Practical classes 13: SENSE ORGANS

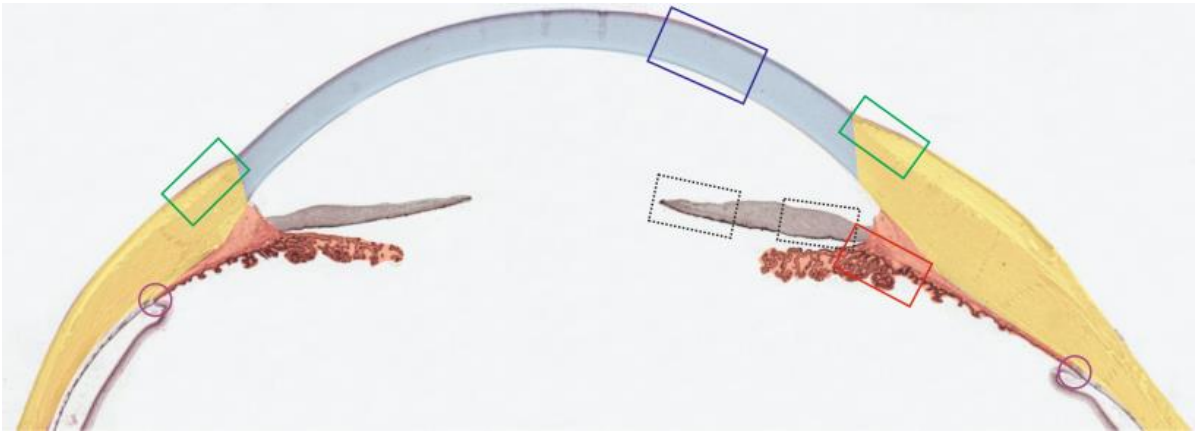
ANTERIOR SEGMENT OF THE EYE

The eye is the most important sensory organ that conveys our vision. Through the eye, we perceive the image of the surrounding world through light that is projected onto the light-sensitive retina. In terms of its structure, the eye is the most complex sensory organ. The wall of the eyeball is made up of three concentric layers. The outer layer, the fibrous coat, differentiates into the sclera and cornea. The middle layer of the eyeball wall is the vascuar coat (uvea). This is a layer composed of loose connective tissue containing numerous blood vessels and melanocytes. These pigment cells, together with the retinal pigment epithelium, form a black chamber inside the eye that prevents light reflection. The portion of the uvea from the optic nerve exit to the ora serrata is referred to as the choroid. In the inner layer of the eyeball, the nervous coat, lies the retina. Its anterior part covering the ciliary body and the posterior surface of the iris is double-layered and forms the blind part of the retina, as it lacks photoreceptors and nervous cells. The optic part of the retina extends from the ora serrata to the papilla of the optic nerve. The optic nerve fibres convey information from the eye to the brain for further processing.

Due to the size of the eye, we present the tissues of the eye on two slides; the lens and vitreous body are usually damaged and removed during processing. The most important structures include the cornea, the sclera, the ciliary body, the iris, and the blind portion of the retina.

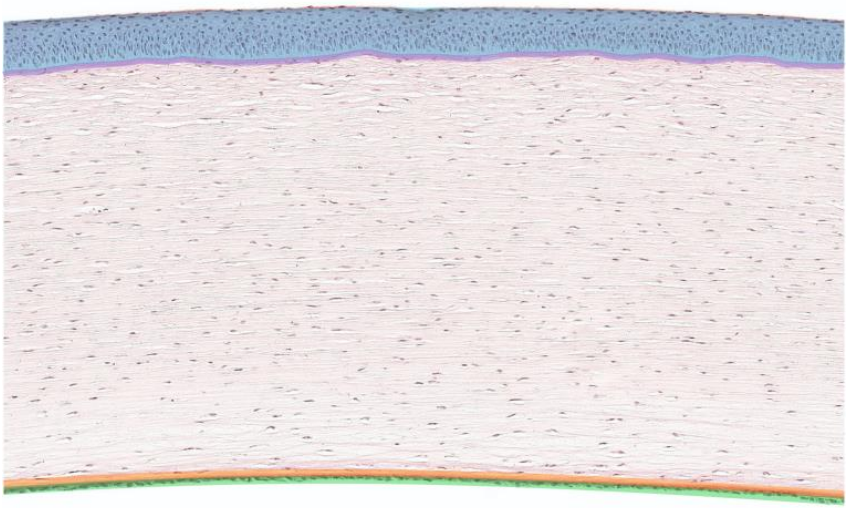
ORIENTATION IN THE SLIDE

The **anterior segment of the eye** is so characteristic that the preparation can be recognized at a glance. Macroscopically, the most important structures can be recognised. The **cornea** is the anterior, ventrally protruding structure (blue in the slide), which laterally in the area of limbus transitions into the **sclera** (yellow). The transition region contains Vogt's palisades, which represent a niche for limbal epithelial stem cells (indicated by the green rectangle). The **iris** is clearly visible in the slide (grey), with the opposing processes separated by the pupil. The iris is attached to the **ciliary body**. The posterior surface of the iris and ciliary body is covered by the blind part of the retina with a well-defined pigment epithelium, which changes into the optic retina in the region of the **ora serrata** (purple rings).



