Functional Anatomy of the Sensory Organs

Human Anatomy Department
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Plan of the lecture

1. General characteristics of the sensory organs.
2. Special types of senses.
3. Hearing.
4. Equilibrium (balance).
5. Vision.
6. Organ of smell (olfaction).
7. Organ of taste.
8. Developmental abnormalities of the organs of sense.

Sense organs

- The sense organs have been described as **''windows for the brain''** because through them we achieve awareness of the environment.
- The sense organs enable us to:
  - hear warning sounds,
  - see dangers,
  - distinguish fragrances,
  - avoid ingesting toxic substances,
  - perceive sensations of pain, temperature, pressure and touch.

Senses are structures with which the nervous system receives excitations from the environment and from the body's own organs. These excitations reached the SNC are converted into sensations.

All the organs are divided into two groups:

- Organs of **external sensibility** which receive nerve impulses from the exteroceptive field, the exteroceptors:

a) the organ of vision (or sight),
b) the organ of hearing,
c) the organ of taste,
d) the organ of smell,
e) the organs of cutaneous sense.

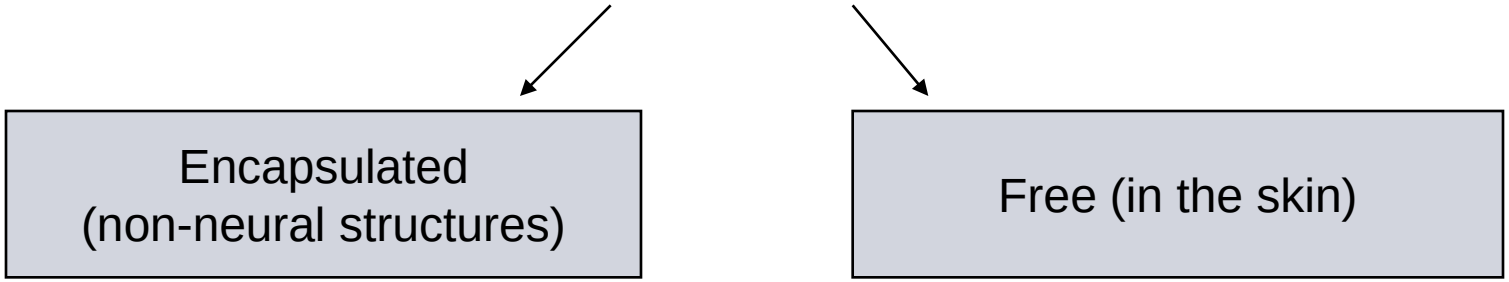
- **Organs of inner sensibility**:

a) organs that receive impulses from the proprioceptive field (the muscle – joint sensation), as well as from organ of balance (the inner ear);
b) organs receiving nerve impulse from the interoceptive field (internal organs and vessels).

Categories of receptors

Sensory receptors can be categorized on basis of structure or function:

- Structurally - dendritic endings of sensory neurons



- The photoreceptors in the retina are highly specialized neurons.
- The taste buds on the tongue and hair cells in the inner ear are modified epithelial cells and they respond to environmental stimuli and activate sensory neurons.

Functional Categories

Sensory receptors can be grouped according to the type of stimulus energy they transduce

- **chemoreceptors**, such as the taste buds, olfactory epithelium, respond to chemical stimuli in the environment, or blood.
- **photoreceptors** – the rods and cones in the retina - respond to light.
- **termoreceptors** - respond to changes in temperature.
- **mechanoreceptors** such as the touch and pressure receptors in the skin and the hair cells within the inner ear – respond to mechanical stimuli.
- **nociceptors**, or **pain** receptors, are stimulated by chemical released from damaged tissue cells and thus are a type of chemoreceptors.

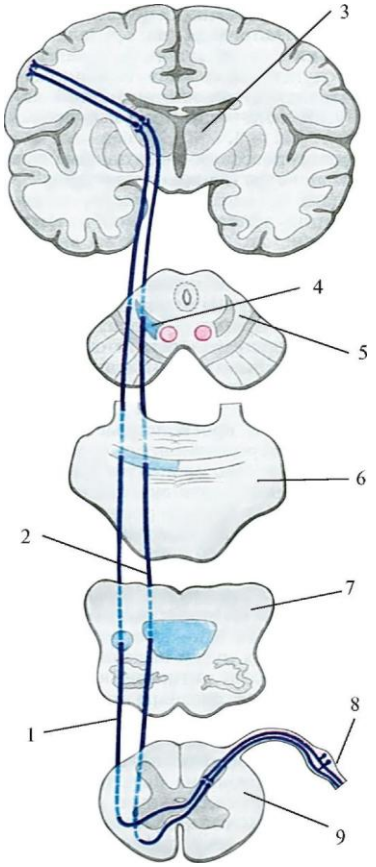
Analysers

- Each analyser consists of three links:

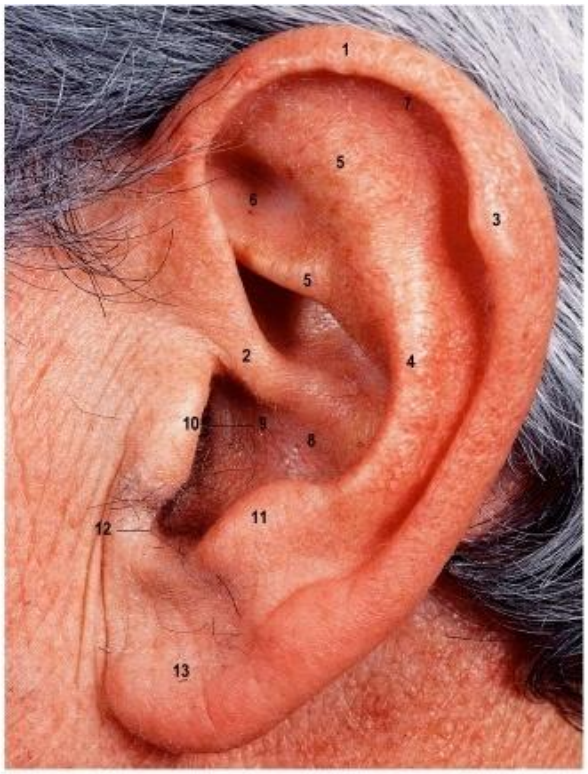
a) the **receptor** which transforms the energy of the stimulus into a nervous process;

b) the **conductor** which conveys the nerve excitation;

c) the **cortical end** of the analyser where the excitation is perceived as a sensation.

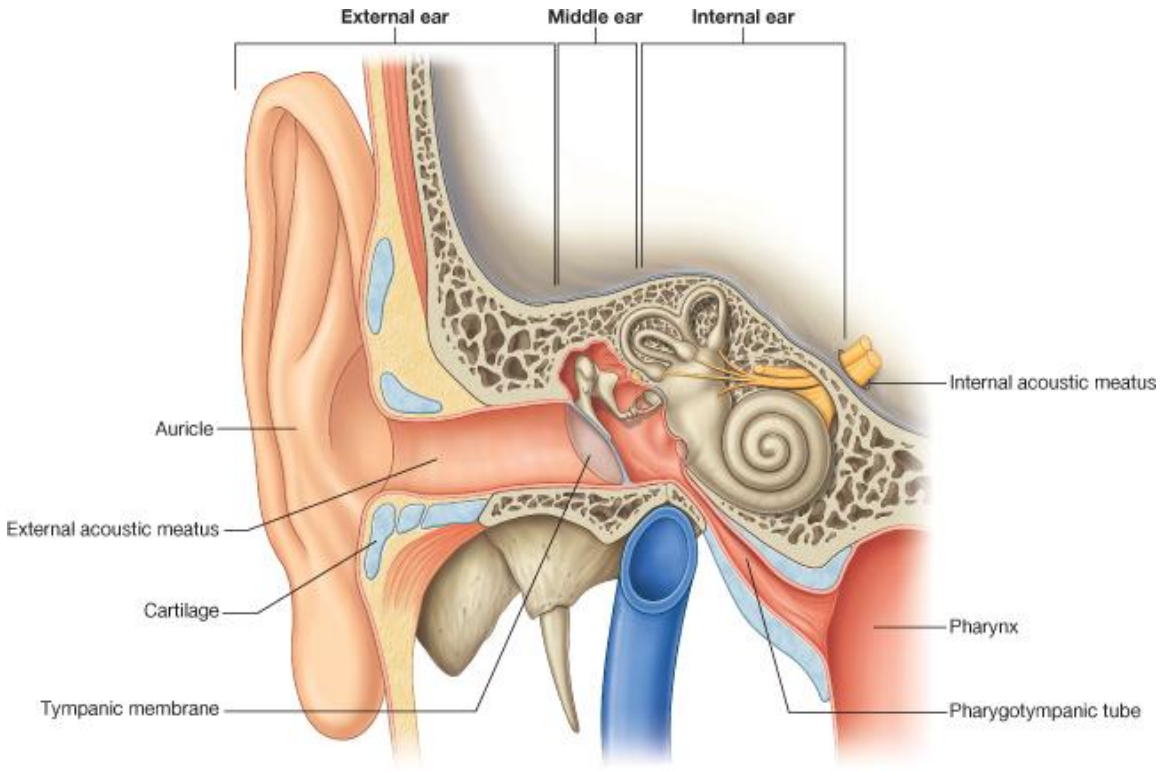


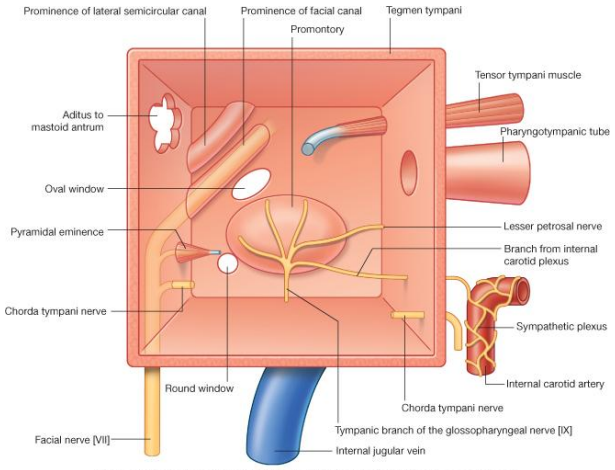
The external ear

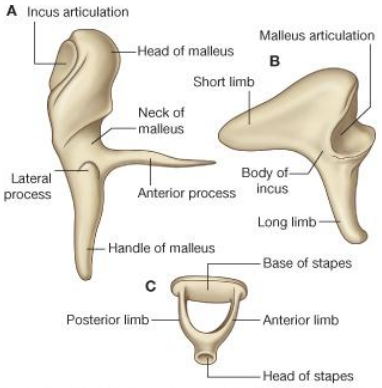


1. Helix. **2.** Crus of helix. **3.** Auricular tubercle. **4.** Antihelix. **5.** Crura of antihelix. **6.** Triangular fossa. **7.** Scaphoid fossa. **8.** Concha of auricle. **9.** External acoustic meatus. **10.** Tragus. **11.** Antitragus. **12.** Intertragic notch. **13.** Lobule of auricle.

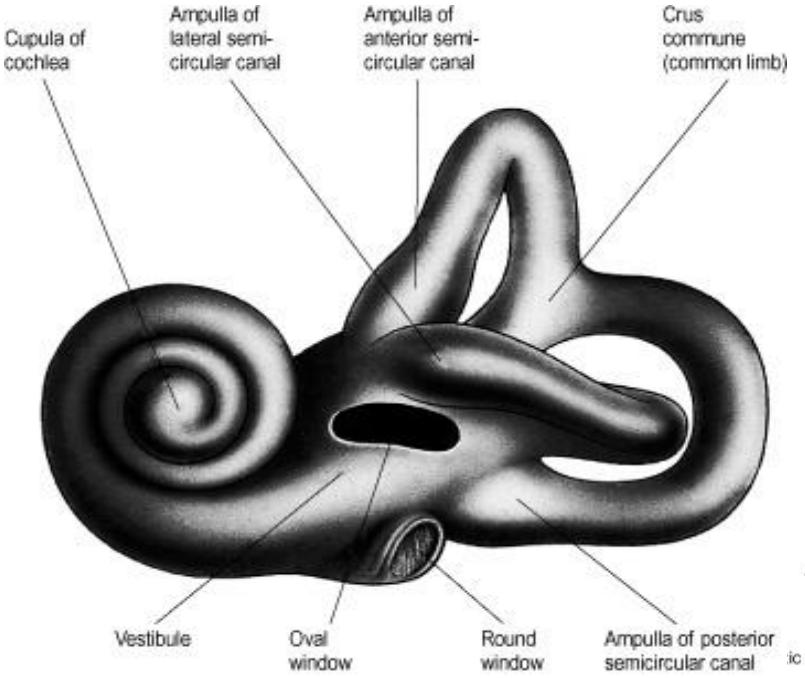
The middle ear







Internal ear – bony labyrinth



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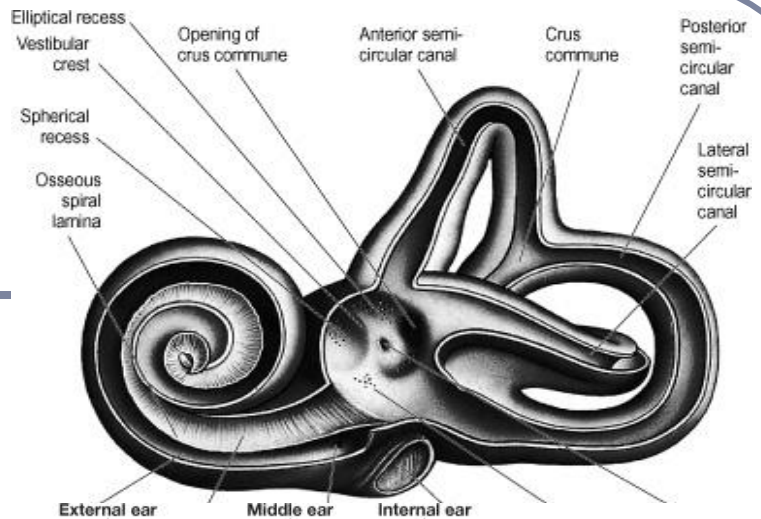

