

# Development of the auditory and balance system

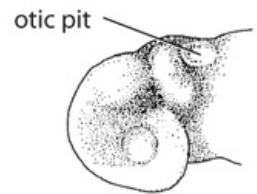
The ear consists of three sections:

1. **inner**,
2. **middle**,
3. **external**.

## Inner ear

Auditory placode arises day 22 from the ectoderms on either side of the *rhombencephalon*. The **ventral part** of the sac gives rise to the **sacculus** and the **ductus cochlearis**. **Dorsal** is for the **utricle** and the **ductuli semicirculares** and the **ductus endolymphaticus**. Together, therefore, it gives the basis for the membranous labyrinth. The mesenchyme around the *ductus cochlearis* gives rise to the cartilage, which later vacuolizes to form the *scala tympani* and *scala vestibuli*. Gradually, other structures of the inner Ear are also formed.

During the 6th week, three semicircular ducts (*ductus semicirculares*) are formed as sheathed utricle processes. The enlarged part of the ducts is called the *ampulla*. The two ampullae then merge into one. The ampullae contain the *crista ampularis* = the kinetic component of the equilibrium organ. The static part develops in the sacculus and utricle - *maculae staticae*. Excitations are conducted by the nervus vestibulocochlearis, which forms the ganglion *vestibulocochleare*.



otic plaque

## Otocyst

Around day 22 of embryonic development, an **otic placode** is present on each side of the future rhombencephalon (in the region of the 3rd cerebral sac) in the form of a thickened ectoderm. In the week 4, the otic placode, after induction from the mesoderm and rhombencephalon via **growth factor FGF8** begins to inwardly calcify as an *otic sac*, which is called an **otocyst** after detachment. The otocyst is formed by the ectodermal epithelium, which, after invagination, moves closer to the rhombencephalon region and a statoacoustic ganglion begins to form in the mesenchyme.

Around 5th week the otocyst divides into two parts:

- (a) **Ventral region** (induced from the ventral part of the rhombencephalon by means of the SHH), from which the future *sacculus* and *ductus cochlearis* (cochlear part) emerge.
- (b) **Dorsal region** (induced from the dorsal part of the rhombencephalon by WNT), from which the future *utricle*, *ductus endolymphaticus* and *ductus semicirculares* (vestibular part) will arise.

## Ductus cochlearis

- In 6th week, a ductus cochlearis grows out of the lower part of the sacculus, which grows to a length of 2.5 turns and remains in connection with the sacculus through a narrow **ductus reuniens**.

The \*ductus cochlearis is embedded in the mesenchyme, which turns into cartilage that forms the basis for the future bony labyrinth.

- At week 10, vacuolization occurs in this cartilaginous base and 2 perilymphatic spaces are formed:
  1. **scala vestibuli** - a space separated by the vestibular membrane,
  2. **scala tympani** - space separated by the basilar membrane

The ductus cochlearis is connected laterally to the cartilage by the **ligamentum spirale**, medially it is supported by the cartilage process = **modiolus**.

The cells in the ductus cochlearis are initially of the same size but gradually differentiate into cylindrical cells that form 2 mounds:

- **Inner** - future limbus spiralis.
- **Outer** - hair cells arranged in sections:
  1. external (1 row of cells),
  2. internal (3-4 rows of cells)

## Fibrous cells

- The hair cells are actually sensory cells of audition, their processes touch the tectorial membrane, which is jelly-like and attached to the limbus spiralis. The stereocilia of the hair cells protrude above the level of the

tunnel of Corti and penetrate into the membrana tectoria.

- The sensory cells of the Corti's organ are secondary sensory cells that convert mechanical stimuli (which originate from sound waves) into nerve impulses. These are further transmitted by the dendrites of the ggl. spiral cells, which are at the base of the sensory cells and go up the modiolus to the fundus meatus acustici interni to the ggl. spirale. Axons of ggl. spirale cells exit the fundus meatus acustici interni as *n. cochlearis*.

### ***Ductus semicirculares***

- In the utricular part, 3 fertilized processes appear in 6th week. The central portions of the walls of these processes adhere to each other, fuse and finally **apoptotically** disappear to form 3 semicircular ducts - ductus semicirculares (anterior, posterior, lateral).
- The semicircular ducts have an enlarged part - **ampulla** and **non-enlarged part**. The unexpanded portions of the anterior and posterior semicircular canaliculi fuse together and thus 5 (not 6) openings enter the utriculus (3 contain the ampulla, 2 are unexpanded).
- In the ampullae are other sensory formations - **cristae ampullares**. These are raised ridge-like edges that protrude from the wall of the ampullae. They contain sensory and support cells.

### ***Utriculus and sacculus***

- Utriculus and sacculus are sacs, in the wall of which are receptors of gravity - maculae staticae. They are also secondary sensory cells which receive stimuli and convert them into nerve excitations which they transmit through the endings of the sensory fibres of the vestibular nerve.
- From the sensory cells protrude the stereocilia, of which there is still one typically longer cilia.
- The apical surface of the cells is covered with a high gelatinous layer of glycoproteins into which the cilia are embedded. On the surface of this layer are calcium carbonate crystals called **otoliths** which exert their weight in the direction of gravity on the gelatinous layer and hence on the stereocilia.
- The deformation of the cilia is transferred to the nerve impulse and then conducted higher into the CNS.
- The ductus utriculosaccularis is a thin canal connecting the utriculus and sacculus.

