

## Embryology, Anatomy and physiology of The Eye



### Objectives:

- Very brief embryology.
- Anatomy of orbit, extraocular muscles, eyelid and lacrimal system.
- Anatomy of visual pathway.
- Anatomy of eye globe.
- Physiology of the eye.
  - Vision
  - Intraocular pressure.

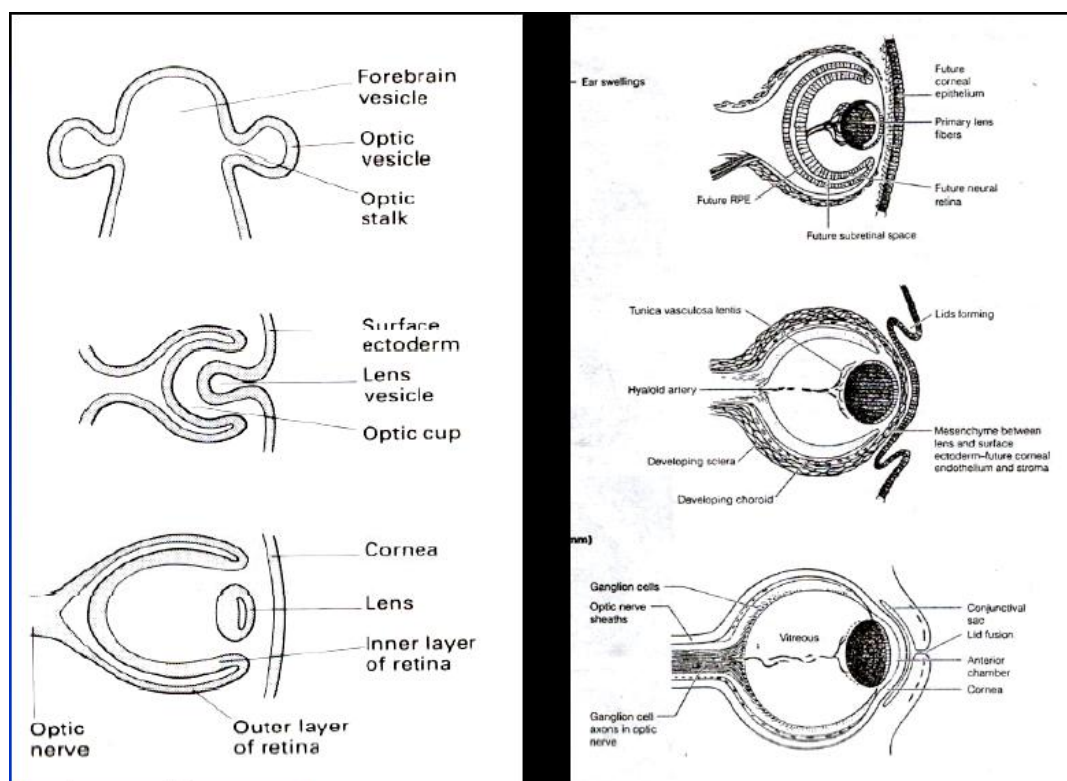
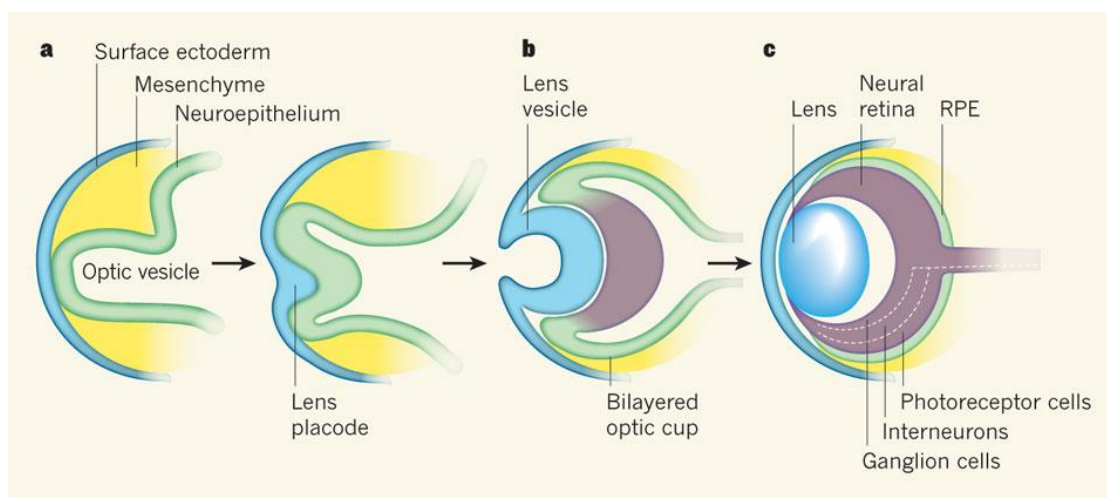
### Sources:

- Lecture slides.
- Clinical Anatomy.
- Essential of Ophthalmology.
- Toronto notes.

Kindly, go through the original slides for more pictures (especially extra ocular muscles part)

## Embryology:

- Early eye development results from a series of inductive signals. This highly specialized sensory organ is derived from:
  - A) Neural ectoderm: differentiates into the retina, the posterior layer of the iris, and the optic nerve.
  - B) Mesoderm: between the neuroectoderm and surface endoderm gives rise to the fibrous and vascular coat of the eye.
  - C) Surface ectoderm: forms the lens of the eye and corneal epithelium.



