Neuroscience II
Spring 2024
Lecture I
The Eye: . Optics of vision and and function of the eye .

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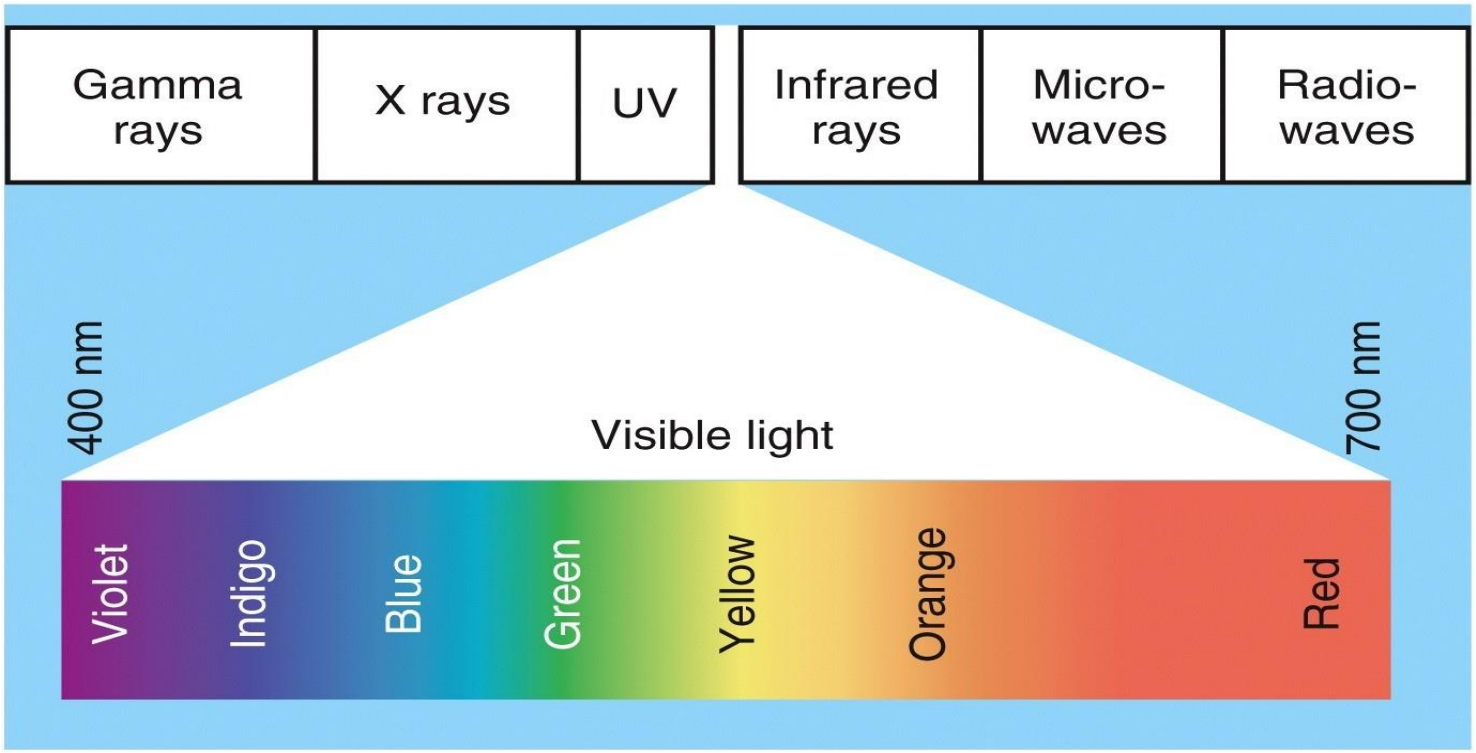
Objectives

- Review familiarity with the basic principles of optics, including the physics of light refraction, focusing, depth of focus and so forth (Review)
- List the types of lenses and recognize how they work (Review)
- Determine the power of lenses and its measurements in diopters (Review)
- Identify the structural components of eye the and describe their function
- Describe accommodation for near vision and explain the mechanism of accommodation
- Define the pupil reflex and outline the neuronal circuit for this reflex
- Define Horner syndrome and list the main symptoms of Horner syndrome and explain its pathophysiology
- Define Near accommodative triad
- Describe the formation and circulation of aqueous humor
- Define intraocular pressure and glaucoma

Outline of visual system functions

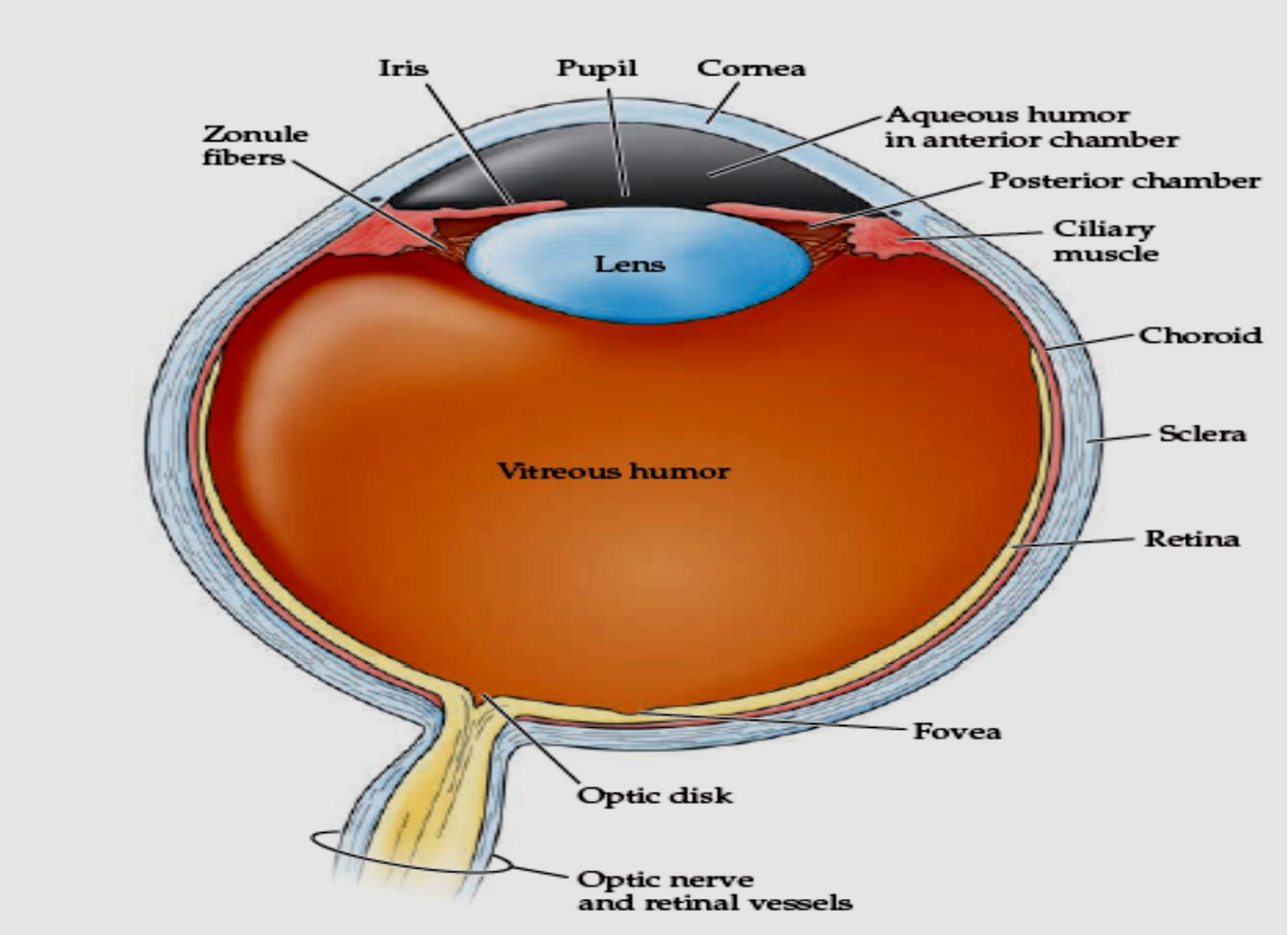
- The functions of a visual system :
  - Detect electromagnetic radiation (EMR) emitted by objects
  - Humans can detect light with a wavelength between 400-700 nM
  - Perceive color (hue) which is related to the wavelength of light
  - Determine brightness is related to the intensity of the radiation
  - Discriminate shape and figure from background
  - Detect movement of objects

Our vision uses visible light which is part of the electromagnetic spectrum with wavelengths from about 400 to 700 nm.



(a) Electromagnetic spectrum

Physiological anatomy of the eye



Functional anatomy of the eye

- The eye is a fluid-filled sphere enclosed by three layers of tissue
- Sclera :
  - forms the outermost tissue layer of the eye and is composed of a tough, white, fibrous tissue.
  - It is continuous with the cornea, and it is in continuity with the dura of the central nervous system
  - Supports eyeball
  - Provides attachment for muscles
  - At the front of the eye, however, this opaque outer layer is transformed into the cornea, a highly specialized transparent tissue that permits light rays to enter the eye
  - Along with the fluid system of the eye and lens the cornea contributes to light refraction and focusing of visual image on the retina

Functional anatomy of the eye Uveal tract

The immediately adjacent layer of tissue to the sclera includes three distinct, but continuous structures collectively referred to as the uveal tract.

