Physiology 435 team

PHYSIOLOGY OF THE EYE

Objectives:

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

Done by:

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Color index: Important - Further explanation - Doctors Notes - Numbers.

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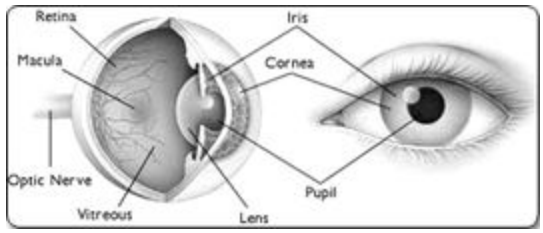
*Please check out this link before viewing the file to know if there are any additions or changes.

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.

❖ **The eye is:** a **fluid-filled** sphere enclosed by three specialized tissue layers, which are:

1. **The sclera:** which is a tough outer covering of **connective tissue**.
2. **The choroid:** the middle layer, containing **blood vessels**.

Why is it highly vascular ? because the capillaries in the choroid are the primary source of nourishment for retinal photoreceptors & oxygen to rods and cones.

3. **The retina:** is the innermost layer which contains **light sensitive cells** (located in the post 2/3 of choroid).

❖ **Functions of vision:**

1. **Discriminates between light & dark.**
2. **Detects movement.**
3. **Detects color (Adaptive value of color vision).**

Anatomy of the eye:

To refresh: Anatomy of the eye (11:24)

1. Sclera- الصلبة العينية:

- Thick, white fibrous tissue for protection-spherical appearance.
- **Choroides:**
  - Inside sclera, **highly vascular!**
  - Its capillaries are the primary source of nourishment for retinal photoreceptors and oxygen to rods and cons.
  - Post. 2\3 of choroid has retina (inner most lining).

2. Cornea- القرنية:

- Modified ant 1/6 of sclera that is Transparent, avascular to allow light to enter the eyes.
- **Source of its nutrition:** tears and aqueous Humor.
- **Refractive or diopteric power: 40-45 D** at its anterior surface. أعلى قيمة انكسارية!

IN HUMANS, THE CORNEA HAS RESIDENT IMMUNE CELLS

The cornea has no blood supply, it gets it directly through the air… How ?

- O2 first dissolves in the tears and then diffuses throughout the cornea.
- In the open eye, the environment supplies almost all O2 needed for tissue respiration.
- However, In the closed eye about ⅔ of the O2 demand is met by diffusion from the capillaries, and the rest from the anterior chamber.

طول ما العين مفتوحة بتاخذ الاوكسجين من الهواء واذا تسكرت بتاخذه من aqueous humor والـcapollaries

3. Conjunctiva- الملتحمة:

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

4. Pupil- الحدقة - البؤبؤ:

- A hole located behind the center of cornea, that controls & allows light **to enter** the eye "strikes to the retina".
- **Appears black because**, as you look through the lens, you see the **heavily pigmented** back of the eye (choroid and retina).

5. Iris- القزحية:

- The colored part of the eye.
- The eyes appear **brown to black** when the iris contains a **large** amount of melanin, and **blue** due to low melanin.
- **It has**:

Radial muscle	Circular muscles

dilates the pupil as in dim light	**Constrict** the pupil as in bright light
supplied by **sympathetic**.	by parasympathetic

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6. Ciliary muscles:

- Thick anterior part of choroid to which attached suspensory ligaments (zonule).
- The Ciliary Body (& its suspensory ligament) and lens divide the eye into :
  - **Anterior cavity** → contains a fluid called Aqueous Humor.
  - **Posterior cavity** → contains fluid called Vitreous Humor.

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7. Lens - العدسة:

- It is a transparent, biconvex, semisolid structure in the eye.
- **Function:** helps focus images on the retina to facilitate clear vision.
- **Dioptric power:** **15-20 D**
- **Held in place by:** **zonule** "lens ligament= suspensory ligament" which are attached to ant part of ciliary body.
- **Crystallins:** proteins found in the lens, and are arranged like the layers of an onion which make the refractive media of the lens.

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8. Uvea- العنبية - طبقة العين الوقائية:

- choroid + iris + ciliary muscles.

