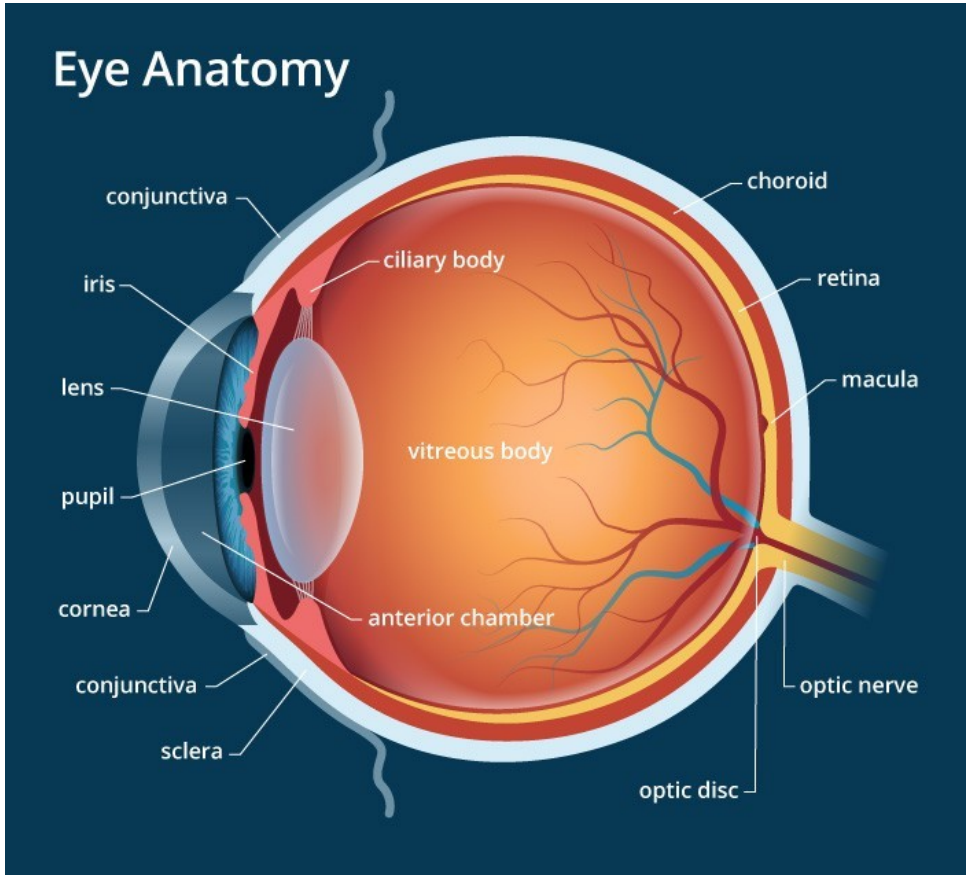
Lecture 1
The Eye: I. Optics of Vision
Chapter 50

Dr Iman Aolymat

Functional anatomy of the eyeball

Cornea

- Transparent →allows for light passage of into eye
- functions as fixed lens.
- very sensitive to pain, touch, pressure and cold→ rich nerve supply
- Not vascularized → nourished by aqueous humor



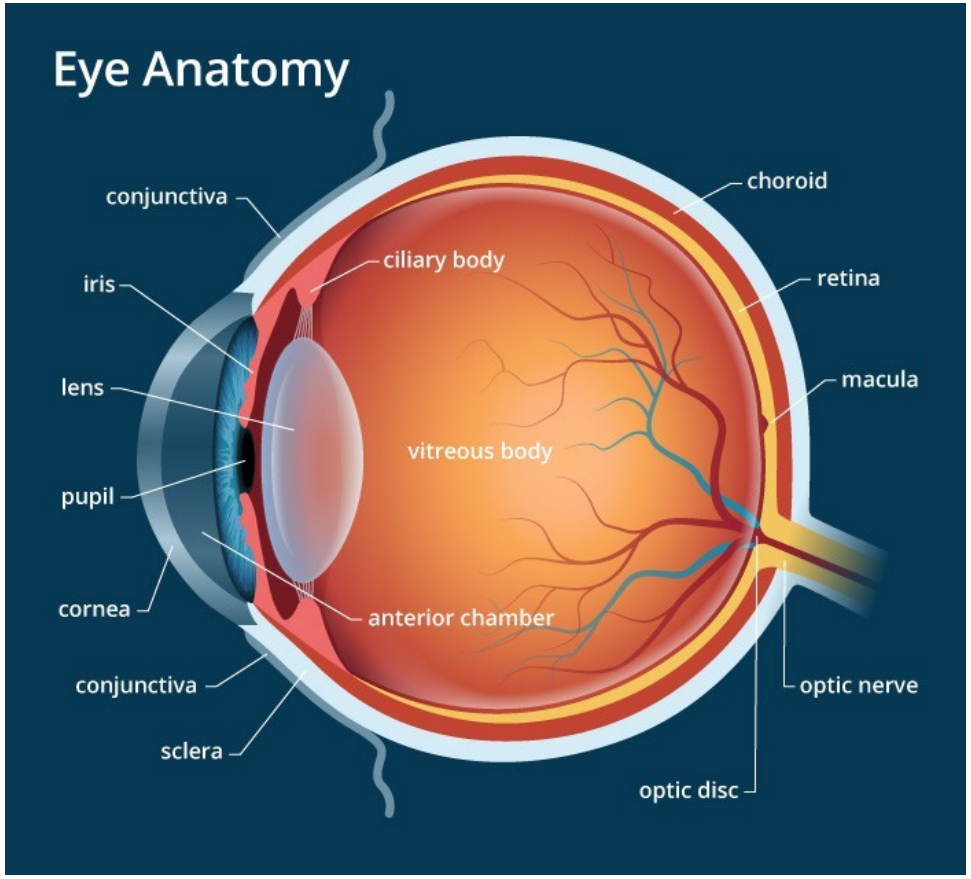
Functional anatomy of the eyeball

Conjunctiva

- covers exposed part of eye
- protection and lubrication-thin film of tear.

Sclera

- tough white tissue that covers all of eyeball except the cornea
- Supports eyeball
- provides attachment for muscles



Functional anatomy of the eyeball

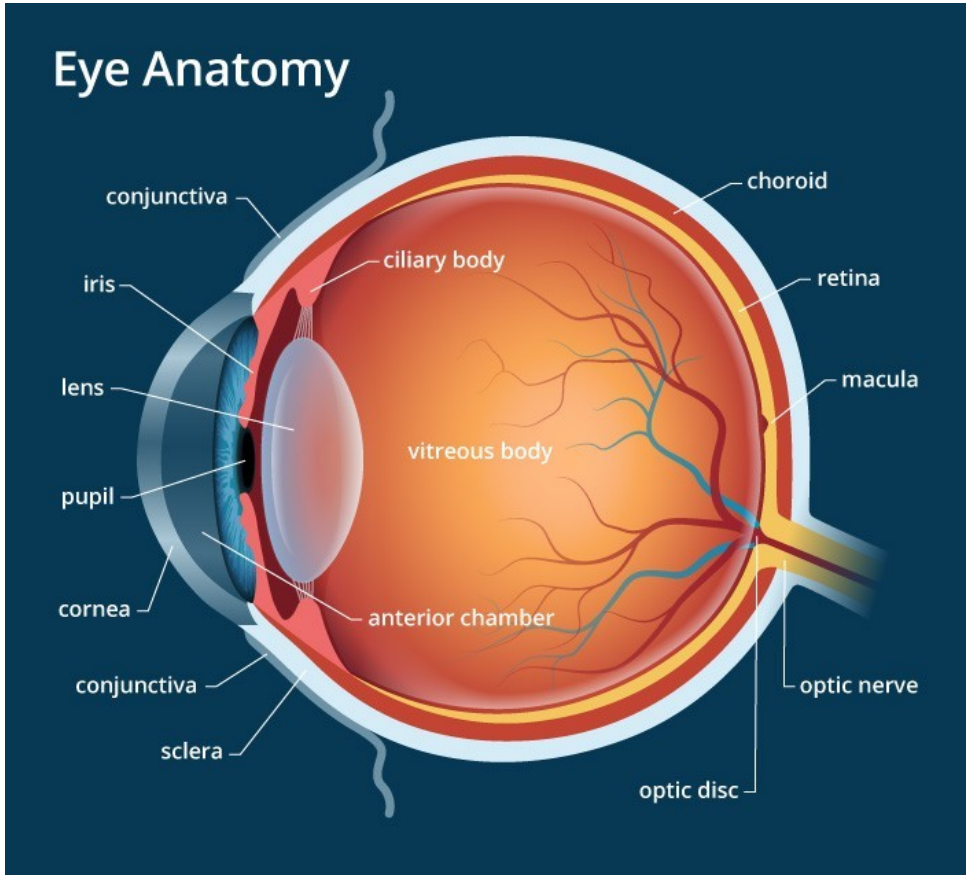
Iris

- regulate amount of light entering eye through Black hole in iris/where light enters
- formed by 2 type of muscles:

  ✓ Constrictor pupillae /iris sphincter muscle/pupillary constrictor muscle→ constriction of pupil.