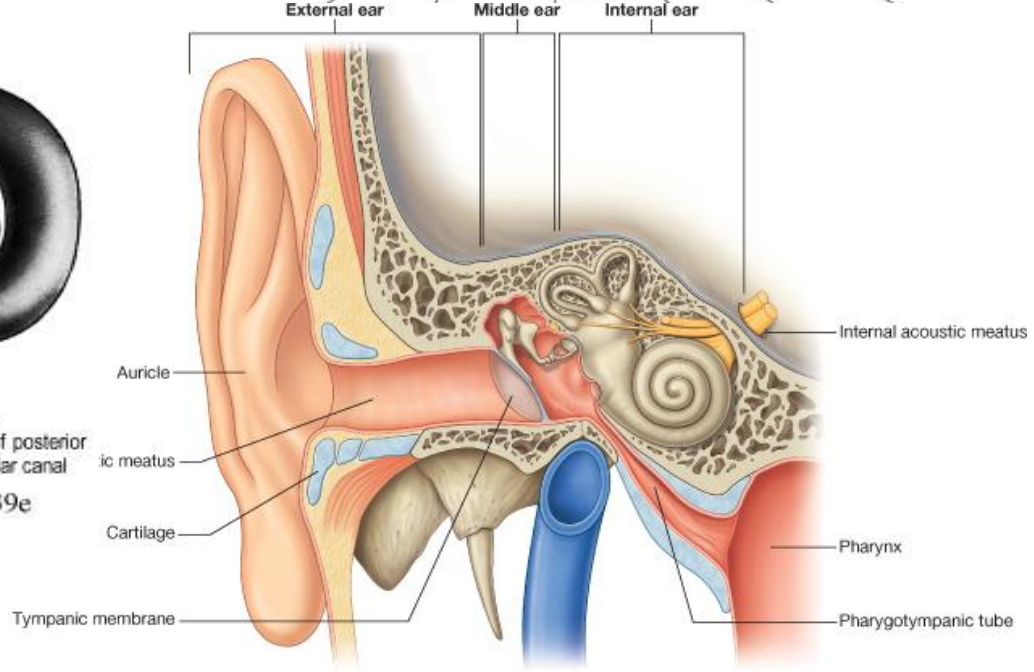

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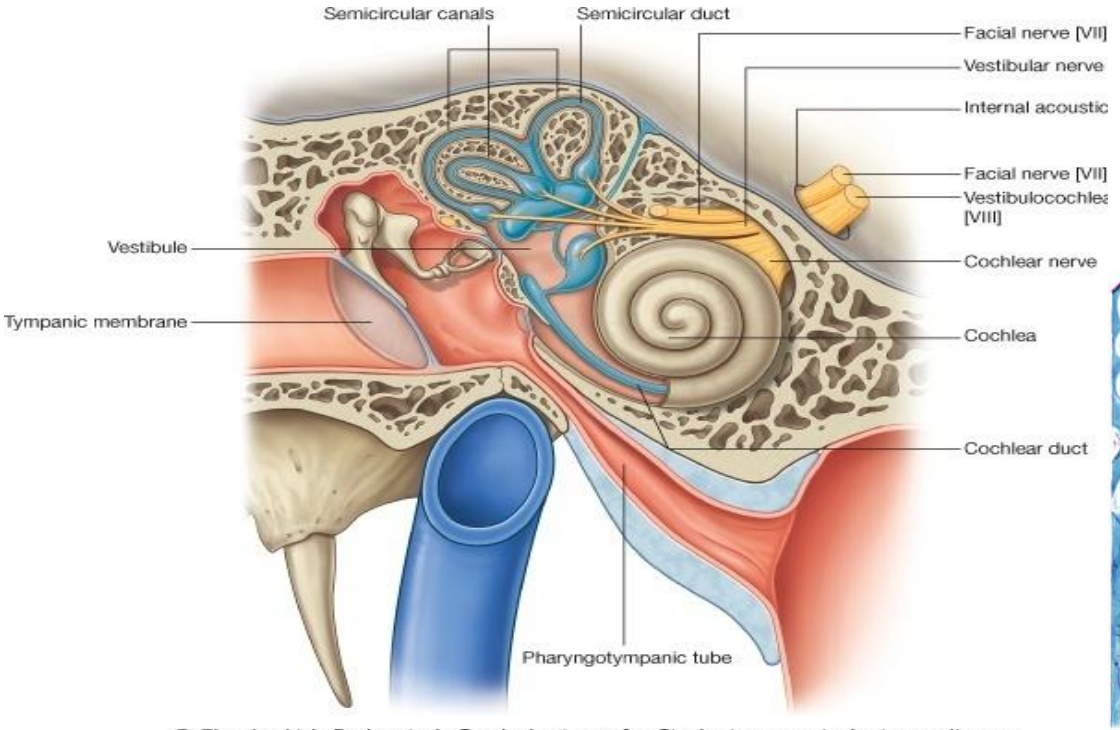
Internal ear – membranous labyrinth



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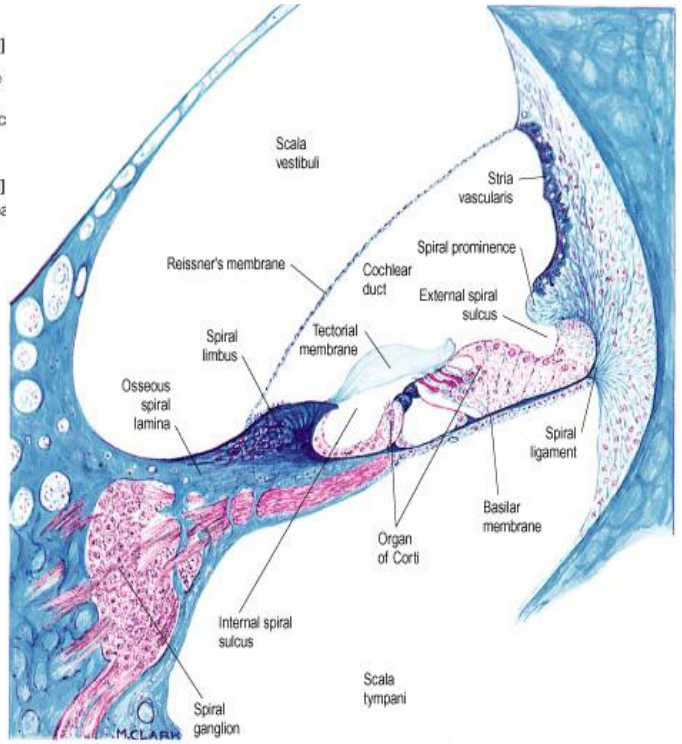

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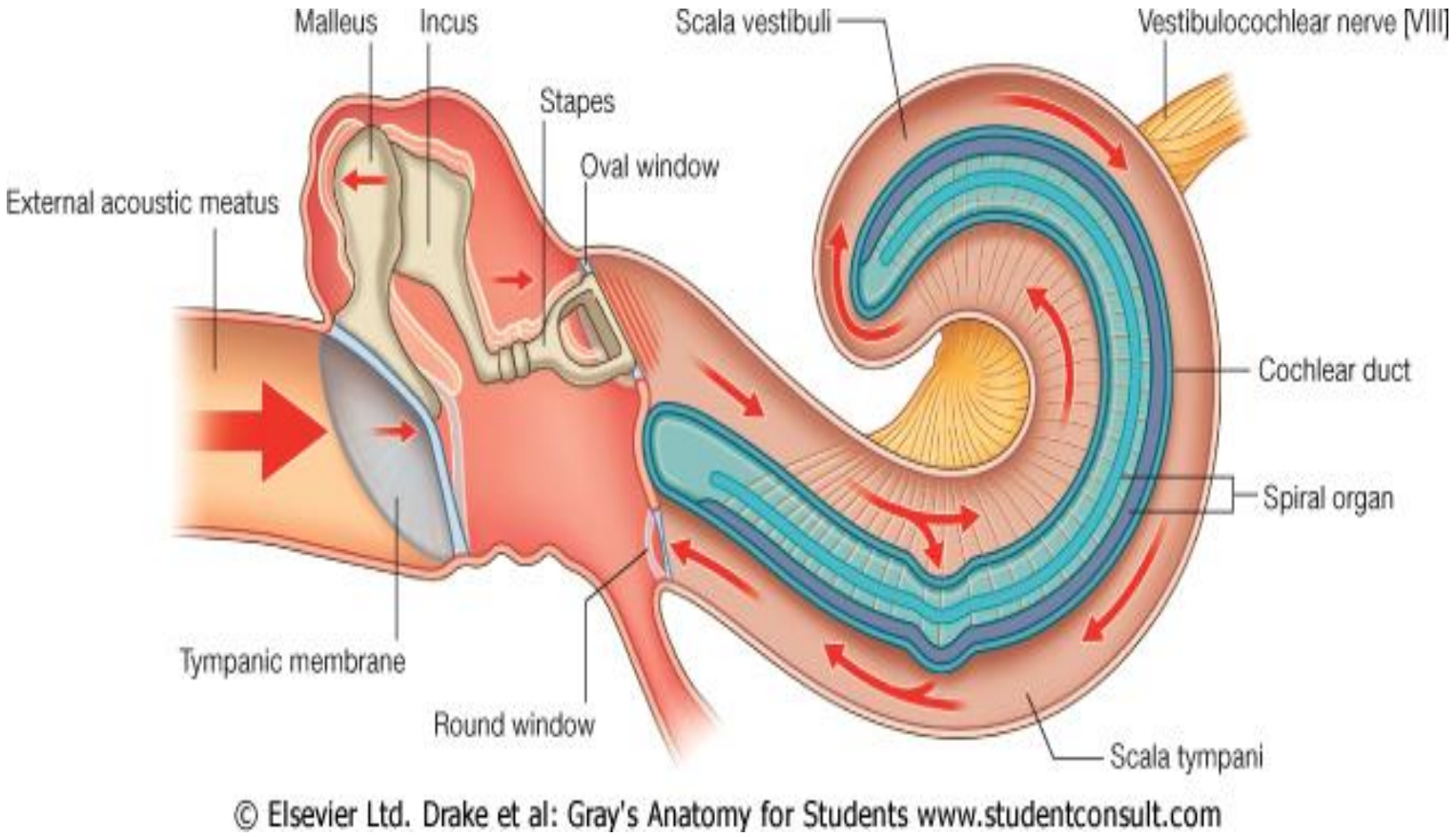
Transmission of sounds

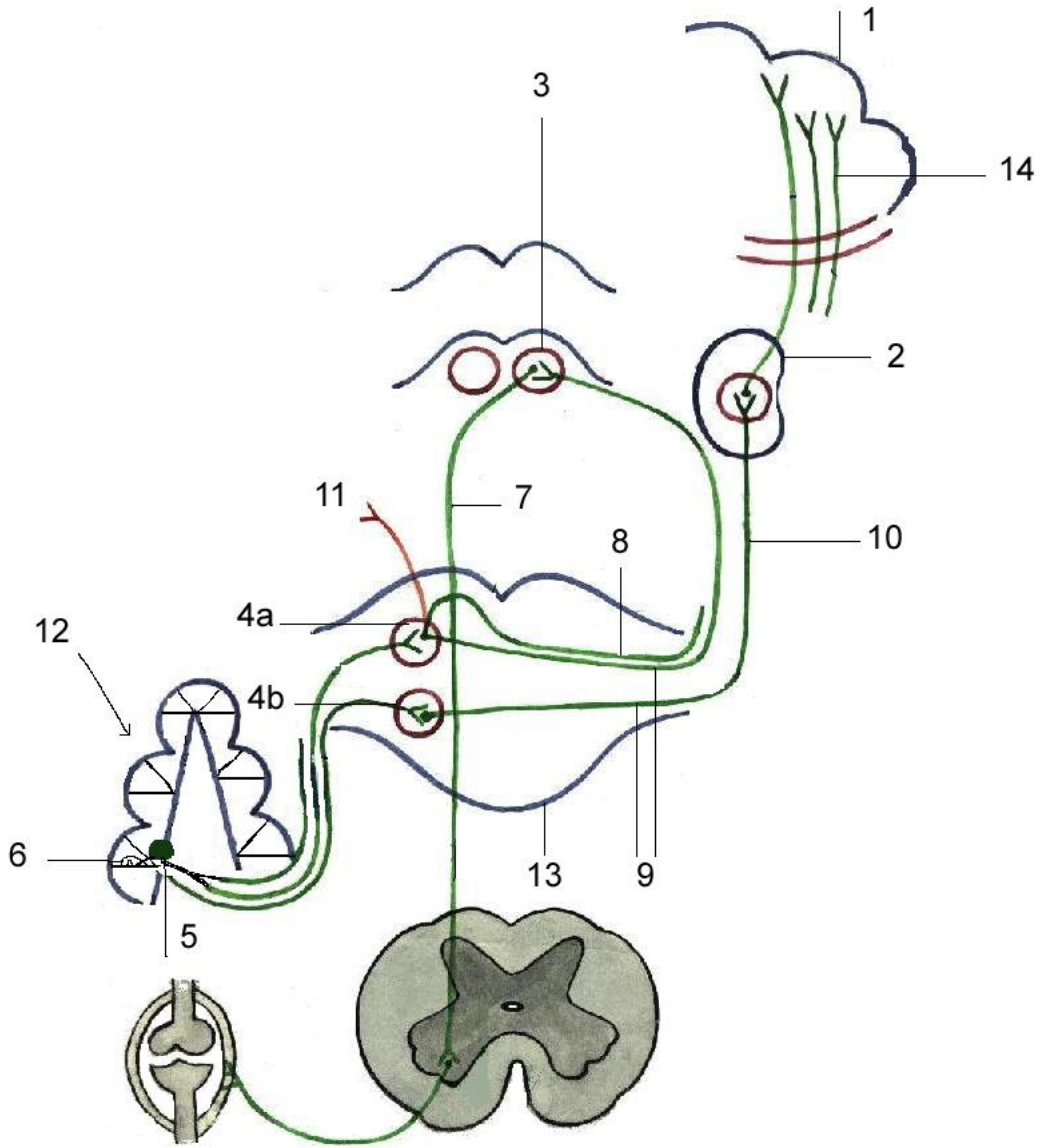


Pathways of the organ of hearing

a) The body of the first neuron – spiral ganglion.

b) The body of the second neuron – ventral and dorsal cochlear nuclei in the pons.

c) The body of the third neuron – medial geniculate body and inferior colliculi of the tectal lamina (midbrain).



Pathways of the organ of balance (equilibrium)

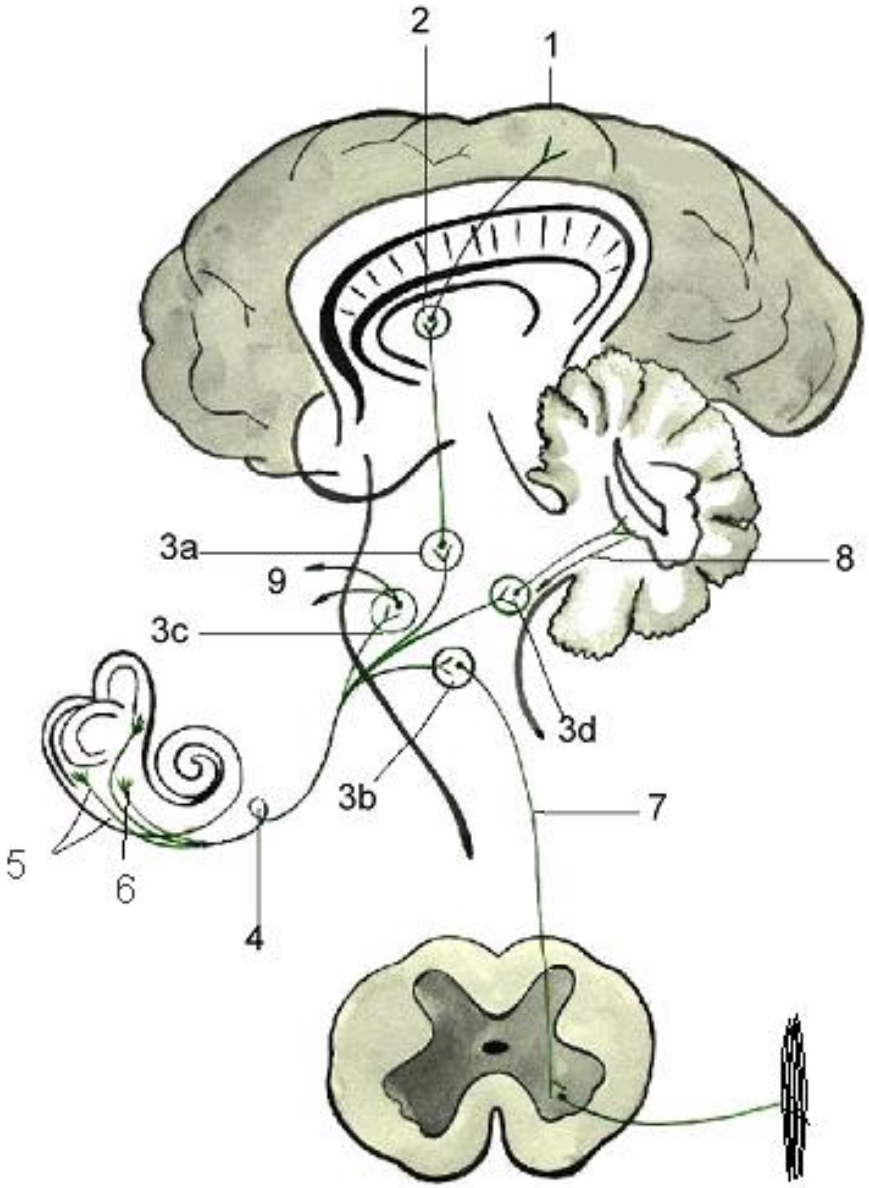
a) The body of the first neuron – vestibular ganglion (Scarpa).

b) The body of the second neuron – superior, inferior, medial and lateral vestibular nuclei in the pons.