Cataracts

- **Cataracts** are the most common cause of vision loss in people over age 40 and is the principal cause of blindness in the world.

❖ What is "Cataracts"?

- A **cloudy** or **opaque** area/areas in the lens.
- The **proteins** in some lens fibers become denatured & coagulate to form opaque areas.
- When a cataract has obscured light transmission so greatly that it impairs vision.

(The protein clumps up clouding the lens & reducing the light reaching the retina, leading to blurred vision)

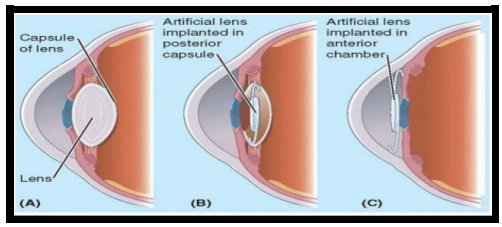
❖ Treatments: (Surgery involves removing the cloudy lens & replacing it with an artificial lens)

1. **Extracapsular cataract extraction:**

   Removing the lens but leaving the capsule to put synthetic lens.

2. **Intracapsular lens extraction**:

   Removing the lens & capsule, & implanting a synthetic lens in the anterior chamber.

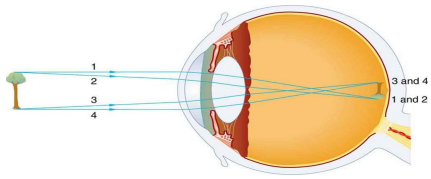


Cataracts: animation (2:18min)

Image-forming & the Chambers of the eye

❖ Image forming:

- The lens system of the eye will focus an image on the retina upside down **the image is inverted & reversed** with respect to the object. However, the brain perceives objects in the upright position despite the upside-down orientation on the retina.

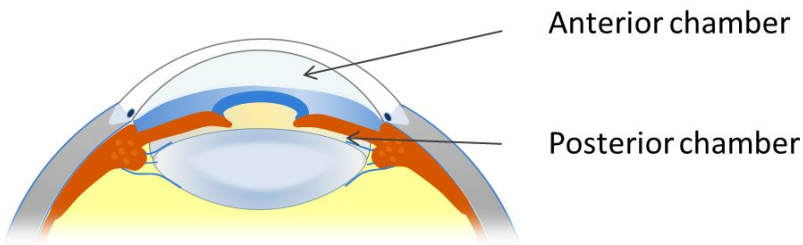


- **Why we don't see the image is inverted & reversed?**
  - Because the brain "LEARNS" early in life to coordinate visual images with the orientations of objects.

❖ Chambers of the eye: The eye has 2 chambers:

- **Anterior chamber of the eye:** (Between iris & cornea). filled with aqueous humor
- **Posterior chamber of the eye:** (Between iris & ciliary muscles).

"The Iris is between both Anterior & Posterior chambers."

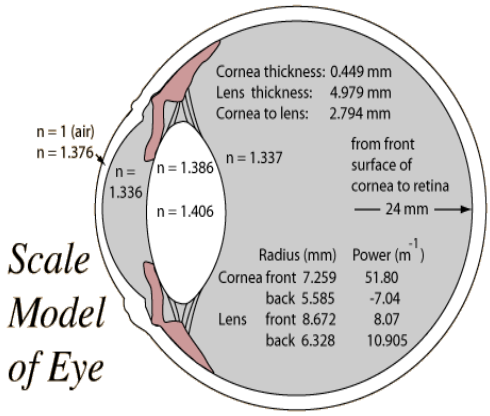


Refractive media of the eye:

Light is refracted through 4 media. 1st the **cornea** (the clear layer on the outside of the eye), then the **aqueous humor** (liquid), then the **lens** (which can change shape slightly to allow objects near and far to focus), and then there is the **vitreous humor** (liquid filling most of the inside of the eye) all of which light needs to pass through before it reaches the retina.

❖ The interface between:

1) Air & the ant. surface of the **cornea**.
2) Post. surface of cornea & the **aqueous** humor.
3) Aqueous humor & the ant. surface of **lens**.
4) Post. surface of lens & the **vitreous humor**.



