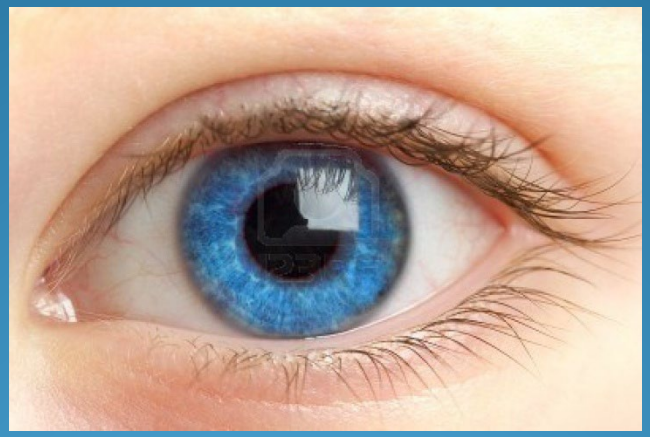
Advanced Anatomy and Physiology of the Eye



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Introduction

- Terminology
- Anatomy
- Refractive Errors
- Spherical Correction
- Cylindrical Correction
- Presbyopia
- Muscle Imbalances
- Unequal refractive errors
- Visualizing the Rx

Terminology – A&P

- Anatomy is the branch of biology concerned with the study of the structure of organisms and their parts.
  - Anatomy of the eye is the study of the eye structure and parts
- Physiology is the study of the function of body parts
  - Physiology of the eye is the study of the function/functions of the eye structure and parts
    - In other words how do the parts work?

Terminology

- Emmetropia
- Ametropia
- Myopia
- Hyperopia

Terminology

- Astigmatism
- Corneal astigmatism
- Lenticular astigmatism
- Regular astigmatism
- Irregular astigmatism

- Simple myopic astigmatism
- Compound myopic astigmatism
- Simple hyperopic astigmatism
- Compound hyperopic astigmatism

Terminology

- Presbyopia

- Greek
  - Presby = Old
  - Opia = Sight

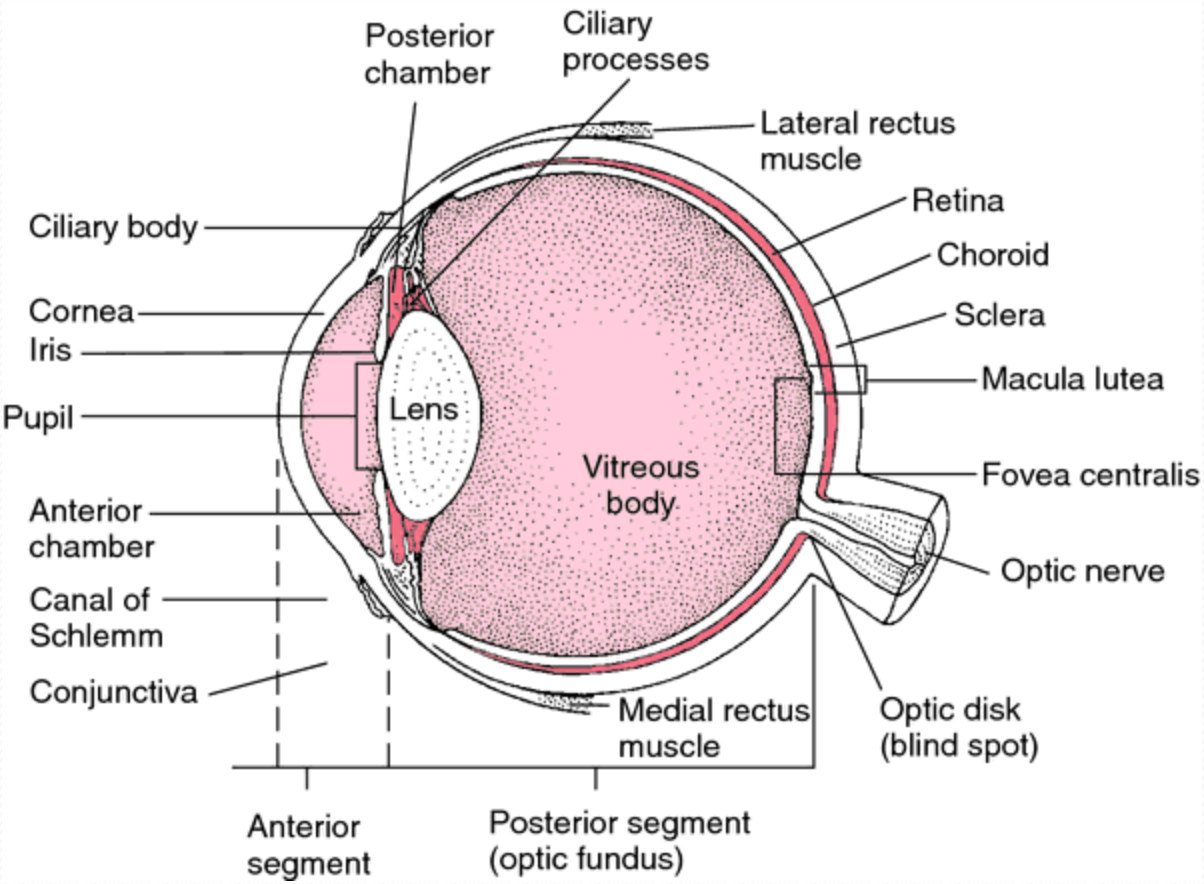
Index of Refraction

- Cornea = 1.37
- Aqueous humor = 1.33
- Crystalline lens = 1.42
- Vitreous humor = 1.33

Dioptric Power

- Cornea
  - +42.00D to +45.00D
  - Performs about 80% of the refraction or bending of light rays within the eye
- Crystalline Lens
  - +15.00D - +20.00 D
  - Depending on textbook

Anatomy


Posterior chamber
Ciliary processes
Lateral rectus muscle
Retina
Choroid
Sclera
Macula lutea
Fovea centralis
Optic nerve
Optic disk (blind spot)
Medial rectus muscle
Ciliary body
Cornea
Iris
Pupil
Lens
Vitreous body
Anterior chamber
Canal of Schlemm
Conjunctiva
Anterior segment
Posterior segment (optic fundus)

Four Refractive Mediums of the Eye

- The cornea
- The aqueous humor
- The crystalline lens
- The vitreous humor

Extraocular Structures

- Eyelids
- Orbit
- Lacrimal glands

Eyebrows

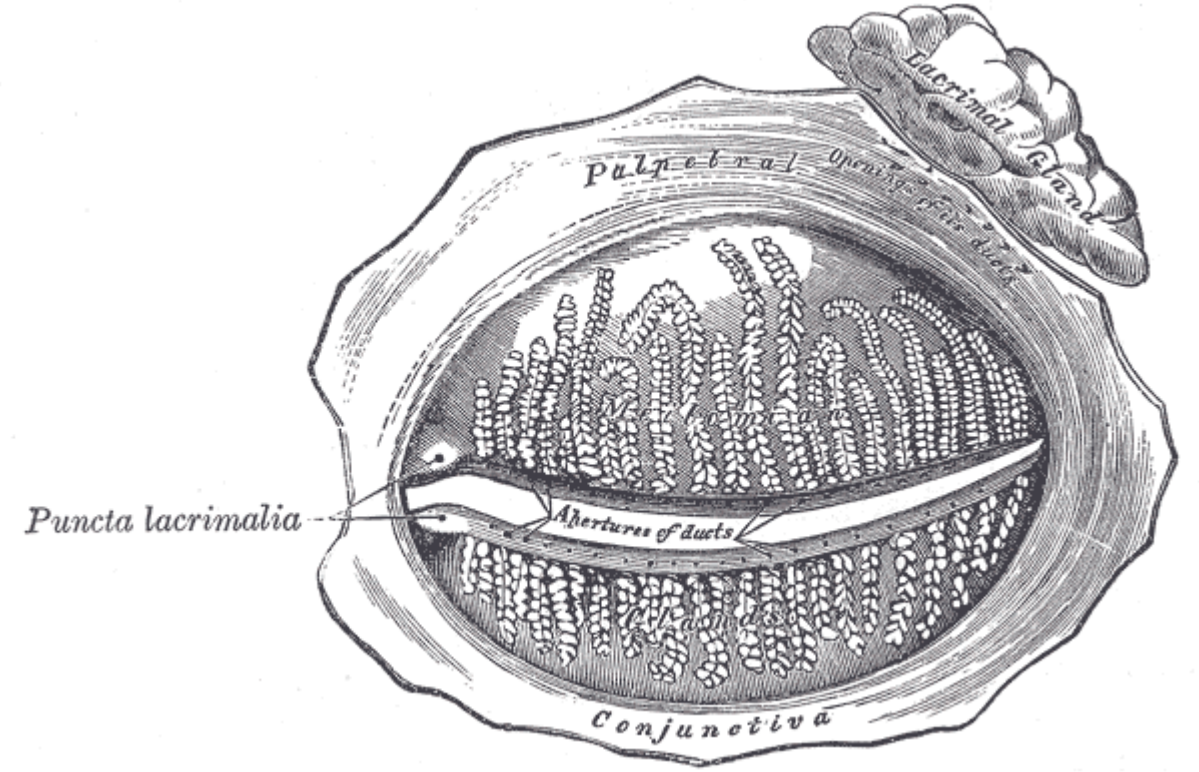
- Help shield the eye from strong light
  - Hairs grow laterally, so they protect the eye from perspiration and rain from running into eye
  - Sebaceous glands present to help protect eye
  - Help to give facial expression

Eyelids

- Palpebrae
  - Folds of tissue
- Termed palpebral aperture
  - While opened
  - Not always same size

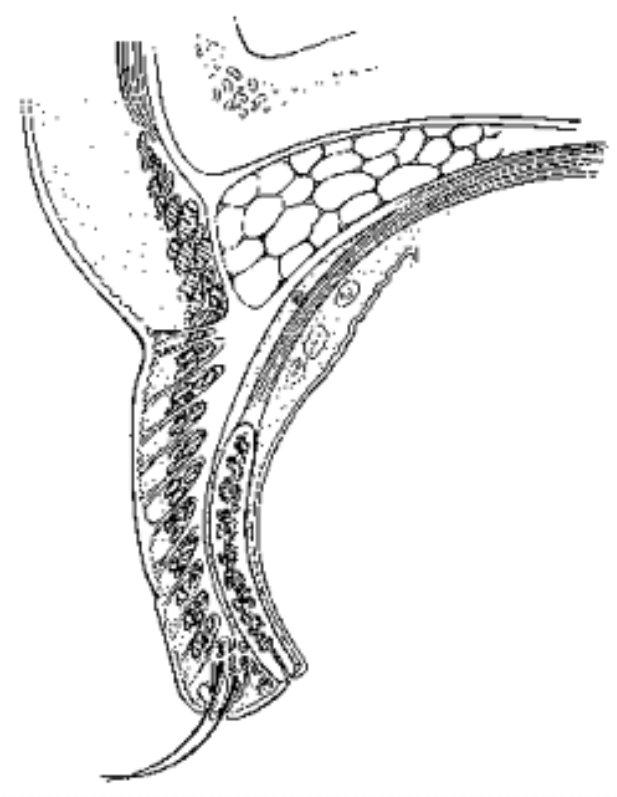
- Contain Meibomian glands
- Contain Sebaceous glands
  - Glands of Zeis
  - Glands of Moll

Glands of the Eyelids



Eyelids

- Important in health of eye
  - Lined by palpebral conjunctiva
  - Help to keep eye moist
  - Help to distribute tears, oxygen and nutrients/flush away debris
  - Protects the eye from light and injury
  - Lids are elastic/loose
    - Lose elasticity with age

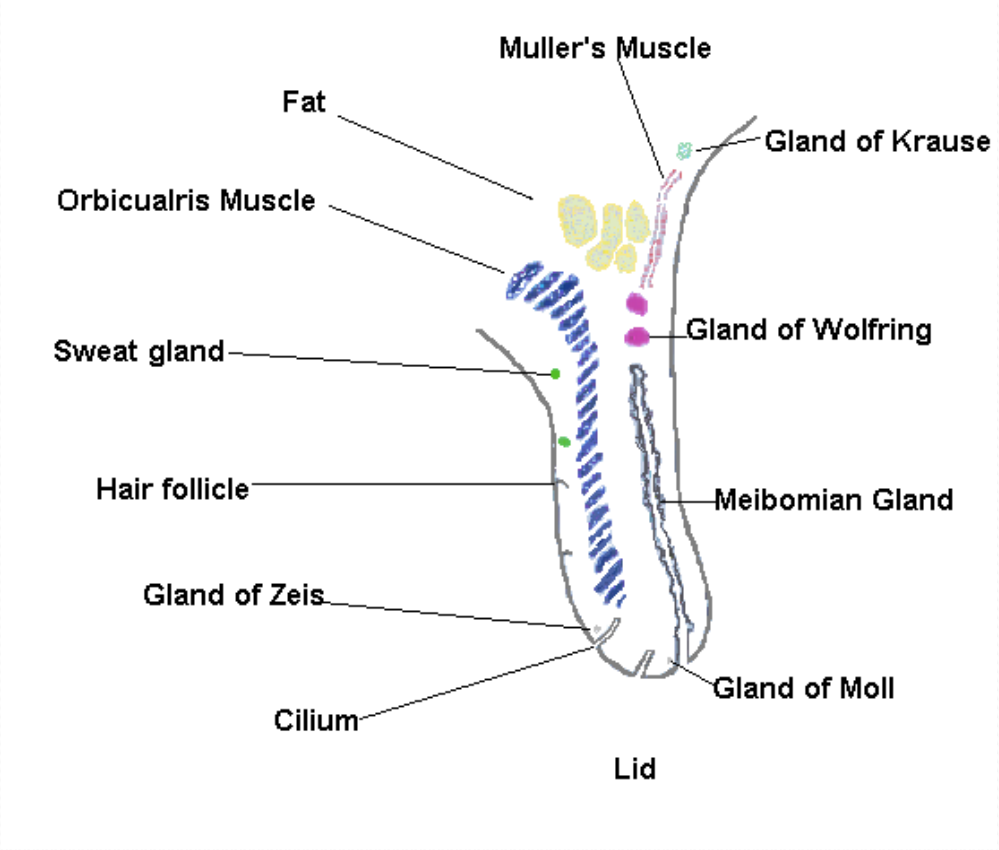


Eyelids

- Cilia
  - On lid margin
  - Surrounded by glands of Zeis
  - Excessive or altered secretions may cause blepharitis

Eyelids

- Muscles of eyelid
  - Levator Muscle
    - Elevates the eyelid
    - Some function in pumping tears away
  - Orbicularis Oculi Muscle
    - Closes the eye
    - Furrowing
    - Squinting
  - Muller's muscle
    - Short unstripped muscle
    - Contracted while awake
    - When tired, it is relaxed

