Physiology

Modified no.6

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الدكتور: فاطمة الريالات

Neurophysiology

Color code

- Slides
- Doctor
- Additional info
- Important

Vision II

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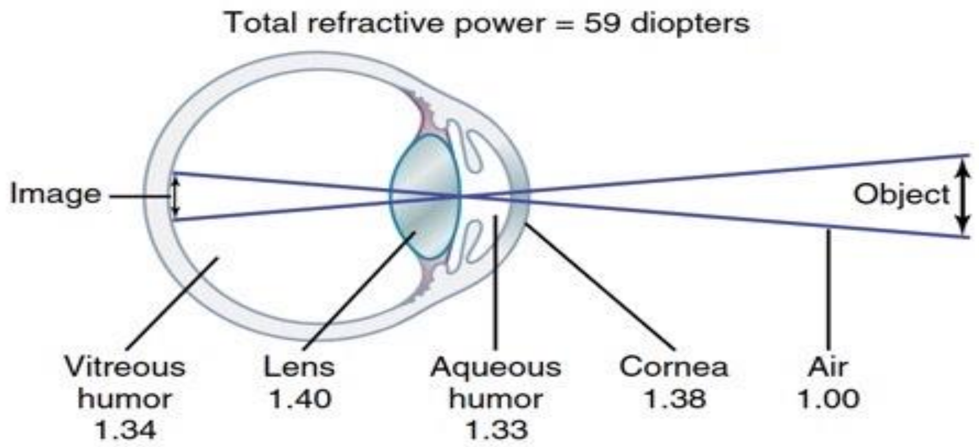
Refraction

- The lens system of the eye is composed of four refractive interfaces each with its own refractive index:

- (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.
- (4) the interface between the posterior surface of the lens and the vitreous humor.



Refraction

- To simplify things, we calculate a single refractive power for all interfaces of the eye. This is called the reduced eye. If the focal length of the reduced eye is 17 mm = 0.017 m, then the refractive power is 1/0.017m = 59 diopters.
- In the reduced eye, a single refractive surface is considered to exist, with a total refractive power of 59 diopters when the lens is accommodated for distant vision.
- About two-thirds of the 59 diopters of refractive power of the eye are provided by the anterior surface of the cornea (not the lens) because the cornea is more curved than the lens. [the higher the curvature, the higher the refractory power]
- However, the principal reason for this phenomenon is that the refractive index of the cornea is markedly different from that of air, the difference in the refractive index between the cornea and air = 0.38, which is higher than the difference between any other two interfaces in the eye, eg: aqueous humor and lens.