  ✓ Dilator pupillae/pupillary dilator muscle → dilatation of pupil.
- Iris separates space between cornea and lens

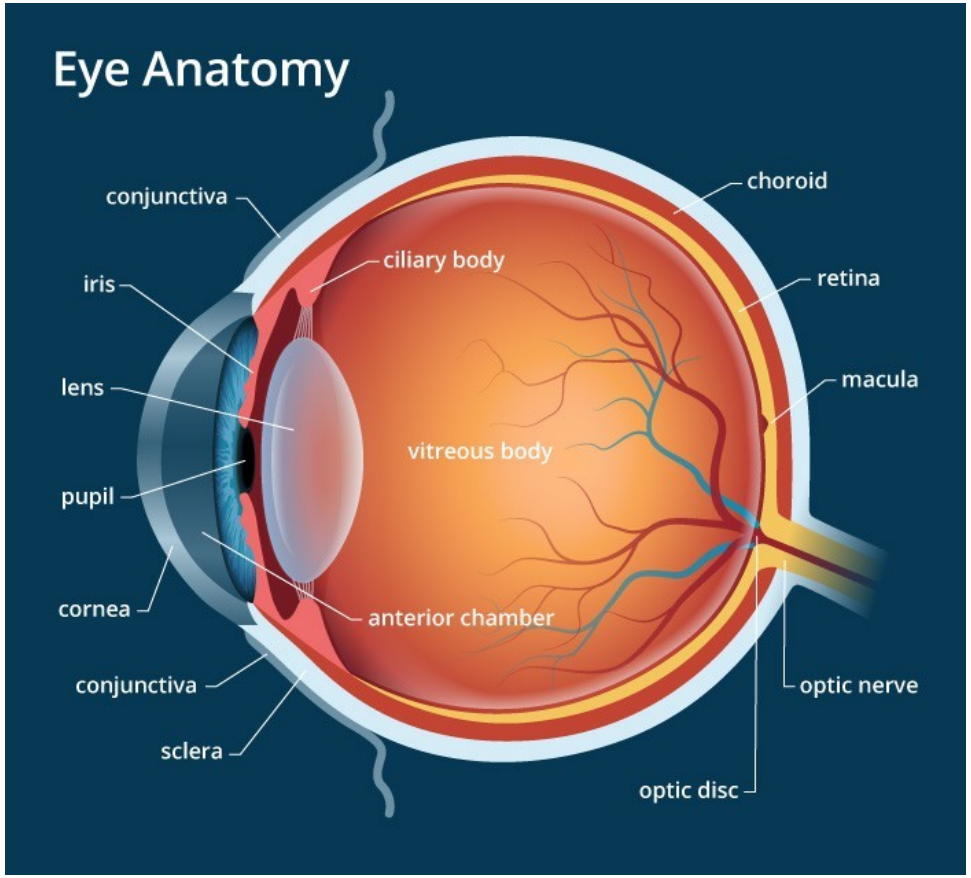
into anterior & posterior chambers-communicate with each other through **pupil**



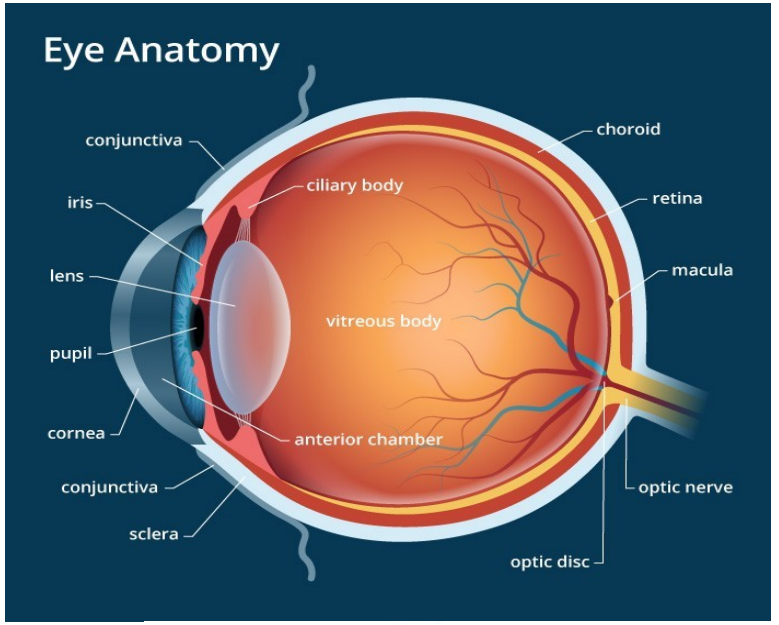
Functional anatomy of the eyeball

Lens

- Biconvex and elastic
- Avascular (nutrition mainly from the aqueous humor)
- refracts light rays & helps to focus image of objects on retina.
- supported by the suspensory ligaments
- Suspensory ligaments from the lens are attached to ciliary body.



Functional anatomy of the eyeball



Retina

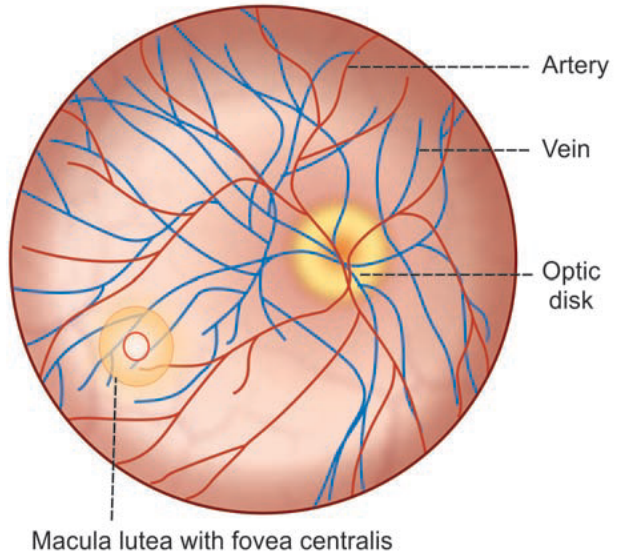
- Contains light-receptive cells (rods and cones)
- Converts light to electrical signals

Macula lutea

- yellow spot

Fovea centralis

- depression in center of macula lutea.
- 0.5 mm in diameter
- Here, all the layers of retina are very thin.
- Fovea is the region of most acute vision because it contains only cones.



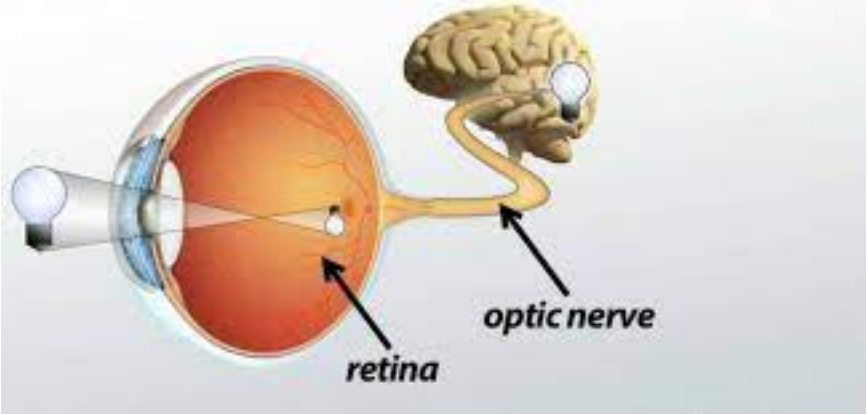
Macula lutea with fovea centralis

Blind spot (Optic disk/Papilla)

- near the center of the posterior wall of eyeball
- formed by convergence of axons from ganglion cells, while forming the optic nerve.
- No rods/cones

Functional anatomy of the eyeball

Optic nerve: transmits electrical impulses from retina to brain



Functional anatomy of the eyeball

Lids and Lashes

- protection of the eye
- cutoff the light during sleep
- distribute tears which wash and lubricate the eyes

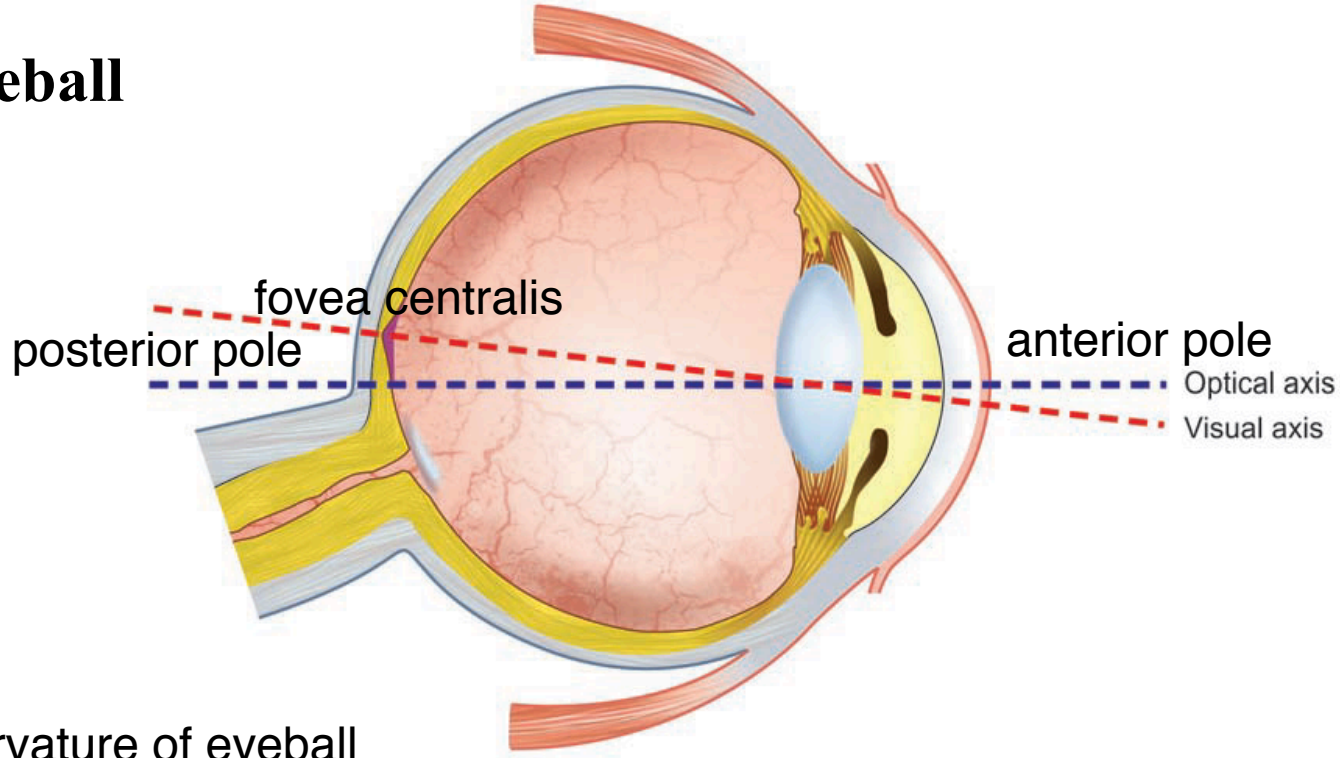
Lacrimal gland

- washing and lubrication
- contains lysozyme that kills bacteria.
- Secretion of tears is controlled by the **parasympathetic fibers of facial** (VII cranial) nerve

