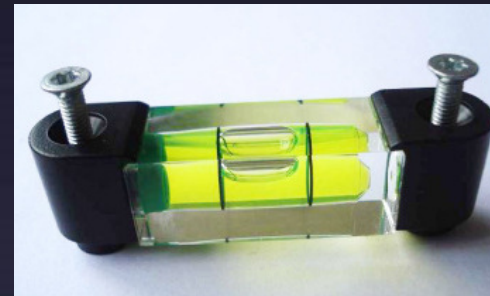


# PHYSIOLOGY OF INNER EAR IN BALANCE



***Dr Syed Shahid Habib***  
**Professor & Consultant**  
**Clinical Neurophysiology**  
**Dept. of Physiology**  
**College of Medicine & KSUMC**



# 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 Disorders

9/24/2019

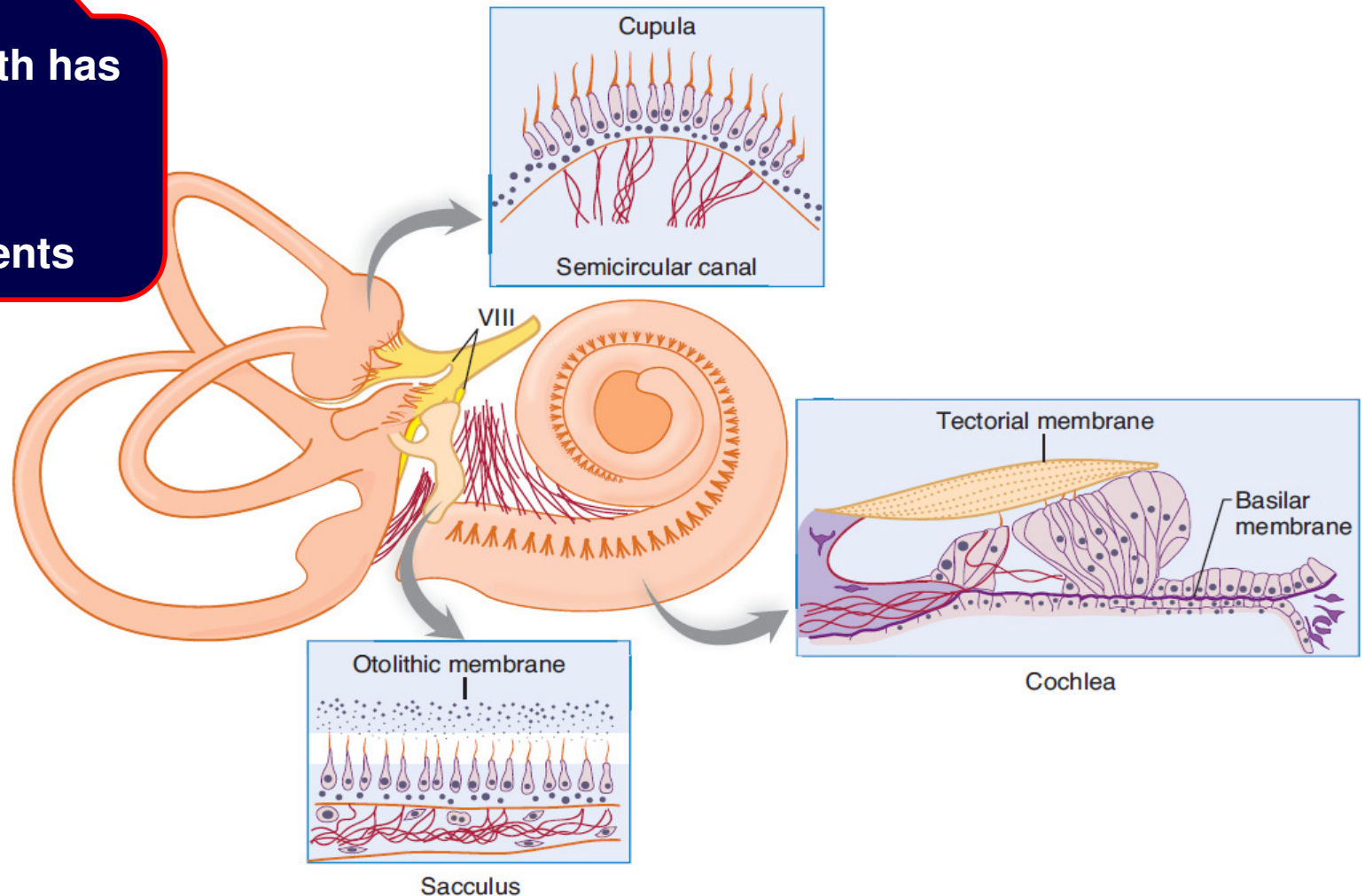


- **Cochlea** (**Organ of Corti** containing receptors for hearing)
- **Semicircular canals** (**Crista ampullaris** containing receptors that respond to head rotation)
- **Utricle & Sacculle** (**Macula** contain otolith organs and receptors that respond to gravity and head tilt)

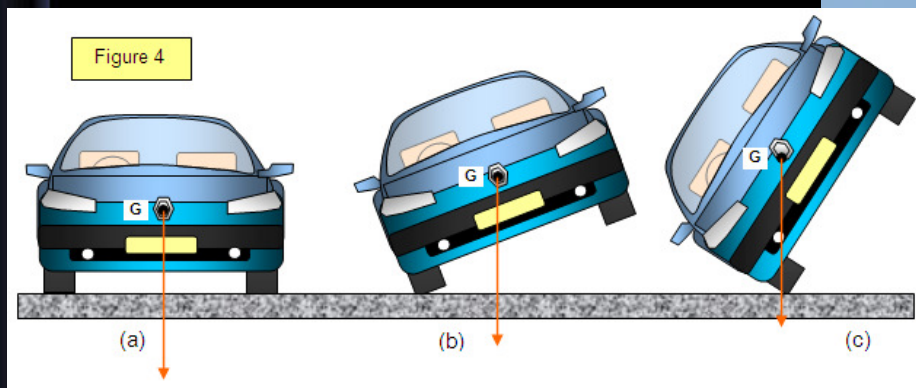
The labyrinth has

**3**

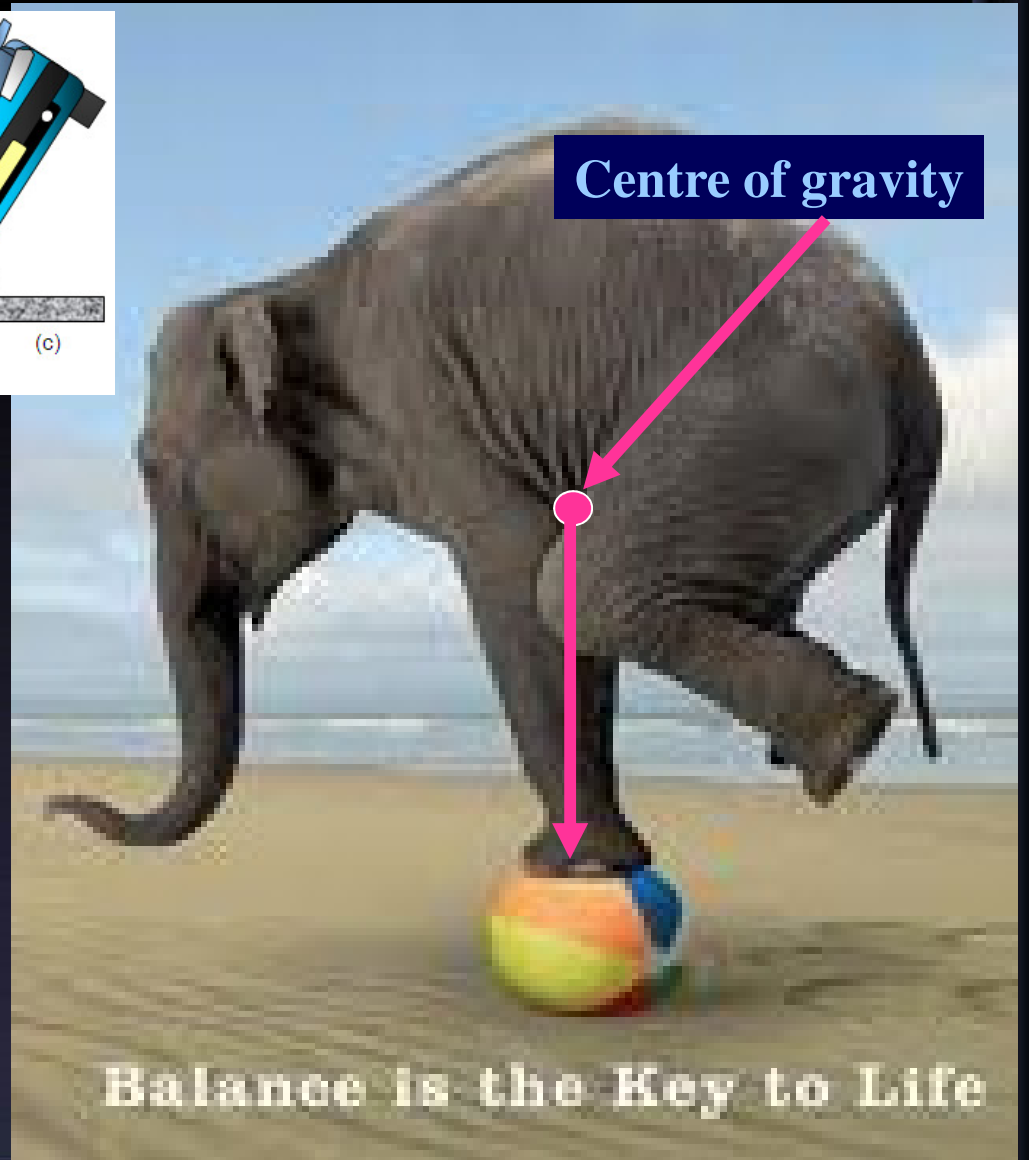
Components



To balance the centre of gravity must be above the support point at which the weight is evenly dispersed



The **center of gravity** of an object is the point at which weight is evenly dispersed and all sides are in balance.



