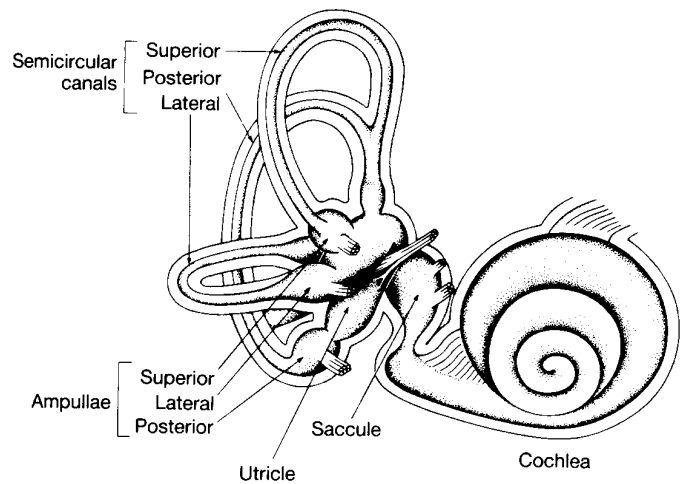


INTRODUCTION TO VESTIBULAR SENSES

A. Located in the inner ear (labyrinth)

1. body labyrinth: cavity within temporal bone
2. membranous labyrinth: two concentric tubes
  - a. space between outer and inner filled with perilymph (similar to CSF)
  - b. inner filled with endolymph (high in  $K^+$ )



B. Sensory organs of inner ear

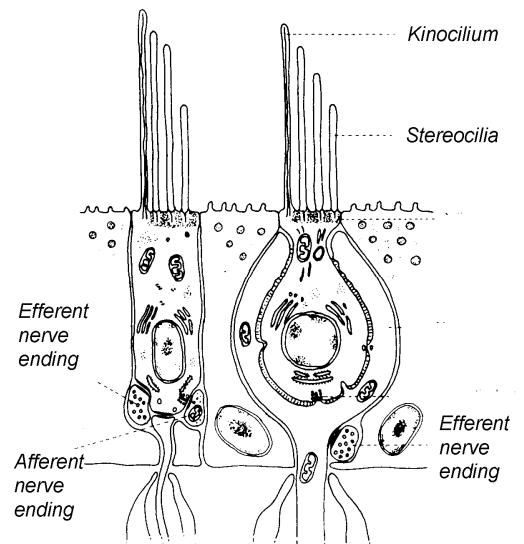
1. Cochlea (hearing); innervated by cochlear branch of C.N. VIII
2. Vestibule (orientation and equilibrium); innervated by vestibular branch of C.N. VIII
  - a. Utricle and saccule (2 organs); sense linear movement and gravity
  - b. Semicircular canals (3 canals oriented in mutually perpendicular planes); sense rotational (angular) movement

Note: Alternative names for C.N. VIII: Vestibular-cochlear, auditory, acoustic-vestibular

SENSORY ENDINGS

A. Hair Cells

Note: Hair cells cannot generate action potentials but they can depolarize; when depolarized, they release excitatory neurotransmitter to the excitable(1st order) afferent nerve endings at their base



B. Sensory response

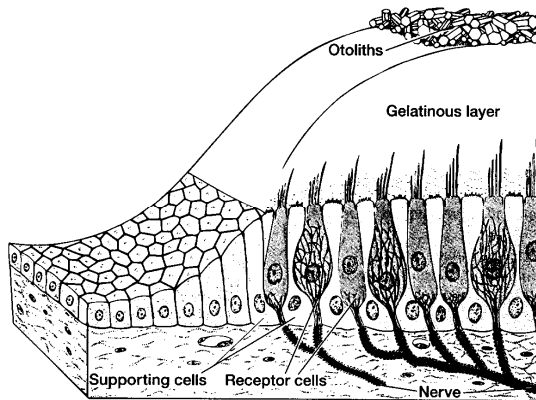
1. Firing rate of afferent fiber innervating hair cell depends on bending of cilia
  - a. cilia bend toward kinocilium (long cilia)  $\Rightarrow$  frequency  $\uparrow\uparrow$
  - b. cilia bend away from kinocilium  $\Rightarrow$  frequency  $\downarrow\downarrow$

