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# TOPIC: PHYSIOLOGY OF BALANCE

The semicircular canals of the inner ear help you with balance. When you move your head, fluid inside the semicircular canals moves as well. This movement of the fluid moves the hairs of the canals, creating nerve impulses that travel up to your brain and let it know that your head is off balance.

The inner ear (also called the labyrinth) contains 2 main structures the cochlea, (which is involved in hearing), and the vestibular system (consisting of the 3 semicircular canals, saccule and utricle), which is responsible for maintaining balance.

The vestibular system is the sensory apparatus of the inner ear that helps the body maintain its postural equilibrium. The information furnished by the vestibular system is also essential for coordinating the position of the head and the movement of the eyes.

There are two sets of end organs in the inner ear, or labyrinth:

- The semicircular canals, which respond to rotational movements (angular acceleration);
- Utricle and saccule within the vestibule, which respond to changes in the position of the head with respect to gravity (linear acceleration).
  The information these organs deliver is **proprioceptive** in character, (dealing with events within the body itself), rather than **exteroceptive**, (dealing with events outside the body), as in the case of the responses of the cochlea to sound. Functionally these organs are closely related to the cerebellum and to the reflex centers of the spinal cord and brainstem that govern the movements of the eyes, neck, and limbs.

Although the vestibular organs and the cochlea are derived embryologically from the same formation, **the otic vesicle**, their association in the inner ear seems to be a matter more of convenience than of necessity. From both the developmental and the structural point of view, the kinship of the vestibular organs with the lateral line system of the fish is readily apparent. The lateral line system is made up of a series of small sense organs located in the skin of the head and along the sides of the body of fishes.
Each organ contains a crista, sensory hair cells, and a cupula, as found in the ampullae of the semicircular ducts. The cristae respond to waterborne vibrations and to pressure changes.

The first investigator to present evidence that the vestibular labyrinth is the organ of equilibrium was French experimental neurologist Marie-Jean-Pierre Flourens, who in 1824 reported a series of experiments in which he had observed abnormal head movements in pigeons after he had cut each of the semicircular canals in turn. It was not until almost half a century later that the significance of his findings was appreciated and the semicircular canals were recognized as sense organs specifically concerned with the movements and position of the head.

**Detection of angular acceleration: dynamic equilibrium**

Because the three semicircular canals (superior, posterior, and horizontal) are positioned at right angles to one another, they are able to detect movements in three-dimensional space.

When the head begins to rotate in any direction, the inertia of the endolymph causes it to lag behind, exerting pressure that deflects the cupula in the opposite direction. This deflection stimulates the hair cells by bending their stereocilia in the opposite direction.

Decompression reverses both the direction of endolymph movement and the turning of the head and eyes. The hydrodynamic concept was proved correct by later investigators who followed the path of a droplet of oil that was injected into the semicircular canal of a live fish. At the start of rotation in the plane of the canal, the cupula was deflected in the direction opposite to that of the movement and then returned slowly to its resting position. At the end of rotation it was deflected again, this time in the same direction as the rotation, and then returned once more to its upright stationary position. These deflections resulted from the inertia of the endolymph, which lags behind at the start of rotation and continues its motion after the head has ceased to rotate. The slow return is a function of the elasticity of the cupula itself.

## Detection of linear acceleration: static equilibrium

The gravity receptors that respond to linear acceleration of the head are the maculae of the utricle and saccule. The left and right utricular maculae are in the same, approximately horizontal, plane and, because of this position, are more useful in providing information about the position of the head and its side-to-side tilts when a person is in an upright position. The saccular maculae are in parallel vertical planes and probably respond more to forward and backward tilts of the head.

These sensory organs, particularly the utricle, have an important role in the righting reflexes and in reflex control of the muscles of the legs, trunk, and neck that keep the body in an upright position. The role of the saccule is less completely understood. Some investigators have suggested that it is responsive to vibration as well as to linear acceleration of the head in the sagittal (fore and aft) plane. Of the two receptors, the utricle appears to be the dominant partner. There is evidence that the mammalian saccule may even retain traces of its sensitivity to sound inherited from the fishes, in which it is the organ of hearing.

## Disturbances of the vestibular system

The relation between the vestibular apparatus of the two ears is reciprocal. When the head is turned to the left, the discharge from the left horizontal canal is decreased, and vice versa. Normal posture is the result of their acting in cooperation and in opposition. When the vestibular system of one ear is damaged, the unrestrained activity of the other causes a continuous false sense of turning (vertigo) and rhythmical, jerky movements of the eyes (nystagmus), both toward the uninjured side. When the vestibular hair cells of both inner ears are injured or destroyed, as can occur during treatment with the antibiotics gentamicin or streptomycin, there may be a serious disturbance of posture and gait (ataxia) as well as severe vertigo and disorientation.

The vestibular system may react to unaccustomed stimulation from the motion of an aircraft, a ship, or a land vehicle to produce a sense of unsteadiness, abdominal discomfort, nausea, and vomiting. Effects not unlike motion sickness, with vertigo and nystagmus, can be observed in the later stages of acute alcoholic intoxication