Balance is the Key to Life

# 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.

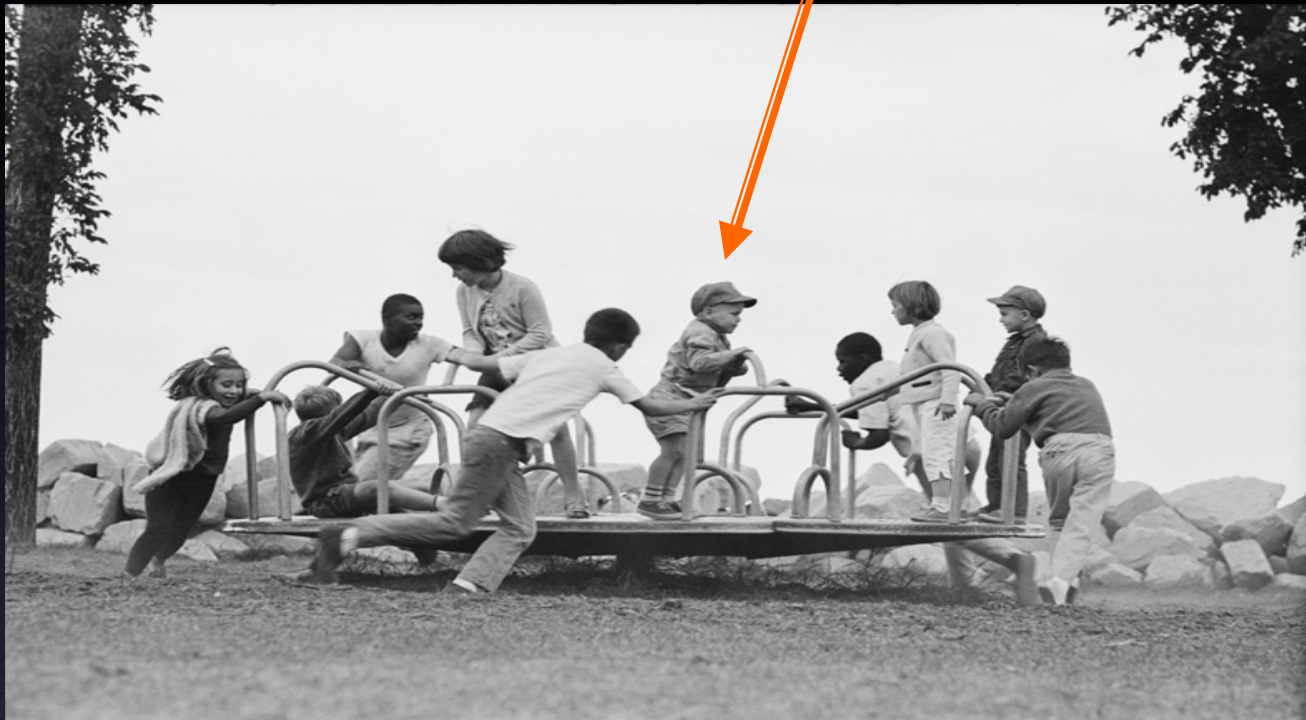
There are 2 types of Equilibrium

» Static

» Dynamic

# Static Equilibrium

keep the body in a desired position

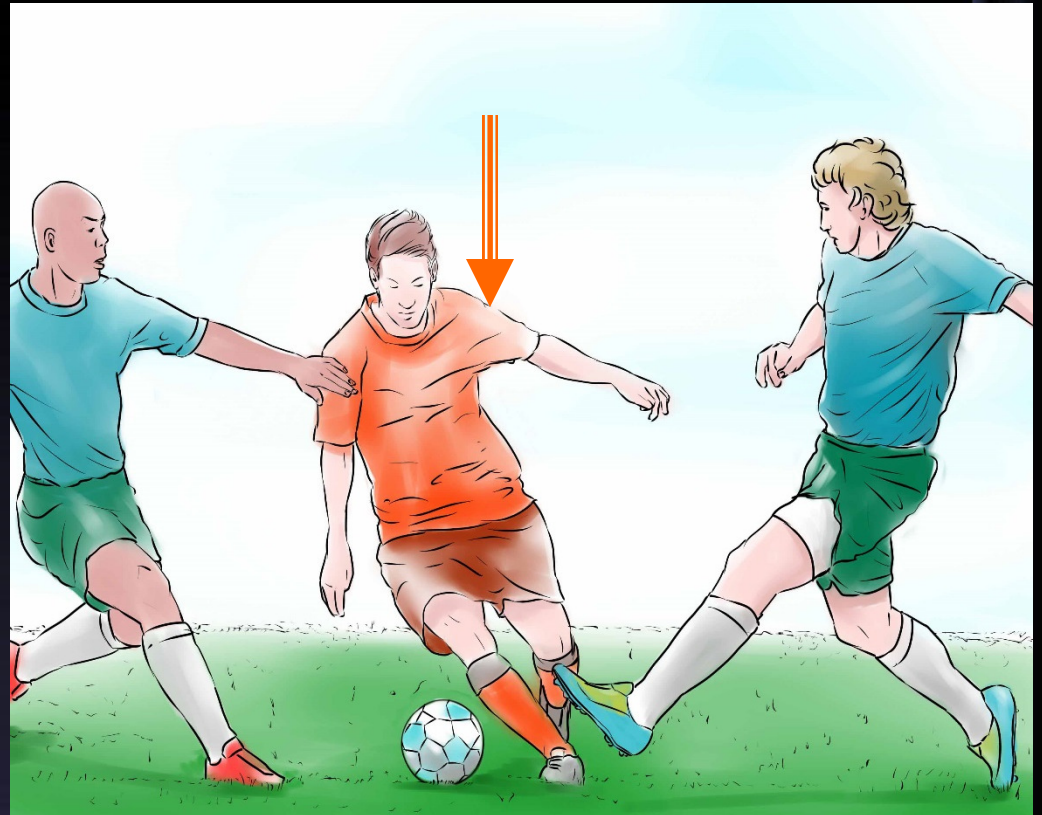


Static equilibrium –The equilibrium is maintained in a **FIXED POSITION**, usually while standing on one foot or maintenance of body posture relative to gravity while the body is still.

# Dynamic Equilibrium to move the body in a controlled way

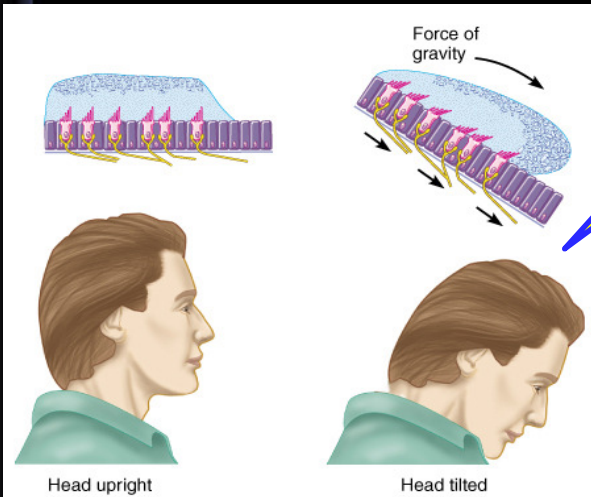
Static Equilibrium -  
sense the position of the  
head, maintain stability  
and posture

Dynamic Equilibrium  
(semicircular canals) -  
balance the head during  
sudden movement



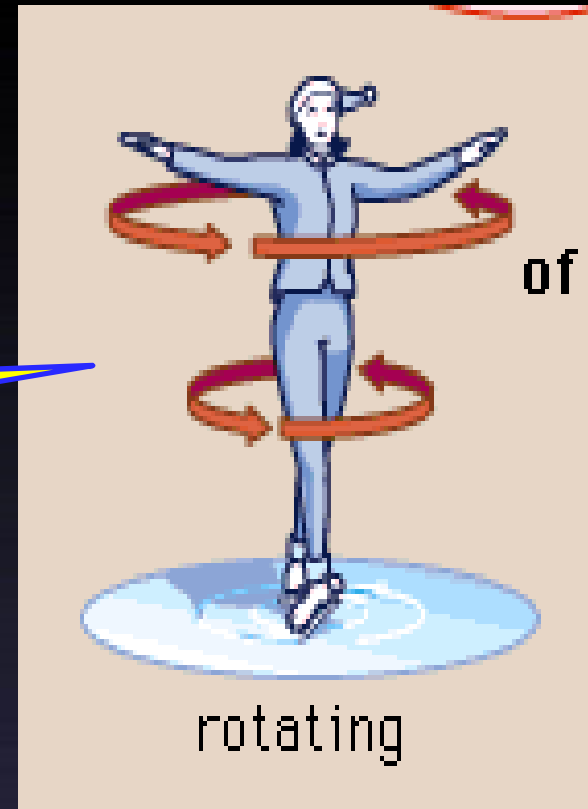
Dynamic equilibrium The equilibrium must be maintained **while performing a task** which involves MOVEMENT e.g. Walking the beam – maintenance of the body posture (mainly the head) in response to sudden movements. Tracking a moving object.