Meibomian glands and some sebaceous glands

- secrete oil which coats the surface of eyes and keeps tears from evaporating

Functional anatomy of the eyeball



Morphology

- **Anterior pole** = center of anterior curvature of eyeball
- **Posterior pole** = center of posterior curvature of eyeball

- **Optic axis =** Line joining anterior & posterior poles
- **Visual axis =** line joining a point in cornea, little medial to anterior pole & fovea centralis, situated lateral to posterior pole
- Light rays pass through the visual axis of eyeball

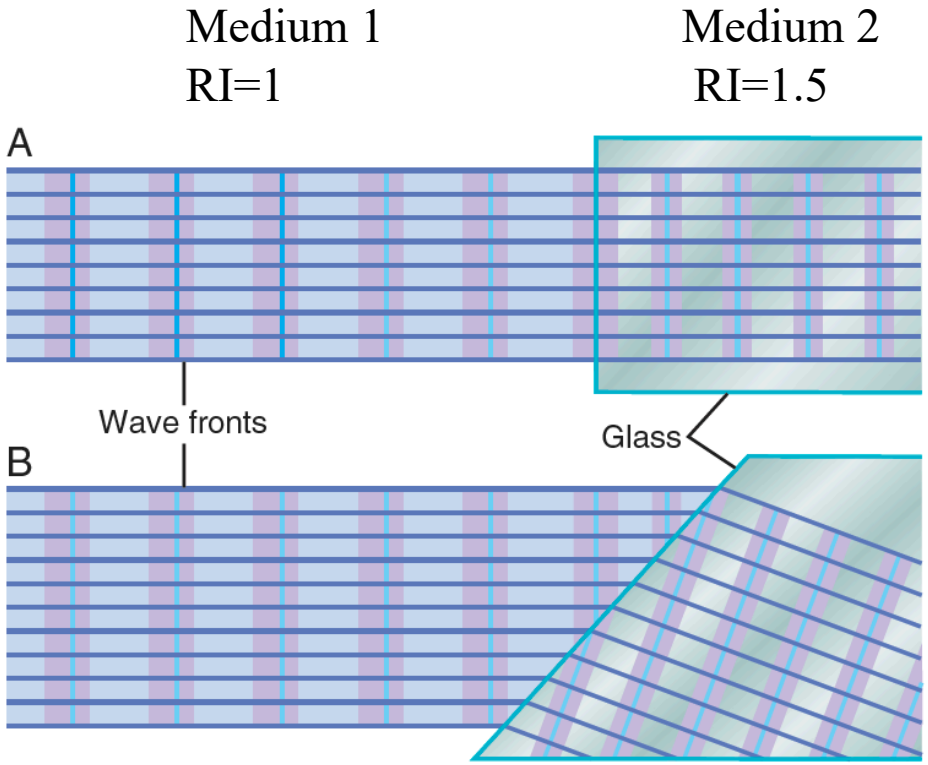
Refraction of Light

- Refraction of light= bending of light as it passes from one transparent substance into another.
- speed of light in air 300,000 km/sec.
- light speed **decreases** when it passes through a transparent substance.
- **refractive index** = speed of light in **air**/speed of light in **substance**.
- e.g. speed of light in substance = 200,000 km/sec,

R.I. = 300,000/200,000 = 1.5.

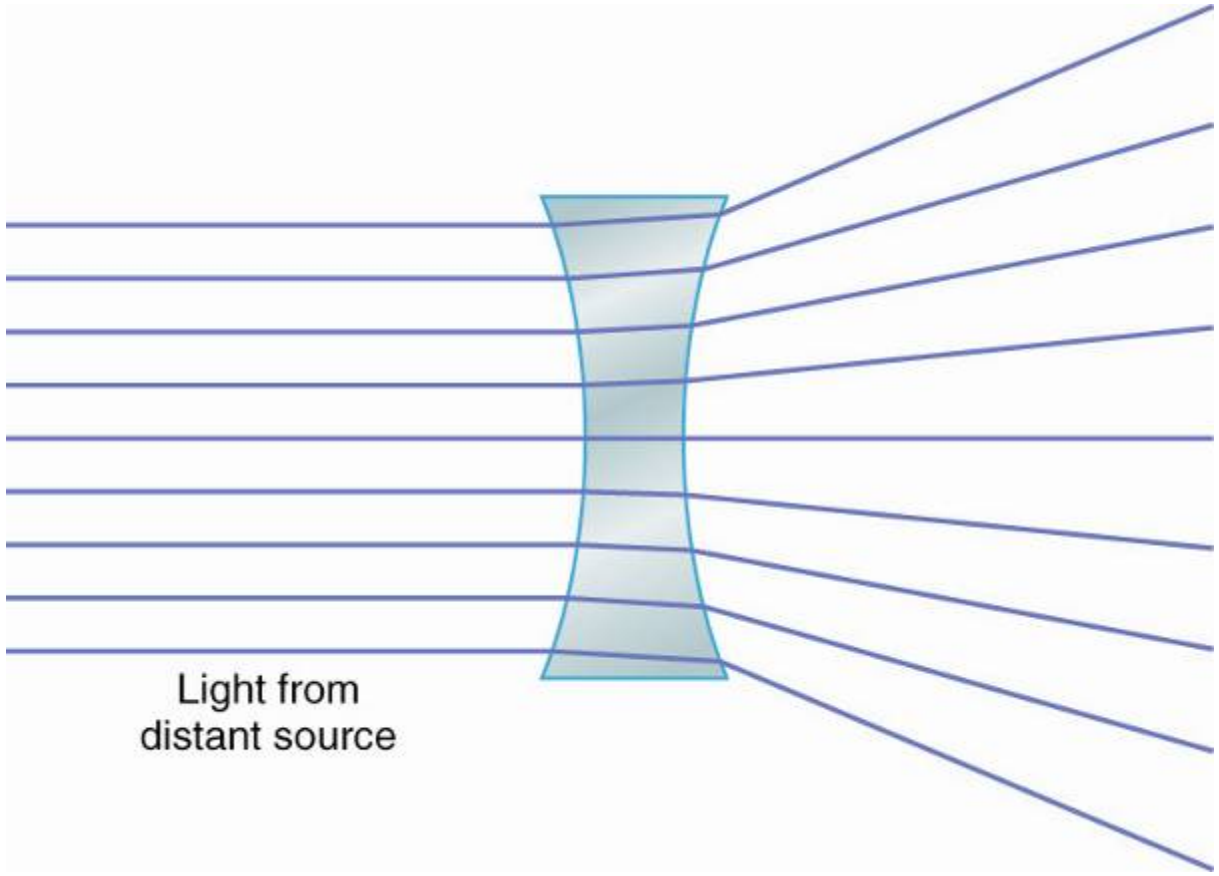
Refraction of Light

- A- interface is perpendicular→ No refraction + ↓ speed of light in M2 + ↓ wave length
- B-*angulated interface* → refraction.
- the degree of refraction increases as the *difference in R.I. increases* and the *degree of angulation increases*.
- eye have different R.I. and cause light rays to bend.
- These structures bend the light so that a clear image is produced (tears/ cornea/ lens)
- these light rays are eventually focused on the retina.



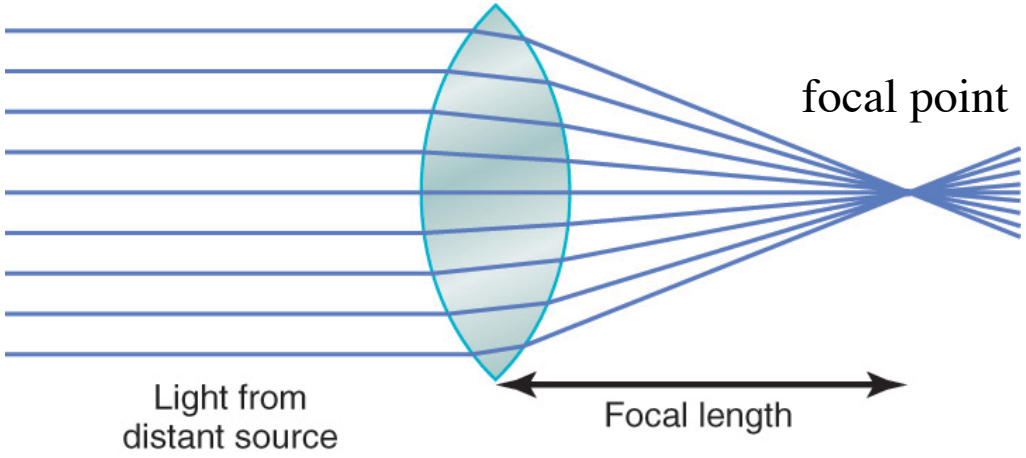
Refractive Principles of a Lens (cont'd)

- concave lens diverges light rays.