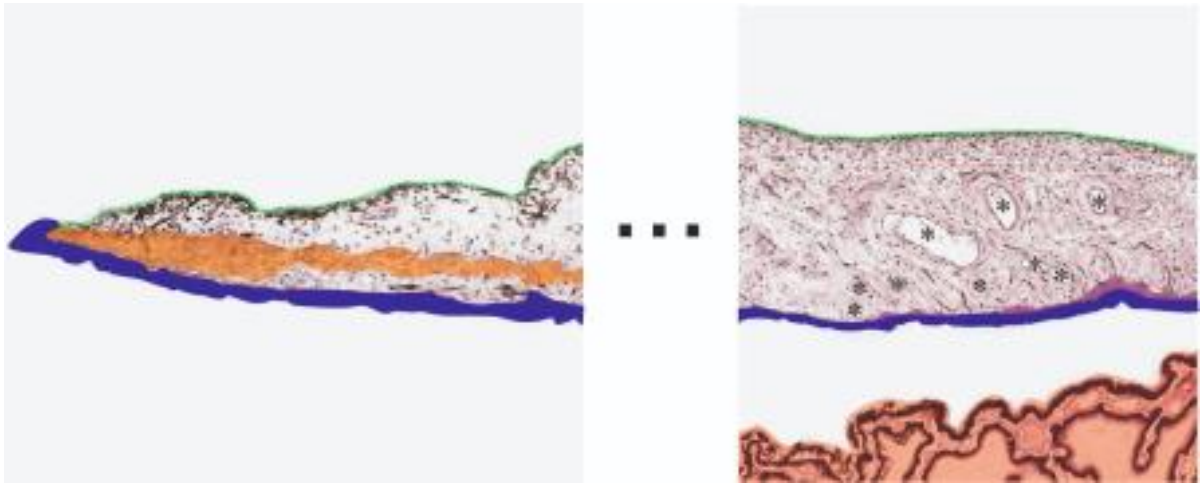
CORNEA

A detailed structure of the **cornea** corresponds to the area indicated by the blue rectangle on the anterior segment (see Fig. above). The surface is covered by the **anterior epithelium of the cornea**, which is stratified squamous non-keratinized (shown in blue in the interactive slide). At the edges of the cornea, it transitions into a stratified columnar epithelium of the conjunctiva that lines the anterior part of the sclera. The corneal epithelium sits on a clearly visible **Bowman's membrane** (shown in purple), which consists of the basal lamina and adjacent layer of condensed extracellular matrix. Beneath this is the **corneal stroma** occupying the largest part of the corneal in a section. The stroma is formed by a regular dense connective tissue that lacks blood vessels. The connective tissue consists of many layers of regularly arranged collagen lamellae and not very numerous flattened keratocytes, whose flattened dark nuclei are clearly visible in the image. The surface facing the anterior chamber of the eye is lined by a continuous simple squamous epithelium referred to as the **posterior corneal epithelium** (green). This epithelium sits on **Descemet's membrane** (orange) corresponding to the basement membrane that separates the posterior epithelium from the connective tissue layer.



IRIS

The iris emerges from the anterior part of the ciliary body - the two images indicated in the figure of anterior segment with dotted rectangles are chosen so that the left image captures the edge of the iris facing the pupil and the right image captures the area near the ciliary body. The surface in contact with the anterior chamber is lined by a discontinuous layer of simple squamous epithelium (anterior epithelium - shown in green). Underneath is the anterior limiting layer containing connective cells and melanocytes (due to their high melanin content, they are coloured dark brown). The deeper **stroma of the iris** resembles a gelatinous connective tissue, which, in addition to the cell types mentioned above, also contains a vascular plexus (clearly visible lumina of blood vessels are marked with an asterisk). Near the pupil, the circularly arranged smooth muscle can be seen (orange), which here forms the **pupillary sphincter muscle** (m. sphincter pupilae). The **pupillary dilator muscle** (m. dilatator pupilae) is adjacent the posterior border layer; it is arranged radially and is formed by myoepithelial cells (purple).

