CNS

PHYSIOLOGY

4

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Easing in:

you already know that we have general (pressure, touch, temperature, etc) and special (vision, audition, olfaction, etc.) types of sensation.

Receptors of special types of sensation are generally located in specific areas:

- vision—eyes (retina)
- hearing—ears
- taste—dorsal part of the tongue and pharynx
- smell—nose
- equilibrium—ears

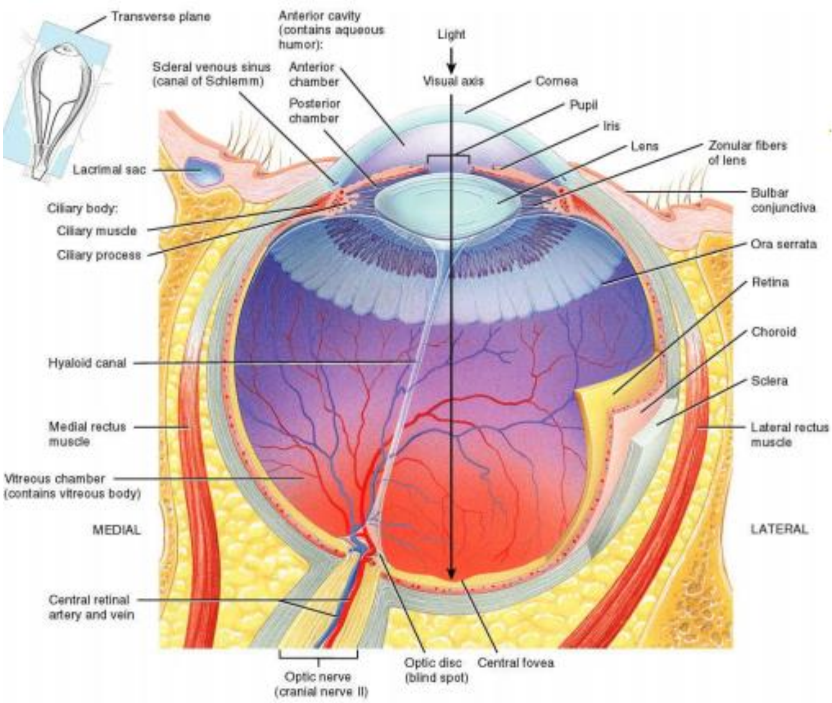
Vision

Wandering down memory lane: a flashback to MSS

- We'll first start by going over the anatomy of the eye.

The eye consists of three layers:

- **the first and outermost layer is the sclera**, it surrounds 4/5 of the eyeball, as the last 1/5 is made up of **cornea** anteriorly.
  - The sclera is made of very dense connective tissue.
  - The cornea is a transparent, avascular part; its thickness is important to determine if one can undergo **laser surgery** or not since **it** involves changing of corneal thickness to correct the visual abnormality.



- **Interesting about the cornea:** It's not exposed to the immune system! thus it doesn't have an antigenic activity, which facilitates corneal transplantation.

- **the middle layer is the choroid**, it's very vascular and continuous anteriorly with the **ciliary body**. A part of **it** is the ciliary muscle which continues anteriorly as the iris. And as you know the iris is the colored part of the eye and it has a hole called the **pupil**.
  - Connecting the ciliary body and the lens' capsule are the suspensory ligaments, which through the work of the ciliary muscle change the shape of the lens.

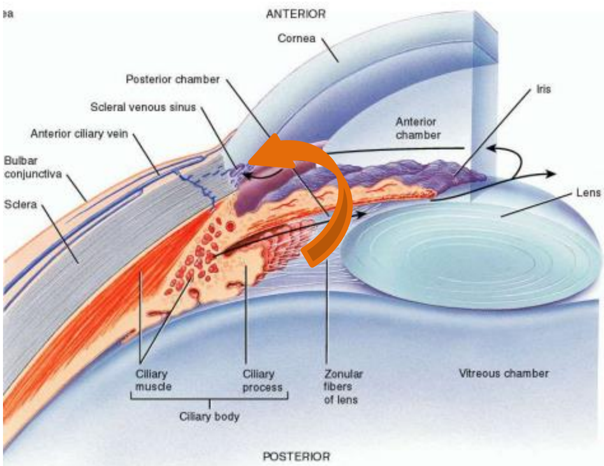
- The lens is made up of multiple layers of protein, and it’s flexible; it has some fluidity that allows it to be pressed into a flatter shape (less convex) or into a fatter shape (more convex), depending on the capsule tightness around it.
- The lens also divides the eyeball into 2 cavities, one that lies between the lens and cornea called the **anterior cavity**, and one that extends behind to the retina called the **posterior cavity,** and the two are connected through the pupil**.**