Connections of the vestibular nuclei:

- with spinal cord by means of vestibulo-spinal tract;
- with cerebellum through the cerebello-vestibular and vestibulo-cerebellar fibres (tracts);
- connections through the medial longitudinal fascicle with the IIIrd, IVth, VIth, IXth and Xth pairs of cranial neves.

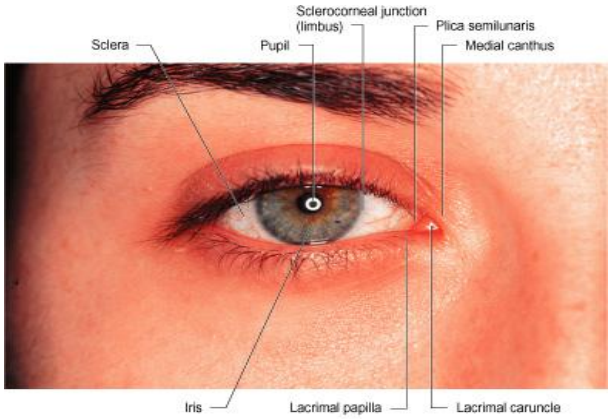
a) The body of the third neuron – is in the thalamus and it ends in the cortex of the temporal lobe.



Organ of vision

- Eye and auxiliary apparatus

  The eye consists of 3 coats:
- The outer or fibrous coat: cornea and sclera
- The middle or vascular coat: the choroidea, the ciliary body and the iris.
- The innermost one – retina.



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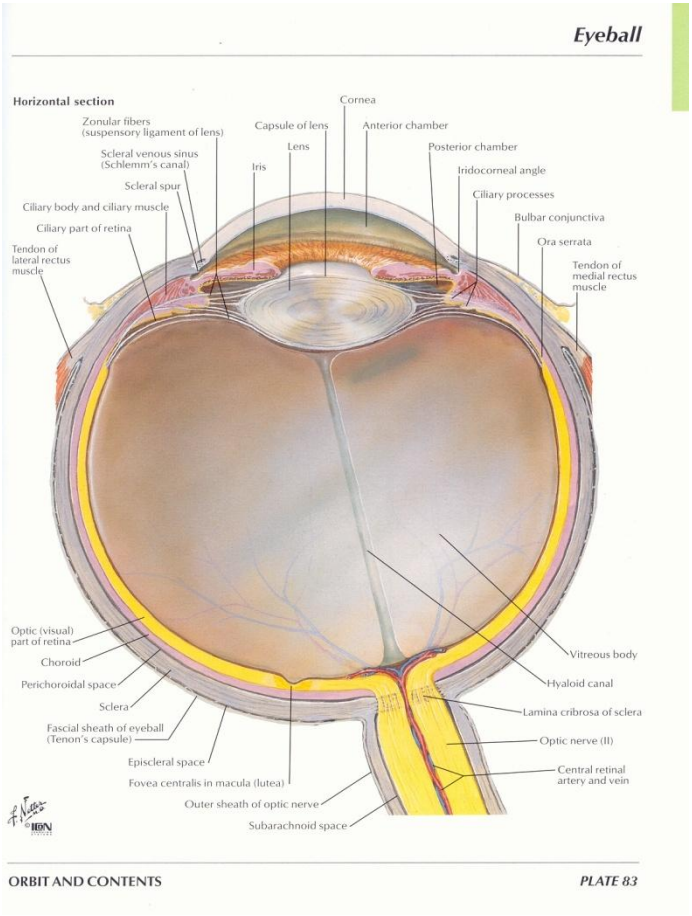
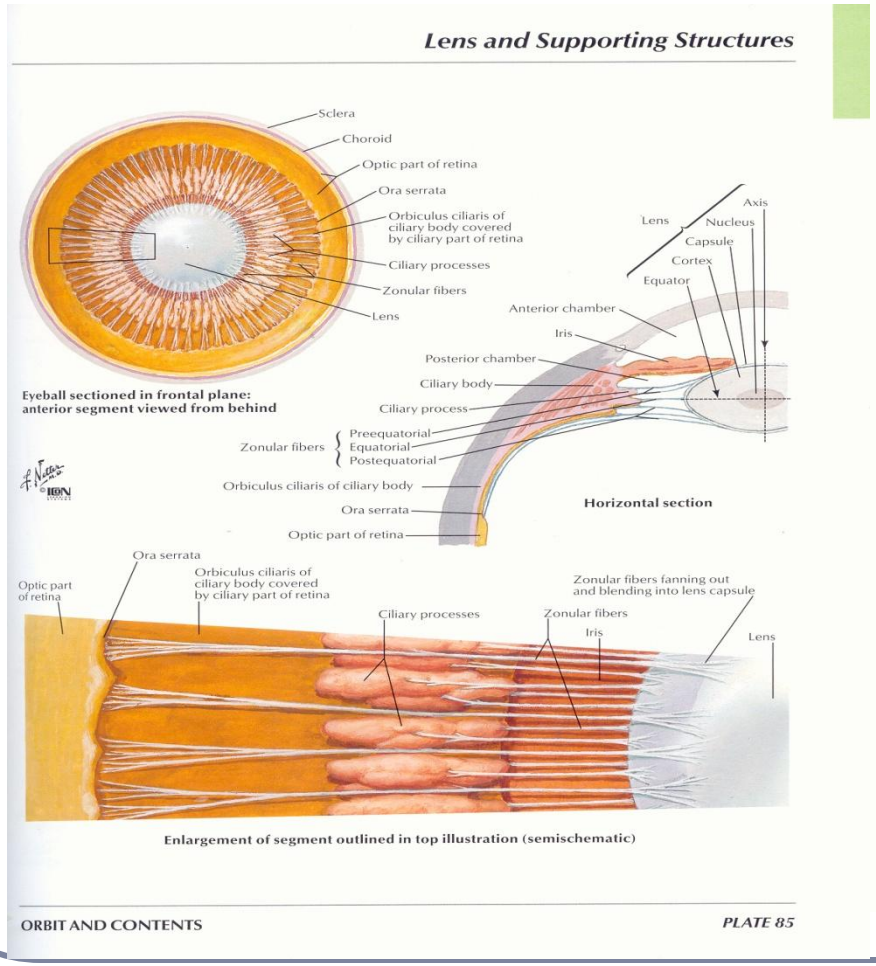
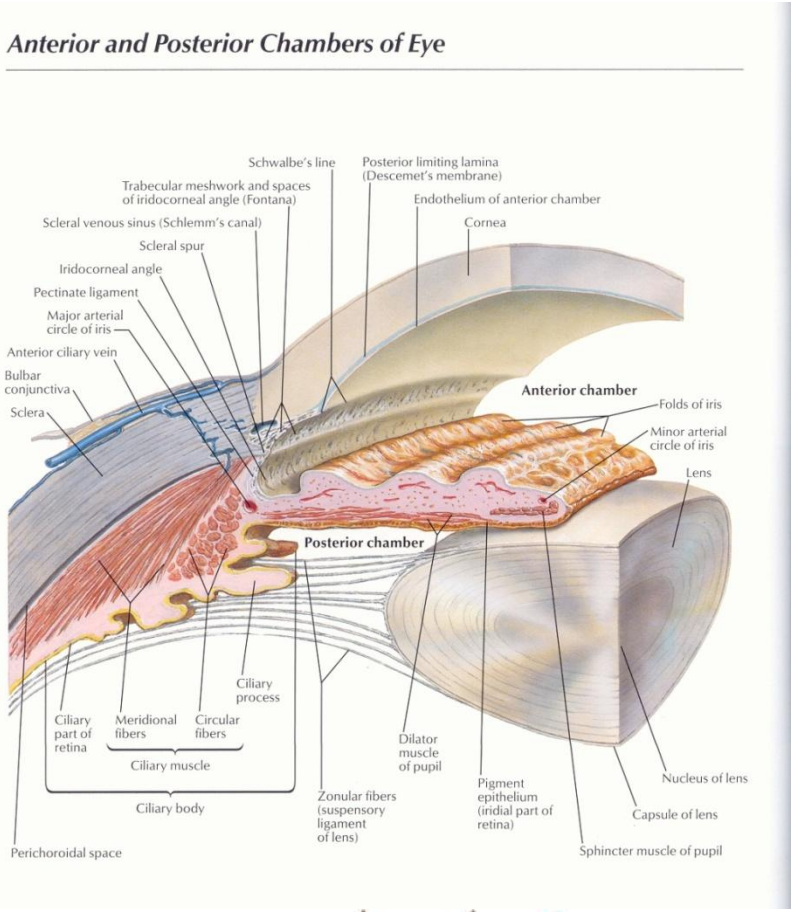
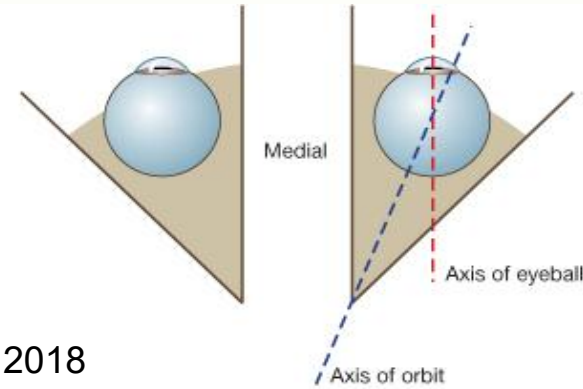
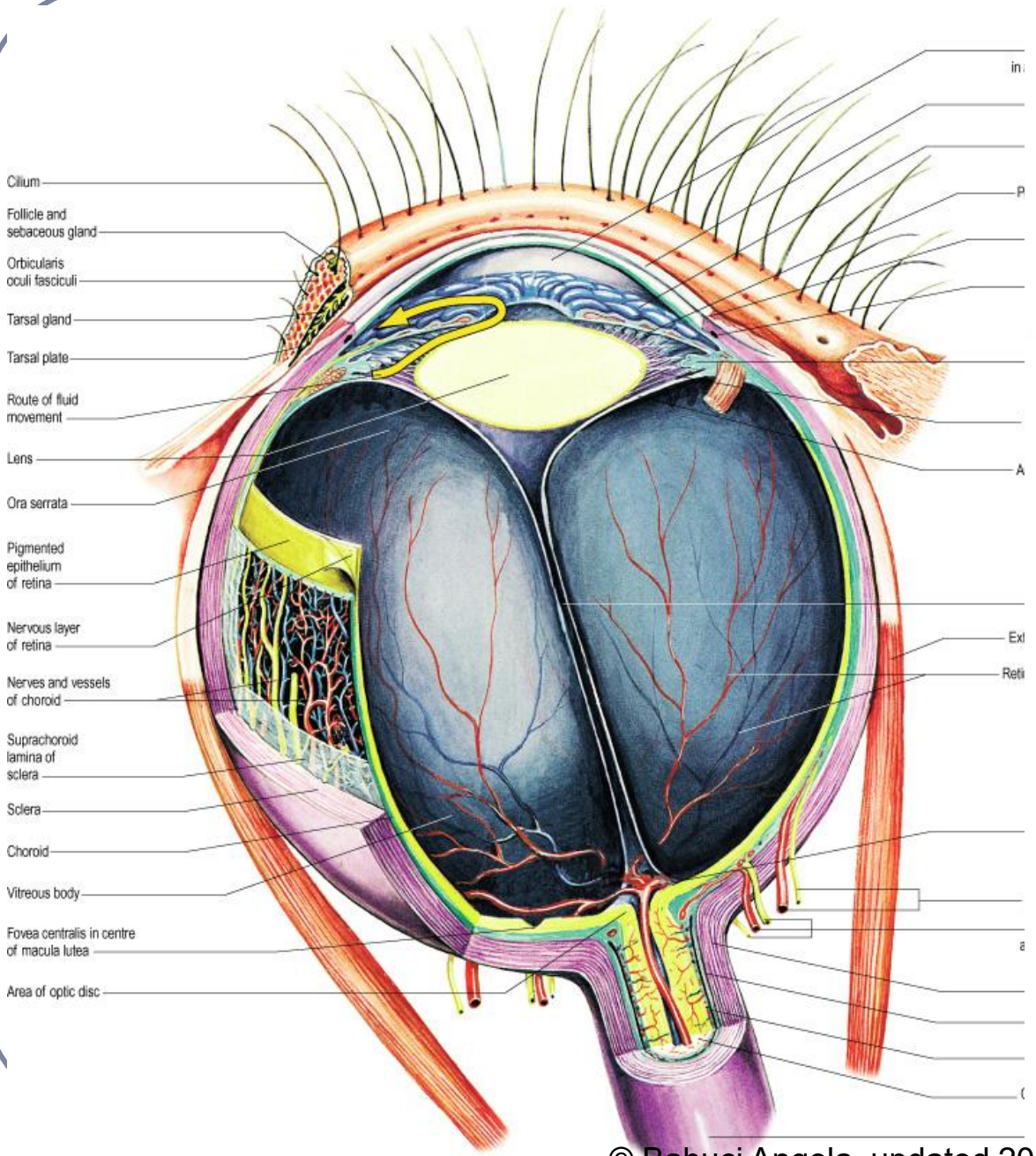


