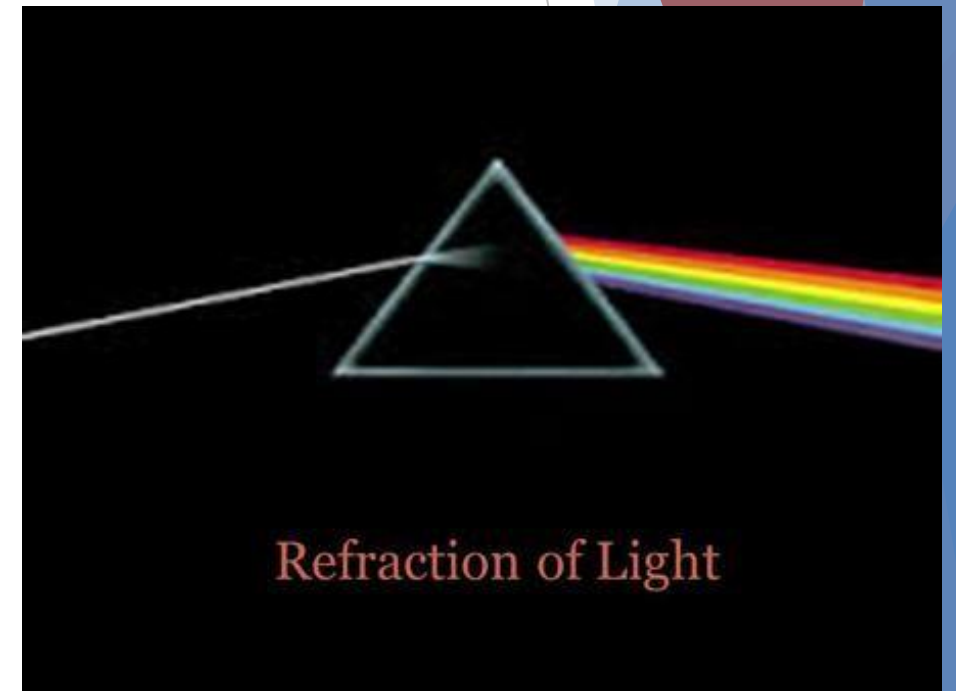


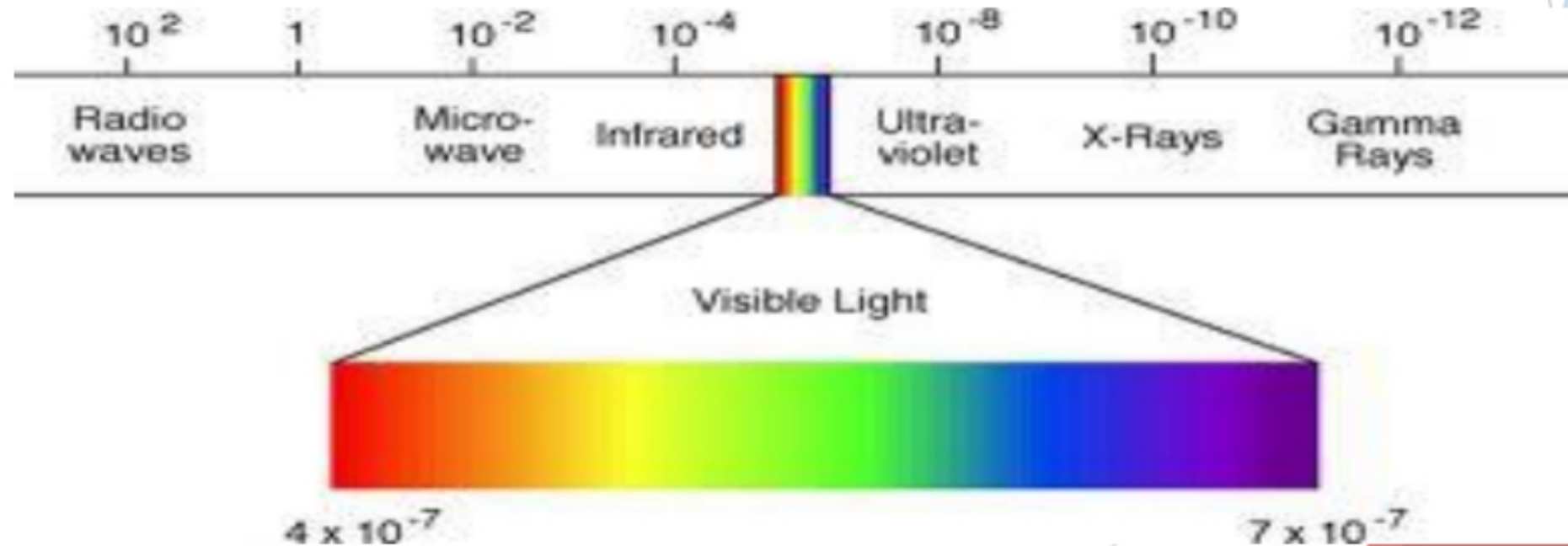
# Optics and Refraction for 5<sup>th</sup> year students

Mutaz Gharaibeh, MD



# Physical optics

- The visible part of the EM spectrum, to which the retina is sensitive, lies between the wavelengths **390nm & 760nm**.
- Light should be correctly focused on the retina for the eye to generate accurate visual information.