- The anterior cavity: is further divided into 2 chambers, anterior to the iris, and posterior to the iris -between the lens and the iris-
- It contains a fluid called the aqueous humor which gives it great importance, since this fluid is the nutrition provider to the avascular cornea.

- The posterior cavity fluid is called the vitreous humor and it’s derived from the embryonic mesenchyme.

Fluid System of the Eye

- The intraocular fluid keeps the eyeball round and distended.



As we mentioned we have 2 fluid chambers:

1. Aqueous humor which is a freely flowing fluid in front of the lens.

It’s almost always in a constant dynamic amount, because it gets produced by the ciliary processes of the ciliary body at a rate of 2-3 microliters/min then it flows between the ligaments of the lens, through the pupil into the anterior chamber, goes between the cornea and the iris, through a meshwork of trabeculae to enter the canal of schlemm which empties into aqueous veins and then into extraocular veins.

2. Vitreous humor which is a gelatinous mass with little flow of fluid, derived from the embryonic mesenchyme (doesn’t get renewed like the aqueous) lies behind the lens.

Intraocular Pressure

- Normally it is 15 mm Hg with a range of 12-20 mm Hg.
- The level of pressure is determined by the resistance to outflow of aqueous humor through the canal of Schlemm and the amount of its production.
- An increase in intraocular pressure caused by an increase in resistance to outflow of aqueous humor through the canal of schlemm can subsequently cause a form of damage to the optic nerve resulting in a condition called Glaucoma.
- And this can cause blindness due to compression of the axons of the optic nerve.

- The inner most layer is the retina, it's a very important layer as it's a neural layer that develops from ectoderm and contains the **visual receptors**, which can be divided into two types, rods and cones.
- In the central part of the retina (**macula lutea**), there's a slight depression called (**fovea**), which has the highest concentration of cones receptors that're important for sharp color vision and highest acuity of vision.
- The retina consists of six layers, only one of which contains light-sensitive photoreceptor cells (the outermost layer), and Light must pass through the overlying layers to reach them. However, in the central fovea, the inner layers of the retina are absent, so the light has an almost unrestricted passage to the cone cells. This meets its function as it is the point of sharpest vision.
- Another part of the retina is the **optic disc** (superomedial to the central fovea), where optic nerve fibers pass through along with retinal artery & veins. It is a blind spot (no rods and cones).

  Retinal vessels are the most superficial vessels in our body, and we can visualize them with ophthalmoscopy. We can examine them in cases like atherosclerosis.

- The vitreous humor is the pressing force that keeps the retina and choroid adherent together -it's important since the retina depends on the choroid for its nutrition-
- It may leak sometimes due to trauma, between the retina and choroid separating them, and causing what's known as retinal detachment.
- Retinal detachment causes the receptors on the retina to separate from the choroid which is what keeps them alive, and this separation eventually leads to neural death, ultimately causing blindness.
- Retinal detachment would actually be one of the very few ophthalmic emergencies. It has to be reattached in less than 48 hrs or the patient loses sight.

A visit to the physics world

Refractive index

- Speed of light is **greatest in air*** with a magnitude of nearly 300,000 km/sec. logically, light speed decreases when it passes through another transparent substance.

- When light travels **between two different media it refracts** (gets bended) due to this change of speed.

- **The refractive index** is the ratio of the speed of light in air to the speed of light in the substance.