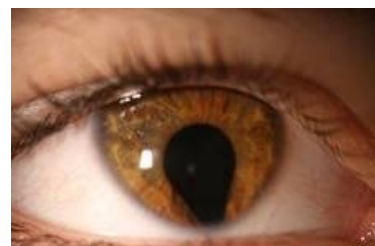
- The eye is essentially an outer growth from the brain (neural ectoderm).
- On both sides of the brain, lateral bud develop and elongate forming the optic vesicle which is connected to the forebrain by optic stalk.
- Invagination of the optic vesicle to form optic cup and the optic stalk to form choroidal fissure inferiorly.
- After the invagination:
  - The innermost layer represents future neurosensory retina (photoreceptor > bipolar > ganglion)
  - The outermost layer represents the future retinal pigmented layer.
  - There is a space between the inner and the outer layers from where retinal detachment<sup>(1)</sup> arise.

The retina develops from the walls of the optic cup (the outer growth of the forebrain). The outer thinner layer of the optic cup becomes the retinal pigment epithelium, and the thicker layer differentiates into the neural retina. The two layers are separated by an intraretinal space. This space gradually disappears as the two layers of the retina fuse.

- (1) Retinal detachment: recreation of the potential space between the two layers of the retina that is formed during the embryologic life.
- Surface ectoderm invaginate to form the lens viscle. At embryonic life, Cornea and lens are vascular to supply generation cells.
    - With time, defloration of hyalite arteries and disappearance of these vessels from the cornea and lens (which come infranasaly) to give clear cornea and lens.
    - The disappearance. Complete fusion of the globe and the lost point is infranasal.
  - Mesodermal tissue invade the developing eye to share in vascular, muscular and supportive tissue of the eye.

### Coloboma :

Congenital defect of the iris, ciliary body, choroid or even optic nerve> it will be exactly infranasal.



## After birth:

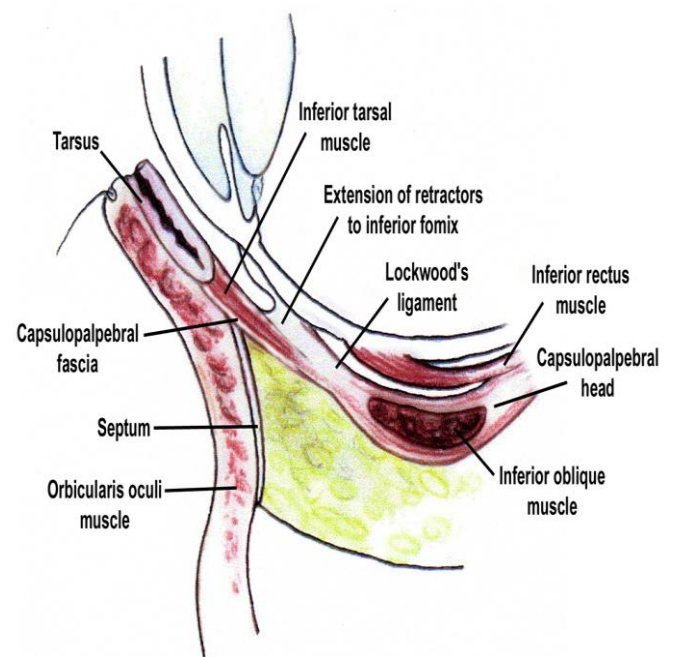
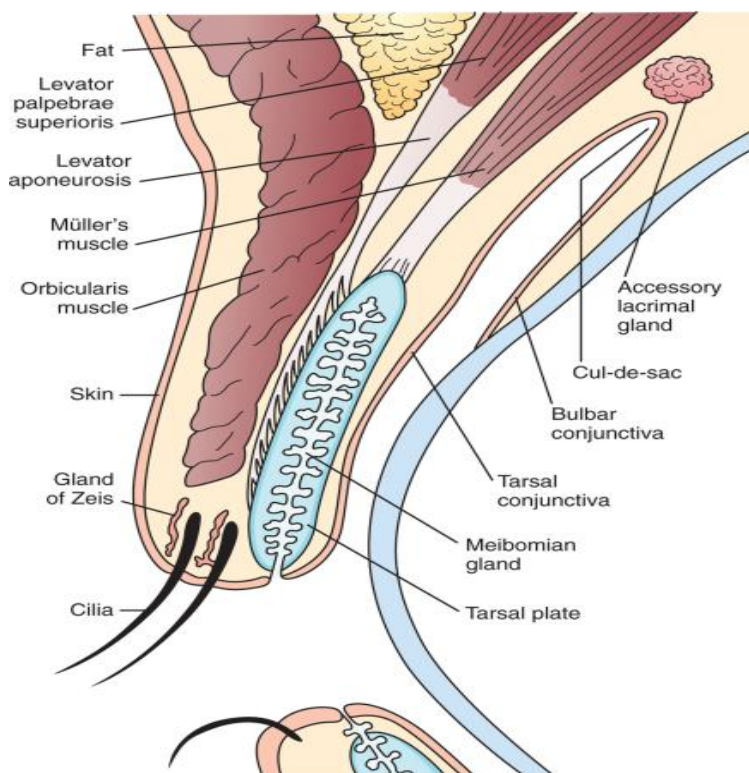
- The eye relatively large in relation to the rest of the body.
- The most comparable organ to adult life is the eye.
- The eye reaches full size by the age of 8 years (emmetropic eye). What is the importance of this?
  - Hypermetropia (small eye) is normal in children.
  - It will disappear spontaneously by the age of 8-10 years.
  - No need to interfere.
- The lens is the only structure in the body that continuous to grow throughout the life.
- Lens's outer epithelial layer grows laterally. What's the importance of this?
  - For cataract management.
  - In children, the nucleus of the lens is soft due to compression from the lateral newly form fibers. Cataract is treated by aspiration of the lens content.
  - In adult and elderly, the lens is hard and too hard respectively. Cataract is treated by taking the nucleus out or emulsifying it within the eye.