❖ Total refractive power = 59 diopters

(when the lens is accommodated for distant vision.)

1. Cornea:

- Its dioptric power is 40-45 diopter at its anterior surface.
- About 2/3 of the 59D 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 clouds up and must be removed, it's typical to replace lens with implant.
- The patient might get repeated clouding, also laser removal is an option.
- whereas the refractive index of the eye lens is not greatly different from the indices of the aqueous humor and vitreous humor).

Internal index of air	1
The cornea	1.38
The aqueous humor	1.33
The crystalline lens	1.40
The vitreous humor	1.34

الفكرة اللي يبي يوصلها الجدول:

كل وسط له refractive index خاص فيه، كلما زاد الفرق بين الوسطين كلما زادت الـ dioptric power..

هنا الفرق بين الهواء والقرنية جدا عالي فراح يكون عندنا الdiopteric power عالي، بعكس الفرق بين العدسة والـaqueous humor القليل جدا! القيم ميب مهمة بناء على كلام د.فاتن :)

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2. The aqueous humor:

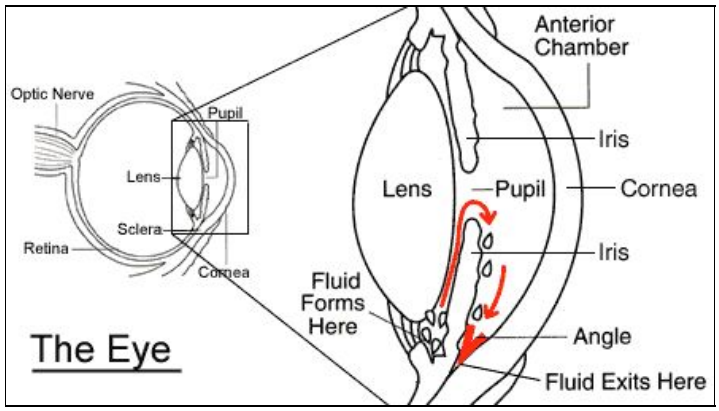
◄ **What is "aqueous humor"?** A transparent, slightly gelatinous (gel-like) fluid similar to plasma.

◄ **Facts:**

- Continually being formed and reabsorbed**.**
- The balance between its formation and reabsorption regulates the total volume & pressure of the intraocular fluid**.**

- Nourishes the cornea & iris**.**

Formation pathway:



Produced in **the ciliary body** (by an active secretion by ciliary processes) → go to the post. Chamber → to pupil → ant. chamber → drained into **canal of Schlemm**[1] in ant. chamber angle, which is a venous channel at the junction between the iris & the cornea (ant. chamber angle).

- This causes intra-ocular pressure **10-20 mmhg.**
- Obstruction of this outlet leads to **increased IOP**, a critical risk factor for **glaucoma,** which may damage the nerve and can be treated with meds or surgery.

لازم يكون فيه توازن بين تكوين و إعادة امتصاص ال aqueous humor، علشان الضغط داخل العين يكون ثابت.

إذا اختل التوازن بحيث ان التكوين يكون اعلى من إعادة الامتصاص ←الضغط بيرتفع وقد يؤدي إلى glaucoma..

Glaucoma:

- **What is it?** (intraocular pressure more than 20mm Hg)
- **Why it causes damage of optic nerve?**

Excessive aqueous humor pushes the lens backwards into vitreous, which pushes against the retina. this compression causes retinal and optic nerve damage, which can cause blindness. "**Obstruction of aqueous humor outlet leads to increased intraocular pressure**."

- **If not treated?**

The axons of the optic nerve are compressed at the optic disc. This lack of nutrition of the optic nerve fibers, causes death of the involved fibers leading to blindness.

Glaucoma Symptoms (3:08min)

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3. Lens:

- Has dioptric power 15-20 D.
- **Even though the refractive power of the eye is 1/3 that of the cornea, it's more important?**

  In response to nervous signals from the brain, its curvature can be increased markedly to provide **accommodation**.

[1] **Schlemm's canal** is a circular lymphatic-like vessel in the eye that collects aqueous humor from the anterior chamber and delivers it into the episcleral blood vessels via aqueous veins. It is named after Friedrich Schlemm (1795–1858), a German anatomist.