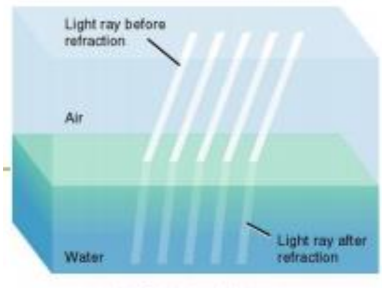
$$\frac{speed\ of\ light\ in\ air\ (300,000Km/s)}{speed\ of\ light\ in\ the\ substance}$$

- **e.g.** speed of light in substance = 200,000 km/sec,
  R.I. = 300,000/200,000 = 1.5.

- Since the speed is fastest in air, this means the index would always be 1 or more

But what IS refraction?

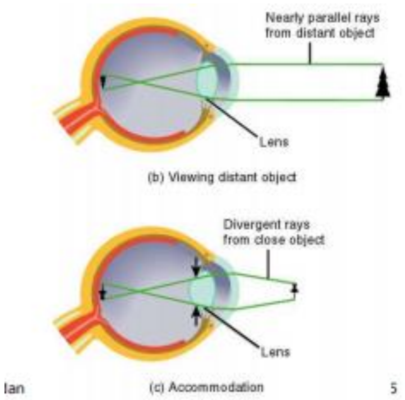
It's Bending of light rays through an angulated interface between two media with different refractive indices.



(a) Refraction of light rays

You can think of the refractive index as a mathematical representation of an intensive physical property of the substance (first year flashbacks 🙂), as it depends on its density. It means, 'how many times slower light will be in this substance compared to its speed in air' *for simplicity we said 'air', but the accurate calculations are compared to light's speed in 'space' or 'vacuum'

- The degree of refraction and the resulting degree of angulation of light increases as the **difference in their R.I.** increases.

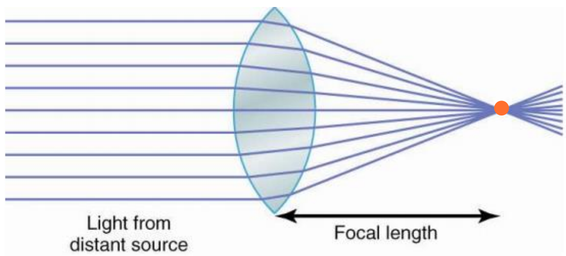


- The features of the eye (like cornea, lens, humor) have different R.I. and thus they cause light rays to bend.
- This results in light rays eventually being focused on the retina whether the object is near ('point source') or far ('parallel lines'). ***discussed soon**

Refractive principles of a lens

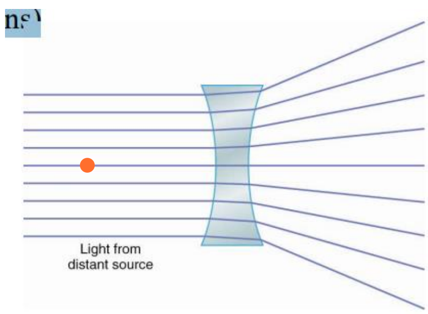
- There're two major types of lenses

1.Convex Lenses that focus light rays



- Also known as converging lenses, because they converge (collect) light rays in the **focal point**.
- **Images in this lens are seen upside down**

2.Concave Lenses which diverge (separate) light rays



- Also known as diverging lenses
- There isn't a true focal point for this lens, but we can imagine that there's one **here (orange point)**

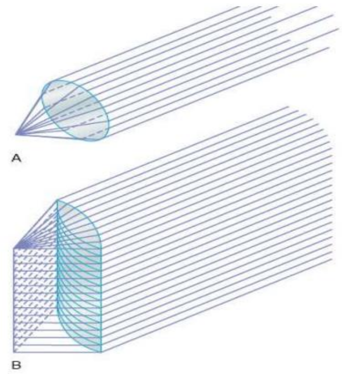
- **the direction of the focal point is different in each lens**, that's why we say that a convex lens is a positive lens (the focal point is in front of it) , while the concave lens is a negative lens (the focal point is behind it) since it diverges the rays away.
- **Focal length of the lens:** The distance between the center of the lens and the focal point.

- Keep in mind that we **don't actually have diverging lenses in our eyes**, it's just that we change the amount of converging refraction to suit the state of the image we're trying to see. (we need to FOCUS images)

We also have other types of lenses!