- The iris has a bluish color due to little or no pigment on the anterior surface but it becomes darker as the child grow up.
- The eye developing embryo and during early infant life is a distensible organ, so high IOP > enlargement of the eye which lead to:
  - 1- corneal and sclera stretching : sclera stretching > thinner than normal > reveals the underlying blue choroids.
  - 2- MyopiaBothe lead to congenital glaucoma.
- In adult, the eye won't enlarge with high IOP.

## Anatomy:

### A. The eyelid:

- They provide a protective covering for the eye, and spread of the pericornial tear film.
- The lids are closed by: Orbicularis oculi muscle (Facial n.) and retracted by:
  - 1- Levator palpebrae muscle, innervated by Oculomotor nerve
  - 2- Muller's muscle(superior tarsal muscle), innervated by Sympathetic fibers.
  - 3- Lower lid retractors.



**Surgical anatomy of lower eyelid**

- The eye lid is composed of 2 lamellae:
  - 1- **The anterior lamella:** composed of the following layer: skin, subcutaneous tissue and orbicularis muscle. Contraction of the anterior lamella will cause outward deviation of the lid margin (**ectropion**).
  - 2- **The posterior lamella:** composed of tarsus(tarsal plate) and conjunctiva, contraction of the posterior lamella will cause inward deviation of the margin (**entropion**).





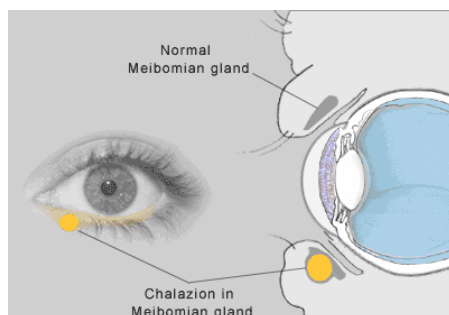
## The eye lashes:

- Function:
  - 1- Remove the dust
  - 2- Accentuate the impulse before reaching the eye so once you touch them the eye will close.
- Direction of the eye lashes:
  - 1- Upper lid: downward & anteriorly then upward
  - 2- Lower lid: upward & anteriorly then downward
- In entropion, lashes are directed against the globe (trichiasis) leading to corneal opacity due to continuous friction of the cornea and epithelial cell abnormality.

## Tarsus (tarsal plate):

- A fibrous tissue forming the skeleton of the eyelid
- Its length in the upper lid 10 mm while in the lower lid 5 mm.
- It has meibomian glands (modified sebaceous glands) that secrete oily material (component of the pericorneal tear film) to minimize evaporation of tears. (there are 30 upper and 20 lower).

Chalazion: chronic granulomatous inflammation of meibomian gland .



## Orbital septum:

- It's the continuation of the periosteum and tarsus.
- Highly resistant to infections, so the infection will spread according to the venous drainage of the affected site:
  - If the infection was in front of the septum > the venous drainage is through the periauricular or retromandibular veins (periseptal cellulitis).
  - If the infection was behind the septum > the venous drainage is directly to the cavernous sinus (orbital cellulitis).

## Muscles of the eyelid:

### A. Upper eyelid elevators:

- 1- **levator palpebrae superioris**: the main muscle, attached to the anterior surface of the tarsus, innervated by oculomotor nerve. The first 40 mm is muscular and the remaining 14-20 is the [aponeurosis](#), it separates the lacrimal gland into orbital and palpebral lobes.
- 2- **Whitnall's ligament** (superior transvers ligament): is a condensation of [levator muscle sheath](#) that acts as a check ligament to prevent excessive lid elevation.
- 3- **Muller's muscle (superior tarsal muscle)**: innervated by sympathetic fibers, it is attached to the upper part of the superior tarsus, it's responsible for closing the eye as emotional expression Not for blinking, and takes the upper hand in elevating the lid if the levator muscle suppressed.

### B. The lower eyelid retractors:

- 1- **Capsulopalpebral fascia**: which is analogous to the levator aponeurosis, it's arise from the inferior rectus muscle sheath.
- 2- **Lockwood's suspensory ligament**: which is analogous to whitnall's suspensory ligament: it is arise from the Inferior rectus muscle, innervated by oculomotor nerve.
- 3- **Inferior tarsal muscle**: which is analogous to muller's muscle, it is innervated by sympathetic fibers.