# Acceleration is of two types Linear & Angular (Rotational)



Linear

Angular



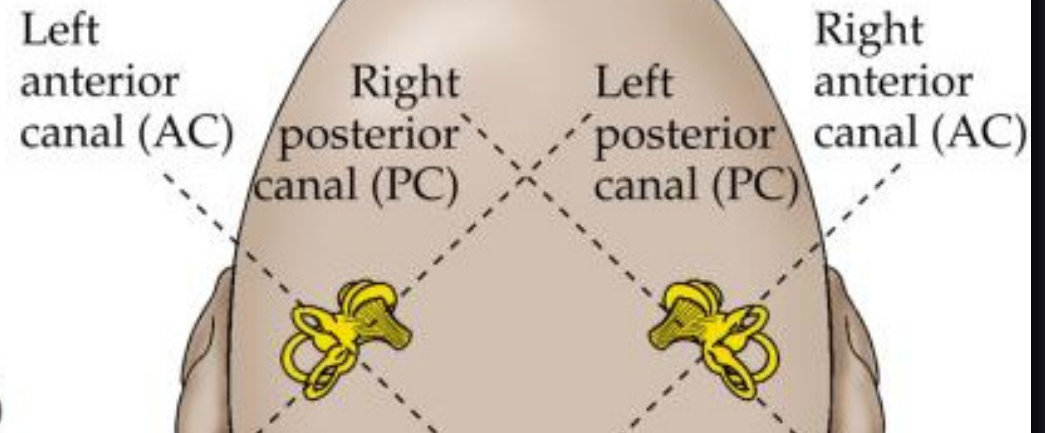
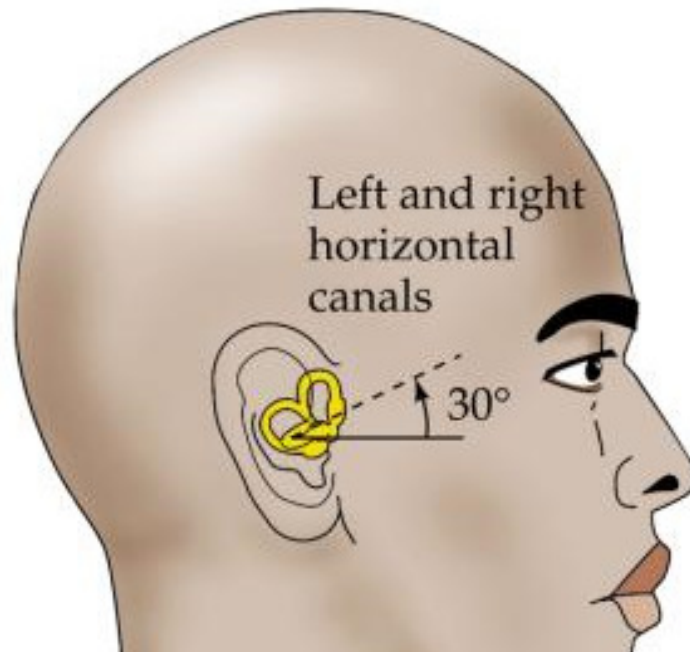


# The vestibular Apparatus

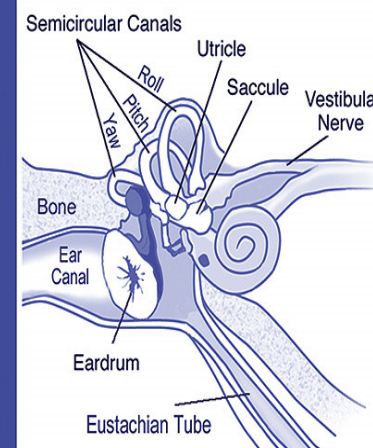
## Components

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

(C)



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



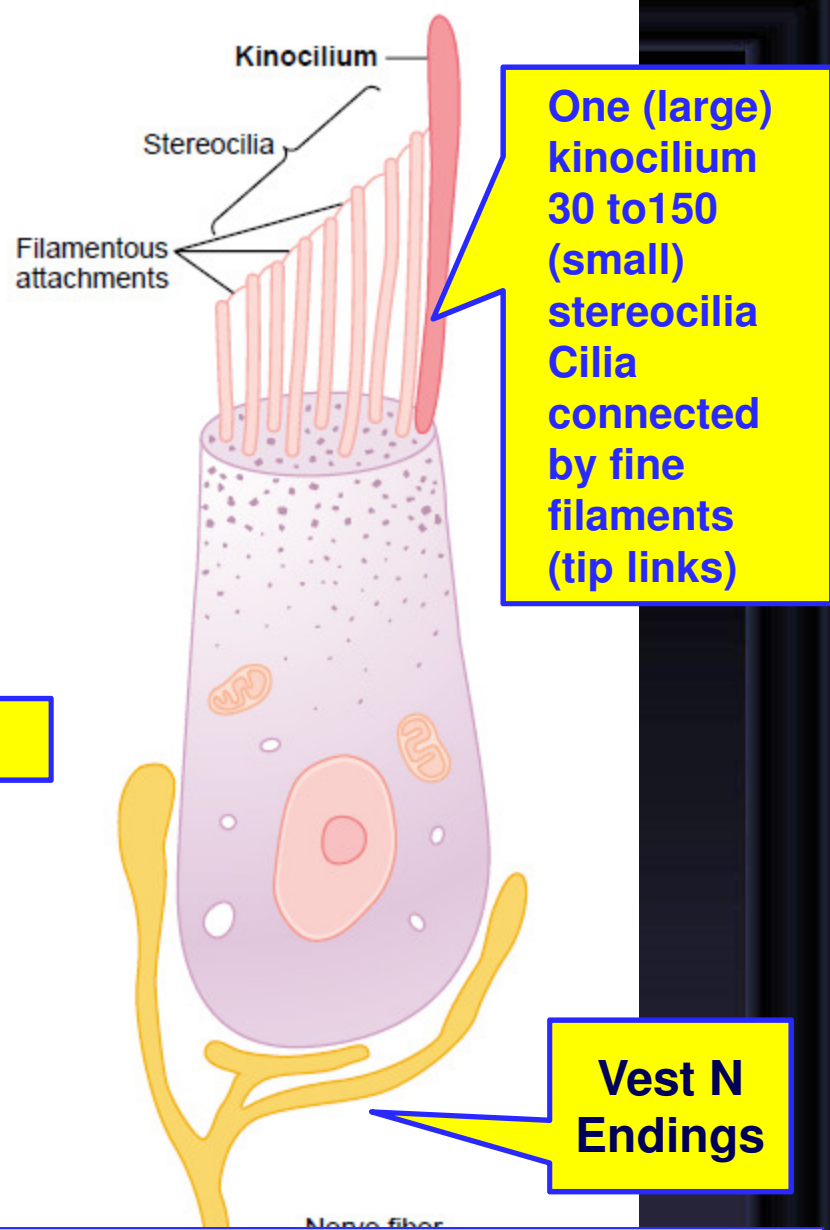
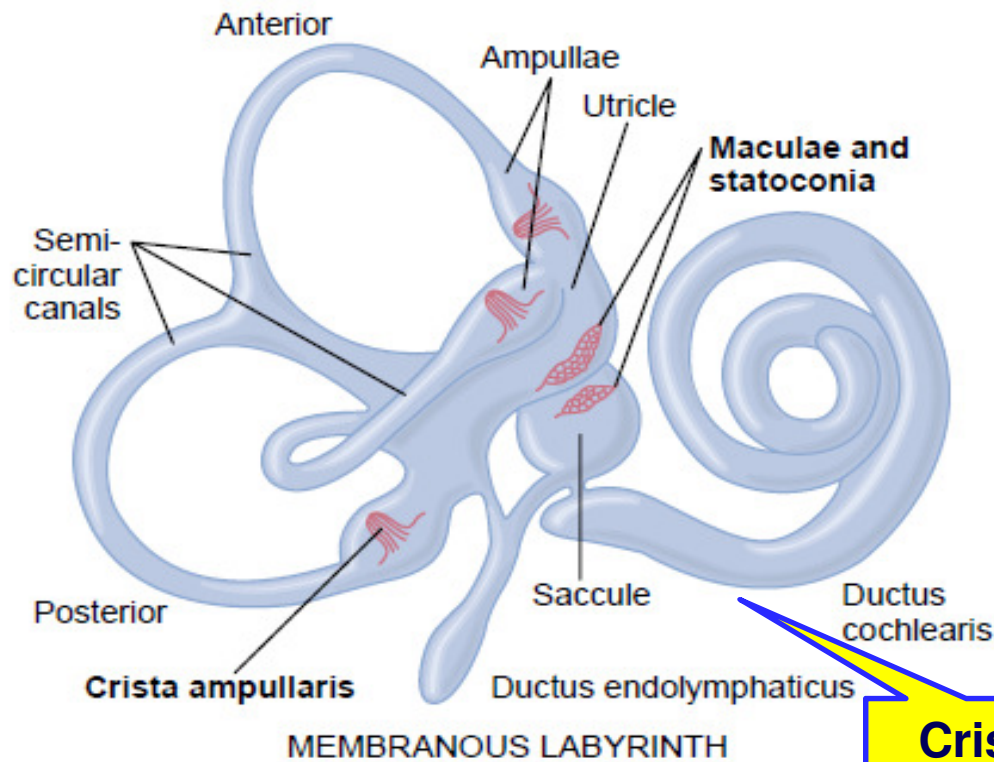
# Maintaining Equilibrium

