Special Sense

Plate 16.297 Olfactory Mucosa

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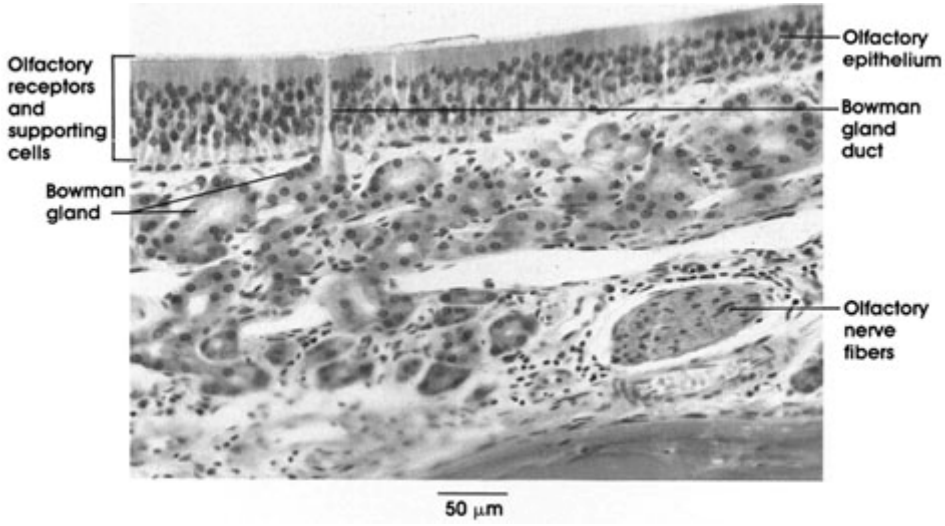
Peer Review Status: Externally Peer Reviewed

OLFACTORY MUCOSA



Rodent, 10% formalin, H. & E., 218 x.

Olfactory epithelium: Thick pseudostratified epithelium containing (1) sustentacular (supporting) cells, (2) bipolar receptor neurons, and (3) basal cells. Cells are densely packed and difficult to differentiate in thick sections. The nuclei of these cells are layered (from the outside) in the order given above. No goblet cells are located in this region, but the area is flushed by seromucous glands located beneath the epithelium.

Glands of Bowman*: Located in the lamina propria. Branched tubuloalveolar glands that secrete a seromucus. The secretions keep the surface moist, facilitate solution of substances being smelled, and subsequently cleanse the olfactory receptors of the olfactory stimulus.

Olfactory nerve fibers: Non-myelinated axons of bipolar receptor neurons. Nerve bundles are located deep in the lamina propria.

Plate 16.298 Olfactory Epithelium

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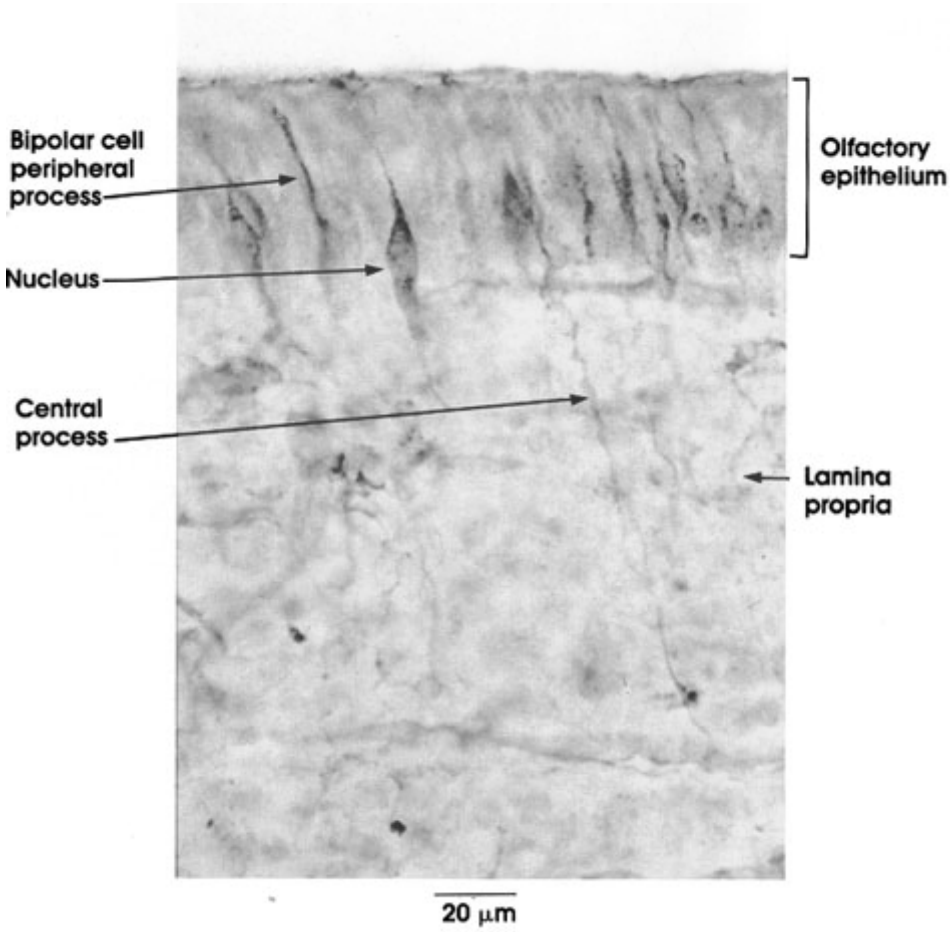
OLFACTORY EPITHELIUM
Bipolar receptor neurons



Dog, 10% formalin, silver diaminohydroxide, 500 x.

In this plate, a special staining technique is used to demonstrate the olfactory receptor (bipolar) neurons in the olfactory mucosa.

The nuclei of the receptor cells are usually deeply located in the epithelium. From the nuclear region of the neuron, a delicate peripheral neural process reaches the exposed surface of the epithelium. At the opposite pole of the cell, an unmyelinated axon extends centrally. The axons of receptor cells are gathered together to form the olfactory nerve (cranial nerve 1). The olfactory nerve terminates in the olfactory bulb, where synaptic contacts are established with neurons, whose axons form the olfactory tract.