Accommodation

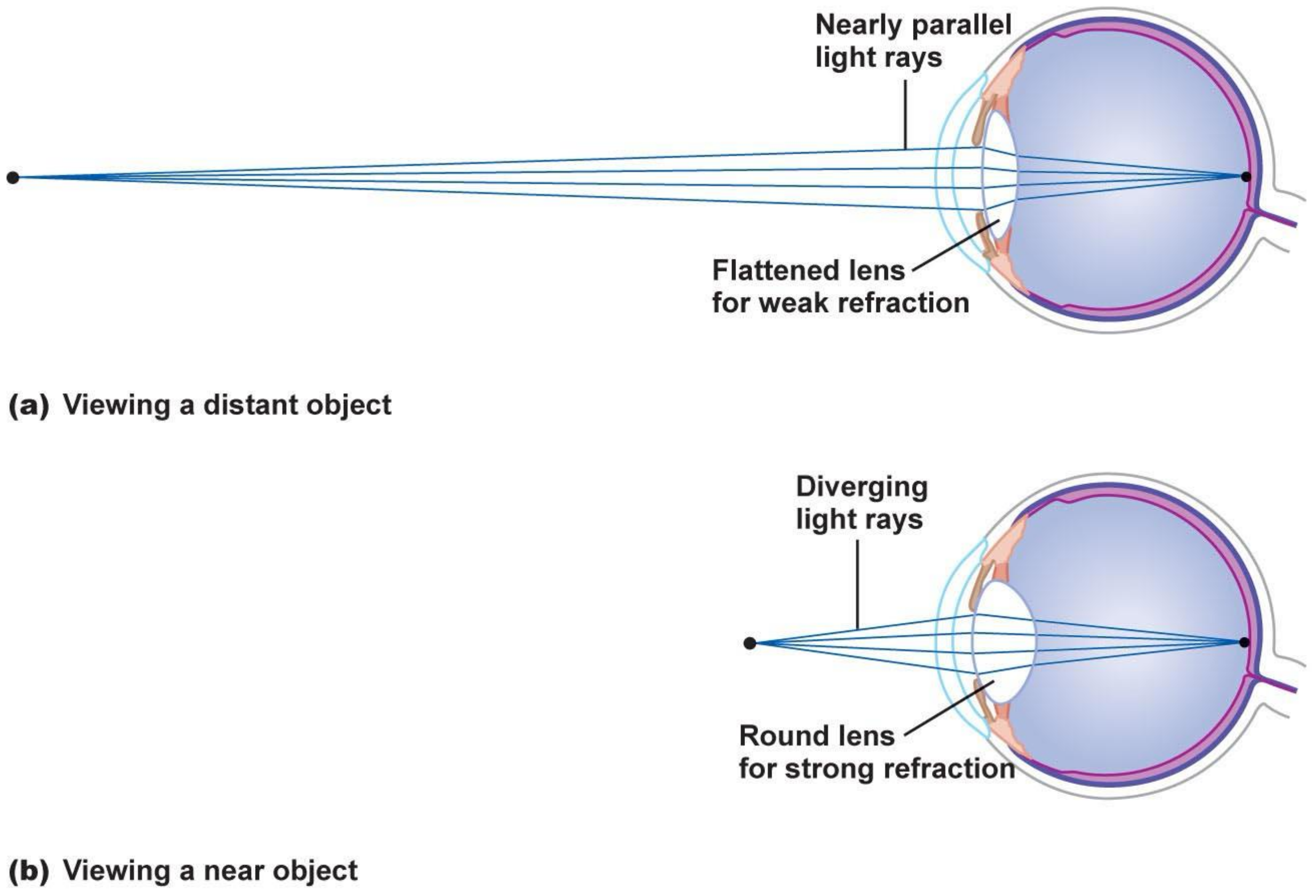
- However, the importance of the internal lens is that in response to nervous signals from the brain, its curvature can be increased markedly to provide "accommodation,"

- The ability to adjust the strength of the lens is known as accommodation.
- This allows us to adjust our vision for far and near objects by changing the curvature of the lens.

Accommodation

- In a young person, the lens is composed of a strong elastic capsule filled with viscous, proteinaceous, but transparent fluid.

- However, about 70 suspensory ligaments attach radially around the lens, pulling the lens edges toward the outer circle of the eyeball.
- These ligaments are constantly tensed by their attachments at the anterior border of the choroid and retina.
- The tension on the ligaments causes the lens to remain relatively **flat** under normal eye conditions.



- The light that comes from a far object is parallel by the time it reaches the eye, so it is easy for the convex lens to focus it on the cornea.
- On the other hand, the light from a near object is divergent and hasn't yet become parallel.
- Therefore, we need a high refractive power to focus the light from the **near** object, and this is achieved by increasing the curvature, decreasing the focal length and increasing the refractive power.