## **SEMI-CIRCULAR CANALS** (ANT,POST,LAT)

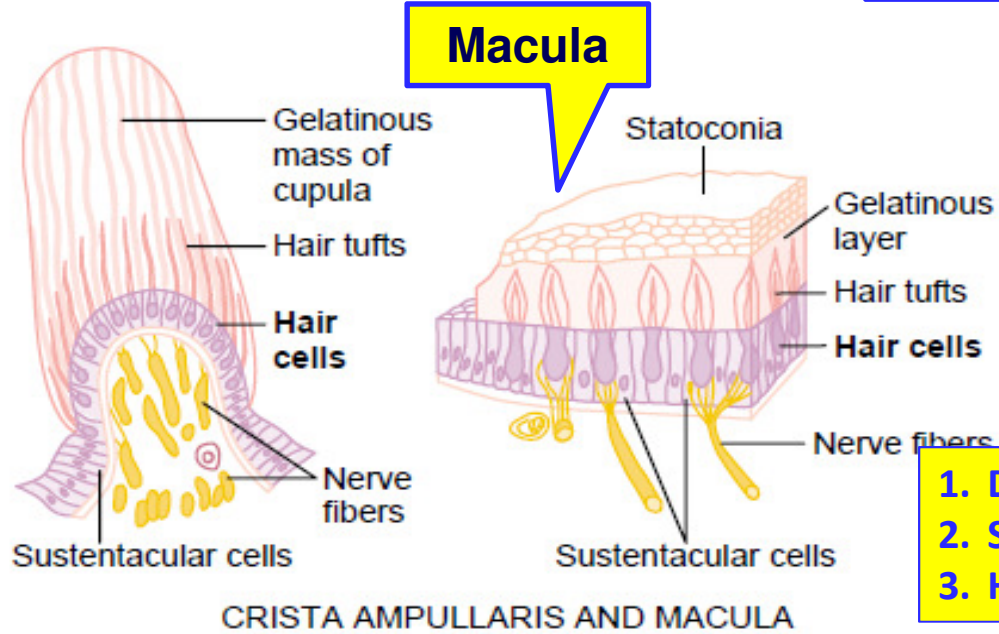
- **Crista ampullaris**
- **Hair cells in each crista are oriented in the same direction**
- **Dynamic Equilibrium and angular motion**
- **Predictive Function**

## **VESTIBULE** (SACCULE AND UTRICLE)

- **Maculae**
- **Hair cells in each macula are oriented in all direction**
- **Otoliths** (calcium carbonate crystals)
- **Static equilibrium and Linear Acceleration**
- **No Predictive Function**



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

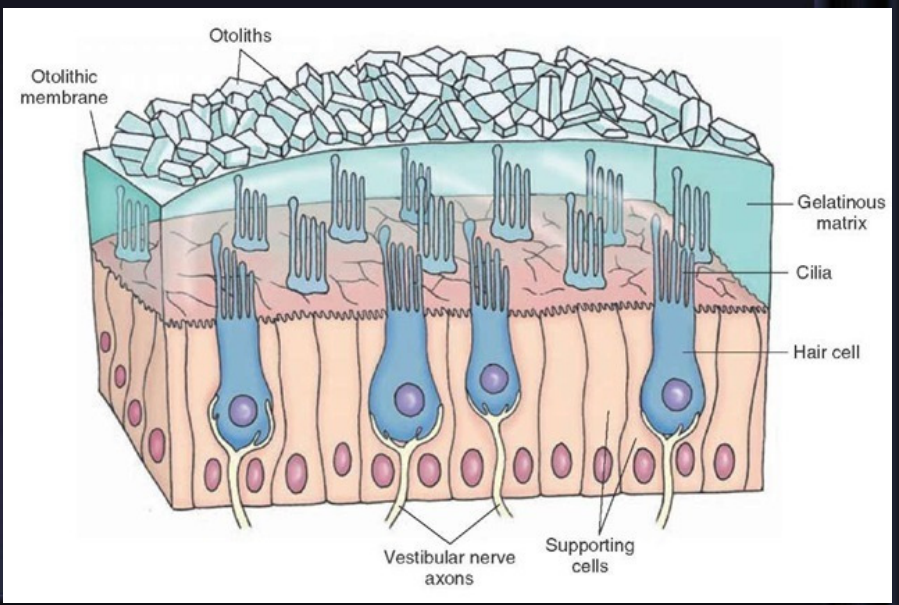
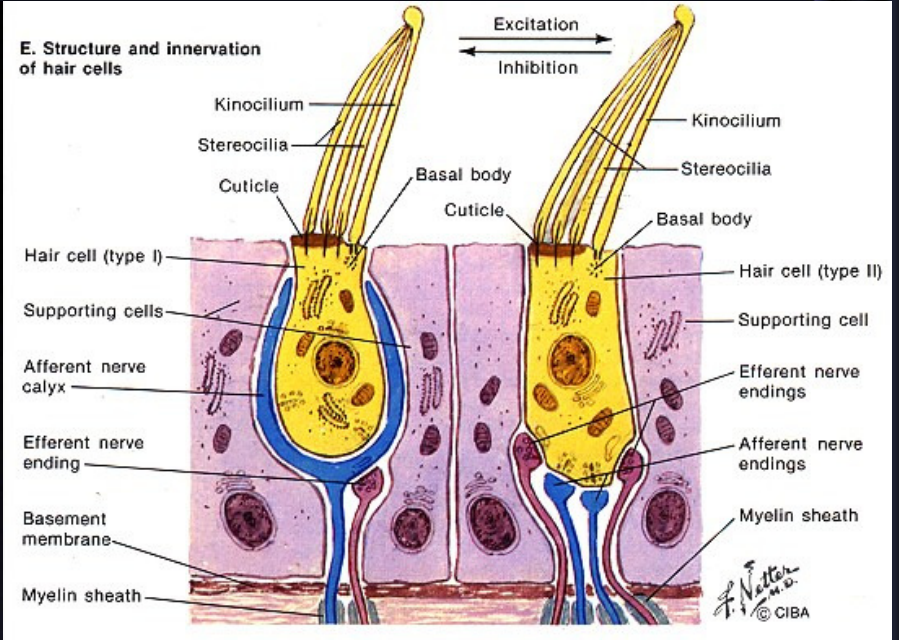
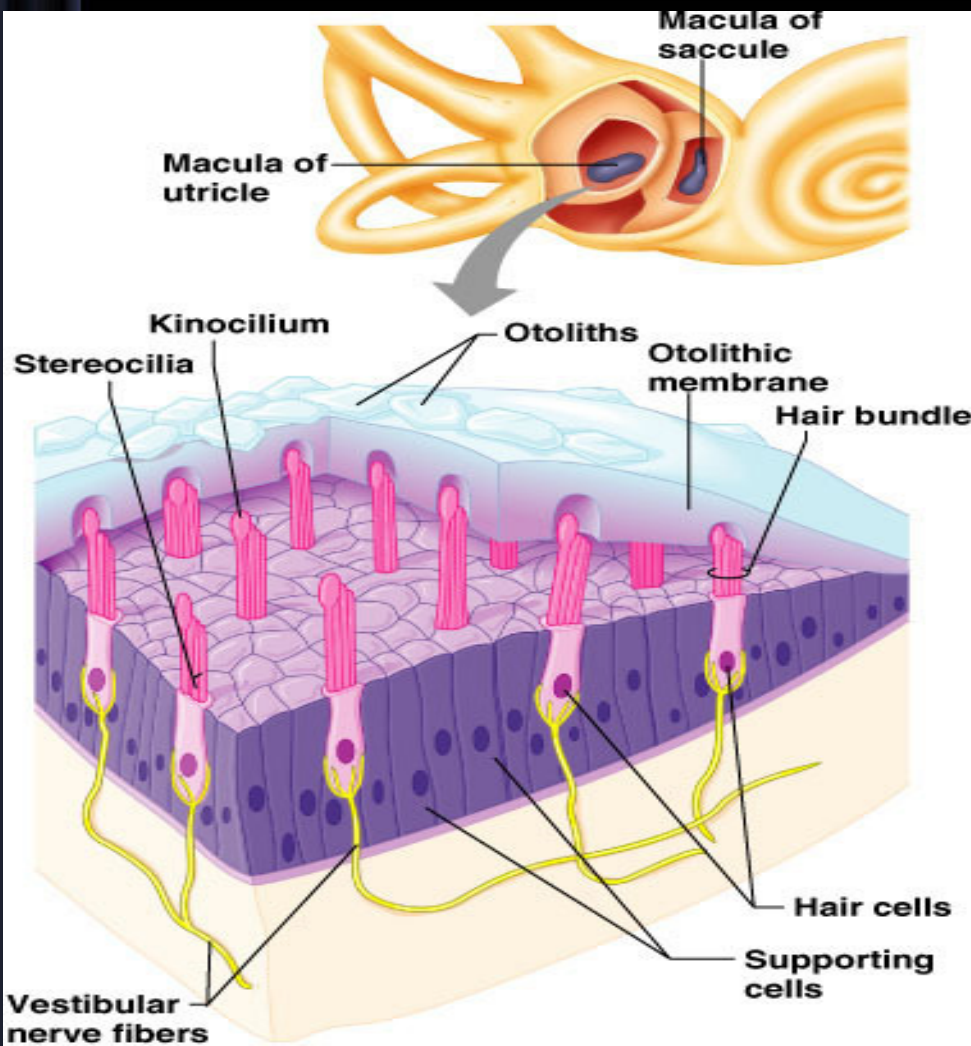