The olfactory bipolar neurons are located between the more numerous sustentacular cells

Plate 16.299 Taste Bud

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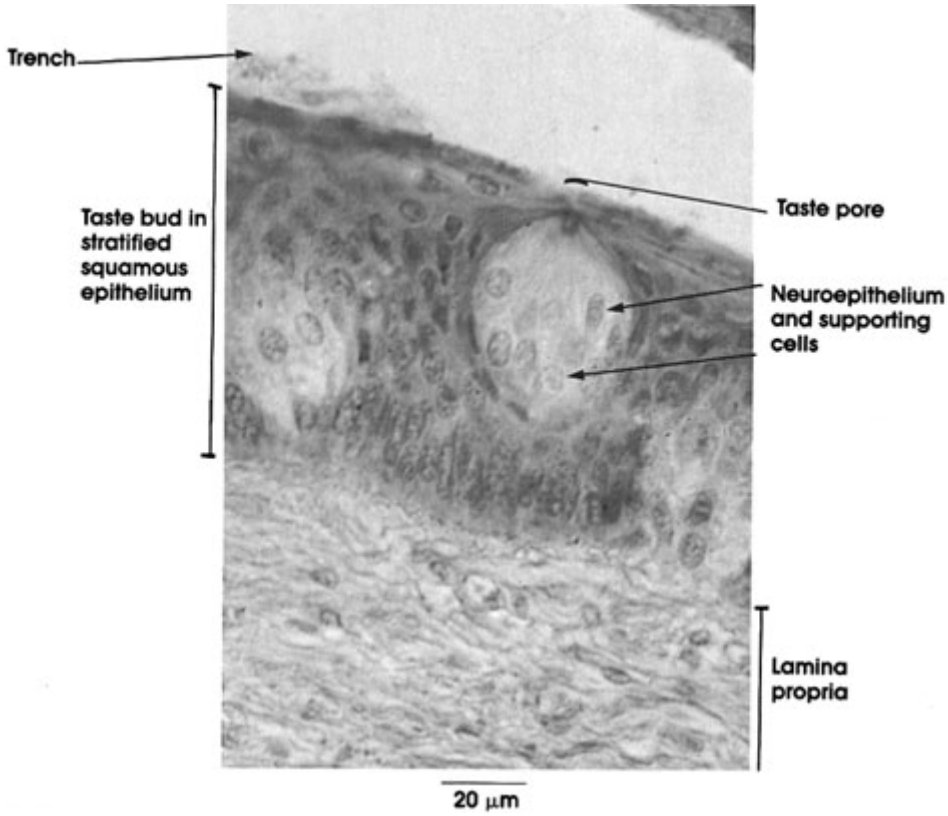
TASTE BUD
Tongue
vallate papilla



Human, Zenker's fluid,
phosphotungstic acid hematoxylin stain, 612 x.

Taste buds are located in the tongue epithelium of vallate (circumvallate) papillae, and occasionally in the fungiform papillae and in the surface epithelium around them. A few taste buds are also present in the palate and epiglottis.

Trench: Surrounds vallate papillae. Covered by non-keratinized stratified squamous epithelium.

Taste bud in stratified squamous epithelium: Barrel-shaped. Extends from the basement membrane to the free surface of the stratified squamous epithelium covering the papilla. Taste buds are the receptor organs of taste.

Taste pore: The opening of the taste canal at the surface of the epithelium.

Neuroepithelial and supporting cells: The two types of cells are packed within the concavity of the taste bud. The neuroepithelial cells are slender, dense, and spindle-shaped. They constitute the taste receptor cells. Supporting cells or sustentacular cells are stouter and lighter.

Lamina propria: Connective tissue core of the papilla.

Plate 16.300 Conjunctiva and Cornea

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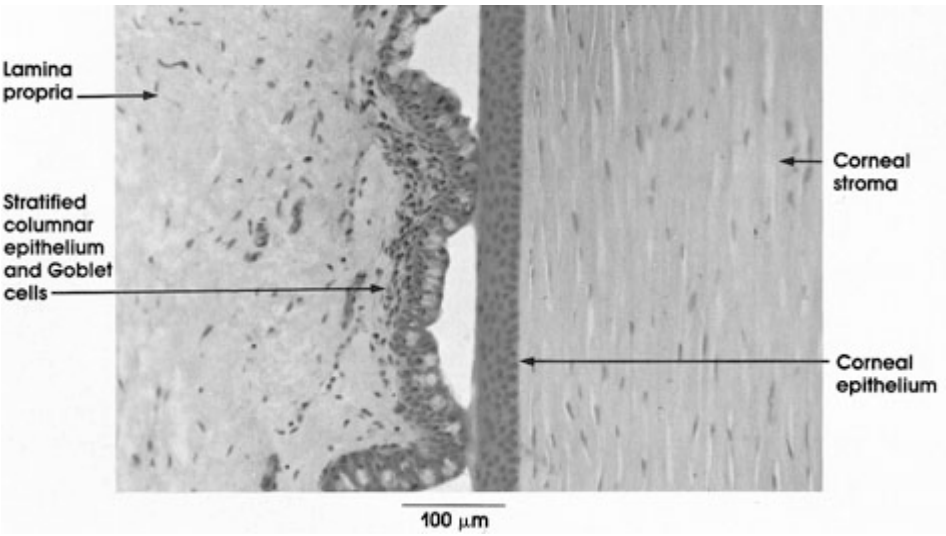
CONJUNCTIVA AND CORNEA



Rhesus monkey, 10% formalin, H. & E., 162 x.

This plate includes part of the cornea (right) and the covering bulbar conjunctiva (left). The conjunctiva at this site is composed of the following elements.

Lamina propria: A loose, superficial fibroelastic connective tissue stroma, which becomes increasingly dense at deeper levels. Rich in blood vessels.

Stratified columnar epithelium: Eight to ten cells thick. Superficial layers near the cornea rich in goblet cells.

Plate 16.301 Cornea

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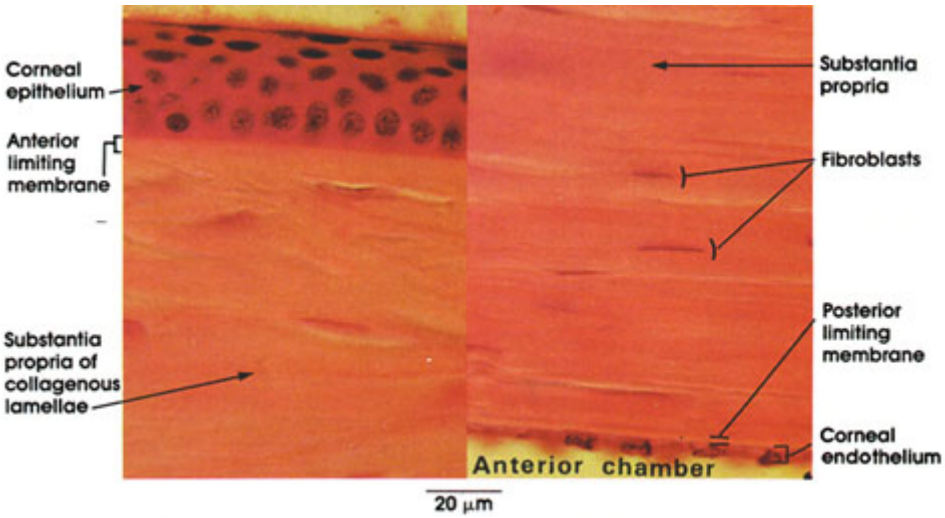
CORNEA



Rhesus monkey, 10% formalin, H. & E., 612 x.

The cornea is the bulging front portion of the eye. It is nonvascular and transparent. Microscopically, five distinct layers can be recognized.

Corneal epithelium: Non-keratinized stratified squamous type of epithelium. Note that the basal layer of cells is columnar, and the most superficial are flattened.

Anterior limiting membrane: The second layer of the cornea was described by Sir William Bowman, an English surgeon, and therefore is called Bowman's membrane. This membrane appears homogeneous and structureless by light microscopy. By electron microscopy, it is shown to be composed of fine collagenous fibrils.

