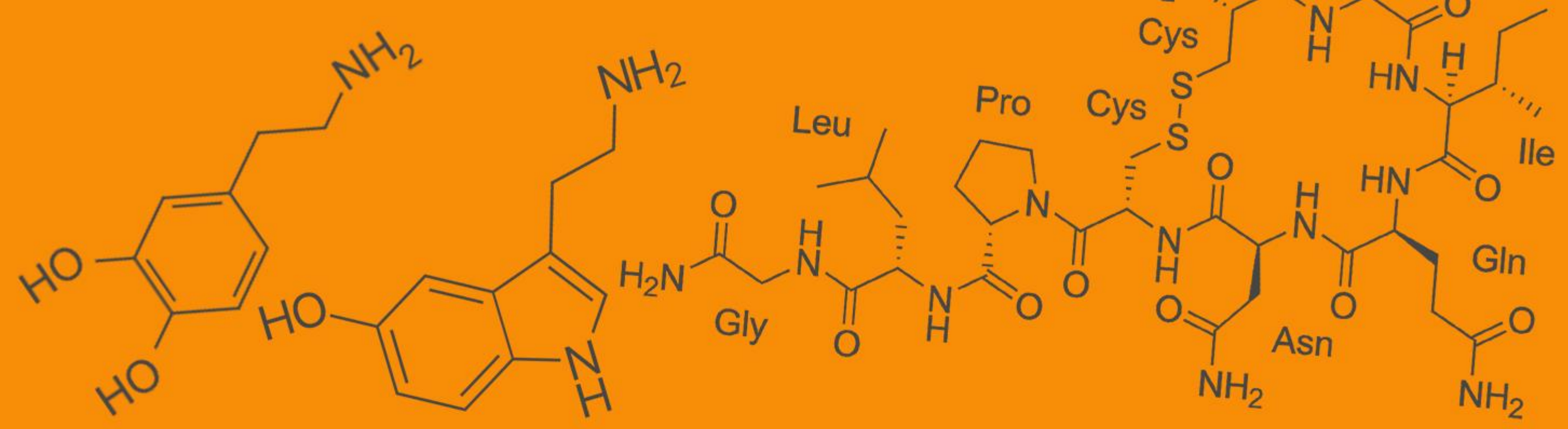


MEDICINE438's CNS PHYSIOLOGY

Lecture IX: Physiology of the Eye and Refraction

IMPORTANT | MALE SLIDES | EXTRA | FEMALE SLIDES | LECTURERS' NOTES

1 PHYSIOLOGY OF THE EYE AND REFRACTION

Lecture Nine

OBJECTIVES

- Describe different components of the eye and the function of each & understand the eye's protection media.
- Describe the refraction of light as it passes through the eye to the retina.
- Identifying the refractive media of the eye.
- Know fluid system of eye & glaucoma.
- Know binocular vision.
- Know layers of retina, blind spot, and fovea centralis.
- Explain the different light sensitivities of the fovea, peripheral retina and optic disk.
- Know principles of optics and errors of refraction.
- Light pathway in the eye.

Introduction

- Human vision is one of the most complex visual systems among animals.
- The eye is a complex sensory organ, which capable of transduction physical stimuli of light rays into electrical and chemical signals that can be interpreted by the brain to construct physical images.