Both eyelids are closed by the action of the orbicularis oculi muscles, innervated by facial cranial nerve. It has three anatomic parts: the [palpebral portion \(pretarsal and preseptal\)](#) involved with involuntary blinking, and the [orbital portion](#) involved with voluntary, forced lid closure.

Ptosis: dropping of the upper eyelid due to decreased tone of the muscle and power to elevate the eyelid

Ptosis (drooping of the eyelid)



## B. Lacrimal Apparatus

- Lacrimal gland secretes tears into the upper fornix of the conjunctival sac which are spread over the surface of the cornea as a tear film by blinking of the lids.
- Tears accumulate at the inner canthus and drain into the lacrimal sac via the puncta & canaliculi.
- The sac is continuous inferiorly with the nasolacrimal duct which opens into the nasal cavity just beneath the inferior turbinate.
- Normally , lacrimal gland is not palpable. You can only palpate the lacrimal fossa
- Lacrimal gland is composed of:
  - 1- Main lacrimal gland> reflex lacrimation.
  - 2- Accessory lacrimal glands (Krause & wolfring)> basal lacrimal secretion.
- What is the function of Horner's muscle?

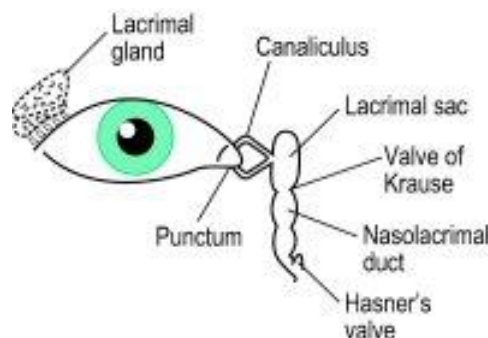
It's part of orbicularis muscle that attached to the lacrimal wall of the lacrimal sac.

contraction of orbicularis> closure of the eyelid.

contraction of horner's muscle> distention of lacrimal sac> -ve pressure> suck the tear from lake lacrimalis.

Relaxation of orbicularis> open eye

Relaxation of Horner's muscles> +ve pressure in the sac> push the tear to the nose.



- tow valves reverse the muscle action< they are open closing the eye (tear will go to the sac), and close while opening the eye to prevent tear regurgitation to the eye.

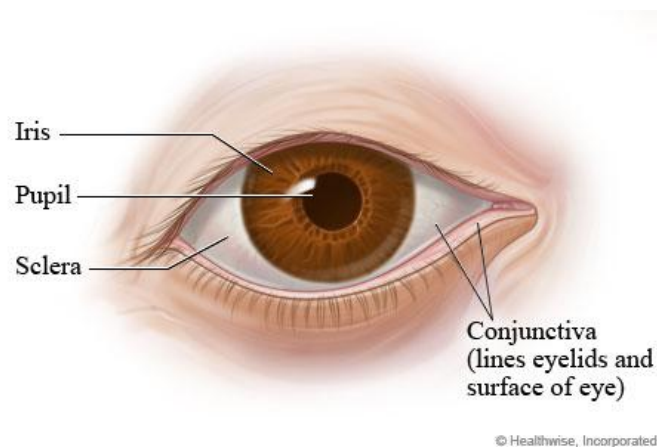
In Bell's Palsy:

pump failure due to:

- occlusion of any part of gland
- epiphoria (excessivetearing)
- very difficult to Rx

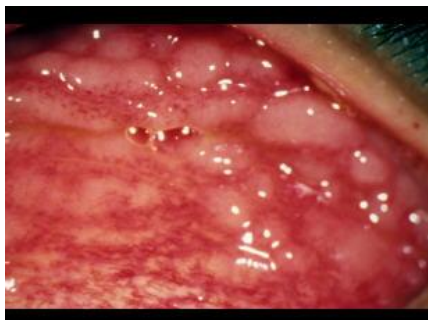


## C. Conjunctiva



- It is a clear, vascular, mucous membrane composed of non keratinized epithelium with goblet cells and underlying loose stromal tissue (substantia propria).
- Anatomically the conjunctiva is divided into two parts:
  - 1- **The bulbar conjunctiva:** covers the anterior sclera and is loosely adherent, except at its attachment to the corneal-scleral junction (the limbus), where it fuses with Tenon's capsule.
  - 2- **The palpebral (tarsal) conjunctiva:** covers the inner surface of the eyelids, where it is firmly attached to the tarsal plates.
- **The fornices** (superior and inferior fornices) are the blind pouches where the conjunctiva reflects upon itself between the bulbar and palpebral surfaces. This prevents objects, like contact lenses, from traveling behind the eye.

- **Follicles:** aggregation of lymphocyte forms dome shaped gray area surrounded by blood vessels (no central vessel)
- **Papillae:** proliferation of the epithelium with central blood vessel, mostly due to ocular disease, FB, contact lens.