Substantia propria: Constitutes nine tenths of the thickness of the cornea. Composed of collagen fibrils, fibroblasts, and cementing substance. The fibrils are arranged in lamellae that run parallel to the surface of the cornea. The fibroblasts are flattened and lie between the fibrous lamellae. A mucopolysaccharicle cements the different lamellae and the collagenous fibrils within lamellae together. The metachromatic protein polysaccharide ground substance and the arrangement of fibrils within the substantia propria contribute to the transparency of the cornea.

Posterior limiting membrane: The posterior limiting membrane of the cornea was described by the French surgeon Descemet in 1758 and is known by his name. English anatomists state that it was first described by Benedict Duddell, an English oculist. This membrane appears homogeneous in the light microscope. Electron microscopy reveals a wide basement membrane made of atypical collagen.

Corneal endothelium: Low cuboidal epithelium. The term *endothelium* is a misnomer, since this epithelium is bathed by aqueous humor of the anterior chamber and not blood or lymph.

Plate 16.302 Eye

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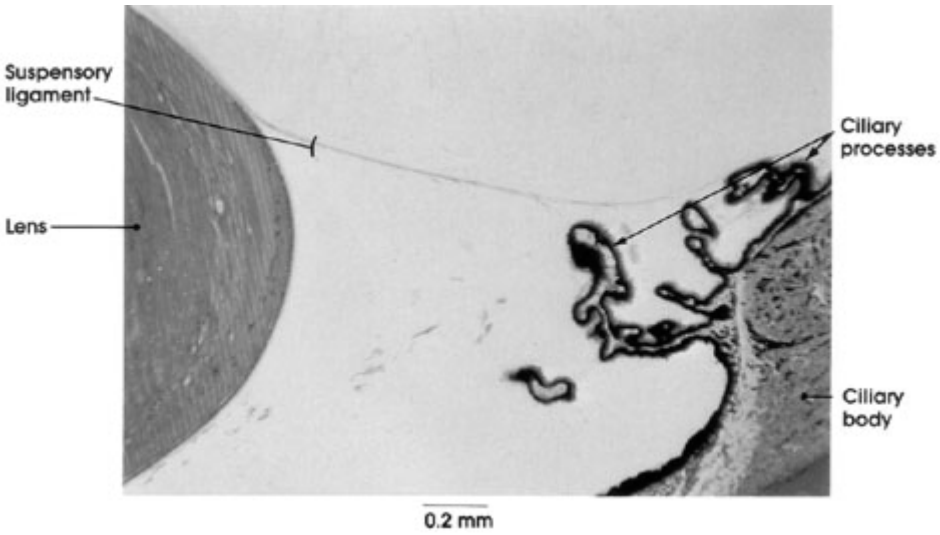
EYE



Rhesus monkey, 10% formalin, H. & E., 50 x.

Ciliary body: A ring of muscle and vascular tissue, part of the vascular and pigmented tunic of the eye, which includes, in addition, the choroid and iris. The ciliary body is attached to the lens by the suspensory ligament. Contraction of muscle of the ciliary body results in lens accommodation.

Ciliary processes: Ridges of the ciliary body as it approaches the iris. Run in a meridional plane. Provide an anchor for the suspensory ligaments of the lens. Produce aqueous humor.

Suspensory ligament: Made up of delicate collagenous fibers that stretch between the lens capsule and ciliary processes from which the lens is suspended. The suspensory ligament is under tension when the eye is at rest and relaxes when the lens accommodates, as in near vision.

Lens: Transparent biconvex disc enclosed in a homogeneous elastic capsule and located behind the iris. Made up of concentric layers of lens fibers and a cement substance. Changes in configuration of the lens are important in accommodation. The lens, cornea, and the vitreous are the important refractive media of the eye.

Plate 16.303 Ciliary Muscle and Ciliary Processes

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CILIARY MUSCLE AND CILIARY PROCESSES

Rhesus monkey, 10% formalin, H. & E., 612 x.

Ciliary processes: Ridges of the ciliary body as it approaches the iris run in a meridional plane. They provide an anchor for the suspensory ligaments of the lens.

Zonular fibers of suspensory ligament: Seen attached to the ciliary processes. Inelastic and radially arranged fibers from which the lens is suspended. Extend from ciliary processes to the lens capsule. When the eye is at rest, zonular fibers under tension from elastic fibers in the choroid stretch the lens. Tension in zonular fibers is reduced when ciliary muscles contract. This results in a change in the shape of the lens (accommodation). The lens becomes more spherical owing to its inherent elasticity.

Columnar epithelium: Columnar or cuboidal epithelium, which covers the ciliary processes. Indistinct cell borders. Elaborates aqueous humor.

Posterior chamber: The space between the iris and suspensory ligament of the lens. Contains aqueous humor.

Ciliary muscle: Smooth muscle fibers intermixed with melanocytes. Runs in three directions: circular, radial, and meridional. Circular fibers lie at the inner edge of the ciliary body. Contraction of ciliary muscles releases tension in suspensory ligament of the lens and of the lens capsule, thus allowing the lens to change shape to accommodate for near vision. The ciliary muscle is a continuation of the suprachoroid layer.

Melanocytes: Pigment-laden cells scattered in the connective tissue elements between muscle fibers.

Plate 16.304 Iris and Lens

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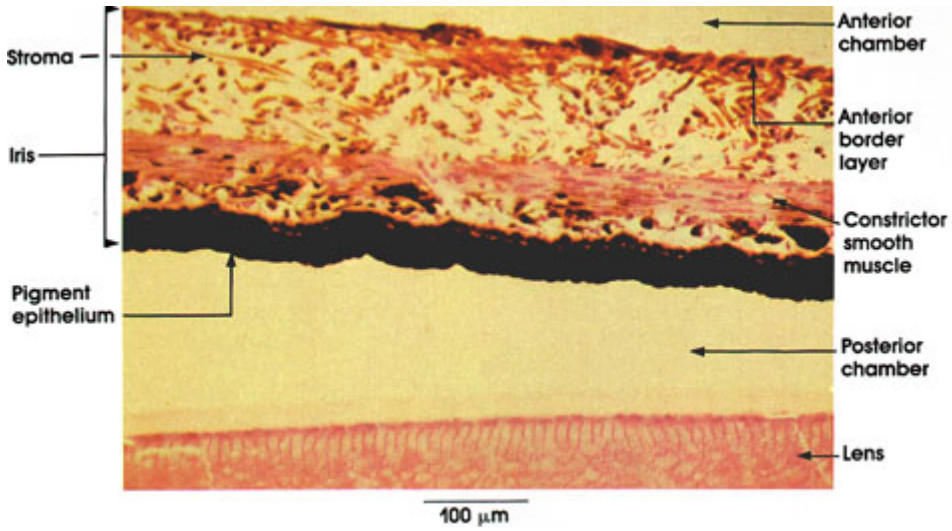
IRIS AND LENS



Rhesus monkey, 10% formalin, H. & E., 162 x.

The iris, like the ciliary body, is a continuation of the retina and choroid. It is attached to the ciliary body and extends in front of the lens. All the layers of the iris are shown in this figure except the endothelial cell layer, which outlines the anterior boundary of the iris. This is a thin and delicate layer, which is difficult to see in ordinary light microscopic preparations.