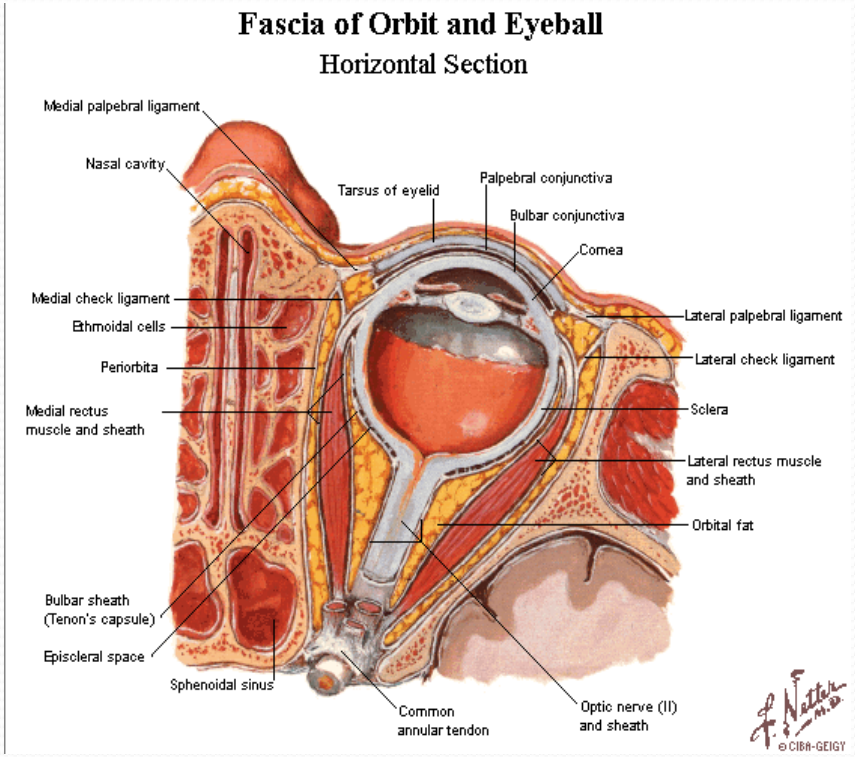


The Bony Orbital Cavity

- Seven bones
  - The Maxilla — From the upper jaw
  - The palate bone — From the roof of the mouth
  - The frontal bone — Of the forehead
  - The sphenoid bone — The great wing
  - The zygomatic bone — From the cheek
  - The ethmoid bone — Spongy in structure
  - The lacrimal bone — For the tear duct

The Bony Orbit

- Creates quadrilateral pyramid
  - Forward - globes of eyes
  - Rear - Optic canal



The Bony Orbit

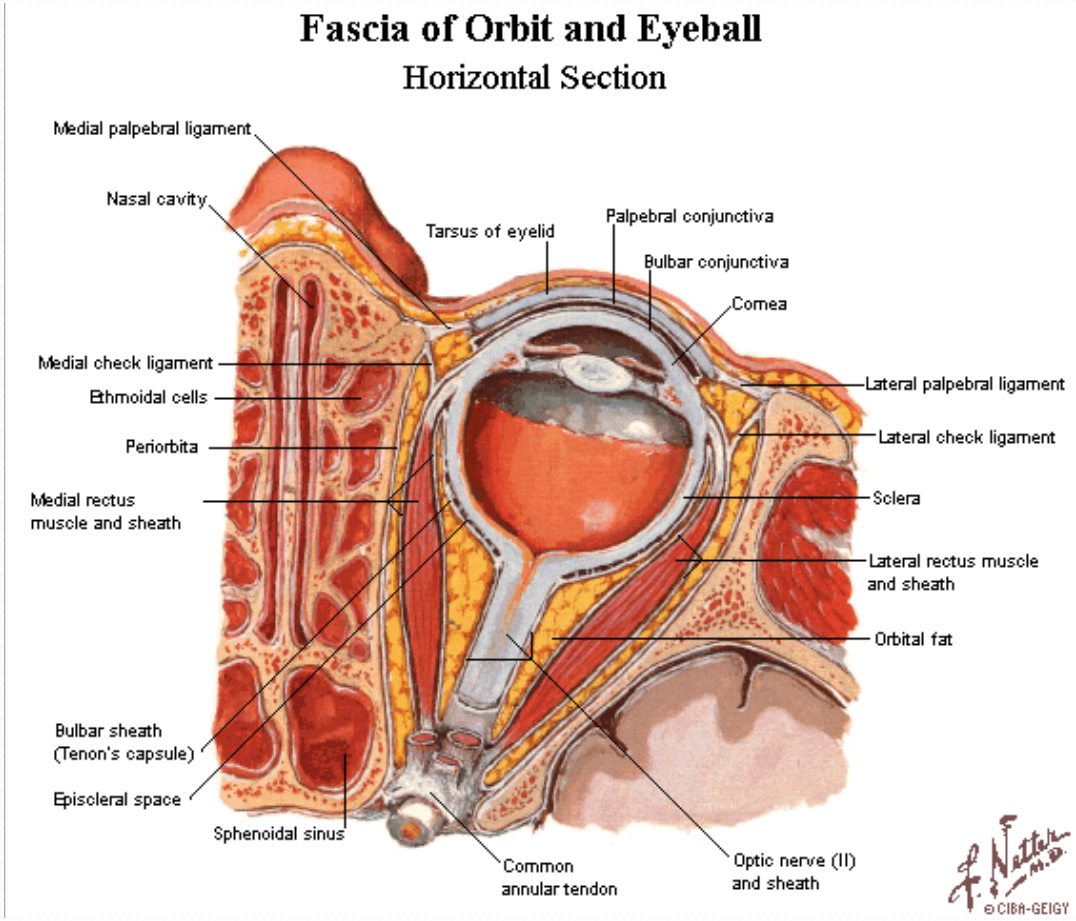
- Orbit divided into four main parts
  - The Roof
  - The Medial Wall
  - The Orbital Floor
  - The Lateral Wall
- Average size of orbital margin in adults
  - 35 mm high x 40 mm wide

The Bony Orbit

- Orbit changes with age
  - Changes occur with development of bony structure
  - Sinuses have influence on the orbit

The Bony Orbit

- Contents of Orbit
  - Muscles
  - Nerves
  - Vessels
  - Fatty tissues
  - Eyeball

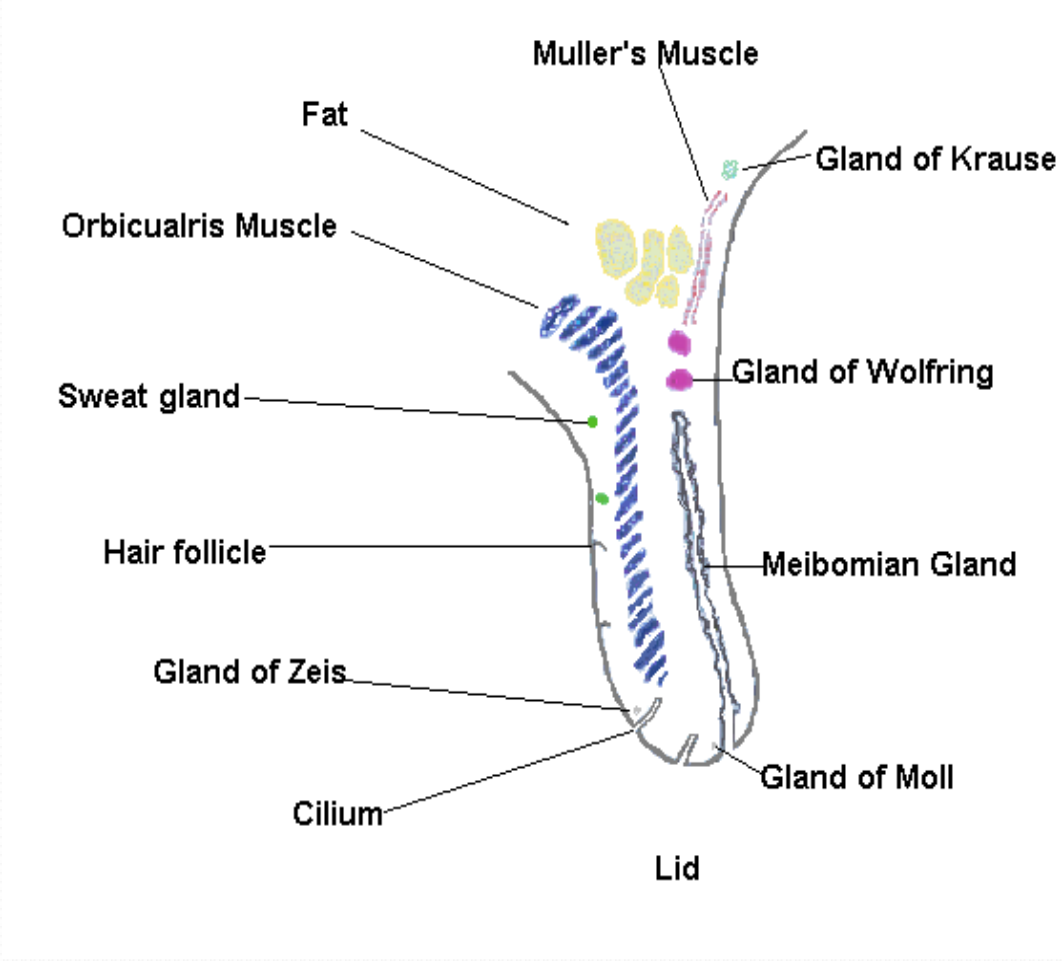


Lacrimal Apparatus - Tear Production

- Lacrimal glands
  - Provides reflex tear secretion
    - Irritation
    - Coughing
    - Sneezing
    - Taste or smell
    - Emotion
  - Newborns have minimal output of reflex tears

Lacrimal Apparatus - Tear Production

- Accessory glands
  - Provides basic tear secretion
    - Steady state
  - Wolfring
  - Krause

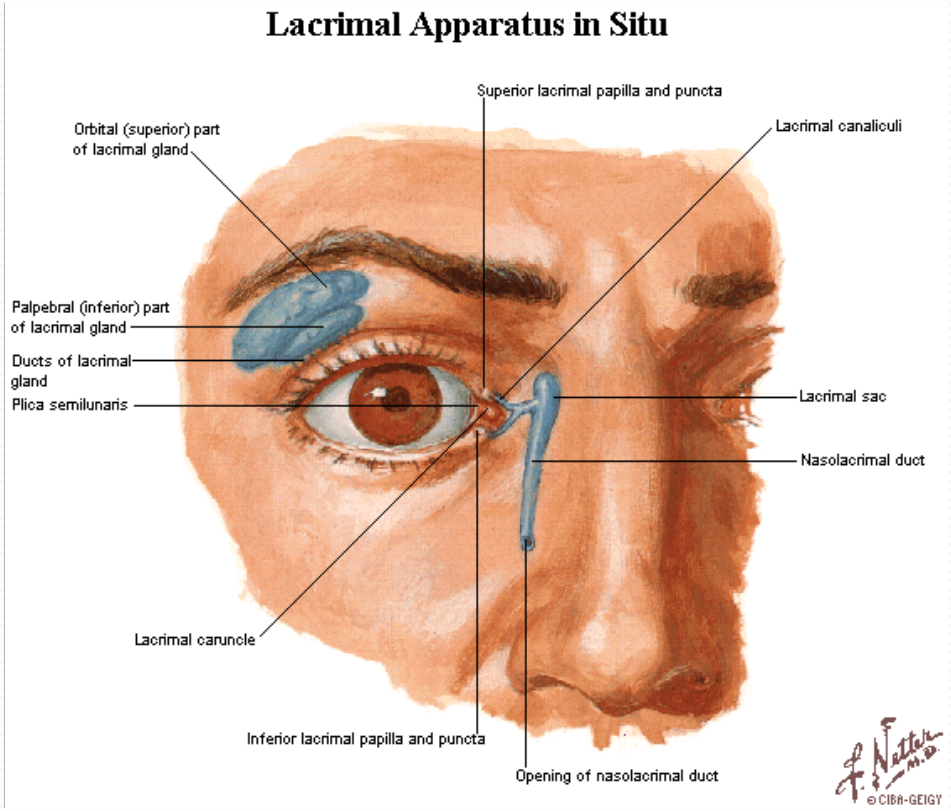


Lacrimal Apparatus - Tear Production

- Normal tears contain various antibacterial and immune substances to clean and protect eyes
  - Lysozymes
  - Immunoglobulin
  - Depressed in patients with tear deficiency
    - Patients frequently suffer from blepharitis

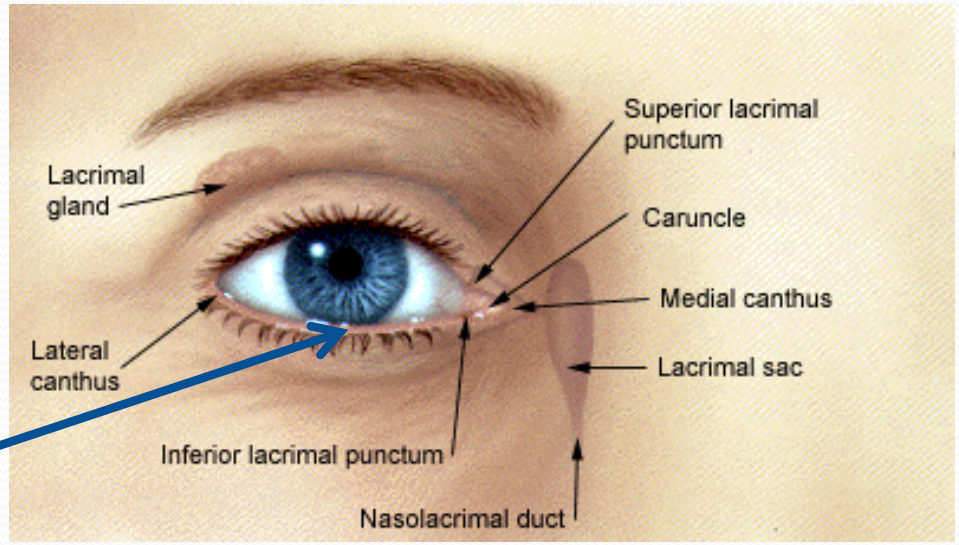
Lacrimal Apparatus

- Tear drainage
  - Through lacrimal punctua
  - Into canaliculi
    - Tear canals
  - Into nose via lacrimal duct



Lacrimal Apparatus

- Kinetics of the tears
  - Forms thin film over both cornea and conjunctiva
  - Creates tear meniscus
    - Prism
    - Lake

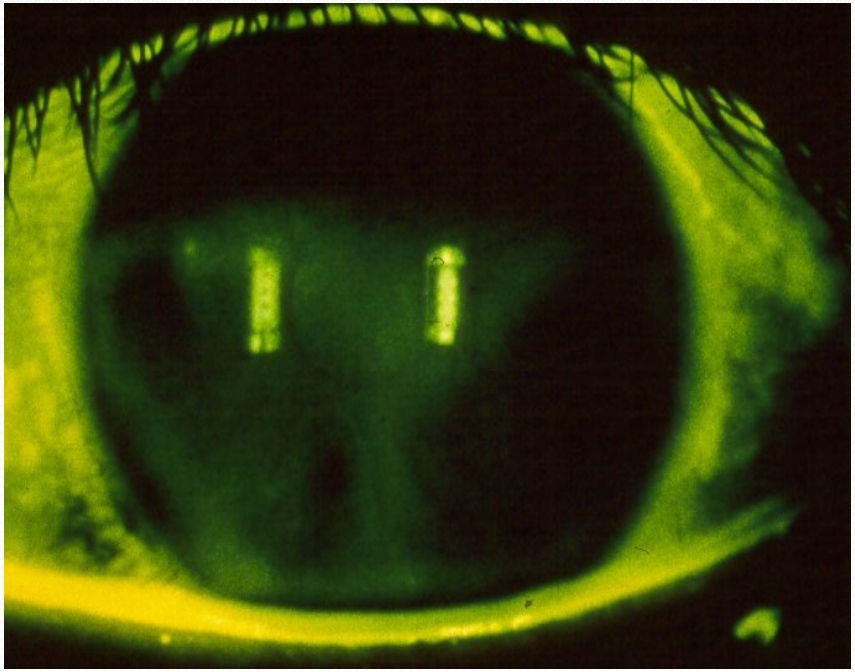


Kinetics of Tears

- Tears move upward and downward with each blink
  - Spreads tears over entire eye and conjunctiva
  - Moves from temporal to nasal