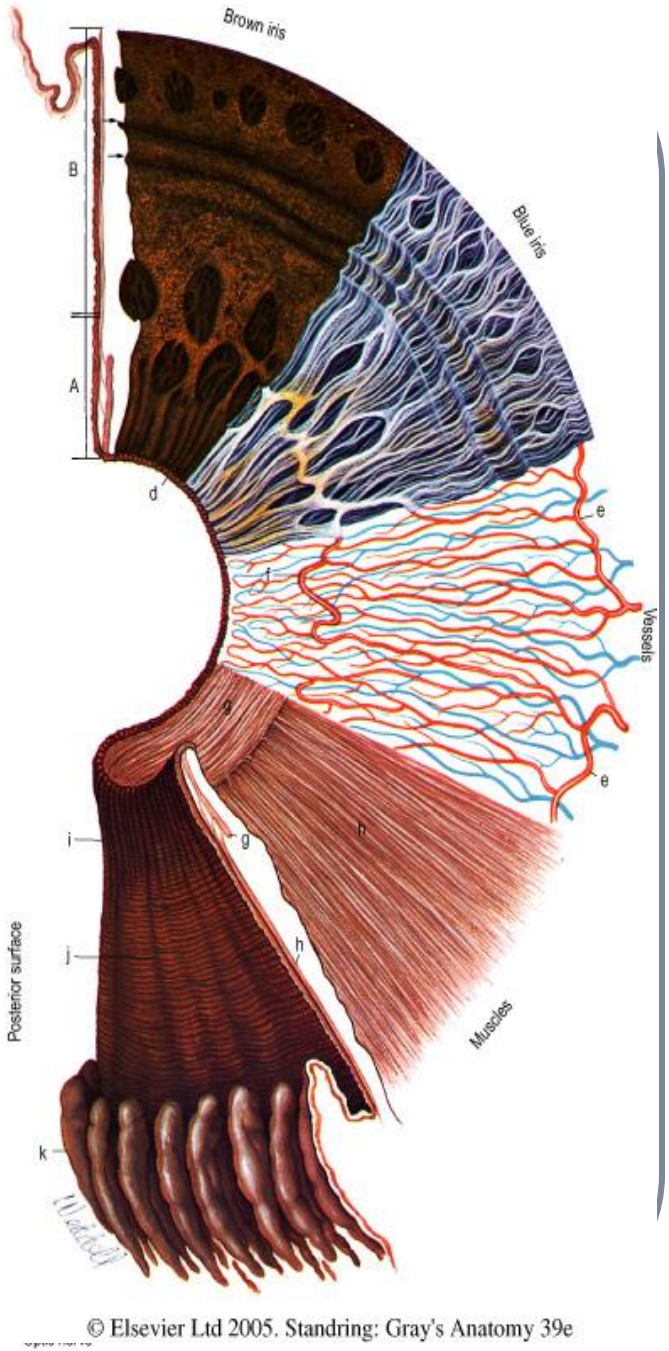
Structure of the ciliary body











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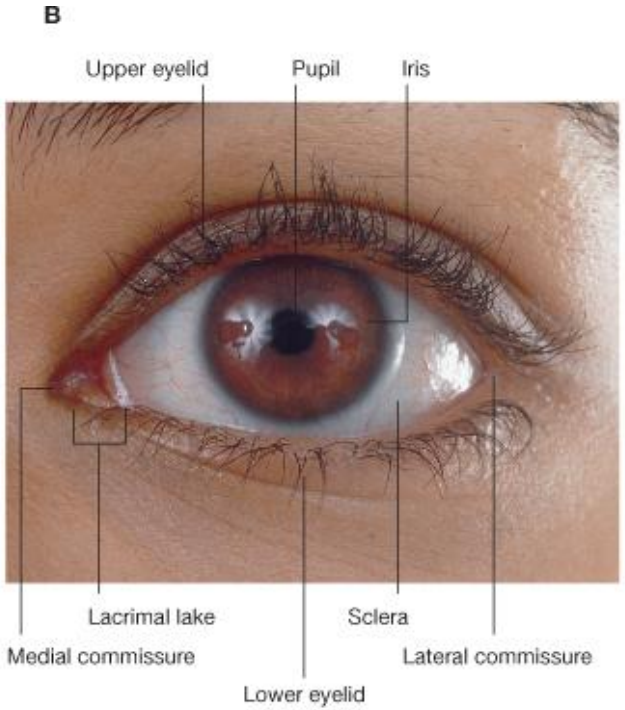
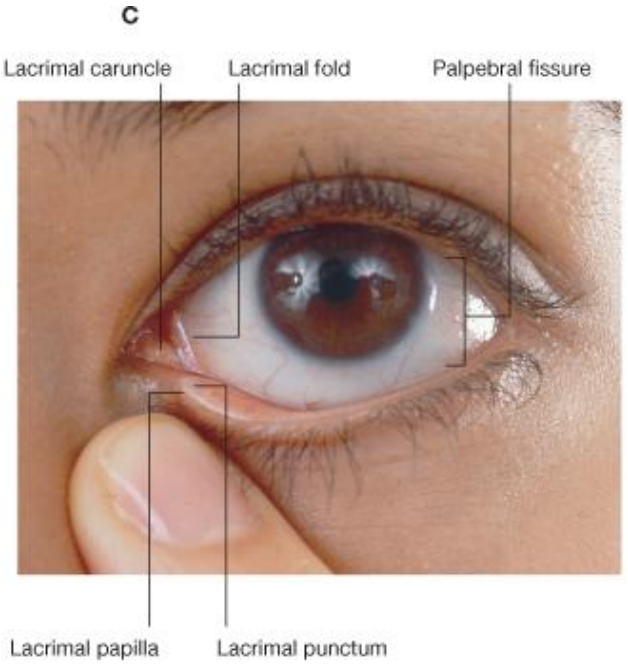
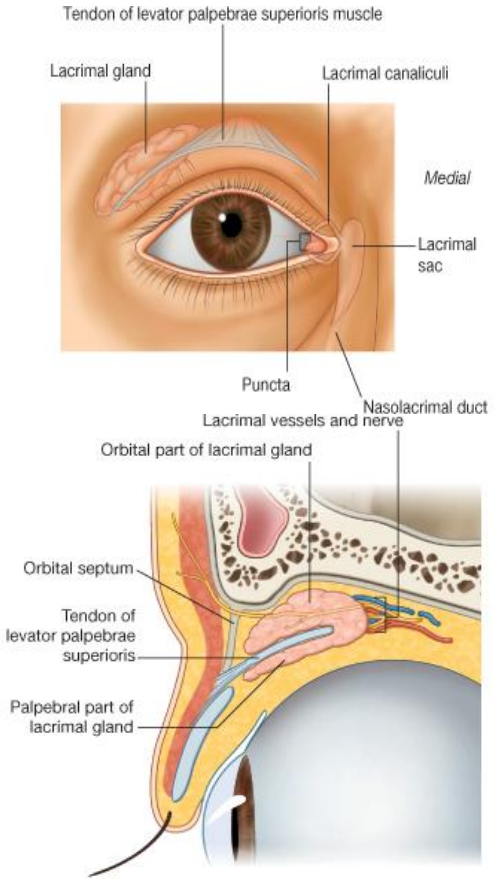
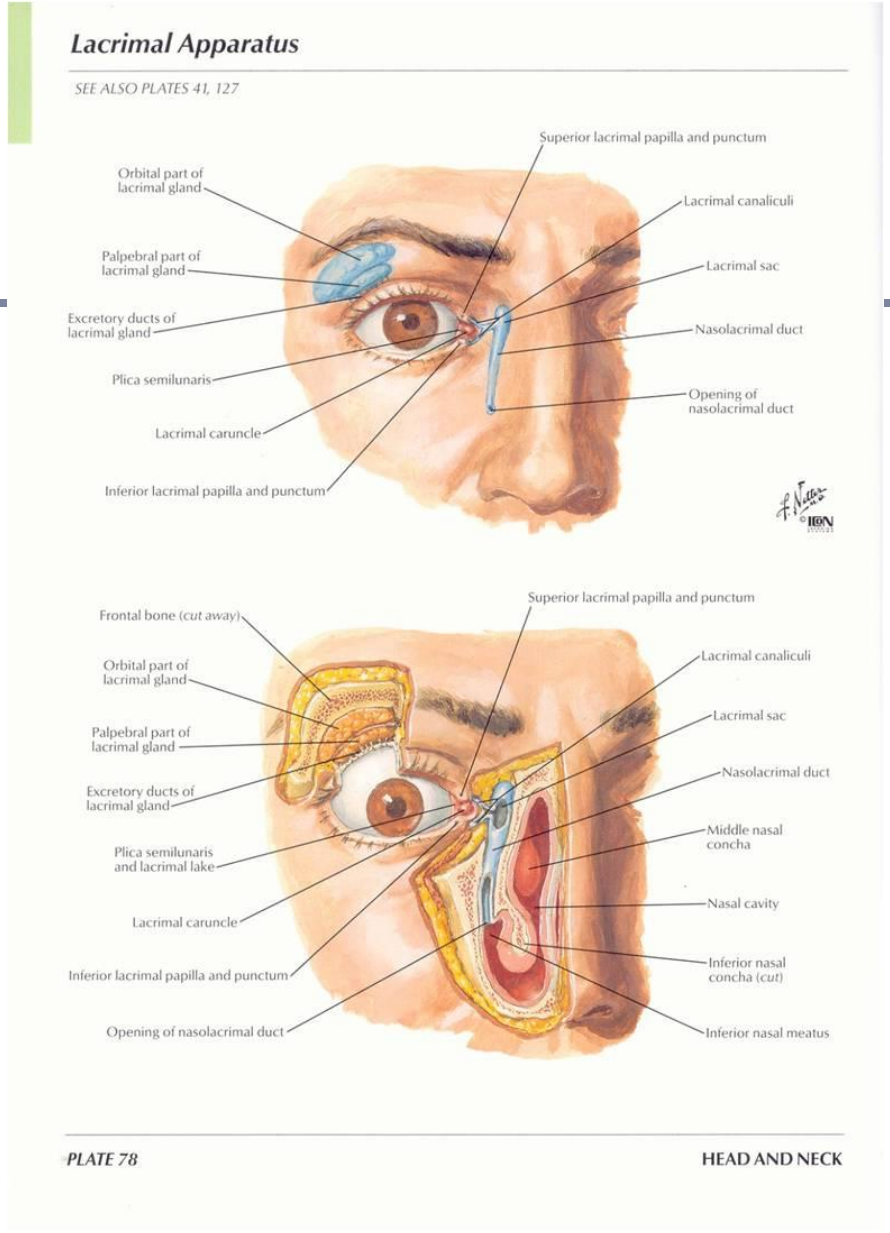
Auxiliary apparatus of the eye



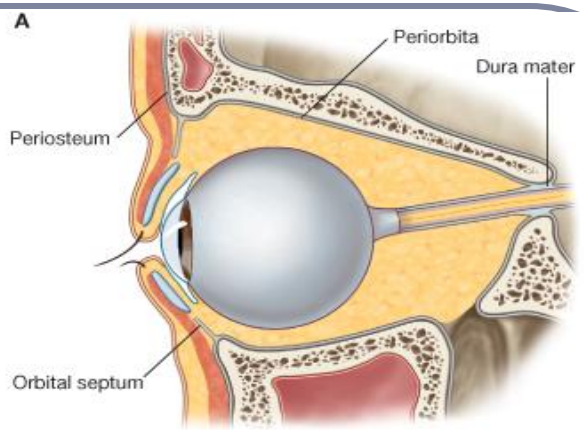


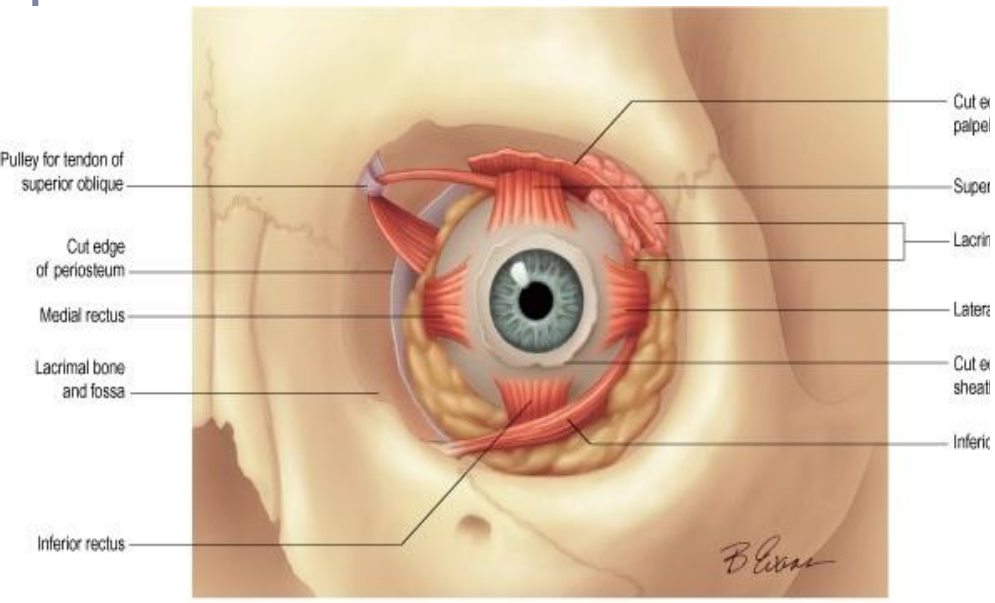
The lacrimal apparatus

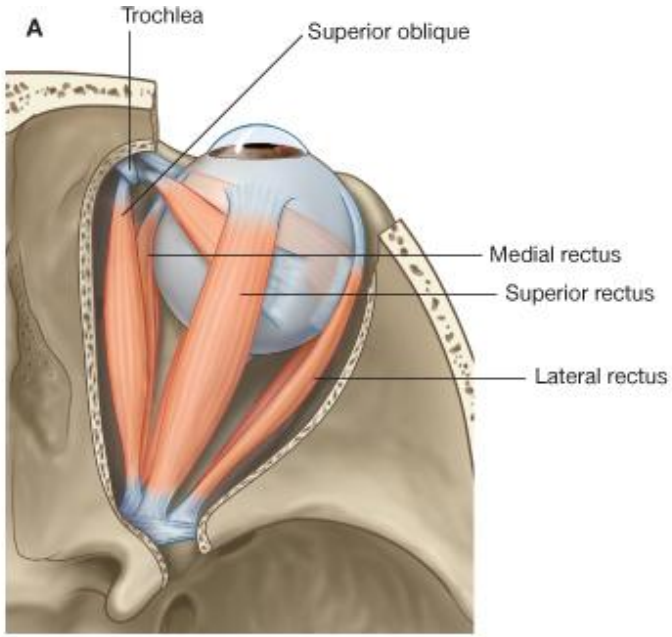




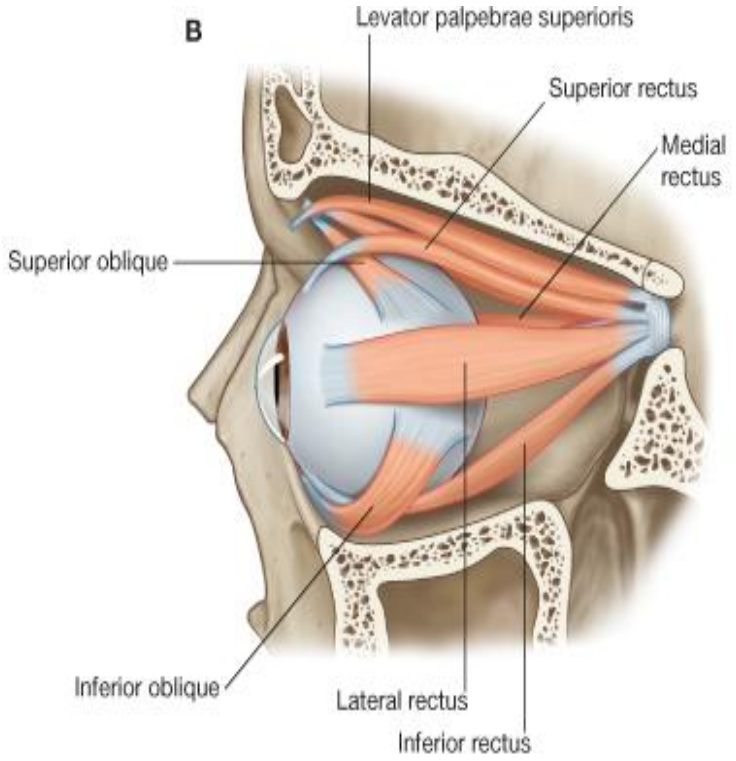
The striated muscles of the eye







Movement of the eye



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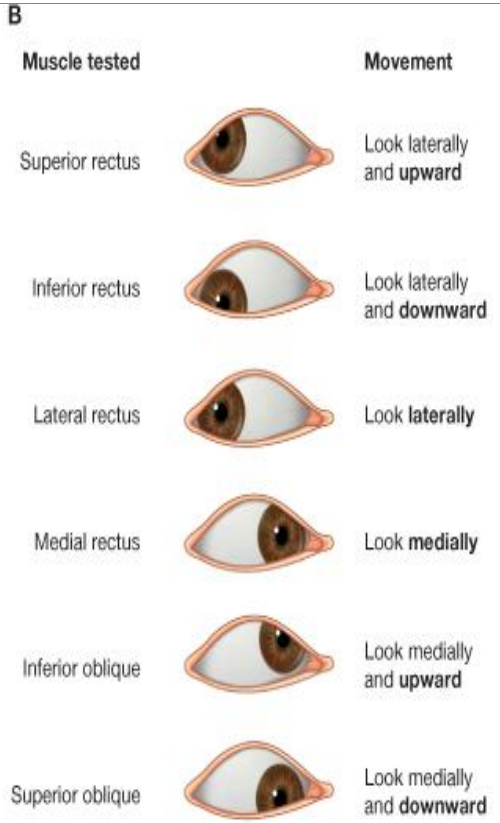