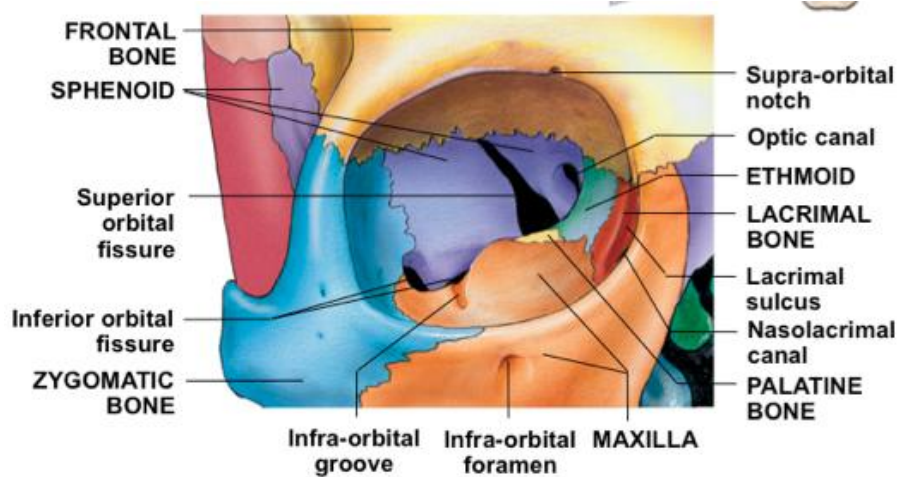


## D. THE ORBIT

- As a socket, contains & protect the eye.
- The weakest parts are the floor & the medial wall.
- The orbit has for sides combose of seven bones:

Orbit	Bones
Roof	Sphenoid (lesser wing) Frontal
Lateral wall	Sphenoid (greater wing) Zygomatic
Floor	Maxilla Palatine zygomatic
Medial wall	Sphenoid Maxilla  Ethmoid lacrimal

- Surrounded by nasal sinuses.
- Important openings are:
  - 1- Optic foramen.
  - 2- Superior orbital fissure.
  - 3- Inferior orbital fissure.



## Direction of the orbit:

- Medial wall: straight ahead.
- Lateral wall: deviated 45 degrees to each medial wall, both lateral walls forming 90 degrees to each other.
- The eye within the globe tends to follow the orbit, so it will be deviated laterally during sleep, anesthesia or death.
- What keeps the eye in straight position is the medial rectus muscle, What is the importance of this?!

In assessing nystagmus before surgery, because even inward nystagmus will be replaced by lateral nystagmus by anesthesia.

## Openings of the orbit:

- A. Optic foramen( In the lesser wing of sphenoid), it transmits:
  - Optic nerve.
  - Ophthalmic artery.
- B. Orbital fisser (superior & inferior):
  - Superior orbital fissure (between greater and lesser wings of sphenoid) it transmits:
    1. Trochlear nerve.
    2. Abducent nerve.
    3. Oculomotor nerve.
    4. frontal nerve.
    5. lacrimal nerve.
    6. Nasociliary nerve.
    7. Branch of the ophthalmic division of trigeminal artery.
    8. superior ophthalmic vein.
  - Inferior orbital fissure (between maxilla and greater wing of sphenoid) it transmits:
    1. Infraorbital nerve.
    2. Maxillary nerve and it zygomatic branch.
    3. Sympathetic nerve.
    4. Inferior ophthalmic vein.

## E. Extraocular muscles:

- Four recti & two oblique muscles.
- All are supplied by Oculomotor n. except superior oblique (Trochlear n.) & lateral rectus (Abducent n.).

Muscle	Action from primary position	origin	Innervations
Medial rectus	Adduction	Annulus of Zinn	CN 3
Lateral rectus	Abduction	Annulus of Zinn	CN 6
Superior rectus	1- Elevation 2- Intorsion 3- Adduction	Annulus of Zinn	CN 3
Inferior rectus	1- Depression 2- Extorsion 3- Adduction	Annulus of Zinn	CN 3
Superior oblique	1- Intorsion 2- Depression 3- Abduction	Orbital apex above annulus of Zinn	CN 4
Inferior oblique	1- Extorsion 2- Elevation 3- Abduction	Behind lacrimal fossa	CN 3

## F. The eye (Globe):

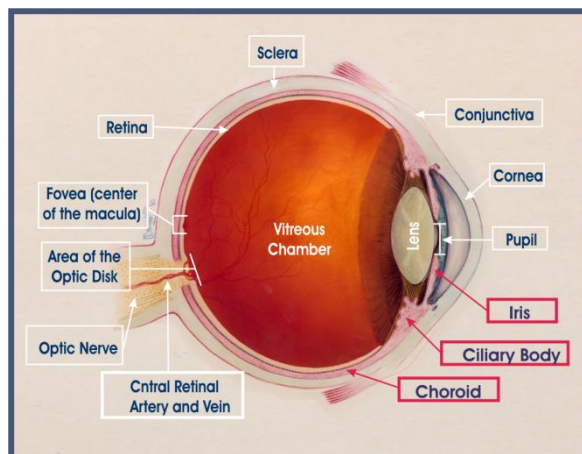
Two spheres with different radii:

- Cornea, window of the eye.
- Sclera, opaque shell.
- The eye measures approximately 24 mm in all its main diameters.

### The coats of the eye:

Three layers:

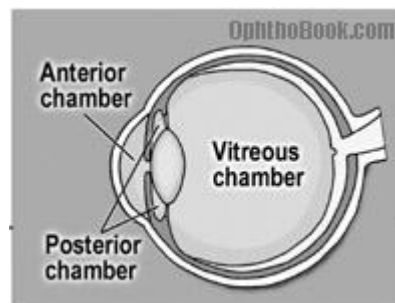
1. **The outer:** inelastic coat, transparent cornea and opaque sclera.
2. **The middle:** vascular coat, The Uvea: choroid, ciliary body and iris.
3. **The inner:** The Retina, extends forwards to within 6 mm of the limbus.