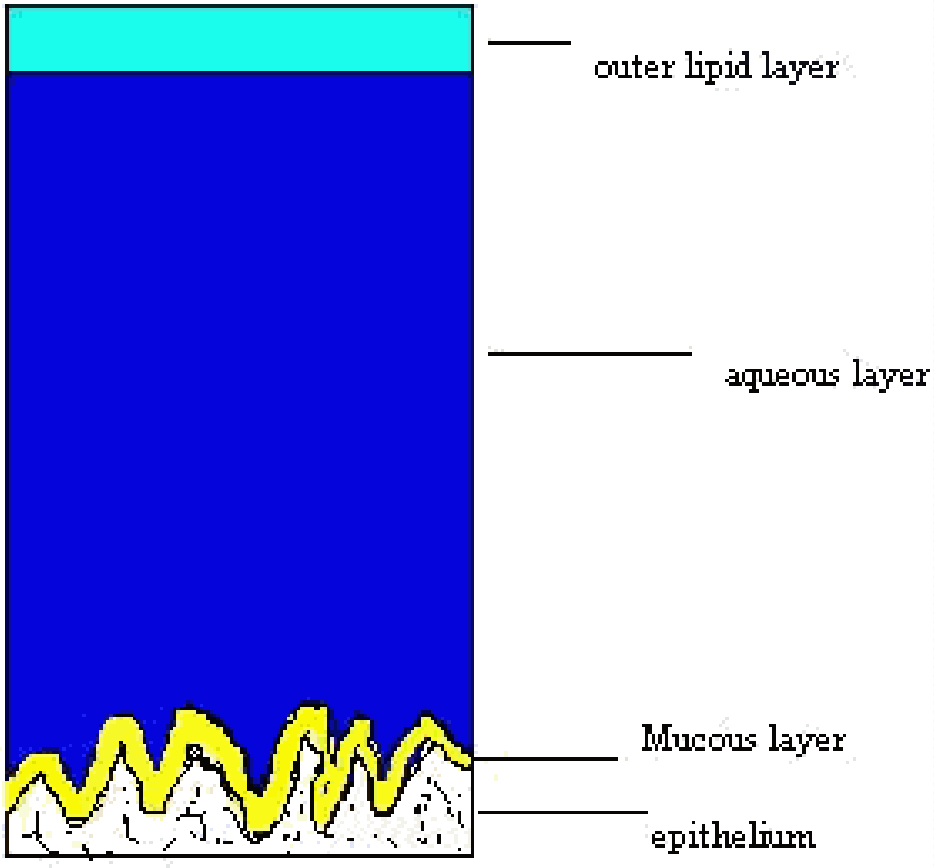
Tear Film / Precorneal Tear Film

- Function
- Provides a smooth optical surface over the cornea,
- Flushes away cellular debris, foreign matter from the cornea and conjunctival sac and carbon dioxide
- Provides nutrition for the cornea
  - Supplies glucose and oxygen
- Provides an antibacterial function



Tear Film / Precorneal Tear Film

- Tear Film
  - Trilaminar structure
  - Three Layers
    - Lipid
    - Aqueous
    - Mucin



Tear Layer

- Outer Layer - Oily
  - Lipid
    - Produced by Meibomian glands and glands of Zeis
    - Approximately 0.1 micron thick
    - Prevents evaporation

Tear Layer

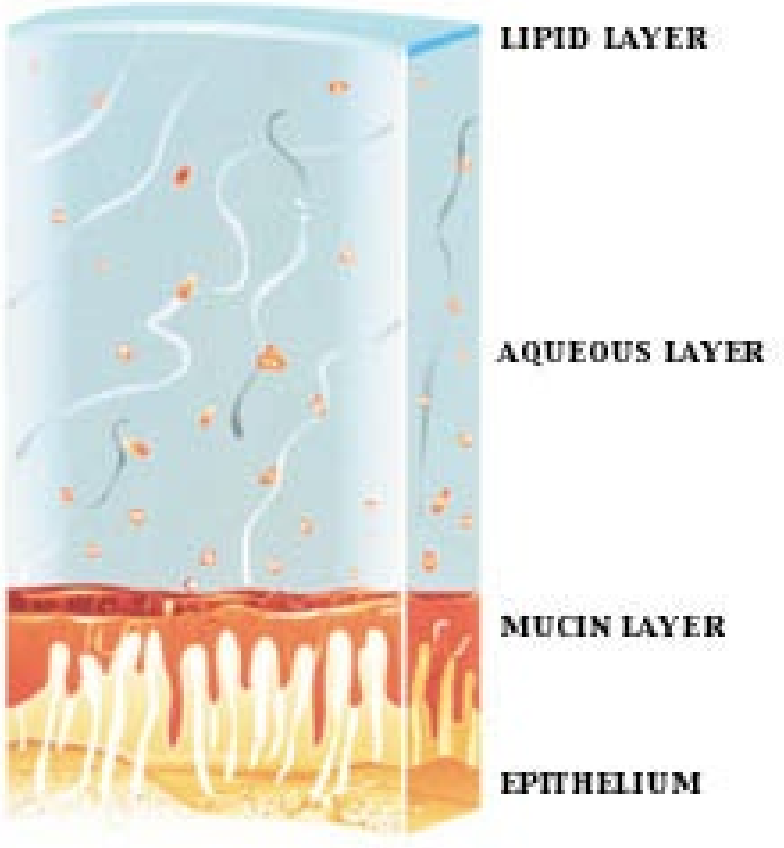
- Middle Layer - Aqueous
  - Volume – 7 microns
    - Provides oxygen
    - Provides nutrients
  - Produced by lacrimal glands, accessory glands of Krause and Wolfring

Tear Layer

- Inner Layer – Mucin/Mucoid/Mucous
  - Produced by goblet cells
  - Attaches tears to cornea
  - Decreases surface tension

Tear Film / Precorneal Film

- Composition
- Glucose
  - 2.5 to 4.1 mg/100ml
- Protein
- Enzymes
  - albumin, globulin, and lysozyme
- pH
  - 7.4
  - between 7.3 to 7.7



Tear Film / Precorneal Film

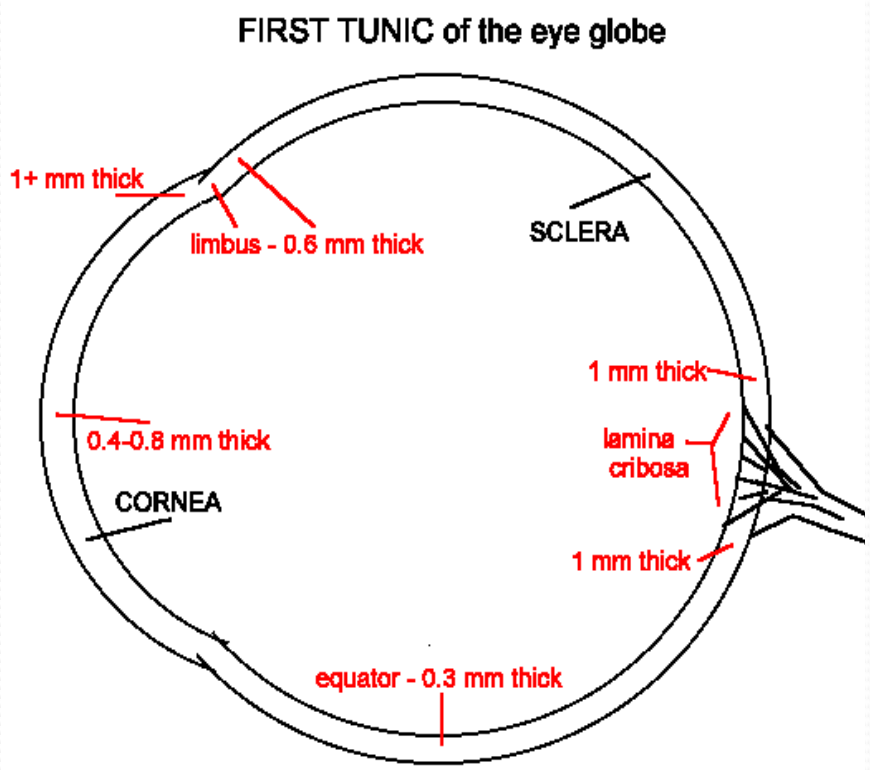
- Tests and Tear Integrity
- Schirmer
- Tear BUT
- Rose Bengal

The Tunics of the Eye

- Outer tunic
  - Fibrous tunic
  - Consists of:
    - Cornea
    - Sclera
    - Additionally the limbus
- Middle tunic
  - Vascular pigmented tunic
    - Consists of:
      - Choroid
      - Ciliary body
      - Iris
- Inner tunic
  - Extension of the brain
  - Nervous tunic
    - Retina

First Tunic of the Eye

- ***Outer Tunic of the eye – Outer Coats of the eye***
  - Cornea
  - Sclera
    - Corneo/Scleral junction
      - Limbus

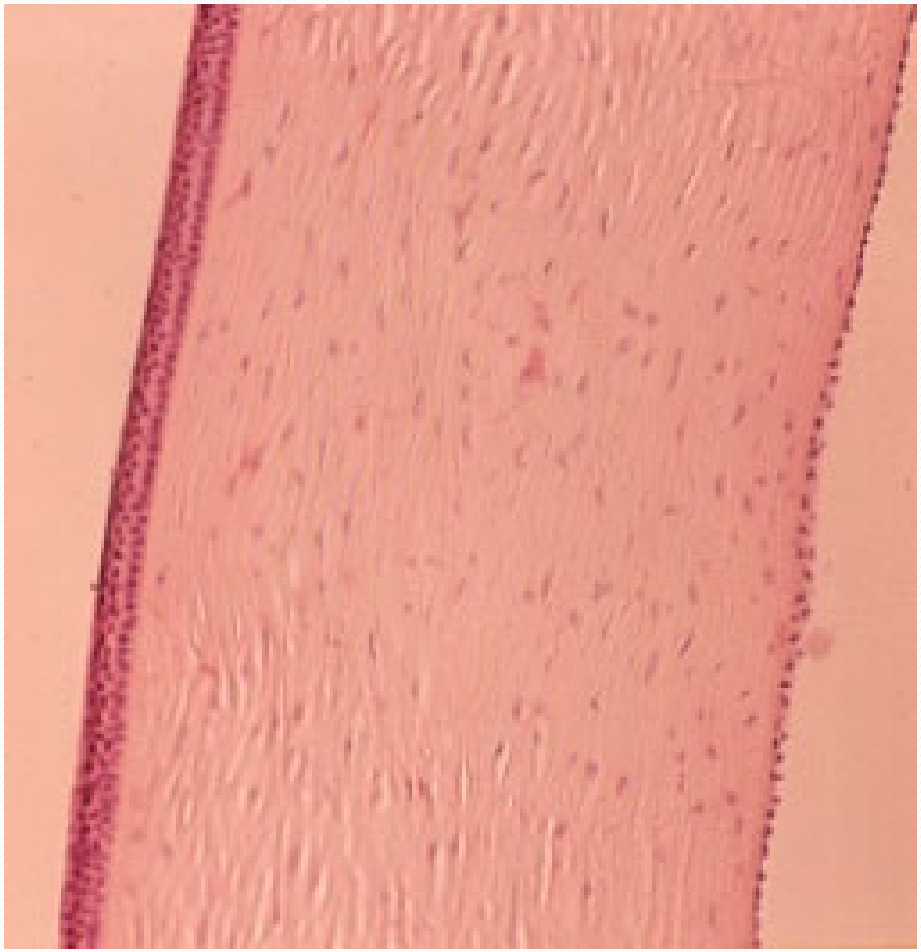


Cornea

- Physical dimensions
  - Average central thickness: 520µm or 0.52mm
  - Peripheral thickness: 670µm or 0.67 mm
  - Horizontal diameter: 11 to 12 mm
  - Vertical diameter: 9 to 11 mm

Corneal Structure

- Five layers
  - Epithelium
  - Bowman's layer
  - Stroma
  - Descemet's membrane
  - Endothelium



Epithelium

- 50 µm or 0.50 mm in thickness
- 5 – 7 cell layers deep
  - Outermost layer
    - Superficial/squamous cells
    - Microvilli
  - Middle layer
    - Wing cells
  - Innermost layer
    - Columnar cells or Basal cells
- Basement Membrane
- Repair rather quickly

Bowman's Layer

- 10 µm = .10 mm in thickness
- Extremely tough - Has high elastic properties
- Transparent acellular layer
- Condensation of collagen fibers and proteoglycans
- Collagen fibers are continuous with those of stroma
- Maintains epithelial structure
- Does not regenerate after injury scarring
- Barrier to most molecules

Stroma

- 90% corneal thickness
- Composed of collagen fibrils 30 µm in diameter.
- Run parallel to the surface
- Regular arrangement and spacing of collagen fibers result in corneal clarity
- Lamellae are 2 µm thick (.02 mm)
- Heals with scar formation
- Inflammatory cells infiltrate from vessels at the limbus
- Vessels often invade the stroma during chronic inflammation

Descemet's Membrane

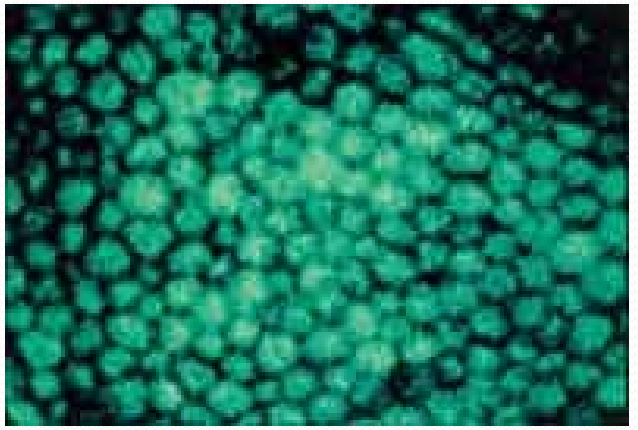
- Posterior limiting layer, 8-12 μm thick
- Comprised of two layers
  - Anterior banded layer – developed during embryology
  - Posterior non-banded layer – produced by endothelium throughout life
- Condensation of collagen fibers Basement membrane for endothelium
- Will retain shape of stroma when changes occur due to edema or other causes of corneal shape alteration: striae
- Does regenerate after injury