4. The vitreous humor:

- The transparent, colorless, gelatinous mass.
- Fills the vitreous chamber between the post. surface of lens and the retina (for nourishing retina & keep spheroid shape of the eye).
- It is clear & allows light to pass through.
- **VITREOUS HUMOUR** REMAINS FROM BIRTH.

Lens-retina distance =15mm

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

Dioptric power of the eye:

Cornea .....40-45 D (max refraction)

Lens ..... 15-20 D

Accommodation by lens .... +12 D

Vision: Crash Course A&P #18 (9:38min)

External protection of eye & Retina

❖ **Our eyes are protected by :**

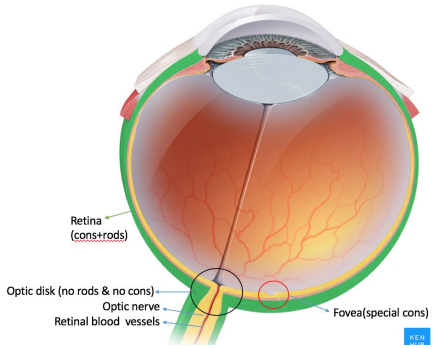
1. **Bony orbit[2]:** protect the eye while allowing it to move freely in a wide arc.
2. **Eyelids[3]:** by keeping the cornea moist.
3. **Conjunctiva:** They reflexively close quickly (blink) to form a mechanical barrier that protects the eye from foreign objects, wind, dust, insects, and very bright light.
4. **Tears:** secreted from lacrimal gland and has lubricating and antibacterial effect, and it keeps the cornea moist, clear, and provide nutrition and oxygen to the cornea.

***Tears contain:** bactericidal enzymes + immunoglobulin A to help its antibacterial function.

Retina - الشبكية:

❖ It is the third and inner coat of the eye which is a light-sensitive layer of tissue.

❖ **It has:**



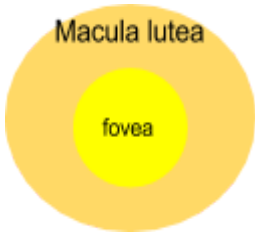
1. **Photoreceptor:** Rods & Cons.
2. **Optic disk(the blind spot):**
   - 3mm medial depressed area on the posterior part of eyeball.

[2] the **orbit** is the cavity or socket of the skull in which the eye and its appendages are situated.
[3] An **eyelid** is a thin fold of skin that covers and protects the human eye. جفن العين

- **Optic nerve** leave the eyeball through optic disk
- **Retinal blood vessels** enters the eyeball through optic disk
- It has **no photoreceptors** = blind

3. Fovea centralis:

- A depressed area in macula lutea (yellow spot in lutea).
- **Only cons!** "To help in vision acuity".
- **High visual acuity= color vision & details detection.**
  - When we look at a certain thing just like you do now reading this sentence. Rays from the screen fall on your fovea (your eye does that to give you an acute detailed image).
  - When attention is attracted to or fixed on an object, the eyes are normally moved so that light rays coming from the object fall on the fovea.



*Cons=Colors. Rods=black and white.

❖ Retinopathy (in diabetes):

Vessels have weak walls – causes hemorrhaging and blindness

Binocular vision

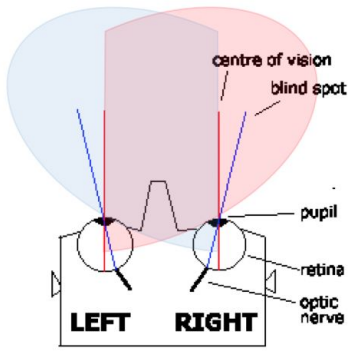
❖ Binocular vision in our eyes:

- Are the areas in the **center** of visual field of the two eyes which any object in this area will be seen by both eyes.