Crista

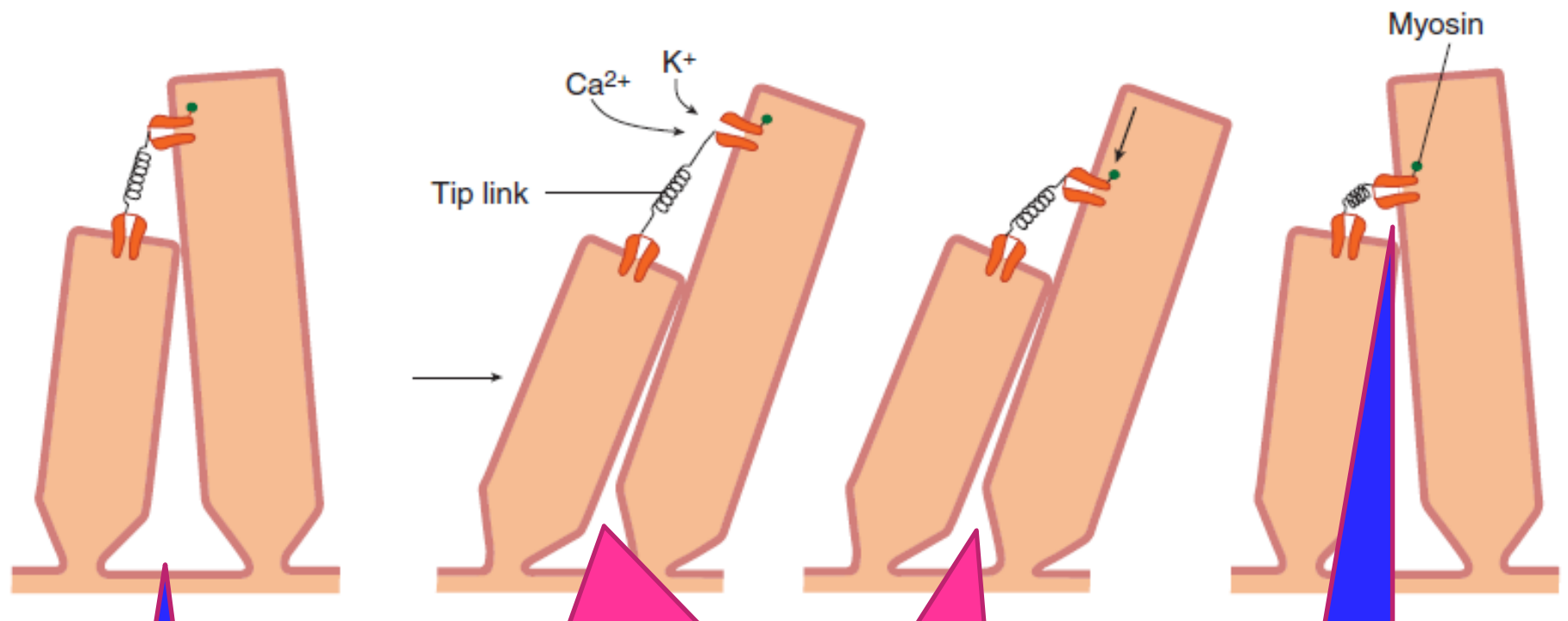
Macula

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

# Maculae



# Role of tip links in responses of hair cells



**Resting position**

**Stereocilium is pushed toward a taller one, the tip link is stretched and opens an ion channel in its taller neighbor.**

**Channel moves down by molecular motor and release tension**

**The motor will move back up the stereocilium to resting position**

# Hair cells in Utricle & Saccule

Vestibule (between cochlea and semi-circular canals) contains static equilibrium receptors called maculae.

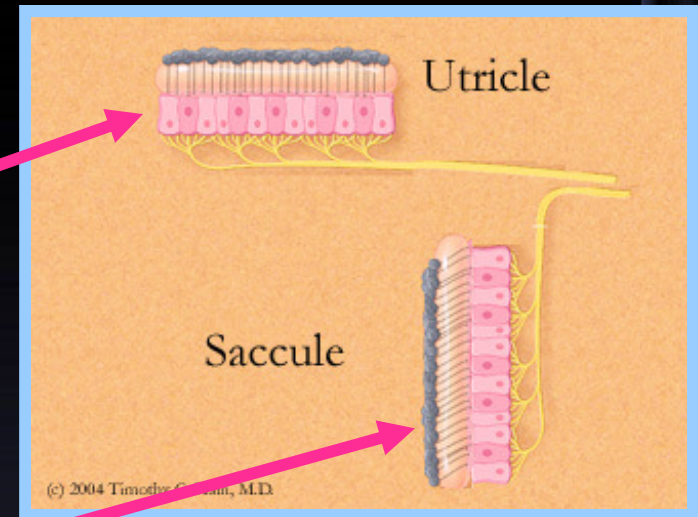
In upright position: (Head vertical)

- **IN UTRICLE:**

- Macula in horizontal plane
- Hairs pointing upwards
- Hair cells signal head movements in any direction

- **IN SACCULE:**

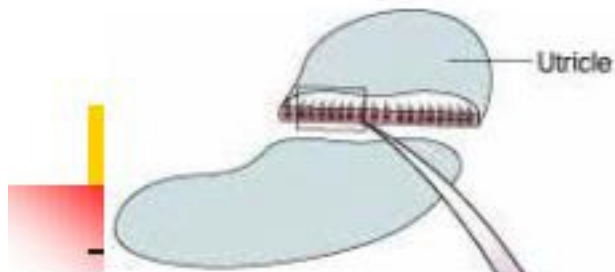
- Macula in vertical plane
- Hairs pointing laterally
- Hair cells operate when one is lying down



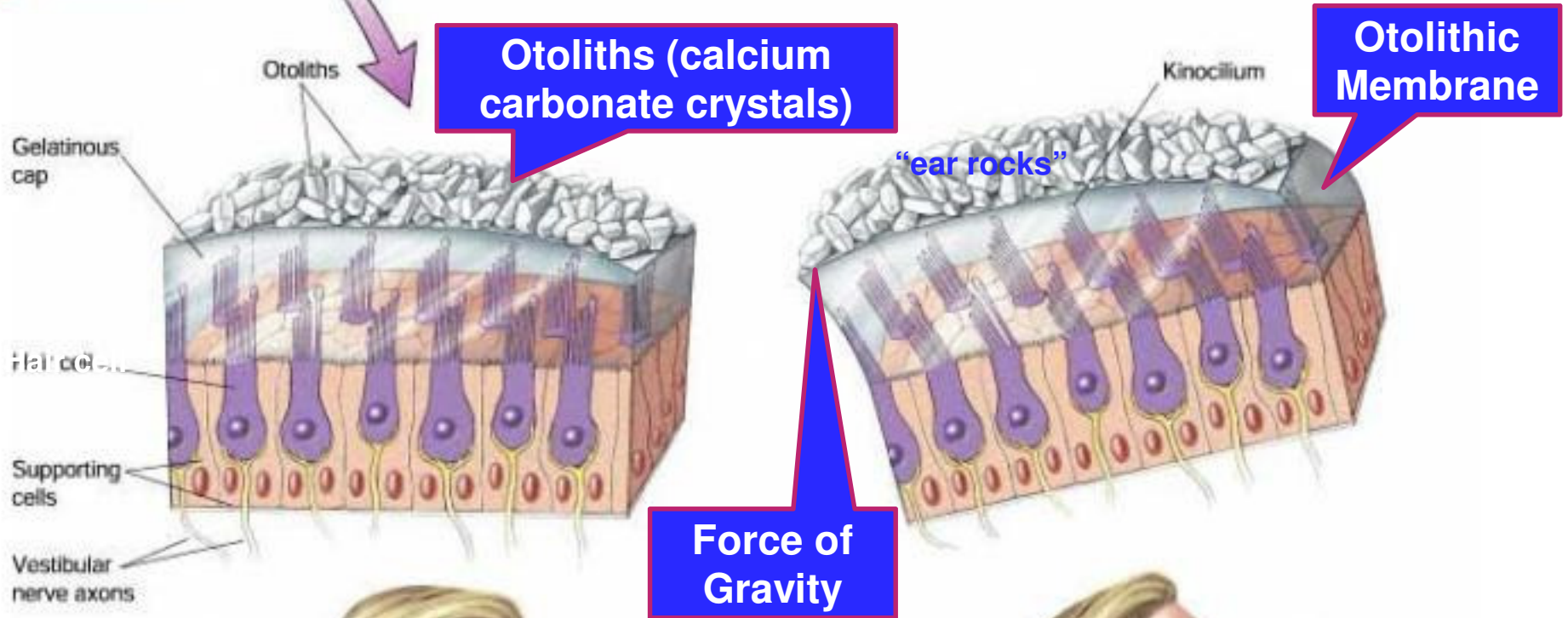
\*Saccular maculae detect vertical acceleration