- Choroid :
  - The largest component of the uveal tract is the choroid: which is composed of a rich capillary bed that nourishes the retinal photoreceptors;
  - a major feature is a high concentration of the light-absorbing pigment melanin in what is called the *pigment epithelium*
- Ciliary body An extension of the choroid near the front of the eye . It a ring of tissue that encircles the lens and consists of two parts:

  1. a muscular component that adjusts the refractive power of the lens and a vascular component (the so-called ciliary processes) that produces the fluid that fills the front of the eye. (produces aqueous humor).

Functional anatomy of the eye

- Iris : the most anterior component of the uveal tract is the iris, the colored portion of the eye that can be seen through the cornea. It contains two sets of muscles with opposing actions, which allow the size of the pupil (the opening in its center) to be adjusted under neural control (ANS)

Physiological anatomy of the retina

- The **retina** is derived from the neural tube and is, therefore, part of central nervous system.

  - It consists of two parts, the retinal pigment epithelium, which separates the middle, choroid coat of the eyeball from the other innermost component and the neural retina
  - The neuronal retina consists of different layers
  - It is the light sensitive components of the eye
  - The innermost layers are located nearest the vitreous chamber, whereas the outermost layers are located adjacent to the retinal pigment epithelium and choroid.

Fluid chambers and fluid system

- Anterior chamber : A chamber just beyond the cornea located between **cornea and the lens**
- posterior chambers : The region between the and Iris **iris zonule fibers and lens**
- These chambers are filled with the aqueous humor, a clear, watery liquid that supplies nutrients to Lense and cornea (Lense and cornea are none vascular) and maintains intraocular pressure
  Aqueous humor is produced by the ciliary processes in the posterior chamber (the region between the lens and the iris) and flows into the anterior chamber through the pupil

Vitreous Humor

- Vitreous Humor : Also known as vitreous fluid . is a transparent, colorless, gel-like substance that fills the space between the lens and the retina within the eye.
- The vitreous humor is composed of mostly water, along with a small percentage of collagen, glycosaminoglycans (sugars), electrolytes (salts), and proteins. It helps maintain the round shape of the eye and clarity and shock absorbance.
- Vitreous humor also contains phagocytes
- The vitreous humor is contained in a protective layer called the vitreous membrane. Vitreous humor is more viscous than water but still lets light through.
- Vitreous humor is responsible for about 80% of the volume of your eye.

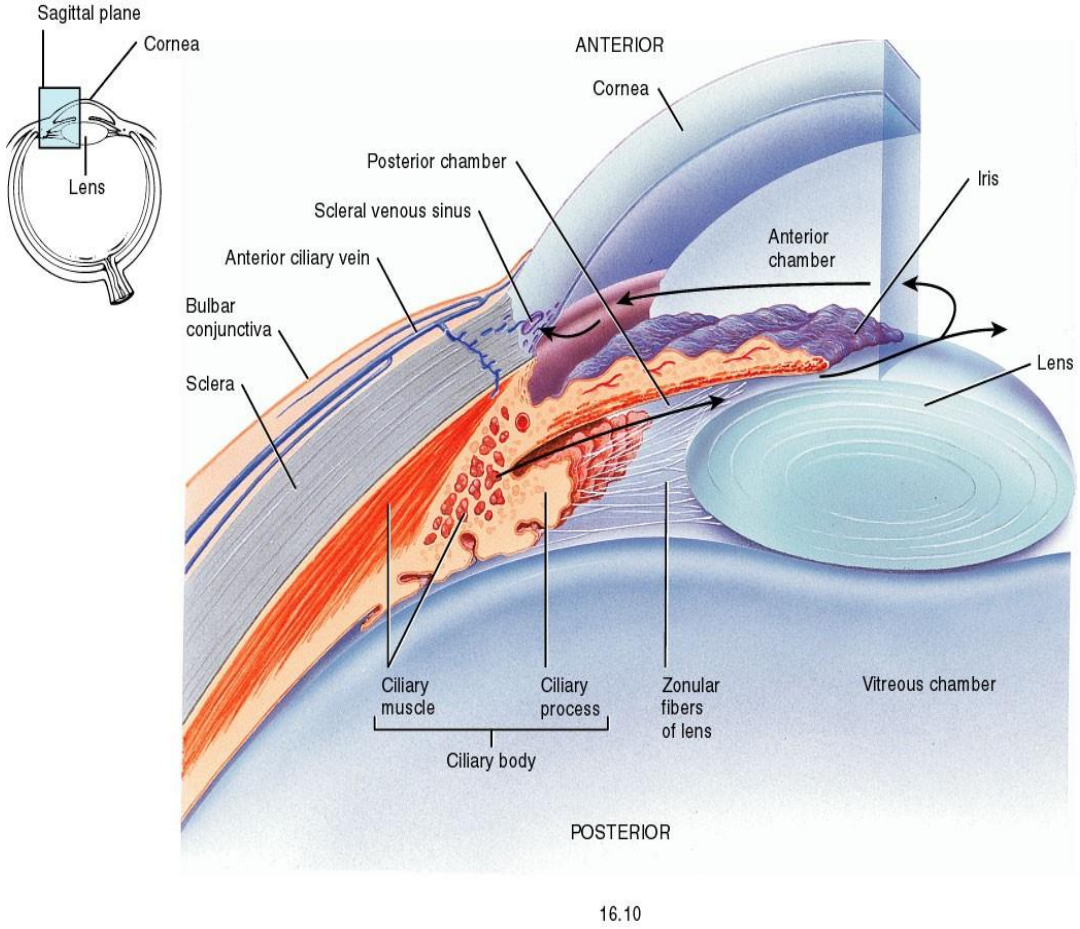
Structure of ciliary body and eye chambers and fluid system of the eye

Anterior chamber (between the cornea and iris).

Posterior chamber (between the iris, zonule fibers and lens).

The first two chambers are filled with aqueous humor (freely flowing fluid formed by the ciliary processes of ciliary body)

Vitreous chamber (between the lens and the retina). vitreous humor which is behind the lens gelatinous mass with little flow of fluid.

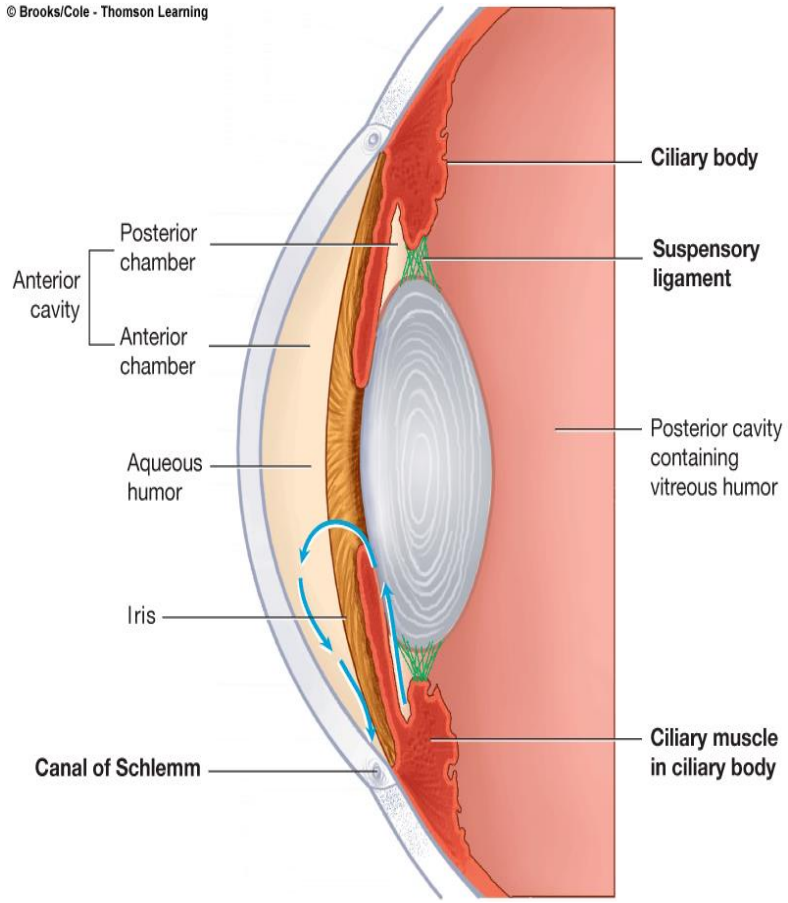


Function of Intraocular fluid

- Composed of water Na . Cl as well amino acids, ascorbic acid, and glucose.
- maintains sufficient pressure in the eyeball to keep it distended
- Maintains intraocular pressure
- Maintains the shape of the eyeball
- Supplies nourishment to the lens and cornea (they are avascular structures)
- Drains metabolic end products.