Anterior chamber: Located anterior to the iris and communicates with the posterior chamber through the pupil. Contains aqueous humor.

Anterior border layer: A condensation of the stroma of the iris. Formed principally of pigment cells containing a variable amount of yellowish-brown pigment. Thickness of this layer determines the color of the iris. It is thin in blue-eyed individuals and thick in brown-eyed individuals.

Stroma: Consists of loose connective tissue, in which are found a large number of blood vessels. Pigment connective tissue cells are scattered in this loose connective tissue stroma.

Constrictor smooth muscle fibers: Constricts the pupil. Supplied by the parasympathetic postganglionic neurons of the oculomotor nerve located in the ciliary ganglion.

Pigment epithelium: Continuation of the ciliary epithelium. Vast amounts of melanin pigment obscure cell boundaries and nuclei.

Posterior chamber: Between the iris and the lens. Communicates with anterior chamber through the pupil. Contains aqueous humor.

Plate 16.305 Iris

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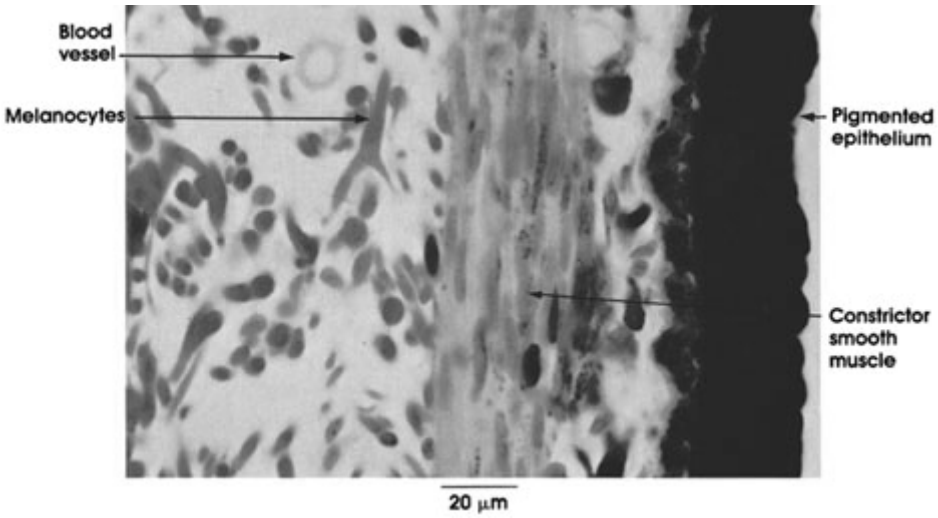
Peer Review Status: Externally Peer Reviewed

IRIS



Rhesus monkey, 10% formalin, H. & E., 612 x.

Pigmented epithelium: On the posterior surface of the iris. A layer of cuboidal cells whose outlines are masked by the heavy pigment.

Constrictor smooth muscle: The fibers are arranged circumferentially at the margin of the pupils. Contraction will constrict the pupil. Supplied by parasympathetic postganglionic neurons of the oculomotor nerve located in the ciliary ganglion.

Blood vessels: In the iris stroma. Have a thick adventitial layer forming a unique fibrous acellular wall.

Melanocytes: Spindle-shaped connective tissue cells, with long processes containing yellow-brown pigment, scattered in the loose stroma of the iris. Most commonly seen along the anterior border of the iris. The number of pigment cells varies with the individual's complexion.

Plate 16.306 Retina

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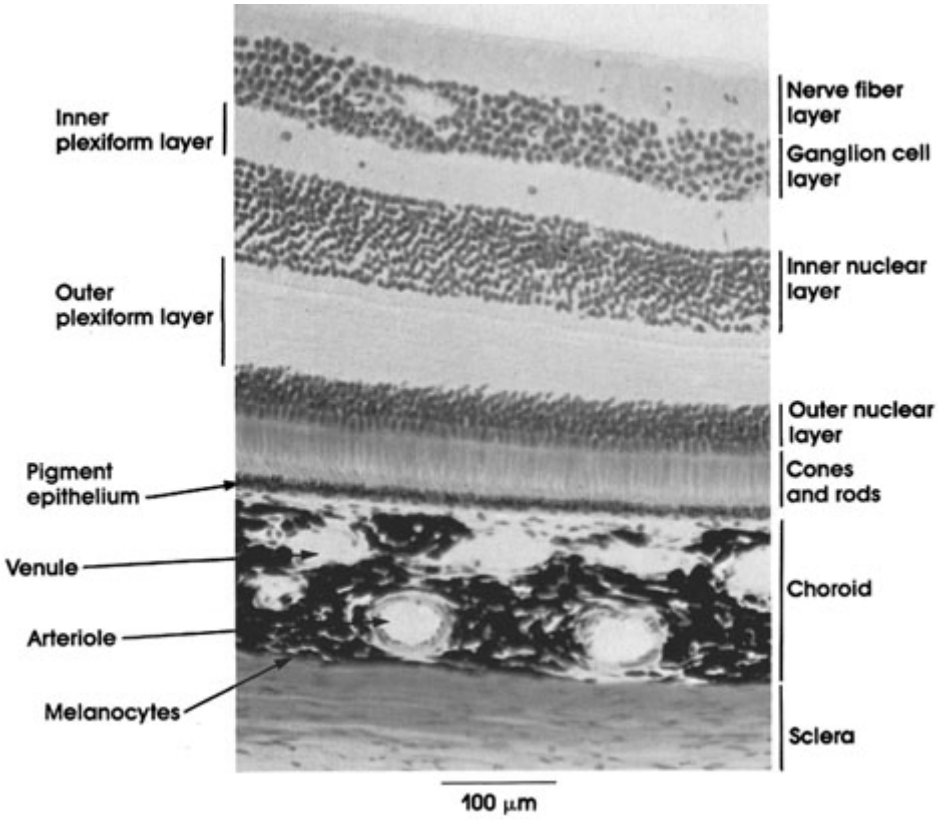
Peer Review Status: Externally Peer Reviewed

RETINA



Rhesus monkey, Helly's fluid, H. & E., 162 x.

Nerve fiber layer: Consists of non-myelinated axons of ganglion cells. They converge at the optic disc to form the optic nerve. Fibrous neuroglial cells are scattered among nerve fibers.

Ganglion cell layer: Composed of multipolar ganglion cells. Only nuclei are seen by this method of staining.

Inner plexiform layer: Also known as inner synaptic layer. Contains processes of amacrine cells, axons of bipolar cells, and dendrites of ganglion cells.

Inner nuclear layer: Contains the nuclei of bipolar neurons and association neurons (horizontal and amacrine cells), as well as the nuclei of supporting (Müller's*) cells.

Outer plexiform layer: Also known as outer synaptic layer. Contains axons of rod and cone cells, dendrites of bipolar cells, and processes of the horizontal cells.

Outer nuclear layer: Contains rod and cone cell bodies and nuclei. Cone nuclei are ovoid and limited to a single row (compare with fovea in Plate 307). Rod nuclei are rounded and distributed in several layers.