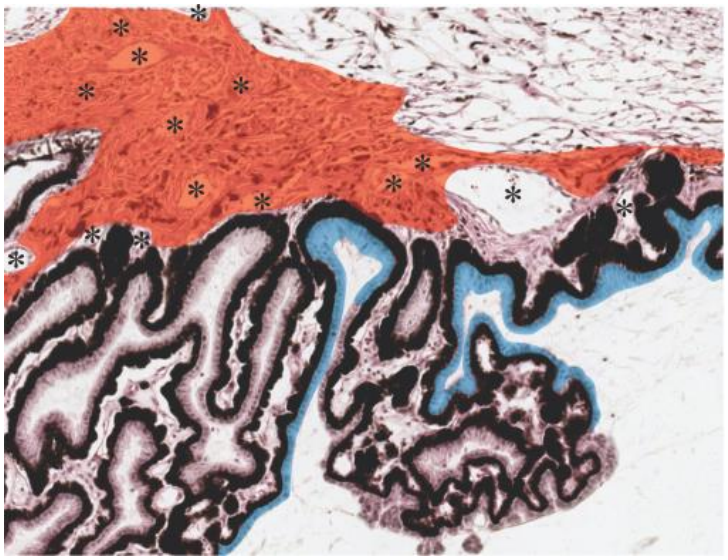


The **posterior epithelium** covering the surface adjacent to the posterior chamber of the eye is lined by two layers of highly pigmented cells (blue) - this layer is a part of the retina (iridical part of the blind retina).

CILIARY BODY

In the region of the ora serrata, the choroid transitions into a ciliary body, which gradually expands ventraly. The underlying loose connective tissue contains a large number of pigment cells (brown) and numerous blood vessels (the lumen of visible vessels is marked with an asterisk in Fig.) that supply sufficient fluid for the secretory activity of the gland. Ventrally,

the smooth muscle cells of the **ciliary muscle** (in red) also increase in number and reveal a rather complex arrangement. The posterior surface of the ciliary body smooth (pars plana), while anteriorly it forms processes. Numerous **ciliary processes** can also be found in the detail, the position of which is indicated by the red rectangle in the first image above. The inner surface of the ciliary body is lined by two layers of columnar epithelial cells. The outer layer, which is delineated against the connective tissue by the basal lamina, is composed of highly pigmented cells (dark brown). The inner layer of the epithelium has a light cytoplasm (non-pigmented cells) - in the interactive image on the right two areas of this epithelium are shown in blue. The inner layer of the epithelium has a light cytoplasm (not pigmented cells) - in the interactive image on the right two areas of this epithelium are marked in blue; the non-pigmented epithelium of the ciliary



processes lacks the basal lamina (instead, during development, these cells produce zonula ciliaris); however, in the area of contact with the vitreous body, the surface of the non-pigmented epithelium is already covered by the basal lamina. Both epithelial layers represent the blind retina, called **pars ciliaris retinae**.

SUMMARY

Identification of the slide is easy due to its characteristic anatomy. The most crucial thing is to describe all three layers of the eyeball. In the anterior segment, we pay the most attention to the **cornea** (identification of five layers with the avascular stroma), the anterior epithelium of the cornea is continuous with the conjunctiva (microscopically, it is necessary to check the presence of stratified columnar epithelium). Of the derivatives of vascular coat, the **iris** and the **ciliary body** are particularly important in the slide. From the retina, the main focus should be on the description of the blind part of the retina, possibly identifying the area of its transition into the optic retina at the area of *ora serrata*.