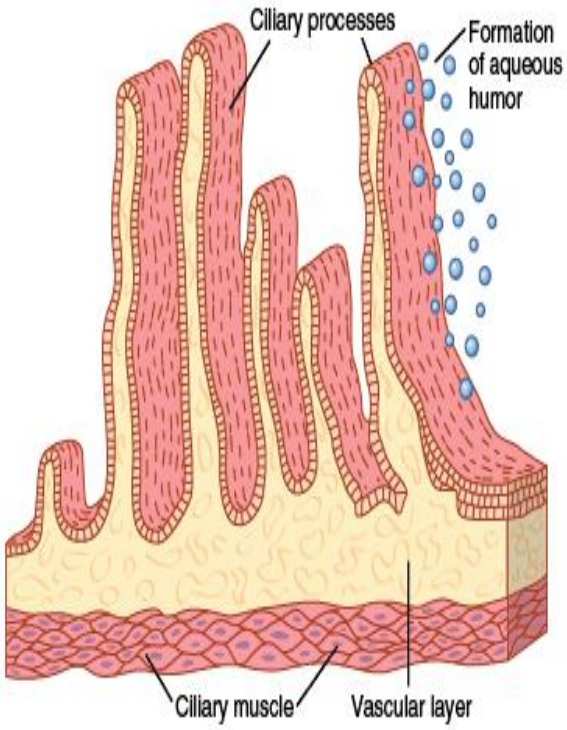
Flow of intraocular fluid

- Ciliary processes → posterior chamber → pupil → anterior chamber of the eye → angle between cornea and iris → trabecular meshwork → canal of Schlemm (Sclera venous sinus) → aqueous veins → extraocular veins.
- Canal of Schlemm: porous, thin-walled vein.
- Filled with aqueous humor, not blood.
- Rate of formation of fluid is : 2-3 µL/min
- Rate of drainage the canal of Schlemm (2.5 µl/min) equals the inflow from the ciliary body, thus maintaining constant pressure.
- The entire volume of fluid in the anterior chamber is replaced about 12 times a day.



Mechanism of formation of intraocular fluid by the ciliary processes

- Aqueous humor is formed almost entirely as an active secretion by the epithelium of the ciliary processes.
- Secretion begins with active transport of Na ions into the spaces between the epithelial cells.
- The sodium ions pull chloride and bicarbonate ions along with them to maintain electrical neutrality
- Then, all these ions together cause osmosis of water from the blood capillaries lying below into the same epithelial intercellular spaces; the resulting solution washes from the spaces of the ciliary processes into the anterior chamber of the eye. In addition, several nutrients are transported across the epithelium by active transport or facilitated diffusion, including amino acids, ascorbic acid, and glucose



Intraocular fluid and Intraocular pressure

- The average normal intraocular pressure is about 15 mm Hg, with a range from 12 to 20 mm Hg.
- At normal pressure intraocular pressure (Normally 15 mmHg with a range of 12-20 mmHg) when the rate fluid leaving the into anterior chamber of the eye eye through the canal of Schlemm (2.5 µl/min) equals the inflow from the ciliary body, thus maintaining constant intraocular pressure.

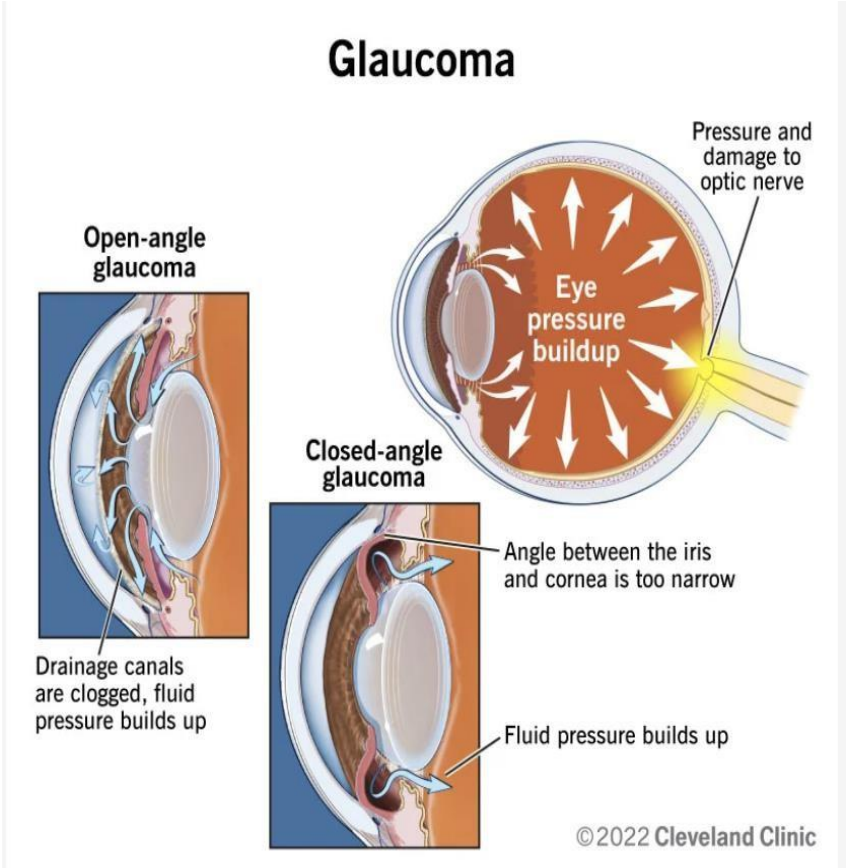
Intraocular fluid and Intraocular pressure

- The level of pressure is determined by the rate of formation and rate of drainage and resistance to outflow of aqueous humor in the canal of schlemm.
  - increase in intraocular pressure 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.

Glaucoma

- Glaucoma caused by abnormally high intraocular pressure (sometimes 60-70 mm Hg).
- The increase in intraocular pressure caused by
  - an increase in resistance to outflow of aqueous humor through a network of trabeculae in the canal of Schlemm (Open angel glaucoma)
  - Angle-closure glaucoma happens because your enlarged iris blocks fluid from draining properly in your eye
- It is a leading cause of blindness.
- Rising pressure compresses optic nerve axons at the optic disc, blocking axonal flow and leading to a lack of nutrition for fibers.
- Compression of retinal artery may also contribute to damage by reducing nutrition to the retina.

Glaucoma


Glaucoma
Open-angle glaucoma
Drainage canals are clogged, fluid pressure builds up
Pressure and damage to optic nerve
Eye pressure buildup
Closed-angle glaucoma
Angle between the iris and cornea is too narrow
Fluid pressure builds up
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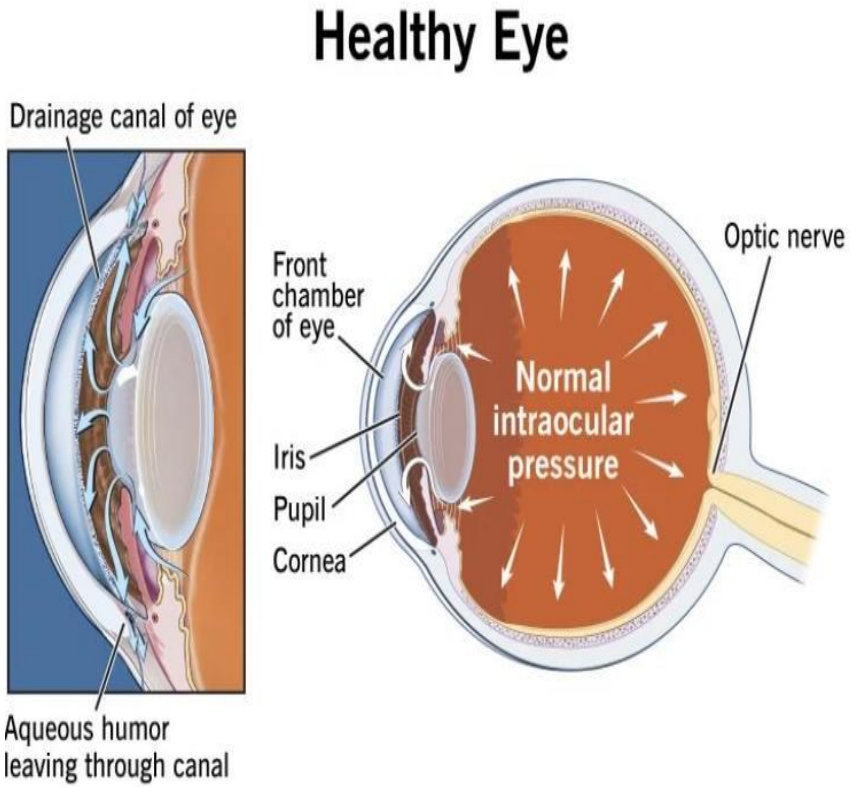
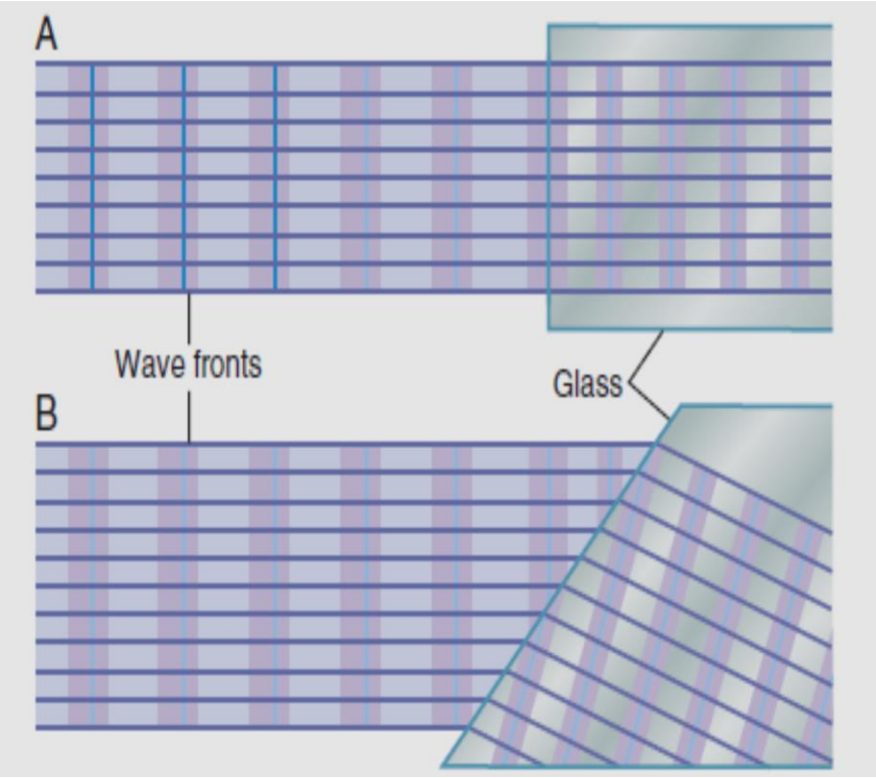