Cones and rods: Light-sensitive end portions of rod and cone cells. Contain an unstable, light-sensitive substance (rhodopsin in rods and iodopsin in cones). Both pigments play an important role in the visual process. Rhodopsin and iodopsin consist of vitamin Al aldehyde conjugated to a specific protein (rod opsin and cone opsin).

Pigment epithelium: Single layer of pigmented cuboidal cells firmly bound to the choroid layer. Contains melanin pigment.

Choroid: Heavily pigmented layer of loose connective tissue characterized by extreme vascularity. Provides nourishment for the outer portions of the retina.

Sclera: Firm external coat of the eye. Composed of dense collagenous connective tissue. A narrow pigmented zone near its internal surface merges with the choroid. The tendons of the six extraocular striated muscles insert on the sclera.

Plate 16.307 Retina

Ronald A. Bergman, Ph.D., Adel K. Afifi, M.D., Paul M. Heidger, Jr., Ph.D.
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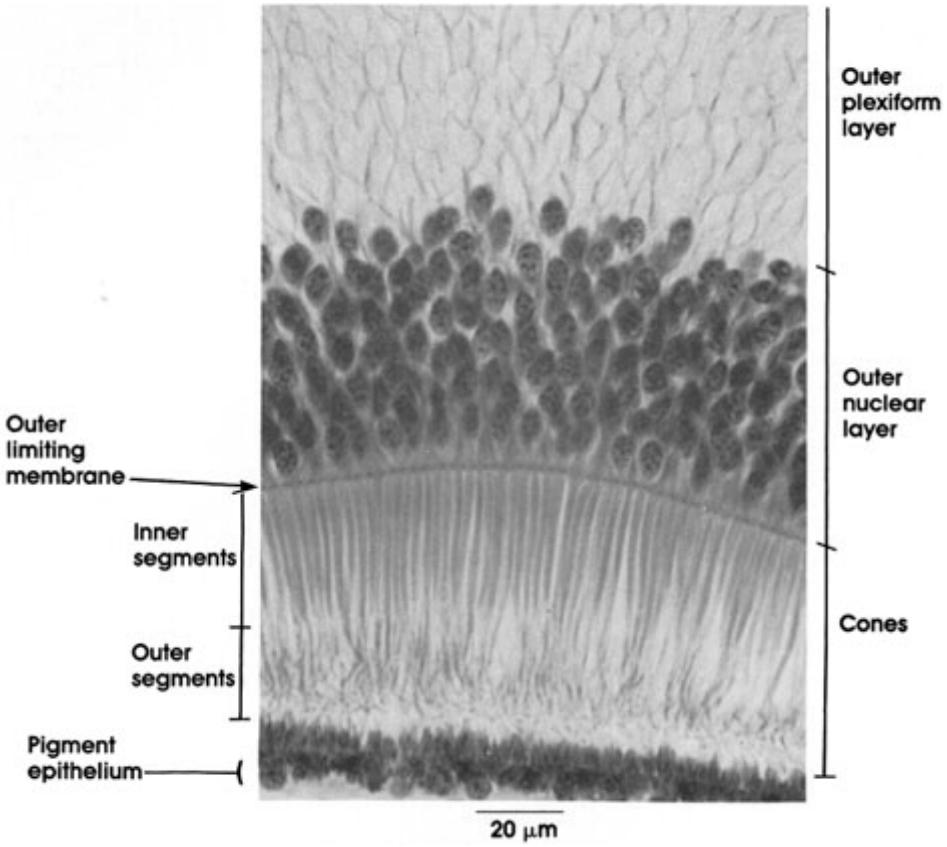
RETINA
Fovea centralis



Rhesus monkey, Helly's fluid, H. & E., 612 x.

Outer plexiform layer: Contains axons of cone cells, dendrites of bipolar neurons, and processes of horizontal cells.

Outer nuclear layer: Nuclei of visual receptor cells. Note ovoid nuclei of the cones. Multiple rows of nuclei are characteristic of the fovea.

Outer limiting membrane: Sieve-like sheet. Region of junctional complexes between the outer ends of the tall supporting Müller cells and the adjoining photoreceptor cells. Not an actual membrane. The visual cells pass through perforations in this so-called membrane.

Cones: Light-sensitive end portions of cone cells. Respond to light of high intensity. Function is visual acuity and color perception. Compare cones in fovea with those seen in other regions of the retina (Plate 308).

Inner segments: Thicker proximal segments of the cones. Rich in mitochondria.

Outer segments: Slender distal segments of cones. Consist largely of stacked discs 0.014 μm thick. Contain iodopsin, an unstable, light-sensitive visual pigment, which chemically is composed of vitamin A, aldehyde conjugated to a specific protein (cone opsin).

Pigment epithelium: Single layer of pigmented cuboidal cells firmly bound to the choroid layer. Cells contain melanin pigment. The cytoplasmic processes of the pigment cells interdigitate with the outer segment of cones.

Plate 16.308 Eye

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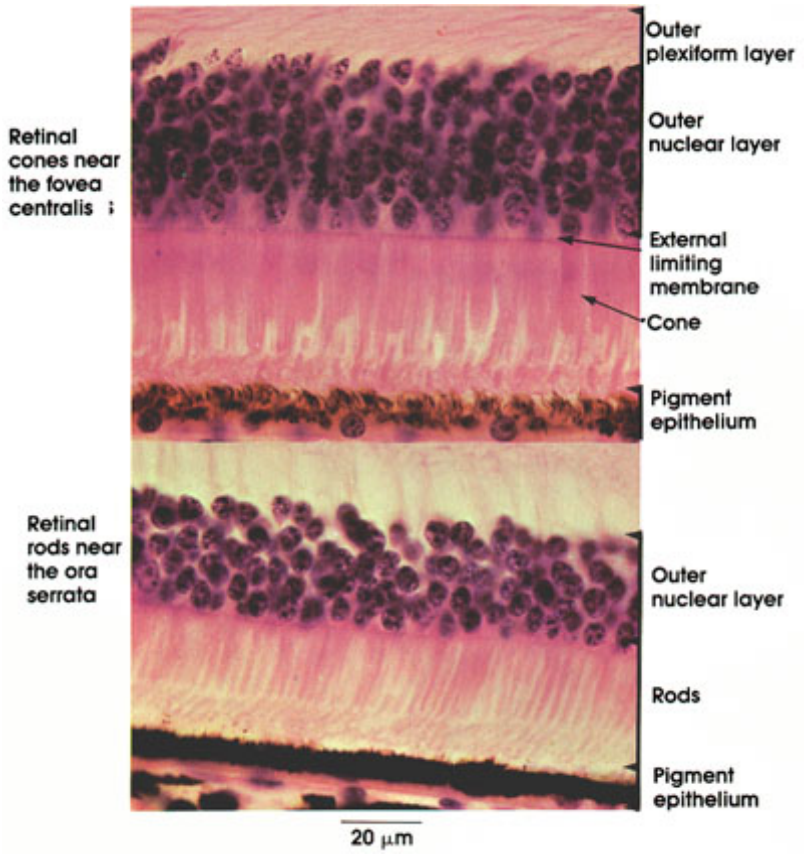
Peer Review Status: Externally Peer Reviewed

EYE
Cone and rod vision



Rhesus monkey, 10% formalin, H. & E., 612 x.

