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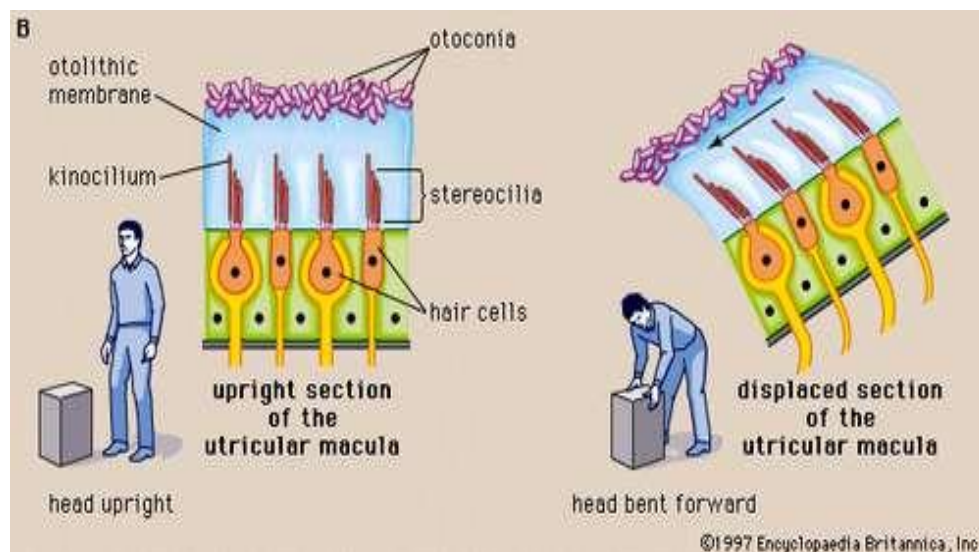
DEPARTMENT OF NURSING

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PHYSIOLOGY OF 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); 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 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 anatomists of the 17th and 18th centuries assumed that the entire inner ear, including the vestibular apparatus, is devoted to hearing. They were impressed by the orientation of the semicircular canals, which lie in three planes more or less perpendicular to one another, and believed that the canals must be designed for localizing a source of sound in space. 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. The plane of the movements was always the same as that of the injured canal. Hearing was not affected when he cut the nerve fibres to these organs, but it was abolished when he cut those to the basilar papilla (the bird's uncoiled cochlea). 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.

Postural balance is controlled by intricate connections between the vestibular, visual and proprioception system. Among these, the vestibular system is one of the key factors in

coordinating and maintaining balance. The peripheral apparatus for the vestibular system consists of the semicircular canals, which sense head rotation; and the otoliths, which sense gravity and linear acceleration. The central vestibular pathways form a large network from the vestibular nuclei, ocular motor nuclei, integration centers in the pons and rostral midbrain, vestibulocerebellum, thalamus, to the multisensory vestibular cortex areas in the temporoparietal cortex. The most important structures for the central vestibular pathways are those mediating the vestibulo-ocular reflex (VOR), and the descending pathways into the spinal cord along the medial and lateral vestibulospinal tract which mediate postural control. The cortical structures involved in vestibular function are the parietoinsular vestibular cortex, the retroinsular cortex, the superior temporal gyrus and the inferior parietal lobule. Activation of the cortical network during vestibular stimulation is not symmetrical; dominance is stronger in the nondominant hemisphere, in the hemisphere ipsilateral to the stimulated ear and in the hemisphere ipsilateral to the slow phase of the vestibular caloric nystagmus. Disorder of the vestibular pathway, anyway along its various tracts, may result in balance and coordination impairments and lead to misperception of motion.