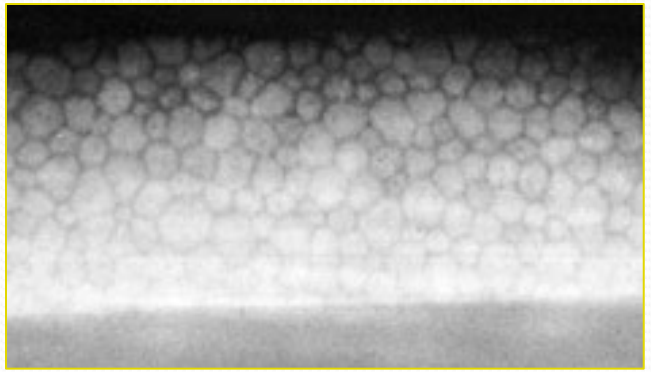
Endothelium

- Single layer of hexagonal shaped cells (20µm in diam), 4-6 µm thick
- Barrier between aqueous humor and corneal stroma
- Maintains corneal deturgescence
  - Pump water out of the stroma through active transport of ions into the anterior chamber
- Site of active pump
- Does not regenerate
- Affected by CL wear

Polymegathism, pleomorphism, and guttata

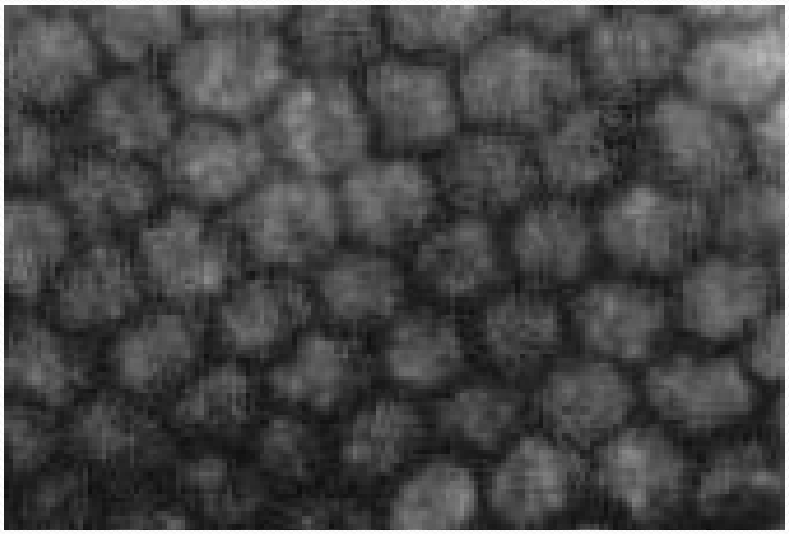
- Require glucose and oxygen
- Do not replicate: cell count decreases with age and intraocular surgery
- Cells change size and shape with age and contact lens wear



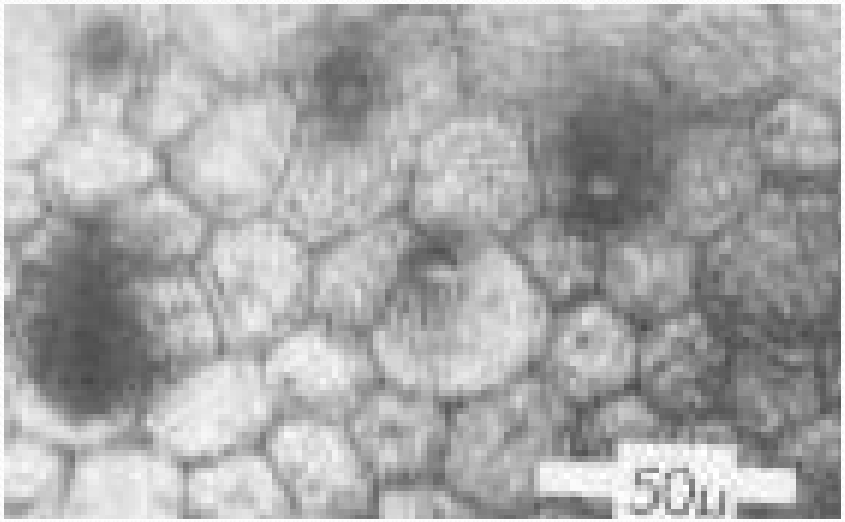


Guttata - Guttae

- Normal endothelium

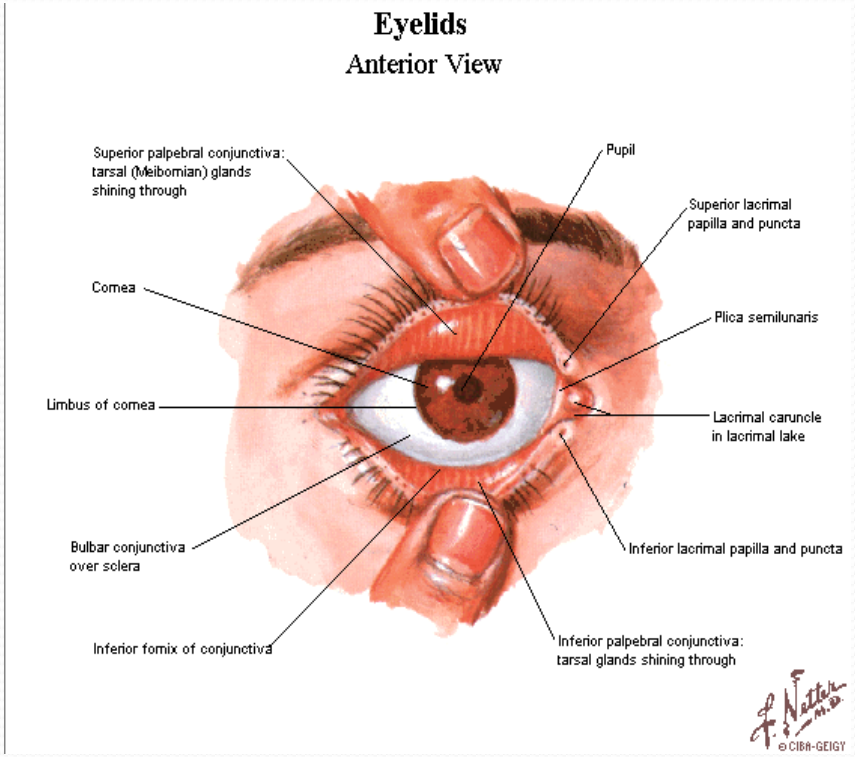


- Guttata - Guttae



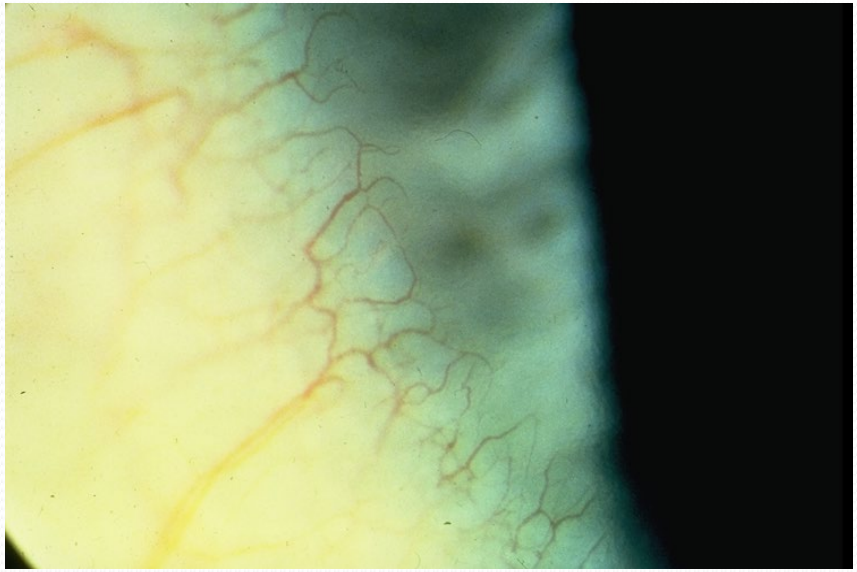
Sclera

- White of the eye
- Fibrous
- Smooth
- Prevents light from entering the eyeball
- Three types of scleral tissues
  - Episcleral layer
  - Stroma or substantia propria
  - Lamina fusca



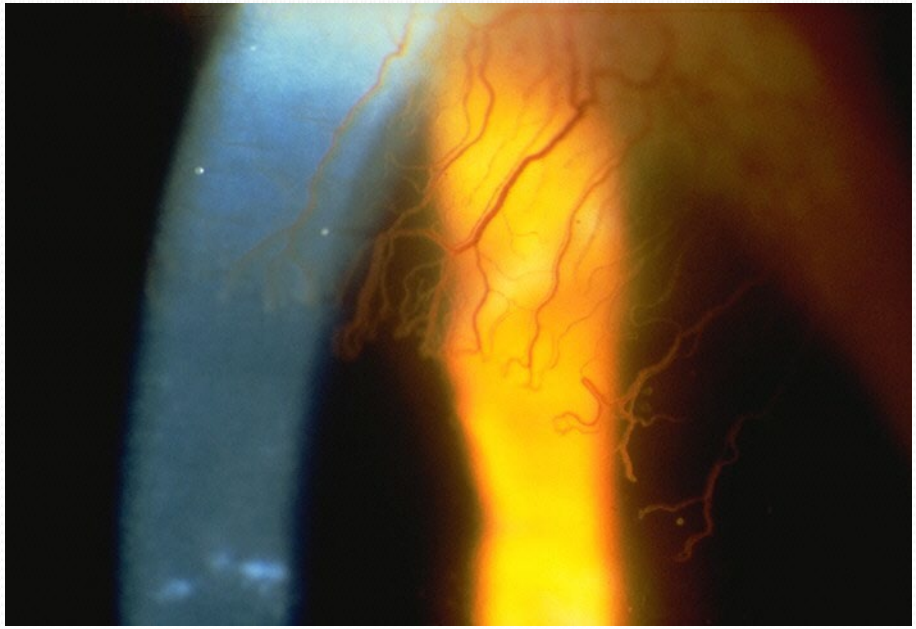
Limbus

- Corneo-scleral junction
- Vascular transition zone between avascular cornea and the highly vascularized conjunctiva
- Vessels should be seen to just penetrate the cornea and loop back towards the conjunctiva



Limbus

- Under corneal stress, blood vessels may be seen to grow into the cornea (neovascularization)
- This is an important sign to watch for especially in hydrogel contact lens wear



Conjunctiva

- Thin mucous membrane, running continuous from lid to corneal limbus
  - Palpebral - lids
  - Bulbar - globe
- Contains goblet cells
  - Produce mucins
- Glands of Krause
- Glands of Wolfring
- Inflammation
  - Conjunctivitis
    - Bacterial
    - Viral
    - Allergic
    - Chemical
    - GPC
  - Symptoms
    - Pain
    - Photophobia
    - Impaired vision
    - Discharge

Conjunctiva

- Blood Supply
  - Becomes injected when conjunctiva is inflamed
- Innervation
  - Very sensitive

The Middle Tunic of the Eye

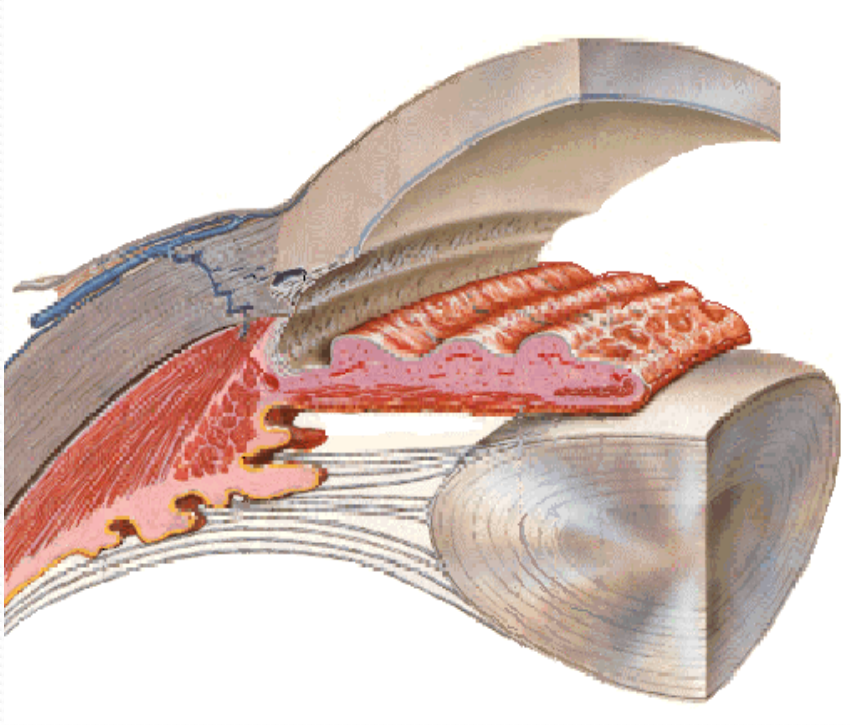
- The Vascular Tunic
  - The Uvea or Uveal tract
- Contains
  - Choroid
  - Ciliary body
  - Iris
    - Pupil

Choroid

- Vascular layer of the eyes
- Located between the sclera and retina
- Choroid
  - Rich in blood vessels
  - Stretches from optic disc to ora serrata
  - Thickness varies from .1 mm to .2 mm
- In some older people, Bruck's membrane can crack and degenerate
  - Causes partial obstruction of the capillaries
  - Vessels can leak blood into the retina
  - Can be beginning of age related macular degeneration

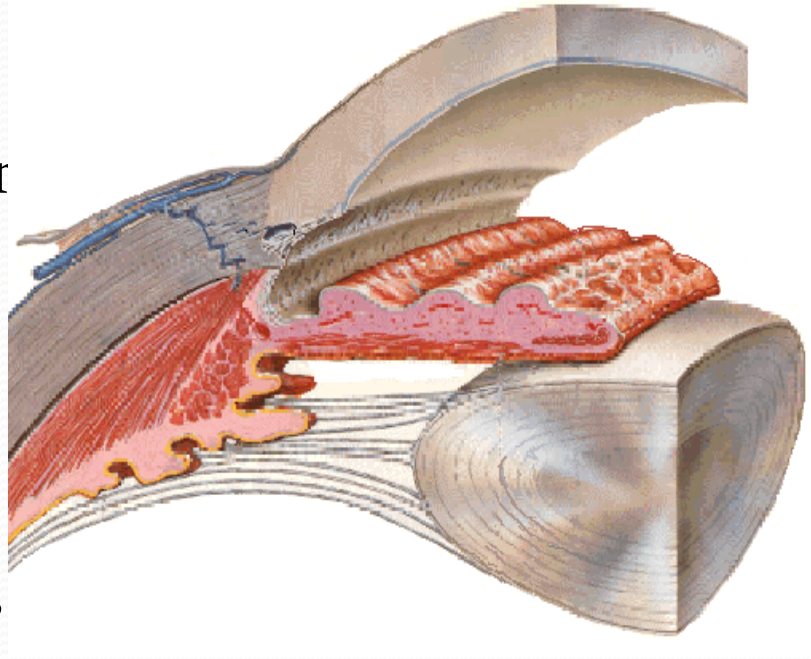
Ciliary Body

- Annular portion of the uvea
- Triangular shape between choroid and root of the iris
  - Ciliary epithelium
  - Stroma
  - Ciliary muscle



