Internal ear

The internal ear consists of a series of bony cavities (the **bony labyrinth**) and membranous ducts and sacs (the **membranous labyrinth**) within these cavities. All these structures are in the petrous part of the temporal bone between the middle ear laterally and the internal acoustic meatus medially.

The bony labyrinth consists of the **vestibule**, three **semicircular canals**, and the **cochlea**. These bony cavities are lined with periosteum and contain a clear fluid (the **perilymph**).

Suspended within the perilymph but not filling all spaces of the bony labyrinth is the membranous labyrinth, which consists of the **semicircular ducts**, the **cochlear duct**, and two sacs (the **utricle** and the **saccule**). These membranous spaces are filled with **endolymph**.

The structures in the internal ear convey information to the brain about balance and hearing:

- the cochlear duct is the organ of hearing;
- the semicircular ducts, utricle, and saccule are the organs of balance.

The nerve responsible for these functions is the vestibulocochlear nerve [VIII], which divides into vestibular (balance) and cochlear (hearing) parts after entering the internal acoustic meatus.

Bony labyrinth

The vestibule, which contains the oval window in its lateral wall, is the central part of the bony labyrinth. It communicates anteriorly with the cochlea and posterosuperiorly with the semicircular canals.

A narrow canal (the **vestibular aqueduct**) leaves the vestibule, and passes through the temporal bone to open on the posterior surface of the petrous part of the temporal bone.

Semicircular canals

Projecting in a posterosuperior direction from the vestibule are the **anterior**, **posterior**, and **lateral semicircular canals**. Each of these canals forms two-thirds of a circle connected at both ends to the vestibule and with one end dilated to form the **ampulla**. The canals are oriented so that each canal is at right angles to the other two.

Cochlea

Projecting in an anterior direction from the vestibule is the cochlea, which is a bony structure that twists on itself two and one-half to two and three-quarter times

around a central column of bone (the **modiolus**). This arrangement produces a cone-shaped structure with a **base of cochlea** that faces posteromedially and an apex that faces anterolaterally. This positions the wide base of the modiolus near the internal acoustic meatus, where it is entered by branches of the cochlear part of the vestibulocochlear nerve [VIII].

Extending laterally throughout the length of the modiolus is a thin lamina of bone (the **lamina of modiolus**, or **spiral lamina**). Circling around the modiolus, and held in a central position by its attachment to the lamina of modiolus, is the cochlear duct, which is a component of the membranous labyrinth.
Attached peripherally to the outer wall of the cochlea, the cochlear duct creates two canals (the **scala vestibuli** and the **scala tympani**), which extend throughout the cochlea and are continuous with each other at the apex through a narrow slit (the **helicotrema**):

- the scala vestibuli is continuous with the vestibule;
- the scala tympani is separated from the middle ear by the secondary tympanic membrane covering the round window.

Finally, near the round window is a small channel (the **cochlear canaliculus**), which passes through the temporal bone and opens on its inferior surface into the posterior cranial fossa. This provides a connection between the perilymph-containing cochlea and the subarachnoid space.

Membranous labyrinth

The membranous labyrinth is a continuous system of ducts and sacs within the bony labyrinth. It is filled with endolymph and separated from the periosteum that covers the walls of the bony labyrinth by perilymph.
Consisting of two sacs (the utricle and the saccule) and four ducts (the three semicircular ducts and the cochlear duct), the membranous labyrinth has unique functions related to balance and hearing:

- the utricle, saccule, and three semicircular ducts are part of the vestibular apparatus (i.e. organs of balance);
- the cochlear duct is the organ of hearing.

The general organization of the parts of the membranous labyrinth places:

- the cochlear duct within the cochlea of the bony labyrinth, anteriorly;
- the three semicircular ducts within the three semicircular canals of the bony labyrinth, posteriorly;
- the saccule and utricle within the vestibule of the bony labyrinth, in the middle.

Organs of balance

Five of the six components of the membranous labyrinth are concerned with balance. These are the two sacs (the utricle and the saccule) and three ducts (the anterior, posterior, and lateral semicircular ducts).

Utricle, saccule, and endolymphatic duct

The utricle is the larger of the two sacs. It is oval, elongated and irregular in shape and is in the posterosuperior part of the vestibule of the bony labyrinth.

The three semicircular ducts empty into the utricle. Each semicircular duct is similar in shape, including a dilated end forming the ampulla, to its complementary bony semicircular canal, only much smaller.

The saccule is a smaller, rounded sac lying in the anteroinferior part of the vestibule of the bony labyrinth. The cochlear duct empties into it.

The utriculosaccular duct establishes continuity between all components of the membranous labyrinth and connects the utricle and saccule. Branching from this small duct is the **endolymphatic duct**, which enters the vestibular aqueduct (a channel through the temporal bone) to emerge onto the posterior surface of the petrous part of the temporal bone in the posterior cranial fossa. Here the endolymphatic duct expands into the **endolymphatic sac**, which is an extradural pouch.

Sensory receptors

Functionally, sensory receptors for balance are organized into unique structures and in each of the components of the vestibular apparatus. In the utricle and saccule this sense organ is the **macula of utricle** and **macula of saccule**, respectively, and in the ampulla of each of the three semicircular ducts it the **crista**.