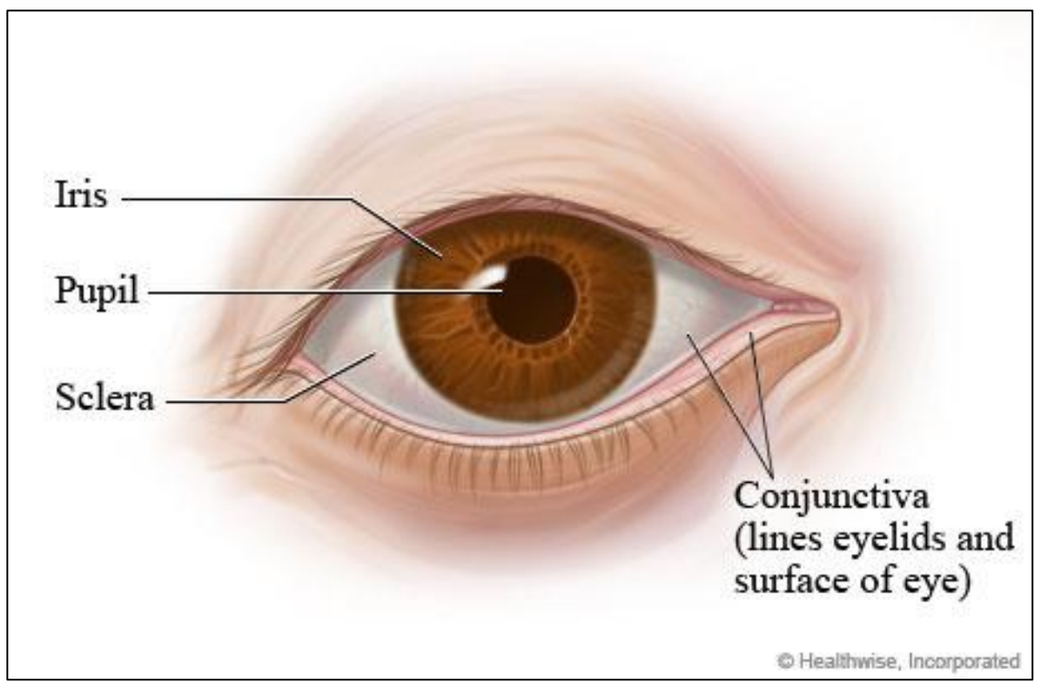


Figure 9-1

EYE HAS (1) Refracting Media. (2) Coats (Sclera, Choroid and Retina)

The Eye Is A Fluid-filled Sphere Enclosed By Three Specialized Tissue Layers

The Choroid
(the middle layer containing blood vessels)

The Sclera
(a tough outer covering of connective tissue)

The Retina
(the innermost layer which contains light sensitive cells)

OUTER FIBROUS LAYER

Sclera (thick ,white fibrous tissue for protection- spherical appearance)

Cornea The transparent anterior portion.

- (Modified anterior 1/6th of sclera) to allow light to enter the eyes, transparent , avascular.
- Nutrition is provided by aqueous humor and tears.

Conjunctiva

- Transparent membrane cover anterior surface of eye, reflected on inner surface of eyelids
- Covered with thin film of tears for protection, wetness, cleaning.

MIDDLE VASCULAR LAYER

Iris

- It is the colored part of the eye.
- Has aperture (pupil) to control and allow light to enter the eye.
- Has radial muscle dilates the pupil as in dim light (supplied by sympathetic)anand constrictor pupillae (circular muscles constrict the pupil (by parasympathetic), as in bright light.

Pupil Behind center of cornea, control & allow light to enter the eye, appears black because, as you look through the lens, you see the heavily pigmented back of the eye (choroid and retina)

Ciliary Body

Consist of:

- Ciliary Muscles
- Ciliary Glands
- Suspensory ligaments which are attached to the lens
- Thick anterior part of choroid to which attached suspensory ligaments (zonule) and is attached to lens.

Choroid Highly vascular structure.

- Outermost layer of retina depends mostly on diffusion from choroid blood vessels for nutrients, especially oxygen.
- Inside sclera
- The capillaries in the choroid are the primary source of nourishment for retinal photoreceptors & oxygen to rods and cones
- Posterior 2/3 of choroid has retina
- (innermost layer lining)

INNER NEURAL PART (RETINA)

Outer Pigmented Part

Inner Neural Part Containing

1. Photoreceptors

A. Rods

Are best for vision in dim light (scotopic vision) , are better for detection of flicker (sudden movement of objects)

B. Cons

Are best for vision in daylight or bright light. Color vision (color perception) Perception of detail (acuity of vision)

2. Optic Disc 3mm medial & above post pole of eye- optic nerve leave & retinal blood vessels enter. no photoreceptors so it is blind spot)

3. Fovea Centralis Depression or spot inside macula lutea, yellow pigmented at post pole of eye. Contains only cones, high visual acuity for colors vision & details detection.