Spherical Lenses that converge light in a **'Focal point'**

Cylindrical Lenses that converge light in points on a **'Focal line'**



What is the Focusing Power of the lens?

It's a property of the lens that indicates how **capable the lens is of changing the courses** of light rays (bending them), in order for them to be focused in a certain point (positive power/ convergence) or separated away from a certain point (negative power/ divergence).

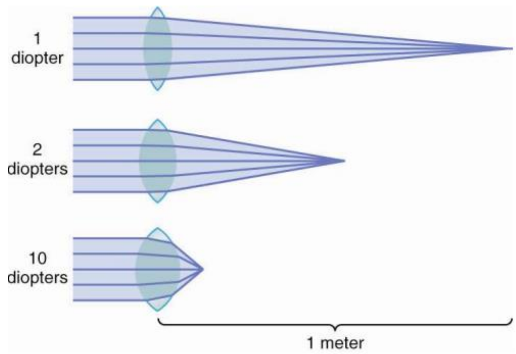
- **Conclusion: A shorter focal length indicates MORE power**

And of course, since we're still in the physics world, there's some math included :D

The unit used to express the power is called a **Diopter** NOT a Degree

$$Diopter = \frac{1}{(focal\ length\ in\ meters)}$$

- **1 diopter** is the ability to **focus parallel light rays at a distance of 1 meter** (a focal length of 1m)

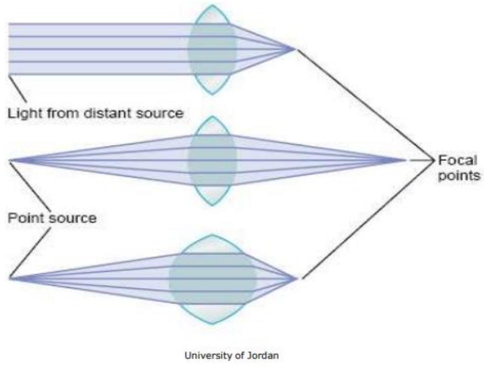


- **E.g.** If a convex lens has a focal length of ½ a meter, what would its power be?
  2 Diopters

› A Focal length of 10 cm = power of 10 diopters (pay attention to the units)

- The increase in convexity, increases the ability of the lens to bend the light in a smaller angle, thus **more convexity = shorter focal length = more power by the equation**

Notice here how the convexity of the lens also affects the refraction when the source of light is different in its location.



When the source of the light was in parallel lines (distant) a certain convexity was strong enough to refract it to an efficient length to be focused where we want it, however, when it was a point (near) it took more focal length to collect the focal point, and a considerable change in the lens' convexity was required to increase the power enough to achieve the right length.

- keep this in mind because it's what our eyes' lenses do!
- conclusion: changing the convexity of the lens changes the power (positive relation), and the focal length (inverse relation).

To focus an image on the retina our eyes have 4 requirements:

1.Light refraction or bending of the light by the refractive media – Cornea, Aqueous humor, Lens and Vitreous humor.

- The retina is considered to be 17 mm behind the refractive center of the eye (the focal length)
- Therefore, **the eye has a total refractive power of 59 diopters** (1000 mm/17mm)
  *That means If we replace the 4 media with one lens 'a reduced eye' it would have the refractive power of 59 (60) diopters.
- Most of the refractive power of the eye results from the surface of the cornea, which contributes around 42 diopters out of the total of 60 for all media, that's why the cornea is so important.

2. Accommodation:

Which is defined as an increase in the curvature of the lens for near vision.

- The near point of vision is the minimum distance from the eye an object can be clearly focused with maximum accommodation used. *discussed down

3. Constriction (meiosis) for near and dilation (Mydriasis) of the pupil for far.

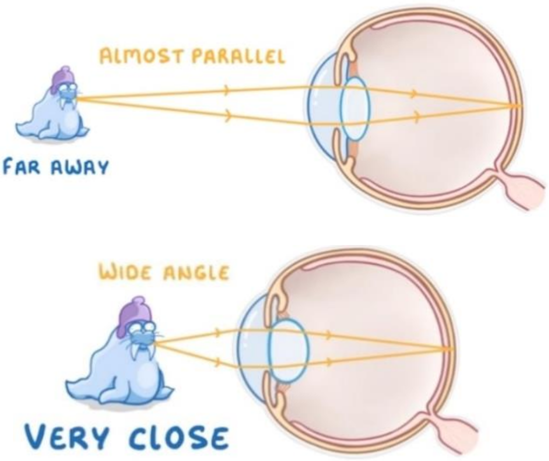
4. Convergence and divergence of the eyes for binocular vision.