## The Chambers of The Eye:

### Three optically clear spaces:

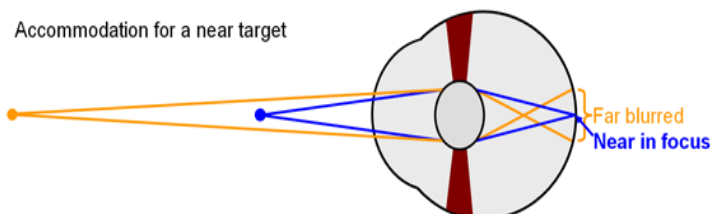
1. **The anterior chamber:** in front of the iris
2. **The posterior chamber:** immediately behind the iris. These two chambers which communicate through the pupil are filled with clear aqueous humour.
3. **The vitreous cavity:** filled by gel-like structure, The Vitreous.



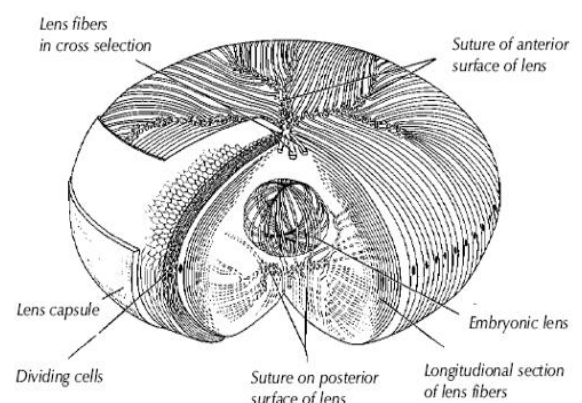
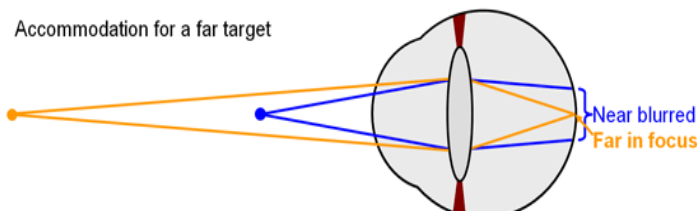
## The Lens:

- The crystalline lens is the only structure continuously growing throughout the life.
- Located between the posterior chamber and the vitreous cavity, separates the anterior and posterior segments of the eye.
- It's a sac of gelatinous proteins surrounded by a basement membrane (the capsule) created by the lens epithelial cells.
- The lens grows by elongation and transformation of the epithelial cells into lens fibers.
- Zonular fibers suspend the lens from the ciliary body and enable the ciliary muscle to focus the lens by changing its shape (accommodation).
- Cornea has the main refraction power but the lens has a changeable refraction.
- The refractive power of the lens changes with aging.
- During childhood and early adulthood >> soft lens
- With aging >> decrease elasticity >> decrease accommodation.
- Accommodation power in children = 14 diopter (1\14).
- Accommodation power by the age of 16 = 1 diopter.

Accommodation for a near target



Accommodation for a far target



## Ciliary body:

It's responsible for aqueous fluid secretion >> accumulates in the posterior chamber >> anterior chamber >> trabecular meshwork >> drained through Schlemm's canal.

Angle closure glaucoma: adhesion between iris and lens >> prevent aqueous movement to anterior chamber. It's treated surgically.

## Retina:

- Retina is delicate transparent light sensing inner layer of the eye that function like a film in a camera. Light travels through the retina to the photoreceptors in the outermost layer. These rod and cone photoreceptor cell convert the light into neural signals that pass back through the retina to the ganglion cells whose axons form the optic nerve.
- The retina has nine distinct layers:
  1. **The internal limiting membrane:** is the inner basement membrane
  2. **The nerve fiber layer:** contains unmyelinated ganglion cell axons that then form the optic nerve and finally synapse with nuclei of cells in the lateral geniculate body.
  3. **The ganglion cell layer:** is composed of a single layer of ganglion cells, except in macula, where it's multilayered.
  4. **The inner plexiform layer:** contains the synapses between the bipolar cell and ganglion cell or amacrine cell.
  5. **The inner nuclear layer:** contains the cell bodies of the bipolar, amacrine, horizontal, and muller cells.
  6. **The outer plexiform layer:** contains the synapses between photoreceptors and the bipolar cells
  7. **The outer nuclear layer:** is composed of the photoreceptor cell nuclei.
  8. **The external limiting membrane**
  9. **The photoreceptor layer:** contains the rods and cones (120 million rods and 6 million cones)
- The macula is located in the posterior pole, temporal to the optic nerve, it's 5-6 mm in diameter and provides the sharpest vision.
- Within the macula is fovea, a central depression of the inner retinal surface. The photoreceptor in the fovea are only cones.

Types of retinal detachment:

1. Traction retinal detachment.
2. Exudative retinal detachment (choroid).
3. Rhegmatogenous retinal detachment (liquefied vitreous).