EXTERNAL PROTECTION OF THE EYE

1. Bony orbit
2. Lids and eyelashes, blinking keep cornea moist
3. Conjunctiva:
   - Lines the eyelids and covers the sclera.
   - It is a transparent epithelium covered with mucus and tear and prevent entrance of microbes and dust into the eye.
4. Tears from lacrimal gland has:

- Antibacterial, lubricating effect
- Keep cornea moist & clear & provide nutrition to the cornea)

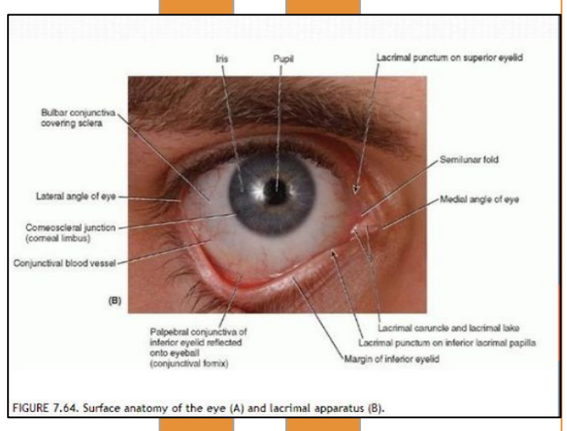


FIGURE 7.64. Surface anatomy of the eye (A) and lacrimal apparatus (B).

Figure 9-2

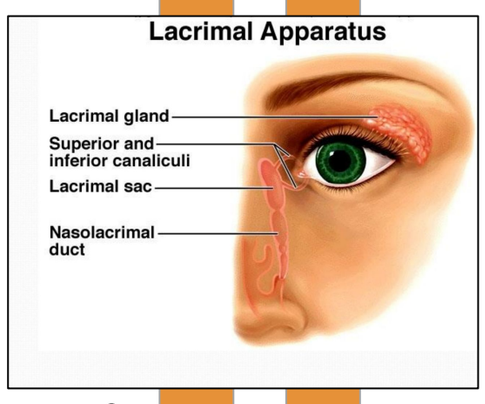


Figure 9-3

The Papillary Muscles

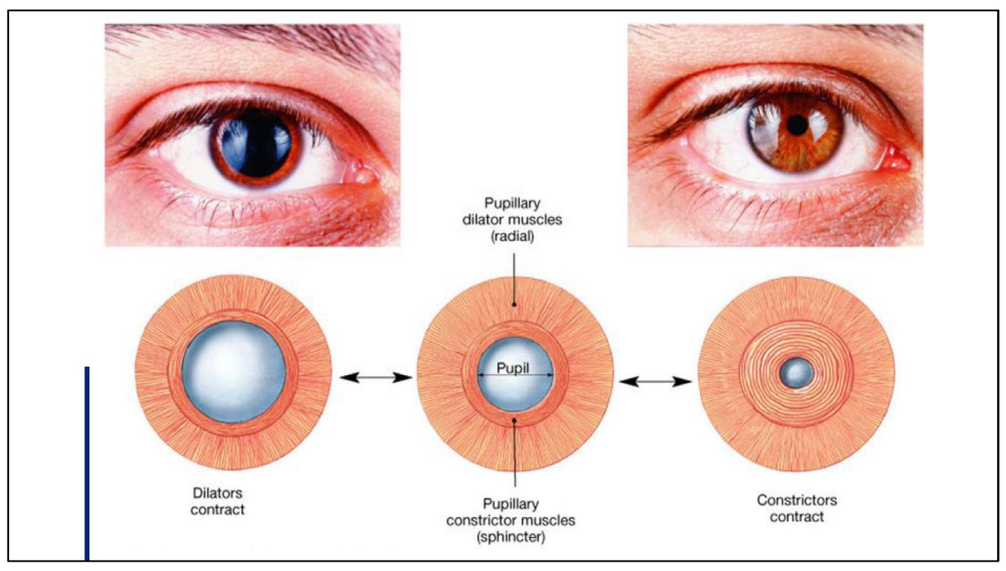


Figure 9-4
The Papillary Muscles: consists of radial and circular parts.

The Lens

Transparent, biconvex, semisolid, dioptric power 15-20 D.

- Held in place by zonule also called lens ligament or suspensory ligament
- Attached to anterior part of ciliary body
- Within the cells of the lens, proteins called crystallins are arranged like the layers of an onion,this makes up the refractive media of the lens.
- Lens helps focus images on the retina to facilitate clear vision.