Accommodation

- As we said, the retina is fixed 17 mm behind the refractive center of the eye. In order for us to see clear images, all light rays must be focused on the fovea of retina, at the focal length of 17 mm. however, not every object is placed on the perfect distance to be refracted on the retina by the resting state of the eye.

Elaboration:

The angle between light rays is narrower in farther objects, which means, the amount of refraction required is less; thus, a smaller convexity is needed (lower power), as the object gets nearer, the angle increases, and the power of the lens required is more.



Near objects for example, can be refracted to a focal point behind the retina (in resting lens state), and this creates a blurry image, and our brains HATE blurry images, that's where our hero (the lens) jumps in with accommodation:

- Usual Refractive power of the lens is 20 diopters, but it can be increased to 34 diopters by changing its shape - making it fatter (more convex), and **this is basically what accommodation is.**

Conclusion: Accommodation is necessary to focus the image on the retina.

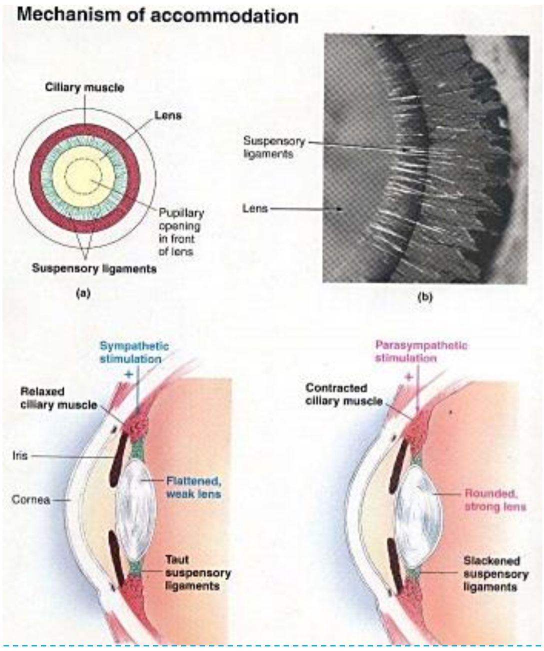
Side note: **because our lenses are convex, the image would be focused upside down on the retina.**

Mechanism of Accommodation

- The Lens is held in place by suspensory ligaments of the ciliary muscle which under normal resting conditions cause the lens to be **almost flat**.
- **Contraction of the ciliary muscle** attached to the ligaments pulls the ligaments forward and causes the lens to become fatter (more convex) which increases the refractive power of the lens.

Conclusion: **CON**traction – more **CON**vexity / **L**axity – **L**ess convexity

If you couldn't imagine it, the animation in "this" video might help.



Sympathetic causes relaxation in this muscle's case

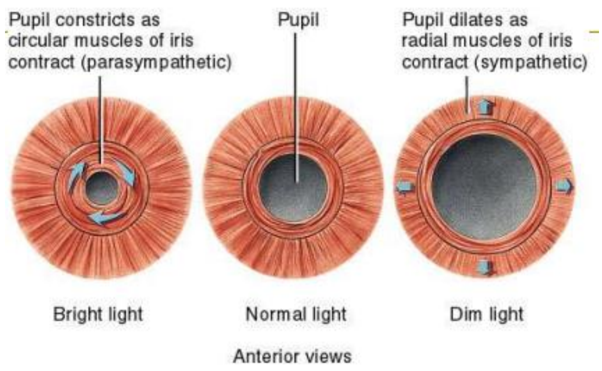
› The parasympathetic fibers of the 3rd cranial nerve (oculomotor) cause contraction of the ciliary muscle AND the circular iris muscles, which takes us to the third requirement →

Pupil light response

- The iris consists of two muscles:

› A **Circular muscle** that is supplied by **parasympathetic innervation**, and when contracted it **causes meiosis** (constriction of the pupil).