This figure shows variation in retinal structure near the fovea centralis and at the periphery of the retina (ora serrata). In both sites, the layers of the retina are diminished. Absent are the ganglion cell layer, the inner plexiform layer, and the bipolar cell layer. The fovea constitutes the zone of greatest visual acuity. At the fovea, the photoreceptors are thin, slender elements (cones). They resemble rods more than cones. See Plate 307. The thinning of the retina at the fovea reduces to a minimum tissue through which light passes, and hence improves visual acuity. Note ovoid nuclei of cones in the outer nuclear layer. Multiple rows of these nuclei are characteristic of this region. Typical cones, which predominate here, function for sharp vision and color perception. It is estimated that there are 6 to 7 million cones in the retina.

Near the ora serrata, rods increase in number and in thickness, and become shorter. The cones decrease in number and also become shorter at the periphery of the retina. Rods number approximately 100 million and function for night vision and black and white discrimination. Note the multiple rows of rounded rod nuclei in the outer nuclear layer. The pigmented epithelium layer is similar in both fovea and ora serrata. It is firmly bound to the choroid layer and contains melanin pigment.

Plate 16.309 Eyelid

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EYELID

Rhesus monkey, 10% formalin, H. & E., 50 x.

The eyelid is a fold of skin; superficially, the keratinized epidermis blends internally with a mucous membrane (the conjunctiva). These layers are supported by a dermal core of connective tissue in which striated and smooth muscle, glands, and hair follicles are located.

Eyelash follicle: A row of short stout hairs are found at the free margin of the lid. Penetrate deep into the dermis. Their follicles are similar to those found elsewhere in the body but lack the arrector pili smooth muscle.

Skin: Thin layer of epidermis continuous with the conjunctiva.

Fat lobule: Scattered in the connective tissue core of the eyelid.

Orbicular muscle: Skeletal muscle bundles that lower the eyelids.

Conjunctiva: Mucous membrane lining the inside of the eyelid. The epithelium is stratified columnar with goblet cells scattered among the superficial cells.

Meibomian gland: The tarsal glands of the eyelids, first noted by Casserius in 1609 and described by Heinrich Meibom, a German anatomist, in 1666. These are simple, branched alveolar sebaceous glands disposed in a plane perpendicular to the lid margin. The glandular alveoli are connected by short lateral ducts to a long central excretory duct lined with stratified squamous epithelium. The glands open at the inner free margin of the lid at the junction of the skin and conjunctiva. Secretion of the glands serves to lubricate the surface of the lids.

Plate 16.310 Lacrimal Gland

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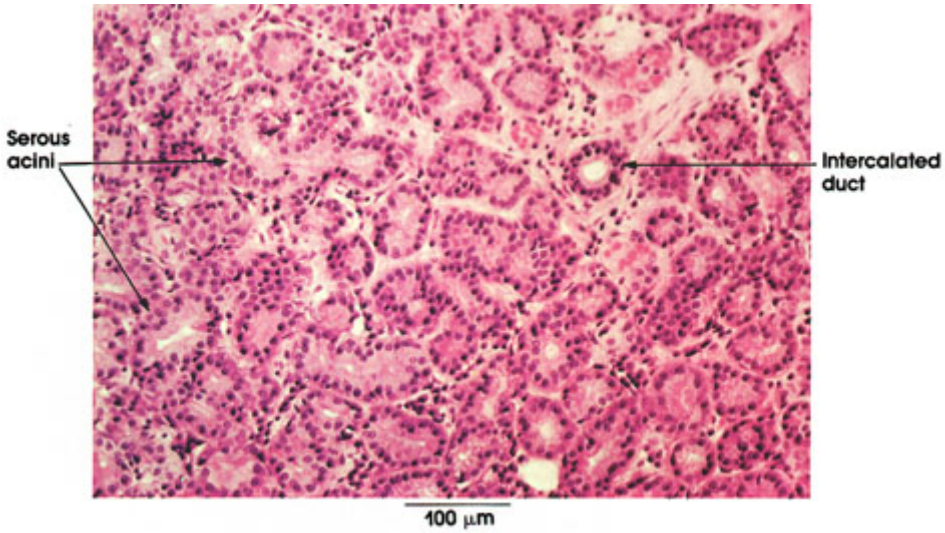
LACRIMAL GLAND



Human, 10% formalin, H. & E., 126 x.

The lacrimal gland is composed of a number of compound tubuloalveolar serous glands. The serous acini are made up of tall cells with basal nuclei. The secretory product fills the apical cytoplasm. The acini are separated by a thin connective tissue stroma. The aqueous secretion (tears), after flushing the conjunctivalcorneal surfaces, drains into ducts that carry it, via the nasolacrimal duct, to the anterior portion of the inferior meatus of the nose.

Plate 16.311 Organ of Corti

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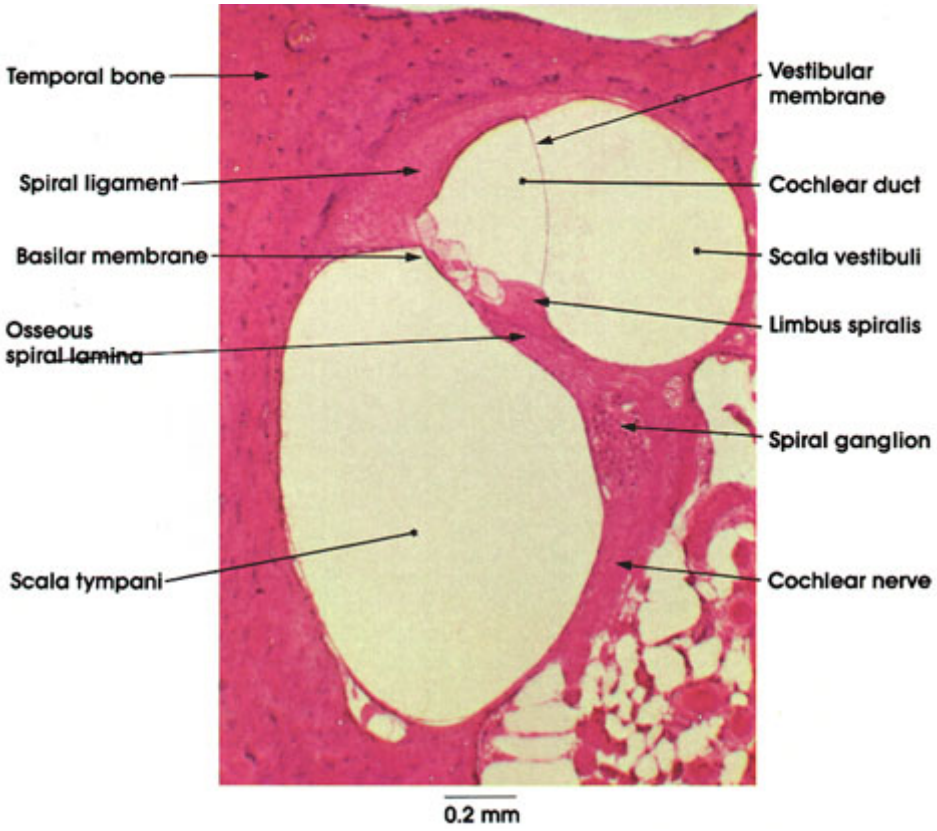
ORGAN OF CORTI



Cat, Müller's* fluid, H. & E., 50 x.