- \* Our eyes converge light rays
- \* The Light rays emitted or reflected by the objects diverge as they leave the object
- \* The closer the object to us the greater its divergence power that is why our eyes have to meet this with a great convergence power
- \* Why is visual acuity tested at 6 meters?? For the light rays to be as parallel as possible

Refractive Index  
(Index of Refraction):  
A value calculated from the ratio of the speed of light in a vacuum to that in a second medium of greater density

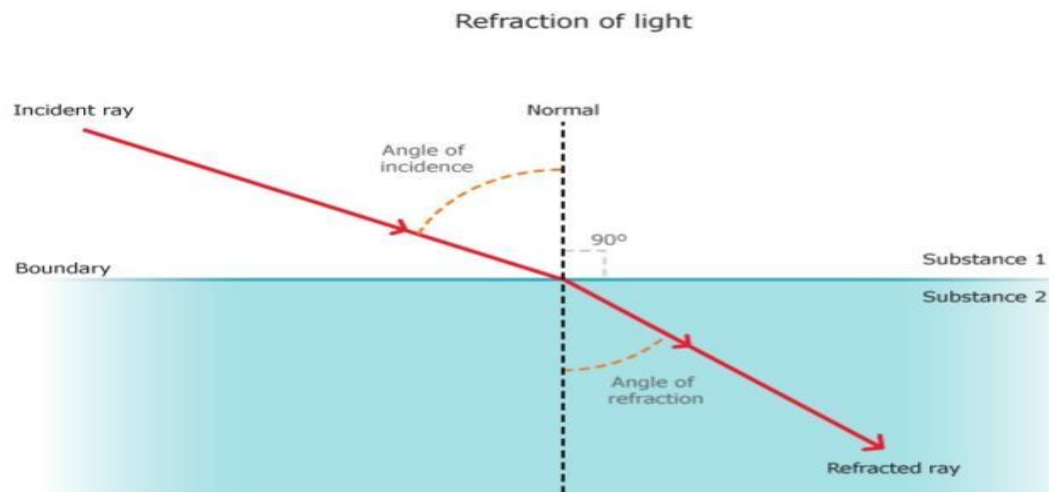
RI of the crystalline lens ~ 1.4  
RI of the cornea ~ 1.37  
RI of the aqueous humor ~ 1.33

Diopter:  
A unit of refractive power, which is equal to the reciprocal of the focal length (in metres) of a given lens

Light travels in a straight line. But when it reaches another medium it will bend. This is called refraction.

This is how lenses work, and also how we see.

Why is the cornea responsible for 2/3 (~40 dpt) of the refractive power of the eye despite being of lower RI compared to the lens (~20 dpt) ? Because the transition of light from the air into the cornea is accompanied by the largest change in RI



The focus must be adjustable to allow clear vision for both near & distant objects (accommodation).

Refractive components of the eye or the focusing power is :

- \*\* 2/3 (cornea and “air/tear” interface), fixed power
- \*\* 1/3 lens, power increases with accommodation

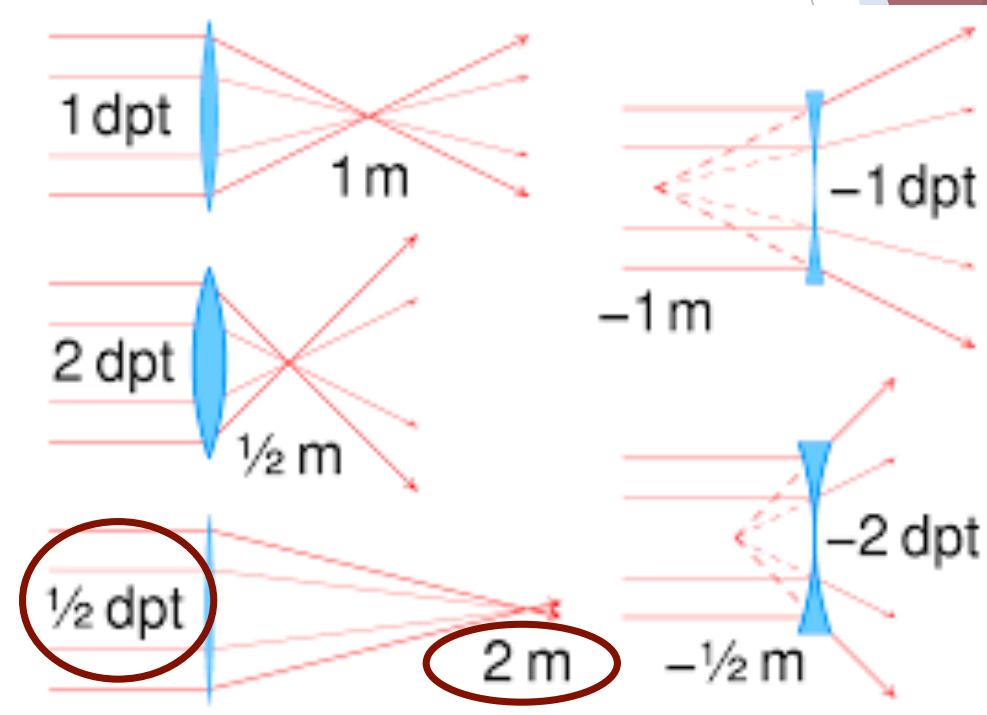
These two elements converge parallel rays because :-

- 1) Cornea has higher refractive index than air.
- 2) lens has higher refractive index than aqueous and vitreous humours.
- 3) Cornea & lens are spherically convex in shape