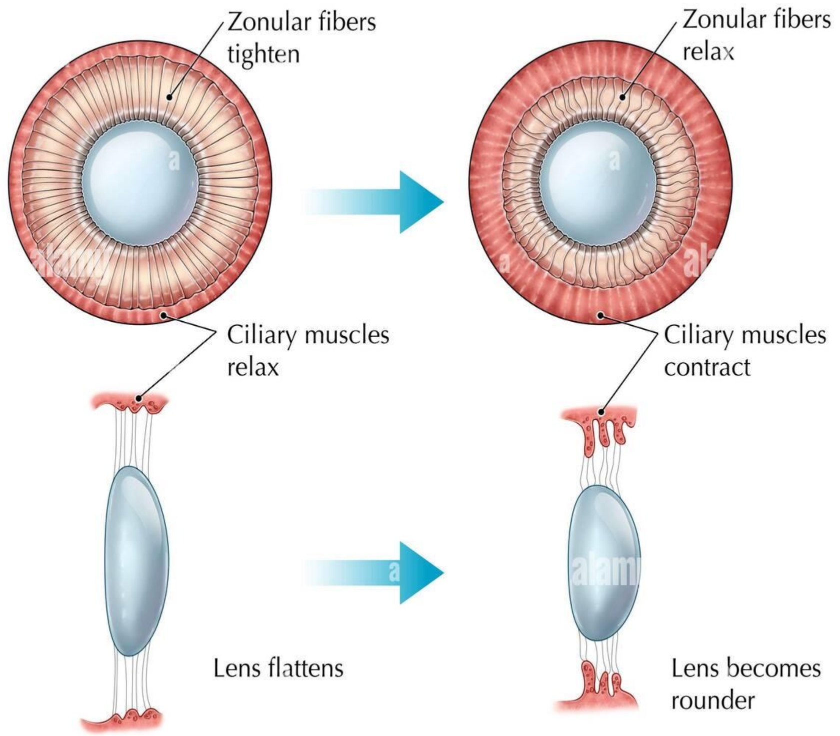
Accommodation

- Also located at the lateral attachments of the lens ligaments to the eyeball is the ciliary muscle, which has two separate sets of smooth muscle fibers—meridional fibers and circular fibers.

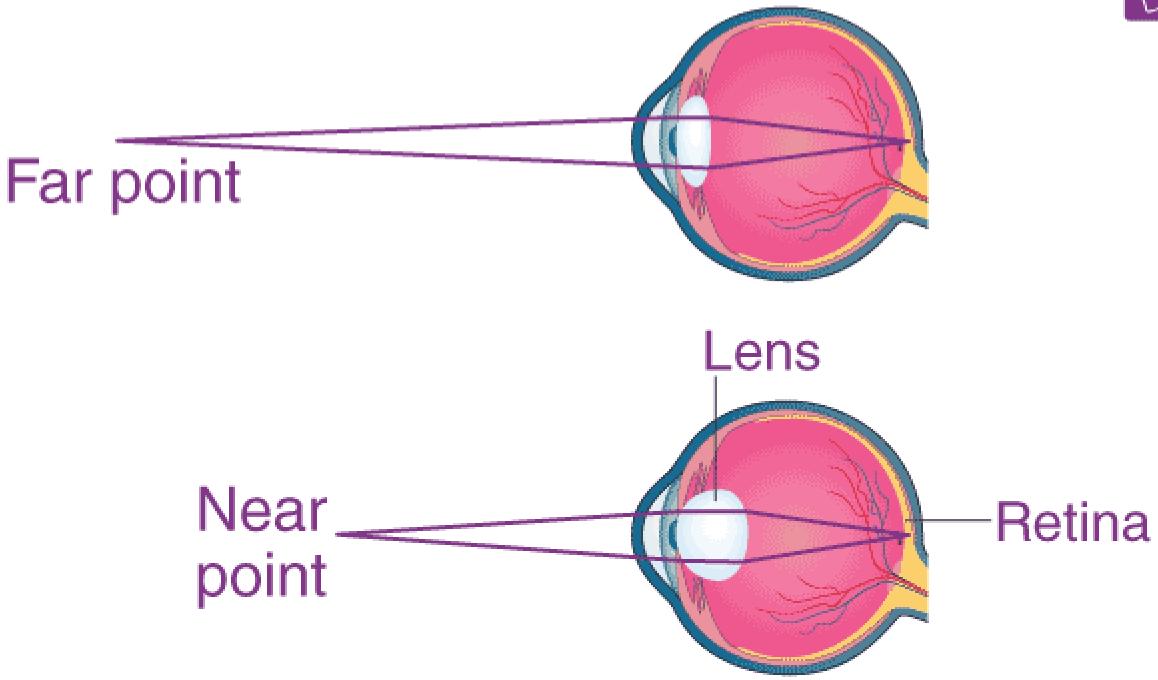
- Contraction of either set of smooth muscle fibers in the ciliary muscle relaxes the ligaments to the lens capsule, and the lens assumes a more spherical shape because of the natural elasticity of the lens capsule.