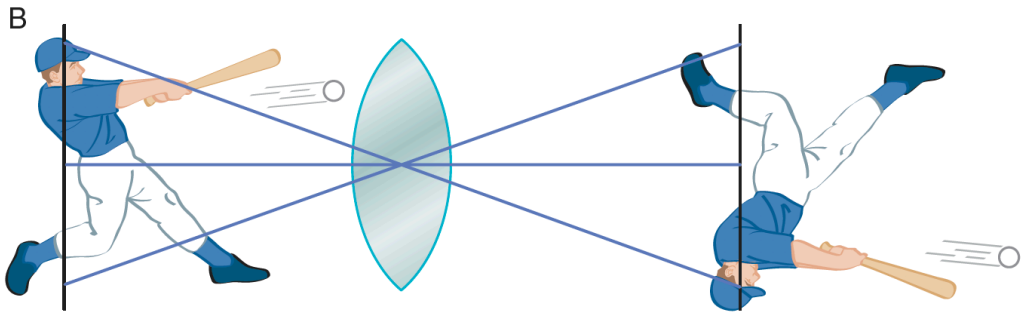


Refractive Principles of a Lens

- convex lens focuses light rays



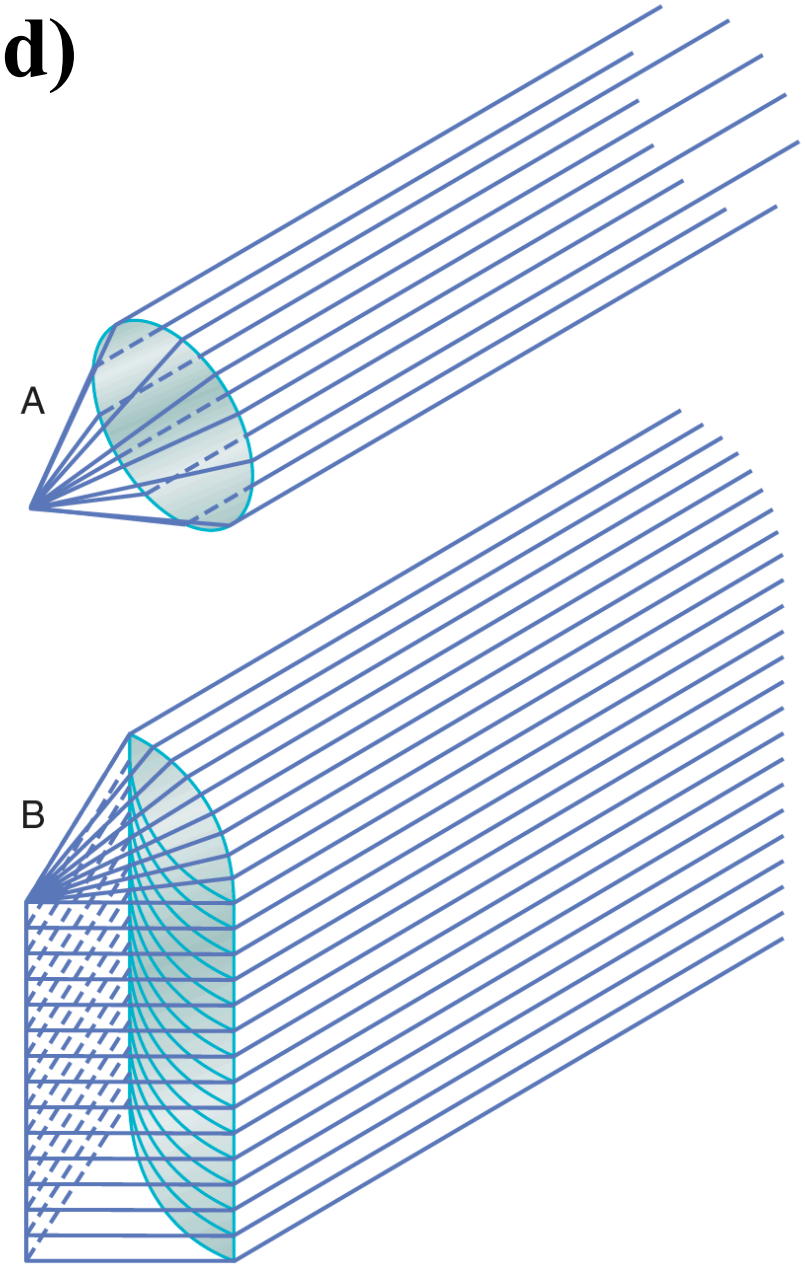
the distance from the center of the lens to the focal points



Formation of an Image by a Convex Lens

Refractive Principles of a Lens (cont'd)

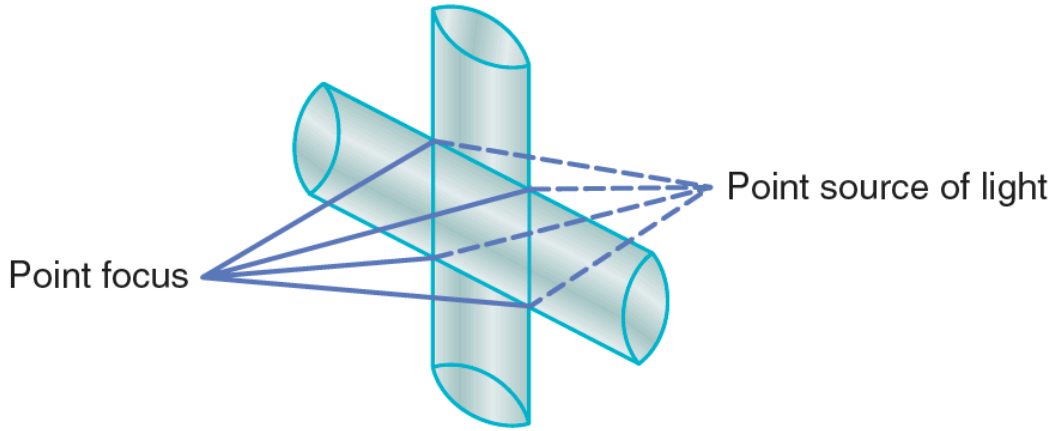
spherical lens bends light to a focal point



Convex cylindrical lens bends light rays to a focal line.

Refractive Principles of a Lens (cont'd)

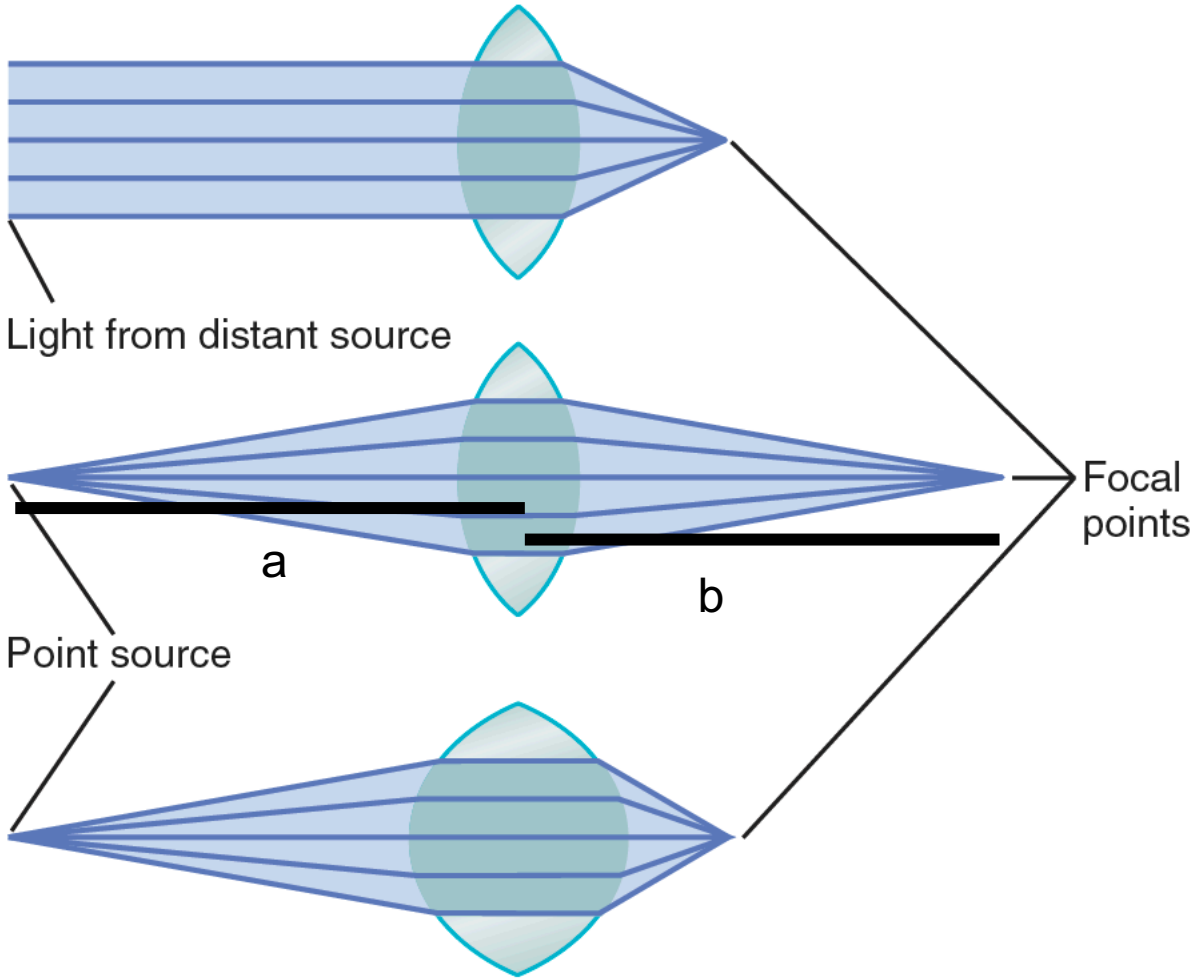
Combination of Two Cylindrical Lenses at Right Angles Equals a Spherical Lens



Refractive Principles of a Lens

$$\frac{1}{f} = \frac{1}{a} + \frac{1}{b}$$

f= focal length
a=distance of the point source of light from the lens
b =distance of focus