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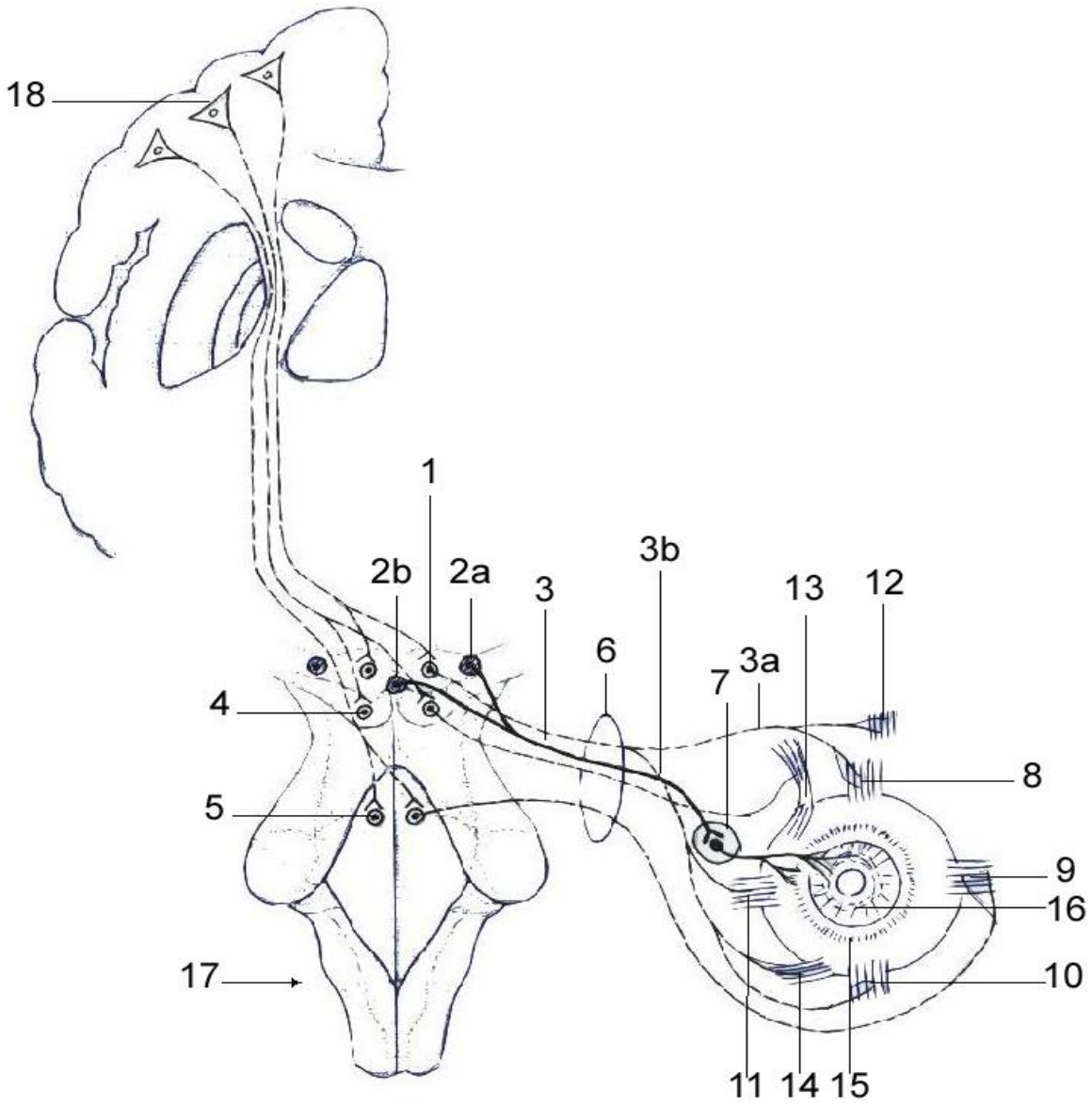
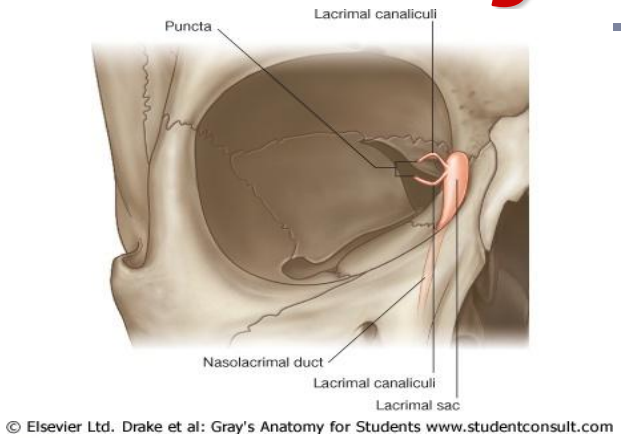
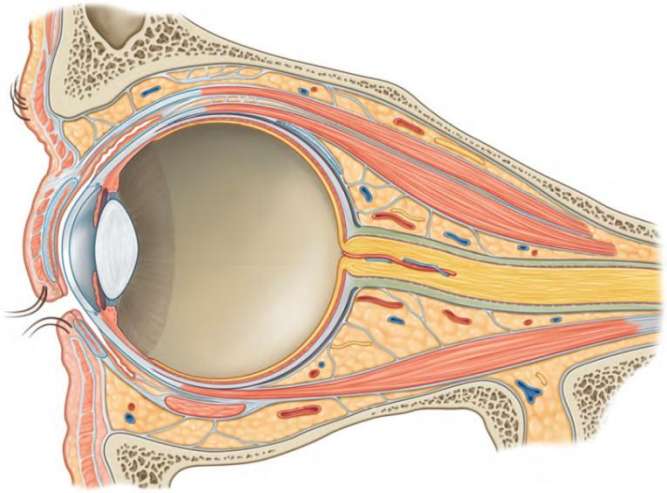
Innervation of the striated muscles of the eye



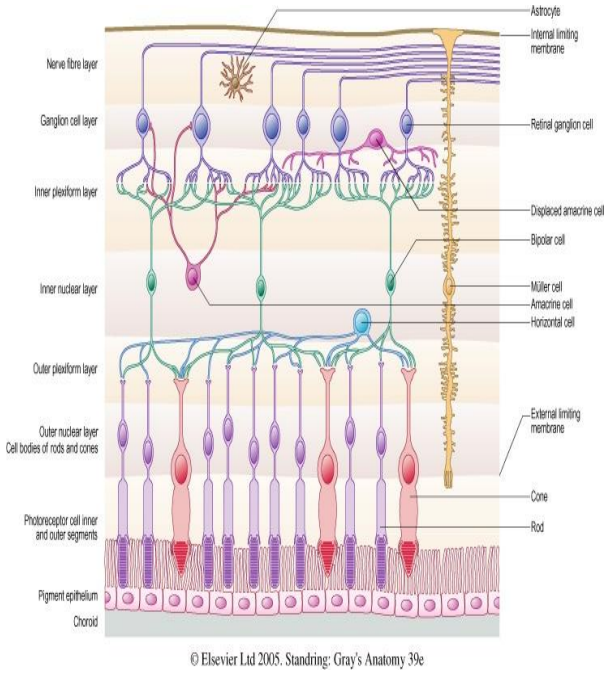
Auxiliary apparatus of the eye





- Outside the eye is enveloped by *fascia bulbi* (Tenon's capsule), separating it from the orbital fat, and forming a socket for the eyeball.
- The inner surface of the Tenon's capsule is loosely attached to the sclera by delicate bands of episcleral connective tissue.
- Posteriorly, it is traversed by ciliary vessels and nerves.
- It fuses with the sclera and with the sheath of the optic nerve where it enters the eyeball.
- The Tenon's capsuleis is strongly connected to the sclera posteriorly and at the level of the corneoscleral junction at the limbus.
- The *fascia bulbi* is perforated by the tendons of the extraocular muscles and it continues as muscular fascia.

Pathways of the optic analyser



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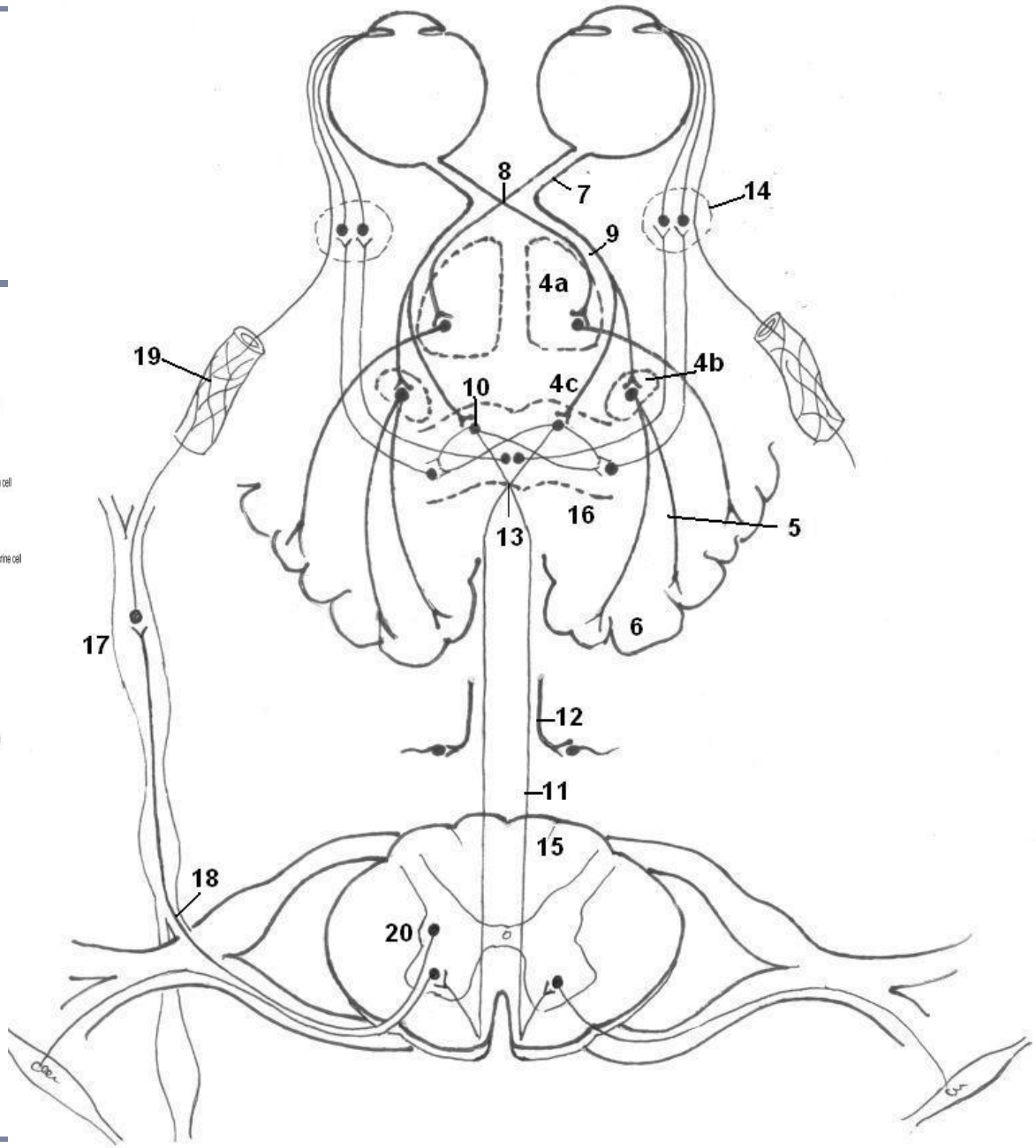

Examination of the fundus of the eye

- Fundus photograph of the right eye.
- The central retinal vessels are seen emanating from the optic disc.
- Retinal arteries are lighter in colour and narrower than the veins.
- The avascular centre of the macular region can be seen temporal (laterally) to the disc.

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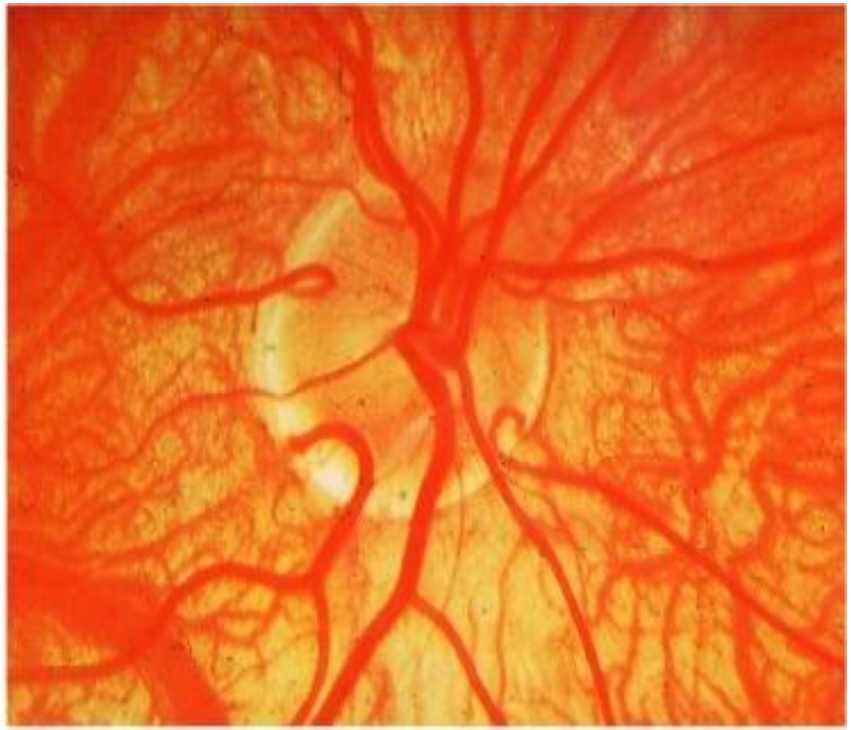
Gray‘s anatomy, 40th edition.