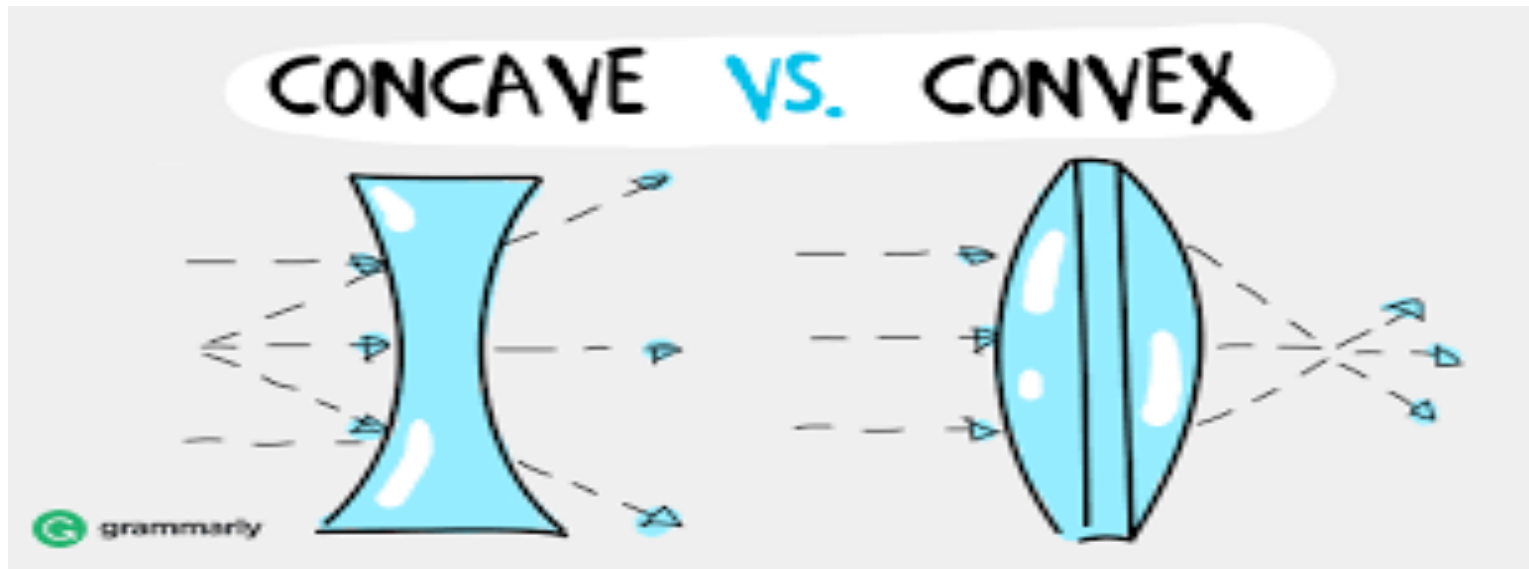
**Diopter (D)** : measurement of the refractive power of a lens, equal to the reciprocal of the focal length in meters “ 1/meters” . Simply describes the power of the lens.



Black lenses > convex  
Red lenses > concave



- \*\*\*\* A negative lens is a diverging lens ,concave ,corrects for myopia
- \*\*\*\* A positive lens is a converging lens ,convex ,corrects for hypermetropia.



# causes

Refractive errors can be caused by:

- Eyeball length (when the eyeball grows too long or too short)
- Problems with the shape of the cornea (the clear outer layer of the eye)
- Aging of the lens (an inner part of the eye that is normally clear and helps the eye focus)

Examples:

1. Nuclear cataract > at first causes nearsightedness ( lens RI becomes 1.6 instead of 1.4 )
2. Trauma to the eye > loss of the lens > leads to hyperopia ( needs to be fixed with ~ 20 dpt )

# Presbyopia

- A normal aging process, when near images can't be focused on the retina due to reduced accommodative ability.
- The focus is behind the retina as in hyperopia.
- Makes it hard for middle-aged and older adults to see things up close. It happens because the lens (an inner part of the eye that helps the eye focus) stops focusing light correctly on the retina (a light-sensitive layer of tissue at the back of the eye). Or weak ciliary muscle
- Presbyopia is a normal part of aging. Everyone gets presbyopia as they get older — usually after age 45. Many people have another refractive error in addition to presbyopia.





# symptoms

symptoms of presbyopia include:

- Trouble seeing things up close
- Needing to hold reading materials farther away to focus on them
- Eye strain (when your eyes feel tired or sore)
- Headache
- ▶ Presbyopia gets worse over time, but it usually stops getting worse after age 65.

# Definitions

There are 4 common types of refractive errors:

- ▶ **Nearsightedness (myopia)** makes far-away objects look blurry
- ▶ **Farsightedness (hyperopia)** makes nearby objects look blurry
- ▶ **Presbyopia:** Loss of accommodative ability of the lens resulting in difficulties with near tasks. i.e. makes it hard for middle-aged and older adults to see things up close
- ▶ **Astigmatism:** the curvature of the cornea and/or lens is Not spherical and therefore causes image blur on the retina. Optical power on different planes is not equal. i.e. can make far-away and nearby objects look blurry or distorted

Uneven corneal curvature/ multiple focal points

- **Aniseikonia:** a difference of image size between the 2 eyes as perceived by the patient. The image needs to be seen by both eyes in the same size for the brain to form a 3D image of it. This doesn't happen in the case of aniseikonia so the brain becomes troubled by this and consequently 'deletes' the problematic eye leading to amblyopia (lazy eye).
- **Anisometropia:** a refractive power difference between the 2 eyes (usually > 2D)  
Examples: One eye suffers from myopia and the other from hyperopia / unilateral congenital cataract post-op
- **Aphakia:** ( Phakos=lens), aphakia is no lens.
- **Pseudophakia:** artificial lens in the eye.  
Loss of accommodation/ reading glasses for life

Unilateral congenital cataract:  
We do the surgery > this leads to anisometropia > glasses are used to fix this problem > however glasses cause aniseikonia on the other hand