\*Utricle maculae horizontal acceleration

Inform the brain of orientation of head in space



**Anatomy: Maculae of Utricle or Sacculle  
Physiology: Linear acceleration of head**

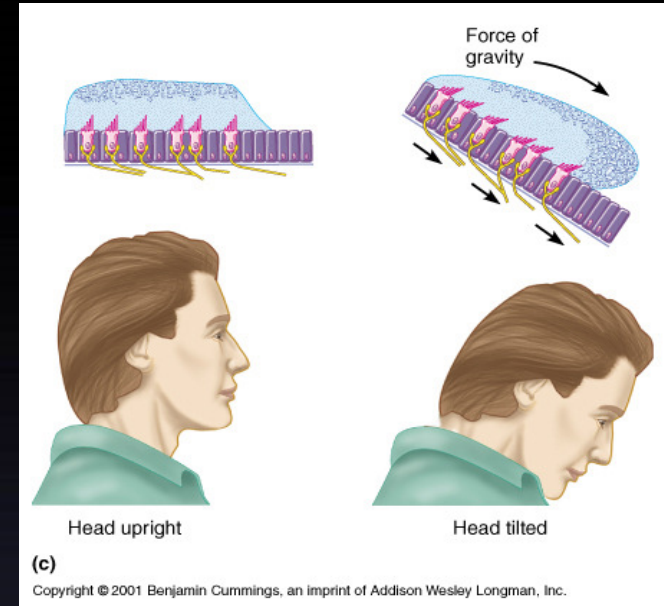


**In macula: hair cells are oriented in different direction and tilt Of Head In Any Direction is Signaled**

# Function of utricle and saccule

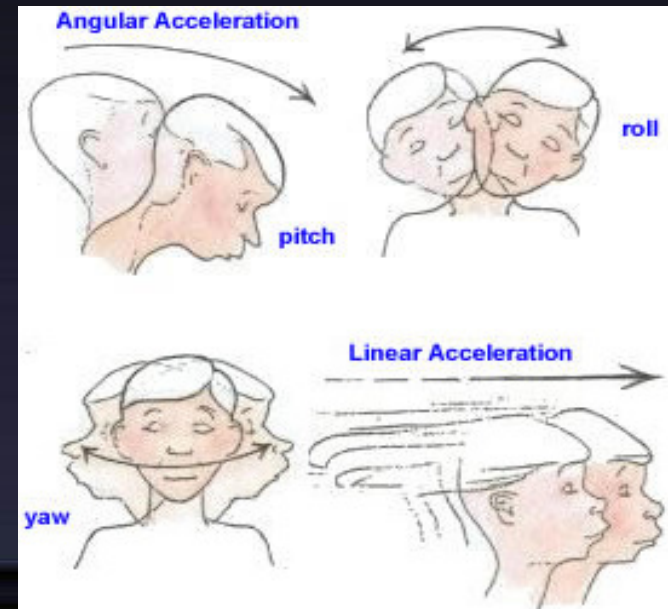
## Detection of static tilt

- 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???)



## Detection of linear acceleration:

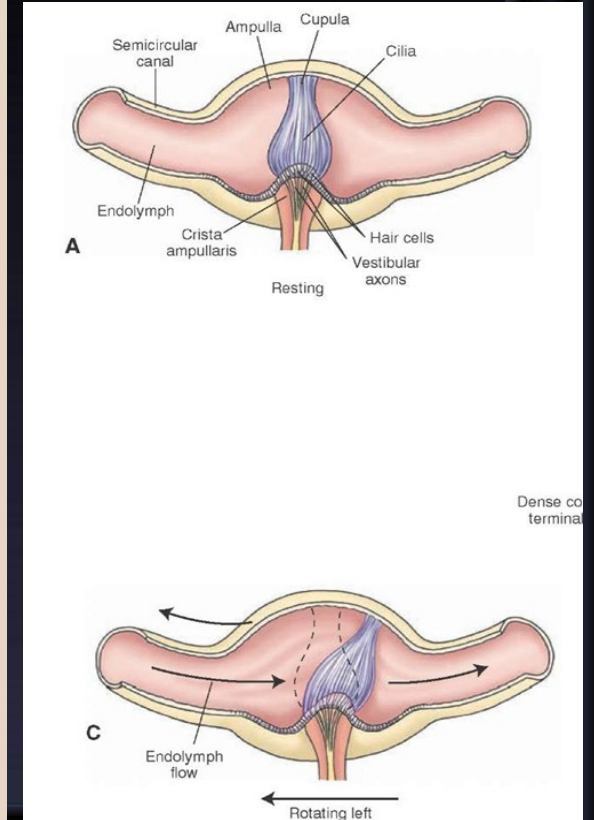
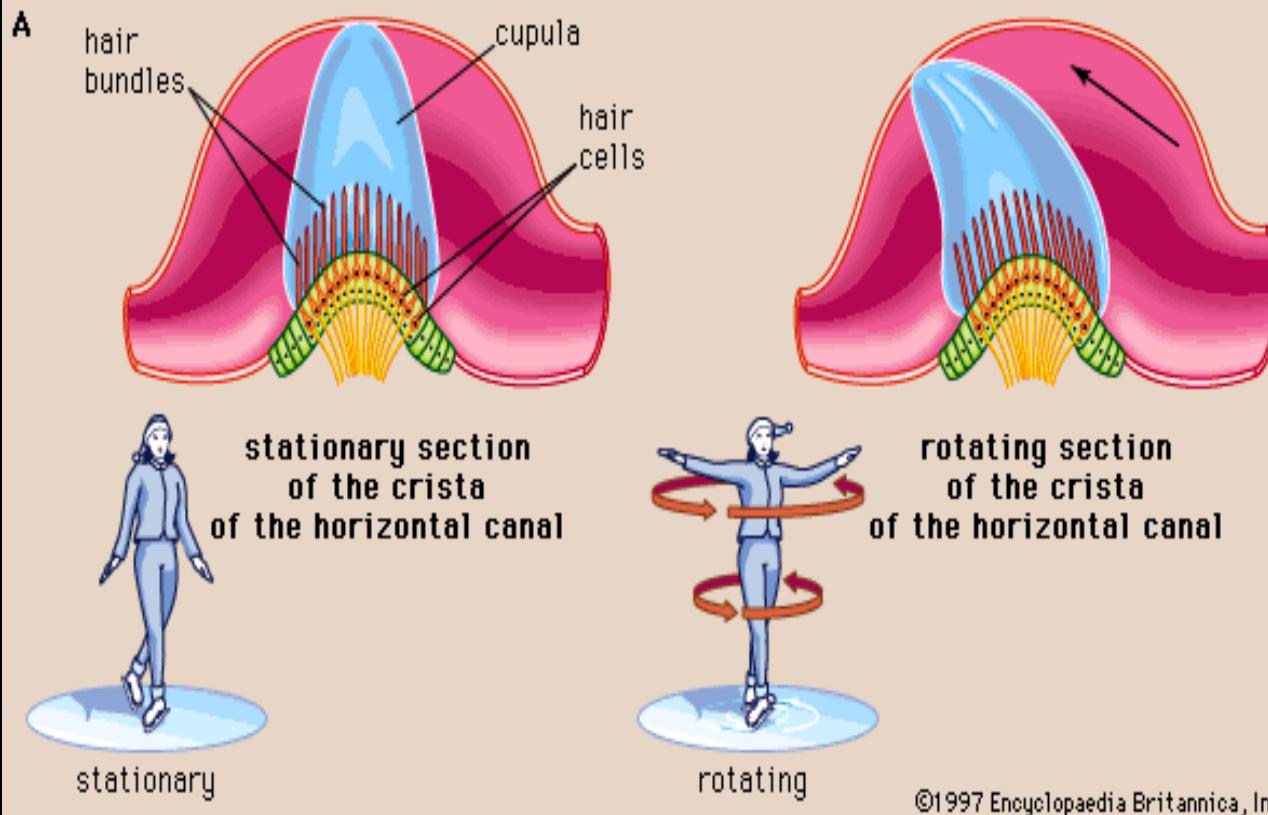
Sudden acceleration >>> Falling backwards >>> Otoliths falls back on hairs >>> sensation of mal-equilibrium >> Correction by leaning forward

