

## THE EYE

- **Chambers (distinct & interconnected):**
  - Anterior
    - Boundaries:
      - Posterior to cornea (endothelium)
      - Anterior to...
        - Iris ("washer"-shaped)
        - Part of the lens (center)
    - Content: *aqueous humor* **3 mL/DAY**
      - Produced by ciliary body (see posterior chamber)
      - similar to CSF or blood plasma but v. little protein
  - Posterior ("washer"-shaped; chamber parallels the iris)
    - Boundaries:
      - Posterior to...
        - Iris epithelium
      - Anterior to...
        - Ciliary process
        - Zonule fibers (suspensory fiber of the lens)
        - Part of the lens (outer ring)
      - Its outer edge contacts the ciliary process
    - Content: *aqueous humor*
      - Produced by ciliary body
      - Fluid pressure (posterior chamber) causes aqueous humor to flow b/w iris & lens → thereby reaching the anterior chamber
      - Nourishment to:
        - Lens
        - Other structures (bordering Ant/Post. Chambers)
    - Blood-retinal & blood-aqueous barriers (separate aqueous from CT & blood)
      - Occluding Zonules of
        - Blood vessels of the iris
        - Neural retina
        - Epithelial cells of the pigment epithelium (retina)
        - Ciliary body
        - Corneal endothelial cells
  - Vitreous Chamber/Cavity
    - Boundaries:
      - Anterior & Medial to the retina ("cup"-shaped)
      - Posterior to...
        - Ciliary Body
        - Zonule Fibers
        - Lens
    - Contents: *Vitreous Gel* (thick gelatinous fluid; **3 mL/day**)
      - Produced by Hyalocytes
      - Composition:
        - Hyaluronic Acid
        - Collagens (types I & II)
      - Function:
        - Support shape of eye
        - Maintains position of the retina; prevents retinal detachment
      - Regenerates poorly

~~Tunics (layers) of the wall of the eye (outside → inside):~~

## • TUNICS (LAYERS) OF THE "WALL OF THE EYE" (OUTSIDE → INSIDE)

- **Fibrous layer** – Fxn = protection & support of the eye
  - **CORNEA (clear)**
    - Chief refractive component of eye
    - Avascular
    - Normally, nearly free of WBC's
    - 5 Layers (outer → inner):
      - *Anterior Corneal Epithelium*
        - Stratified Squamous Non-keratinized (SSNK)
        - Renewed once a week; capable of repair
        - Contains many sensory-free nerve endings
      - *Bowman's Layer*
        - Acellular condensation of underlying collagenous layer
        - Fxn: resist penetration & slows bacterial invasion
        - Incapable of repair/regeneration
      - *Corneal Stroma (substantia propria)*
        - Components:
          - Cells: keratocytes (specialized fibroblast)
          - Ground Substance: corneal proteoglycan
            - Keratin
            - Chondroitin sulfate
          - Fibrils: Type I collagen
            - Fibril arrangement → "clarity"
              - Lamellae of fibrils ⊥ fibrils above & below
              - Uniform diameter & interfibrillar spacing
        - Doesn't regenerate; damage = scarring
      - *Descemet's Membrane*
        - Thickened basal lamina of underlying corneal endothelium
        - Capable of regeneration
      - *Corneal Endothelium*
        - Simple squamous (SS) to simple cuboidal (SC)
        - Not part of vasculature (despite name)
        - Part of blood-aqueous barrier (possesses O. Zonules)
          - Regulates ion content of the corneal stroma
          - Helps maintain hydration of substantia propria (SP), t/f....
          - Corneal endothelium damage may lead to permanent SP damage (regenerates poorly)
  - Clinical Correlation:
    - *Corneal Opacity* – can be caused by damage to endothelium, disrupting ion balance in the stroma or invasion of WBC's due to infection
    - *Corneal Transplants* – the cornea can be transplanted b/c it is avascular, decreasing the likelihood of graft rejection
    - *Surgical Remodeling* – permanent refractive changes can be surgically produced by reshaping the cornea to increase or decrease its power (radial keratotomy, LASIK)