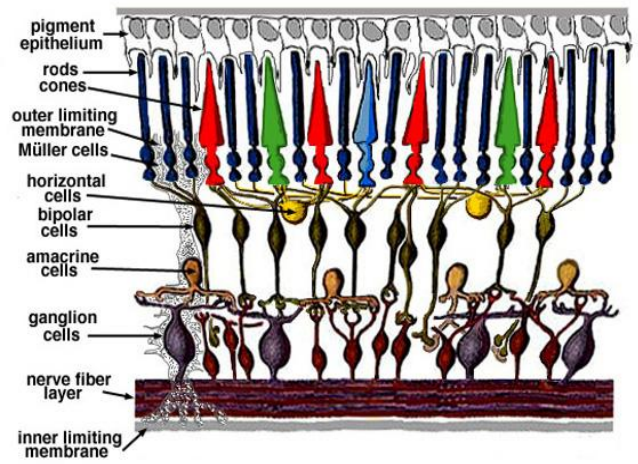
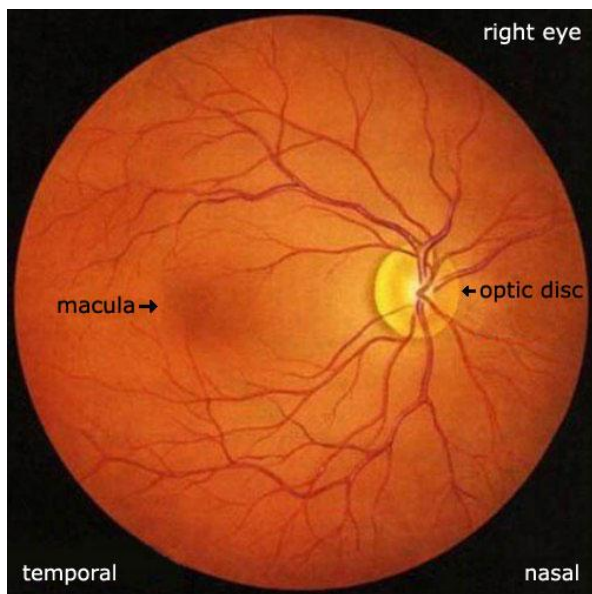
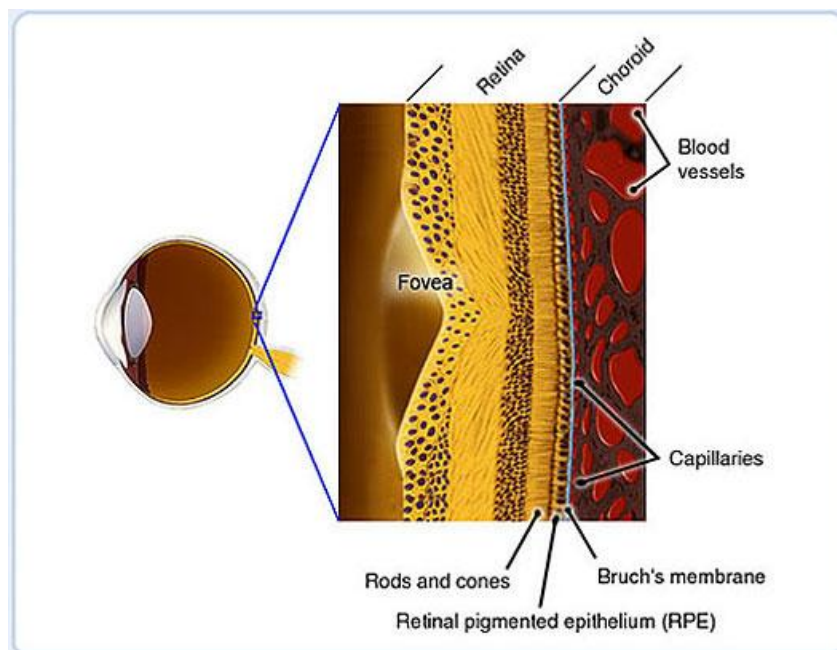