*Refer to the image in the next slide

And think about the ciliary muscles as they're sphincters



Additional Image showing the difference between a relaxed ciliary muscle (left) and a contracted one (right)



Additional Image showing the accommodation of the lens.

Notice how in the second image, the lens adjusts for a **closer** object by increasing its **curvature** which increases the **refractive power**.

Accomodation

- Ciliary muscle is controlled almost entirely by parasympathetic nerve signals transmitted to the eye through the third cranial nerve from the **third nerve** [oculomotor not optic] nucleus in the brain stem.

- Stimulation of parasympathetic nerves contracts both sets of ciliary muscle fibers, which relaxes the lens ligaments, thus allowing the lens to become thicker and increase its refractive power.

To recap:

- Far obj --> parallel rays --> weak refraction power is needed --> flattened lens --> ciliary muscles relax --> suspensory ligaments contract.

- Near obj --> divergent rays --> strong refraction power is needed --> rounded lens with high curvature --> ciliary muscles contract --> suspensory ligaments relax. [accommodation happens here].

Near vision

- Adjustment for near vision can be achieved by three methods:

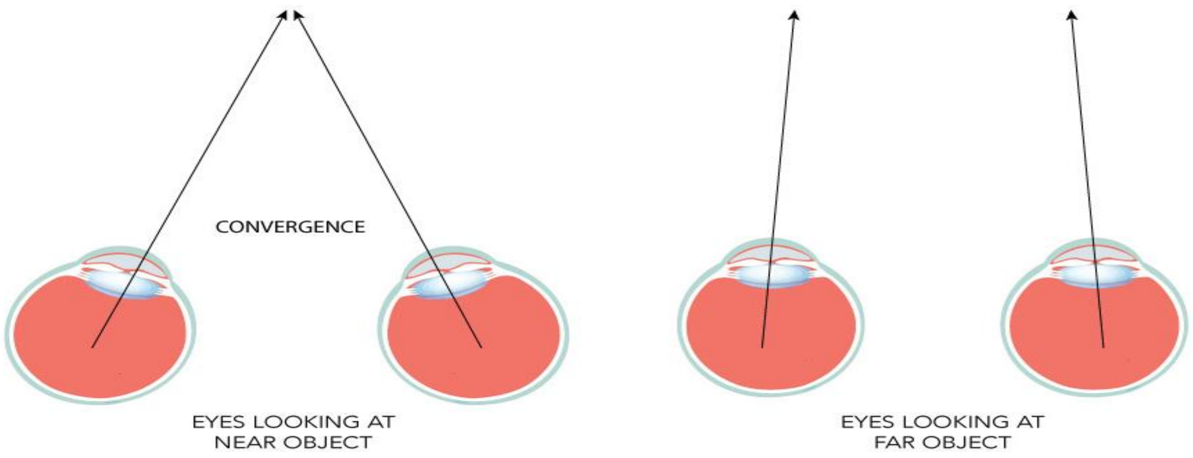
1) Accommodation (which we talked about)

2) Pupillary constriction: when the pupil constricts (myosis), it allows less light to enter the eye making it easier to converge the light. Constriction of the circular muscle of the iris allows for this adjustment.

Light entering through constricted pupil (above) vs through relaxed pupil (below)

3) Convergence:

- When looking at a far object the light rays reach the center of the retina, and photoreceptors will transduce the rays to the CNS.
- When the signal reaches the visual cortex there is a specific area that adds the images from each eye together. If they match, I can see the image as one despite we have two eyes.
- When looking at a near object, the light rays will be divergent and will not reach the center of the retina. When the signals from each eye reach the cortex, they cannot be added to form one image. This will cause double vision (diplopia).
- To adjust for this, the eyes will rotate medially (as in the image on the left) so that the light rays reach corresponding points in the retina and form one image. This is what happens when you bring your finger between your eyes.