Healthy Eye
Drainage canal of eye
Aqueous humor leaving through canal
Front chamber of eye
Iris
Pupil
Cornea
Normal intraocular pressure
Optic nerve

Light Refraction

This bending of light rays at an angulated interface is known as *refraction. Figure B T*he degree of refraction increases as a function of the following:
(1) the ratio of the two refractive indices of the two transparent media; and

(2) the degree of angulation between the interface and the entering wave front.

Figure A When light rays hits a perpendicular transparent surface no refraction occurs . However , the velocity of light transmission and wavelength decreases



Refractive Index

- Speed of light in air 300,000 km/sec.
- Light speed decreases when it passes through a transparent substance.
- The refractive index is the ratio of the speed of light in air to the speed of light in the substance. If the speed of light in
- A substance is 200000 km/sec then the

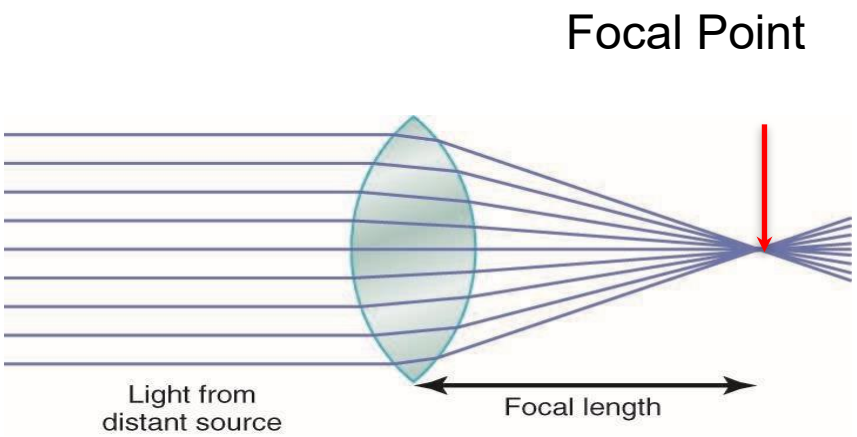
, R.I. = 300,000/200,000 = 1.5.

Light refraction

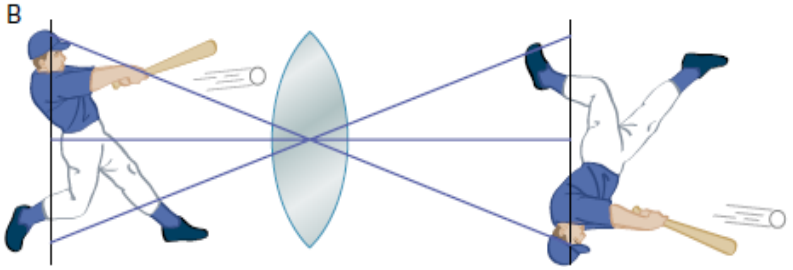
- Light rays are bent when they pass from a medium of one density into a medium of a different density, except when they strike perpendicular to the interface
- Parallel light rays striking a biconvex lens are refracted to a point **(focal point** or
- **principal focus** behind the lens.
- The focal point is on a line passing through the centers of curvature of the lens, the principal axis
- The distance between the lens and the principal focus is the focal length.
- Refractive power is greatest when the curvature of a lens is greatest.
- The refractive power of a lens is measured in **diopters,** the number of diopters being the reciprocal of the principal focal distance in meters. For example, a lens with a principal focal distance of 0.25 m has a refractive power of 1/0.25, or 4

Refractive Principles of a Lens

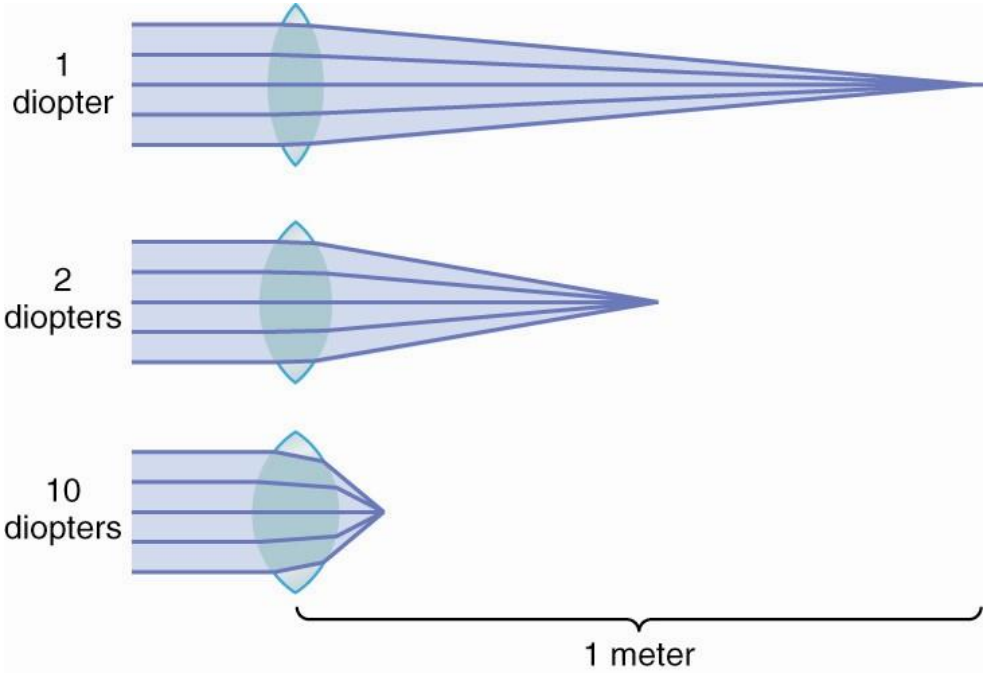
A biconvex lens, which is functionally similar to the eye's lens system, is flat only at its center. The curved surfaces of a biconvex lens will bend parallel light rays to focus an image of the object emitting the light a short distance behind the lens at its focal point.



Formation of an image by convex Lense



The Refractive Power of a Lens



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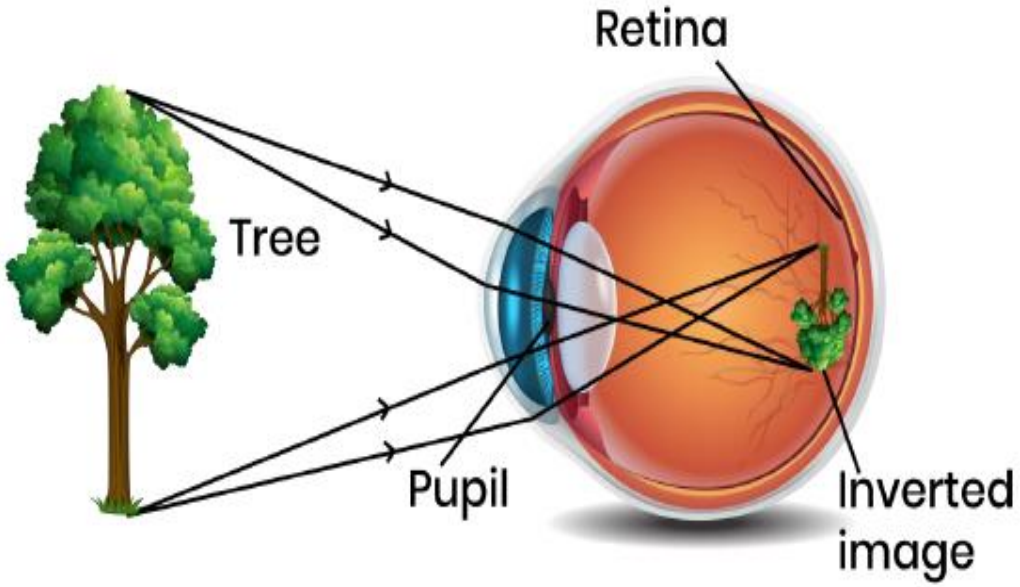
The lens of the eye

- Biconvex and elastic
- High percent of protein
- Avascular (nutrition mainly from the aqueous humor)
- Refracts light & helps to focus image of objects on retina.
- Supported by **suspensory ligaments**
- Suspensory ligaments from the lens are attached to **ciliary body**

Light refraction by the eye

- The features of the eye have different R.I. and cause light rays to bend, and these light rays are eventually focused on the retina.
- Anterior and posterior surfaces of cornea refract light , both surfaces of lens further refract light into exact focus on retina
- images are inverted (upside down) and reversed right to left
- The refractive power of a lens and the eye is measured in diopters
- The human eye has a refractive power of 60 diopters at rest.