❖ It allows us to :

1. **Have a large visual field.** (كل عين تغطي مجال رؤية واسع)
2. **Cancel the effect of blind spots.**

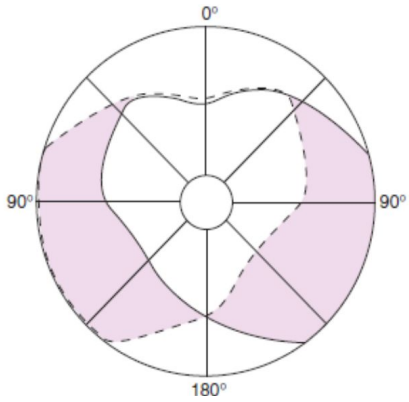
blind spots=optic disk, the optic disk of the right eye is in the medial side so the rays coming from the right aspect of right eye will be reflected in the no receptor spot (optic disk) and the same goes for the left,the overlapping of the binocular vision covers the blind spots)



3. **Stereoscopic vision[4].**
4. **One eye lesion does not affect the other.**

[4] three-dimensional vision produced by the fusion of two slightly different views of a scene on each retina.

❖ Mononuclear and binuclear visual fields:



- **The dashed line** → the visual field of the left eye.
- **The solid line** → the visual field of the right eye.
- **Common area** → viewed with binuclear vision.
- **Colored area** → viewed with mononuclear vision.

الخط المتقطع يحدد مجال رؤية العين اليسرى و الخط العادي للعين اليمنى و هناك مجال مشترك بينهما

يساعدنا على تحديد عمق الأشياء بدقة.

Principles of the optics:

❖ Types of lenses:

- **Biconvex lens** "عدسة مقعرة"= **converge** = عدسة مقعرة -مجمعة
- **Biconcave lens** "عدسة محدبة"=**divergent** =عدسة محدبة-مشتتة

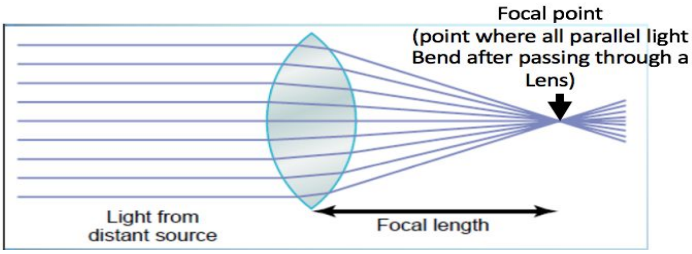
CoCAVE = كهف = اذا دخلت كهف مظلم بتضيع و بتشتت.

❖ Refractive power= 1/ focal distance (مقلوب البعد البؤري)

- We measure refractive power by Diopter[5].
- **R.P. = 1\ principal focal distance in meters**
  - **E.g: if the focal distance is 25 cm what is the refractive power?**
    - Then, the refractive power = 1/ 0.25 meter = 4 Dioptre (**always use meters for focal distance**).
    - **التعريض بالمتر ! التعويض بالمتر ! التعويض بالمتر ! التعويض بالمتر!**
- The **greater** the curvature of the lens, the **greater** the refractive power of the eye.
  - The normal refractive power for our eyes is 59-60 D. if the curvature of lens increase,the focal distance will decrease, the refractive power will increase.
- Refractive power is measured in **convex** lens by the term of focal distance. But the **concave** lenses doesn't have a focal point or a focal distance(because it diverges the rays). So we measure it compared to a known convex lens.

[5] is a unit of measurement of the optical power of a lens or curved mirror, which is equal to the reciprocal of the focal length measured in metres (that is, 1/metres).

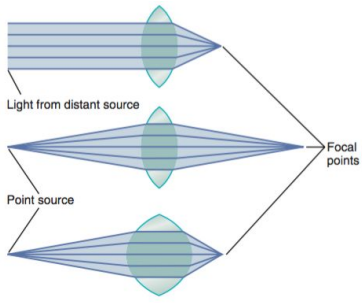
- **For example** : if a concave lens diverges light rays of a 4D refractive power of convex lens , it said to have -4 refractive (dioptric) power.



تأثير العدسات المقعرة والمحدبة متعاكس بالنسبة لل refractive power
بمعنى : إذا وضعت عدسة مقعرة و أمامها أخرى محدبة و لهما نفس مقدار ال refractive power الناتج النهائى سيكون 0 .