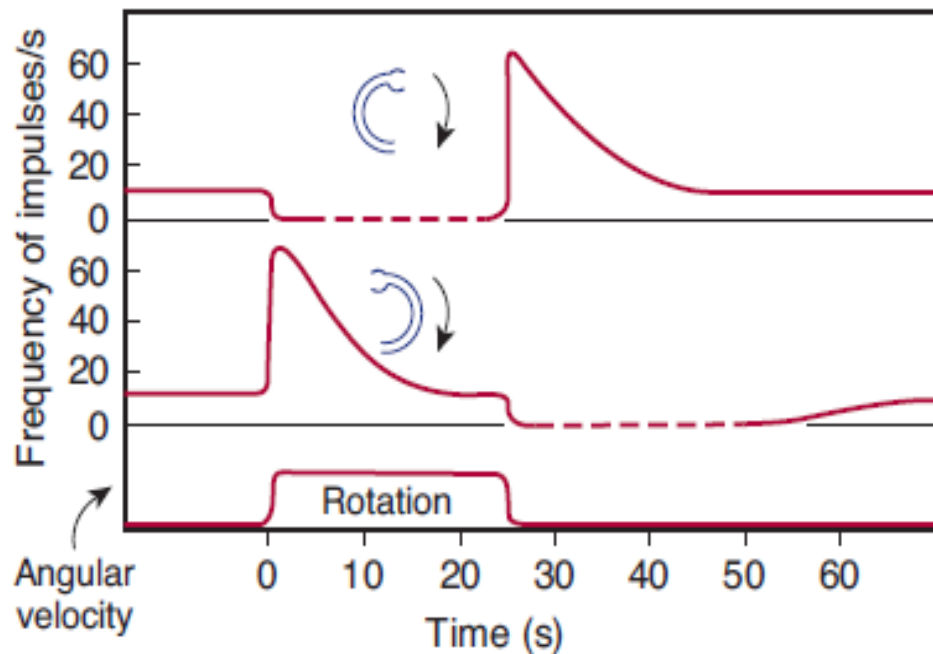
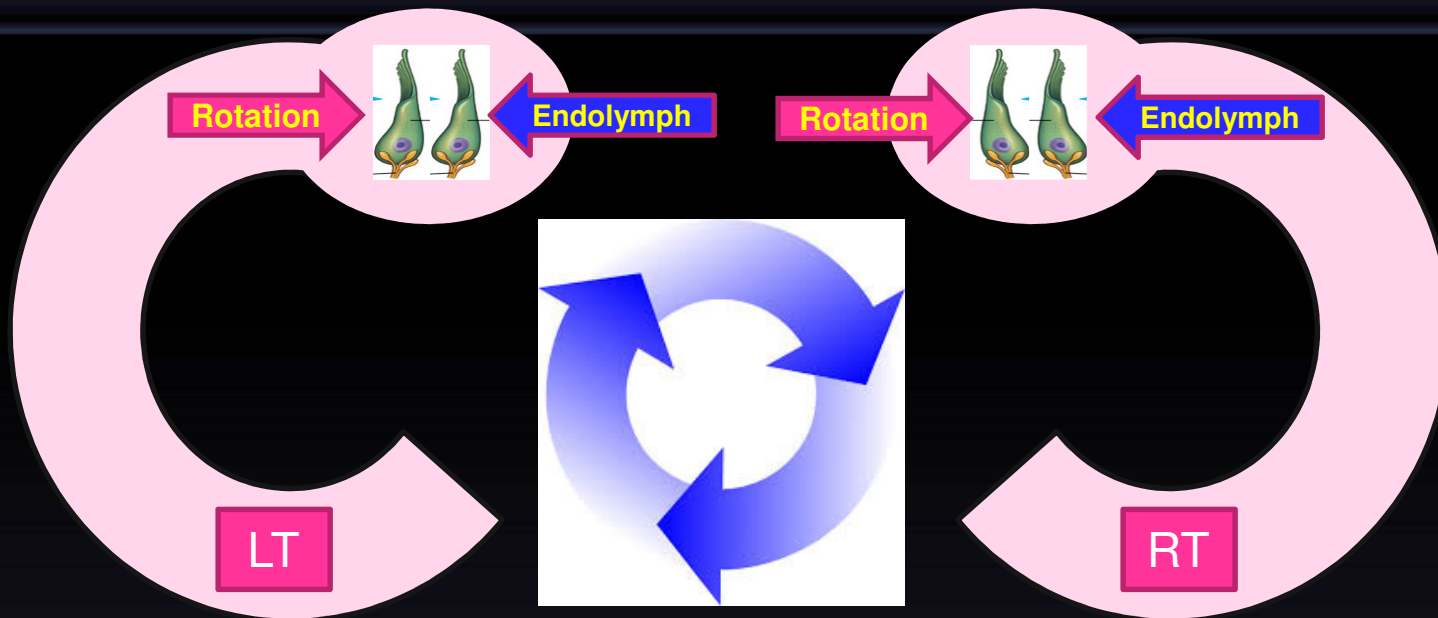