The utricle responds to centrifugal and vertical acceleration, while the saccule responds to linear acceleration. In contrast, the receptors in the three semicircular ducts respond to movement in any direction.

Organ of hearing

Cochlear duct

The cochlear duct has a central position in the cochlea of the bony labyrinth dividing it into two canals (the scala vestibuli and the scala tympani). It is maintained in this position by being attached centrally to the lamina of modiolus, which is a thin lamina of bone extending from the modiolus (the central bony core of the cochlea), and peripherally to the outer wall of the cochlea.
Thus, the triangular-shaped cochlear duct has:

- an outer wall against the bony cochlea consisting of thickened, epithelial-lined periosteum (the **spiral ligament**);
- a roof (the **vestibular surface membrane**), which separates the endolymph in the cochlear duct from the perilymph in the scala vestibuli and consists of a membrane with a connective tissue core lined on either side with epithelium;
- a floor, which separates the endolymph in the cochlear duct from the perilymph in the scala tympani and consists of the free edge of the lamina of modiolus, and a membrane (the **basilar membrane**) extending from this free edge of the lamina of modiolus to an extension of the spiral ligament covering the outer wall of the cochlea.

The **spiral organ** is the organ of hearing, rests on the basilar membrane, and projects into the enclosed, endolymph-filled cochlear duct.

Vessels

The arterial supply to the internal ear is divided between vessels supplying the bony labyrinth and the membranous labyrinth.
The bony labyrinth is supplied by the same arteries that supply the surrounding temporal bone-these include an anterior tympanic branch from the maxillary artery, a stylomastoid branch from the posterior auricular artery, and a petrosal branch from the middle meningeal artery.
The membranous labyrinth is supplied by the **labyrinthine artery**, which either arises from the anterior inferior cerebellar artery or is a direct branch of the basilar artery-whatever its origin, it enters the internal acoustic meatus with the facial [VII] and glossopharyngeal [IX] nerves and eventually divides into:

- a **cochlear branch**, which passes through the modiolus and supplies the cochlear duct;
- one or two **vestibular branches**, which supply the vestibular apparatus.

Venous drainage of the membranous labyrinth is through vestibular veins and cochlear veins, which follow the arteries. These come together to form a **labyrinthine vein**, which eventually empties into either the inferior petrosal sinus or the sigmoid sinus.

Innervation

The vestibulocochlear nerve [VIII] carries special afferent fibers for hearing (the cochlear component) and balance (the vestibular component). It enters the lateral surface of the brainstem, between the pons and medulla, after exiting the temporal bone through the internal acoustic meatus and crossing the posterior cranial fossa.

Inside the temporal bone, at the distal end of the internal acoustic meatus, the vestibulocochlear nerve divides to form:

- the **cochlear nerve**, and;
- the **vestibular nerve**.

The vestibular nerve enlarges to form the **vestibular ganglion**, before dividing into **superior** and **inferior parts**, which distribute to the three semicircular ducts and the utricle and saccule.

The cochlear nerve enters the base of the cochlea and passes upwards through the modiolus. The ganglion cells of the cochlear nerve are in the spiral ganglion at the base of the lamina of modiolus as it winds around the modiolus. Branches of the cochlear nerve pass through the lamina of modiolus to innervate the receptors in the spiral organ.

Facial nerve [VII] in the temporal bone

The facial nerve [VII] is closely associated with the vestibulocochlear nerve [VIII] as it enters the internal acoustic meatus of the temporal bone. Traveling through the temporal bone, its path and several of its branches are directly related to the internal and middle ears.

The facial nerve [VII] enters the internal acoustic meatus in the petrous part of the temporal bone. The vestibulocochlear nerve and the labyrinthine artery accompany it.

At the distal end of the internal acoustic meatus, the facial nerve [VII] enters the facial canal and continues laterally between the internal and middle ears. At this point the facial nerve [VII] enlarges and bends posteriorly and laterally. The enlargement is the sensory **geniculate ganglion**. As the facial canal continues, the facial nerve [VII] turns sharply downward and running in an almost vertical direction, it exits the skull through the stylomastoid foramen.

Branches

Greater petrosal nerve

At the geniculate ganglion, the facial nerve [VII] gives off the greater petrosal nerve. This is the first branch of the facial nerve [VII]. The greater petrosal nerve leaves the geniculate ganglion, travels anteromedially through the temporal bone, and emerges through the hiatus for the greater petrosal nerve on the anterior surface of the petrous part of the temporal bone. The greater petrosal nerve carries preganglionic parasympathetic fibers to the pterygopalatine ganglion.

Continuing beyond the bend, the position of the facial nerve [VII] is indicated on the medial wall of the middle ear by a bulge

Nerve to stapedius and chorda tympani

Near the beginning of its vertical descent, the facial nerve [VII] gives off a small branch, the nerve to stapedius, which innervates the stapedius muscle, and just before it exits the skull the facial nerve [VII] gives off the chorda tympani nerve.

The chorda tympani does not immediately exit the temporal bone, but ascends to enter the middle ear through its posterior wall, passing near the upper aspect of the tympanic membrane between the malleus and incus. It then exits the middle ear through a canal leading to the **petrotympanic fissure** and exits the skull through this fissure to join the lingual nerve in the infratemporal fossa.