POSTERIOR SEGMENT OF EYE

ORIENTATION IN THE SLIDE

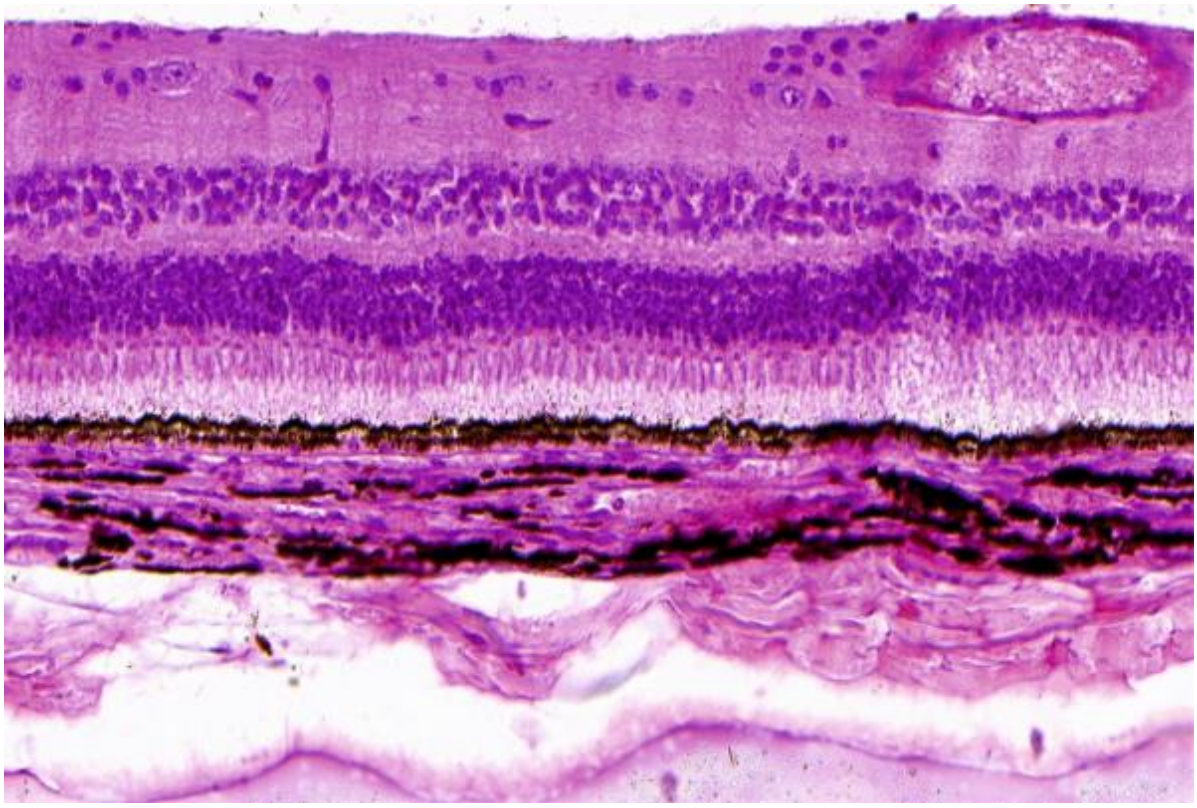
The **posterior segment of the eye** is again clearly characteristic, so that the slide can be recognized at a glance. Macroscopically, the **optic nerve** and its sheaths and the concave part of the eyeball, which consists of three distinct parts: the **retina** (or its optical part), **choroid** and **sclera** can be recognised. In the optic nerve, it can be observed how the diameter of the nerve increases with the gradual myelination of the nerve fibres. The confluence of nerve fibres produces the papilla nervi optici; in this area the retina contains no photoneurons (blind spot). The central vessels arising from the optic nerve are marked in red; their branches visible in the ocular background participate in the nutrition of the retina (left part of the image). The spaces between the layers represent artifacts resulting from the detachment of these parts during dehydration and tissue processing.

CHOROID

The choroid is adjacent to the retina, so that the two layers can be observed in their natural relationship. The boundary between them is formed by the **Bruch's membrane** (lamina vitrea), the course of which is marked by a green line in the image. Underlying Bruch's membrane is the basal lamina of the retinal pigment epithelium, which merges with the basal lamina of the adjacent capillaries - their small

lumina can be seen adjacent to the choroidal layer known as the **lamina choriocapillaris**. The lumina of the larger blood vessels are then found in

the **lamina vasculosa**. The last layer of the choroid, adjacent to the sclera, is the **lamina suprachoroidea**. In general, the choroid contains a loose connective tissue with a high content of pigment cells and blood vessels.



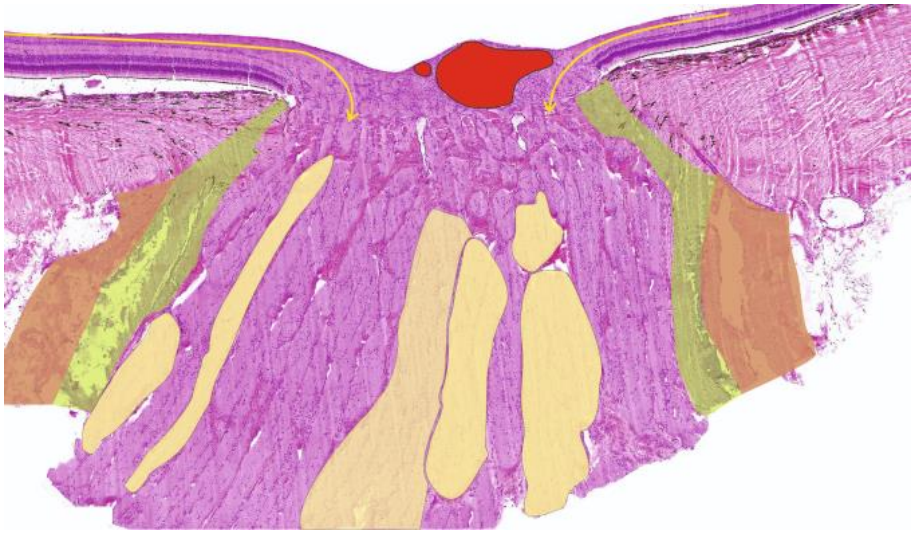
RETINA

The optic retina exhibits a strict laminar arrangement. We start the description from the **pigment epithelium**, which is arranged as a simple cuboidal epithelium. Pigment is particularly well evident in the apical cytoplasm. Long dark microvilli extending between the outer segments of the photosensitive cells are clearly visible in the image. The **layer of rod and cone segments** contains the elongated ends of photosensitive cells that detect light falling on the retina. The **external limiting membranae** represents the complex of adhesive junctions between the processes of Müller cells. The **outer nuclear layer** is formed by the accumulation of the bodies (and nuclei) of rods and cones. Axons of these unipolar cells (1st neuron of the optic pathway) synaptically connect to dendrites of the 2nd neuron of the optic pathway in the **outer plexiform layer** (light unstained layer lacking cell nuclei). The perikarya of bipolar cells are embedded in the **inner nuclear layer** along with the nuclei of Müller, amacrine, and horizontal cells. Axons of bipolar neurons form synapses with dendrites of ganglionic cells (3rd neuron of the optic pathway); synapses are part of the **inner plexiform layer**. The **ganglion**