Uvea = choroid + iris + cilliary muscles

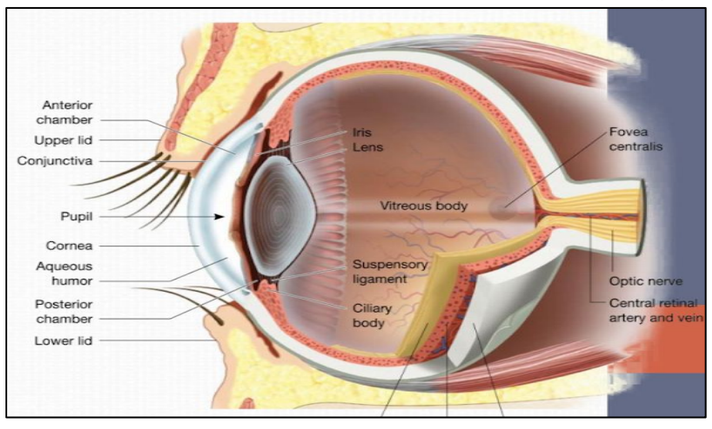


Figure 9-5

The Anterior & Posterior Cavities

The Ciliary Body (& its suspensory ligament) and lens divide the eye into:

Anterior Cavity

- Which contains a fluid called Aqueous Humor.
  The anterior cavity is further divided into:
- Anterior chamber (in front of the iris)(between the iris and cornea)
- Posterior chamber (behind the iris; between the iris and lens)(between the iris and ciliary muscles)

Posterior Cavity

- Which contains vitreous Humor.

Lenses and Principles of Optics

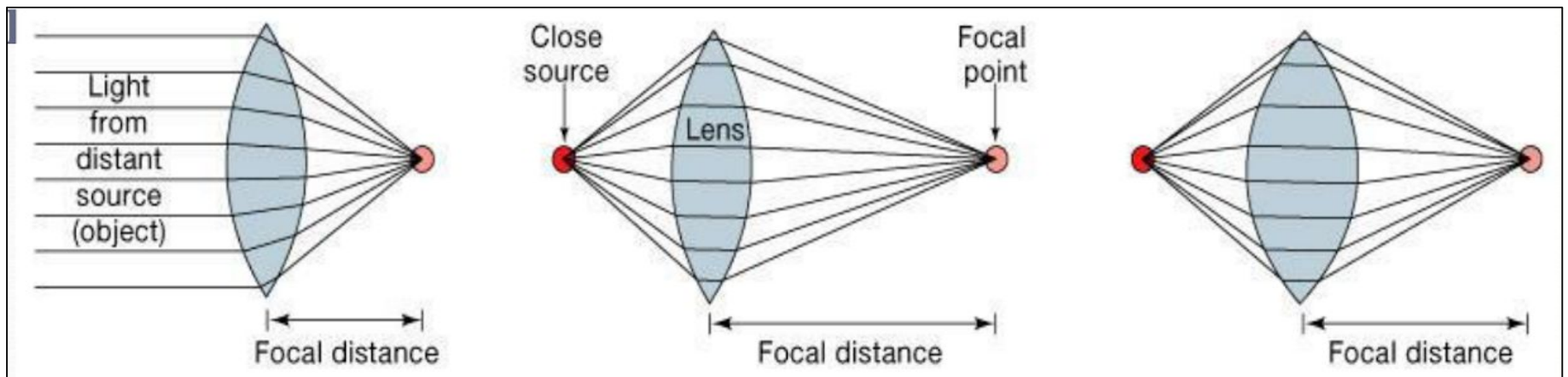


Figure 9-6 Showing the image forming mechanisms.

Principle Focus

Parallel rays strike biconvex lens are refracted in a point called PF.

Principle Axis

PF lies on line pass through centers of lens Curvatures.

Principal Focal Distance

Distance between lens & PF

- Biconvex lens (converge) & biconcave lens (diverge)
- Diopter (measure of refractive power)

Refractive Power = 1 / **Principal focal distance.**

Example: If Principal focal distance of a lens is 25cm, so its R.P =1 /0.25 meter = **4D**

- *The greater the curvature of the lens, the greater the refractive power of the eye*

Emmetropic eye: *is the normal eye has image on retina, has diopteric power 59-60D*

- *It can see all distant objects clearly with its ciliary muscle relaxed & see close objects clearly with ciliary muscles contracted.*
- Normal eye: Emmetropia
- Concave lenses "neutralize" the refractive power of convex lenses.
- Thus, placing a -1 diopter concave lens immediately in front of a 1 diopter convex lens results in a lens system with zero refractive power.