› A **Radial muscle**, that is supplied by **sympathetic innervation**, and when contracted it **causes mydriasis** (dilation of the pupil).



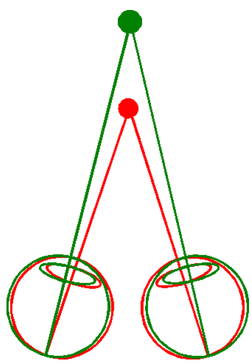
Aside from the pupil's response to dim and bright lighting; near objects reflect a lot of light compared to distant objects, this causes the pupil to constrict more when looking near and dilate more when looking at distant objects.

Convergence and divergence of the eyes for binocular vision

Our eyes are coordinated and move together in the same direction, right? Yeah

BUT sometimes when we're looking at objects that are in between our eyes, the light coming from them **doesn't exactly hit the retina in the right spot**, that's why we don't see our noses, to see them, axes of the eyeballs must change so the light hits the retina right.

Let's say we place our index in between our eyes, and move it back and forth, **Convergence** is what we do when we bring our finger closer, **our eyeballs rotate a bit medially**, and **divergence** is what we do when we take our finger farther, **our eyeballs rotate back laterally** to the middle of the orbit (but not outer than that because we're not chameleons)



› Note: if this does not happen correctly, double vision occurs, which is different from strabismus/ squint.

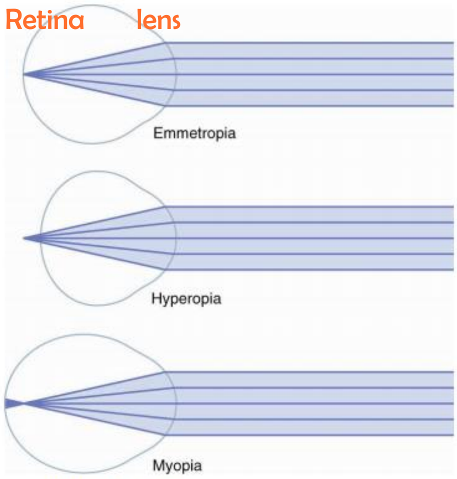
Now put on your doctor face because we're discussing some issues

Presbyopia (aging associated far sightedness)

Presbyopia is the **Inability to Accommodate**

› It's caused by progressive denaturation of the proteins of the lens making the lens less elastic.

› Begins about 40-50 years of age.



University of Jordan

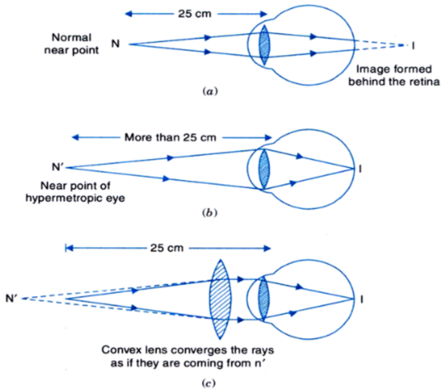
Errors of refraction

- Are two, **Myopia** which is **near sightedness** and **Hyperopia** which is **far sightedness** (also called hypermetropia).

The **Emmetropic** eye is a **normal eye**, in which the image is always focused on the retina.

1. Far Sightedness

In certain cases, the distance between the lens and the retina is shorter than normal, so the image gets focused behind the retina by the resting eye, resulting in far sightedness which for a certain extent can be fixed by increasing convexity of the lens.

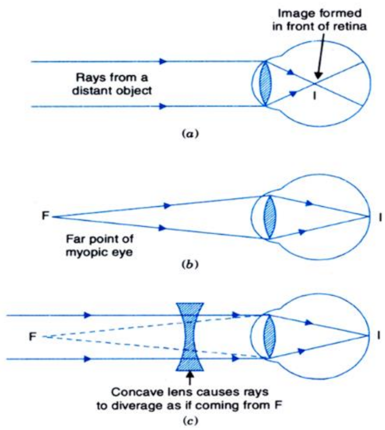


- Far sighted people like everyone else use accommodation to form images on the retina, however, because these people **start accommodation on distances that don't require accommodation in normal eyes**, by the time their eyes look at a distance let's say of 40 cm, they would've reached the maximum level of accommodation possible, and can't see objects that are closer than that.