Focal length of a lens and its errors:

❖ Focal length of a lens:



- There is a difference in focal length between these two lenses due to the curvature of the lens.

- **Focal length formula:**

$\frac{1}{f} = \frac{1}{a} + \frac{1}{b}$ f=is the focal length of the lens for parallel rays.

a= is the distance from the point source of light to the lens

b= is the focal length on the other side of the lens

- **Emmetropic eye:** العين الطبيعية.

  -
  - The normal eye has image on the retina, has diopteric power 59-60D.
  - Can see all distant objects clearly with its ciliary muscle relaxed & see close objects clearly with ciliary muscles contracted.

❖ Errors of refraction:

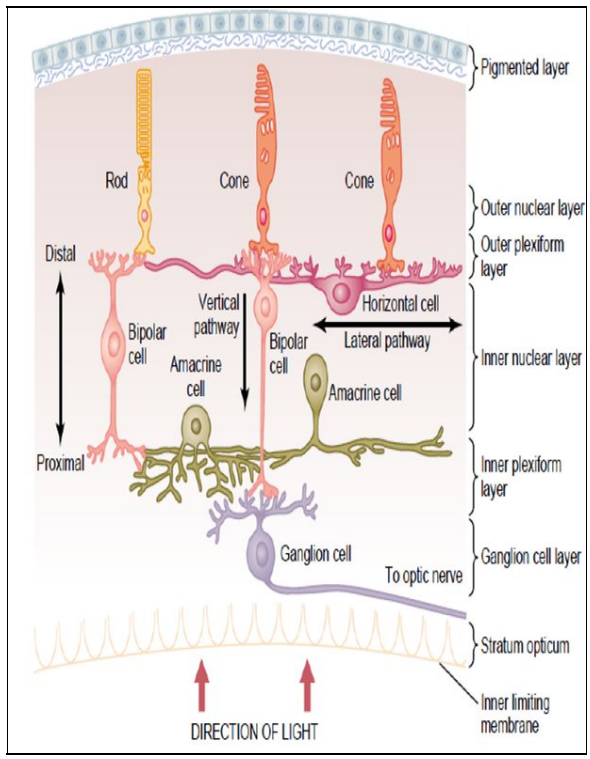
Error	1-Hyperopia, farsightedness hypermetropia[6]:	2-Myopia, nearsightedness[7]:	3-Presbyopia:	4-astigmatism:
Focus :	**Behind** retina	**In fron**t the retina.	**Behind** retina	rays refracted to different foci > blurred vision. **Light focus in more than one focal point**
Facts:	-Small eyeball- weak lens system.	**-Genetic** large eyeball or too much refractive power of lens system	- Eye near point **recedes by age due to loss of**	- Mainly uneven & nonuniform corneal curvature and very

[6] Distant objects being seen more distinctly than near ones.
[7] Objects being seen distinctly only when near to the eye.

	-Causes: headache and blurred vision. -Continuous accommodation to bring image on retina causes <u>muscular effort on ciliary muscle</u> **&** <u>prolonged convergence</u> **, this leads to headache** & finally **squint.** في هذه الحالات من شدة التركيز علي العضلة تؤدي إلى صداع و حول.	or cornea due to: ***it's too curved surface.** * **long antero-posterior diameter of the eye.** -Extensive close work as in studying.	**accommodation.** هذه الحالة هي من حالات بعد النظر الفيزيولوجية.	little due to uneven lens curvature.
Correction By	**Biconvex lens.** النظارات المقعرة تزيد من قوة إنكسار الضوء.	**Biconcave lens** to diverge rays before strike the lens	**Biconvex lens**	**Cylindrical lens** which bends light rays in only one plane (a focal line)

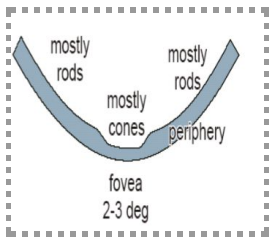
Layers of Retina

❖ **<u>10 layers of Retina, The most important are (from outer to inner):</u>**



1. **<u>Pigment cell layer "outermost layer":</u>**
   - **what is its value?**
     - **Absorb light & Prevent its reflection back.**
   - The pigment layer also **stores large quantities of vitamin A.**
     - This vitamin A is an important precursor of the photosensitive chemicals of the rods and cones.