Ciliary Body

- Ciliary processes highly vascular and contain lymphatic spaces
  - Produces aqueous humor
  - In some cases of inflammations such as iritis, blockages can occur, causing papillary block glaucoma, thus the need to keep the eye dilated



Ciliary Body

- Ciliary muscle system controls change in crystalline lens for accommodation

Iris

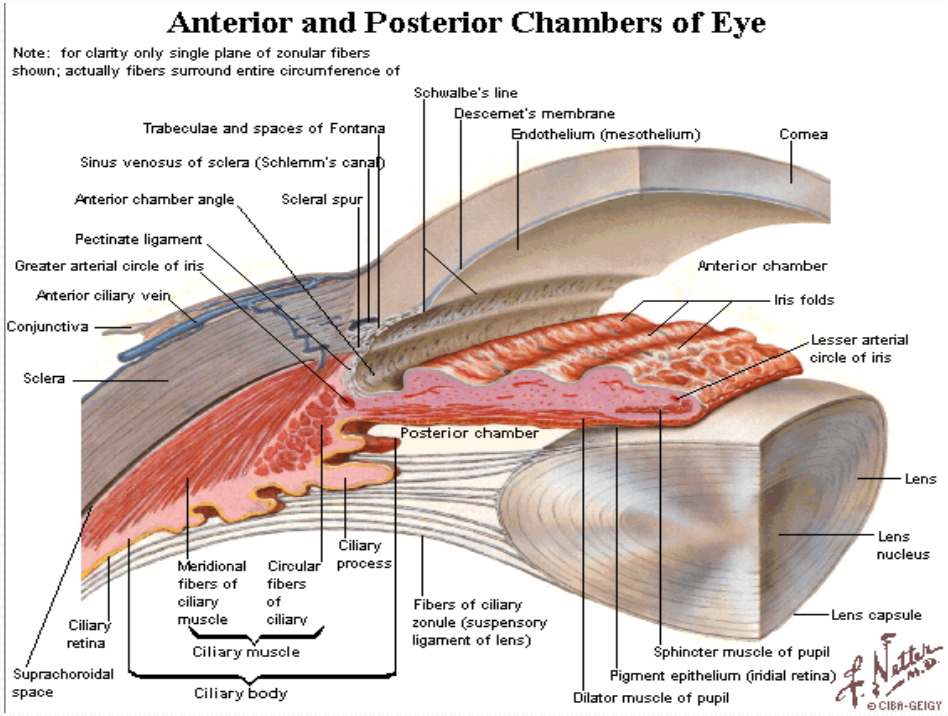
- Thin vascular membrane
- Average diameter is horizontally 11 - 12 mm
- Average diameter vertically is 9 – 11 mm
- Sphincter muscle and dilator muscle constricts or dilates the pupil
- Iris separates anterior and posterior chambers, creating angle
- Heavily pigmented
  - Colors vary according to the amount of pigment
- Inflammation of iris (iritis)
  - Can be seen as flare with slitlamp

Anterior and Posterior Chambers

- Contains Aqueous
  - Clear colorless - liquid
    - Similar index of refraction as vitreous
    - N = 1.33
  - Pressure of 15-18mm of mercury
  - Increased pressure can cause glaucoma
- Primarily nourishes internal avascular structures
- Brings nutrients and oxygen to lens and cornea
- Removes wastes

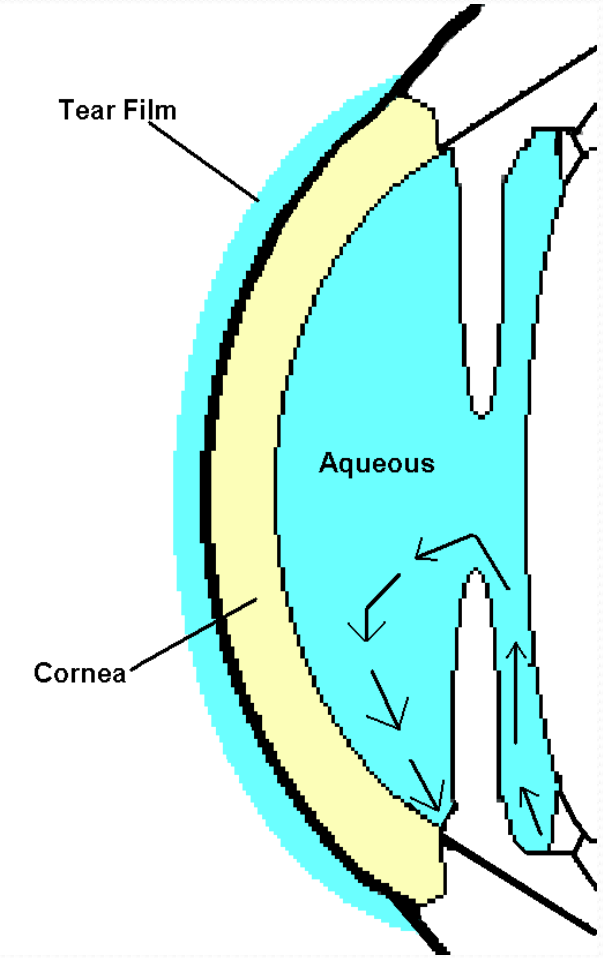
Anterior and Posterior Chambers

- Anterior chamber angle important
  - Drainage through Schlemm's canal
    - Inner ocular pressure
    - Production and drainage of aqueous must remain constant
    - Some aqueous used up by cornea and lens
  - Pressure average 15 mm Hg



Anterior and Posterior Chambers

- Aqueous flow
  - Drains through Schlemm's canal
  - Trabecular meshwork
  - Anterior chamber depth varies with age, size of the eye, and whether cataract surgery has been performed



Pupil

- Aperture (Opening)
- Positioned central or slightly nasal
- Undilated pupil size between averages between 2 - 4 mm
  - Dilated up to 9 mm
- Controlled by muscle
  - Muscles of the iris
    - Sphincter
    - Dilator

Pupil

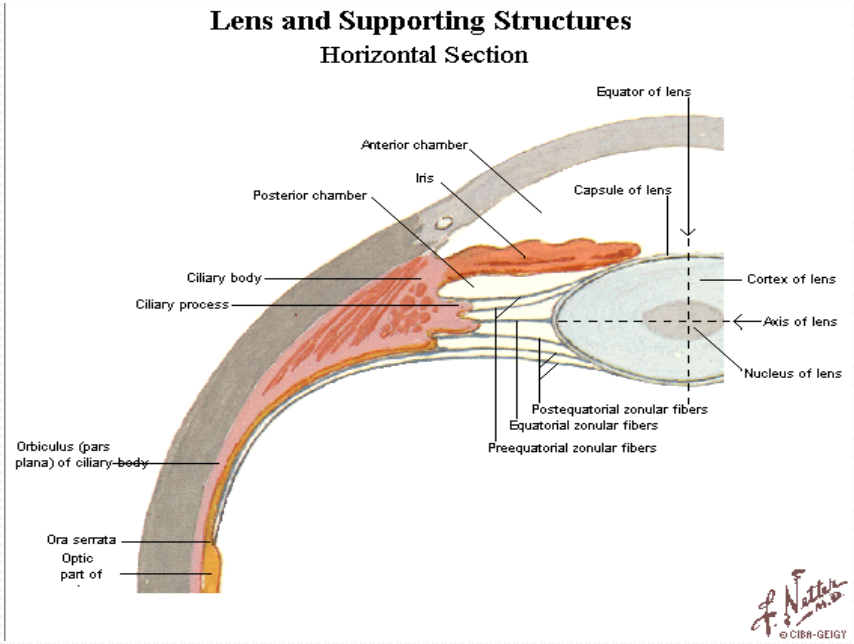
- Smaller at birth
- Largest at early childhood
- Size diminishes with age
  - Senile miosis
  - Pupil reacts to light slower with age
- Difference in pupil size is called anisocoria
  - 17% of people have under 1mm difference
  - 4% have pronounced difference
    - Could indicate pathological problems
    - Should be referred

Pupil

- Three responses watched for during exam
  - Direct pupil constriction
  - Consensual Reflex
  - Bilateral constriction when viewing near objects
- Dilation of pupil performed with mydriatics
- Constriction of pupil performed with miotics

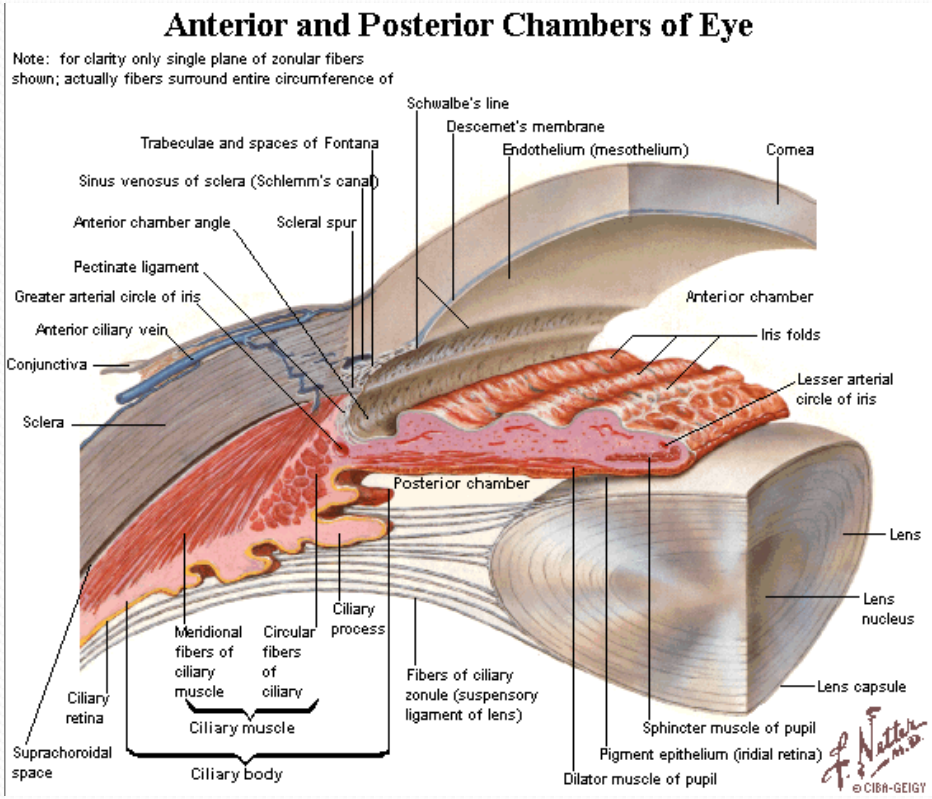
The Crystalline Lens

- Biconvex, transparent body located between the vitreous and the back of the iris
- Semisolid, consisting of elastic capsule surrounding the lens substance
- Avascular structure
  - Nourished and oxygenated by diffusion from the aqueous
    - Minimal from vitreous
  - High demand for glucose
    - Supplied by aqueous



The Crystalline Lens

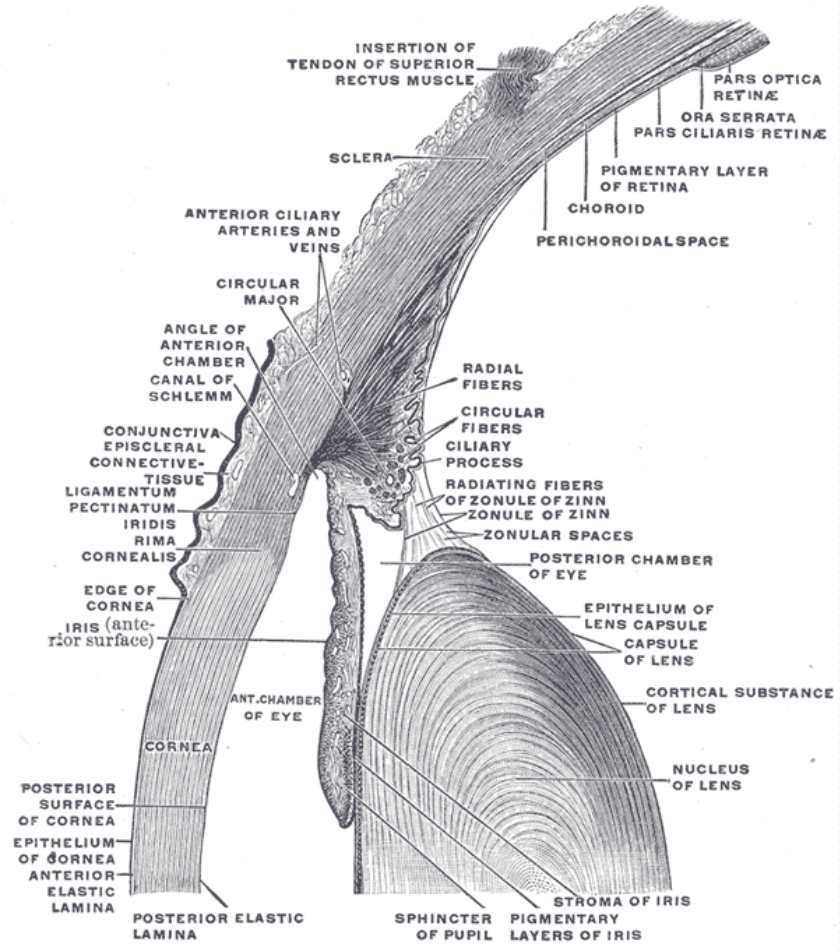
- Onion like structure continues to add layers throughout life
- Equatorial diameter is 5 - 6 mm in children
  - Increases to 9 - 10 mm in adults
- By about age 70, the nucleus comprises virtually the entire lens
- The lens flattens with age and becomes harder
- Lens is approximately 66% water and 33% protein



The Crystalline Lens

- Age related changes - cataract
  - Senile
    - Cortical
    - Nuclear
  - Metabolic
    - Diabetic
- Chemical cause
  - Poison
  - Medication
- UV produced
  - Sunshine Cataract
- Congenital
  - Sometimes maternal rubella
  - Others
- Dehydration
  - Due to poor hygiene
  - Heat
  - Diarrhea

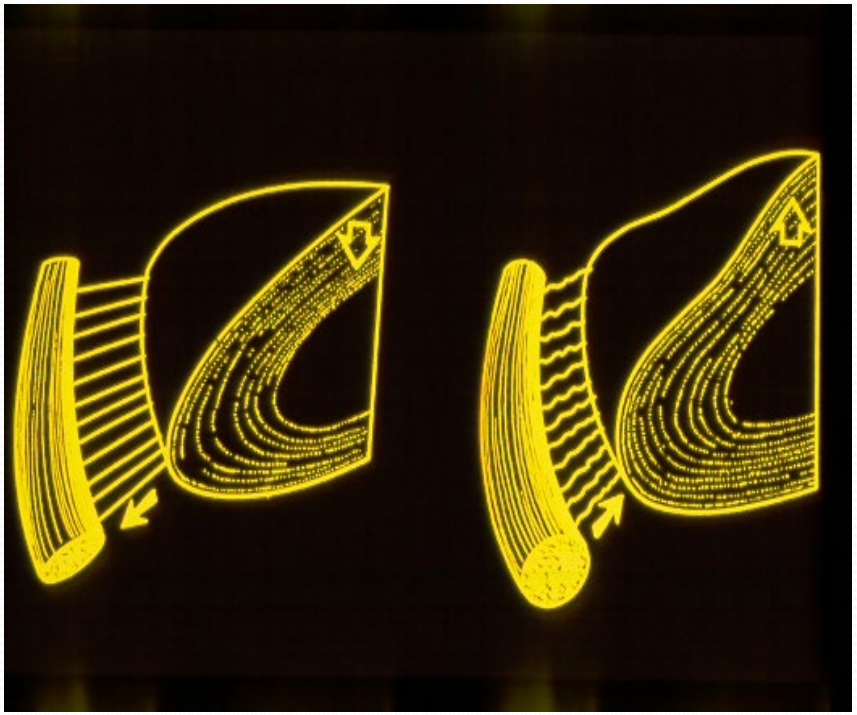
Accommodative Anatomy



- The Crystalline Lens
- The Ciliary Body
  - Ciliary Muscle
- The Zonules of Zinn
  - Suspensory Ligaments