Lens-retina distance = 15mm, 17mm

Dioptre (s) = 1 / Focal length (in meters)

Dioptric Power Of The Eye

- Cornea: 40-45 D
- Lens: 15-20 D
- Accomodation by lens .... +12 D

BOX 9-1: GUYTON AND HALL & QUANTUM ELECTRODYNAMICS

REFRACTIVE INDEX

Light rays travel in air at a velocity of 300,000 km/s, however they travel much slower through transparent solids and liquids (note that the velocity of light is constant in all mediums, and for every observer, however in a medium photons (the particles of light) get scattered by electrons present within the dense medium, the greater the curvature, the greater the scattering and the greater is the refractive index and power).

- The refractive index of a transparent substance is the ratio of velocity of light in the air to the velocity of light in the substance (the scattering of light). Hence, the refractive index of air itself is 1.00, and if light travels through a particular type of glass at 200,000 km/s then the refractive index is 300,000/200,000 which would be equal to 1.5.
- The focal distance can be calculated by the following equation: 1/f = 1/i + 1/o, in which i is the distance of image from the lens, and o is the object distance from the lens.

The Refractive Media of the Eye

1. The interface between air and the anterior surface of the cornea,
2. The interface between the posterior surface of the cornea and the aqueous humor,
3. The interface between the aqueous humor and the anterior surface of the lens of the eye,
4. The interface between the posterior surface of the lens and the vitreous humor.

A total refractive power of 59 diopters when the lens is accommodated for distant.

The internal index of refraction of air itself is 1 (refer to BOX 9-1)

- The Cornea: 1.38
- The Aqueous Humor: 1.33
- The Crystalline Lens: 1.40
- The Vitreous Humor: 1.34.

The Cornea

- Its dioptric power is 40-45 diopter at its anterior surface.

About two thirds of the 59 diopters of refractive power of the eye is provided by the anterior surface of the cornea.

- The principal reason for this is that the refractive index of the cornea is markedly different from that of air.

The Lens

- Has dioptric power 15-20 D -(1/3 refractive power of eye), more mportant than the cornea.
- The reason being that In response to nervous signals from the brain, its curvature can be increased markedly to provide "accommodation,

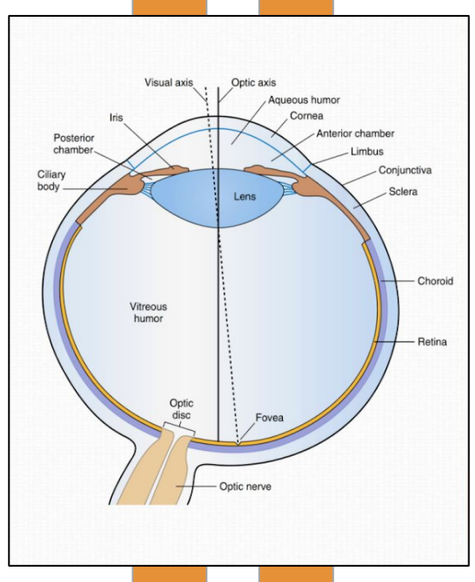


Figure 9-7

Aqueous Humor

Fluid produced by ciliary body (ciliary processes) to posterior chamber to pupil to anterior chamber to canal of schlemm at angle of anterior chamber to veins.

- The aqueous humour is a transparent, slightly gelatinous (gel-like) fluid similar to Plasma
  - Obstruction of this outlet leads to increased intraocular pressure, a critical risk factor for glaucoma
- Nourishing avascular structures (cornea ,lens)
- Causes intraocular pressure 10-20mm Hg

Produced at a rate of 2-3 microliter/min by active transport of NA+, followed by Cl- and HCO3- and then osmosis of water and contains many nutrients like amino acids , ascorbic acids (vitamin C) and glucose.

Vitreous Humor

- Is the transparent, colourless, gelatinous mass .
- Fills the vitreous chamber between the posterior surface of lens and the retina

(for nourishing retina & keep spheroid shape of the eye)

- The vitreous humour is clear and

allows light to pass through.

- It remains from birth. Both water and dissolved substances can diffuse slowly in the vitreous humors.

Figure 9-8

Glaucoma

What is glaucoma?
(intraocular pressure more than 20mm Hg)

- Obstruction of Aquous humor outlet leads to increased intraocular pressure. Pushes the lens backwards into vitreous,

which pushes against the retina.