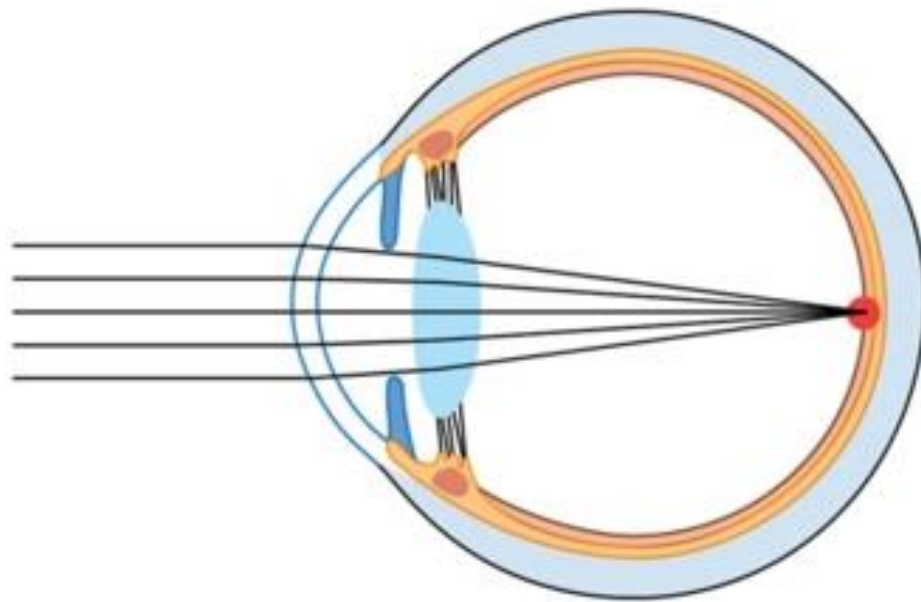
# symptoms

The most common symptom is blurry vision. Other symptoms include:

- Double vision
- Hazy vision
- Seeing a glare or halo around bright lights
- Squinting
- Headaches
- Eye strain (when your eyes feel tired or sore)
- Trouble focusing when reading or looking at a computer

# Refractive errors

**Emmetropia** :- when parallel rays of light from a distant object are brought to focus on the retina with the eye at rest “not accommodating”.



**Emmetropia**  
(normal vision)

# Hypermetropia

## Aka Farsightedness (Hyperopia)

a refractive error that makes nearby objects look blurry. It happens when the shape of the eye makes light focus behind the retina (a light sensitive layer of tissue at the back of your eye), instead of on it.

A lot of children are farsighted, this makes sense as they have small weak eyes. So it's a stage in normal development of the eye (physiologic), or due to any cause that shortens the globe (pathological Hyperopia).

Special forms: Ectopia lentis (displacement of lens from its normal position).

Post operative aphakia. Marfan : up & out / Homocystinuria : down & in

Rays of light converge behind the retina, which causes blurring of vision for near objects ± distant objects.

Hypermetropes must accommodate with distant gaze to bring image into retina.

\* Patients with hyperopia are at a greater risk of angle closure glaucoma (small eye)

\*\* Rule of 4

At 1 year of age up to +3.0 is acceptable (  $1+3 = 4$  )

However this rule has its limitations and can't be followed always

\*\* At 5 y.o anything beyond +1.0 isn't considered normal

\*\* Let's say that this 5 y.o kid has +3.0 we prescribe him +2.0 glasses & we let accommodation take care of that +1.0 left behind ( however; we can't generalize this and think it applies on all patients)

# Hypermetropia- why?

- ▶ Farsightedness happens when your eyeball grows too short from front to back, or when there are problems with the shape of your cornea (clear front layer of the eye) or lens (an inner part of the eye that helps the eye focus).
- ▶ These problems make light focus behind the retina, instead of on it – and that makes nearby objects look blurry.  
*The final outcome might be: emmetropia - myopia - hyperopia - amblyopia*
- ▶ Most people who are farsighted are born with it, but it may not cause vision problems until you get older. You're more likely to be farsighted if other members of your family are farsighted too.
- The length of the eyeball is shorter than it should be.
- stage in normal development of the eyes—at birth eyes are hypermetropic
- *> 12 y.o*  
When persists in adulthood it represents an imperfectly developed eye.

