

VSC227 ESE LEARNING OBJECTIVES

SPECIAL SENSES

Define the structures which give rise to the vestibular system.

Understand how rotation and acceleration are detected in the vestibular system.

Define the roles of the semicircular canals, utricle and saccule in this process.

Vestibular System

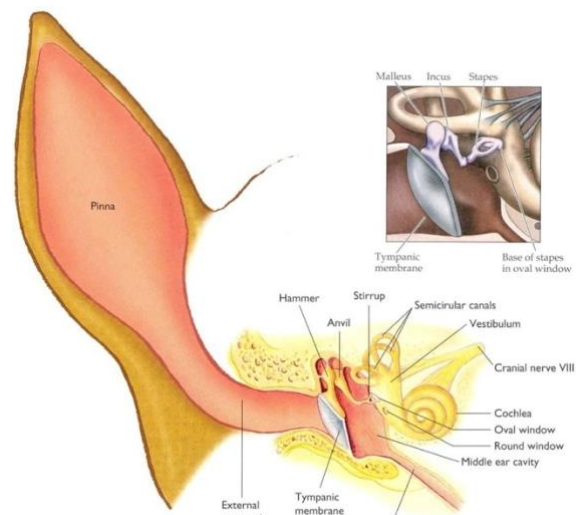
- Special proprioceptive system – sensing gravity
- enables animal to maintain orientation in its environment with respect to gravity
- helps to maintain position of eyes, trunk and limbs in relationship to movements and positioning of head
- Receptor in inner ear → CNVIII → vestibular nuclei in brain stem

Confers Information on:

- Position
- Movement / direction (rotational / linear acceleration)
- Speed
 - By acceleration calculation
 - By angular speed calculated by physiological nystagmus → A form of involuntary eye movement that is part of the vestibulo-ocular reflex (VOR), characterized by alternating smooth pursuit in one direction and saccadic (jerky) movement in the other direction.

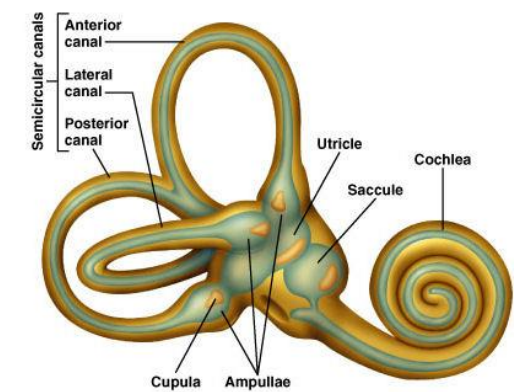
Anatomy of the Ear

- Acts to focus sound on the tympanic membrane
- Selectively boosts sound pressure at different frequencies by factor of 30-100
- In Humans optimal at 3kHz, giving best selective hearing at ranges of 2-5kHz
- Selective for speech which occurs at around 3kHz
- Also acts to filter sound frequencies to give indication of direction
- Allows pinpointing of sound sources with accuracy
- External anatomy:
 - pinna
 - concha
 - auditory meatus
- Ossicles
 - Malleus
 - Incus
 - Stapes



Vestibular Apparatus

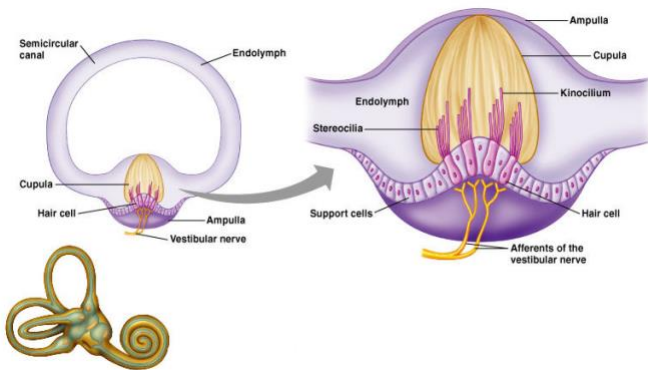
- 3 semicircular canals
- utricle
- saccule
- Canals filled endolymph
- Base of each is *ampulla*
- Vestibular apparatus located in the bony labyrinth
- Semi-circular canals detect rotational movement:
 - Are positioned in perpendicular planes
 - Detect rotation in 3 dimensions
 - Anterior canal: up/down (nodding)
 - Posterior canal: Up/down, side to side (ear to shoulder)
 - Lateral canal: Rotation side to side (saying no)
- Utricle and saccule detect acceleration
 - Utricle: Forwards/backwards acceleration
 - Saccule: Acceleration up/down