- Compression causes retinal and optic nerve

damage that can cause blindness

- Without treatment, glaucoma can cause blindness within a few years.
- Glaucoma is most often inherited, meaning it is passed from parents to children.
- Less common causes of glaucoma include a blunt or chemical injury

to the eye, severe eye infection, blockage of blood vessels in the eye and inflammatory conditions of the eye.

Glaucoma usually occurs in both eyes, but it may involve each eye to a different extent.

Cataracts

- Lens clouds up and must be removed.
- Typical to replace lens with implant
- Can get clouding repeated
- Laser removal

Cataracts" occurs in older people. is a cloudy or opaque area or areas in the lens

- The proteins in some lens fibers coagulate to form opaque areas .
- Cataract impairs vision

Retinopathy In Diabetes

Vessels have weak walls – causes hemorrhaging and blindness.

Binocular Vision

Are the areas in the centre of visual field of the two eyes in which any object in this a will be seen by both eyes, and the benefits of it are:

1. Large visual field.
2. cancel the effect of blind spot.
3. Stereoscopic vision.
4. One eye lesion does not affect vision.

Monocular and binocular visual fields, (Figure 9-7) The dashed line encloses the visual field of the left eye and the solid line, that of the right eye. The common area (heart-shaped in the center) is viewed with binocular vision. The colored areas are viewed with monocular vision.

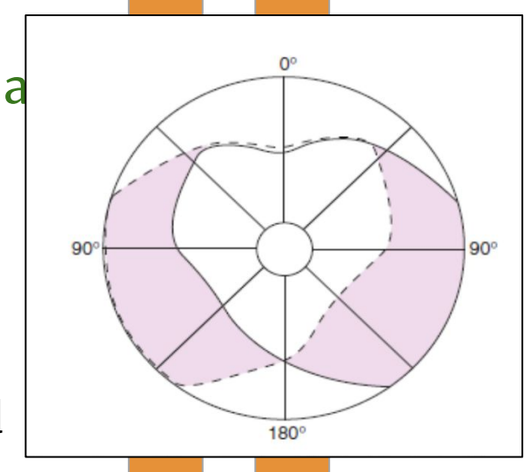
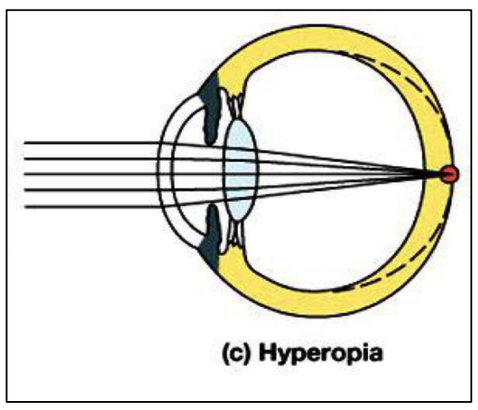
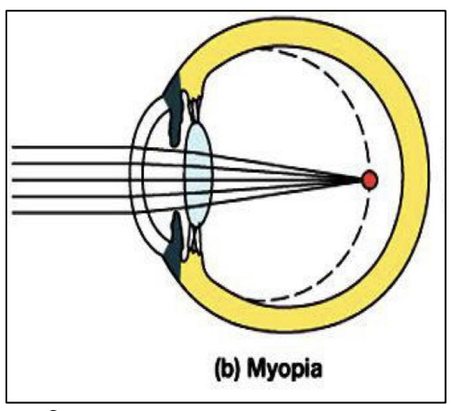
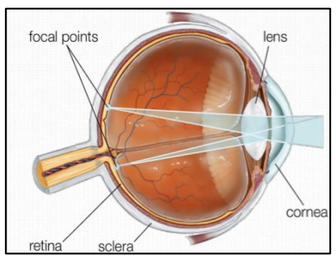