- this **minimum distance they can see clearly at** is called **the near point**, for normal eyes this near point is less, about (25 cm) so these people can see farther objects, but they cannot squish their lens more to see closer objects.

- **Fixing the problem:** Because these eyes can't converge the light to the perfect degree and trying to do so overworks their ciliary muscles, they need something to converge the light a little so that their lenses finish the work instead of trying to do all of it, so logically, the lenses used in their glasses should be **CONVEX**, you're right!

2. Near sightedness



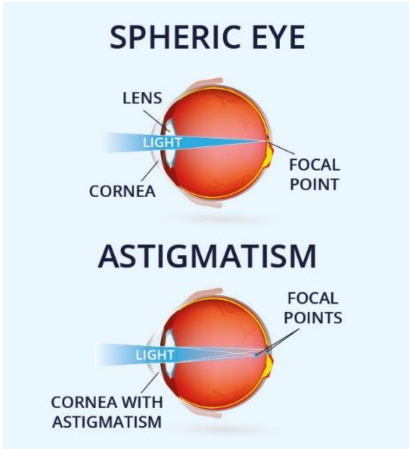
Myopia, however, is the opposite, the distance between the retina and the lens is more than normal, **so the focus is formed in front of the retina.**

- **Fixing the problem:** in myopia the patient cannot use accommodation to deal with the problem, because the lens at resting is in its least convex form (you can't flatten it more to see farther), and increasing convexity only makes it worse, so the only way to fix it, is with **glasses that diverge the light rays** (i.e. concave lens) so that the least convexity of the lens is strong enough to converge the rays to the prefect focal length. ***you can contact me if you don't get it :'(**

keep in mind that this is only one case, causes of myopia and hyperopia can be related to the position of the lens, its accommodation ability, its shape, and the horizontal diameter of the eyeball like the example we discussed.

other errors of vision:

Astigmatism



The cornea is made up of multiple spherical layers, and these intersect in one point, sometimes one of the planes isn't in line with the others, creating another point of focus, causing blurriness and double vision.

'unequal focusing of light rays due to an oblong shape of the cornea'

We fix it by using cylindrical lenses that help focus the wrong plane correctly.

Cataracts (الماء الأبيض-الساد)

'cloudy or opaque area of the lens'

- The lens can be analogous to egg whites, it's transparent, however, denaturation of the protein (coagulation) in the lens clouds it (it loses transparency) just like when boiling an egg!
- This creates the condition called cataract where there's no light passage, and in that case the lens needs to be replaced :'(

Visual Acuity Test (explained by the book)

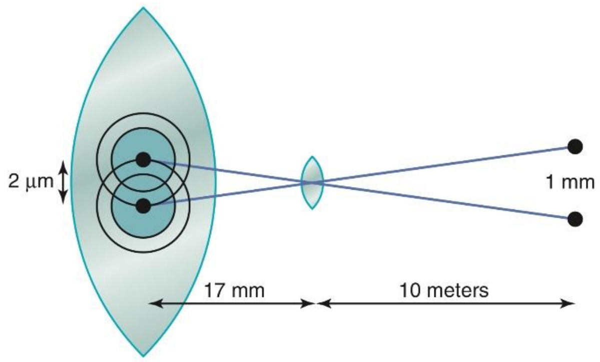


Figure 50-16. Maximum visual acuity for two-point sources of light.

It's used to test the **ability of the eye to discriminate details** or for simplicity 'to distinguish 'two points'', and it's expressed by degrees of angles.

As we know: To sense two points, they must hit two different receptors

Side point: the diameter of a foveal cone receptor is 1.5 micrometers

These two light points form an angle when they reach the lens, normally this angle is—1 min or less, abnormal cases have an angle of more than 1 min

Note: from all the units of angular measurement, we're familiar with the degree unit. Now, you need to know that each degree is divided into 60 minutes, and each minute is further divided into 60 seconds, which means that the degree = 3600 seconds.