cell layer contains multipolar neurons, which are again greatly reduced in number compared to the previous nuclear layer. The neurites of these nervous cells form a **layer of nerve fibres**, the convergence of which gives rise to the optic nerve. This layer is separated from the vitreous body by the **inner limiting membrane** formed by the terminal processes of Müller cells and the basal lamina. The branches of central artey and vein also run through the inner layers and can be seen in some places on the retina.

OPTIC NERVE

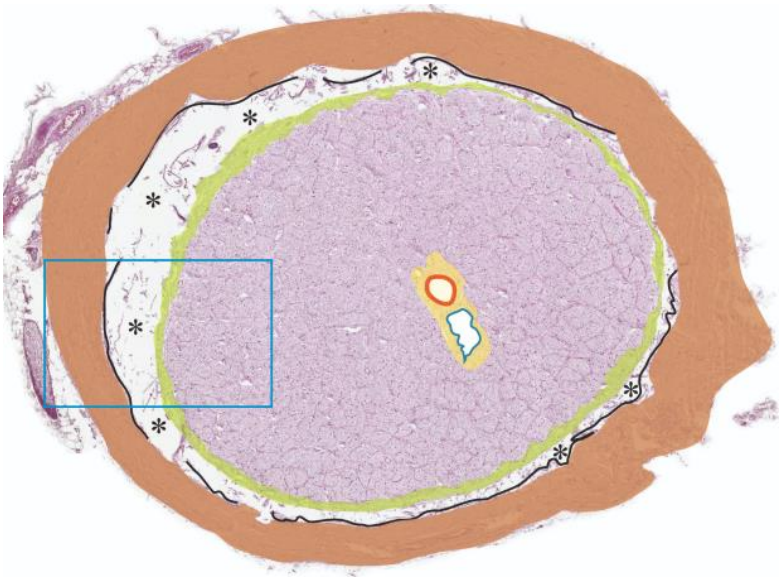
In the area of the exit of the optic nerve from the retina, the nerve is seen in a longitudinal section. The optic nerve, like the retina, is a derivative of the CNS and therefore needs to be described in a different way than the peripheral (cerebrospinal) nerves. For example, the coverings of the nerve are different here because they are also derived from the CNS coverings. The dura mater of dense connective tissue forms an **external sheath** (vagina externa nervi optici marked in brown) which passes into the sclera. The **inner sheath of the optic nerve** corresponds in character to the leptomeninges (light green) and transitions into the loose connective tissue of the choroid. The **myelinated nerve fibers** of the optic nerve are continuations of ganglion cell axons that converge from the retinal nerve fiber layer (yellow arrows). Inside the optic nerve, the nerve fibers are organized into small bundles (several are indicated in yellow), and the perineurium, which is characteristic of PNS nerves, is absent on the surface of the bundles. The nuclei of the cells inside the nerve belong to the glial cells of the CNS (i.e., these are not Schwann cells!). Large blood vessels pass through the centre of the nerve (**central retinal artery and vein** - in red). These features are better seen in a transverse section of the optic nerve - see the following slide.



OPTIC NERVE

ORIENTATION IN THE SLIDE

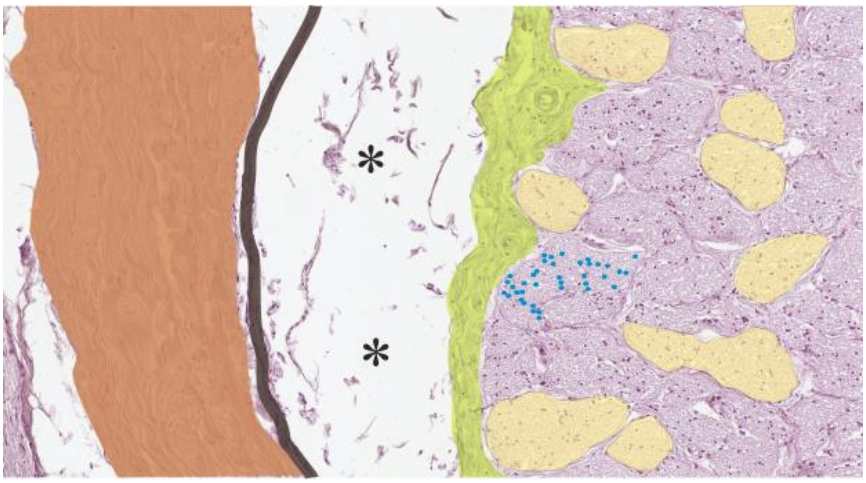
Under smallest magnification, a nerve with a compact arrangement can be identified on a cross-section. Unlike the PNS nerves, there are no separate bundles, between which the epineurium runs. Instead, the sheaths of this nerve have an arrangement typical of CNS coverings. Externally, the nerve is encircled by a thick layer of dense connective tissue, strikingly resembling the dura mater (**outer sheath of the optic nerve**, *vagina externa nervi optici*, marked in brown in the interactive slide), overlying a layer of flattened cells (which is analogous to the arachnoid membrane - marked with a black line). The layer of loose connective tissue covering the immediate surface of the nerve corresponding to the pia mater (light green) is separated from the arachnoid membrane by the subarachnoid space (*). The leptomeninges form the **inner sheath of the optic nerv**e (*vagina interna nervi optici*). Furthermore, the connective tissue area (shown in yellow) can also be found inside the nerve in the space surrounding large blood vessels (**central retinal artery and vein** of the optic nerve, *arteria et vena centralis retinae* - in red and blue). This is another striking sign pointing to the CNS nerve. This is because the peripheral nerves are accompanied by large vessels externally, whereas here the large blood vessels enter and run within the optic nerve.