2. Mechanism

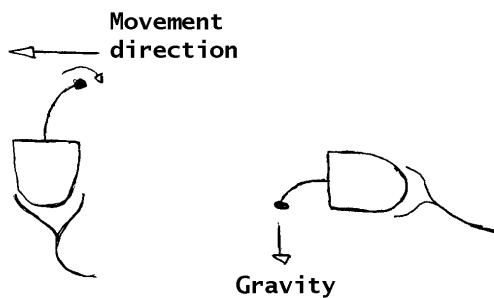
cilia bend toward kinocilium  $\Rightarrow$  hair cell  $K^+$  channels open  $\Rightarrow$  hair cell soma depolarize  $\Rightarrow$  hair cell  $Ca^{2+}$  channels open  $\Rightarrow$  excitatory transmitter released from hair cell, diffuses to afferent ending  $\Rightarrow$  afferent APs

## UTRICLE AND SACCULE

- A. Afferent Endings: cilia of hair cells embedded in gelatinous matrix with dense otoliths (crystals of  $\text{CaCO}_3$ )



- B. Hair cells organized in a sensory epithelium (macula); two macula, one in utricle and one in saccule
- B. Adequate Stimulus: linear acceleration and gravitational attraction



Note 1: Each hair cell unit is polarized; i.e. it increases firing rate when it bends in a particular direction and decreases firing rate when it bends in the opposite direction

Note 2: Because the hair cells are variously oriented, linear acceleration/gravity from all directions is sensed

Note 3: Hair cell units do not respond to constant velocity; otoliths and cilia will return to their rest position if velocity is continuously maintained

## C Role

1. sensation of acceleration and orientation in space

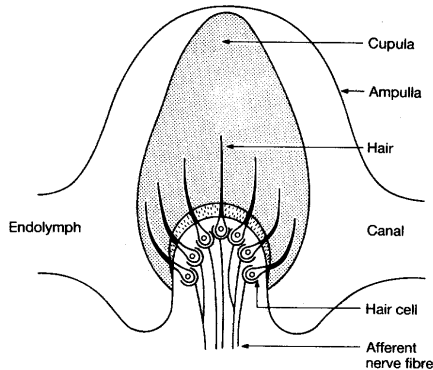
Note: orientation in space is derived from a combination of visual cues, proprioceptive input, cutaneous pressure, as well as utricle and saccule input

2. somatic reflex response to acceleration and gravity

Note: utricle & saccule input very important when other cues, particularly vision, are absent or impaired

### SEMICIRCULAR CANALS

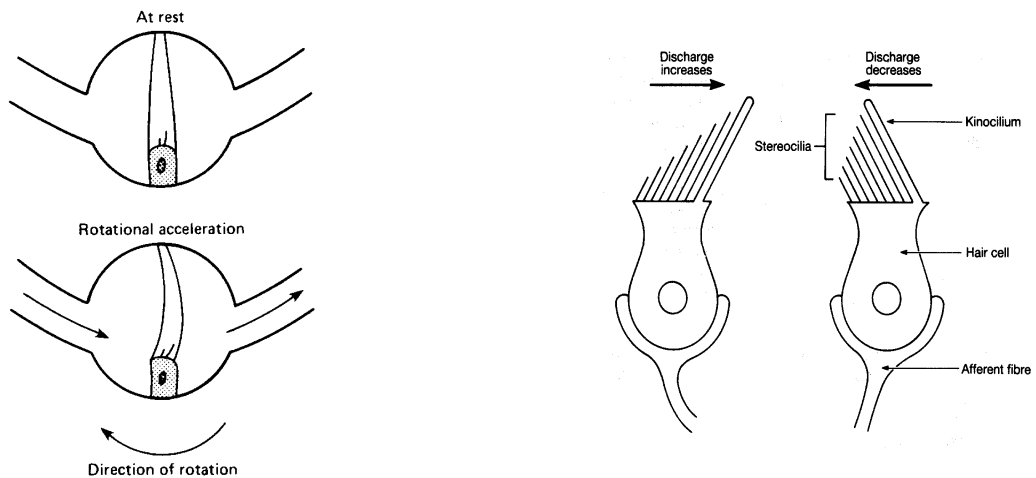
A. Afferent Endings: hair cells embedded in gelatinous cupula in ampulla