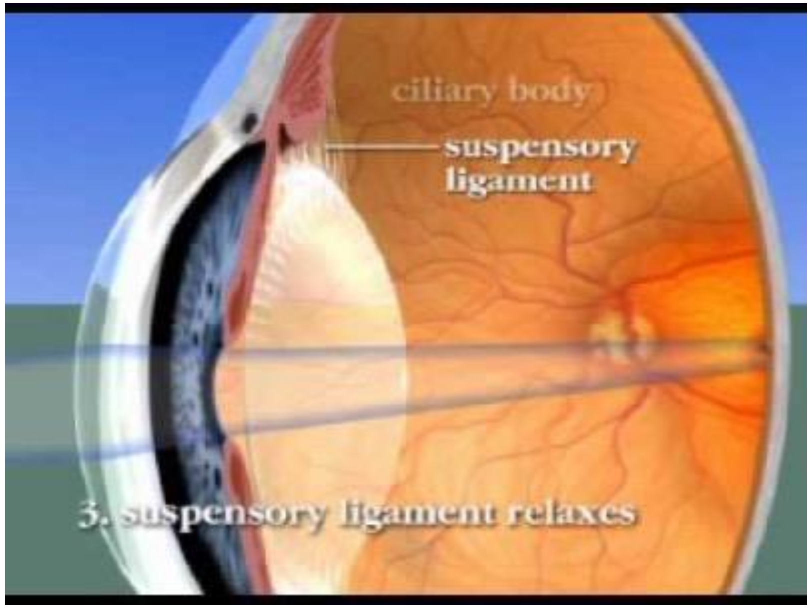


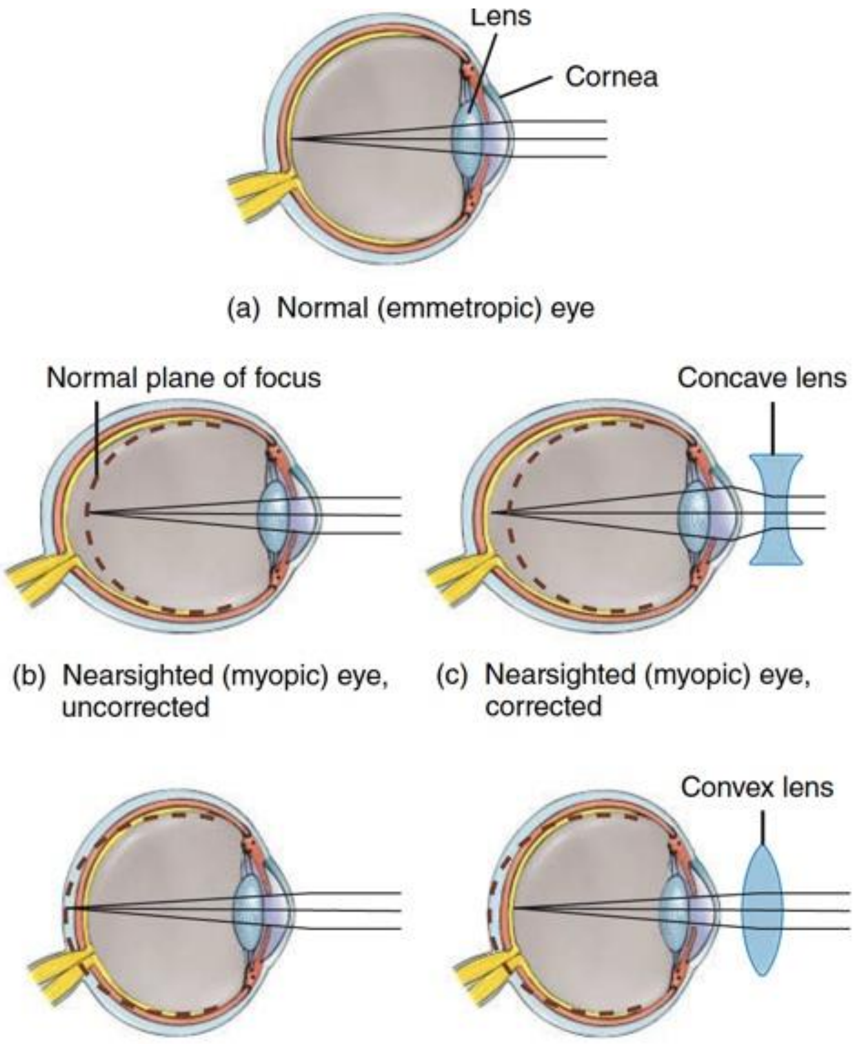
Accommodation

- In children, the refractive power of the lens of the eye can be increased voluntarily from 20 diopters to about 34 diopters, which is an "accommodation" of 14 diopters.
- To make this accommodation, the shape of the lens is changed from that of a moderately convex lens to that of a very convex lens.
- As a person grows older, the lens grows larger and thicker and becomes far less elastic, partly because of progressive denaturation of the lens proteins. The ability of the lens to change shape decreases with age.
- The power of accommodation decreases from about 14 diopters in a child to less than 2 diopters by the time a person reaches 45 to 50 years and to essentially 0 diopters at age 70 years.
- Thereafter, the lens remains almost totally **nonaccommodating**, a condition known as **presbyopia**.

- Once a person has reached the state of presbyopia, each eye remains focused **permanently** at an almost constant distance; this distance depends on the physical characteristics of each person's eyes.

- The eyes can no longer accommodate for both near and far vision. To see clearly both in the distance and nearby, an older person must wear bifocal glasses, with the upper segment focused for far-seeing and the lower segment focused for near-seeing (e.g., for reading).





(a) Normal (emmetropic) eye

(b) Nearsighted (myopic) eye, uncorrected

(c) Nearsighted (myopic) eye, corrected

(d) Farsighted (hyperopic) eye, uncorrected

(e) Farsighted (hyperopic) eye, corrected

- A normally functioning eye which can accommodate is called an emmetropic eye.

- Pathological conditions related to refractive error:

1-myopia: larger eyeball or stronger lens with higher refractive power than ordinary ones, so the focal length is shorter.