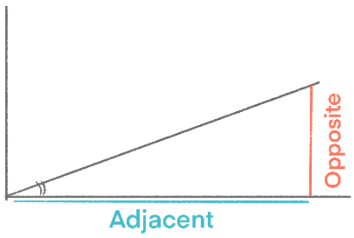
Elaboration: (the doctor didn't exactly explain it like this, so just understand, memorize green)

A person can normally distinguish 2 separate points if they lie **at least 2* micrometers apart on the retina**, the normal visual acuity of the human eye for discriminating between two-point sources of light is about 25 seconds of arc (25/3600 of a degree).
* Why 2 micrometers ?
To ensure that it is larger than the foveal cone receptor diameter which is 1.5 micrometers.

That is, when light rays from two separate points strike the eye with an angle of at least 25 seconds between them, they can usually be recognized as two points instead of one.

Meaning that a person with **normal visual acuity** looking at two bright points of light **10 meters away** can barely distinguish the spots as separate entities when **they are 1.5 to 2 millimeters apart.**

Where did those numbers come from?



I'll tell you roughly how. Remember the tangent (الظل) equation of an angle? It equals the **opposite side** over the **adjacent side**.

Now if we know that the opposite is 1.2-2 mm (distance between the 2 points) and the adjacent is 10000 mm (10 m) (distance between the eye and 2 points) we can tell that the angle is tan inverse of this ratio which is 25 seconds here.

From these distances we can find the angle and know whether it's normal or not!

Clinically, what we do is use a chart (Snellen's),

- This chart has letters with details, we set a person 6 meters away from it, then we go down through it until the person can't see clearly anymore, **(most people can see all of the chart levels)**
- If they stopped seeing clearly at let's say the level of 6/12 this means, this person can only at 6 meters see what normal eyes see at 12 meters, meaning, in order for this person to see an object of a certain size that's 12 meters away, it has to be brought 6 meters closer. And we say his sight is 6/12.

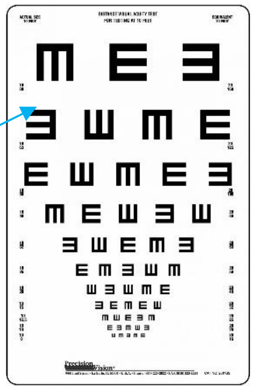
💡 The size of the chart is also standardized to yield right results.

Interpretations:

- 6/6 → ability to see letters of a given size at 6 meters, when they can't be seen on a distance more than 6 meters in a normal eye anyway.
- 6/12 → what a normal person can see at 12 meters, this person must be at 6 meters to see.
- 6/60 → what a normal person can see at 60 meters, this person must be at 6 meters to see.

💡 Defects here are different from refraction errors, but can be dealt with by the same fixing methods, because, what a person with a lowered acuity needs, is for the points to be further away from each other, and what does separation better than diverging lenses?
Fixing: Biconcave diverging lens (negative lens)

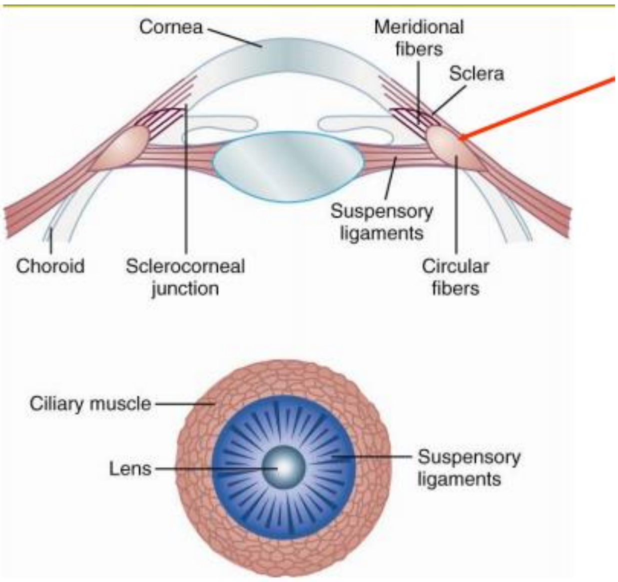
Another chart used for the same purpose is called the tumbling E chart:



I wish you the best of luck

Extra slides diagrams I didn't find necessary:

Accommodation



Myopia and hyperopia