Image formation by the eye



The function of the eye's transparent structures in front of the retina (i.e. cornea, lens) is to transmit and refract the light so it falls on the retina.

•An inverted image is focused by the **cornea** and **lens** onto the **retina**, with an aperture controlled by the **pupil**.

The eye as a camera

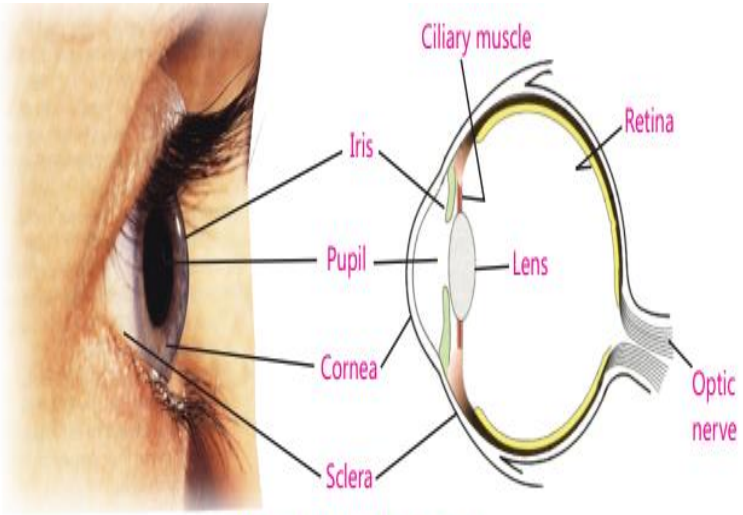
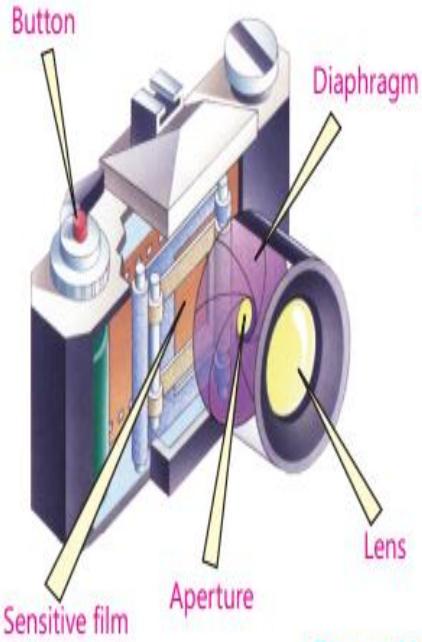


Figure 10.11: Human eye



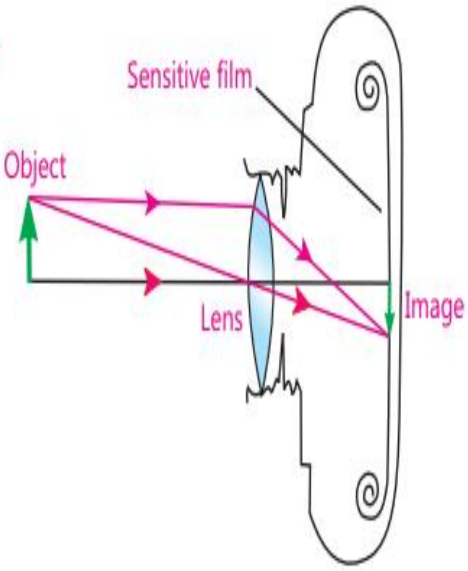
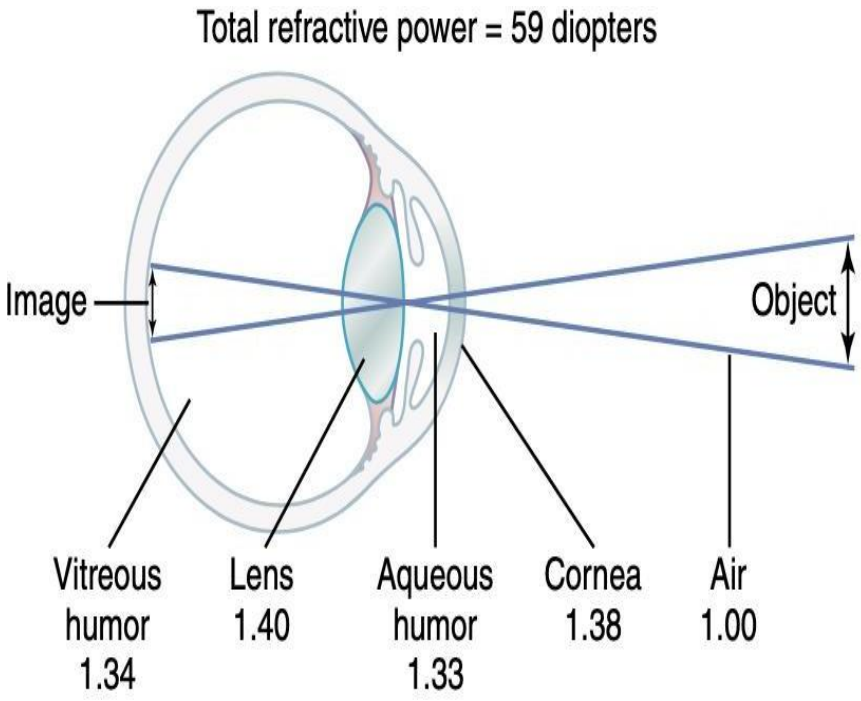


Figure 10.10: Image formation in camera

- Light
- Pupil (variable) aperture system)
- Lens system
- Retina (film)

Optics of the eye
Focusing Power of the Eye

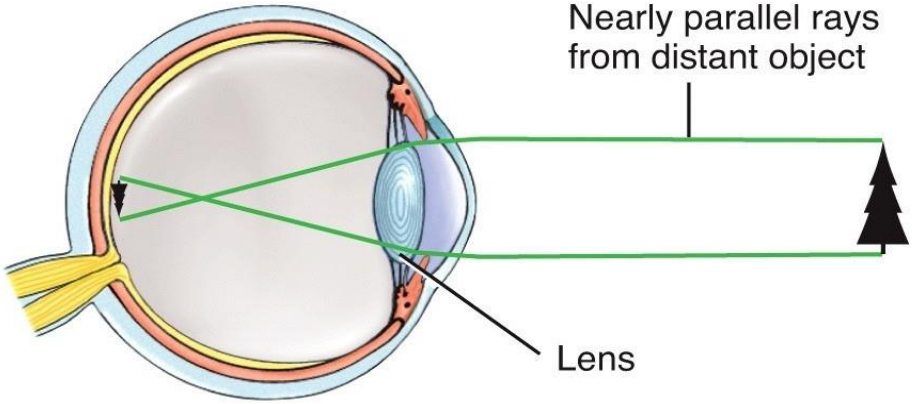
- Most of the refractive power of the eye results from the surface of the cornea.
- Total refractive power of the eye :the retina is considered to be 17 mm behind the refractive center of the eye.
- Therefore, the eye has a total refractive power of 59 diopters (1000/17).
- 4 refractive interfaces:
  - 2/3 refractive power is due to cornea (from cornea).
  - 1/3 refractive power from lens.
  - Refractive power can be changed by changing curvature of the Lense , process know as accommodation



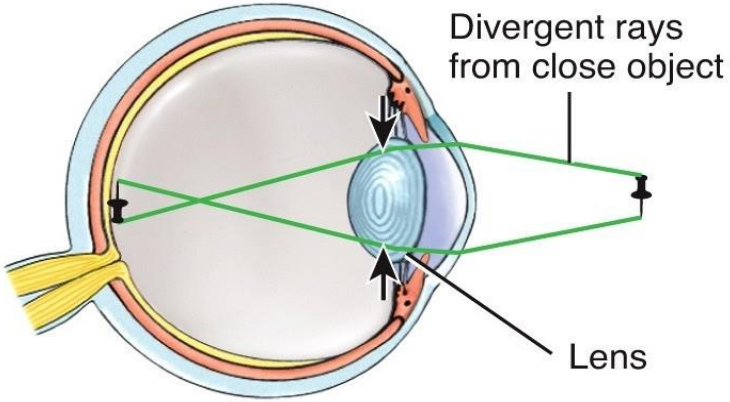
Vision: Light refraction by the eye and image formation at the retina

The normal (**emmetropic**) eye will refract light correctly and focus a clear image on the retina.
Images focused on the **retina** are **inverted and right-to-left reversed** due to refraction. The brain corrects the image.

- The **lens** must **accommodate** to properly focus the near objects object.
- The image is projected onto the **central fovea**, the site where vision is the sharpest.