Figure 9-9

Errors Of Refraction

NAME	DESCRIPTION	CORRECTION
Hyperopia (Farsightedness)  **Figure 9-10**	• Small eye ball with weak lens system. • Focus is behind retina. • Causes headache and blurred vision. • Continuous accomodation to bring image on retina causes muscular effort on ciliary muscles & prolonged convergence, which will lead to headache and finally squint. • An affected individual has to use accommodation even for distant objects. Causes hypertrophy of ciliary muscles.	Biconvex lens
Myopia (Nearsightedness)  **Figure 9-11**	• Genetically large eyeball or too much R.P (refractive power) of the lens system or cornea due to its curved surface , or due to long anterior-posterior diameter of the eye. • However, there is a positive correlation between sleeping in a lighted room before the age of 2 and the subsequent development of myopia. • In young adults the extensive close work involved in activities such as studying accelerates the development of myopia • Focus will be IN FRONT of the retina.	Biconcave lens To diverge rays before strike the lens
Astigmatism  **Figure 9-12**	• Mainly due to Uneven and Nonuniform corneal curvature and very little due to uneven lens curvature, so rays refracted to different foci resulting in blurred vision.	Cylindrical lens Bends light rays in only one plane (a focal line)
Presbyopia	Eye near point recedes by age due to loss of accommodation. Focus behind retina.	Biconvex lens

Light Pathway in The Eye

1. After the light passes through the lens system of the eye and then through the vitreous humor , it enters the retina from inside the eye.
2. It then first passes through the ganglion cells and then through the plexiform and nuclear layers before it finally reaches the the layers of rods and cones located all the way on the outer ridge of the retina.
3. Then impulses pass from the rods and cones the rest of the layersinally to the ganglion cell layer and then to the Optic nerve.
4. Light absorbed by the pigment cell layer which contains Melanin pigment leads The visual acuity to be decreased by this passage through Non-homogenous tissue .However in the Central foveal region of the retina , the inside layers are pulled aside to decreases the loss of acuity . This allows light to pass unimpeded to the cones.

Layers of Retina

- There are five basic classes of neurons in the retina: (1) Photoreceptors, (2) bipolar cells, (3) horizontal cells, (4) amacrine cells, (5) ganglion cells.

- Retina is divided into 10 layers, the most important are :

LAYER	SIGNIFICANCE
1. Pigment Cell Layer (BOX 9-2)	- Vitamin A, outermost layer. - Absorb light & prevent its reflection back. - The pigment layer also stores large quantities of vitamin A an important precursor of the photosensitive chemicals of the rods and cones.
2. Photoreceptor Layer (Rods And Cones)	- Their outer & inner segments), but not cell bodies - Rodes 90-120 million & cones 4.5- 6 million. - Photoreceptor cells are responsible for capturing light and transforming this into generator potential to be used by the nervous system.
3. Outer Nuclear Layer	Cell bodies of rods and cones.
4. Outer Plexiform Layer	Mainly of horizontal cells. - Make synaptic connections with receptors
5. Inner Nuclear Layer	Bipolar cells
6. Inner Plexiform Layer	Amacrine cells interposed between the inner nuclear and ganglion cell layers. - Make synaptic connections with ganglion cells
7. Ganglion Cell Layer	- Large multipolar neurons, axons of which form the optic nerve.
8. Optic Nerve Fiber Layer	- 1.2 million fibers -Horizontal cells (outer plexiform layer) (Make synaptic connections with receptors) - Amacrine cells (inner plexiform layer) (make synaptic connections with ganglion cells)

MULLER CELLS are the major glial element of the retina. Located in the inner nuclear layer.

- providing metabolic support to retina
- Maintaining synaptic levels of neurotransmitters
- Act as a light conductor.

BOX 9-2: GUYTON AND HAL

Significance of Melanin and Visual Acuity

- Melanin prevents light reflection throughout the eyeball, this is important for clear vision.
- The importance of melanin was well illustrated in albino patients (albinism is characterized by absence of melanin), when an albino person enters a bright room light is reflected in all directions inside the eyeball, so that a discrete spot of light that would normally excite few receptors is reflected everywhere and excite numerous receptors. Therefore the visual acuity of albino patients is markedly decreased.
- Note that for visual acuity the emphasis is to have receptor stimulation of discrete small points in the retina, this leaves the adjacent parts of the retina less stimulated (the receptor potential in rods and cones is not an action potential, which means they can be gradually stimulated based on the strength of the stimulus and not follow the all-or-none rule) , thus a person can perceive the difference in stimulation as different details.

Three Types of Retinal Ganglion Cells and Their Respective Fields (BOX 9-3)

1. W cells:

40% with small diameter.

- Sensitive or detecting directional movement in the field of vision, and they are probably important for much of our rod vision under dark.
- Guyton and Hall:

2. X Cells

55% has a medium sized diameter

Transmission of the Visual Image and Color Vision

3. Y Cells

5% only with large diameter

To Transmit Instantaneous & rapid Changes in the Visual Image, either rapid movement or rapid change in light intensity.