2. **<u>Rods and cons:</u>**
   - **<u>Describe their distribution ?</u>**
     - **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 & cones.
4. **Outer Plexiform layer:**
   - Mainly **Horizontal cells**, make synaptic connections with bipolar cells.
5. **Inner nuclear layer:** Has **Bipolar cells**
6. **Inner plexiform layer:**
   - Has **Amacrine cells**, make synaptic connections with ganglion cells.
   - This layer is interposed between the inner nuclear layer and ganglion cell layer.
7. **Ganglion cells layer: their axons form the optic nerve!**
8. **Optic nerve fiber: → (1.2 million fibers)**

❖ **Müller cells are the major glial element of the retin**

- **located in: the inner nuclear layer.**
- Form architectural **support** structure providing metabolic support to retina
- maintaining synaptic levels of neurotransmitters .
- They can be - differentiate into a neural progenitor following injury to the retina,
- act as light conductor which funnels light to the rods and cone CELLS.

Light pathway in the eye:

❖ **Light pathway in the eye:**

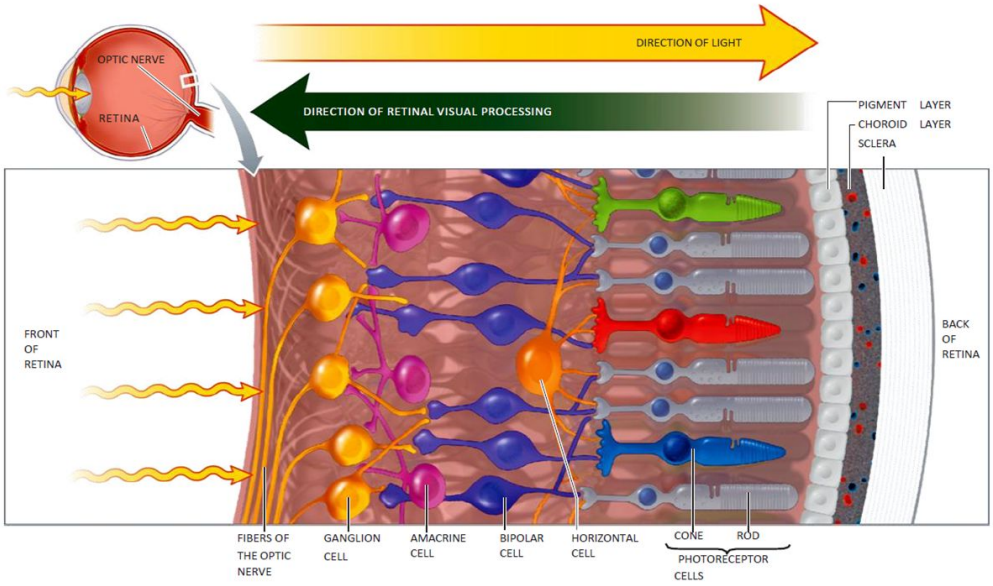
1- After light passes through the lens system of the eye and then through → the vitreous humor

It enters → the inside of the eye.

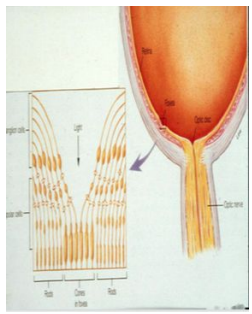
2- It passes first through the **Ganglion cell layer** → Plexiform and nuclear layers, before it finally reaches → the **layer of Rods and cones** locate in the outer ridge of retina.

3- Light absorbed by **Pigment cell layer** that contain Melanin pigment.

4- Then impulses pass to rods and cones to rest of layer → finally to ganglion cell layer → to **optic nerve**.



- The visual acuity **decrease** by this non homogenous tissue. However. In **the central foveal region of the retina**, inside layers are pulled aside to decrease this loss of acuity. This allows light to pass unimpeded to the cones.



★ References:

- 435 girls and boys slides and notes.
- Guyton and hall textbook of medical physiology 12th edition.
- kenhub.com
- Wikipedia.
- Webmd.com