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ASSIGNMENT

Discuss the physiology of balance.

**The physiology of** [**balance:**](https://www.britannica.com/science/proprioception)

The [vestibular system](https://www.britannica.com/science/vestibular-system) is the sensory apparatus of the [inner ear](https://www.britannica.com/science/inner-ear) that helps the body maintain its postural [equilibrium](https://www.britannica.com/science/proprioception). The information furnished by the vestibular system is also essential for coordinating the position of the [head](https://www.britannica.com/science/head-anatomy) and the movement of the eyes. There are two sets of end organs in the inner ear, or labyrinth: the [semicircular canals](https://www.britannica.com/science/semicircular-canal), which respond to [rotational](https://www.britannica.com/science/rotation-physics) movements (angular acceleration); and the [utricle](https://www.britannica.com/science/utricle) and [saccule](https://www.britannica.com/science/saccule) within the [vestibule](https://www.britannica.com/science/vestibule-ear), 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](https://www.britannica.com/science/sound-physics). Functionally these organs are closely related to the cerebellum and to the reflex centres of the [spinal cord](https://www.britannica.com/science/spinal-cord) and [brainstem](https://www.britannica.com/science/brainstem) that govern the movements of the eyes, neck, and limbs.

Physiological sense allowing animals to dynamically maintain an unstable posture

**sense of balance** or **equilibrioception** is the [perception](https://en.wikipedia.org/wiki/Perception) of [balance](https://en.wikipedia.org/wiki/Balance_%28ability%29) and [spatial orientation](https://en.wikipedia.org/wiki/Spatial_orientation). It helps prevent [humans](https://en.wikipedia.org/wiki/Human) and nonhuman [animals](https://en.wikipedia.org/wiki/Animal) from falling over when standing or moving. Equilibrioception is the result of a number of [sensory system](https://en.wikipedia.org/wiki/Sensory_nervous_system)s working together: the eyes ([visual system](https://en.wikipedia.org/wiki/Visual_system)), the inner ears ([vestibular system](https://en.wikipedia.org/wiki/Vestibular_system)), and the body's sense of where it is in space ([proprioception](https://en.wikipedia.org/wiki/Proprioception%22%20%5Co%20%22Proprioception)) ideally need to be intact.

The vestibular system, the region of the inner ear where three semicircular canals converge, works with the visual system to keep objects in focus when the head is moving. This is called the [vestibulo-ocular reflex (VOR)](https://en.wikipedia.org/wiki/Vestibulo-ocular_reflex).[[2]](https://en.wikipedia.org/wiki/Sense_of_balance#cite_note-2) The balance system works with the visual and [skeletal systems](https://en.wikipedia.org/wiki/Skeletal_system) (the muscles and joints and their sensors) to maintain orientation or balance. Visual signals sent to the [brain](https://en.wikipedia.org/wiki/Brain) about the body's position in relation to its surroundings are processed by the brain and compared to information from the vestibular and skeletal systems.



## Vestibular system

*Main article:* [*Vestibular system*](https://en.wikipedia.org/wiki/Vestibular_system)



Diagram of vestibular system

In the vestibular system, equilibrioception is determined by the level of a [fluid](https://en.wikipedia.org/wiki/Fluid) called [endolymph](https://en.wikipedia.org/wiki/Endolymph) in the [labyrinth](https://en.wikipedia.org/wiki/Labyrinth_%28inner_ear%29), a complex set of tubing in the inner [ear](https://en.wikipedia.org/wiki/Ear).

## Dysfunction

Main article: [Balance disorder](https://en.wikipedia.org/wiki/Balance_disorder)

When the sense of balance is interrupted it causes dizziness, [disorientation](https://en.wikipedia.org/wiki/Orientation_%28mental%29) and [nausea](https://en.wikipedia.org/wiki/Nausea). Balance can be upset by [Ménière's disease](https://en.wikipedia.org/wiki/M%C3%A9ni%C3%A8re%27s_disease), [superior canal dehiscence syndrome](https://en.wikipedia.org/wiki/Superior_canal_dehiscence), an [inner ear infection](https://en.wikipedia.org/wiki/Inner_ear_infection), by a bad [common cold](https://en.wikipedia.org/wiki/Common_cold) affecting the head or a number of other medical conditions including but not limited to [vertigo](https://en.wikipedia.org/wiki/Vertigo_%28medical%29). It can also be temporarily disturbed by quick or prolonged acceleration, for example riding on a merry-go-round. Blows can also affect equilibrioreception, especially those to the side of the head or directly to the ear.