Temporal bone: The bone in which the cochlea is located.

Spiral ligament: A projection of thickened periosteum along the outer wall of the osseous canal of the cochlea.

Osseous spiral lamina: A bony shelf projecting from the modiolus across the osseous canal of the cochlea. Follows the spiral turns of the cochlea. Divides the osseous canal of the cochlea into an upper scala vestibuli and a lower scala tympani. The former is continuous with the oval window; the latter ends at the round window. The two scalae are continuous at the helicotrema.

Vestibular membrane: Also called Reissner's* membrane. A thin membrane extending from the upper surface of the limbus spiralis to the upper part of the spiral ligament. It forms the roof of the cochlear duct, which is a part of the membranous labyrinth and houses the organ of hearing.

Limbus spiralis: A thickening of periosteal connective tissue at the outer border of the osseous spiral lamina. The vestibular membrane attaches to the upper surface of the limbus.

Basilar membrane: Forms the base of the cochlear duct. Gives support to the organ of Corti.

Spiral ganglion: Ganglion of the bipolar cells. Peripheral processes contact the hair cells of the organ of Corti, and the longer central processes form the cochlear nerve.

Cochlear nerve: Formed by the central processes of the bipolar cells of the spiral ganglion, these nerve fibers, upon entering the brain stem, terminate in the dorsal and ventral cochlear nuclei (see Plates 105 and 332).

Plate 16.315 Macula Utriculi

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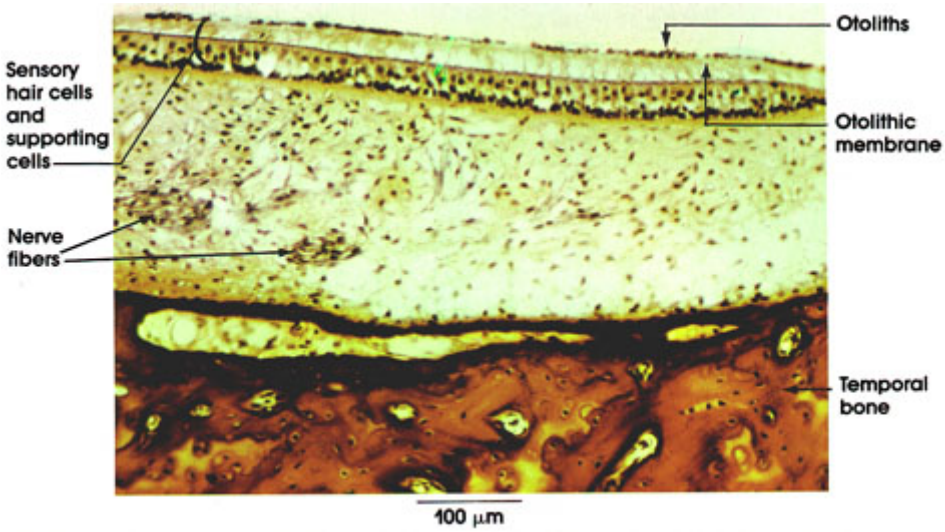
Peer Review Status: Externally Peer Reviewed

MACULA UTRICULI
Membranous labyrinth



Cat, Müller's fluid, iron hematoxylin, 162 x.

Sensory area of the utricle. The sensory epithelium is composed of two types of cells.

Hair cells: Flask-shaped. Nuclei occupy the upper part of the epithelial sheet. These receptors of the macula utriculi are concerned with the orientation of the body with regard to gravity. The receptor cells of the macula sacculi, however, appear to respond primarily to vibratory stimuli.

Supporting cells: Slender. Nuclei are lined up near the basement membrane of the epithelium.

The surface of the macula is covered by a gelatinous material, the otolithic membrane, through which hairs of the hair cells project. The upper surface of the membrane contains densely packed crystals of a calcium carbonate-protein mixture, the otoliths. The utricle and saccule, which are similar in appearance, constitute the "otolith organ."

Nerve fibers: Afferent components of the vestibular portion of the eighth cranial nerve, the vestibulocochlear nerve.

Temporal bone: Forming the osseous labyrinth.

Plate 16.314 Semicircular Canal

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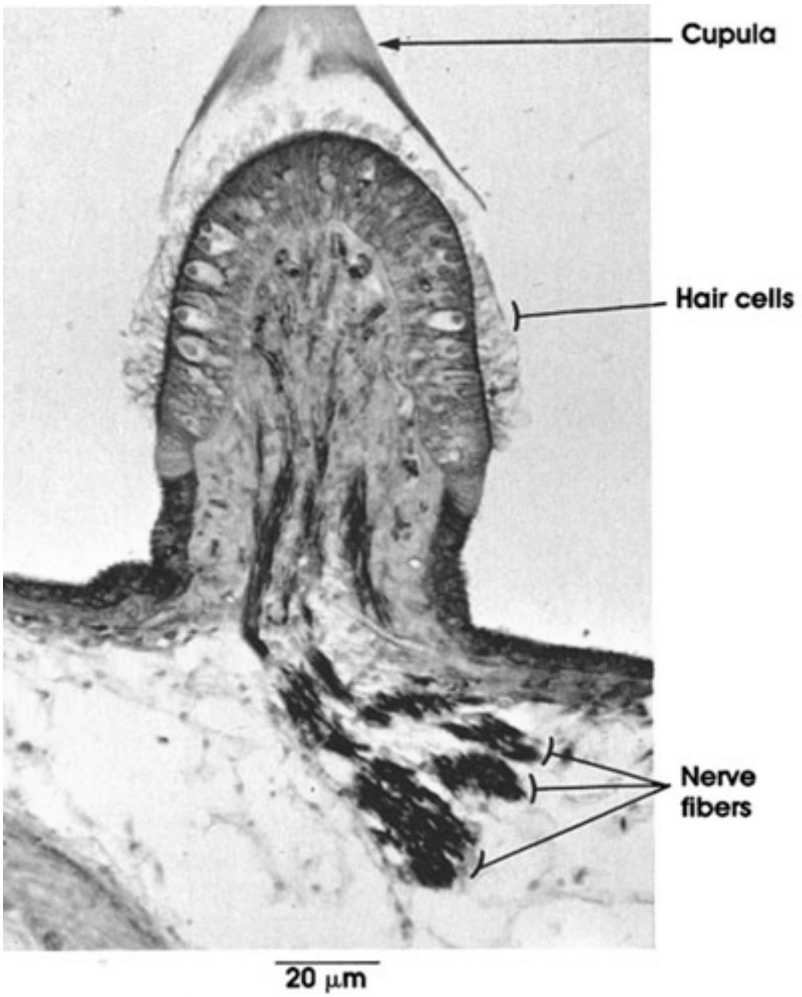
SEMICIRCULAR CANAL
Crista ampullaris



Guinea pig, Müller's fluid, iron hematoxylin stain, 612 x.

Cupula: Gelatinous dome-shaped mass in which the hairs of the hair cells are embedded. Similar to the cells of the otolithic membrane but lacks otoconia. Movements of the cupula are transmitted to the hairs of the receptor cells.