MICROSCOPIC STRUCTURE

A detailed view (the tissue shown in image above is from the area marked by the rectangle) reveals transverse sections of **myelinated nerve fibres** of relatively small sizes, which are arranged in small "bundles" (several of them are marked in yellow), but which do not have a separate covering. Inside the bundle it is possible to distinguish the nuclei of different **glial cells** (blue) - oligodendrocytes, astrocytes and microglia are

found in the n. opticus. The **sheaths of the optic nerve** have the characteristic features of the meninges at higher magnification - dura mater (brown) with iregularly arranged bundles of collagen fibres and relatively few fibrocytes and pia mater (green) containing a larger number of connective cells. The arachnoid membrane (black line), composed of layers of flattened cells, overlies the inner surface of the dura mater, while the subarachnoid space (*) separates it from the pia mater. All these features confirm the fact that the optic nerve is a derivative of the CNS.



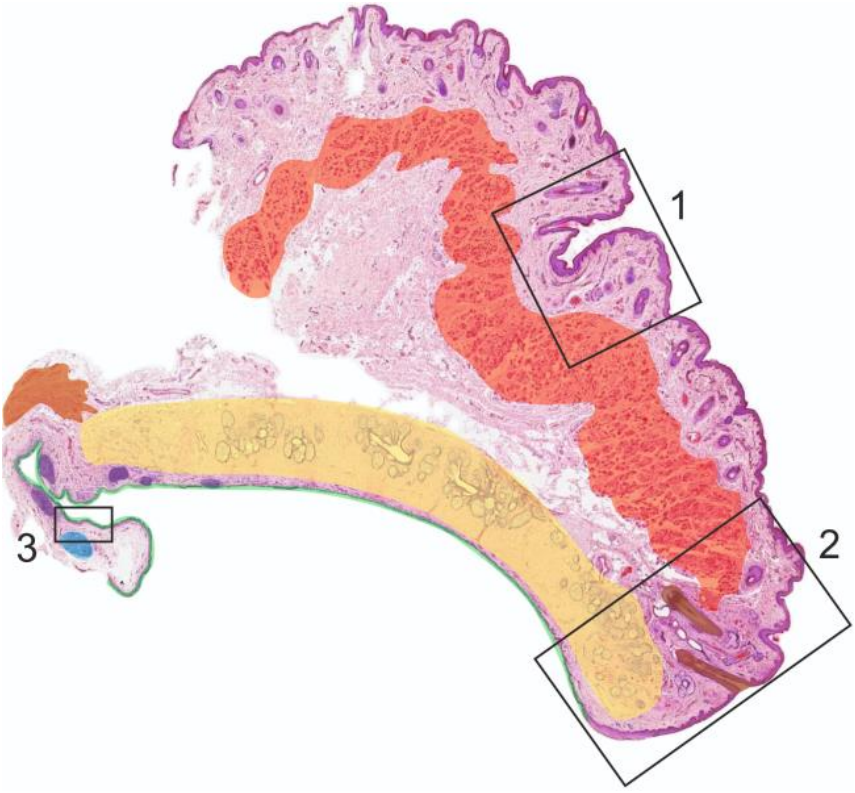
SUMMARY

The identification of the slide is again easy due to its characteristic anatomical structure. The key is to describe all three layers of the eyeball. In the area of the posterior segment of the eye, we pay most attention to the **retina**, in whose laminar structure with10 distinct layers have to be described. We begin the description with the pigment epithelium, which is seated on the Bruch's membrane of the choroid (in the case of detached retina, this layer may be detached from the other layers of the retina). In addition, the **choroid** (where 4 layers can be distinguished) and the **sclera** are well preserved in the posterior segment. The preparation also contains the optic nerve and its sheaths. Its structure can be better described on a separate slide showing a transverse section of the **optic nerve**. Inside the nerve runs the central retinal artery and vein located in the central area of connective tissue. The nerve itself is composed of small myelinated nerve fibres arranged in tiny 'bundles', but lacking a separate sheath, giving the nerve a compact appearance. The sheaths proper are found externally, where they form the **outer and inner sheaths of the optic nerve**, which structurally correspond to the leptomeninges and pachymeninx of the brain. As this is a CNS structure, the corresponding CNS glia should be mentioned when describing the glial cells.