(b) Viewing distant object



(c) Accommodation

Accommodation

- Accommodation : means the increases in the refractive power of the lens , and it is necessary for focusing objects on retina during near vision
- It is a dynamic changes in the refractive power of the lens, which is achieved by modifying the shape and convexity of the lens, to focus to focus the object, at different distances from the eye, clearly on the retina.
- If accommodation fails, the image appears blurry (not clear).
- It is done by changing the curvature of the lens.
- This is brought about by a combination of the **suspensory ligaments** or **zonule** and a circular **ciliary muscle**
- The refractive power of the lens is normally 20 diopters and can be increased by 34 diopters by changing shape of the lens - making it fatter(more convex) through the process of accommodation.

Accommodation

- accommodation is necessary to focus the image on the retina, specially during near vision
- The convexity of the Lense is controlled by tow opposing forces :
- **The internal elasticity of the lens,** which tends to keep the lens more convex A more curved lens refracts light to a greater degree.
- The force exerted by radially arranged **zonule fibers,** which **flatten** the lens when stretched. The zonule fibers are attached to the ciliary muscle

Mechanism of accommodation

- **Near objects:** Ciliary muscle contracts → Decreased tension on suspensory ligaments → Lens becomes more convex → Increased optical power → Image focused on the retina.
- •**Distant Objects:** Ciliary muscle relaxes → Increased tension on suspensory ligaments → Lens flattens → Reduced optical power → Image focused on retina.
- •Accommodation Is Controlled **by Parasympathetic Nerves**. The ciliary muscle is controlled almost entirely by parasympathetic nerve signals transmitted to the eye through the **third cranial nerve.**

Mechanism of Accommodation

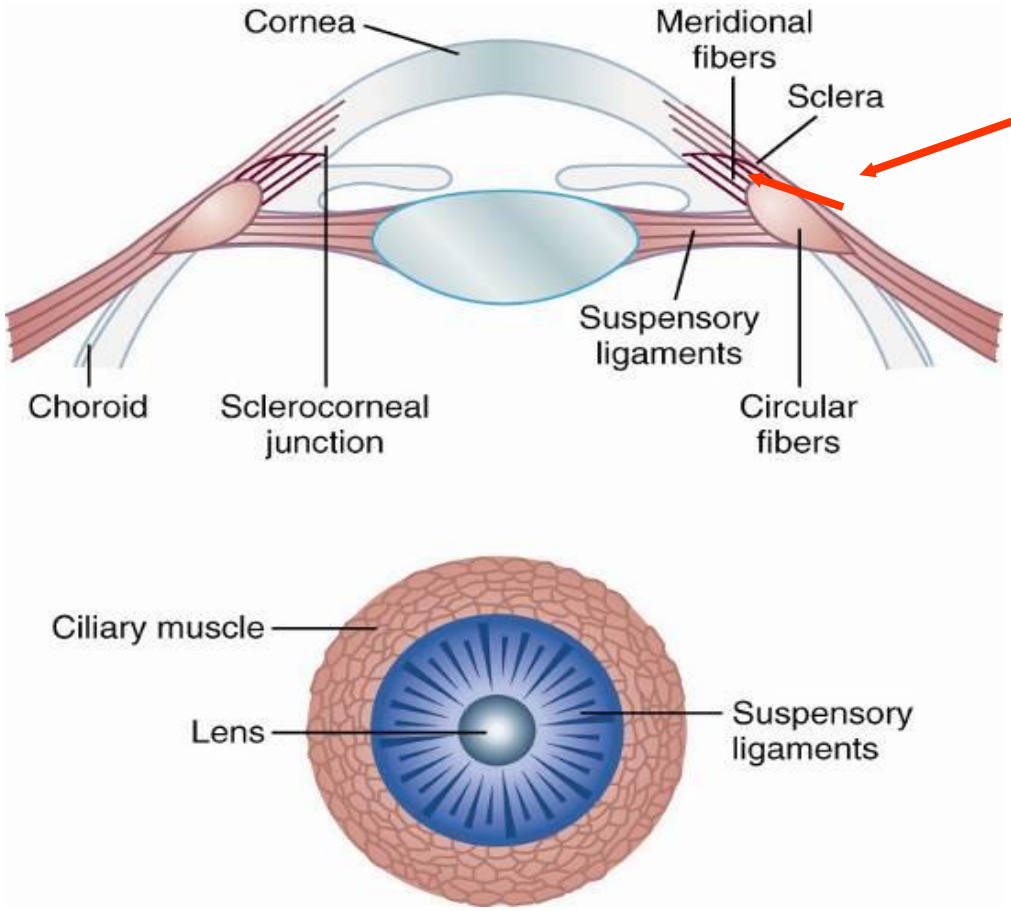


Figure 49-10

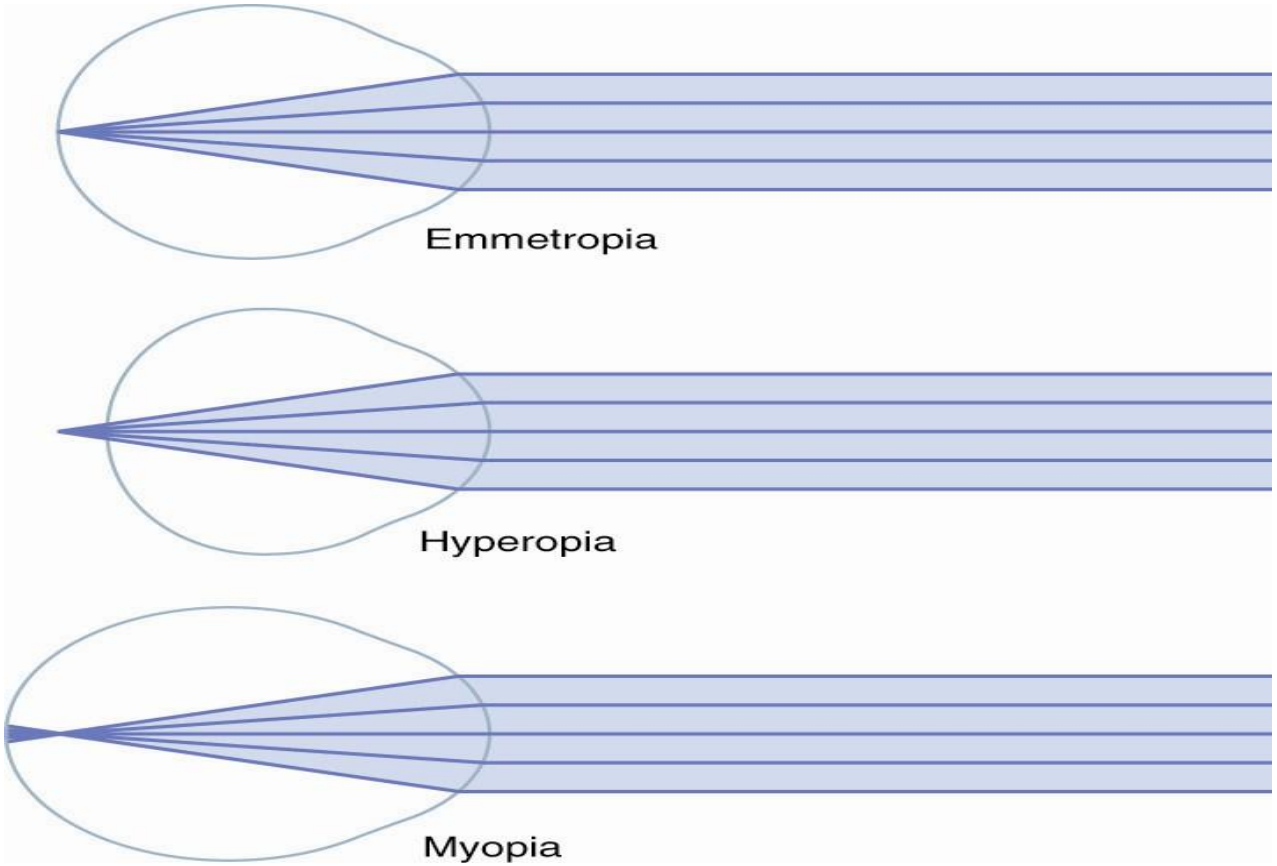
Contraction pulls ligament forward relaxing tension on suspensory ligament making the lens fatter

This occurs during accommodation for near object

Presbyopia

- **Presbyopia** is an irreversible loss of ability to accommodate. Most patients with presbyopia would experience trouble reading the fine print, blurring of near vision and asthenopia (eye strain).
- Presbyopia is a **very common** condition; the main cause of presbyopia is still not well understood. One of the suggested mechanisms is the age-related change of the lens, which **reduces** its intrinsic elasticity du to progressive denaturation of the proteins of the lens.
- Ciliary muscle dysfunction and loss of elasticity in the posterior zonules may also play a role in the development of presbyopia. makes the lens less elastic.
- begins about 40-50 years of age. It is important to remember these patients have reduced accommodation, but the rest of the near triad remains intact. (Normal convergence and normal pupil reflex)