# Hypermetropia -symptoms

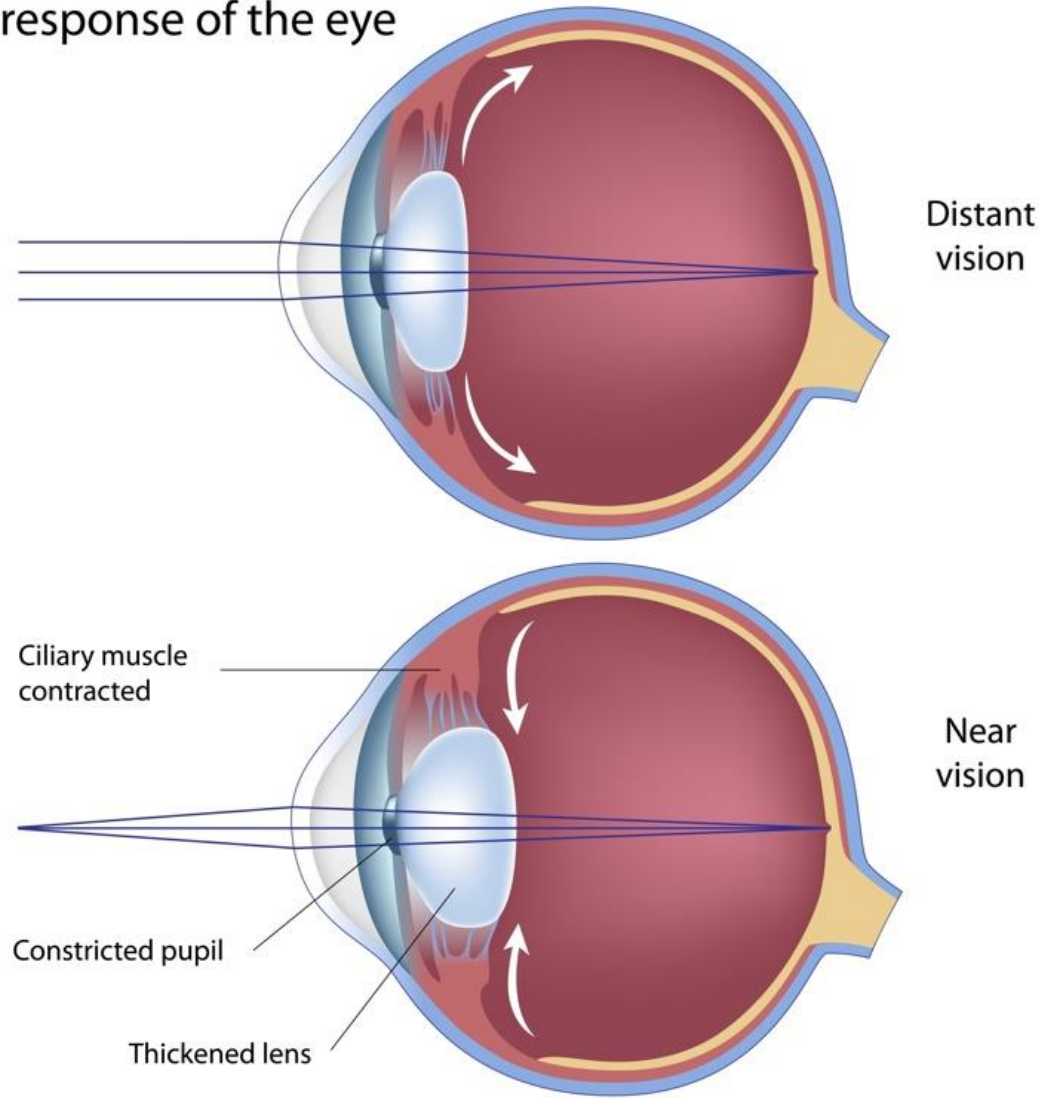
\*\* Additional \*\*

- ▶ The most common symptoms of farsightedness are:
  - Trouble seeing things up close
  - Eye strain ; ciliary muscle is straining to maintain accommodation (when your eyes feel tired or sore)
  - Headaches – especially when reading
- ▶ If you have mild farsightedness, you may not notice any symptoms. That's why it's important to get regular eye exams
- ▶ Children with severe farsightedness may also be at higher risk for other eye problems, like **strabismus (crossed eyes)** or **amblyopia (lazy eye)**.

In a child with an equal degree of long sight in both eyes, a convergent squint may develop because of increased accommodative effort to focus distant, and particularly nearby objects. *Accommodative esotropia*

For children aged 12-30 months, AAPOS guidelines consider the child at risk for hyperopia greater than +4.5 diopters; for children aged 31-48 months, hyperopia greater than +4.0 diopters is considered a risk factor for amblyopia, and for children older than 49 months, farsightedness of more than +3.5 diopters is considered an amblyopia risk factor.

## The near response of the eye





# Myopia

## Nearsightedness

- ❑ a refractive error that makes far-away objects look blurry. It happens when the shape of the eye makes light focus in front of the retina (a light sensitive layer of tissue in the back of your eye), instead of on it.
  - ❑ usually starts between ages 6 and 14 and gets worse until your early twenties
  - ❑ Usually presents in 1<sup>st</sup> or 2<sup>nd</sup> decades ,rarely begins after the age of 25,except in pts with D.M or cataract.
  - ❑ Keratoconus(conical cornea) is a pathological cause of myopia, (comes also with irregular stigmatism).
  - ❑ Blurring of distance vision, the near isn't affected .
  - ❑ Complications ( though rare) : retinal tear or detachment, macular hole, and open angle glaucoma.
  - ❑ Not prevented with refractive correction.
  - ❑ Management: corrected by a diverging lens “concave”, or refractive eye surgery.
- People who have severe nearsightedness (also called high myopia) may also be at higher risk for other eye conditions, like [retinal detachment](#) (when the retina is pulled away from its normal position).

\*\* The axis of cylindrical lenses could be any number between 0-180 degrees

\*\* If the patient has an abnormality in the horizontal corneal axis we prescribe the cylindrical lens with a vertical axis and vice versa as the cylindrical lens will refract light rays that fall perpendicularly on its surface

# Astigmatism

Light rays aren't refracted uniformly in all meridians due to non spherical shape of cornea or lens, parallel rays passing through these different planes are brought to different points of focus.

The cause of astigmatism is unknown. It is usually present from birth, and often occurs together with nearsightedness or farsightedness.

Astigmatism makes it difficult to see fine details, either close up or from a distance.

