SPECIAL SENSES (EYE & INNER EAR)

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Objectives

- Identify the components of the globe of the eye and the layers of the retina
- Correlate the structure and function of the components of the eye
- Identify the components of the cochlea
- Correlate the structure and function of the components of the cochlea
OVERVIEW

CELLULAR STRUCTURES THROUGH WHICH LIGHT PASSES
A. CORNEA
B. LENS
C. RETINA

STRUCTURES WHICH INFLUENCE THE IMAGE
A. IRIS
B. CILIARY BODIES
C. TRABECULAR MESHWORK
Turn the eye so that it is facing you & examine these structures on the front surface of the eye:

- **eyelids** - two moveable covers that protect the eye from dust, bright light, and impact
- **sclera** - this is the tough, white outer coat of the eye that extends completely around the back & sides of the eye
- **cornea** - a clear covering over the front of the eye that allows light to come into the eye (preservative often makes this appear cloudy)
- **iris** - round black tissue through the cornea that controls the amount of light that enters the inner part of the eye (may be colored in humans)
- **pupil** - the round opening in the center of the eye that allows light to enter and whose size is controlled by the iris
Fig. 19-1  Eyelid (sagittal section). Stain: hematoxylin-eosin. Low magnification.
Eye – conjunctiva on white of eye
THREE LAYERS OF THE WALL OF THE EYE

SUPPORTING, VASCULAR, and RETINAL layers
Eye

- Ora serrata
- Hyaloid canal
- Central artery of retina
- Central vein of retina
- CN II (optic)
- Optic disc
- Fovea centralis
- Retina
- Choroid
- Sclera
- Ciliary muscle
- Ciliary process
- Ciliary body
- Zonular fibers
- Limbus
- Scleral venous sinus
- Lens
- Capsule of lens
- Iris
- Cornea
- Pupil
- Sphincter pupillae
- Dilator pupillae
- Anterior chamber
- Posterior chamber
- Anterior cavity
- Vitreous chamber (posterior cavity)
The ora serrata is the serrated junction between the retina and the ciliary body and marks the end of the photosensitive portion of the retina.
Eye human and monkey

- Cornea
- Pupil
- Anterior chamber
- Posterior chamber
- Vitreous chamber
- Optic nerve
- Nerve
- Retina
- Sclera
- Connective tissue
- Chorioid layer
- Ciliary body
- Lens
- Iris
CELLULAR STRUCTURES THROUGH WHICH LIGHT PASSES

A. CORNEA
B. LENS
C. RETINA
CORNEA

FUNCTION:
- PROTECTION
- STRUCTURAL SUPPORT
- FILTER OUT UNDESIRABLE LIGHT RAYS
- FOCUS IMAGE ON RETINA

NUTRITION:
- LIMBUS
- O$_2$ FROM AIR FOR CORNEAL EPITHELIUM
Total refractive power = 59 diopters

Vitreous humor 1.34
Lens 1.40
Aqueous humor 1.33
Cornea 1.38
Air 1.00
Slide 8: Eye

- Endothelium
- Descemet’s membrane
- Stroma
- Bowman’s membrane
- Corneal epithelium
- Conjunctiva
Stroma
Eye – corneal epithelium
lens

invagination

vesicle

eyes

sclera

secondary vitreous

primary vitreous

anterior chamber

eyelid epith.

vessels

gonadal epithelium
LENS

FUNCTION: FOCUS IMAGE ON PHOTOSENSITIVE PORTION OF PHOTORECEPTOR CELLS

NUTRITION: AQUEOUS HUMOR
Bow area of lens

Fibers of zonule

Lens capsule

Lens epithelium

Lens fibers
Eye (toluidine blue) elongation of lens cuboidal cells at bow region
When areas of the lens become opaque or cloudy and vision is impaired, the condition is termed a cataract. In older individuals, denaturation of crystallins commonly begins to occur in lens fibers, making them less transparent and leading to cataracts.
34412 monkey eye
Contraction of muscle reduces tension on zonuales allowing the lens to be more spherical to focus on close objects.
Aqueous humor and ciliary zonule fibers

Production and removal of aqueous humor

1. Aqueous humor is secreted by the ciliary processes into the posterior chamber.
2. Aqueous humor moves from the posterior chamber, through the pupil, to the anterior chamber.
3. Excess aqueous humor is resorbed via the scleral venous sinus.