-If it looks at **far** objects its lens with higher refractive power will do a **stronger convergence** of light rays, so the focal point becomes in **front of the retina**, so the image will be blurry (**blurred vision**).
-In far vision myopic eye is **non accommodated** and vision is not clear.

-In **near** vision eye is **non- accommodated** as its focal point is **on the retina,** so the lens doesn't need to accommodate because it's already highly converged, so it has a **clear vision**.
(this is nearsighted eye "قصر النظر" because close objects are seen clearly, but distant objects appear blurry).

-we correct the far vision of myopic eyes with **biconcave** glasses, to diverge light rays to increase the focal length and bring the focal point to the retina itself.

2-hyperopic: smaller eyeball or weaker lens than normal.

-in **far** vision the lens is not strong enough to do refraction, so the focal point becomes **behind the retina**. Hyperopic eye **accommodates for far** vision while normal eyes just accommodate for near vision. Far vision is clear in the hyperopic eye and has no problem.

-In **near** vision the lens **needs farther and farther accommodation but it's not enough** (so near vision is blurred and not clear).
Hyperopia is called farsightedness "طول النظر" because it describes a condition where distant objects are seen more clearly than near objects.

- **Biconvex** glasses can increase light conversion and correct near vision.
The solution may be glasses, surgery or contact lenses

- Contact lens will adhere to the interior surface so it nullifies the effect of corneal refractive power since it adheres to the cornea, furthermore it provides a wider field of clear vision than glasses because it's on the eye itself.
- with glasses you have to turn your head toward the objects to see them clearly, and you see things smaller than real size because the distance is about 1cm between eyes and glasses.
- the negative effect of contact lenses is having a higher infection rate than glasses, and higher eye dryness.