Most [astronauts](https://en.wikipedia.org/wiki/Astronaut) find that their sense of balance is impaired when in orbit because they are in a constant state of [weightlessness](https://en.wikipedia.org/wiki/Weightlessness). This causes a form of [motion sickness](https://en.wikipedia.org/wiki/Motion_sickness) called [space adaptation syndrome](https://en.wikipedia.org/wiki/Space_adaptation_syndrome).

### Mechanical

There are five sensory organs innervated by the vestibular nerve; three [semicircular canals](https://en.wikipedia.org/wiki/Semicircular_canals) (Horizontal SCC, Superior SCC, Posterior SCC) and two [otolith](https://en.wikipedia.org/wiki/Otolith) organs (Saccule and Utricle). Each semicircular canal (SSC) is a thin tube that doubles in thickness briefly at a point called [osseous ampullae](https://en.wikipedia.org/wiki/Osseous_ampullae). At their center-base each contains an [ampullary cupula](https://en.wikipedia.org/wiki/Ampullary_cupula). The cupula is a gelatin bulb connected to the [stereocilia](https://en.wikipedia.org/wiki/Stereocilia) of hair cells, affected by the relative movement of the [endolymph](https://en.wikipedia.org/wiki/Endolymph) it is bathed in.

Since the cupula is part of the bony labyrinth, it rotates along with actual head movement, and by itself without the endolymph, it cannot be stimulated and therefore, could not detect movement. Endolymph follows the rotation of the canal, however, due to [inertia](https://en.wikipedia.org/wiki/Inertia) its movement initially lags behind that of the bony labyrinth. The delayed movement of the endolymph bends and activates the cupula. When the cupula bends, the connected stereocillia bend along with it, activating chemical reactions in the hair cells surrounding [crista ampullaris](https://en.wikipedia.org/wiki/Crista_ampullaris) and eventually create [action potentials](https://en.wikipedia.org/wiki/Action_potentials) carried by the vestibular nerve signalling to the body that it has moved in space.

After any extended rotation the endolymph catches up to the canal and the cupula returns to its upright position and resets. When extended rotation ceases, however, endolymph continues, (due to inertia) which bends and activates the cupula once again to signal a change in movement.

Pilots doing long banked turns begin to feel upright (no longer turning) as endolymph matches canal rotation; once the pilot exits the turn the cupula is once again stimulated, causing the feeling of turning the other way, rather than flying straight and level.

The HSCC handles head rotations about a vertical axis (the neck), SSCC handles head movement about a lateral axis, PSCC handles head rotation about a rostral-caudal axis. E.g. HSCC: looking side to side; SSCC: head to shoulder; PSCC: nodding. SCC sends adaptive signals, unlike the two otolith organs, the saccule and utricle, whose signals do not adapt over time.

A shift in the [otolithic membrane](https://en.wikipedia.org/wiki/Otolithic_membrane) that stimulates the cilia is considered the state of the body until the cilia are once again stimulated. E.g. lying down stimulates cilia and standing up stimulates cilia, however, for the time spent lying the signal that you are lying remains active, even though the membrane resets.

Otolithic organs have a thick, heavy gelatin membrane that, due to inertia (like endolymph), lags behind and continues ahead past the [macula](https://en.wikipedia.org/wiki/Macula_of_utricle) it overlays, bending and activating the contained cilia.

[Utricle](https://en.wikipedia.org/wiki/Utricle_%28ear%29) responds to linear accelerations and head-tilts in the horizontal plane (head to shoulder), whereas [saccule](https://en.wikipedia.org/wiki/Saccule) responds to linear accelerations and head-tilts in the vertical plane (up and down). Otolithic organs update the brain on the head-location when not moving; SCC update during movement.

[Kinocilium](https://en.wikipedia.org/wiki/Kinocilium) are the longest stereocilia and are positioned (one per 40-70 regular cilia) at the end of the bundle. If stereocilia go towards kinocilium depolarization occurs causing more neurotransmitter, and more vestibular nerve firings as compared to when stereocilia tilt away from kinocilium (hyperpolarization, less neurotransmitter, less firing).

### Neural

First order [vestibular nuclei](https://en.wikipedia.org/wiki/Vestibular_nuclei) (VN) project to [IVN](https://en.wikipedia.org/wiki/Lateral_vestibular_nucleus), [MVN](https://en.wikipedia.org/wiki/Medial_vestibular_nucleus), and [SVN](https://en.wikipedia.org/wiki/Superior_vestibular_nucleus).