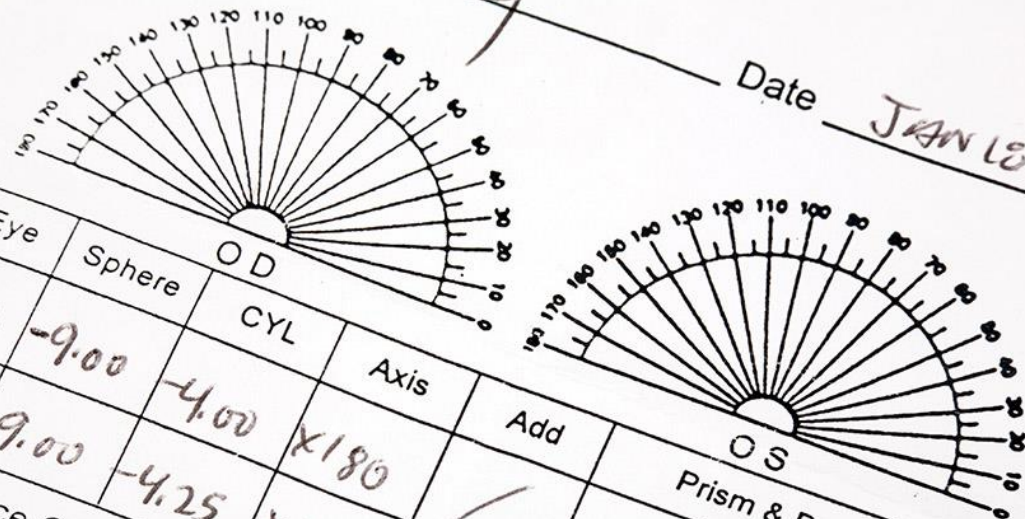
Corrected with a cylindrical lens(planoconvex<sup>(+)</sup> or planoconcave<sup>(-)</sup>) or refractive eye surgery.

Astigmatism is a common eye problem that can make your vision blurry or distorted. It happens when your cornea (the clear front layer of your eye) or lens (an inner part of your eye that helps the eye focus) has a different shape than normal.



**\*\* You have to know how to interpret these \*\***

Date JAN 10/05



Eye	Sphere	OD	CYL	Axis	Add	OS	Prism & Base
O.D.	-9.00	-4.00	X180	/	/	/	20/25
O.S.	-9.00	-4.25	X10	/	/	/	20/30 +2

Distance Only  
Readers Only  
Bifocal

Progressive  
 Trifocal

prescription is not intended for O.D.

cornea



retina



Astigmatism  
only

cornea



retina



Myopia &  
Astigmatism

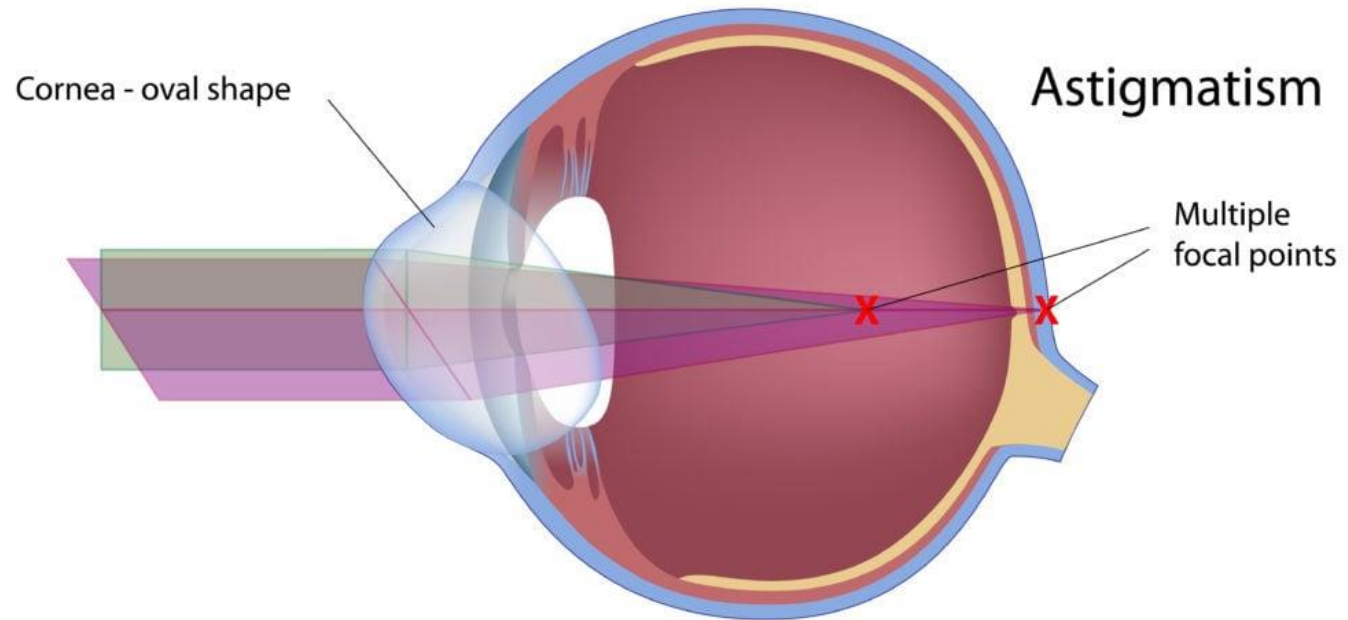
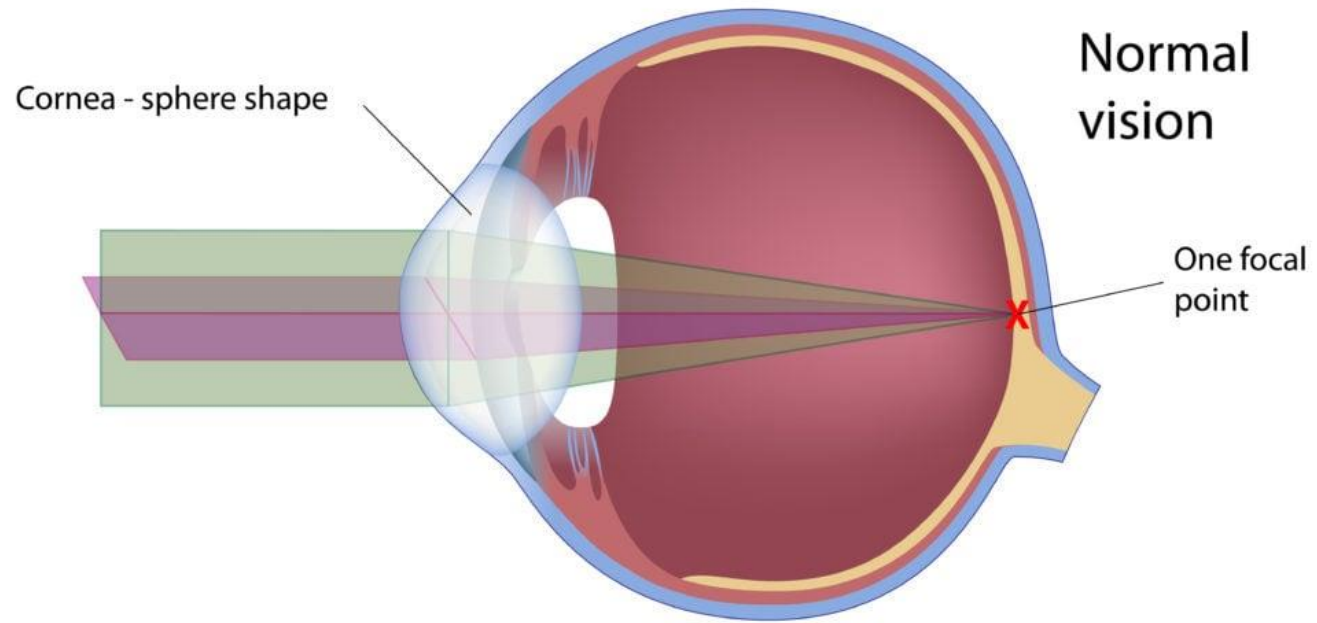
cornea