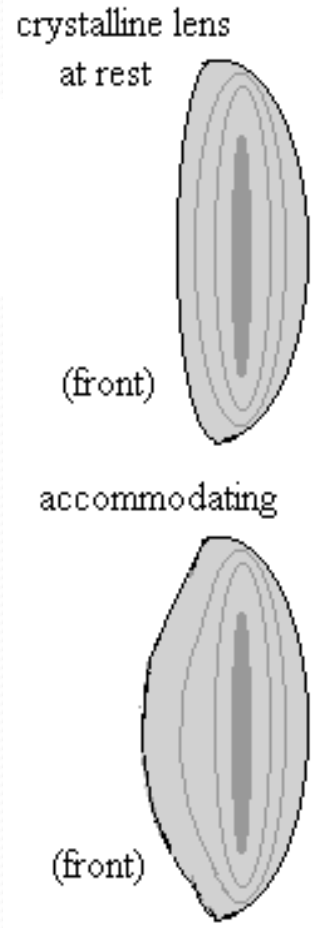
Accommodative Anatomy

- Brain recognizes blurred image
- Ciliary muscle contracts and moves toward lens
- Zonule fibers relax
- Crystalline lens bulges
  - Becomes more convex



Accommodative Anatomy

- Axial thickness changes with state of accommodation
- Between 30 to 35 years of age, the nucleus of the crystalline lens starts turning yellow to yellow brown, and becomes larger
- Amplitude of accommodation is about 15 diopters at birth.
- Diminishes to virtually zero by the age of 61
  - Cells of crystalline lens continue to grow, while capsule remains the same
  - This hardening of the lens produces presbyopia



Vitreous Body

- Transparent gel occupies innermost part of eye
  - Between lens and retina
  - Transports nutrients – minimal
    - Nutrition from retinal vessels, ciliary body, aqueous
  - Gives shape to the eye

  - Slight attachment at ora serrata and at optic disc
    - Attachment weakens with age
    - Gel becomes less viscous with age, starting from back to front
    - Vitreous detachment can be one cause of later retinal detachments

Inner Tunic of the Eye
Retina

- Embryologically, an outgrowth of the brain
  - Connected to brain by optic nerve
    - Optic nerve not a true nerve, but tract
    - Any damage to retina or optic nerve is permanent
- Eyeball is designed around the retina
  - Sclera protects it and gives it shape
  - Choroid nourishes it

Retina Fulfills Double Need

- Rods detect light and movement
  - Long slender cells
  - Provide motion within the field
  - Provide night vision - extremely sensitive to light
  - More numerous toward central and front of retina
- Contains 600 to 1000 loosely stacked lamellae within a cell membrane
  - Contains photopigment rhodopsin
  - Molecules of rhodopsin within membranes of lamellae
  - Contain organelles for producing energy and build up of protein

Retina Fulfills Double Needs

- Cones provide detail
  - Contain iodopsin
  - Not sensitive to small amounts of light
  - Reason for no color vision at night
  - Cones more dense in the macula - fovea
    - No rods in central fovea
    - Greatest - fine vision in the fovea
- Three categories of cones - according to photopigments
  - One most sensitive to short wavelength (blue)
  - One most sensitive to green
  - One most sensitive to red

Retinal Blood Supply

- From retinal artery
- Capillary network is densest near macula
- Absent at the fovea and ora serrata
- Outer layers of the retina as well as fovea are avascular
  - Receive nutrients and oxygen from the choriocapillaris in choroid
- Central retinal artery enters the optic nerve about 10 to 15 mm behind eye
- Arteries send out capillaries to two levels of retina
  - Nerve fiber layer
  - Region between inner nuclear and outer plexiform layers

Retinal Metabolism and Visual Process

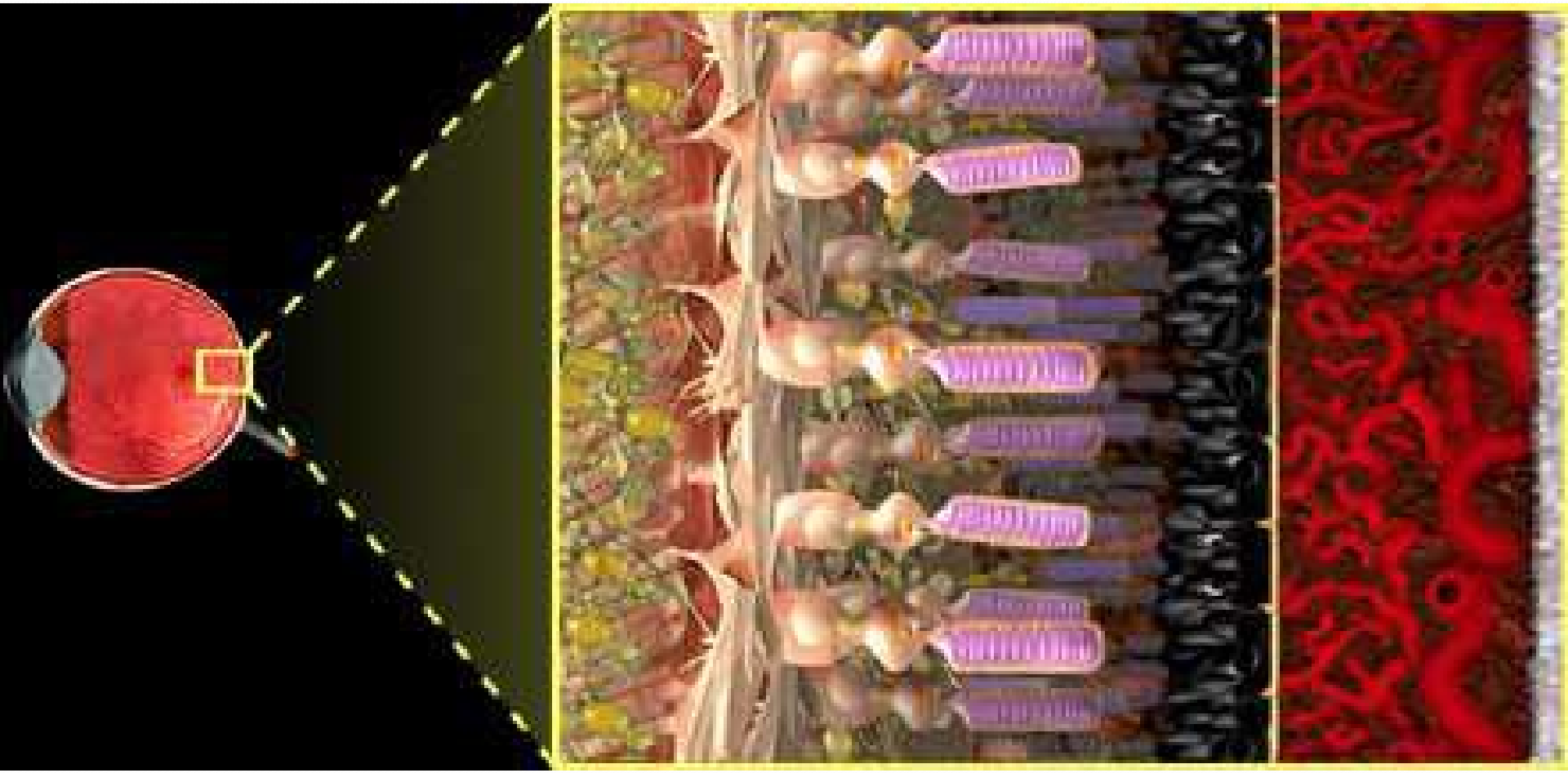
- Proper nutrients and oxygen required for visual process
- Items come from capillaries in choroid and central retinal artery
- Small amounts of nutrients come from circle of Zinn and vitreous
- Carbohydrate essential to produce energy
  - Drop in sugar critical
- Glycogen stored in retina in glial cells
  - Serves as buffer in changes in concentration of glucose in tissues

Retinal Metabolism and Visual Process

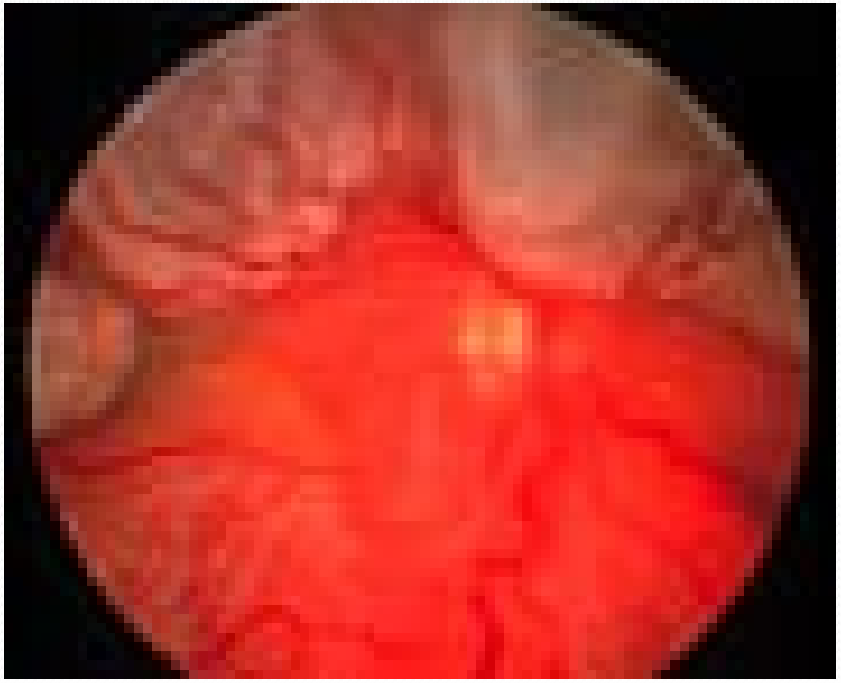
- Retinal photoreceptors sensitive of wavelengths from 380 nm to 750 nm

- In poor light, a person sees blue light better than red
  - Ocular system tends to be more myopic, I.e. “twilight myopia”

Visual Pathway

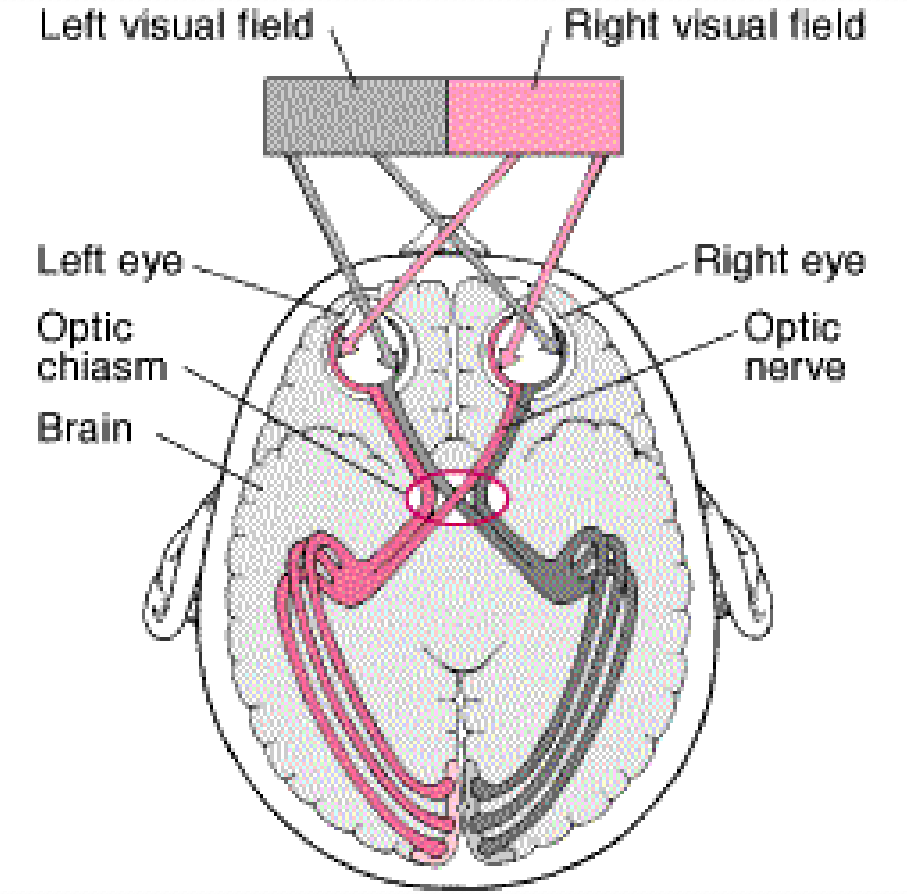


Retinal Detachment



Visual Pathway

- Optic Chasm
- Optic Tracts
- Optic Radiations
- Visual Cortex



Muscle Imbalances

- Terminology
- Muscles of the Eye
- Possible Corrections

Extraocular Muscles

- Diplopia
- Tonicity
- Fusion
- Muscle imbalances
  Strabismus
- Amblyopia

Extraocular Muscles

- Rectus means “straight”
- There are four rectus or “straight” extraocular muscles

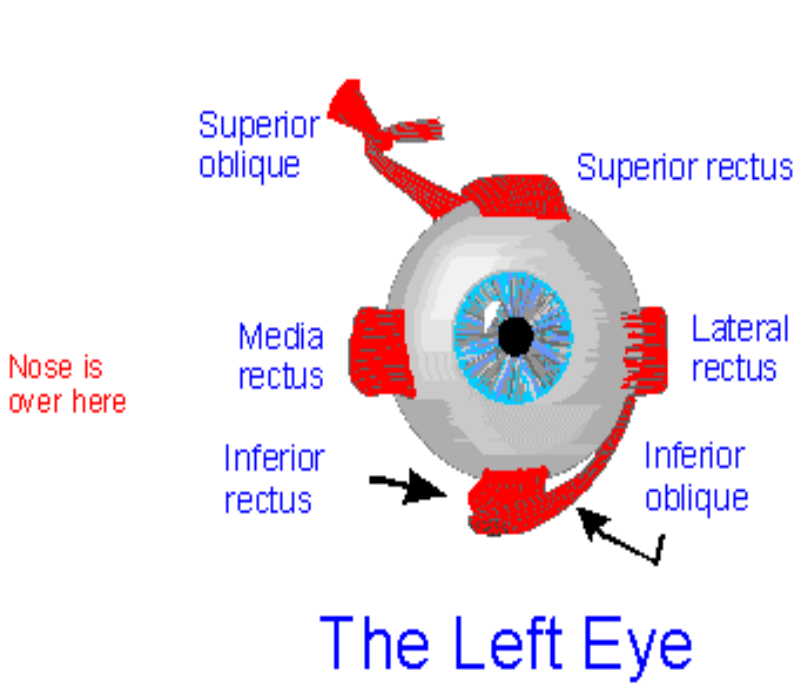
- Oblique means “slanting”
- There are only two oblique or “slanting” extaocular muscles