Ciliary zonule fibers SEM
Slide 8: Eye

Lens

- Lens fibers
- Anterior epithelium
- Capsule
- Attached zonula fiber

Nuclear zone: transitional area from cells to fibers
Retina

(a) Central artery of retina  Central vein of retina  Retina  Sclera  Choroid  Optic disc

(b) Optic nerve  Macula lutea  Fovea centralis

- Photoreceptor cells
- Rod
- Cone
- Horizontal cell
- Bipolar cells
- Amacrine cell
- Ganglion cells
- Axons of ganglion cells to optic nerve

- Impulse response to light through retina
- Incoming light

- Choroid
- Pigmented layer
- Neural layer
- Retina
- Intraocular layer (IL)
- Neuroepithelial layer (NFL)
- Gliotic layer (GL)
- Inner plexiform layer (IPL)
- Inner nuclear layer (INL)
- Outer plexiform layer (OPL)
- Outer nuclear layer (ONL)
- Outer limiting layer (OLL)
- Retinal capillaries (RCL)
- Pigment layer (PL)
RETINA

FUNCTION: PHOTORECEPTION OF IMAGE PROCESSING BY NEURONS PREVENT BACKSCATTER OF LIGHT

NUTRITION: CHOROID, RETINAL BLOOD VESSELS
CONES have pigments for the primary colors (red, green, and blue)
Fig. 19-5  Retina, Choroid, and Sclera (panoramic view). Stain: hematoxylin-eosin. Medium magnification.

Fig. 19-6  Layers of the Choroid and Retina (detail). Stain: hematoxylin-eosin. High magnification.
Slide 8: Eye

10 Retina layers

1. Pigmented epithelium
2a. Layer of rods
2b. Layer of cones
3. External limiting membrane
4. Outer nuclear layer
5. Outer plexiform layer
6. Inner nuclear layer
7. Inner plexiform layer
8. Ganglion layer
9. Nerve fiber layer
10. Inner limiting membrane
Photoreceptor cells

Rod cell phototransduction

Cone cell
Functions of Retinal pigment epithelium

1. Vitamin A storage
2. Phagocytosis of rod tips
3. Absorption of light
4. Nutrients to retina
5. Blood retinal barrier
Typical retina

macula
Fovea centralis: a shallow depression with only cone cells at its center; ganglion cells and other conducting neurons are located only at its periphery. It lies directly opposite of the pupil and is where visual acuity or sharpness is maximal.

Macula lutea: This surrounds the fovea centralis. Here all layers of the retina are present and the two plexiform layers are rich in various carotenoids, which give the area a yellowish color. The carotenoids have antioxidant properties and filter potentially damaging short wavelength light, thus helping to protect the cone cells of the fovea.
Eye (toluidine blue)
macula

blind spot
STRUCTURES WHICH INFLUENCE THE IMAGE

A. IRIS
B. CILIARY BODIES
C. TRABECULAR MESHWORK
FUNCTION: IRIS
REGULATE AMOUNT OF LIGHT THAT REACHES RETINA
BLACKENED POSTERIOR SURFACE TO STOP LIGHT RAYS
DILATOR (MYOEPITHELIAL) AND CONSTRICITOR (smooth) MUSCLES
NUTRITION: LOCAL BLOOD VESSELS
Slide 8: Eye

- Iris
- Sclera
- Choroid
- Uvea
- Vascular choroid with melanophores

- Posterior choroid layer
- Ciliary body
- Iris
- Uvea

- Choroid
- Sclera
Slide 8: Eye

Iris:
- Pigmented epithelium
- Dilator pupillae
- Pupillae constrictor

Ciliary body:
- Ciliary processes
- Ciliary muscle
- Canal of Schlemm
The dilator pupillae muscle is controlled by the sympathetic innervation.
Slide 8: Eye

Ciliary processes

Zonula fibers
Vitreal, non-pigmented ciliary epithelium layer
Scleral, pigmented ciliary epithelium layer

Lens
Zonula fibers connected to lens
The sphincter pupillae muscle is innervated by the parasympathetic innervation.
Pigmented epithelium of iris

Pupillae constrictor

Lens
IRIS

DILATOR (MYOEPITHELIAL) AND CONSTRUCTCTOR (smooth) MUSCLE
CILIARY BODIES

FUNCTION:
- CONTRACTION OF MUSCLE CHANGES LENS THROUGH ZONULES
- CILIARY PROCESSES SECRETE AQUEOUS HUMOR
- BLACKENED REGION STOPS LIGHT RAYS

NUTRITION: LOCAL BLOOD VESSELS
A detached retina occurs when the pigmented epithelium and the photoreceptor layer of the retina separate.
Eye – ciliary muscle
Eye – secretory cells
Secreatory epithelium and pigmented epithelium for the CILIARY BODIES.
Aqueous humor is produced by ciliary processes. It then flows into the posterior chamber of the anterior cavity through the pupil into the anterior chamber, and finally drains through the canal of Schlemm.
TRABECULAR MESHWORK

FUNCTION: RESISTANCE TO OUTFLOW OF AQUEOUS HUMOR

NUTRITION: LOCAL BLOOD VESSELS, PROBABLY AQUEOUS HUMOR
Ciliary muscle

Canal of Schlemm

Trabecular meshwork

Cornea

End of Descemet’s membrane

Corneal epithelium

Bowman’s membrane

Stroma

Descemet’s membrane

Endothelium
Trabecular meshwork and Canal of Schlemm:

1. Anterior chamber
2. Canal of Schlemm
3. Endothelial cell
4. Trabecular meshwork
Eye – trabecular meshwork and canal of Schlemm

The canal of Schlemm functions to drain the aqueous humor from the anterior chamber via the trabuclar meshwork.
Ear