Hair cells: Flask-shaped cells that occupy the outer part of the epithelium but do not reach the basement membrane. Nuclei close to the lumen. A tuft of hairs is found in the apex of each cell. Compare hair cells to the adjacent tall, columnar sustentacular cells with basal nuclei that reach the basement membrane.

Nerve fibers: Myelinated processes of the vestibular nerve lose their myelin close to the hair cells of the crista. Naked fibers ramify among the hair cells of the crista, forming a dense arborization.

Plate 16.313 Semicirular Canal

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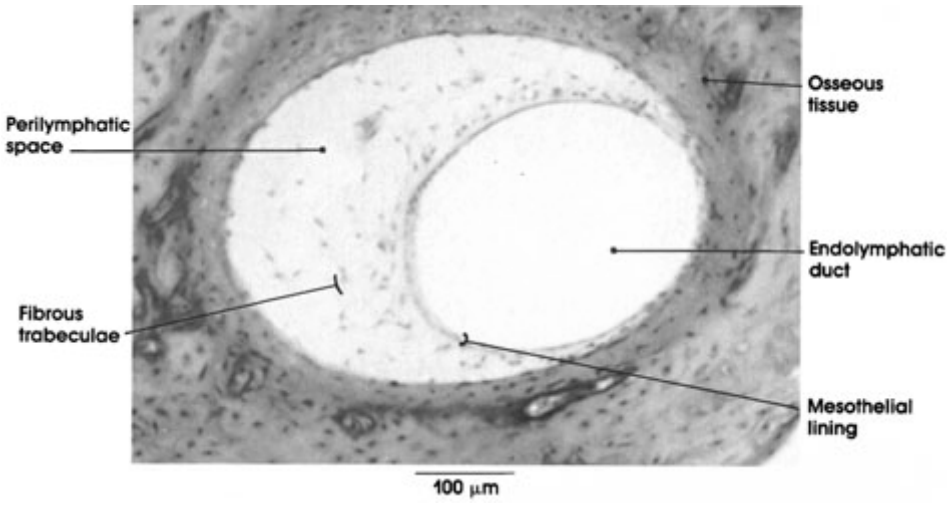
SEMICIRCULAR CANAL
Temporal bone



Cat, Müller's fluid, H. & E., 162 x.

Perilymphatic space: Intervenes between the osseous labyrinth and the membranous labyrinth. Traversed by fibrous trabeculae. Contains the fluid, perilymph.

Osseous tissue: Compact bone forming the osseous labyrinth. The surface facing the perilymph has a periosteum covered by mesenchymal tissue.

Endolymphatic space: The stimulation of the vestibular receptors (the crista ampullaris and the two maculae) depends upon the movement of endolymph, the fluid contained within the endolymphatic space in the semicircular canals, saccule, and utricle. See Plates 314 and 315. Note the mesothelial lining enclosing the endolymphatic space.

Plate 16.312 Organ of Corti

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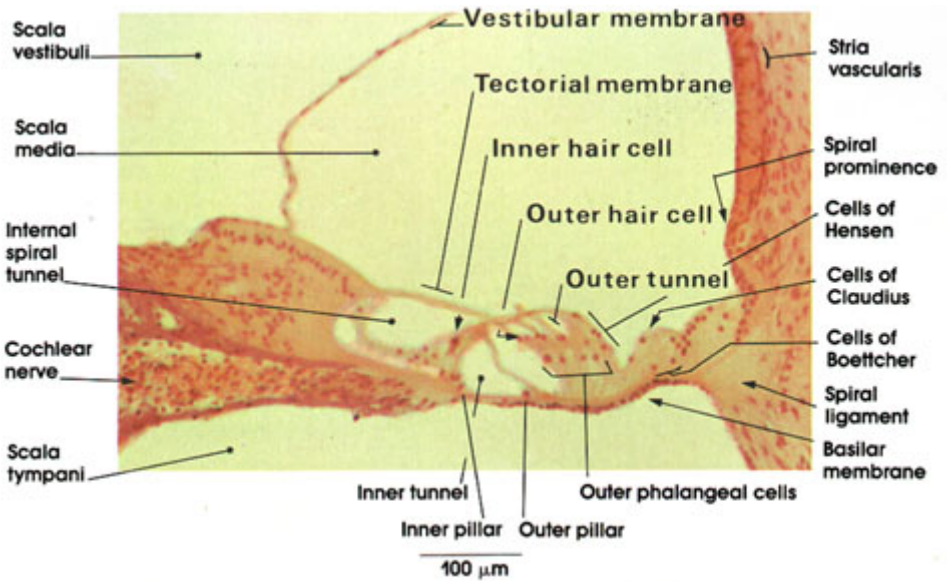
ORGAN OF CORTI
Cochlea



Guinea pig, 20% formalin, H. & E., 162 x.

This plate is a cross section of the bony cochlea and shows three compartments: the upper, scala vestibuli; the lower, scala tympani; and the middle, scala media. The scala vestibuli and scala tympani are perilymphatic spaces. The scala vestibuli reaches the inner surface of the oval window. The scala tympani reaches the inner surface of the round window. Both scalae communicate at the helicotrema at the apex of the cochlea. The scala media or cochlear duct is part of the endolymphatic system and contains the organ of Corti. The vestibular membrane or Reissner's membrane forms the roof of the cochlear duct. The basilar membrane forms the base of the cochlear duct and gives support to the organ of Corti.* The outer wall of the cochlear duct is made up of the spiral ligament, which is a thickening of the periosteum. The crest of the spiral ligament forms the spiral prominence. The part of the spiral ligament between the spiral prominence and the vestibular membrane is the stria vascularis. The epithelium here is thick and pseudostratified. The subepithelial connective tissue is rich in capillaries. The stria vascularis is believed to be active in the production of endolymph and the regulation of its

ion content. The epithelium of the spiral prominence continues onto the basilar membrane. Cells here become cuboidal. Those cells continuing onto the pars pectinata of the basilar membrane are known as cells of Claudius.* In parts of the cochlea, polyhedral cells separate the Claudius cells and the basilar membrane and are known as cells of Boettcher.* The organ of Corti is composed of two types of cells, supporting and hair cells. The supporting cells are tall, slender cells extending from the basilar membrane to the free surface of the organ of Corti. The supporting cells include the outer and inner pillars, inner and outer phalangeal cells, and cells of Hensen.* The inner tunnel within the organ of Corti is bounded below by the basilar membrane and above by the outer and inner pillar cells. The outer phalangeal cells act as supporting elements for the three to four rows of outer hair cells. The cells of Hensen are located adjacent to the last row of outer phalangeal cells. They constitute the outer border of the organ of Corti. The hair cells are of two types: the inner and outer hair cells. The inner hair cells are in a single row. The outer hair cells form three rows lodged between the outer pillar and outer phalangeal cells. The tectorial membrane is in contact with the hairs of hair cells and transmits to them endolymph vibrations. The cochlear nerve is formed by central processes of the bipolar cells of the spiral ganglion. In the inner angle of the scala media, the periosteal connective tissue of the spiral lamina bulges into the scala media overhanging the internal spiral tunnel.