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The vestibular system is the sensory apparatus of the inner ear that helps the body maintain its postural equilibrium. There are two sets of end organs in the inner ear, or labyrinth: the semicircular canals, which respond to rotational movements (angular acceleration); and the 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 centres 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 Physiology Of Balance: Vestibular Function

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); and the 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 centres 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.

Both pairs of maculae are stimulated by shearing forces between the otolithic membrane and the cilia of the hair cells beneath it. The otolithic membrane is covered with a mass of minute crystals of calcite (otoconia), which add to the membrane’s weight and increase the shearing forces set up in response to a slight displacement when the head is tilted. The hair bundles of the macular hair cells are arranged in a particular pattern—facing toward (in the utricle) or away from (in the saccule) a curving midline—that allows detection of all possible head positions. 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. In younger persons the disturbance tends to subside as reliance is placed on vision and on proprioceptive impulses from the muscles and joints as well as on cutaneous impulses from the soles of the feet to compensate for the loss of information from the semicircular canals. Recovery of some injured hair cells may occur.

Routine tests of vestibular function traditionally have involved stimulation of the semicircular canals to elicit nystagmus and other vestibular ocular reflexes. Rotation, which can cause vertigo and nystagmus, as well as temporary disorientation and a tendency to fall, stimulates the vestibular apparatus of both ears simultaneously. Because otoneurologists are usually more interested in examining the right and left ears separately, they usually employ temperature change as a stimulant. Syringing the ear canal with warm water at 44 °C (111 °F) or with cool water at 30 °C (86 °F) elicits nystagmus by setting up convection currents in the horizontal canal. The duration of the nystagmus may be timed with a stopwatch, or the rate and amplitude of the movements of the eyes can be accurately recorded by picking up the resulting rhythmical variations in the corneoretinal direct current potentials, using electrodes pasted to the skin of the temples—a diagnostic process called electronystagmography. An abnormal vestibular apparatus usually yields a reduced response or no response at all.

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. Vertigo accompanied by hearing loss is a prominent feature of the periodic attacks experienced by patients with Ménière disease, which, until the late 19th century, was confused with epilepsy. It was referred to as apoplectiform cerebral congestion and was treated by purging and bleeding. Other forms of vertigo may present the otoneurologist with more difficult diagnostic problems.

Since the advent of space exploration, interest in experimental and clinical studies of the vestibular system has greatly increased.

Investigators are concerned particularly about its performance when persons are exposed to the microgravity of spaceflight, as compared with the Earth’s gravitational field for which it evolved. Investigations include the growing use of centrifuges large enough to rotate human subjects, as well as ingeniously automated tests of postural equilibrium for evaluating the vestibulospinal reflexes. Some astronauts have experienced relatively minor vestibular symptoms on returning from spaceflight. Some of these disturbances have lasted for several days, but none have become permanent.