Examination of the eye

D



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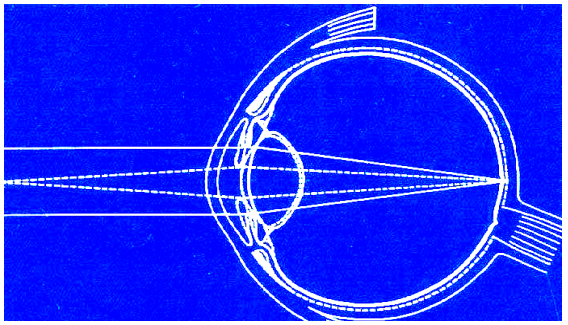
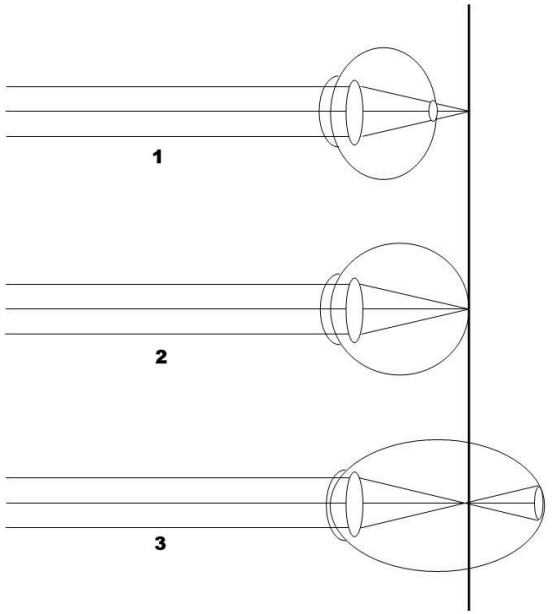
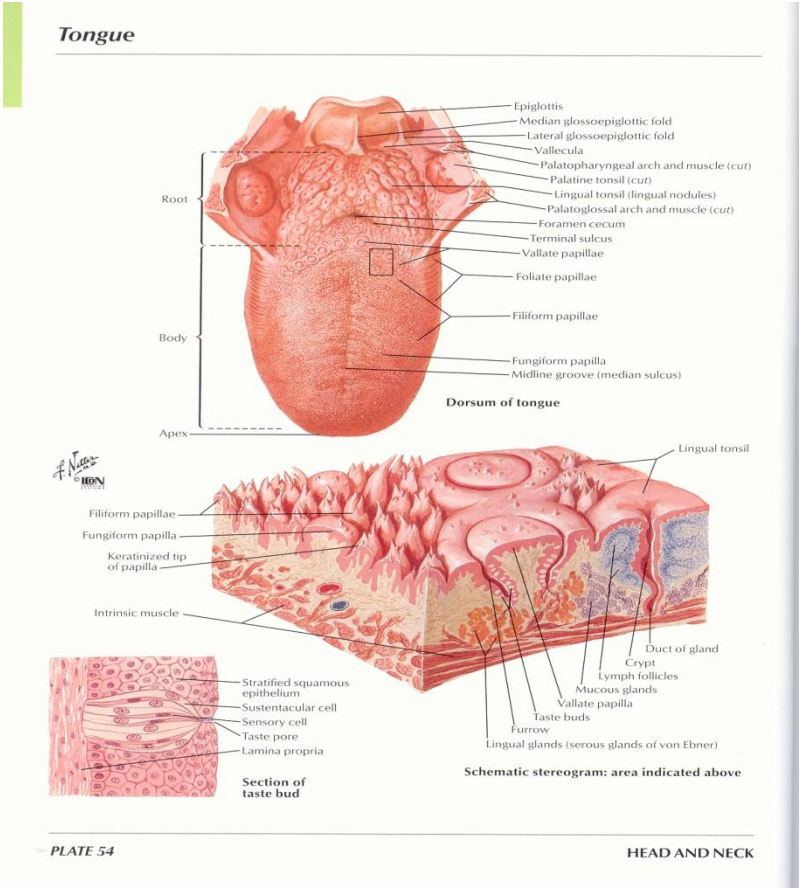
Refraction and functional impairments of the eye

- **Myopia** (nearsightedness) is an elongation of the eyeball that causes light waves to focus at a point in the vitreous body in front of the retina.
- **Hypermetropia** (farsightedness) is a condition in which the eye is too short.
- **Presbyopia** is a condition in which the lens tends to lose its elasticity and ability to accommodate.
- **Astigmatism** is a condition in which an irregular curvature of the cornea or lens of the eye is present.



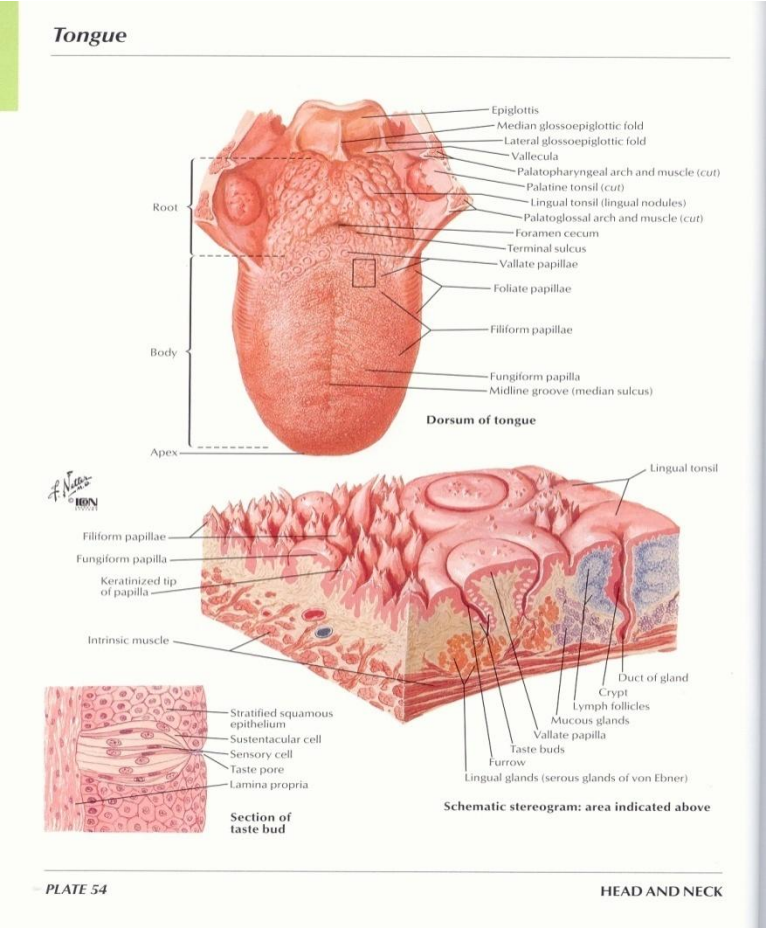


Organ of taste



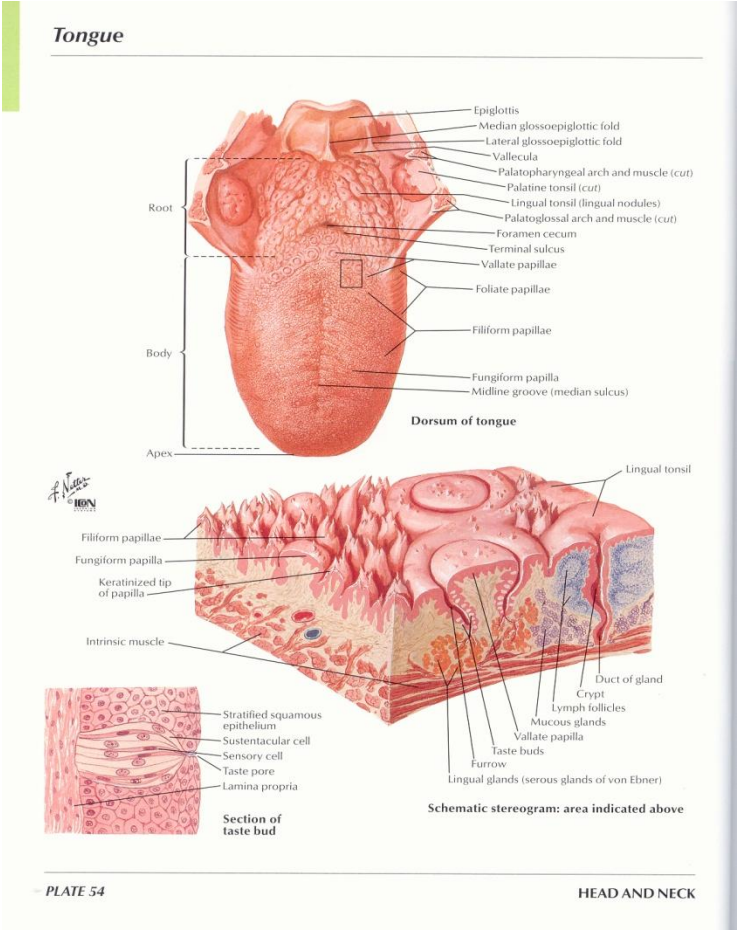
- The taste buds are found only in the *papillae vallatae, fungiformes* and *foliatae*. The *papillae conicae* and *filiformes* do not possess taste buds they accomplish only a mechanical function during mastication.
- Four basic modalities of taste are sensed most acutely in particular regions of the tongue.
- Sweet (tip of the tongue);
- Sour (sides of the tongue);
- Bitter (back of the tongue);
- Salty (over the most part of the tongue).

Organ of taste



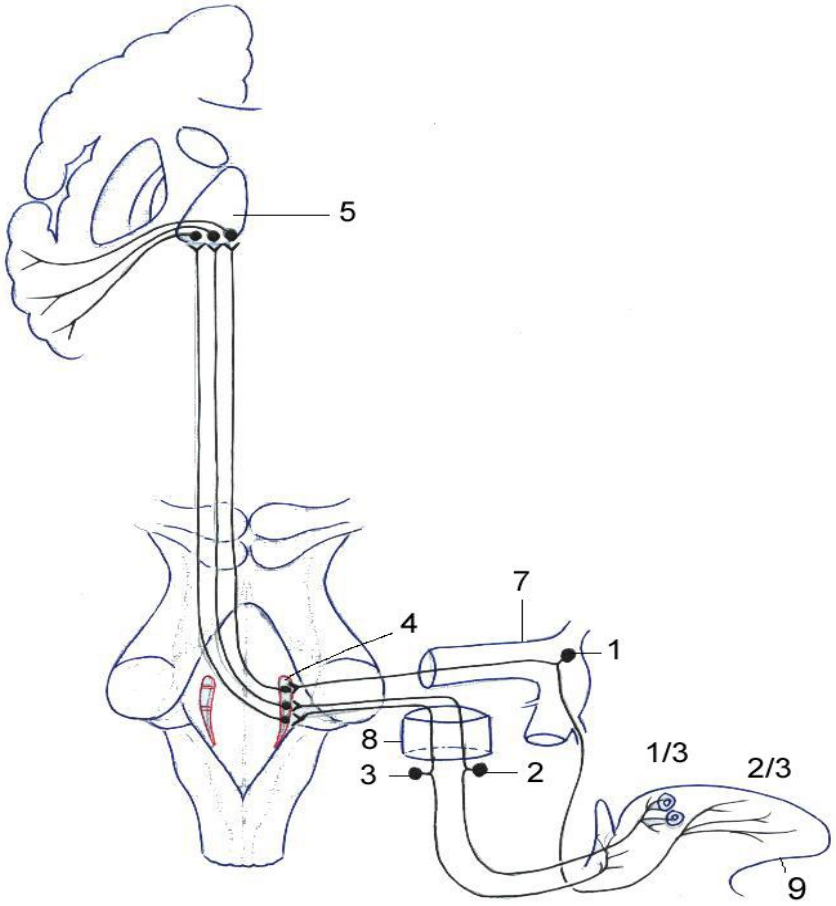
- Taste receptors are specialized epithelial cells that are grouped together into barrel-shaped arrangements called taste buds.
- Taste buds are most numerous on the surface of the tongue but are also present on the soft palate and walls of the oropharynx.

Organ of taste



- Taste buds are elevated by surrounding connective tissue and epithelium to form papillae.
- Fife types of papillae can be identified:
- ***Papillae vallatae***
- ***Papillae fungiformes***
- ***Papillae foliatae***
- ***Papillae conicae***
- ***Papillae filiformes***

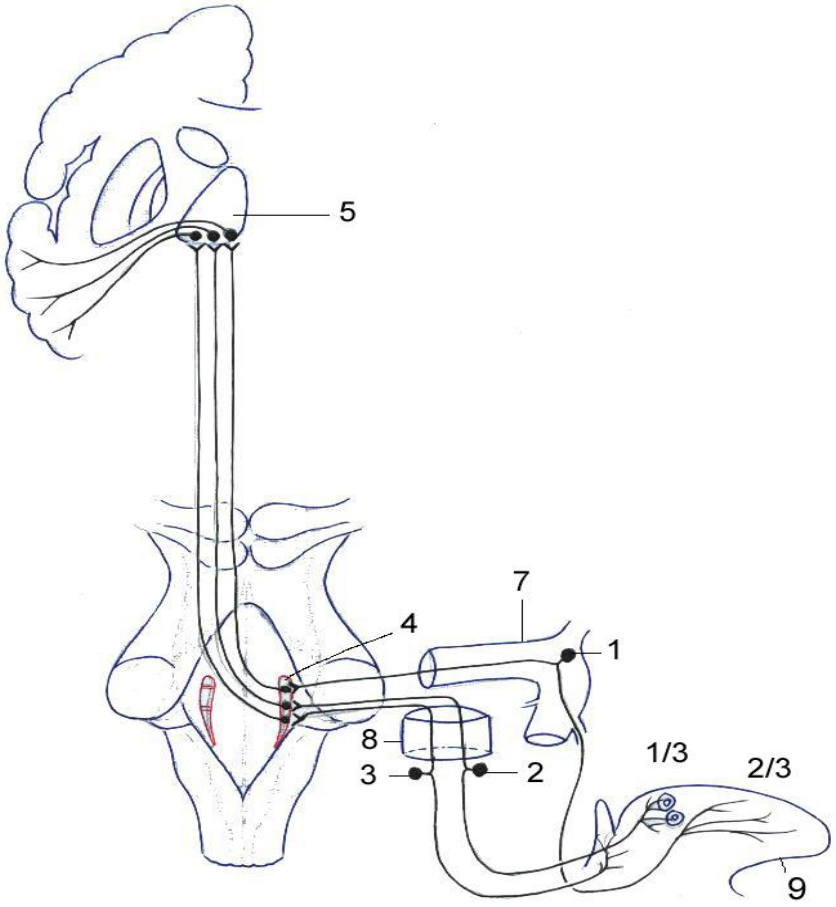
Pathways of the taste analyser



- From the taste receptors the nervous impulse is conducted towards the brain.
- The **first neuron** is contained in the ganglia of the afferent nerves of the tongue.

  The nerves conducting the sense of taste in man are:
- The ***chorda tympani*** nerve, which is a branch of the facial nerve that innervates the anterior two-thirds of the tongue.
- The ***lingual branches*** of the glossopharyngeal nerve, that innervate the posterior third of the tongue;
- The ***pharyngeal branches*** of the glossopharyngeal nerve that supply the soft palate and the palatine arches.
- The ***laryngeus superior nerve,*** which is a branch of the vagus nerve and it supplies the epiglottis.