# Plane of rotation determines the canal to be stimulated:

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



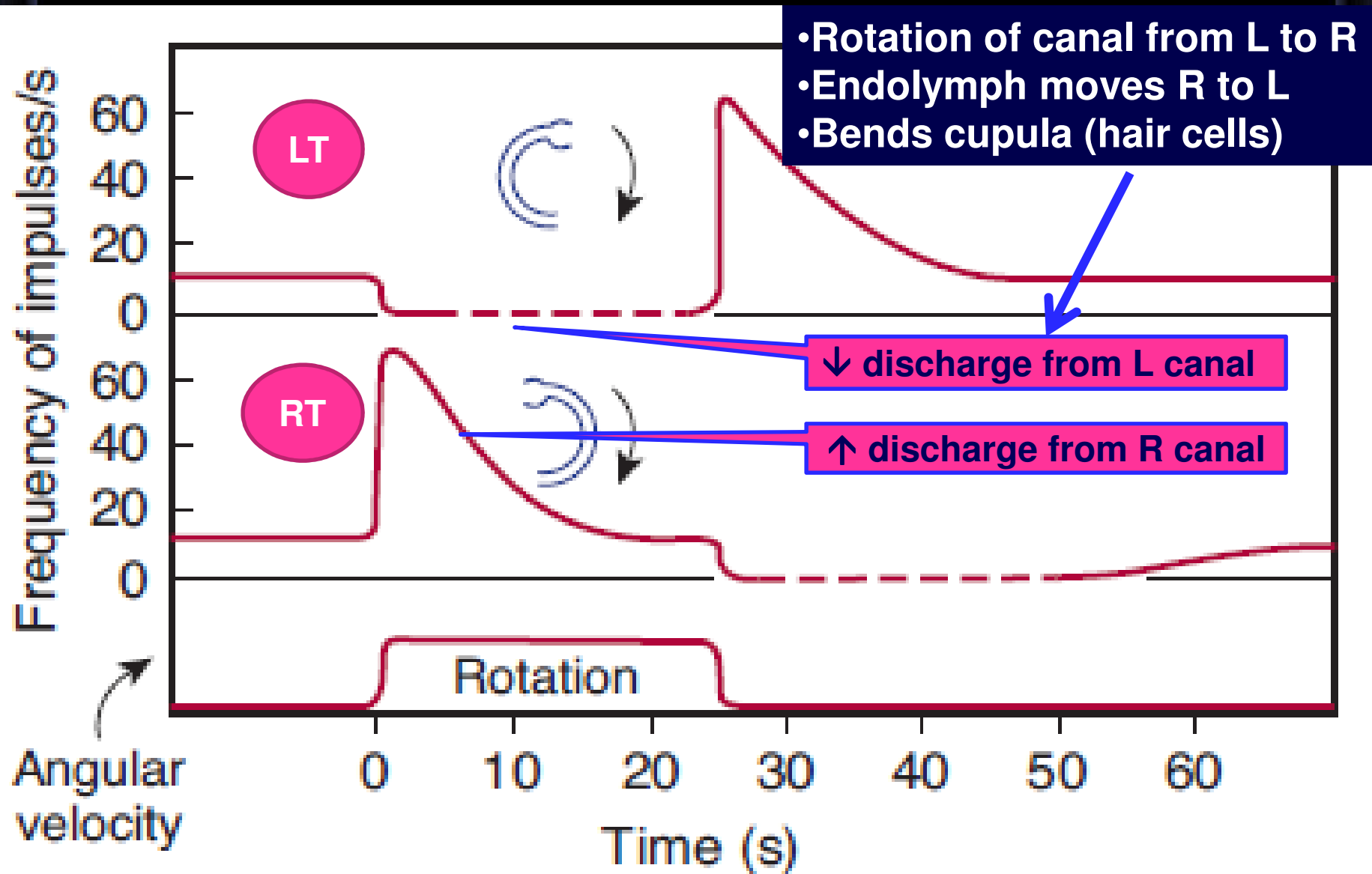


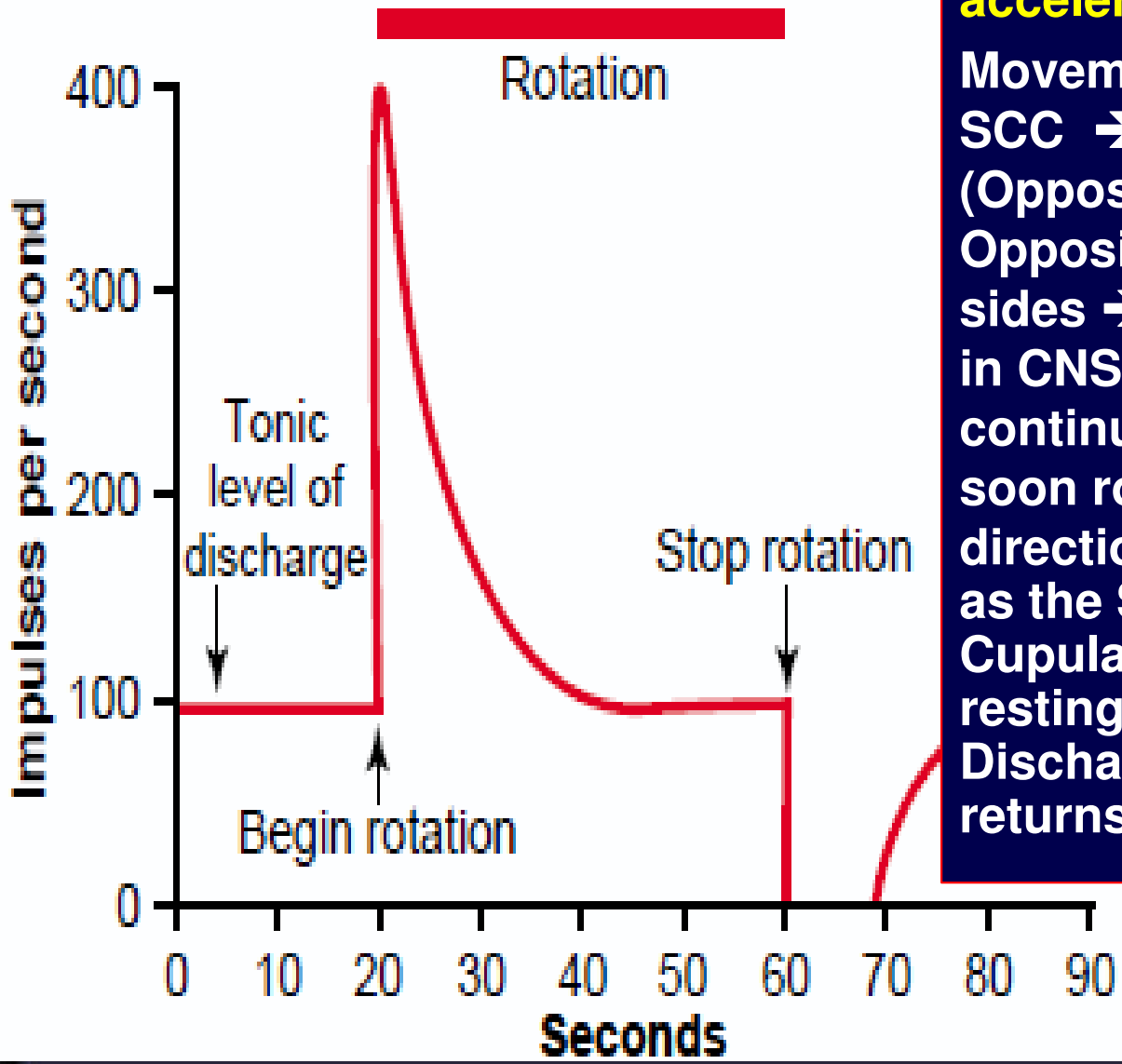
- ↑ discharge from R canal
- ↓ discharge from L canal

- Rotation of canal from L to R
- Endolymph moves R to L
- Bends cupula (hair cells)

Start of rotation  
 End of rotation  
 Changes in rate of rotation

# Rotational Acceleration, Steady Rotation & Deceleration





**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**

# Function of the Semicircular Duct System in the Maintenance of Equilibrium

## SCCs detect ANGULAR ACCELERATION:

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

## & PREDICTIVE FUNCTION SCCs

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 cannot detect that the person is off balance in angular acceleration until after the loss of balance has occurred.

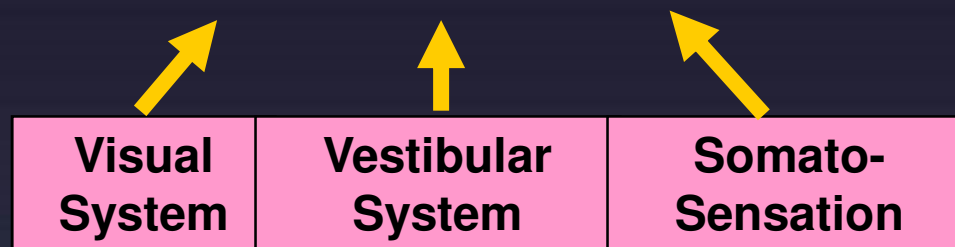
# VESTIBULAR PATHWAY

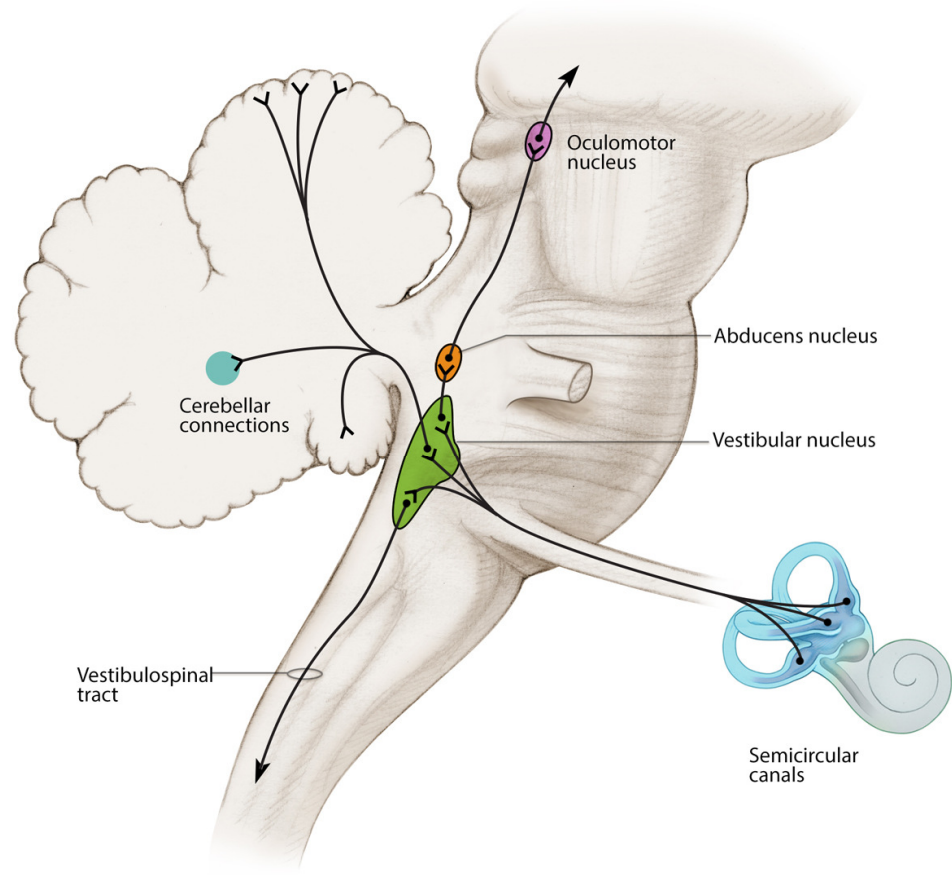
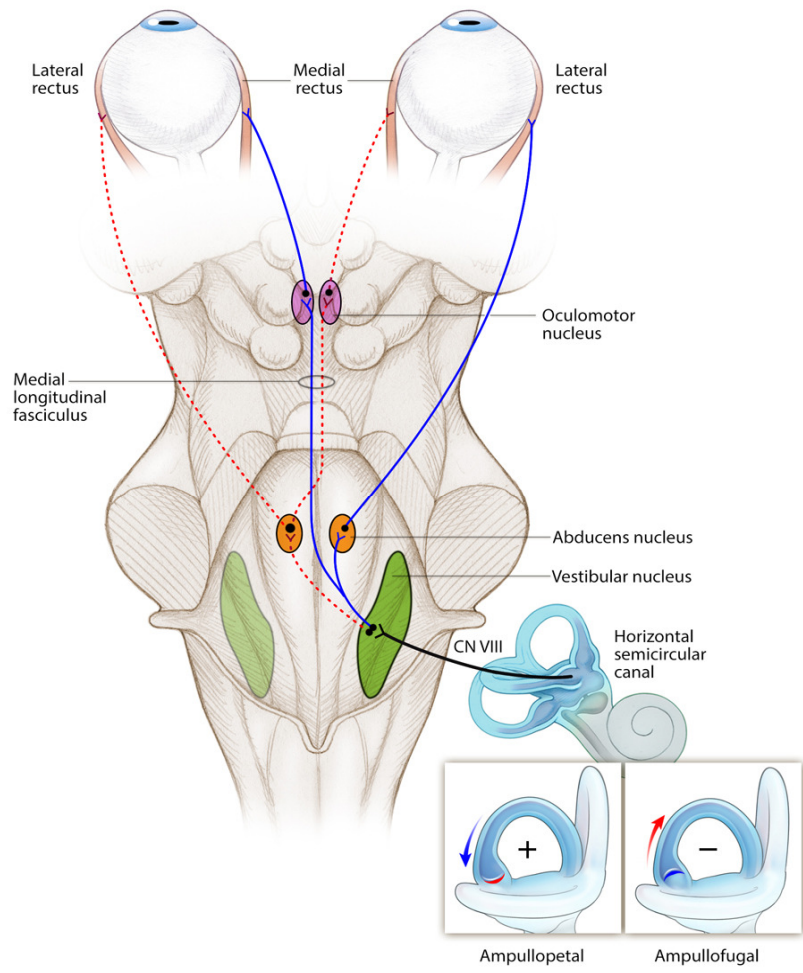
## Neural connections:

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

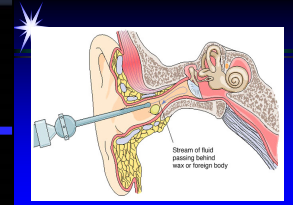
\*\* Impulses maintain equilibrium i.e. facilitate or inhibit the stretch reflex (regulate muscle tone)

## Compare, Select & Combine Senses





# 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.



# Vestibular Disorders

- **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
- **Meniere disease** is an abnormality of the inner ear causing vertigo or severe dizziness, **tinnitus**, fluctuating hearing loss, and the sensation of pressure or pain in the affected ear lasting several hours.
- **Motion sickness** are produced by excessive vestibular stimulation
- **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

Canalith repositioning

Labyrinthine Sedatives (Meclizine)

Antihistamines or scopolamine, a cholinergic muscarinic receptor antagonist.