Optic disc

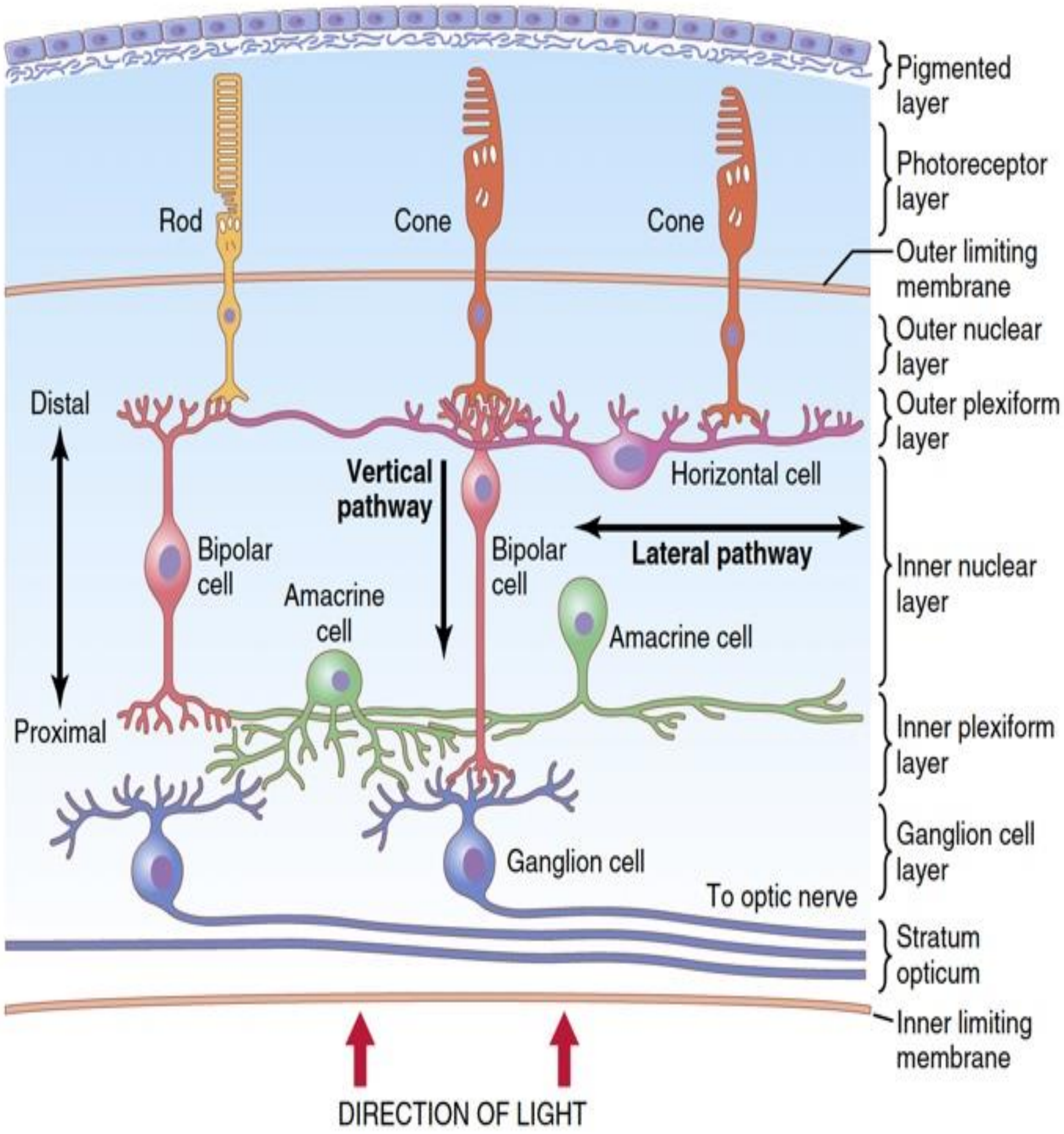
- True or false: all the retina has photoreceptors. (False) since there are no photoreceptors at the optic disc.
- You can't see any light rays at the optic disc.

- The point on the retina at which the optic nerve leaves and through which blood vessels pass is the optic disc.

- This region is often called the **blind spot**; no image can be detected in this area because it has no rods and cones.

- We are normally not aware of the blind spot because central processing somehow "fills in" the missing spot.

