At the end of lecture student must be able to know,

- Vestibular system,
- Overview of vestibular system,
- Vestibular apparatus,
- Vestibule and cochlea,
- Vestibular receptor sense organs and detected stimuli,
- Otolith organ,
- Depolarization of hair cells,
- Macular hair cells in utricle,
- Semicircular canal,
- Push pull activation of semicircular canal,
- CNS vertebral connections,
- Central connections of the vestibular system (cell bodies in vertebral ganglion),
- Vertebral reflexes,
- Nystagmus,
- Vertebral disease,
- S/S of vertebral disease
the vestibular system comprises two components:

- **THE SEMICIRCULAR CANAL SYSTEM**, which indicate rotational movements.

- **THE OTOLITH**, which indicate linear accelerations

**OVERVIEW OF VESTIBULAR SYSTEM**

- Concerned with equilibrium.
- Provides information about position of head in space, angular (rotatory) acceleration and linear acceleration.
- Sensory receptors located in inner ear
- Damage may result in imbalance, circling, head tilt, vertigo and nausea.
- Contained in chambers in petrous portion of temporal bone (the bony labyrinth) and membranous tubes (membranous labyrinth).
- Associated with cochlea and consists of three semicircular canals and two large chambers known as the utricle and saccule.

Labyrinth (inner ear) consists of two structures;

- **BONY LABYRINTH.**
- **MEMBRANOUS LABYRINTH.**

**BONY LABYRINTH.**

- A series of cavities or channels present in the petrous part of temporal bone.
- Membranous labyrinth is situated inside bony labyrinth.
- The space between bony labyrinth and membranous labyrinth is filled with a fluid called perilymph or periotic fluid.

**MEMBRANOUS LABYRINTH.**
The membranous labyrinth is formed by membranous tubules and sacs filled with a fluid called endolymph or otic fluid.

It consists of two portions,

- Cochlea which concerned with sensation of hearing,
- Vestibular apparatus which is concerned with posture and equilibrium.

VESTIBULAR APPARATUS

- Paired semicircular canals,
  - Rostral vertical.
  - Caudal vertical.
  - Horizontal or lateral.

- Otolith organs,
  - Utricle.
  - Saccule.

VESTIBULE AND COCHLEA: TWO SENSORY ORGANS OF THE INNER EAR

VESTIBULAR FLUIDS

- In the bony labyrinth: perilymph, similar to extracellular fluid (low potassium, high sodium).
- In the membranous labyrinth: endolymph, similar to intracellular fluid (high potassium, low sodium); continuous with endolymph of the cochlea.

VESTIBULAR RECEPTOR SENSE ORGANS AND DETECTED STIMULI

OTOLITH ORGAN
- **Utricle and saccule.**

- Both organs are sensitive to linear acceleration:
  - utricle (horizontal)
  - saccule (vertical)

- Hair cell cilia are embedded in a gelatinous otolithic membrane (above the macula) covered with calcium carbonate particles (otoconia or otoliths).

- Tilting of the head moves otoliths due to gravity and bends cilia of hair cells. **DEPOLARIZATION OF HAIR CELLS**

- Bending of stereocilia toward the kinocilium opens potassium channels.

- Potassium influx opens voltage-gated calcium channels which cause liberation of transmitter (glutamate?) onto vestibular ganglion bipolar neurons to produce an action potential. **MACULAR HAIR CELLS IN THE UTRICLE.**

- At rest the utricle cilia stand up straight.

- Tilting of the head allows pull from gravity to pull on the gelatinous cap and bend the hair cells. **SEMICIRCULAR CANALS**
Detect angular or rotatory acceleration. Hair cells are on a raised membrane (crista) and embedded in a gelatinous cupula.

Acceleration causes the fluid to lag behind (due to inertia) and bend cilia of hair cells.

**PUSH-PULL ACTIVATION OF THE SEMICIRCULAR CANALS**

- Canals are oriented in synergistic left-right pairs - RRV/LCV, LRV/RCV, LH/RH.

- Excitation of receptors in one canal is accompanied by inhibition of receptors in its contralateral paired canal.

**CNS VESTIBULAR CONNECTIONS**

- Central vestibular pathways coordinate and integrate information about head and body movement and use it to control the output of motor neurons that adjust head, eye, and body positions.

- Primary vestibular axons (CN VIII) connect to the vestibular nuclei and the cerebellum.

- Vestibular nucleus also gets input from cerebellum and visual and somatosensory systems where the information is integrated.

**CENTRAL CONNECTIONS OF THE VESTIBULAR SYSTEM**

*(CELL BODIES IN VESTIBULAR GANGLION)*
To the vestibular nuclei – in the dorsal medulla adjacent to the lateral wall of the fourth ventricle,

- **Rostral (superior) vestibular nucleus**
- **Medial vestibular nucleus**
- **Lateral vestibular nucleus**
- **Caudal (inferior) vestibular nucleus**

**CENTRAL CONNECTIONS OF THE VESTIBULAR SYSTEM CONT.**

- **TO THE BRAIN STEM** - rostrally in the medial longitudinal fasciculus and reticular formation to influence nuclei of CN III, IV, VI - to coordinate conjugate eyeball movements associated with changes in head position.
- **TO RETICULAR CENTER** - afferents to vomiting center; motion sickness.
- **TO THALAMUS AND CONSCIOUS CENTERS OF SENSORY CORTEX.**
- **TO CEREBELLUM** - caudal cerebellar peduncle.

**CENTRAL CONNECTIONS OF THE VESTIBULAR SYSTEM CONT.**

Spinal cord vestibulospinal tract –

- facilitatory to ipsilateral alpha and gamma motor neurons of extensor muscles,
- inhibitory to ipsilateral alpha motor neurons of flexor muscles.

**VESTIBULAR REFLEXES**

- Vestibulo-ocular reflex – when your head turns to the right your eyes rotate left to maintain fixation on original image (nystagmus, slow phase), then slowly rotate to the right to fixate on new image (nystagmus, fast phase).
• Other connections produce nausea when vestibular and visual information conflict.

• Adaptation to regular motion can result in sensations of movement after the movement ends (wave action in a boat). **NYSTAGMUS (PHYSIOLOGICAL)**

• Alternating sequential movements of the eyes when the head is moving. Purpose is to fixate an image on the retina while the head is moving.

• Consists of a slow component (tracking of an object, pursuit) and a fast component in the opposite direction (saccadic/quick beat).

• Fast component is in the direction of head movement. **NYSTAGMUS (PHYSIOLOGICAL), cont**

• Slow phase of vestibular nystagmus due to excitatory and inhibitory output from neurons of semicircular canals to motor neurons controlling eye muscles.

• Fast component of nystagmus due to excitatory and inhibitory input from pontine reticular formation (saccadic center) to motor neurons controlling eye movement. **VESTIBULAR DISEASE**

• Otitis interna – head tilt (to the side of the lesion if peripheral) and circling.

• Ototoxicity – gentamicin and other aminoglycoside antibiotics kill auditory and vestibular hair cells.

• Vertigo – sensation of rotation without actual movement, common with peripheral (usually) vestibular dysfunction, often associated with nystagmus.

• Strabismus – tonic deviation of the eyes. **SIGNS OF VESTIBULAR DISEASE**

• Asymmetric ataxia (loss of balance with preservation of strength).

• Imbalance - loss of coordination between head, trunk and limbs.

• Heat tilt (toward side of lesion if peripheral).

• Lateral flexion of trunk (concavity toward side of lesion).
• Circle (toward side of lesion).
• Abnormal nystagmus, vomiting.