Close to the lens

More curved lens

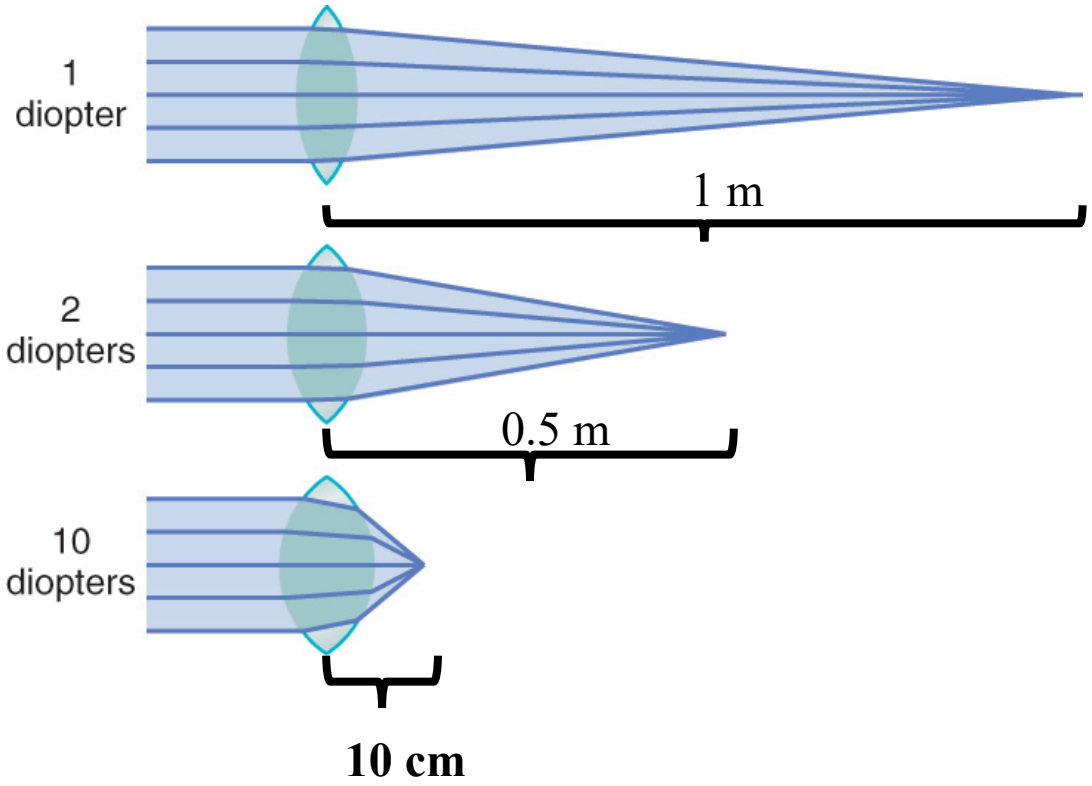
The Refractive Power of a Lens

- The more curved lens→The more a lens bends light rays→ the greater is its **"refractive Power"**

- refractive power is measured in terms
- of diopters.

- The refractive power in diopters of a convex lens =1 m /focal length.

- ↑ dopters→ ↑ refractive power



The end

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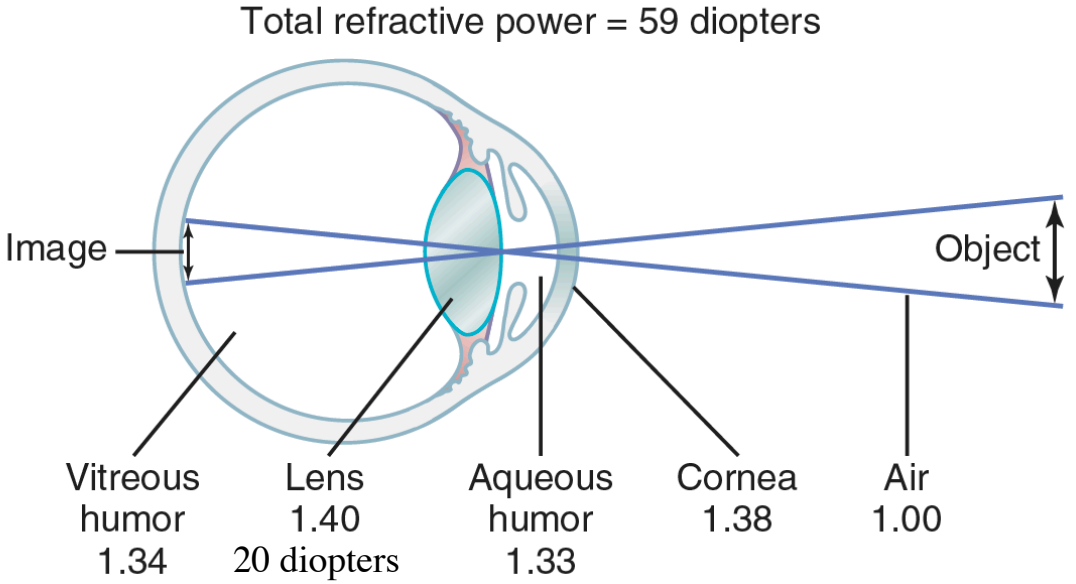
Optics of the eye

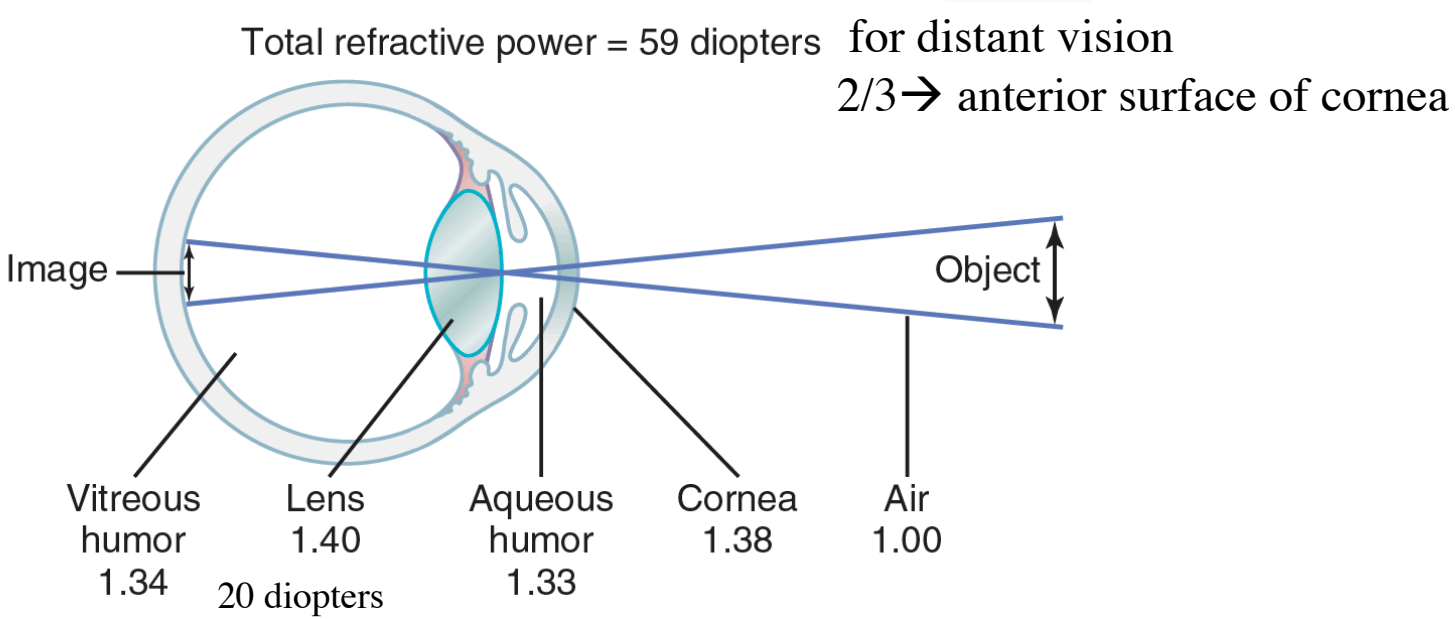
The lens system of the eye is composed of four refractive interfaces:

(1) between **air** and anterior surface of **cornea**
(2) between posterior surface of **cornea** and **aqueous humor**
(3) between **aqueous humor** and anterior surface of **lens** of eye
(4) between posterior surface of **lens** and **vitreous humor**.

Consideration of All Refractive Surfaces of the Eye as a **Single Lens**—The "Reduced" Eye.



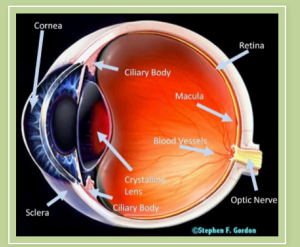
Optics of the eye



- most of refractive power of eye results from surface of cornea
- refractive index of **cornea** is markedly different from that of **air**, whereas the refractive index of the eye **lens** is not greatly different from the indices of the aqueous humor and vitreous humor

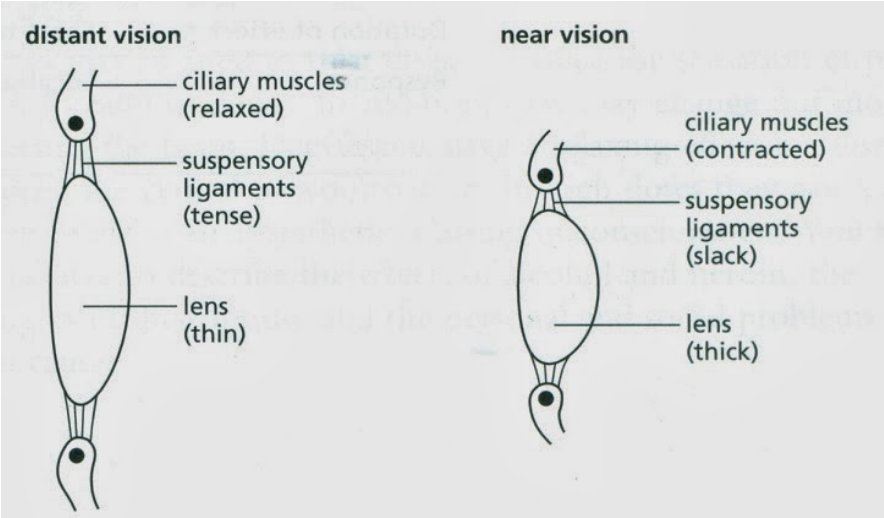
Accommodation

Mnemonic **CCC**



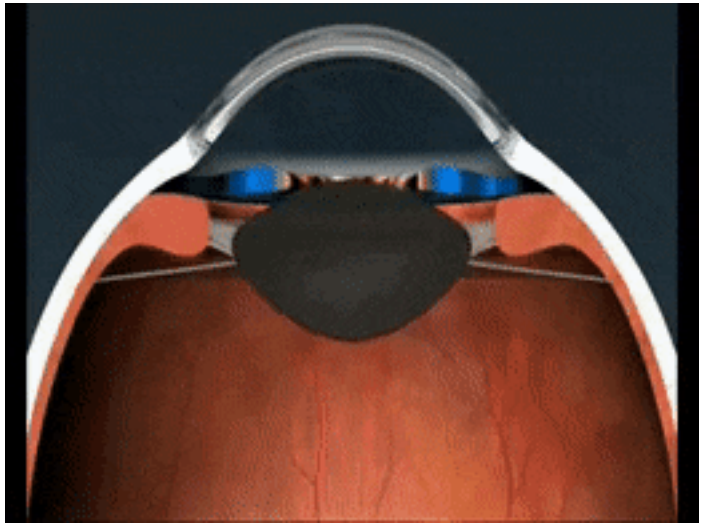
Ciliary muscles
Contracts for
Close vision