Extraocular Muscles

- •**Medial rectus (MR)**—moves the eye toward the nose
- •E**xternal rectus (ER)**—moves the eye away from the nose
- •**Superior rectus (SR)**—primarily moves the eye upward and secondarily rotates the top of the eye toward the nose
- •**Inferior rectus (IR)**—primarily moves the eye downward and secondarily rotates the top of the eye away from the nose
- •**Superior oblique (SO)**—primarily rotates the top of the eye toward the nose and secondarily moves the eye downward
- •**Inferior oblique (IO)**—primarily rotates the top of the eye away from the nose and secondarily moves the eye upward

Extraocular Muscles

- Superior Rectus
  - Moves the eye up
- Superior Oblique
  - Rotates the eye so that the top of eye moves toward nose
- Medial Rectus
  - Moves eye toward nose
- Lateral Rectus
  - Moves eye away from nose
- Inferior Rectus
  - Moves the eye down
- Inferior Oblique
  - Rotates the eye so that the top of eye moves away from nose

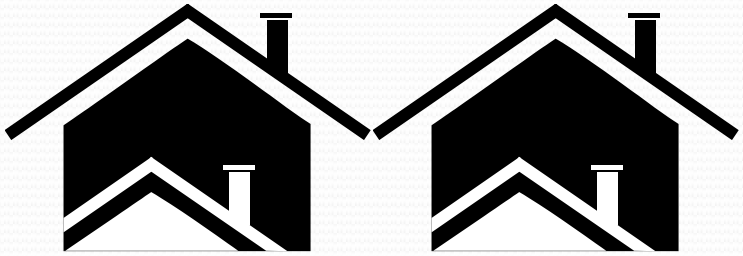


Diplopia

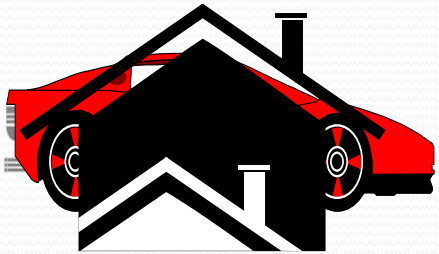
- Double vision
- Two images perceived from a single image
- Caused by muscular imbalance
- Confusion

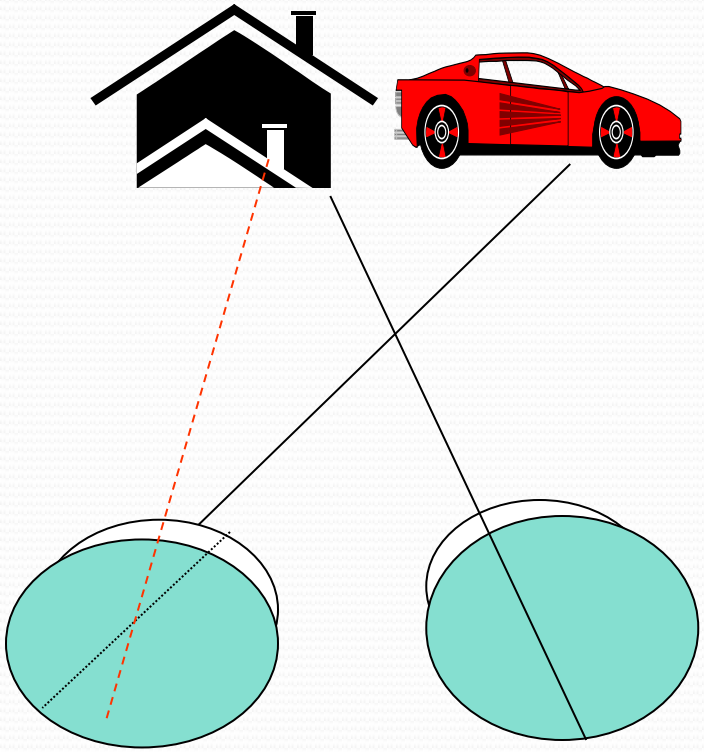
Diplopia

Double Vision



Confusion





Tonicity

- The state of slight contraction of all six extraocular muscles of the eye while at rest in order to hold the eye steady in a fixed position

Fusion

- The ability of the brain to form a single image by coordinating the movements of the two eyes so that the visual images fall on corresponding areas of the retinas of the two eyes

Muscle Imbalances - Terminology

- Orthophoria
- Heterotropia
- Strabismus - Can lead to Lazy eye or Amblyopia

Muscle Imbalances - Terminology

- Eso-
- Exo-
- Hyper-
- Hypo-
- -phoria
- -tropia

Phorias

- Esophoria
  - A tendency of the eye to turn in
- Exophoria
  - A tendency of the eye to turn out
- Hyperphoria
  - A tendency of the eye to turn up
- Hypophoria
  - A tendency of the eye to turn down

Infantile Esotropia

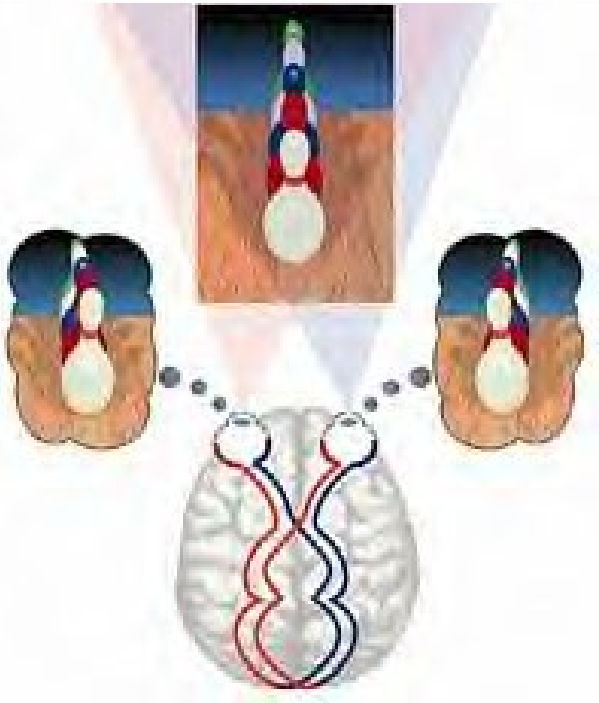
Treatment

- Glasses
- Patching
- Surgery
- Vision Therapy

Amblyopia

- Decreased vision in an eye
- Lazy eye
  - Usually associated with strabismus or anisometropia early in life

Stereopsis

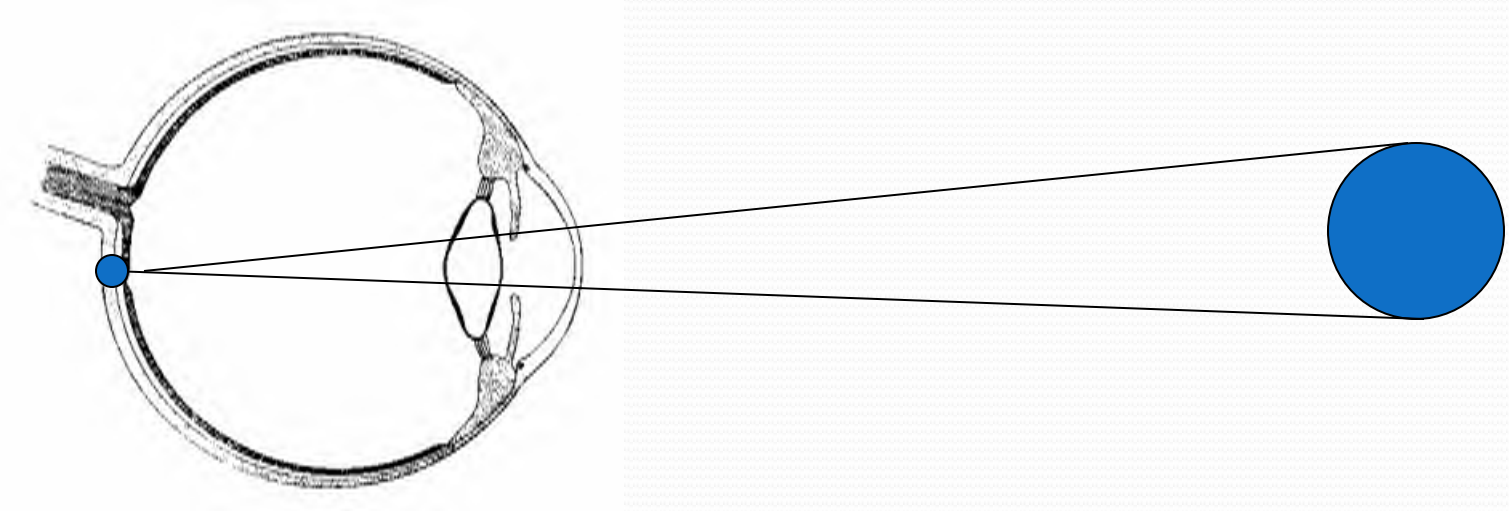


Refraction

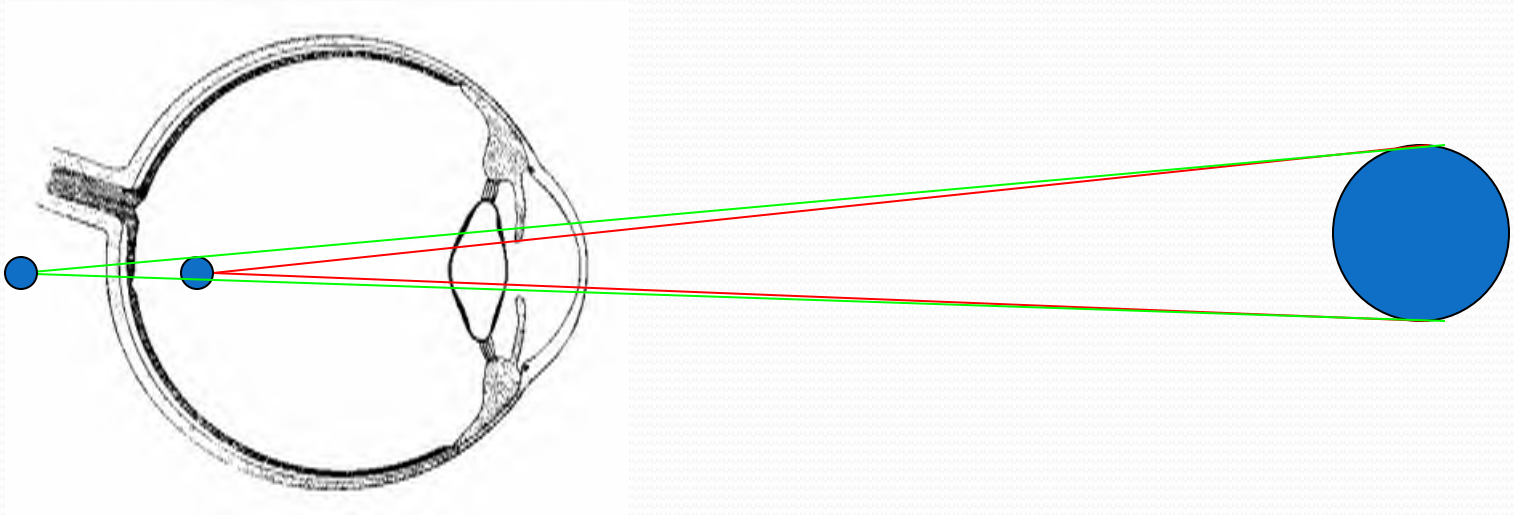
- The “bending” of light as it passes obliquely between two different refractive mediums

- A beam of light that enters a refractive medium perpendicularly is not refracted, but merely slowed down and the path of the beam is unchanged