retina



Myopia only



# Keratoconus



# Any alternatives for glasses

- ▶ Contact lenses
- ▶ Corneal refractive surgery : Laser / LASIK
- ▶ Lens refractive surgery

# Contact lens

- ▶ Soft
- ▶ Rigid
- ▶ Complications:
  - giant papillary conjunctivitis
  - corneal hypoxia
  - neovascularization
  - Corneal abrasion
  - corneal ulcer
  - keratitis



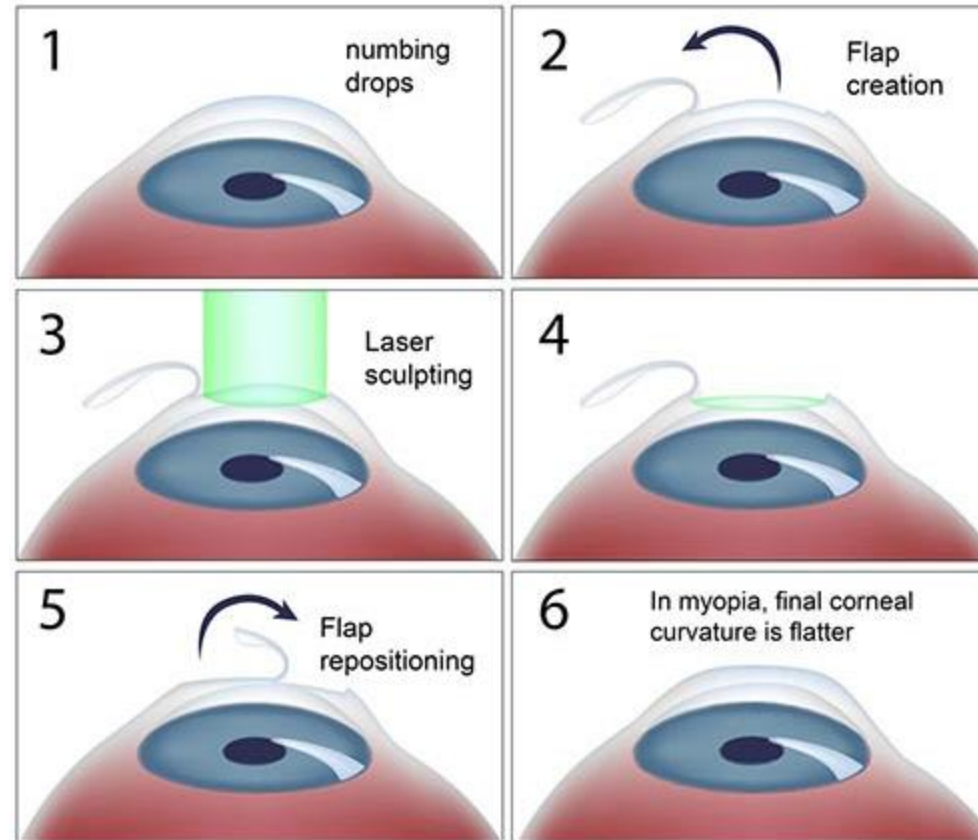


# PRK/LASIK

## LASIK EYE SURGERY

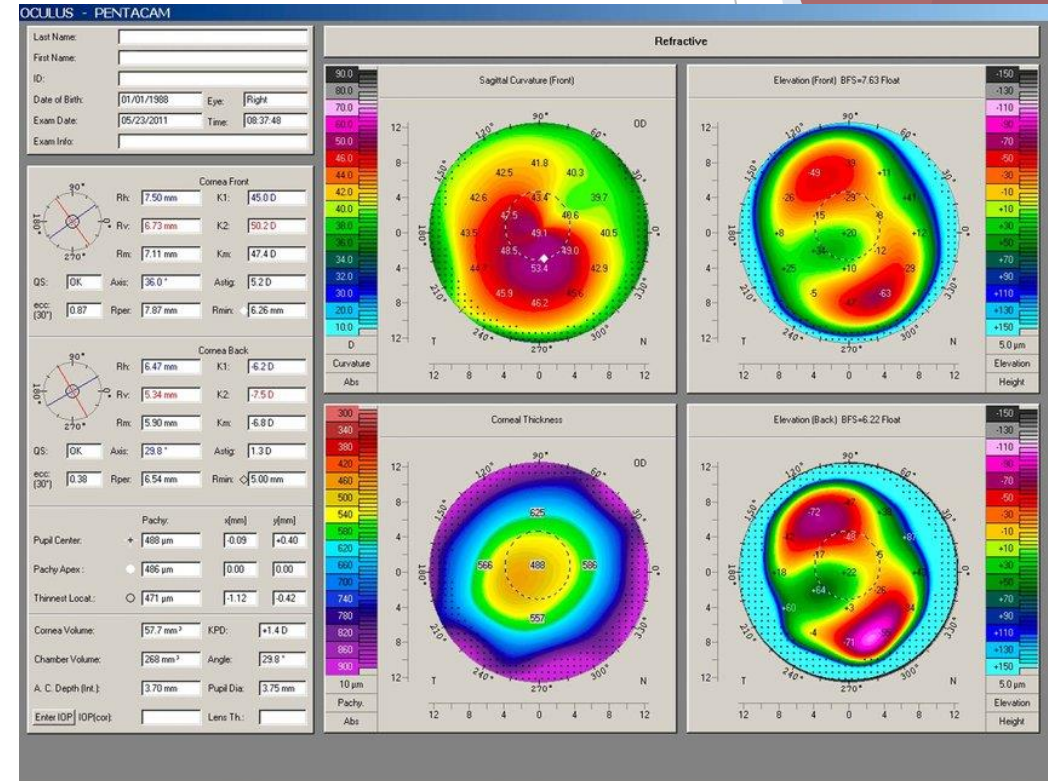
\*\* The key differences are that LASIK creates a flap to allow for quicker recovery time, while PRK removes the top layer of the cornea entirely. This is why LASIK has a much speedier recovery time of a few days, or even hours, compared to up to a month for PRK.