- refractive power of the lens is 20 diopters.
- refractive power can be increased to 34 diopters (in children) by changing shape of the lens – increasing its curvature by **accommodation**.
- accommodation is necessary to focus the image on the retina.



- lens is held in place by suspensory ligament which under normal resting conditions causes the lens to be almost flat (**moderately convex**).

Mechanism of Accommodation



- Eye lens is elastic.
- contraction of ciliary muscle (meridional fibers & circular fibers)→ relaxes the ligaments to the lens capsule→ more convex

•contraction of ciliary muscle (radial fibers) attached to suspensory ligament pulls fibers of the ligament **forward** and causes the lens to become **very convex** which increases the refractive power of the lens.

•under control of the **parasympathetic nervous system** (III, brain stem).

•When the eyes fixate on a near object, the eyes must **converge** →cause a mild degree of pupillary constriction

Accommodation-neuronal pathways

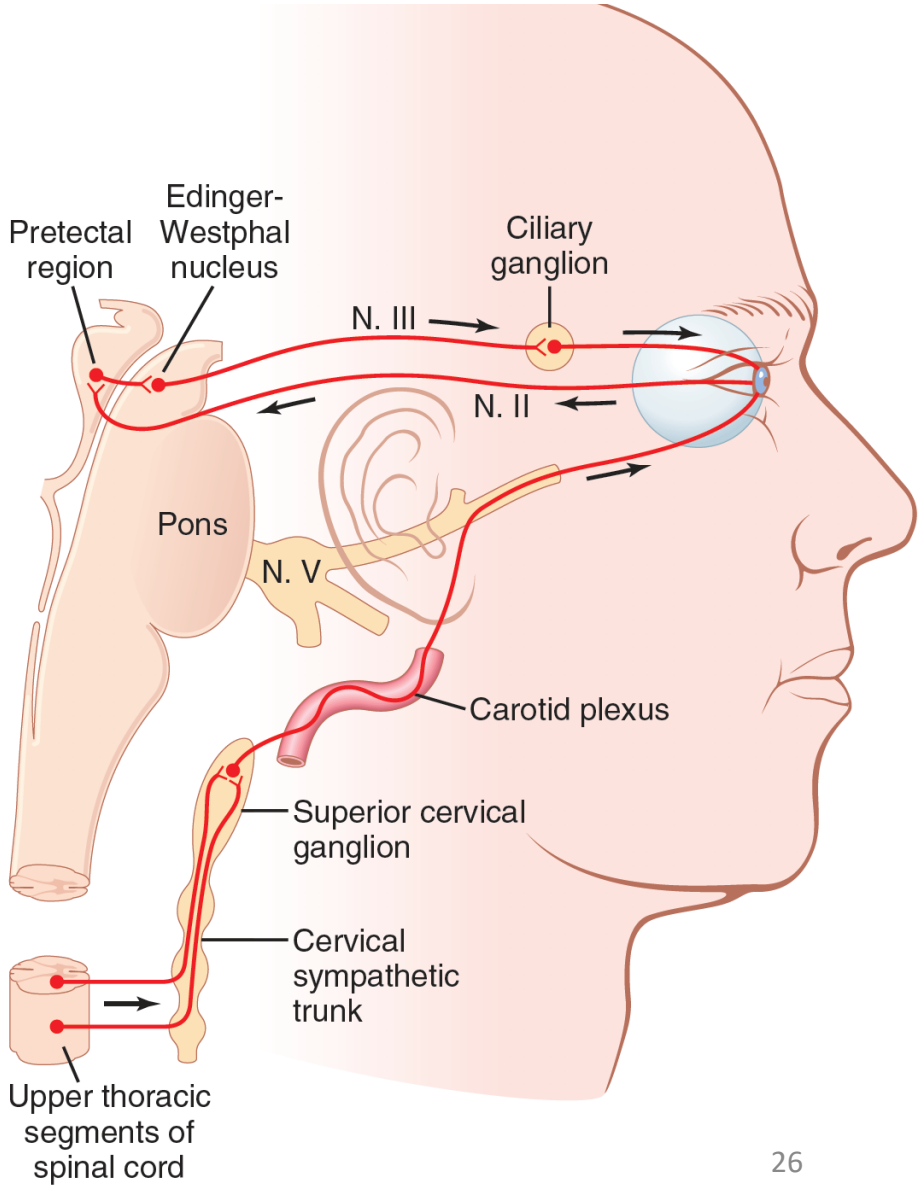
- Afferent- optic nerve
- Center-mid brain (superior colliculus)
- Efferent- oculomotor nerve
- Parasympathetic→ accommodation & meiosis
- Somatic→ eye convergence

Presbyopia; The Inability to Accommodate

- caused by progressive **denaturation** of the proteins of the lens with age.
- makes the lens less elastic.
- begins about 40-50 years of age (~ 2 diopters accommodation power).
- 70 years- 0 diopters
- no longer accommodate for both near and far vision → bifocal glasses, upper segment focused for **distant vision** and lower segment focused for **near vision**

The Autonomic Nerves to the Eyes

- eye is innervated by both parasympathetic and sympathetic neurons.
- **parasympathetic fibers** arise in the Edinger-Westphal nucleus, pass in the 3rd cranial nerve to the ciliary ganglion.
  - postganglionic fibers excite the *ciliary muscle and sphincter of the iris*.
- **sympathetic fibers** originate in the intermediolateral horn cells of the superior cervical ganglion.
  - postganglionic fibers spread along the corotid artery and eventually innervate the *radial fibers of the iris*.



Pupillary diameter

- meiosis: decreasing of pupillary aperture due to stimulation of **parasympathetic** nerves that excite the *pupillary sphincter muscle*.
- Decrease amount of light that enters eye → daylight

- mydriasis: dilation of pupillary aperture due to stimulation of **sympathetic** nerves that excite the *radial fibers of the iris*.
- Increase amount of light that enters eye → darkness

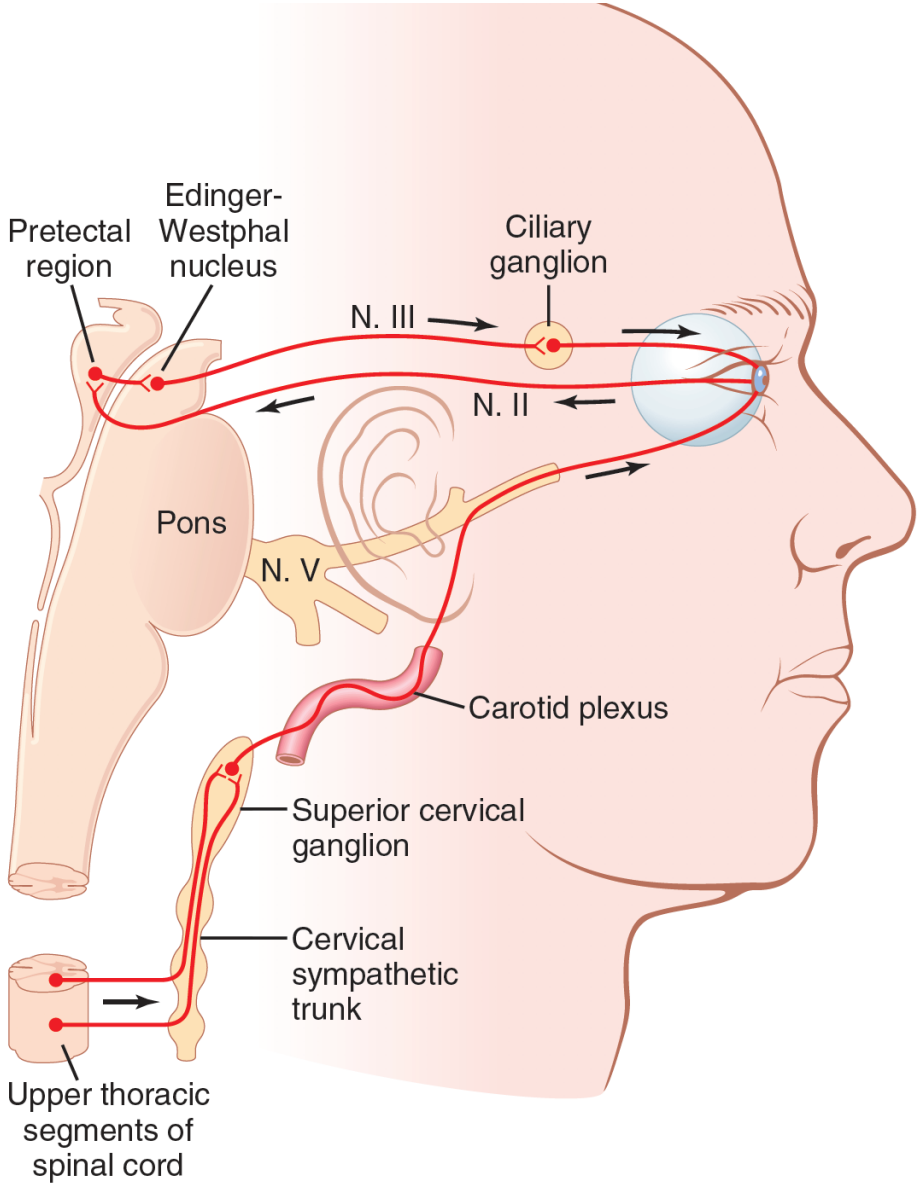
- quantity of light entering eye can change about 30-fold as a result of changes in pupillary aperture (1.5-8 mm).