The [inferior cerebellar peduncle](https://en.wikipedia.org/wiki/Inferior_cerebellar_peduncle) is the largest center through which balance information passes. It is the area of integration between proprioceptive, and vestibular inputs to aid in unconscious maintenance of balance and posture.

[Inferior olive nucleus](https://en.wikipedia.org/wiki/Inferior_olivary_nucleus) (also known as the olivary nucleus) aids in complex motor tasks by encoding coordinating timing sensory info; this is decoded and acted upon in the [cerebellum](https://en.wikipedia.org/wiki/Cerebellum).

[Cerebellar vermis](https://en.wikipedia.org/wiki/Cerebellar_vermis) has three main parts: [vestibulocerebellum](https://en.wikipedia.org/wiki/Vestibulocerebellum) (eye movements regulated by the integration of visual info provided by the [superior colliculus](https://en.wikipedia.org/wiki/Superior_colliculus) and balance info), [spinocerebellum](https://en.wikipedia.org/wiki/Anatomy_of_the_cerebellum) [integrates visual, auditory, proprioceptive, and balance info to act out body and limb movements. Trigeminal and dorsal column (of spinal cord) proprioceptive input, [midbrain](https://en.wikipedia.org/wiki/Midbrain), [thalamus](https://en.wikipedia.org/wiki/Thalamus), [reticular formation](https://en.wikipedia.org/wiki/Reticular_formation) and vestibular nuclei ([medulla](https://en.wikipedia.org/wiki/Medulla_oblongata)) outputs], and [cerebrocerebellum](https://en.wikipedia.org/wiki/Anatomy_of_the_cerebellum) (plans, times, and initiates movement after evaluating sensory input from, primarily, motor cortex areas, via [pons](https://en.wikipedia.org/wiki/Pons) and cerebellar [dentate nucleus](https://en.wikipedia.org/wiki/Dentate_nucleus). It outputs to thalamus, [motor cortex](https://en.wikipedia.org/wiki/Motor_cortex) areas, and [red nucleus](https://en.wikipedia.org/wiki/Red_nucleus)).

[Flocculonodular lobe](https://en.wikipedia.org/wiki/Flocculonodular_lobe) is a cerebellar lobe that helps maintain body equilibrium by modifying muscle tone (continuous and passive muscle contractions).

[Thalamic reticular nucleus](https://en.wikipedia.org/wiki/Thalamic_reticular_nucleus) distributes information to various other thalamic nuclei, regulating the flow of information. It is speculatively able to stop signals, ending transmission of unimportant info. The thalamus relays info between pons (cerebellum link), motor cortices, and insula.

Insula is also heavily connected to motor cortices; insula is likely where balance is likely brought into perception.

The [oculomotor nuclear complex](https://en.wikipedia.org/wiki/Oculomotor_nucleus) refers to fibers going to [tegmentum](https://en.wikipedia.org/wiki/Midbrain_tegmentum) (eye movement), red nucleus (gait (natural limb movement), [substantia nigra](https://en.wikipedia.org/wiki/Substantia_nigra) (reward), and [cerebral peduncle](https://en.wikipedia.org/wiki/Cerebral_peduncle) (motor relay). Nucleus of Cajal are one of the named oculomotor nuclei, they are involved in eye movements and reflex gaze coordination.

[Abducens](https://en.wikipedia.org/wiki/Abducens_nerve) solely innervates the [lateral rectus muscle](https://en.wikipedia.org/wiki/Lateral_rectus_muscle) of the eye, moving the eye with [trochlear](https://en.wikipedia.org/wiki/Trochlear_nerve). Trochlear solely innervates the [superior oblique muscle](https://en.wikipedia.org/wiki/Superior_oblique_muscle) of the eye. Together, trochlear and abducens contract and relax to simultaneously direct the pupil towards an angle and depress the globe on the opposite side of the eye (e.g. looking down directs the pupil down and depresses (towards the brain) the top of the globe). The pupil is not only directed but often rotated by these muscles. (See [visual system](https://en.wikipedia.org/wiki/Visual_system))

The thalamus and superior colliculus are connected via [lateral geniculate nucleus](https://en.wikipedia.org/wiki/Lateral_geniculate_nucleus). Superior colliculus (SC) is the [topographical map](https://en.wikipedia.org/wiki/Topographic_map_%28neuroanatomy%29) for balance and quick orienting movements with primarily visual inputs. SC integrates multiple senses.

Illustration of the flow of fluid in the ear, which in turn causes displacement of the top portion of the hair cells that are embedded in the jelly-like cupula. Also shows the utricle and saccule organs that are responsible for detecting linear acceleration, or movement in a straight line.