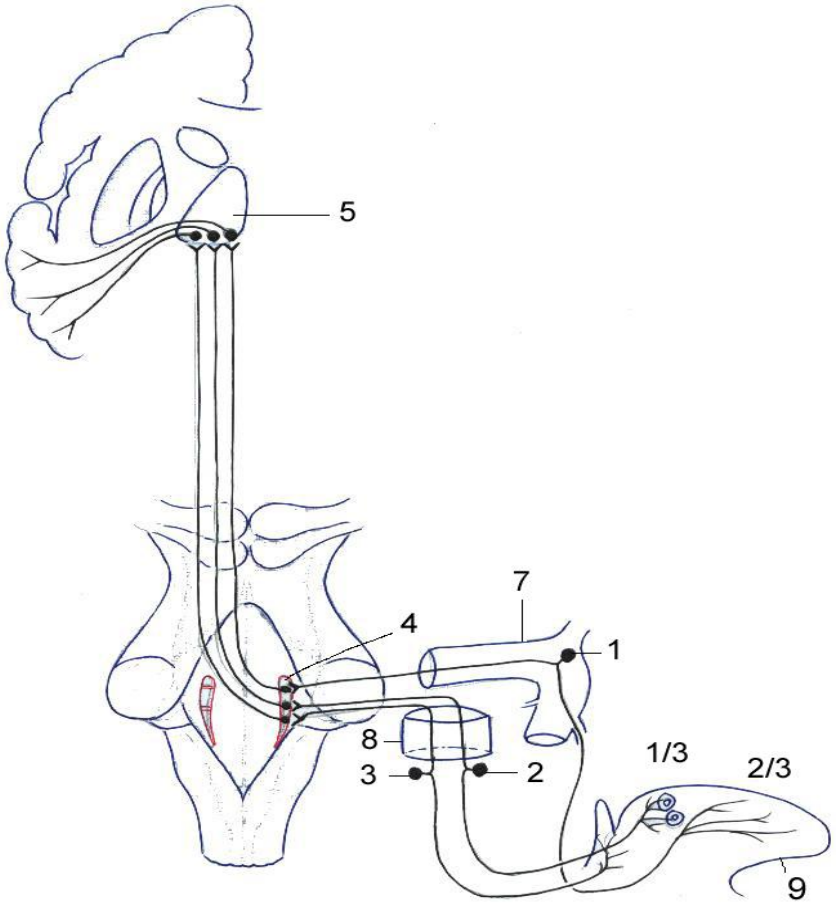
Pathways of the taste analyser



Location of the first neuron

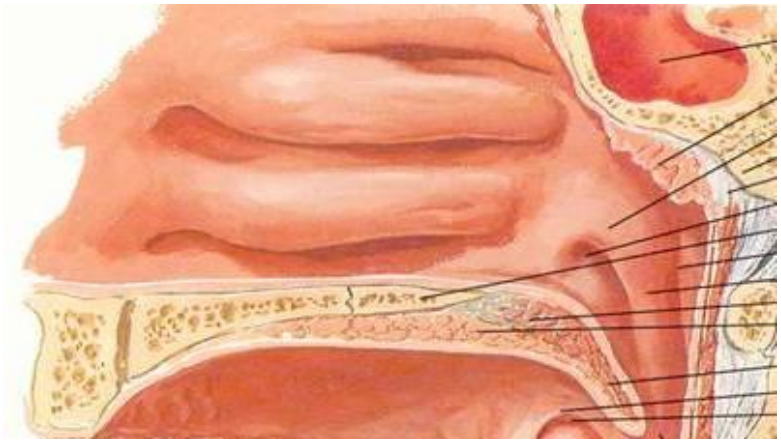
- The **ganglion of the facial nerve** (ganglion geniculi). The peripheral processes of this ganglion run as part of the *chorda tympani* to the anterior two-thirds of the tongue and the central processes pass as part of sensory root of the facial nerve (*n. intermedius*) into the medulla oblongata.
- The **inferior ganglion of the glossopharyngeal nerve**. The peripheral fibers of the cells of this ganglion run as part of the lingual branches, tonsilar branches of the glossopharyngeal nerve, where they come into contact with the receptors. The central processes pass as part of this nerve into the pons.
- The **inferior ganglion of the vagus nerve**. As a part of the superior laryngeal nerve the peripheral processes of the cells of this ganglion, run to the medulla oblongata.

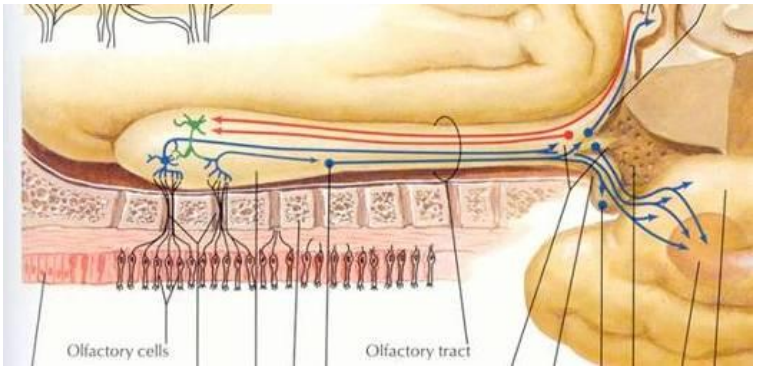
Pathways of the taste analyser



- All above mentioned taste fibers end in the medulla oblongata and in the pons, **in the nucleus of the tractus solitarius**, where the **second neuron** is located.
- The processes of the second neurons ascend from the medulla oblongata and pons to the thalamus, where the **third neuron** is located and from here it extends to the cortical end of the taste analyzer.
- The **taste analyzer** ends in the cortex of the ***parahypocampal gyrus*** in the ***uncus*** and in the ***cornu ammonis*** near to the olfactory centers, as well partially it ends in the inferior part of the ***postcentral gyrus***.

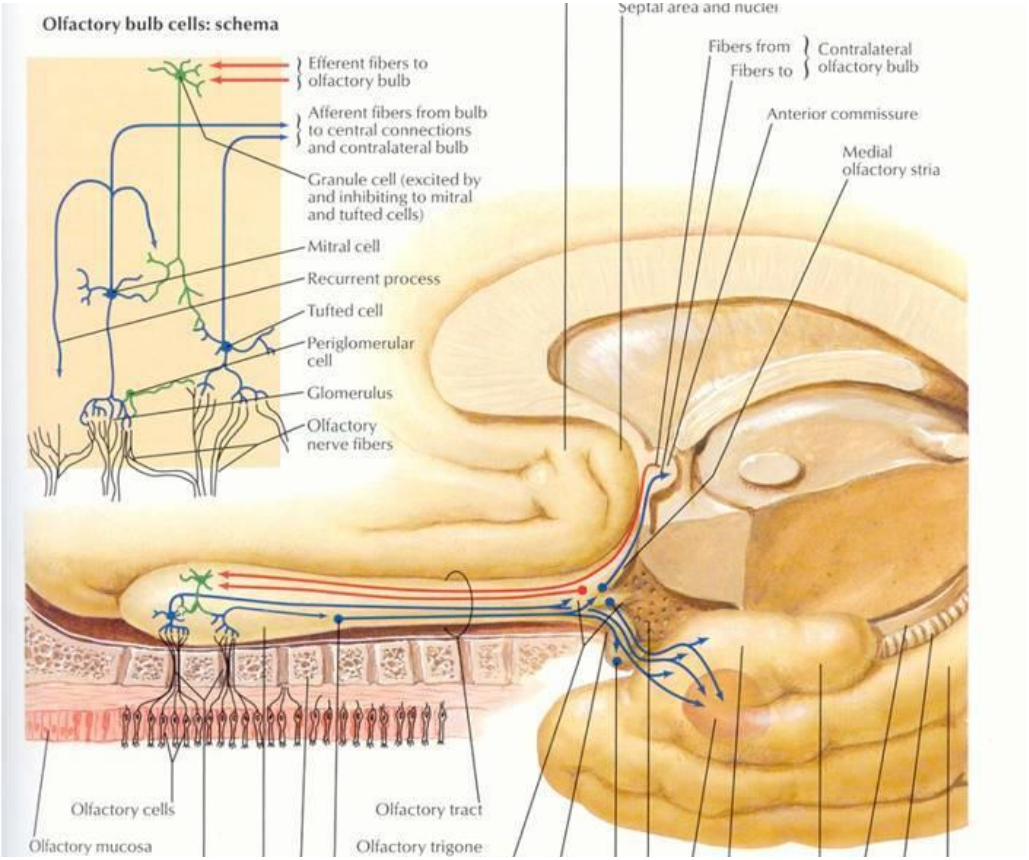
Pathways of the olfactory analyser





- The **olfactory region** in man is placed at the level of the superior nasal conchae and on the opposite part of the nasal septum. In this region are located the **olfactory neuroreceptor cells**, which form the body of the **first neuron**.
- The olfactory receptors are the dendritic endings of the olfactory nerves in association with epithelial supporting cells of the nasal epithelium within the roof of the nasal cavity (the olfactory region).

Pathways of the olfactory analyser



From the nasal cavity the olfactory nerves (there are about 16-20 olfactory nerves, named *fila olfactoria*), enter the cranial cavity through the *cribriform plate* of the ethmoid bone.

In the olfactory bulb the olfactory nerves form synapses with the **mitral cells**, which represent the body of the **second neuron**. The axons of the mitral cells continue within the olfactory tract, olfactory triangle.

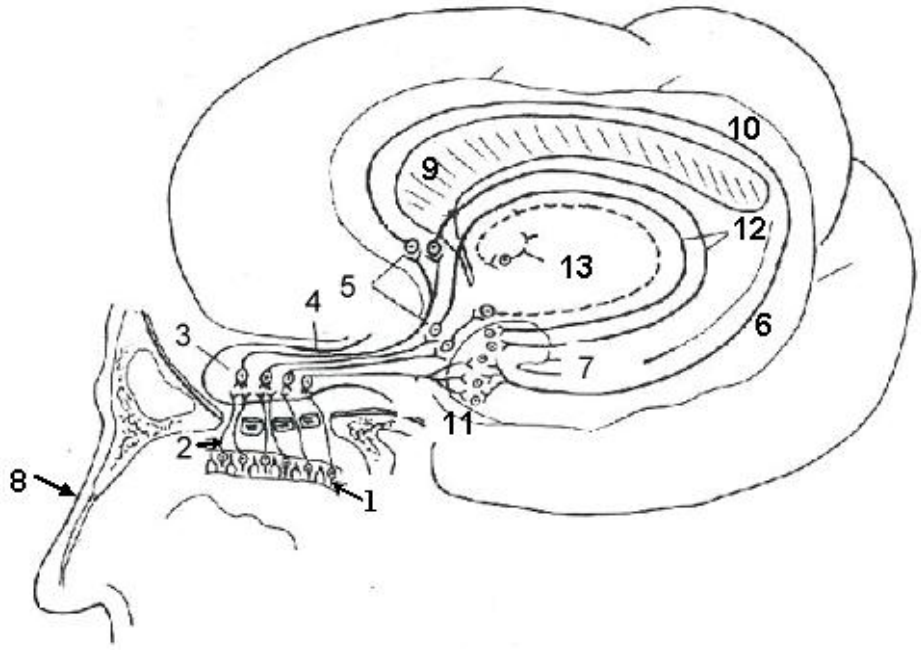
On the neurons of the *trigonum olfactorium* ends a part of fibers of the olfactory tract. Here the olfactory tract forms three olfactory striae:

a) stria olfactoria lateralis

b) stria olfactoria intermedia

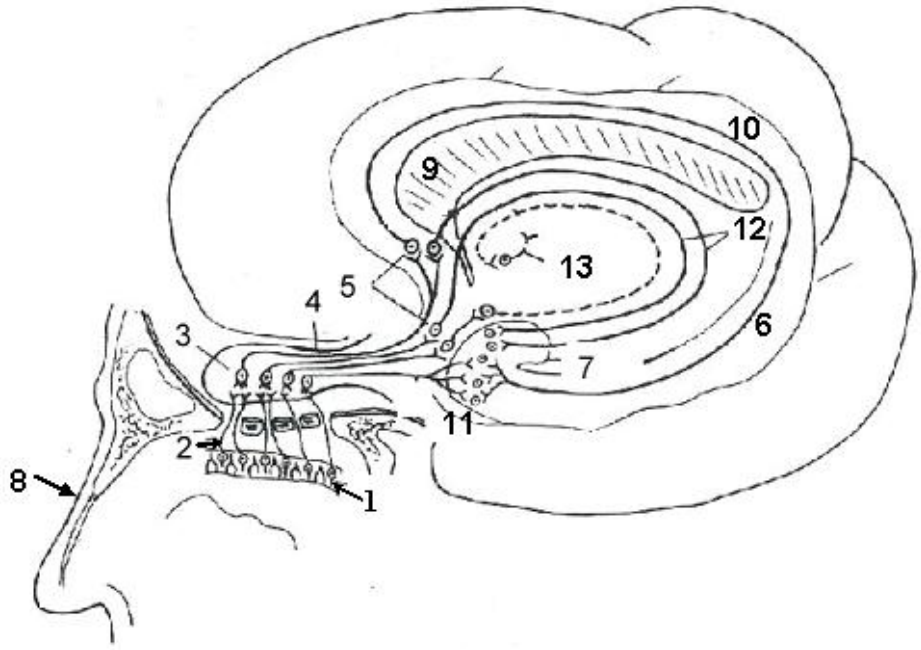
c) stria olfactoria medialis.

Pathways of the olfactory analyser



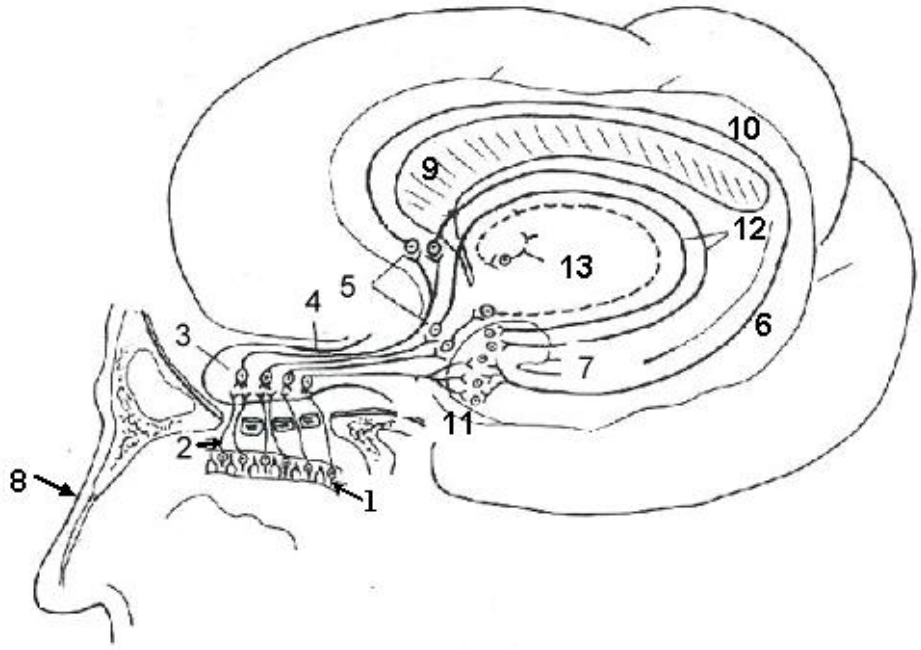
- The fibers of the named olfactory striae by different ways, reach the cortical end of the olfactory analyser – the **uncus**.
- When the olfactory striae rich the *trigonum olfactorium* and the *anterior perforated substance* they form synapses with the body of the **third neuron** that is located at this level for the most part of fibers of the olfactory striae.
- Then the fibers pass through the *septum pellucidum, fornix, the parahypocampal gyrus* and rich the *uncus*, where is located the cortical end of the olfactory analyser.