External ear
Middle ear
Inner ear

Auditory ossicles
Stapes
Incus
Malleus

Petrus part of temporal bone
Vestibular branch of CN VIII
Cochlear branch of CN VIII
Facial nerve (CN VII)
Vestibulocochlear nerve (CN VIII)
Internal acoustic meatus
Bony labyrinth of inner ear

External acoustic meatus
Tympanic membrane
Tympanic cavity
Oval window
Round window
Auditory tube

Elastic cartilage

To nasopharynx
Cochlea and spiral organ of Corti

(a) Sectioned cochlea

(b) Close-up of cochlea

(c) Organ of Corti

(d) Organ of Corti

Vestibular membrane
Basilar membrane
Scala vestibuli
Cochlear duct
Scala tympani
Spiral ganglion
Cochlear branch of CN VIII
Modiolus

Tectorial membrane
Supporting cells
Stereocilia
Inner hair cell
Cochlear branch of CN VIII
Scala tympani
Scala vestibuli
Bony cochlear wall
Cochlear duct
Scala media
Bony cochlear wall
Cochlear duct
Scala media
Cochlear duct
Vestibular membrane
Tectorial membrane
Basilar membrane
Scala tympani
Scala vestibuli
Cochlear branch of CN VIII
Spiral ganglion
Orgn of Corti

Cochlear duct
Tectorial membrane
Outer hair cell
Inner hair cell
Supporting cells
Cochlear branch of CN VIII
Basilar membrane
Scala tympani
Scala vestibuli
Slide 9: Cochlea

- Bony cochlea
- Modiolus

Cochlear branch of CN VIII

Scala vestibuli

Spiral ganglion

Scala tympani

Cochlear duct

Basilar membrane

Vestibular membrane

Modiolus
The scala vestibuli and scala tympani contain perilymph.
Slide 9: Cochlea

- Spiral limbus
- Scala tympani
- Basilar membrane
- Spiral ligament
- Stria vascularis
- Scala media
- Scala vestibuli
- Vestibular (Reissner’s) membrane
- Cochlear nerve
- Spiral ganglion
- Tectorial membrane
Sound waves

Sound waves enter the ear and cause the tympanic membrane to vibrate.

1. Sound waves enter the ear and cause the tympanic membrane to vibrate.
2. Tympanic membrane vibration moves auditory ossicles; sound waves are amplified.
3. The stapes at the oval window generates pressure waves in the perilymph within the scala vestibuli.
4. Pressure waves cause the vestibular membrane to move, resulting in pressure wave formation in the endolymph within the cochlear duct and displacement of a specific region of the basilar membrane. Hair cells in the organ of Corti are distorted, initiating a nerve signal in the cochlear branch of CN VIII.
5. Remaining pressure waves are transferred to the scala tympani and exit the inner ear via the round window.

High frequency

- Vestibular membrane
- Cochlear duct
- Basilar membrane
- Scala vestibuli
- Helicotrema
- Organ of Corti
- Scala tympani

Medium frequency

- Vestibular membrane
- Cochlear duct
- Basilar membrane
- Scala vestibuli
- Helicotrema
- Organ of Corti
- Scala tympani

Low frequency

- Vestibular membrane
- Cochlear duct
- Basilar membrane
- Scala vestibuli
- Helicotrema
- Organ of Corti
- Scala tympani

Relative frequency distribution:

- 20,000 Hz (high frequency)
- 1500 Hz
- 500 Hz
- 20 Hz (low frequency)
Mechanotransduction in hair cells

Mechanical deformation toward the kinocilium opens $K^+$ channels in the stereocilia.

High $[K^+]_e$

Support cell

Depolarization

K$^+$

Ca$^{2+}$

Vesicle

Synapse

Ca$^{2+}$ enters the cell, allowing vesicle fusion and the release of neurotransmitter.

(a)

Tight junction

(b)

Mechanical deformation away from the kinocilium closes $K^+$ channels in the stereocilia.

Tip link

To brain

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A patient complains of “foggy” vision. Upon examination, the patient is diagnosed with age-related cataracts.

What portion of the eye is affected by this condition?

- When areas of the lens become opaque or cloudy and vision is impaired, the condition is termed a cataract. In older individuals, denaturation of crystallins commonly begins to occur in lens fibers, making them less transparent and leading to cataracts.

Between what layers is the separation in a patient with a "detached retina"?

- A detached retina occurs when the pigmented epithelium and the photoreceptor layer of the retina separate.

Why is this detachment so important?

- This is important because when the retina is detached the photoreceptor cells no longer have access to metabolic support from the pigmented layer and choroid and will eventually die, resulting in loss of vision. Prompt repositioning of the retina and reattaching it with laser surgery is an effective treatment.
Many illustrations in these VIBS Histology YouTube videos were modified from the following books and sources: Many thanks to original sources!

- Douglas P. Dohrman and TAMHSC Faculty 2012 Structure and Function of Human Organ Systems, Histology Laboratory Manual - Slide selections were largely based on this manual for first year medical students at TAMHSC.