Emmetropia

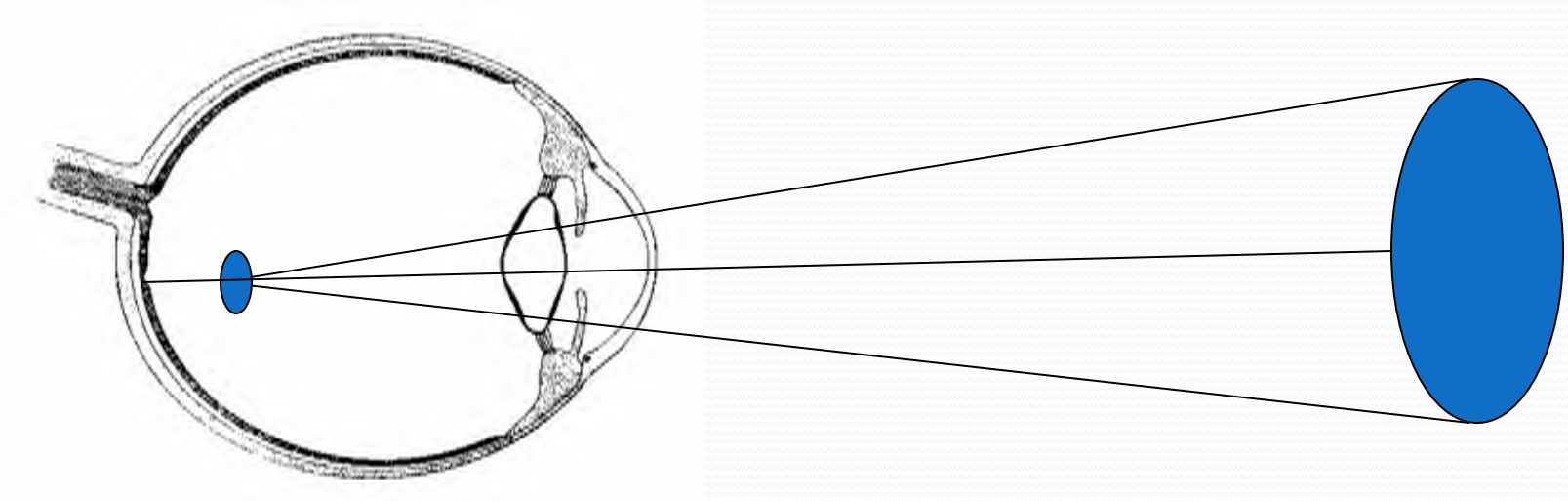


Ametropia

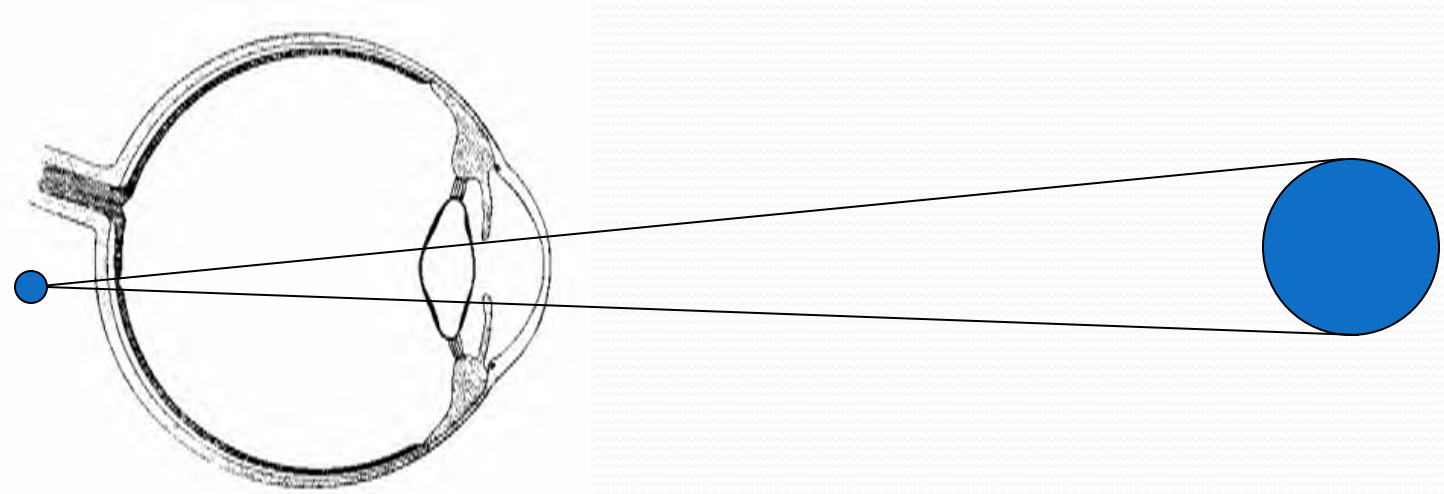


- Myopia
- Hyperopia or Hypermetropia
- Astigmatism

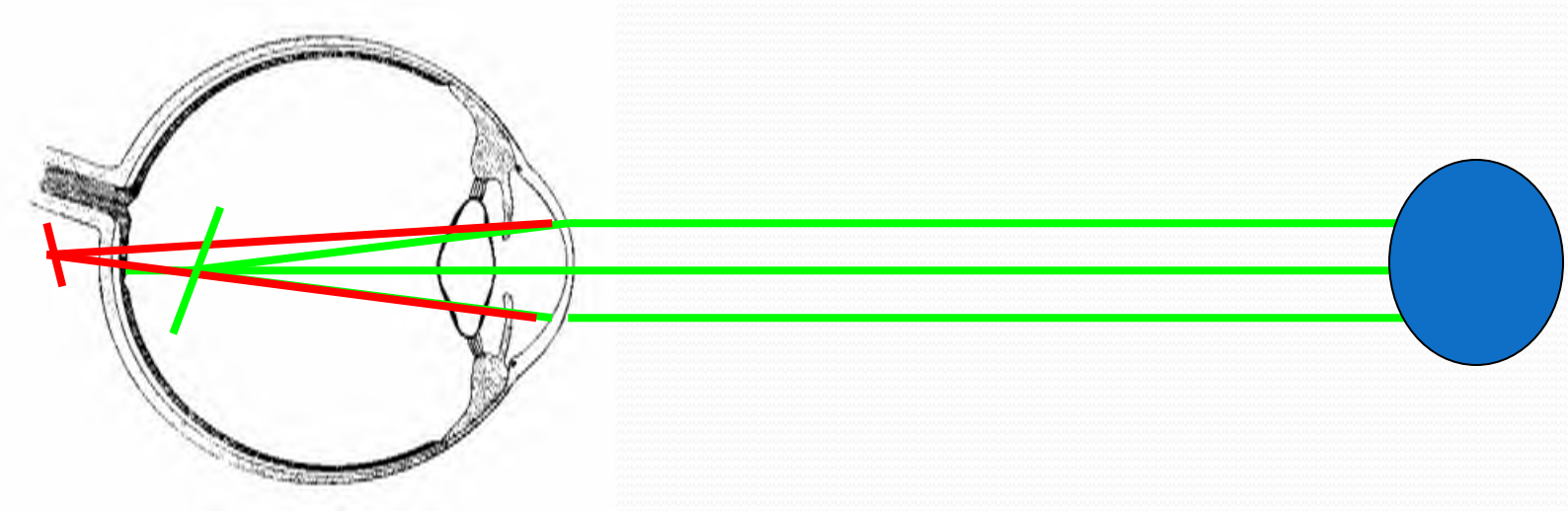
Myopia - Near Sighted - *Short Sight*



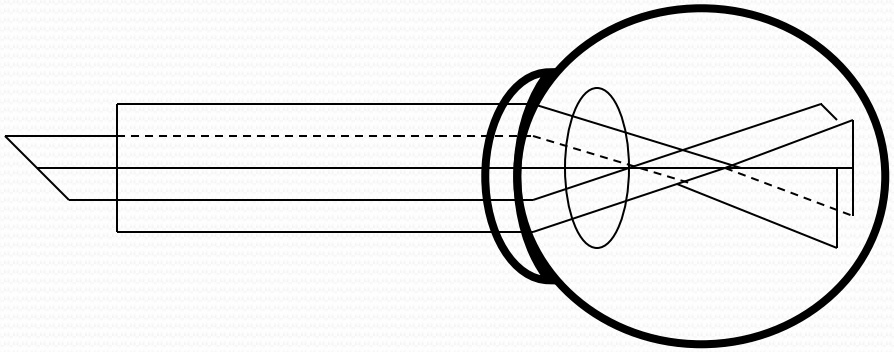
Hyperopia - Farsighted - *Long sight*



Astigmatism



Astigmatism

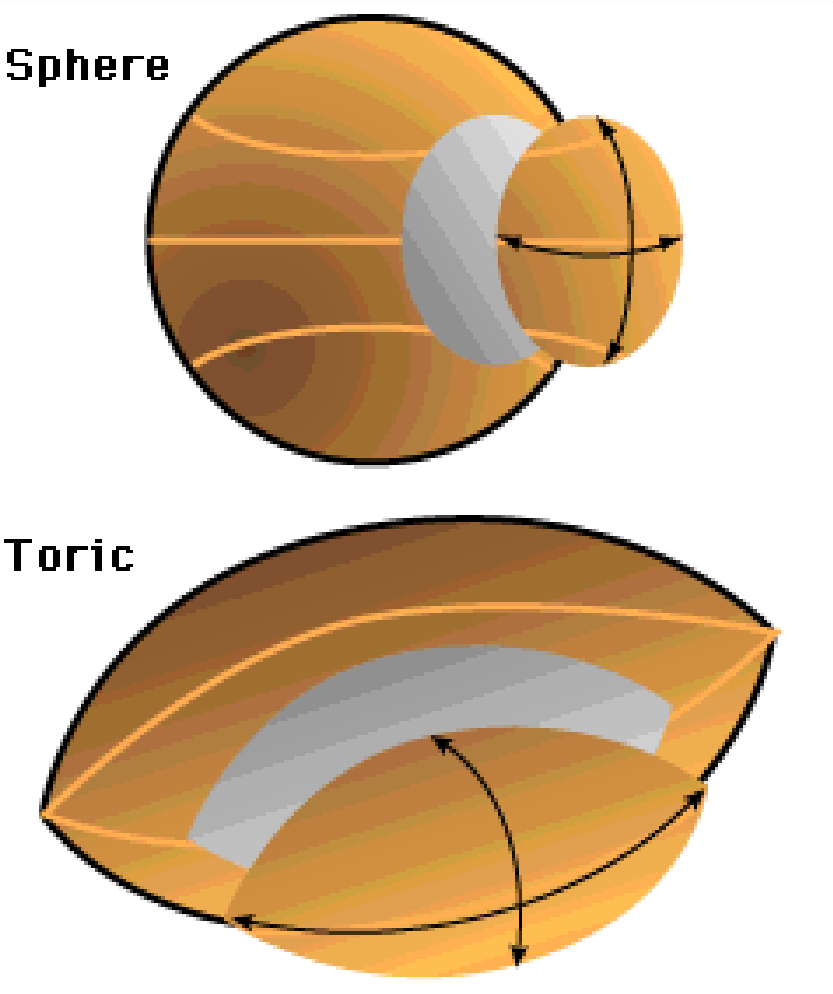


Astigmatism

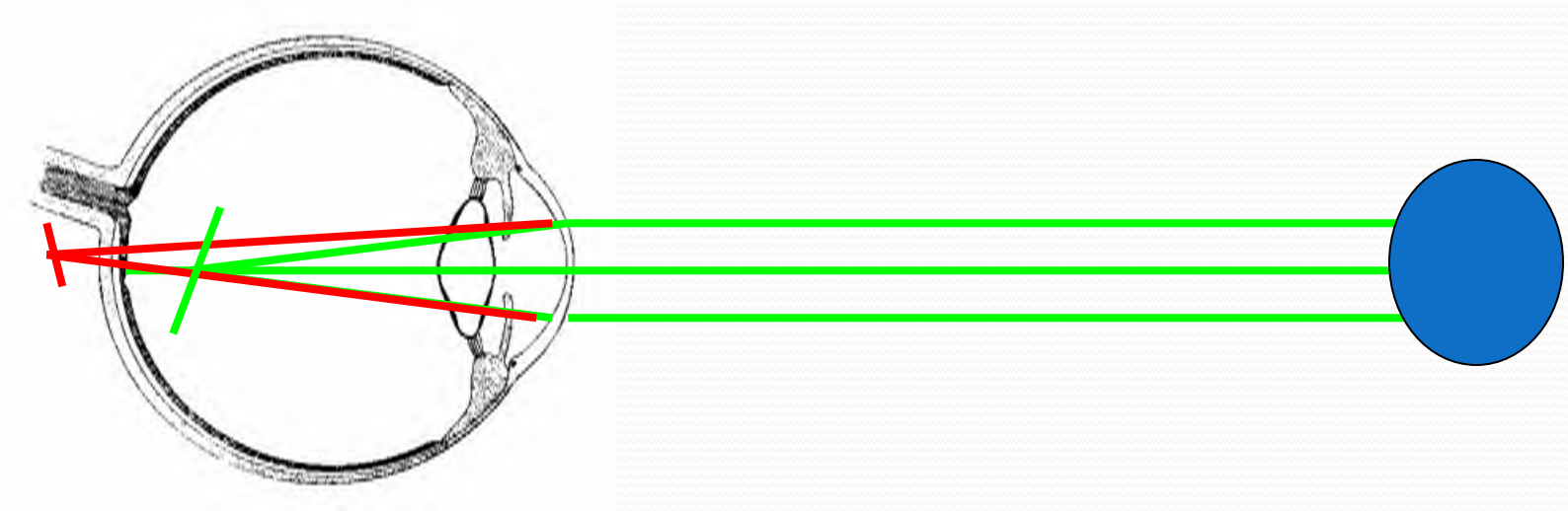
- Corneal astigmatism
- Lenticular astigmatism
- Regular astigmatism
- Irregular astigmatism

- Simple myopic astigmatism
- Compound myopic astigmatism
- Simple hyperopic astigmatism
- Compound hyperopic astigmatism
- Mixed astigmatism

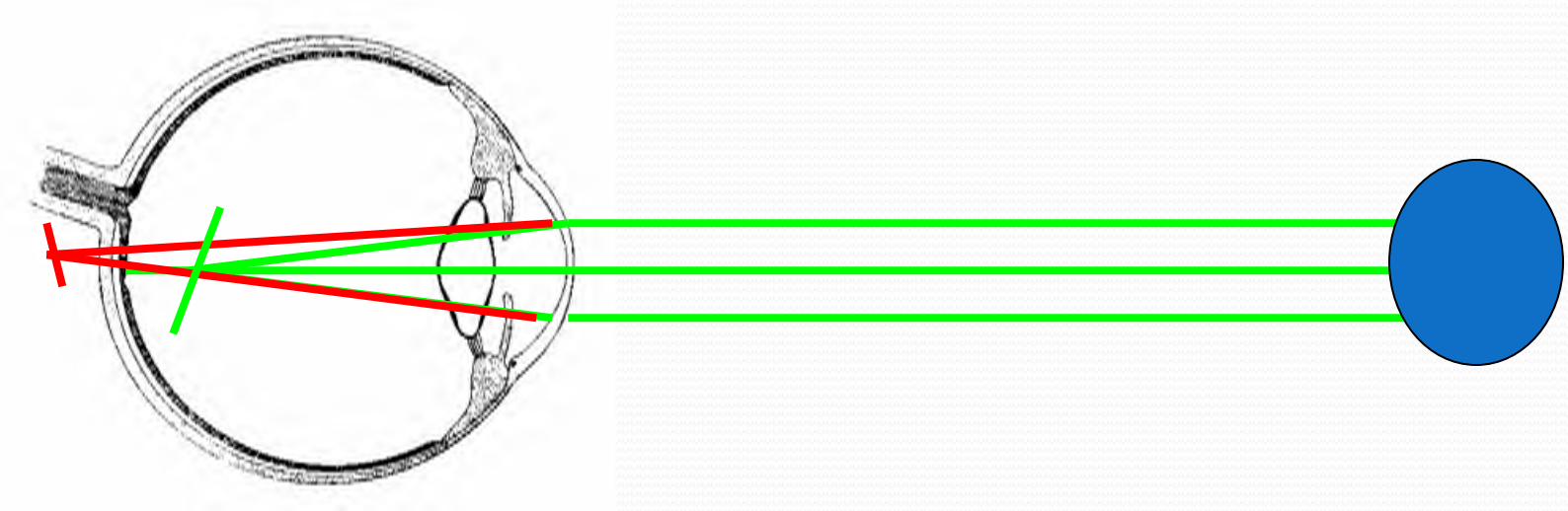
Corneal Astigmatism



Lenticular Astigmatism



Regular Astigmatism



Types of Regular Astigmatism

- Simple myopic astigmatism
- Compound myopic astigmatism
- Simple hyperopic astigmatism
- Compound hyperopic astigmatism
- Mixed astigmatism

Terminology

- Presbyopia

- Greek
  - Presby = Old
  - Opia = Sight

Presbyopia

- Causes
- Treatment
  - Spectacles
  - Contact Lenses

Understanding Presbyopia

- Age-Related Vision Changes

  As we age, our visual system undergoes major changes

- Decline of accommodation
- Senile miosis
- Loss of visual acuity
- Lowered contrast sensitivity
- Increased lighting sensitivity
- Slower speed of visual processing

Change in the Mean Amplitude of Accommodation With Age

Age (Years)	Amplitude (Diopters)
10	10.6 - 13.5
15	10.1 - 12.5
20	9.5 - 11.5
30	6.6 - 8.9
35	5.8 - 7.3
40	4.4 - 5.9
45	2.5 - 3.7
50	1.6 - 2.0
55	1.1 - 1.3
60	0.7 - 1.0

Measured by moving the target toward the subject until first blur is reported (Borish 1970; Turner 1958)

Corrections for Presbyopia

- Rx reading glasses
- OTC readers
- PAL's
- Segmented lenses
- Contacts *(Soft and Rigid)*
  - Mono
  - Bifocals
  - Modified
- Surgery
  - Explain limitations to your patients
- Others

Conclusion

Thank you