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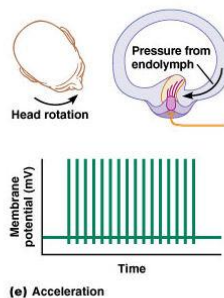
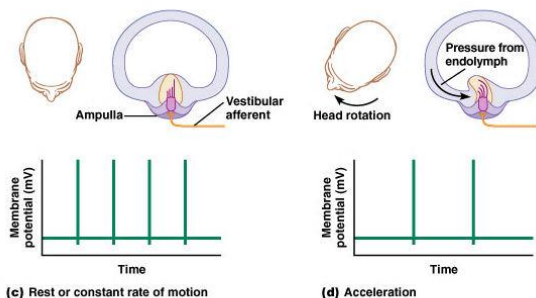
Vestibular Ampullae

- Contain specialised cells for detection of rotational acceleration
- Within each ampulla:
 - the cupula: gelatinous area separated from endolymph, contains stereocilia including specialised stereocilia called *kinocilium*



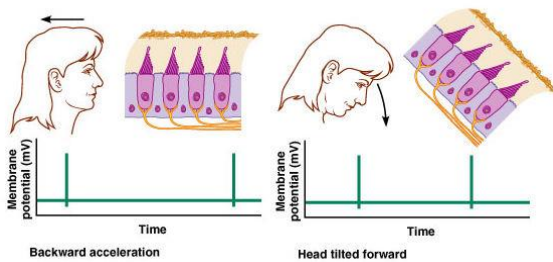
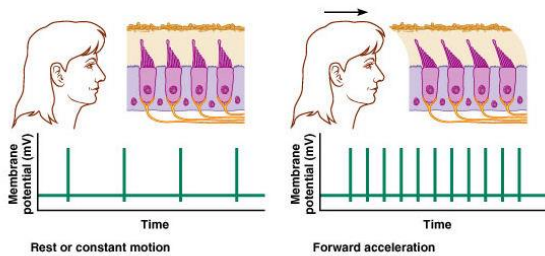
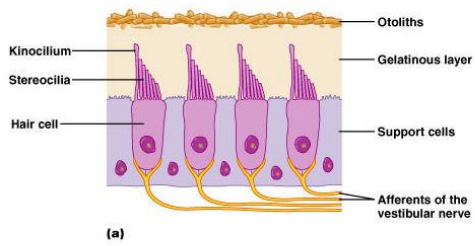
Vestibular Apparatus

- Rotation of the head causes stereocilia to 'bend'
- During rest, cells are upright
 - Partial depolarisation of membranes (always firing)
 - Low frequency activation in afferent neuron
- Rotation of the head causes stereocilia to 'bend'
- During rotation, endolymph bony labyrinth moves with head but moves behind the rotation
- Stereocilia bend in *opposite* direction to movement
- When stereocilia bend away from the kinocilium, hair cells are *hyperpolarised* and frequency of AP in afferent declines
- When stereocilia bend towards the kinocilium, hair cells are *depolarised* and frequency of AP in afferent increases

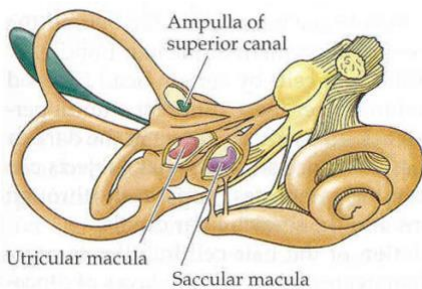


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- Utricle and saccule detect displacements (head tilt) and linear acceleration:
- Hair cells (stereocilia) located on *macula*
- oriented horizontally (utricle)
 - vertically (saccule)
- Slightly different action in ampullae
- Calcium carbonate crystals add mass to the gelatinous material