### ***Ductus endolymphaticus***

The \*Ductus endolymphaticus emerges from the bend of the ductus utriculosaccularis and heads to the posterior surface of the pyramid, where it enters the dura mater through its blind extension, the saccus endolymphaticus (lymph is absorbed there).

## **Middle ear**

The middle ear consists of the **middle ear cavity** (*cavum tympani*) and the **ossicula auditiva** (*ossicula auditiva*) located within it. The middle ear cavity is formed from the endoderm of the first gill process. Laterally, it gives rise to the *recessus tubotympanicus*. Medial part gives rise to the *tuba auditiva* (Eustachian tube). The malleus and incus arise from the first gill arch, the stapes from the second. The primitive middle ear cavity is lined by endodermal epithelium. *Musculus tensor tympani* is innervated from the n. mandibularis, *musculus stapedius* from the n. facialis.

### ***Cavum tympani***

- The mediastinum develops from the pharyngeal intestine, specifically from its 1st gill flap on the lateral side.
- It is lined with entoderm.
- It increases in size up to 2 times during development.
- The medial continuation of the cavum tympani is the tuba auditiva = Eustachian tube, which connects the middle ear cavity to the nasopharynx.
- Laterally, the cavum tympani comes into contact with the 1st gill cartilage and forms the future tympanic membrane at its interface (a layer of surrounding mesenchyme is inserted between the cartilage and the cartilage). The tympanic membrane has 3 layers.

(\*In fish this membrane is called membrana obturans and does not contain mesenchyme - the tympanic membrane and the tympanic membrane are tightly attached to each other.)

### ***Ossicula auditiva***

- Inside the cavum tympani cartilaginous models of the ossicula auditiva = middle ear ossicles are formed.

**Malleus** = anvil (a remnant of the cartilage of the 1st pharyngeal arch - *Meckel's cartilage*). **Incus** = hammerhead (cartilage remnant of the 1st pharyngeal arch). **Stapes** = stipe (remnant of cartilage of the 2nd pharyngeal arch - *Reichert's cartilage*).

- Ossicula auditiva are surrounded by mesenchyme until the 8th month of development, which gradually diminishes and the entodermal epithelium lining the primitive middle ear cavity reaches these ossicles from the walls.
- Entoderm passes to the cuboids in the form of cilia, in which the ligaments later differentiate.
- The ossicula auditiva are the first ossifying bones in the human body (4th month of development).
- The middle ear cavity also expands posteriorly during the fetal period and resorption of tissue occurs, forming

the *antrum mastoideum*. Postnatally, the epithelium from the middle ear cavity penetrates into the processus mastoideus, where epithelium-lined cellulae mastoideae are formed. The antrum mastoideum is connected to the cellulae mastoideae.

- In otitis media, the inflammation may extend to the procc. mastoideus.

## Outer ear

The external ear is made up of the **auricle** (*auricula*), **external auditory canal** (*meatus acusticus externus*), and **drum** (*membrana tympani*), which forms the border with the middle ear. The meatus acusticus externus develops from the ectoderm of the first gill cartilage. In the 3rd month, the cells proliferate and form a solid epithelial plug. In the 7th month it is luminalised. The tympanum consists of 3 parts: the ectoderm, the middle connective tissue layer and the endoderm on the inner side. The auricle develops from 6 mesenchymal ear bumps.

### *Auricula*

- The auricle is formed by 6 mesenchymal bumps (ectomesenchyme covered with ectoderm) surrounding the **1st gill cartilage** at the dorsal end of the 1st and 2nd gill arches.
- 3 bumps anteriorly and 3 posteriorly merge to form the auricle
- Originally, the pinna and external ear canal were located in the cervical region, but due to the development of the mandible, they move into the head region up to eye level.

### *Meatus acusticus externus*

- The external auditory canal develops from the **1st gill cartilage**.
- At the beginning of the **3rd month**, a **epithelial plug** appears at the base of the tympanic membrane due to ectodermal cell proliferation.
- In **month 7** this plug luminalises (if it does not, a type of deafness develops).
- A definitive tympanic membrane is formed at the base, to which the manubrium mallei is attached.

### *Membrana tympani*

The drum has 3 parts:

- **external** - ectodermal (from the 1st gill cartilage),
- **middle** - stratum fibrosum (from the mesenchyme),
- **inner** - endoderm (from the 1st gill process).

## Links

### Related articles

- Hearing track
- Organ of Corti
- Pharyngeal arches
- Hearing
- Developmental disorders of the ear

### Bibliography

- ČIHÁK, Radomír – GRIM, Miloš. *Anatomie 3. 2.*, upr. a dopl. edition. Grada, 2004. 673 pp. ISBN 80-247-1132-X.
- SADLER, Thomas, W. *Langmanova lékařská embryologie*. 1. české edition. Grada, 2011. 414 pp. ISBN 978-80-247-2640-3.