- Depth of focus of the lens system **increases** with *decreasing* pupillary diameter, almost all the rays pass through center of lens, and the central-most rays are always in focus.

Pupillary Light Reflex

- when the amount of light entering the eyes <u>increases</u>, the pupils <u>constrict</u>.
- light through optic nerve to pretectal nuclei.
- from pretectal nuclei fibers pass to Edinger-Westphal nucleus and back through **parasympathetic** nerves to constrict iris sphincter.

- In dark→ reflex is inhibited

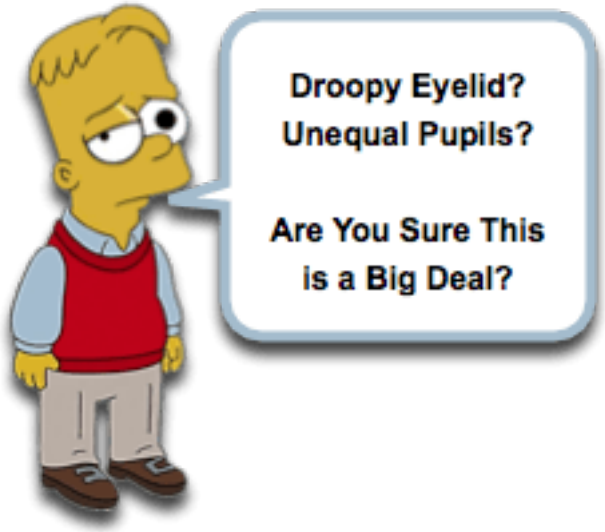


Horner's Syndrome.

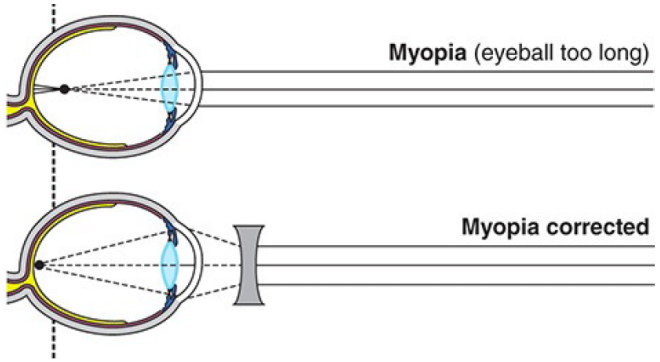
interrupted sympathetic nerves to eye

signs

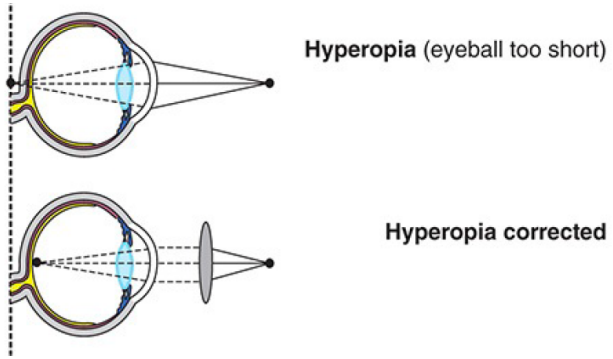
Pupil constricted (asymmetric)
superior eyelid drop
blood vessels on corresponding side of the face and head dilated
Lost sweating (asymmetric)



Errors of Refraction

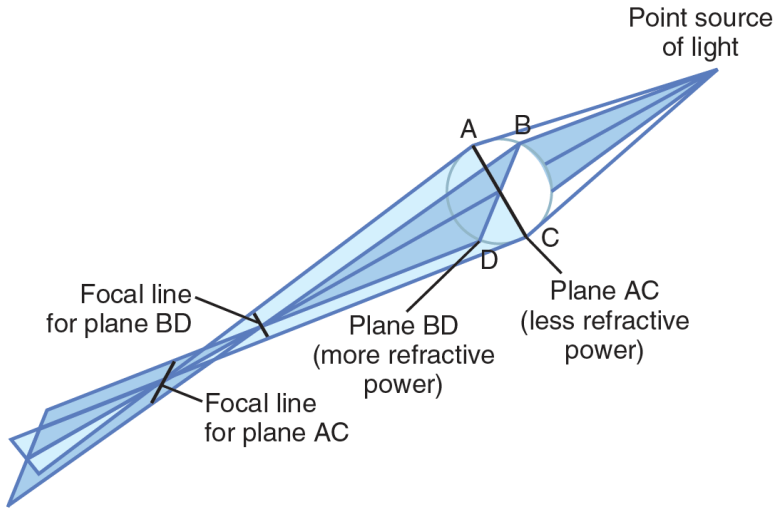


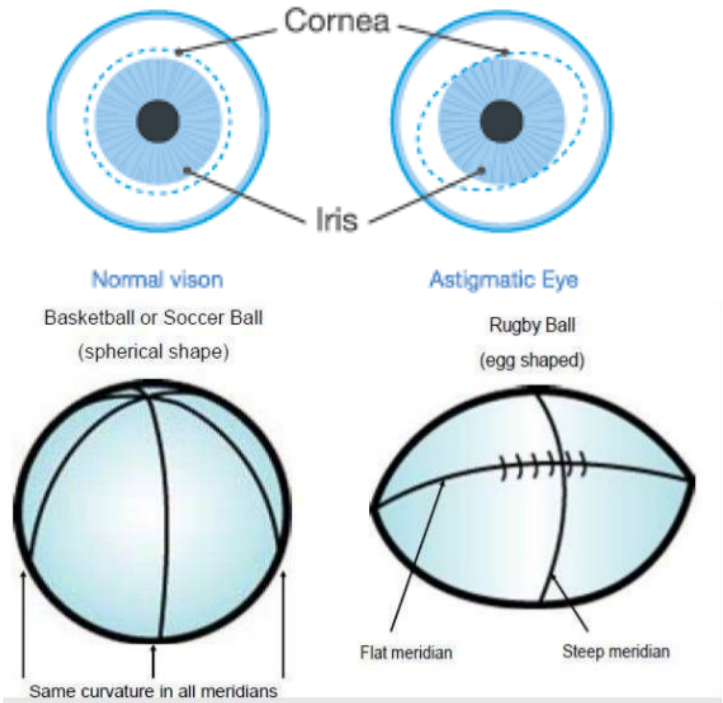
Nearsightedness
Too much refractive power
No mechanism to focus distant objects sharply on the retina.

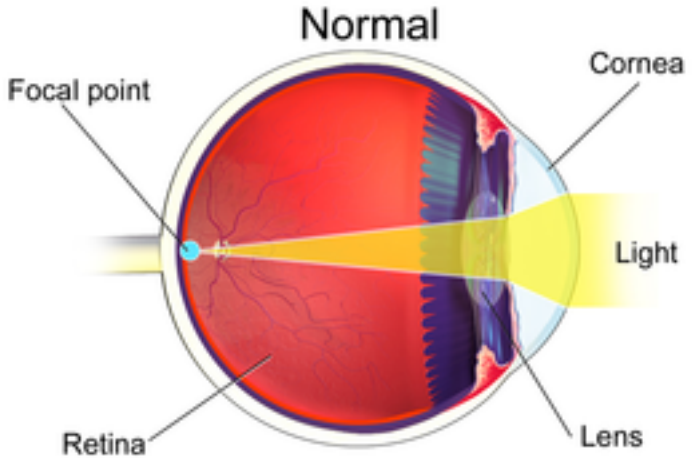


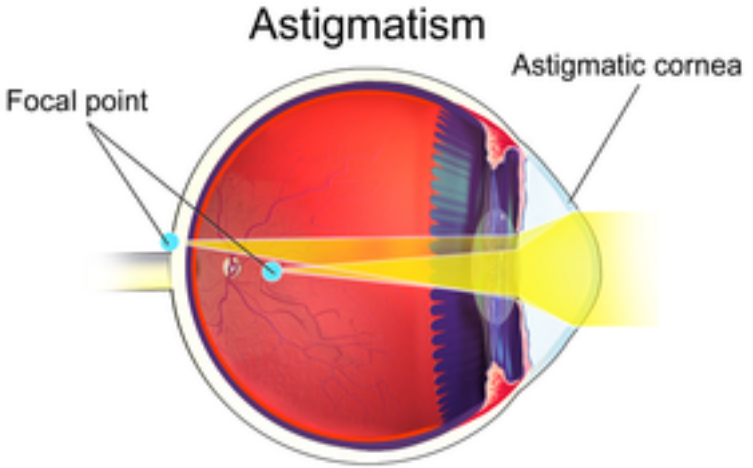
Farsightedness
Farsighted person is capable of focusing distant objects on retina until the ciliary muscle has contracted to its limit
presbyopic, farsighted person is unable to accommodate

Other Errors of Vision









Astigmatic cornea distorts the focal point of light in front of and/or behind the retina

- astigmatism
  - unequal focusing of light rays=visual image in one plane to focus at a different distance from that of the plane at right angles
  - due to an oblong shape (too great a curvature) of the cornea.
  - Corrected with cylindrical lens

Other Errors of Vision

- cataracts
  - cloudy or opaque area of the lens.
  - caused by denaturation and coagulation of lens proteins.