BOX 9-3: GUYTON AND HAL

Retinal Ganglion Cells

- W Cells: These cells have wide dendritic distribution along the retina, thus they are efficient in detecting the shift of focus in the visual field.
- X Cells: Their dendritic fields do not distribute widely within the retina, therefore they transmit signals from discrete, small areas of the retina. Consequently, it is mainly through X Cells that details regarding visual acuity and color are transmitted. Each X Cell receive input from at least one cone, therefore it is most probably responsible for transmitting all color vision.
- Y Cells: Much like W cells these cells have wide dendritic distribution along the retina, Y and W cells make synaptic connections with the superior colliculus and mediate their functions through transmitting information about rapid changes in the visual field.

QUIZ

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1. Which of the following statements is correct regarding retinal ganglion cells?

A) X cells have the fastest conduction rate, and mediate visual acuity.
B) Y cells have a moderate conduction rate, and mediate color vision.
C) W cells have wide dendritic distributions along the retina, which help mediate their functions in detecting directional movements.
D) None of the above

2. Hyperopia can be corrected by:

A) Cylindrical lens
B) Biconcave lens
C) Biconvex lens
D) Eye removal

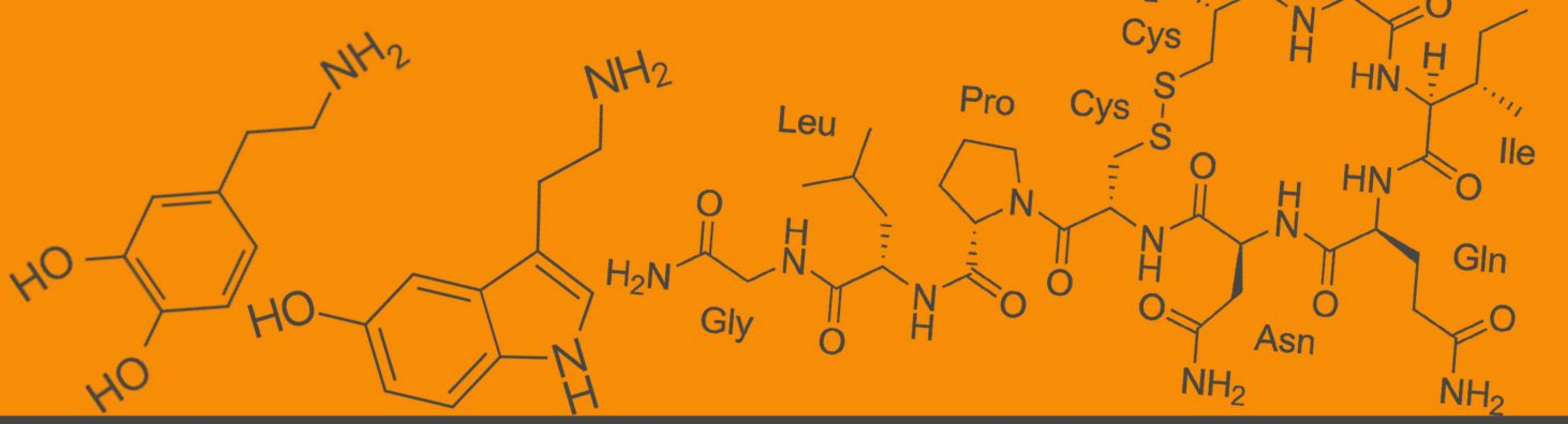
3. Presbyopia usually occurs due to:

A) Lens become less elastic in old age
B) Lens become spherical in old age
C) Loss of blind spot
D) None of the above

4. If an object was 4 cm away from a biconvex lens, and an image was formed 5 cm away from the lens. Calculate the dioptric power of the lens:

A) 45 diopters
B) 2.22 diopters
C) 30 diopters
D) 80 diopters

ANSWER KEY: C, C, A, A



THIS LECTURE WAS DONE BY

Abdulrahman Alsayyed, Nayef Alsaber,
Hameed M. Humaid

FEMALE PHYSIOLOGY CO-LEADERS
Maha Alnahdi, Ghaliah Alnufaei

MALE PHYSIOLOGY CO-LEADERS
Nayef Alsaber, Hameed M. Humaid

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