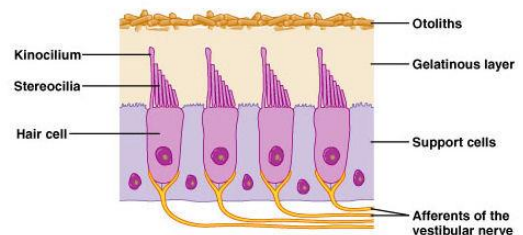


Utricle and Saccule



Structure of Macula

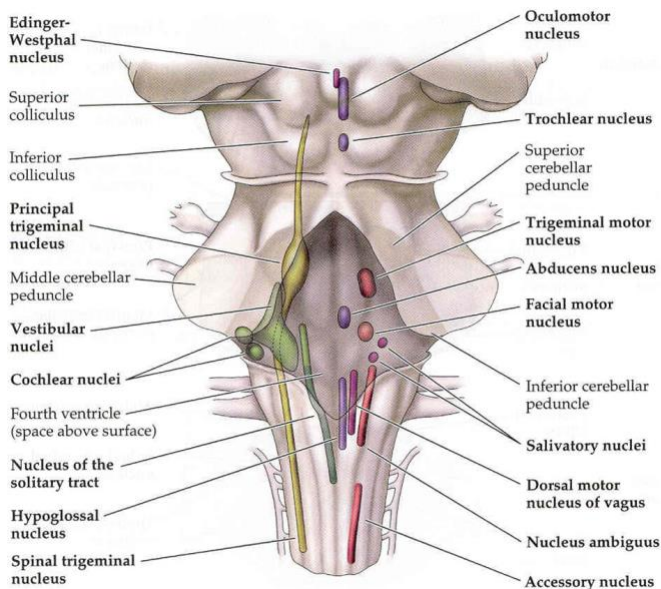
- (Different to cupula)
- Gelatinous layer on top of stereocilia
- *Otolithic membrane* fibrous structure on top of gel layer - calcium carbonate crystals (*otoconia* or *otoliths*)
- Otoconia provide weight, so that when head tilts gravity causes otolithic membrane to shift relative to stereocilia
 - → depolarisation
 - or hyperpolarisation



Define integration of the vestibular system in control of balance and movement.

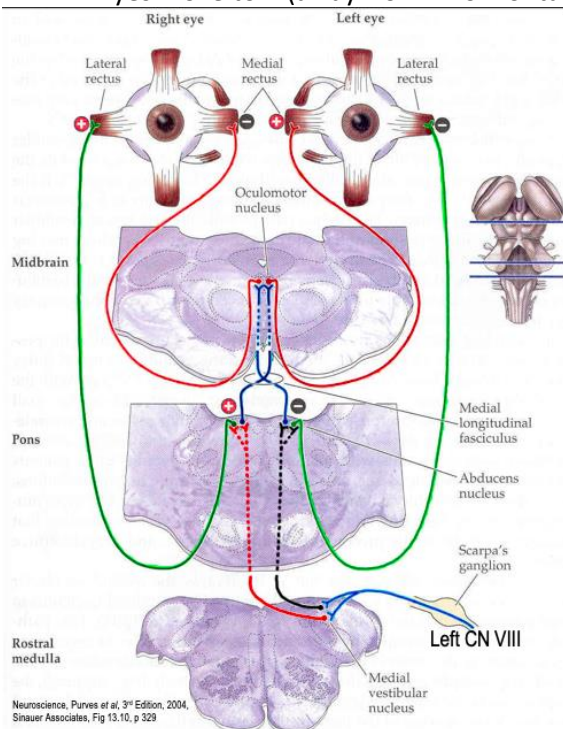
Vestibular Neural Pathways

- CN VIII afferent
- CN VIII cell bodies in *vestibular ganglion*
- Majority of axons terminate in vestibular nuclei in brain stem
- A few enter cerebellum directly, via caudal peduncle (vestibulocerebellar tract)
- Projections to brain stem, thalamus/cortex



Vestibulo-ocular reflex

- Maintains a fixed gaze by counteracting head movement detected in the VS (vestibular system)
- Fibres originating in the (left) semicircular canals project to medial and lateral vestibular nuclei
- One motor pathway to right lateral rectus muscle of right eye
- One motor pathway to left medial rectus, initiates contraction
- Inhibitory pathways cause relaxation of opposite muscles (right medial rectus and left lateral rectus) resulting in eye movement in opposite direction to head.
- Connections to CN III nucleus and contralateral CN VI nucleus excitatory (dashed red)
- Connections to ipsilateral CN IV nucleus inhibitory (dashed black)
- Eyes move to R (away from L horizontal canal) when head rotates to L, and vice versa



Projections to Spinal Cord

- Descending projections
- Vestibulospinal tract
 - Posture
 - Righting reflexes
 - Allows cerebellum to influence movement and posture

Vestibulospinal tract

- Posture
- Righting reflexes