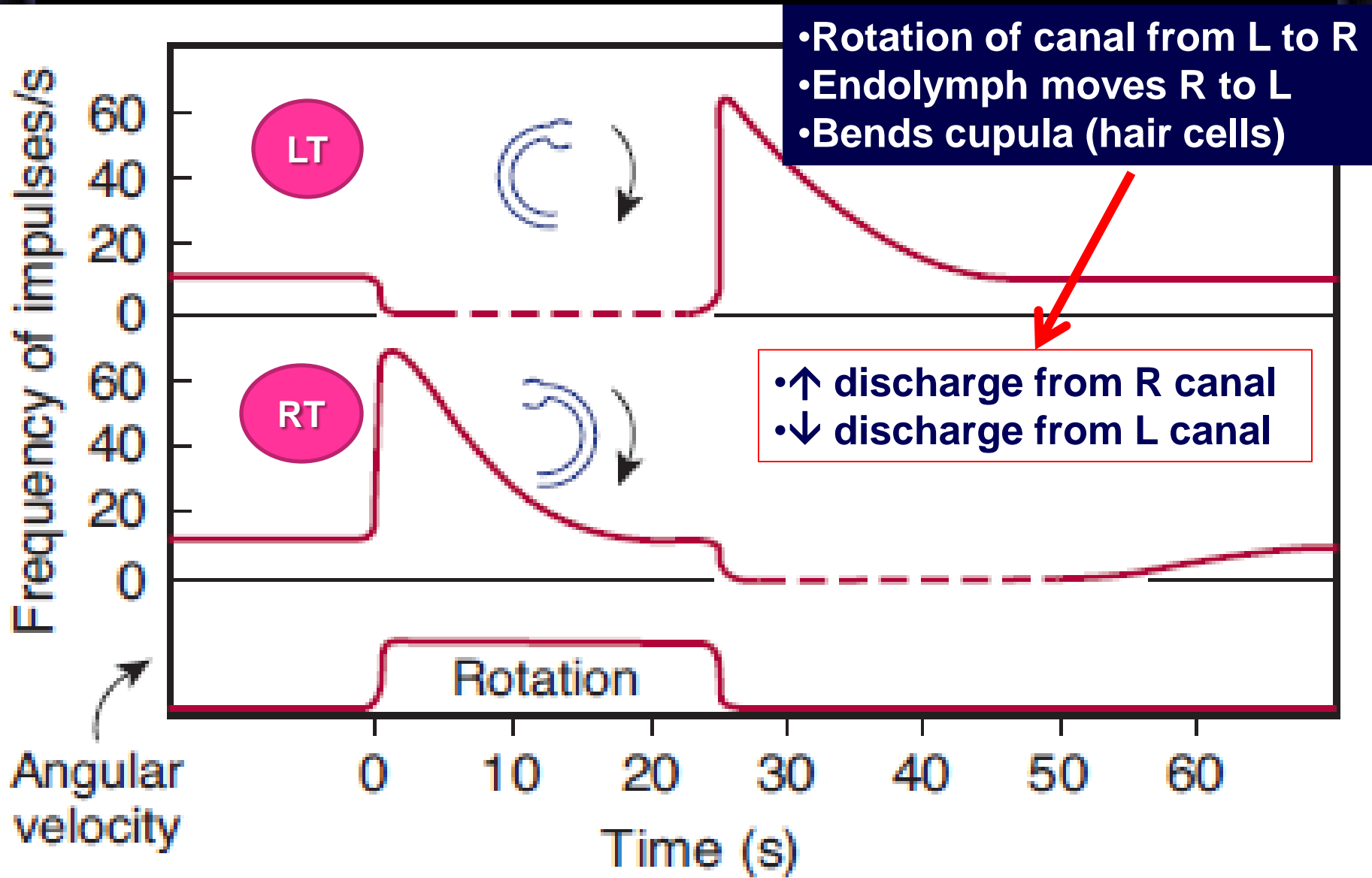


Angular (rotational) acceleration

Movement of endolymph in SCC → Bending of hairs (Opposite on two sides) → Opposite discharge from two sides → Sensation of rotation in CNS → As rotation continues endolymph will soon rotate in the same direction (& speed) as the SCC → Cupula being elastic returns to resting position → Discharge from both sides returns to resting level

No sensation of rotation so long eyes are closed

Rotational Acceleration, Steady Rotation & Deceleration



VESTIBULAR FUNCTION

SCCs detect ANGULAR ACCELERATION:

- The beginning of rotation
- End of rotation
- Changes in rate of rotation (eg; Joy Riding)

Predictive function of SCC in the maintenance of equilibrium:

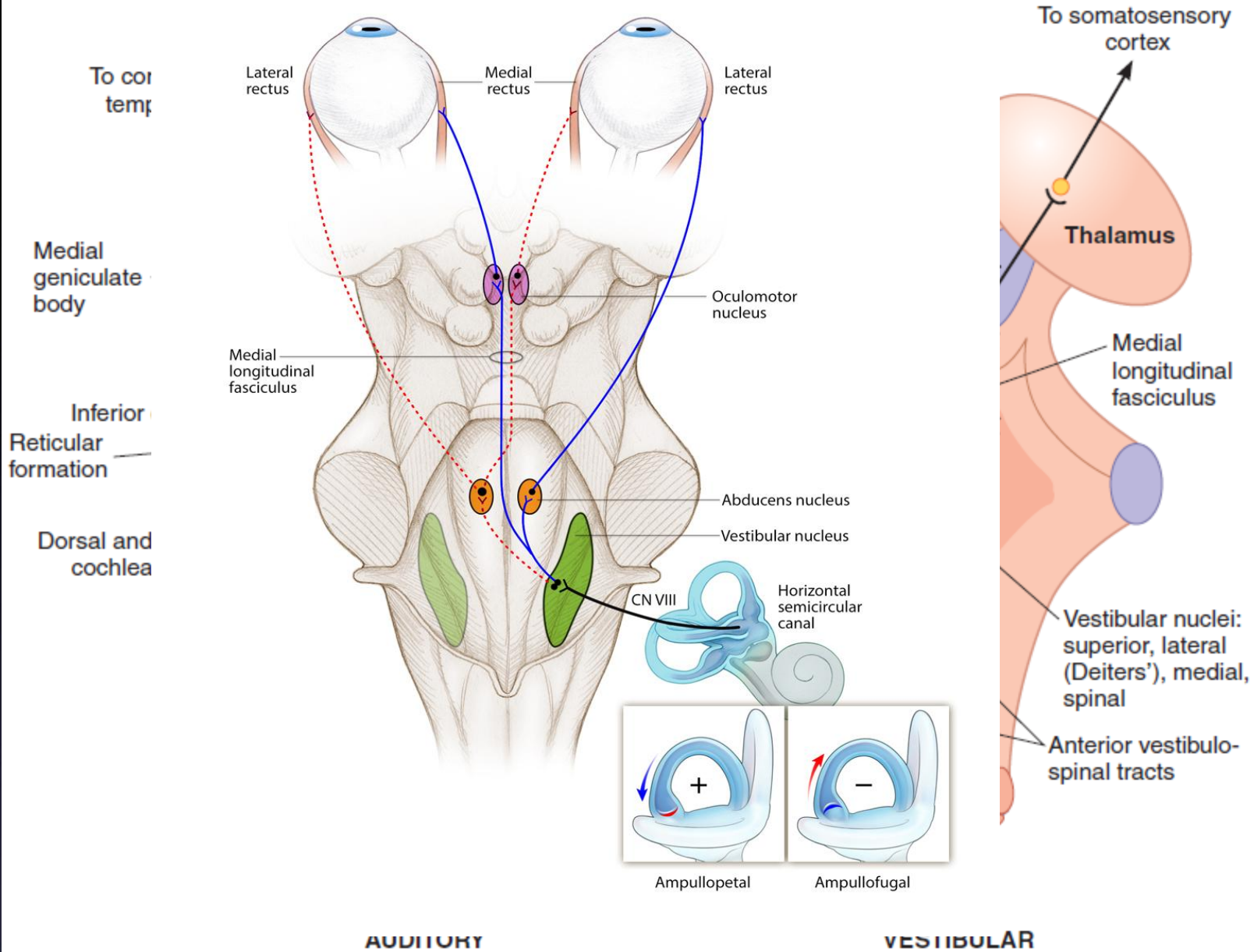
i.e. Predict ahead of time that mal-equilibrium is going to occur → Send impulses to CNS for corrective measures before the start of the fall

VESTIBULAR PATHWAY

Neural connections:

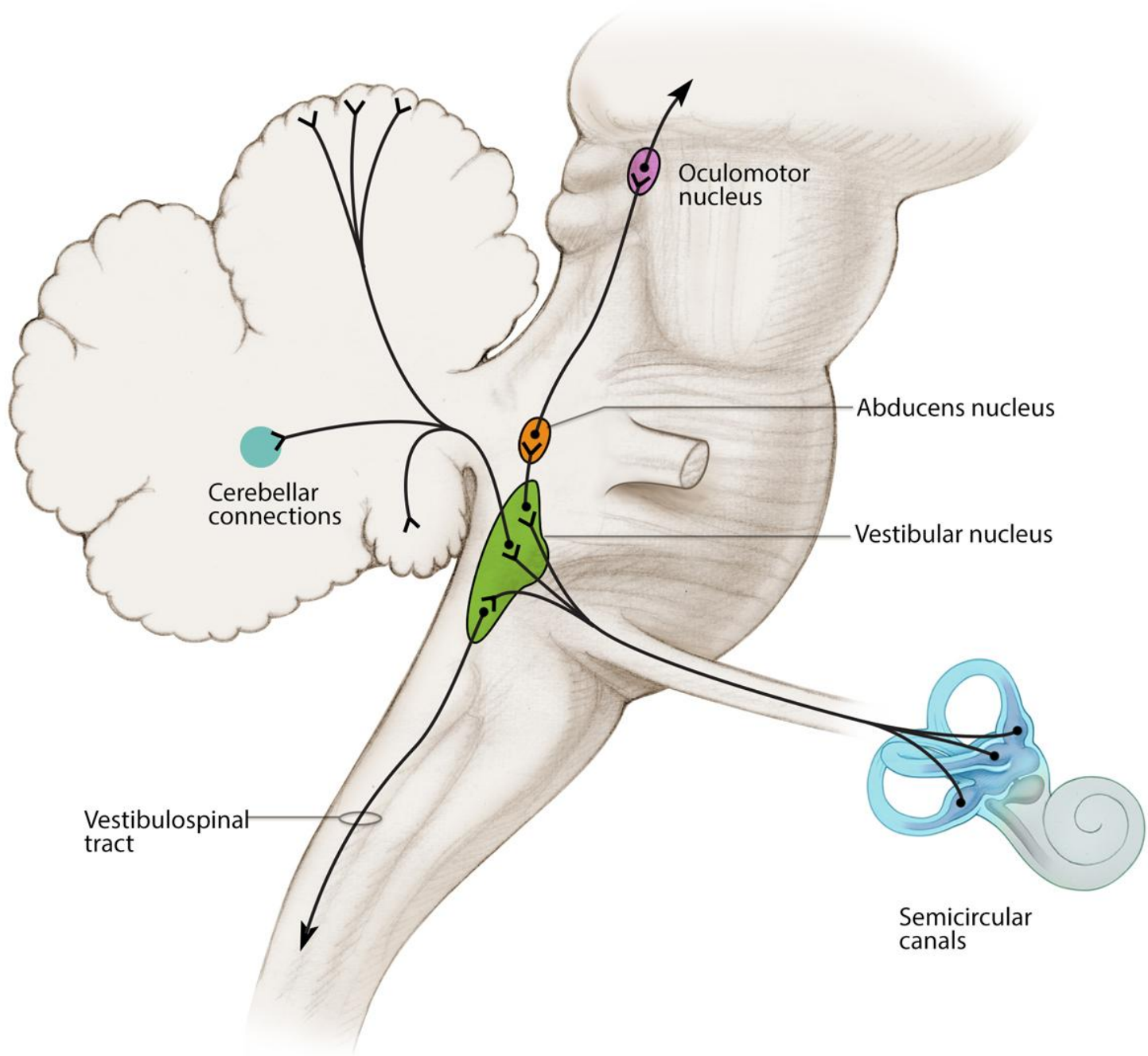
1. Cerebellum
2. Motor nuclei of CNs 3,4 & 6
3. Reticular formation (Spinal cord)**
4. Spinal cord (Vestibulo-spinal tract)**

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

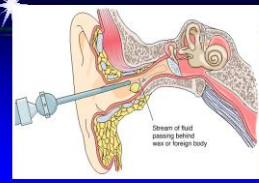


AUDITORY

VESTIBULAR



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 induces 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 a unilateral lesion in the vestibular pathway, nystagmus is reduced or absent on the side of the lesion.

2. Rotation tests

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.

Abnormalities (Motion Sickness)

Clinical signs:

1. **Vertigo: feeling of rotation when body is not**
2. **Nystagmus**

Clinical signs:

- **Nausea**
- **Vomiting**
- **Bradycardia**
- **Hypotension**
- **Sweating**

Mechanism: autonomic stimulation

Vertigo: feeling of rotation when body is not moving

THANKS