EYELID

ORIENTATION IN THE SLIDE

On a transverse section of the eyelid, two distinct surfaces can be recognised: the skin covers the outer surface, while the inner surface facing the eye is covered by the **conjunctiva** (marked by the green line). The slide presented here was scanned for the Virtual Atlas and can be viewed in detail in our collection of virtual slides via SmartZoom software. The eyelid contains a rigid connective **tarsal plate** (yellow) of dense connective tissue near the inner surface, which houses the **Meibomian gland**. At the upper edge, the **smooth muscle** (orange) attaches to the tarsus. The conjunctiva near the conjunctival sac contains numerous lymphoid follicles (purple), and occasionally the slide contains an accessory **lacrimal gland** (blue).



In the slide above, the tarsus is artificially detached from the **orbicularis oculi muscle** (red). A dense connective tissue attached to the tarsus includes the tendon of levator palpebrae muscle (whose muscle tissue is not seen in the slide). The outer surface of the eyelid is covered by a thinly keratinized **epidermis**, dermis (with dermal adnexa) and hypoderm (subcutis). On the lower margin of the eyelid, the **eyelashes** (or their large hair follicles) are clearly visible, to which the ciliary glands (Zeiss and Moll's) are attached.

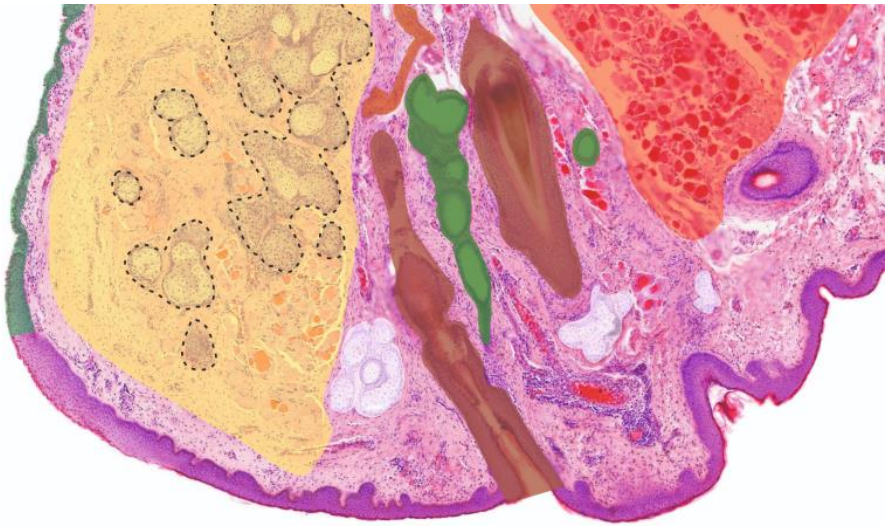
OUTER SURFACE OF THE EYELID

The skin surface of the eyelid is lined by a stratified squamous thinly keratinized **epidermis**. The **dermis** contains small blood vessels, nerves and **cutaneous adnexa**, notably small hair follicles and associated sebaceous glands (not seen in Fig.) and eccrine sweat glands. A detailed description of the skin glands can be found in the e-course Practical classes 2: Glandular Epithelium. The hypoderm (tela subcutanea) lacks fat cells; skeletal muscle fibres belonging to palpebral part of the **orbicular oculi muscle** can be found in deeper area. The situation in the figure corresponds to the area indicated by a rectangle 1 in previous Fig.