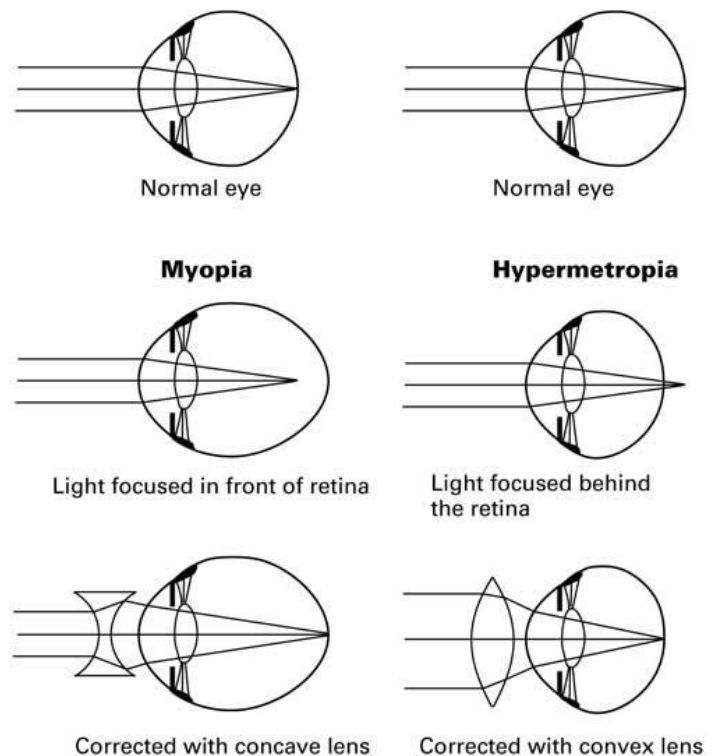
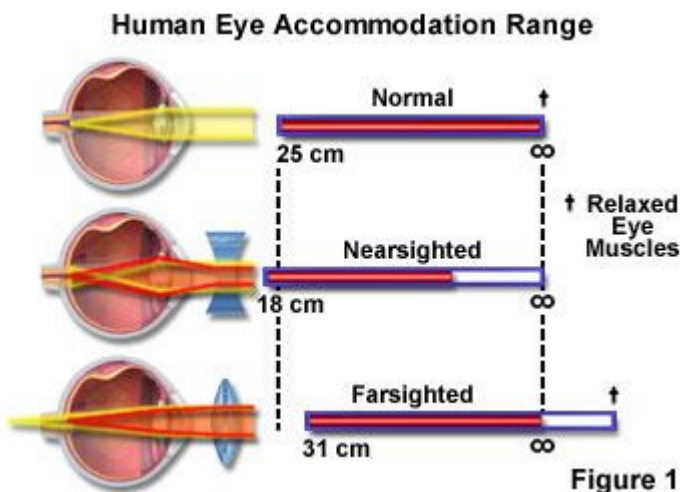
Fig. 2. Simple diagram of the organization of the retina.



# Physiology of The Eye

## Optics of the Eye:

- The eye is like a camera. Light must have a clearly pathway to be clearly focused on the sensory receptors of the retina, i.e., Clear cornea, anterior chamber, lens and vitreous cavity.
- The Refractive power of the eye is about  $\pm 58$  dioptres.
- The cornea is the major refracting element of the eye with a power of approximately 40 dioptres. If the curvature is greater in one meridian than the other  $\rightarrow$  Astigmatism.
- The refractive power of the lens is about 17 dioptres at rest. Accommodation able to change.
- the power of the lens markedly depends on age.
- Emmetropia: Optically normal eye in which rays of light from a distant object are focused on the retina without accommodation.
- Myopia: Light focused on front of the retina, corrected by concave lens.
- Hypermetropia (hyperopia): Light focused behind the retina, corrected by convex lens.



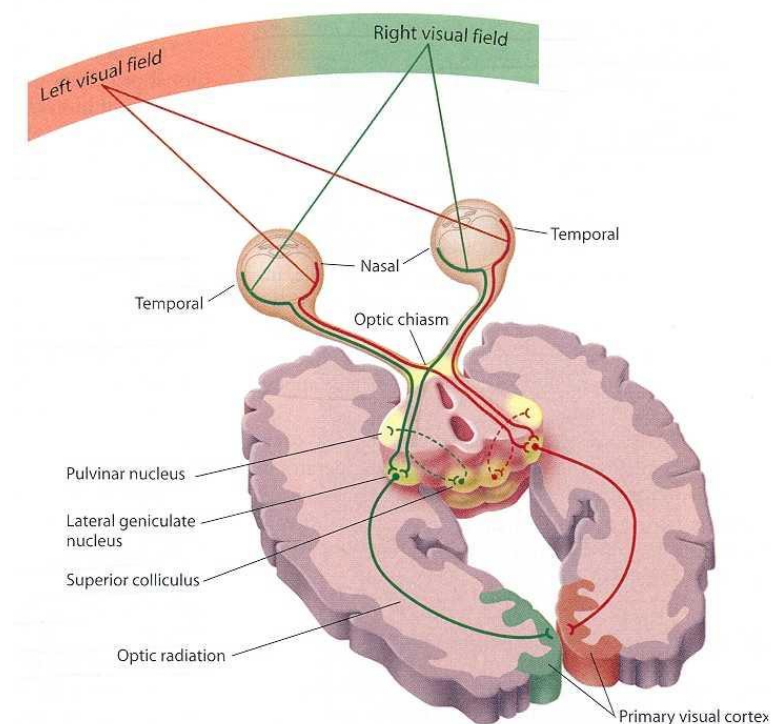
## The intraocular pressure:

- The pressure within the eye is maintained at a steady level by continuous formation & drainage of aqueous.
- Aqueous is secreted by the ciliary epithelium → posterior chamber → anterior chamber (through the pupil ) → drained through the anterior chamber angle.
- The intraocular pressure, (IOP), is normally 10 – 21 mmHg; increased IOP called Glaucoma.
- High IOP almost always due to an obstruction of aqueous outflow.

## VISION:

### The retina:

- The central retina contains yellow pigment, Xanthophyll, the so called macula lutea ( yellow spot).
- It is divided into retinal pigment epithelium & neurosensory retina.
- Photoreceptors contains visual pigment which consists of a large protein (opsin) attached to retinal (vitamin A aldehyde).
- Light splits the opsin from the retinal with initiation of a graded electrical potential → Transmitted through the visual pathway to be processed in the visual cortex (occipital lobe) → vision sense.
- Visual Pathway: Three neurons
  1. Bipolar cell, lies within the retina.
  2. Ganglion cell, synapse in lateral geniculate body.
  3. Third neuron terminates in visual cortex.



Done By:

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