~~▪ BULBAR CONJUNCTIVA (BC)~~

## ■ BULBAR CONJUCTIVA (BC)

- Stratified epithelium w/ goblet cells (mucins)
- Vascularized
- Continuous w/ anterior corneal epithelium
- I think, when you get a bug in the lower eye lid, the BC is the tissue that, , the bug lies on
- SCLERA (white of eye)
  - IDCT; opaque & vascularized
  - Cells: fibroblasts
  - Ground Substance
    - Keratin
    - Chondroitin sulfate
    - h/w , unlike corneal proteoglycan (structure not as "regular")
  - Fibrils: Type I collagen fibrils
    - Vary in diameter
    - Vary in interfibril spacing
  - Clinical Correlation: *Sclera thinning*—axial elongation of the vitreous chamber = Myopia ("nearsightedness")
- LIMBUS (corneaoscleral jxn)
  - Circular region where the sclera joins cornea
  - Site of corneal stem cells
  - A "highly vascular" region
    - Supplies nutrients & cells for the cornea
    - Drains the aqueous humor thru a circumferential *trabecular meshwork*
      - Composed of channels
        - sieve-like (vascular)
        - lined by squamous endothelium
      - Location:
        - Wall of anterior chamber
        - Adj to peripheral rim of corneal endothelium
    - Aqueous pathway: Limbus→Canal of Schlemm (larger channel) → venous system
  - LAMINA CRIBROSA – sieve-like opening in the posterior sclera allows exiting retinal ganglion cell axons to form the optic nerve
- Vascular layer (or uvea)—Fxn = Nutritive & Contractile
  - Supplied by the ciliary ~~arteries~~ **ARTERIES**
  - Supplies adj. structures with oxygen & nutrients
    - Outer retina
    - Sclera
    - Iris
    - Ciliary muscles
  - Drained by four vortex veins
  - Components:
    - CHOROID – a pigmented vascular layer b/w the sclera & retina
      - Produces *choriocapillaris*
        - Layer of fenestrated capillaries
        - Next to pigment epithelium of the retina
      - Fxn—absorbing light that passes through the retina
      - *Bruch's membrane (lamina vitrea)*
        - Thin elastic membrane b/w choriocapillaris & retinal pigment epithelium
        - *Drusen (?)* can be accumulated b/w Bruch's membrane & the pigment epithelium
        - Drusen (internet) = A condition involving retained hyaline bodies in the anterior optic nerve
        - Mentioned during lecture:

- Common variant: Factor H, single nucleotide polymorphism
- Age-related macular degeneration risk
- “Donut” vision (opposite tunnel vision)
- CILIARY BODY – bounded by the *ora serrata* where it meets the retina and the iris
  - Near the retina—relatively flat
  - Closer to the iris—epithelium forms ciliary processes (radially oriented folds)
  - Composition:
    - *Ciliary muscle* (circumferentially arranged)
      - Bundles of smooth muscle
      - Accommodation—regulate focal point of lens
        - Muscle contraction reduces tension on zonule fibers (see below)
        - Allows the lens to become rounder, increasing power
    - Layer of vascularized CT beneath the epithelium
    - Two-layered epithelium:
      - Inner: non-pigmented
        - Secrete aqueous humor
        - Joined by occluding zonules
        - Anchors zonule fibers (the collagenous fibrils of the suspensory ligaments)
      - Outer: pigmented
- IRIS (VASCULAR)
  - Fibromuscular flap
  - Composition:
    - Pigmented cells
    - Vascularized CT
    - Smooth muscle
  - Pupil—free margin forming a hole of variable diameter
    - Analogous to diaphragm of camera to regulate the amount of light falling on the retina
  - Histology:
    - Anterior surface: discontinuous layer of fibroblasts
    - Stroma
      - Composition: loose pigmented highly vascularized CT
      - Iris vessel endothelial cells possess ZO O.R.
    - Two smooth muscle bundles
      - *Pupillary Constrictor Muscle* adj. to PS papillary margin
      - *Pupillary Dilator Muscle* adj. to ciliary margin of the iris extending to papillary margins (nearly) SS
    - Pigmented epithelium
- Clinical Correlation: Glaucoma:
  - Definition: increased intraocular pressure
  - Collagen deposits in the trabecular meshwork during aging

- May block the outflow channels, producing glaucoma that leads to blindness if not treated.
- Current treatments include
  - carbonic anhydrase inhibitors to slow aqueous production
  - laser surgery
- "Tunnel" vision

- **Sensory layer (the retina)** – performs initial analysis of visual image (photoreceptors)
  - Derived from brain & has CNS features
  - Found in posterior 2/3's of the eye
  - Layers:
    - **QUICK SUMMARY may get confusing!** [inner (touching vitreous humor)→outer (touching choroid)]:

NOTE DIFF. B/W "NEURAL" & "NUCLEAR"

Cell Region	"Neural" (retinal layers)	"Nuclear" (nuclei of the cells)
	← <b>GANGLION AXONS TO OPTIC NERVE</b> →	
Ganglion Cells	Inner Neural Layer	Ganglion Cell Body Layer
	← <b>INNER PLEXIFORM LAYER</b> →	
Bipolar Cells +	Middle Neural Layer	Inner Nuclear Layer
	← <b>OUTER PLEXIFORM LAYER</b> →	
Photoreceptors	Outer Neural Layer	Outer Nuclear Layer (nuclei only)
	← <b>PIGMENTED EPITHELIUM</b> →	

- Light travels in eye: cornea→anterior chamber→pupil of iris→lens (passing posterior chamber around anterior of lens & zonule fibers around the edge of lens)→vitreous body→retina
- Light travels in retina: "passes" ganglion axon & cell bodies→"passes" bipolar cells→"passes" photoreceptors→ & **FINALLY absorbed** by pigmented epithelium (outer retinal cells against choroid)
- Signal travels in cells: travels pigmented epithelia cells→synapses in outer plexiform→travels bipolar cells→synapses in inner plexiform→travels ganglion cells→to ganglion axons
- Ganglion axons (unmyelinated) travel: run along "inner" retinal surface (against vitreous humor)→optic disc→leave the eye as the **OPTIC NERVE**
- **Pigmented epithelium**
  - Simple Cuboidal
  - Lays on Bruch's (see Vascular layer/CHOROID) wide membrane of BL reinforced by collagen & elastic fibers
  - Absorb light & destroy used-up tips of the rods
  - **Clinical Correlation: Drusen DONUT VISION**
    - Opaque nodules accumulate b/w Bruch's membrane & the pigment epithelium
    - They can hinder transfer of oxygen & nutrients from the choriocapillaris to the retina
    - Drusen appears during age-related macular degeneration (AMD), a condition resulting in loss of central vision
    - Tyrosine to histidine polymorphism at position 420 of complement factor H is associated with AMD (age-related macular degeneration)
- Occluding Zonules part of blood-aqueous barrier
- **Photoreceptors (outer neural layer)**
  - Layers:
    - **Outer segments**

- Captures & transduces (mediated by G-proteins) photons into electrochemical signals used by neurons
- Classifications:
  - Rods
    - High sensitivity
    - Poor acuity
    - No color discrimination
  - Cones
    - Color vision (varieties of iodopsin)
    - Fine acuity (less convergence in connexn)

Nuclei  
ELM  
↓  
Axons  
ILM

- *Inner segments* – organelles (including nuclei & many mitoch)
- *Outer Nuclear layer* – inner segmental photoreceptor nuclei (only) are considered the outer “nuclear layer of retina”
- *Outer Plexiform Layer* – synaptic contact b/w the photoreceptor nuclei & the bipolar cells (inner nuclei layer of retina)
- *Inner nuclear layer (middle neural layer)*
  - Many cell types
  - Bipolar cells - relays signals from the photoreceptors to the innermost cell layer (the ganglion)
  - Shortest route through retina: rod/cone → bipolar cell → ganglion cell
- *Inner Plexiform Layer* – synaptic contact b/w the bipolar cells (inner nuclei layer of retina) & the Ganglion nuclei
- *Ganglion Cell Layer (inner neural layer)*
  - Inner most cell layer
  - Relays signals from the bipolar cells to the brain via optic nerve (ganglion cell axons)
- *Optic Nerve Fiber Layer*
  - Ganglion cell axons (unmyelinated)
  - relays signals from the ganglion cell bodies to visual centers of the brain
- **Regional Differentiation of the Retina**
  - *Macula Lutea* – yellow-ringed depression (macula = yellow; lutea = spot)
  - *Fovea Centralis* – Central depression of macula lutea
    - The macula lutea inner cell layers have been “displaced” (pushed aside) to a peripheral hump, leaving an area consisting of a small depression in the retina containing only tightly packed cones with straight-through neural connections for high acuity (where vision is most acute)
    - 10 layered retina (only responsible for 7 layers) → 2 layers:
      - Retinal pigmented epithelium cells
      - Cone cells (photoreceptors)
  - Optic Papilla/disk
  - ~~AA~~ *Blind Spot* – no receptors
- **CNS Tract:**
  - Ganglion Cells fibers w/ acquired myelin sheath
  - Accompanying glial cells
  - Meningeal Sheath
- **STAY** Infraorbital section of nerve (center of CNS tract):