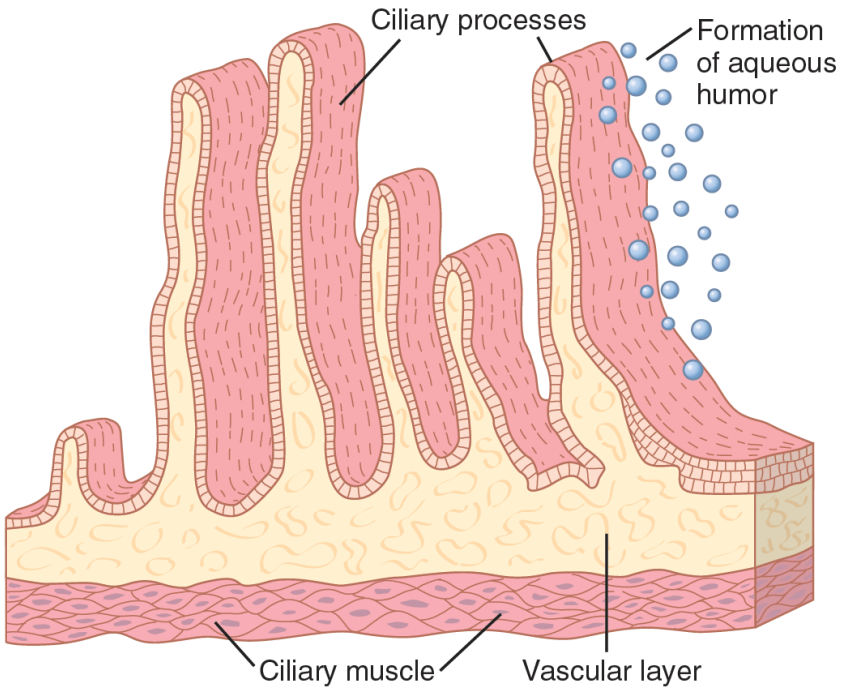
Fluid System of the Eye

- intraocular fluid keeps the eyeball round and distended.
- 2 fluid chambers.
  - aqueous humor which is in front of the lens.
    - freely flowing fluid.
  - vitreous humor which is behind the lens.
    - gelatinous mass (proteoglycan) with little flow of fluid.

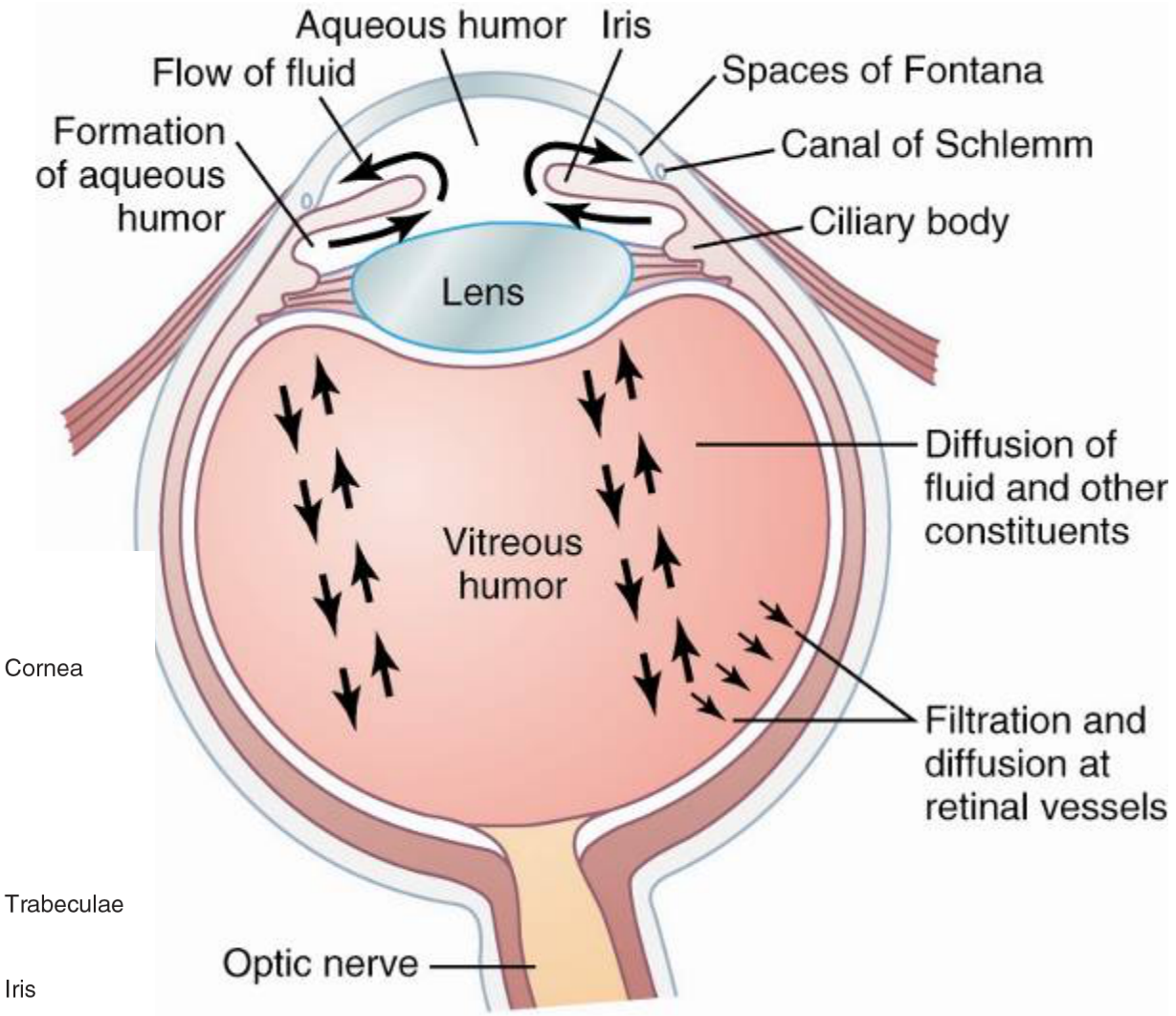
Formation and Flow of Fluid in the Eye

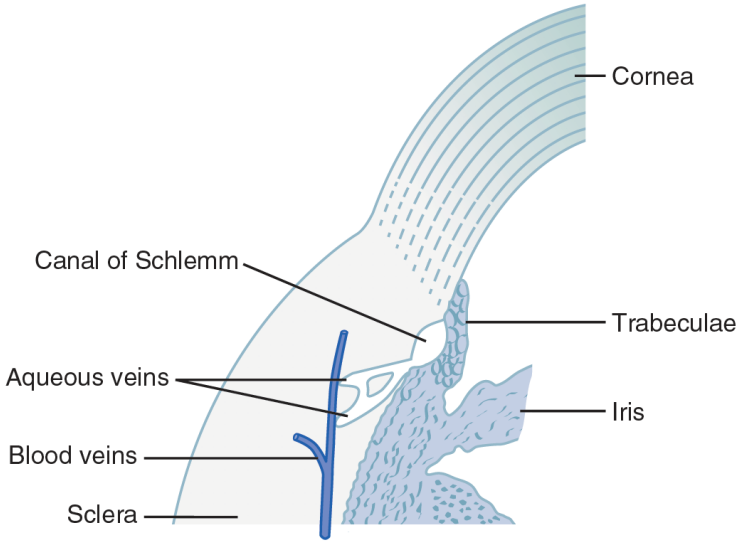
- produced by ciliary processes of ciliary body
- rate of 2-3 microliters/min.

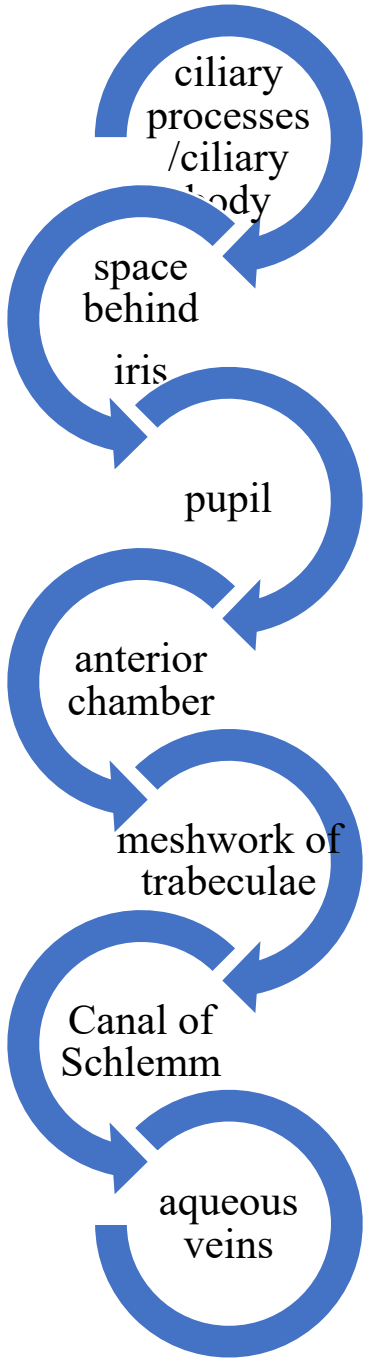
- active secretion- Na secretion, dragging Cl & HCO3, H2O by osmosis
- Nutrients (amino acids, ascorbic acid, and glucose) - active transport / facilitated diffusion



Formation and Flow of Fluid in the Eye







Intraocular Pressure

- normally 15 mmHg with a range of 12-20 mmHg.
- the level of pressure is determined by the resistance to outflow of aqueous humor in the canal of schlemm.

  - increase in intraocular pressure (Glaucoma) caused by an increase in resistance to outflow of aqueous humor through a network of trabeculae in the canal of schlemm.

  - can cause blindness due to compression of the axons of the optic nerve & compression of retinal artery → reducing nutrition to retina

Glaucoma

Cause:

increased resistance to fluid outflow

Acute→ eye inflammation, WBC & tissue debris

Chronic conditions → fibrous occlusion of trabecular spaces in elderly

Treatment: reduces the secretion or increases the absorption of aqueous humor.

The end