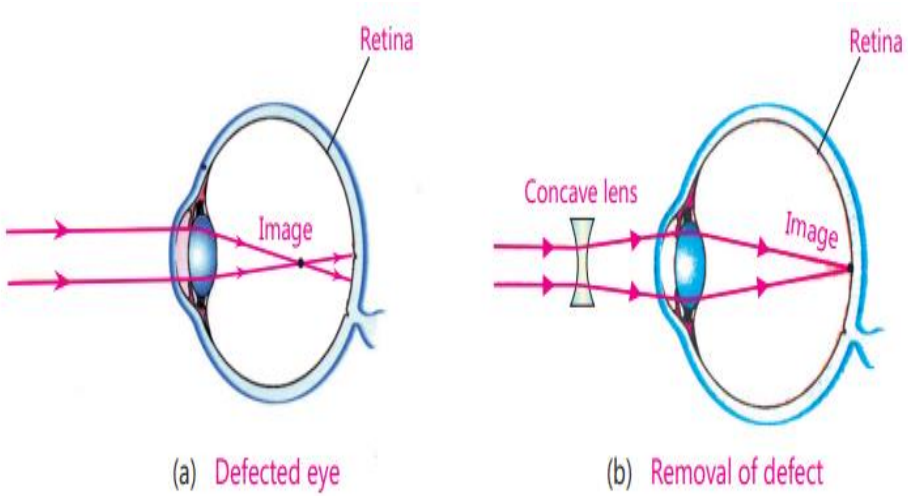
Errors of refraction



Myopia

Short-Sightedness (myopia)

- A person with this defect can see near objects clearly but distant objects appear blurred.
- This defect is caused when the eye lens becomes much thicker or eyeball becomes too
- long. The image of distant object is formed in front of the retina and not at the retina itself.
- This defect is also known as myopia and is corrected by using concave lens of suitable focal length.
- The concave lens diverges the light rays before they enter the eye and hence, the rays are refracted by the eye lens again to meet at the retina



Long-Sightedness (hyperopia)

A person having this defect can see distant objects clearly but near objects appear blurred. This defect is caused when the eye lens becomes thin or the eyeball becomes too

short.

Due to this effect the image of the near object is formed beyond the retina. That is why the near object appears blurred in long-sightedness. This defect is known as

hyperopia and is corrected by using suitable convex lens. The convex lens converges

light rays before they enter the eye. After entering the eye, they are further bent by the eye lens to meet at the retina

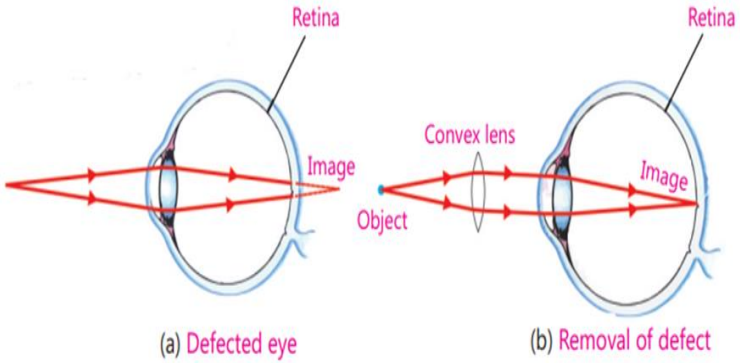


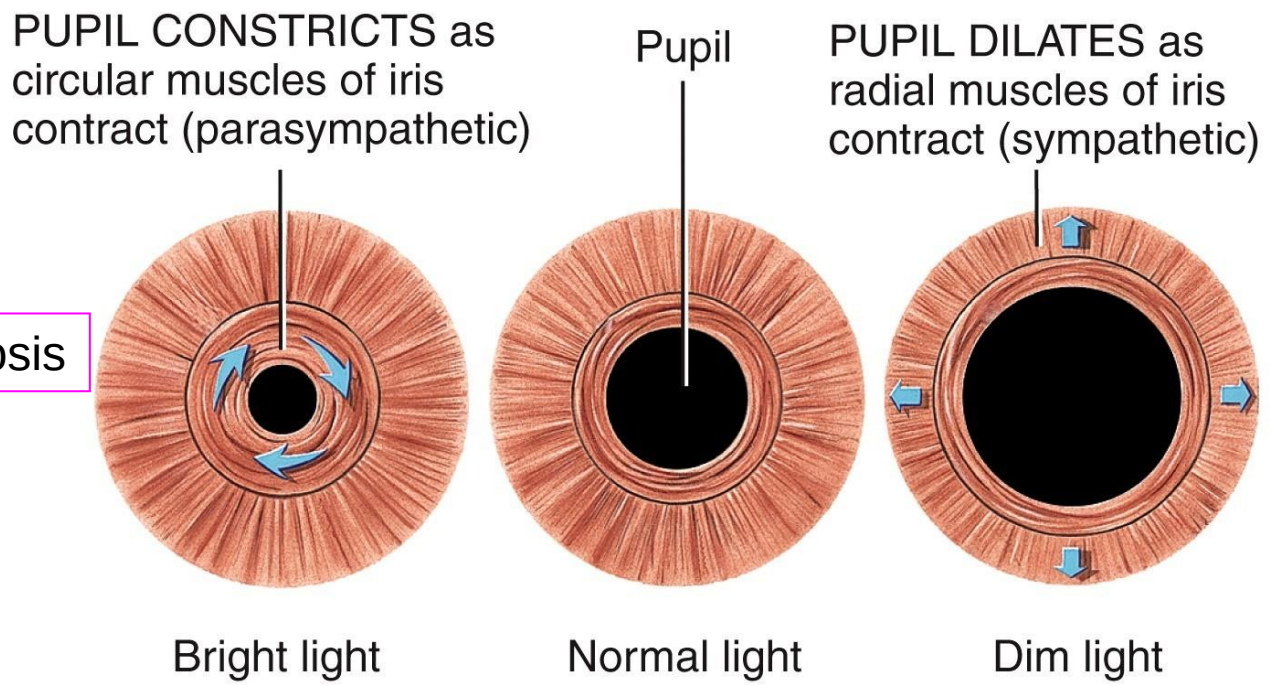
Figure 10.14: Correction of long-sightedness

Myopia

- Short-Sightedness (myopia) A person with this defect can see near objects clearly but distant objects appear blurred.
- This defect is caused when the eye lens becomes much thicker, or eyeball becomes too long. The image of distant object is formed in front of the retina and not at the retina itself.
- This defect is also known as myopia and is corrected by using concave lens of suitable focal length.
- The concave lens diverges the light rays before they enter the eye and hence, the rays are refracted by the eye lens again to meet at the retina

Pupil light reflex

The **iris** (colored portion of the eyeball) controls the size of the **pupil based on autonomic reflexes.**