\*\* PRK is preferable when there is a high risk of trauma to the head ( e.g: people joining the military)



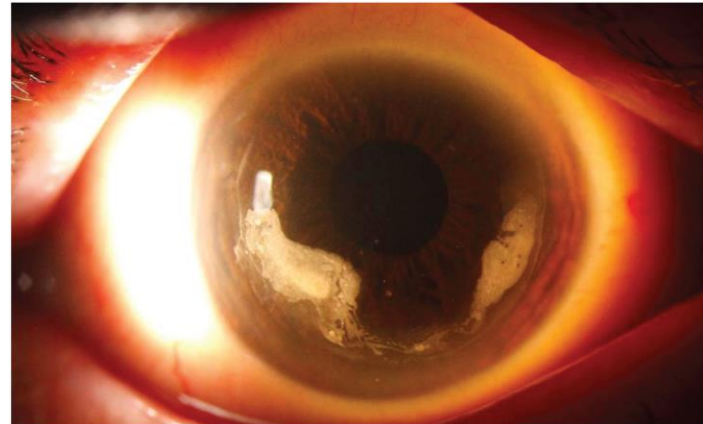
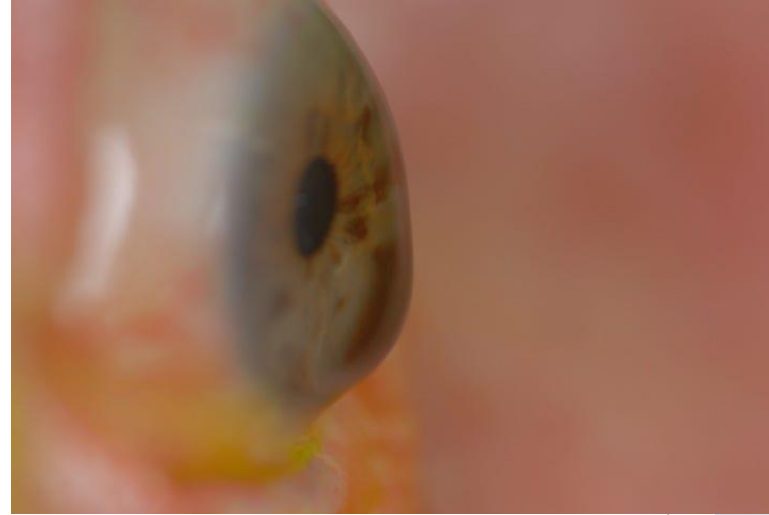
# Prerequisites for corneal refractive surgery

- ▶ Age
- ▶ Stability
- ▶ Contraindications :
  - Collagen tissue disease
  - Pregnancy
  - Lactation
  - Keratoconus
  - Active corneal disease
  - Dryness
  - Etc



# complications

- ▶ Incomplete flap
- ▶ Free flap
- ▶ Flap subluxation
- ▶ Corneal opacification
- ▶ Corneal perforation
- ▶ Under/overcorrection
- ▶ Recurrence
- ▶ Corneal ectasia **Keratoconus**
- ▶ etc



All photos: Edward Manche, MD

Figure 1. Extensive epithelial ingrowth resulted in elevation, opacification and scalloping of the LASIK flap margin in the right eye of of this patient.

THANK You 😊