Pathways of the olfactory analyser



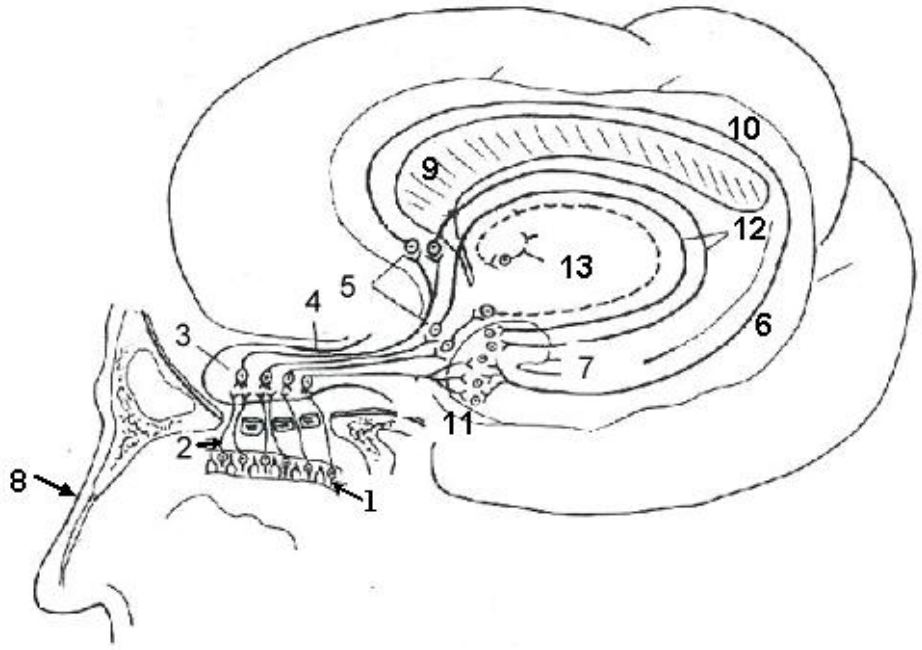
- The axons of the **mitral cells** that form the **lateral olfactory stria** (the thickest one) continue its way backward by sending a part of its fibers to the **uncus**, and another part to the **amygdaliod body**, where they form a synapse with the body of the **third neuron** and then enter the *fimbria hyppocapi, the fornix* to rich the *mamillary bodies*. From the mamillary bodies they continue within the **mamillothalamic tract,** or tract of Vicq d 'Azyr.

Pathways of the olfactory analyser



- The **intermediate olfactory stria** a part of its fibers ends on the neurons of the *anterior perforated substance* on the ipsilateral side.
- Another portion of fibers of the intermediate olfactory stria runs through the *anterior cerebral commissure* to the opposite side, where they also end on the neurons of the anterior perforated substance.
- Axons of the neurons of the anterior perforated substance run through the *septum pellucidum* to the *fornix*, than they pass through the *fimbria hyppocampi* and reach the **uncus**.

Pathways of the olfactory analyser



- The **medial olfactory stria** reaches the *area subcallosa* and here it separates into two bundles of fibers. One bundle runs through the *septum pellucidum, fornix, fimbria hyppocampi* and reaches the **uncus**.
- Another part of fibers of the medial olfactory stria runs within the *gyrus fornicatus* and then through the *gyrus fasciolaris, gyrus dentatus* ends in the **uncus**.

Development of the ear

- In the 3rd week of embryonic life appears the auditory vesicle.
- The germ of the labyrinth forms from the ectoderm on both sides of the posterior cerebral vesicle.
- By the end of the 4th week the endolymphatic duct and the semicircular canals grow on it.
- From the upper part of the auditory vesicle forms the utriculus, from the lower part – sacculus and the narrow part between them transforms into the utriculosaccular duct.
- In the 5th week on the anterior segment of the auditory vesicle appears the cochlear duct with the organ of Corti.
- From the mesenchyme adjoining the membranous labyrinth develops the perilymphatic space.
- In the six month the osseous labyrinth forms.
- The middle ear: tympanic cavity with auditory tube – from pharyngeal pouches and lateral wall of the pharynx.
- Epithelium of the middle ear – from entoderm.
- The auditory ossicles – from the cartilage of the first (malleus and anvil) and second (stirrup) visceral arches.
- The external ear – from the first branchial pouch.

Abnormalities of the ear

- Congenital deafness, usually associated with deaf – mutism.
- Most forms of congenital deafness are caused by genetic factors.
- Rubella virus, affecting the embryo in the seventh or eighth week, may cause severe damage to the organ of Corti.
- The poliomyelitis, *erythroblastosis fetalis*, diabetes, hypothyroidism, and toxoplasmosis can cause congenital deafness.

Abnormalities of the ear

- External ear defects are common and they include minor and severe abnormalities.
- The shape of the auricle varies widely in children with chromosomal syndromes causing mental deficiencies and the external auditory canal does not develop in those children, producing a condition called atresia of the external auditory canal.
- Preauricular appendages and pits are skin tags and shallow depressions, respectively, anterior to the ear.

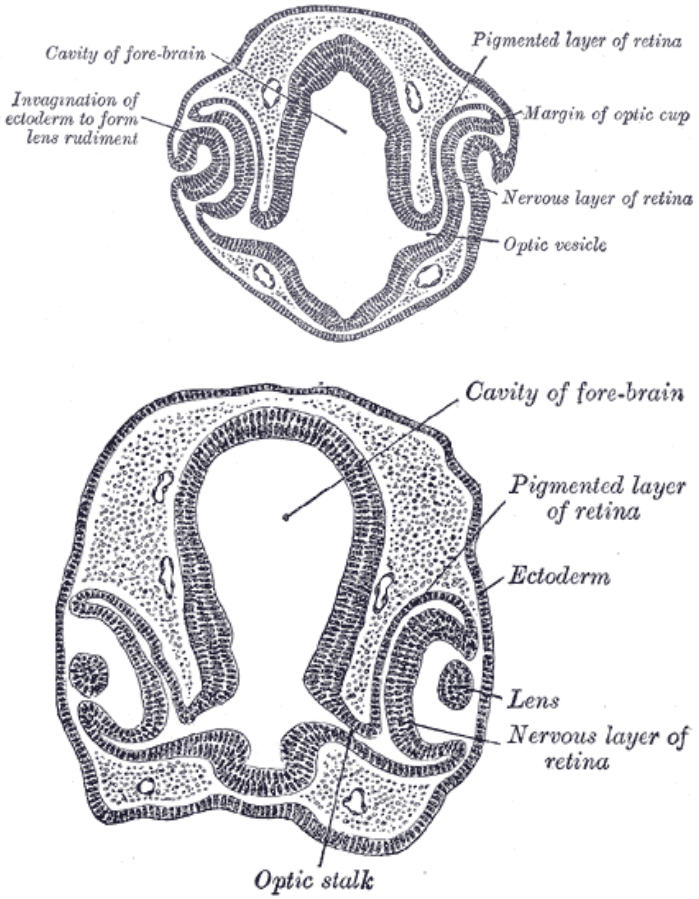
Abnormalities of the ear

- The auricles might be severely deformed, have a crumpled appearance and are often wrongly positioned.
- In a third of patients the external auditory meatus is absent, and there may be ossicular defects which result in conduction deafness.

Congenital defects of the auricle

Development of the eye

- From the 4th week to the 10th one.
- The eye begins to develop as a part of the optivc vesicles on each side of the forebrain.
- Optic vesicles are outgrowings of the brain which make contact with the surface ectoderm .
- Both ectodermal and endodermal tissues contribute to formation of the eye.
- The eye derives from the neuroepithelium, surface ectoderm, and the extracellular mesenchyme which consists of both the neural crest and mesoderm.
- Neuroepithelium forms the retina, ciliary body, iris, and optic nerves.
- Surface ectoderm forms the lens, corneal epithelium and the eyelid.
- The extracellular mesenchyme forms the sclera, cornea, blood vessels, muscles and the vitreous body.



Abnormalities of the eye

- **Microphthalmia** the eye is too small.
- **Aniridia** (absence of the iris).
- The **iridopupillary membrane** may persist instead of being resorbed during formation of the anterior chamber.
- There may be various eye anomalies, including **colobomas** affecting the lateral third of the lower eyelid (75% of cases) and **microphthalmia**.
- **Congenital aphakia** (absence of the lens).
- The **hyaliod artery** may persist to form a cord or cyst.

Anophthalmos and cryptophthalmos

Cyclopia (single eye) and synophthalmia (fusion of the eyes)

Cyclopia. S.S. Gellis and M. Feingold. Atlas of Mental Retardation Syndromes. 1968.

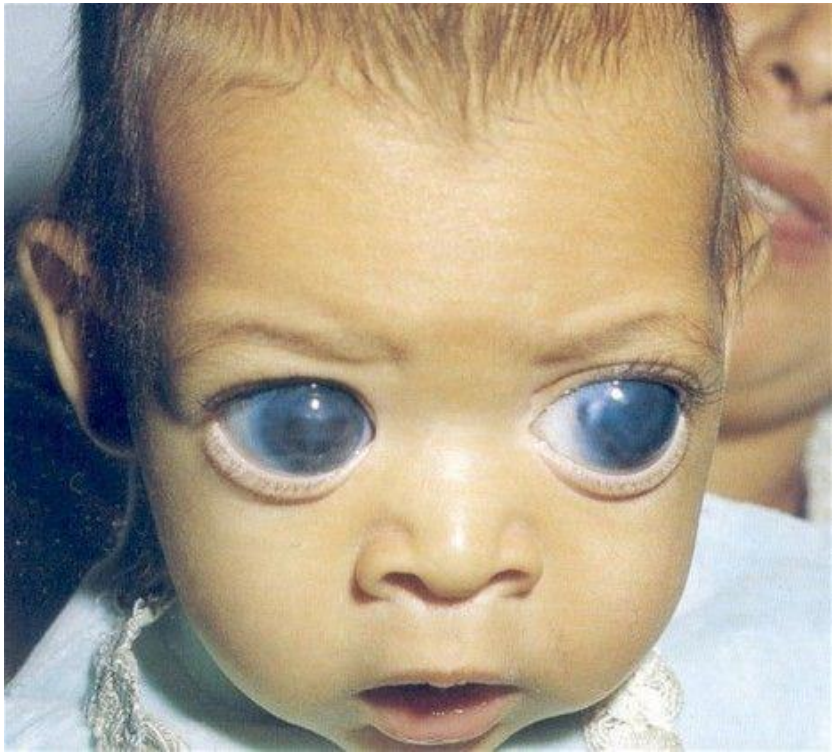
Figura 3. Foto del recién nacido. Se observa ojo único central, con probóscide, confirmando la etmocefalia.

Heterochromia of the iris

Heterochromia of the iris

Abnormalities of the eye

Congenital glaucoma



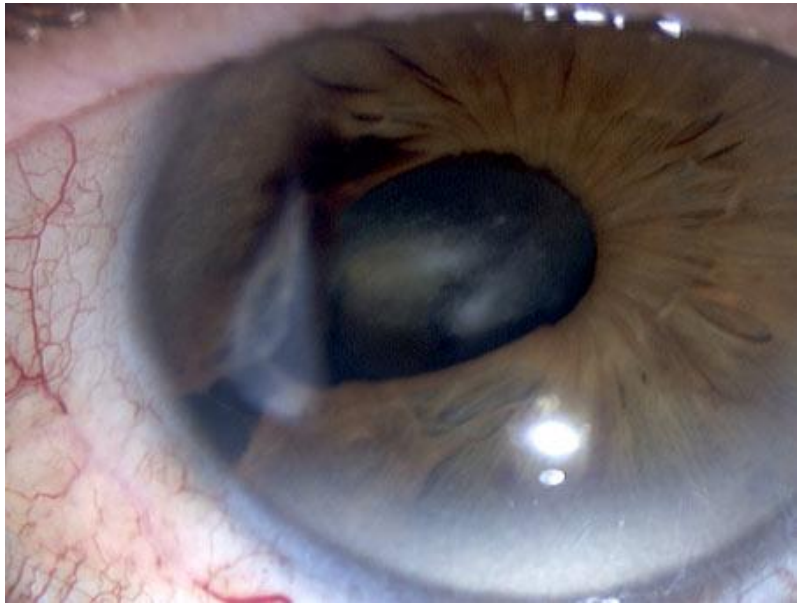
In congenital cataracts the lens become opaque during intrauterine life.

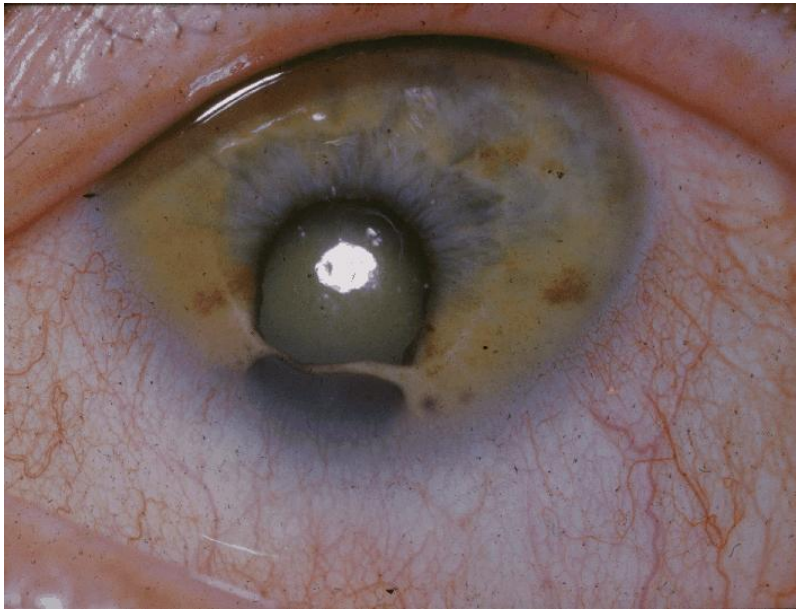
Albinismus

Albinismus

Coloboma of the iris or cat eye

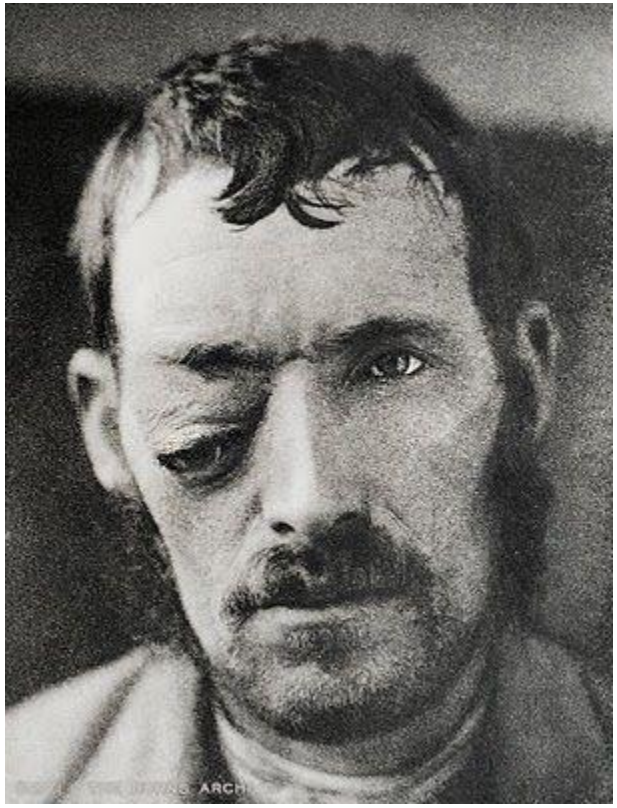
Coloboma may occur if the choroids fissure fails to close





Deformities of the eyelid

Orbital absence with displacement of eye



Double eye

Neurofibromatosis

(this photograph was published in 1871 in America's medical photographic journal)

Retinoblastoma