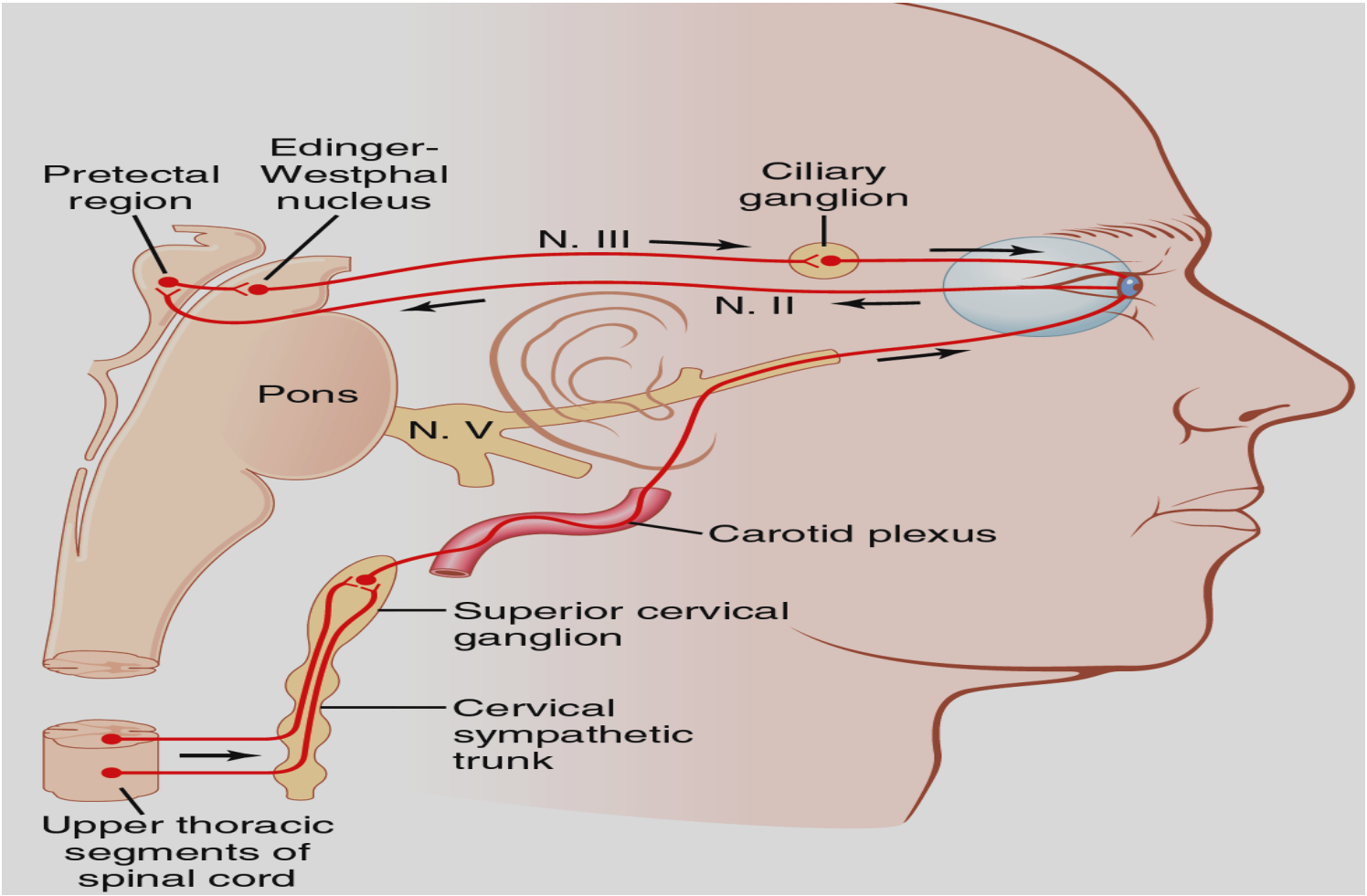
Myosis / Miosis

Mydriasis

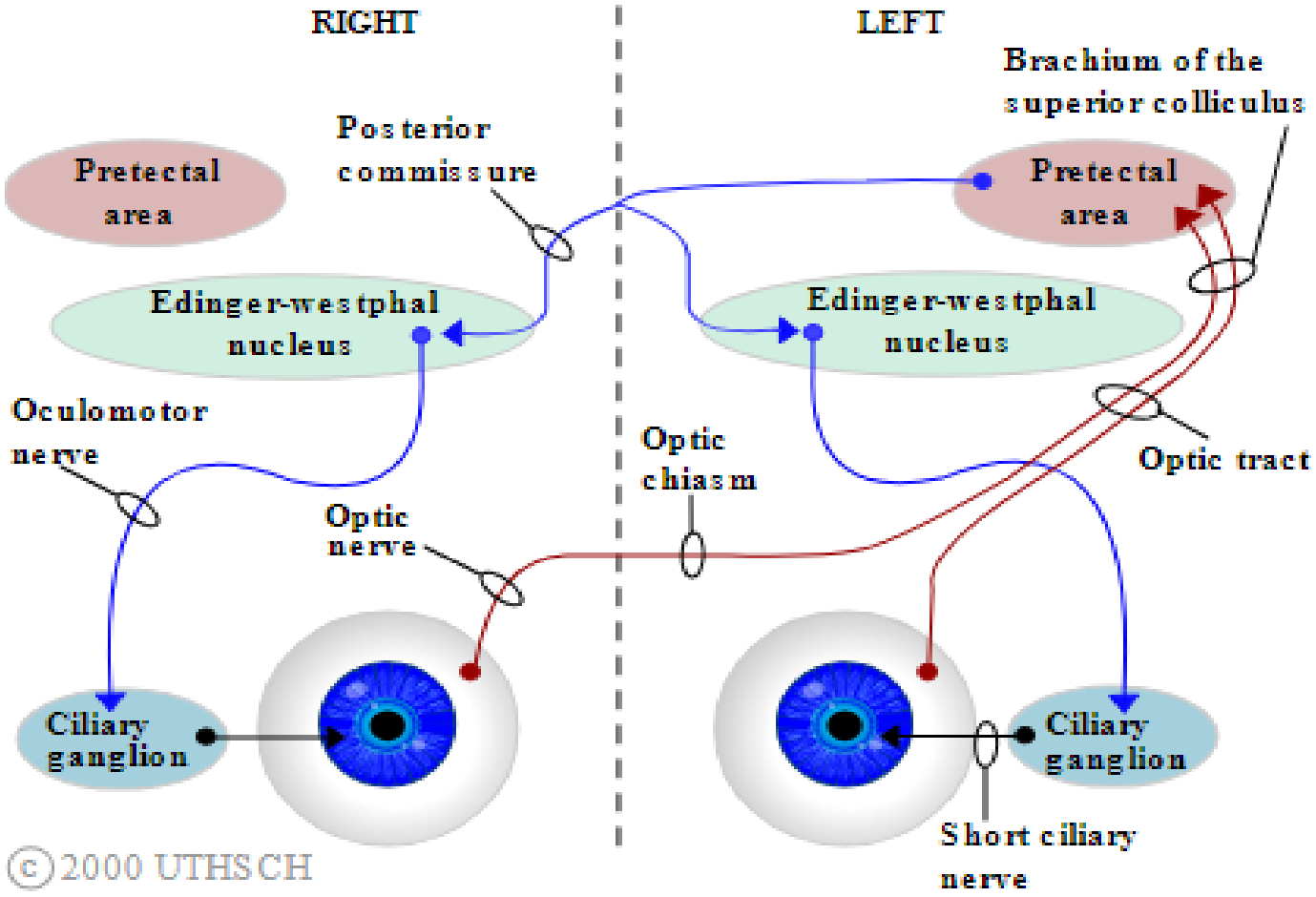
The pupillary light reflex

- The pupillary light reflex is an autonomic reflex that constricts the pupil in response to light, thereby adjusting the amount of light that reaches the retina.
- Can be observed by shining light into the pupil and during day light
- It also occurs during the near response when we look at close near objects
- Pupil constriction adjust the amount of light reaching the retina .The quantity of light entering eye can change about 30-fold as a result of changes in pupillary aperture (1.5-8 mm).
- Pupil constriction increases the depth of focus ((the range of distances from the eye that appear in focus).

Autonomic innervation of smooth muscles of the iris



Neuronal Circuit for pupil reflex

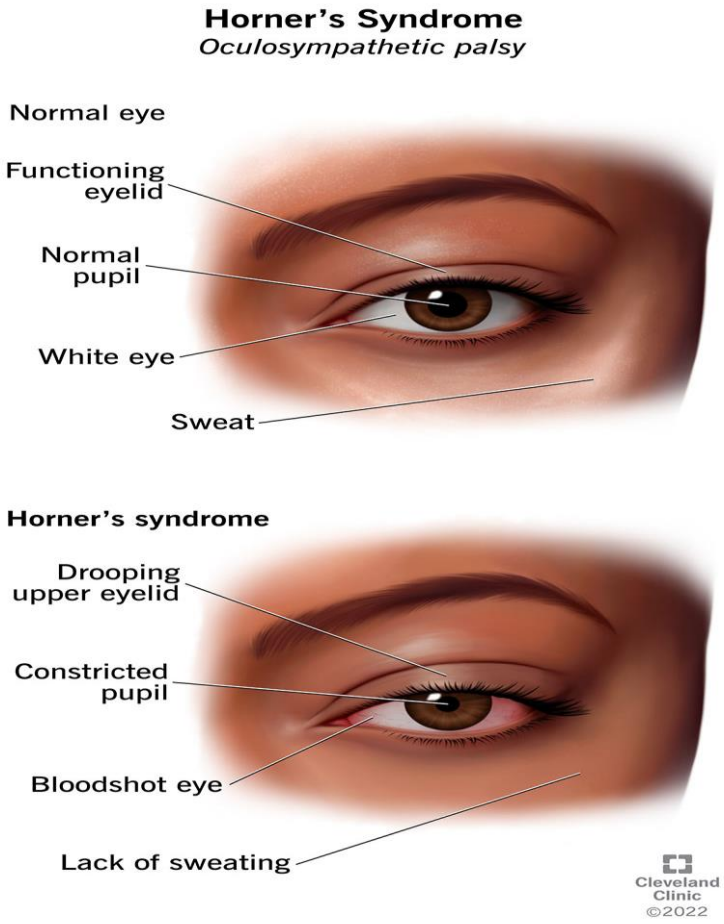


Neural pathway of pupil reflex

- **Pathway:** Afferent pupillary fibers start at the retinal ganglion cell layer and then travel through the optic nerve, optic chiasm, and optic tract, join the brachium of the superior colliculus, and travel to the pretectal area of the midbrain, which sends fibers bilaterally to the efferent Edinger-Westphal nuclei of the oculomotor complex.
- From the E-W nucleus, efferent pupillary parasympathetic preganglionic fibers travel on the oculomotor nerve to synapse in the ciliary ganglion, which sends parasympathetic postganglionic axons in the short ciliary nerve to innervate the iris sphincter smooth muscle via M3 muscarinic receptors[.
- Due to innervation of the bilateral E-W nuclei, a direct and consensual pupillary response is produced
- It is unusual, indeed, when the pupils are not the same size; the lack of a consensual pupillary light reflex is often taken as a sign of a serious neurological disorder involving the brain stem.

Horner syndrome

- Damage to sympathetic innervation of the face .
- Drooping of your upper eyelid (ptosis).
- Constricted pupil (miosis), resulting in mismatched sizes of your pupils.
- Decrease in sweating or lack of sweating on your face (anhidrosis).



Accommodation Reflex
Near accommodative triad

- **Accommodation reaction** – as the object moves closer to the eye, the refractive power of the eye needs to be increased for a clear image to be formed on the retina. This process involves a contraction of the ciliary muscle, which lessens the tension of the zonular fibres. Consequently, the intrinsic elasticity prevails and the curvature of the lens increases.
- **Convergence** – a simultaneous inward movement of both eyes towards each other. This movement is caused by the bilateral contraction of the medial recti. Convergence helps to maintain the focused image on each fovea and facilitates binocular vision.
- **Miosis** – a decrease in the diameter of the pupil. This is achieved by the contraction of the iris sphincter muscles to increase the depth of focus.

Accommodation Reflex
Near accommodative triad