B. Stimulation of Receptors: sequence of events

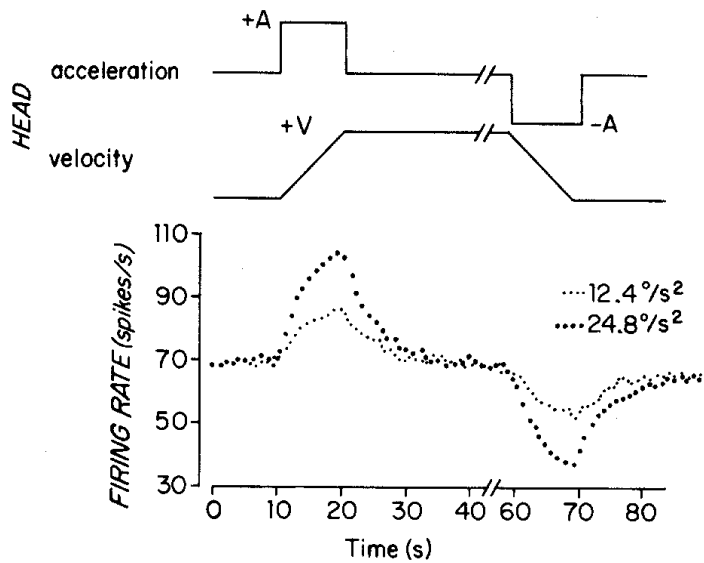
1. movement of fluid or development of pressure gradient in canal (due to endolymph inertia or momentum)
2. cupula and embedded hairs move (flex, bend)
3. primary afferent axons stimulated/inhibited, depending upon direction of movement

C. Adequate Stimulus: angular acceleration



Note response to prolonged rotation on next page ("velocity" refers to angular velocity of rotation, so sequence is begin to rotate, continue to rotate at constant angular velocity, then stop rotating)

SEMICIRCULAR CANALS (continued)



Note: If duration of rotation is brief, only the initial response is seen

D. Orientation

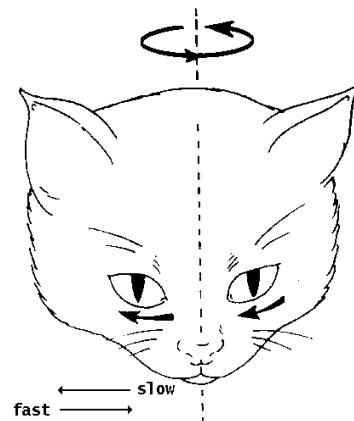
The 3 semicircular canals are oriented approximately at right angles to each other. Thus, angular acceleration in all 3 dimensions can be detected

E. Role

1. Somatic reflex response to rotation (maintain equilibrium by posture adjustment)
2. Reorientation of eyes to fix the visual field: vestibulo-ocular reflex

F. Nystagmus (due to semicircular canal stimulation)

1. Define Nystagmus: pattern of eye movement: slow eye movement in one direction followed by rapid eye movement in the opposite direction
2. Causes: several, one of which is angular acceleration, particularly when the original object of visual fixation passes out of the visual field
  - a. direction of nystagmus is defined as the direction of the fast component
  - b. for brief rotation, nystagmus is in the direction of rotation
  - c. for rotation of long duration
    - 1) upon starting, nystagmus is in the direction of rotation
    - 2) after continuing rotation, no nystagmus
    - 3) on stopping, nystagmus is opposite to previous rotation
3. Nystagmus can be elicited by thermal gradients in the ear (due to endolymph convection currents); used as clinical test



## VESTIBULAR SYSTEM FUNCTIONS

### A. Functions

1. motor coordination (cerebellum)
2. fixation of eye visual field (eye muscles)
3. postural adjustment (spinal motoneurons)
- 4 stabilize head (neck muscles)
- 5 sensation (cerebral cortex)

## PATHOPHYSIOLOGY

A. Vertigo: sensation of whirling in space, often accompanied by nystagmus

B. Deficiencies of posture and balance

C. Motion Sickness

1. Associated with prolonged stimulation of utricle-sacculle or semicircular canals; effects can sum if both are stimulated
2. Signs and symptoms  
nausea (sometimes with vomiting)  
sweating  
vertigo  
headache

D. Meniere's Disease: vertigo, hearing impairment, often tinnitus (may be due to rupture of the membrane separating endolymph from perilymph)