- Retinal Artery
    - Retinal Vein
    - Enter/Leave through optical disk.
    - Clinical Correlation: condition of vessels is a crucial part of the ophthalmoscopic examination
  - Blood Supply to the Retina
    - *Central Retinal Artery*
      - Inner 2/3 of the retina
      - Enters through optic disc & spreads across retinal surface
      - Visible w/ophthalmoscope
    - *Choriocapillaris* (of Choroid)
      - Outer 1/3 of the retina
      - Selectively pass materials from choriocapillaris (of Choroid) to retina (bypassing **retinal pigment epithelium** occluding zonules, part of blood-aqueous barrier)
    - *Blood-Brain Barrier*
      - **Retinal blood vessels** have occluding zonules
    - Clinical Correlation:
      - *Ophthalmoscopic exam*
        - Examining the surface of the retina with an ophthalmoscope allows viewing of the retinal vessels & optic disc
        - Symptoms of diabetes, hypertension and increased intracranial pressure can be detected by this noninvasive procedure
      - *Diabetic Retinopathy*
        - Blood-retina barrier leakage & capillary loss are prominent factors
        - “black spots” in field of vision
- **Lens** – a variable focusing device for maintaining a sharp image of the visual field on the retina
  - Avascular (postpartum)
  - Aneural (postpartum)
  - Composition:
    - *Anterior Lens Epithelium* – anterior ½ of lens; simple cuboidal epithelium
    - *Lens Fiber Cells*
      - In the peripheral cells undergo mitosis (continues throughout life)
      - Cells elongate, differentiate & migrate centrally
      - As cells approach center of lens, they lose their nuclei & most organelles & remain fxn'l for many years
      - Extensive gap jxn contacts in their PM's
    - *Lens Capsule* – thick basal lamina
      - All lens cells contribute to lens capsule/basal lamina
      - Anchors the suspensory ligaments (zonule fibers), which are anchored to the ciliary epithelium
    - *Summary* (Anterior→Posterior):
      - Capsule
      - Anterior Lens Epithelium
      - Fibers (peripheral & elongated)
      - Capsule
  - Clinical Correlation:
    - *Presbyopia*
      - During middle age, lens often becomes resistant to accommodative  $\Delta$ s
      - Time for bifocals
    - *Cataract*

- Lens fiber cells have H<sub>2</sub>O & proteins (crystalins) that become insoluble with age, leading to opacity of lens cells
- May be produced prematurely by UV radiation, steroids, toxins & trauma
- Currently, the lens is removed surgically & replaced w/ a plastic lens of fixed focus
- **Protective Tissues**
  - *Eye Lids (palpebrae)*
    - Fibromuscular structures covered externally by thin skin w/ sebaceous & sweat glands & fine hairs
    - *Eyelashes* – thick hair at the free margin
    - Layers (outside → inside):
      - *Thin Skin*
      - *Obicularis Oculi* – striated muscle that closes the eyelid VII
      - *Tarsal Plate* – CT
        - *Meibomian Glands* HOLOCRINE
          - Specialized sebaceous glands
          - Have their own opening at lid margin
          - Oily secretion – hydrophobic ring around the eye to prevent loss of the tear fluid (prevent evaporation)
      - *Palpebral Conjunctiva*
        - Thin epithel. continuous w/ thin skin of eye (underside of lid)
        - Continues through an arch (fornix) & reflects back onto the bulbar conjunctiva (see Fibrous Tunic of the Eye)
        - Fornix & Bulbar epithelium are stratified w/ goblet cells (highly unusual)
    - **Lacrimal Gland**
      - Compound tubulo-alveolar serous gland lacking striated ducts w/ myoepithelial cells (squeeze out tears)
      - Heavily infiltrated with adipocytes & plasma cells
      - Secretions: *tear fluid*:
        - Secretory IgA (combat infection)
        - Lysozyme (combat infection)
        - UV protectant factors
        - Mixed with:
          - Mucous (conjunctival goblet cells)
          - Oil film (meibomian gland)
      - Figure 27 (p. 282) – structures: lacrimal gland, secretory ducts, canaliculi (superior, inferior, & common), lacrimal sac, nasolacrimal duct, Inferior turbinate, inferior meatus, nasal cavity