FREE MARGIN OF THE EYELID

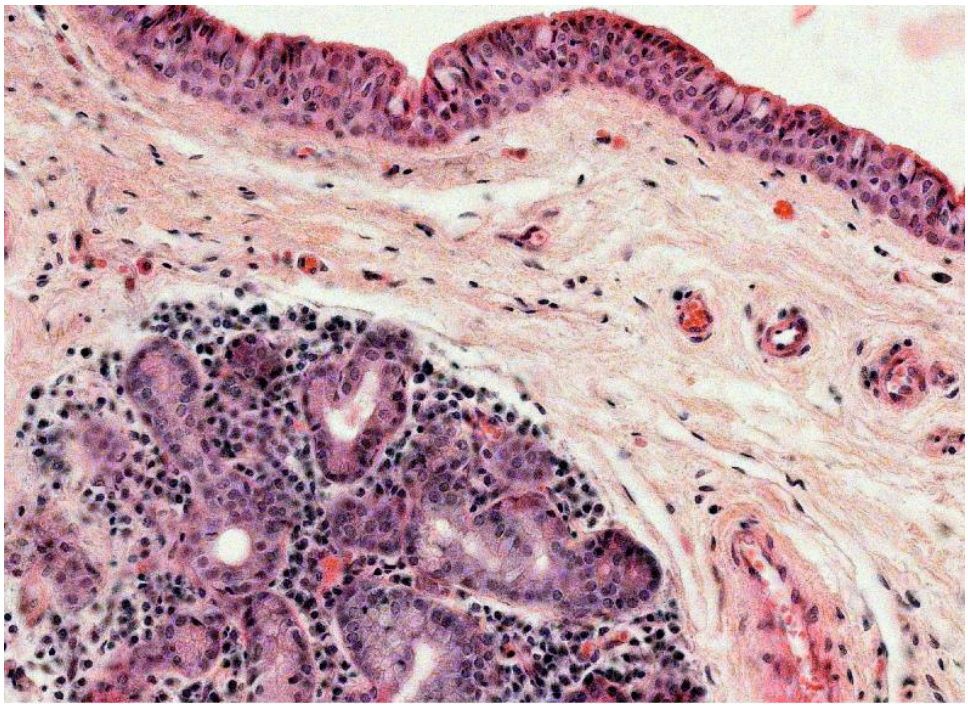
The situation corresponds to the area indicated by rectangle 2. The free margin is covered by thin skin, which contains **eyelashes** in 3-4 rows. Two of their thick hair follicles are labelled in brown in the longitudinal section. The ciliary glands associated to eyelashes include: sebaceous **Zeiss' glands** (shown in white) and the **Moll's glands** (apocrine sweat glands, in green). A detailed description of the cutaneous glands can be found in the e-course Practical Classes 2: Glandular Epithelium. The smooth ciliary muscle is also seen near the eyelashes in the microphotograph (orange). The outer (ventral) surface of the eyelid (right in Fig.) is covered by **thin skin**, under which is the **orbicularis oculi muscle** (red - muscle fibres are visible here in a transverse section); the muscle has several parts and therefore its fibres can also be detected near the eyelashes and the tarsal plate. The core of the eyelid contains the **tarsal plate** (tarsus - yellow) made of dense connective tissue, in which

the **Meibomian** sebaceous **gland** is found; the alveoli of this gland are marked by a dashed line. Its ducts exit just anterior to the inner margin of the eyelid. The inner lining of the eyelid consists of the **conjunctiva**. The surface is covered by a stratified columnar epithelium, the course of which is marked by a green line; beneath the epithelium is the lamina propria mucosae of a loose connective tissue.



CONJUNCTIVA AND LACRIMAL GLAND

The **conjunctiva** covers the inner (concave) part of the eyelid (palpebral conjunctiva) and passes through the superior and inferior fornix to cover the ventral surface of the eyebal (t. conjunctiva bulbi). The situation shows the lining epithelium of the conjunctival sac and corresponds to the part indicated by a rectangle 3. The surface of the conjunctiva is covered by a stratified columnar epithelium in which goblet cells are scattered that contribute to the lubricating function of the tear film. The adjacent connective tissue layer is composed of loose connective tissue that contains numerous small blood vessels. Lymphatic follicles, although not shown in the microphotograph, are an integral part of the lamina propria mucosae. The ducts of the lacrimal gland open into the upper fornix; a portion of the lobe of the accessory **lacrimal gland** is depicted in the lower part of Fig. The secretory portion consists of alveoli (serous acini), which contain a single layer of serous cells as well as myoepithelial cells. The intralobular ducts lined by simple cuboidal epithelium are embedded in the loose connective tissue of the lobe and drain secretions into the interlobular ducts (lined by a double-layered columnar epithelium).



SUMMARY

Macroscopically, the slide is similar to a lip or ear pinna. Therefore, it is necessary to microscopically examine the covering epithelium. The **stratified squamous thinly keratinized epithelium** belongs to the epidermis, whereas the **stratified columnar epithelium** is typical of the conjunctiva. In the dermis, **cutaneous adnexa** can be found: small hair follicles, sebaceous glands associated with them, as well as small sweat glands are found on the ventral side of the eyelid; the **free margin** of the eyelid contains large hair follicles of the **eyelashes**, **Zeiss'** (sebaceous) glands, and **Moll's** (modified apocrine sweat) **glands**. Under the cutaneous surface is the skeletal muscle of the **orbicularis oculi muscle**. Beneath the mucosal surface is a dense connective tussue plate (**tarsus**) containing the large **Meibomian** (sebaceous) **glands**. The smooth **Müller's** (tarsal) **muscle** can be found at the upper edge of the tarsus. Occasionally, the parenchyma of the **lacrimal gland**, consisting of serous acini and intra- and interlobular ducts, may also be seen.