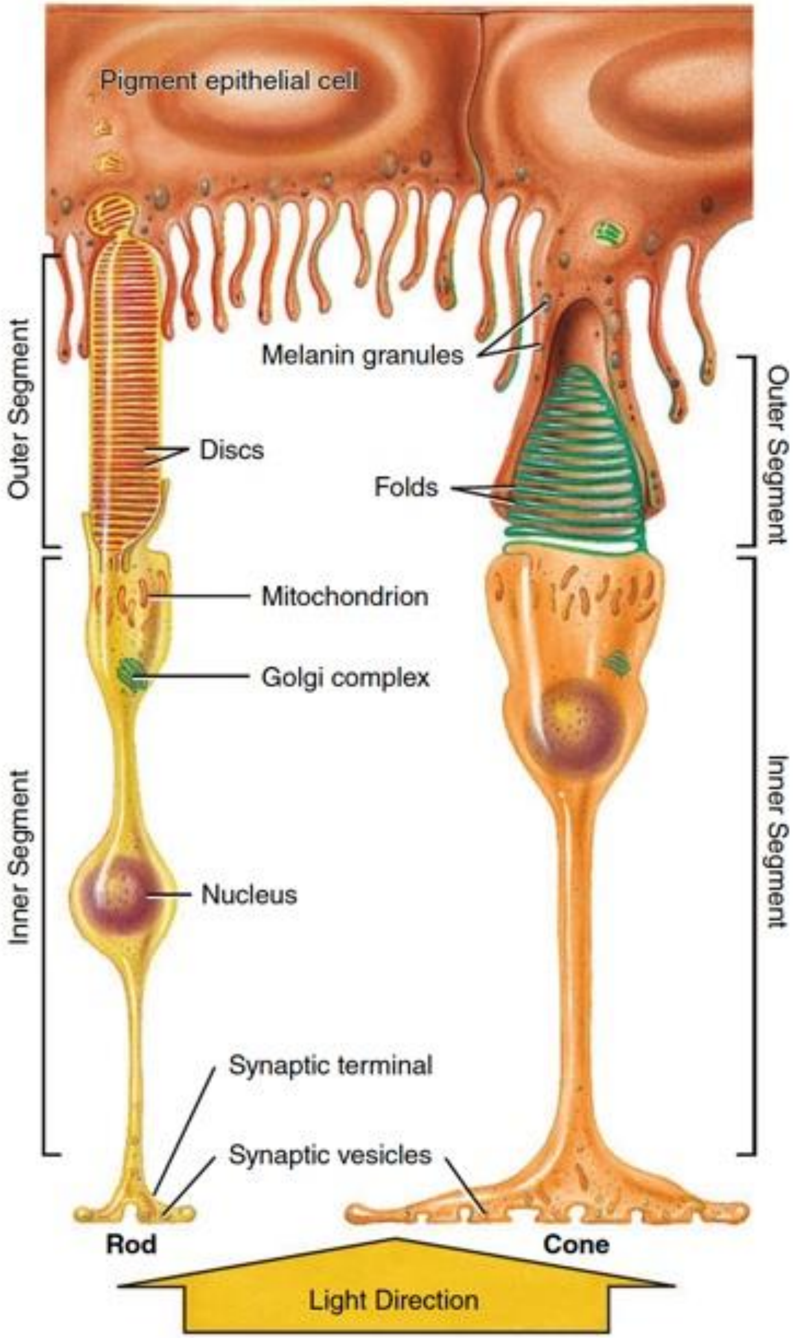
- Put this picture 10 cm in front of you, close your right eye and look at the cross with your left eye
- Stay focused on the cross and move the image slowly far away, you will reach a distance where the left circle disappear
- (if you succeed, congratulations!! You've experienced how the blind spot acts)



- The retina has mainly two layers: pigmented (outer layer) which is near the sclera, and neural (inner layer) which is near the vitreous humor.
- Light crosses vitreous humor and all retinal layers until the photoreceptors in the pigmented layers.
- The retina has 10 layers, it's not necessary to memorize them, but all their names do make sense.

Rods vs cones:

shape
location
number
sensitivity to light
visual acuity
color vision

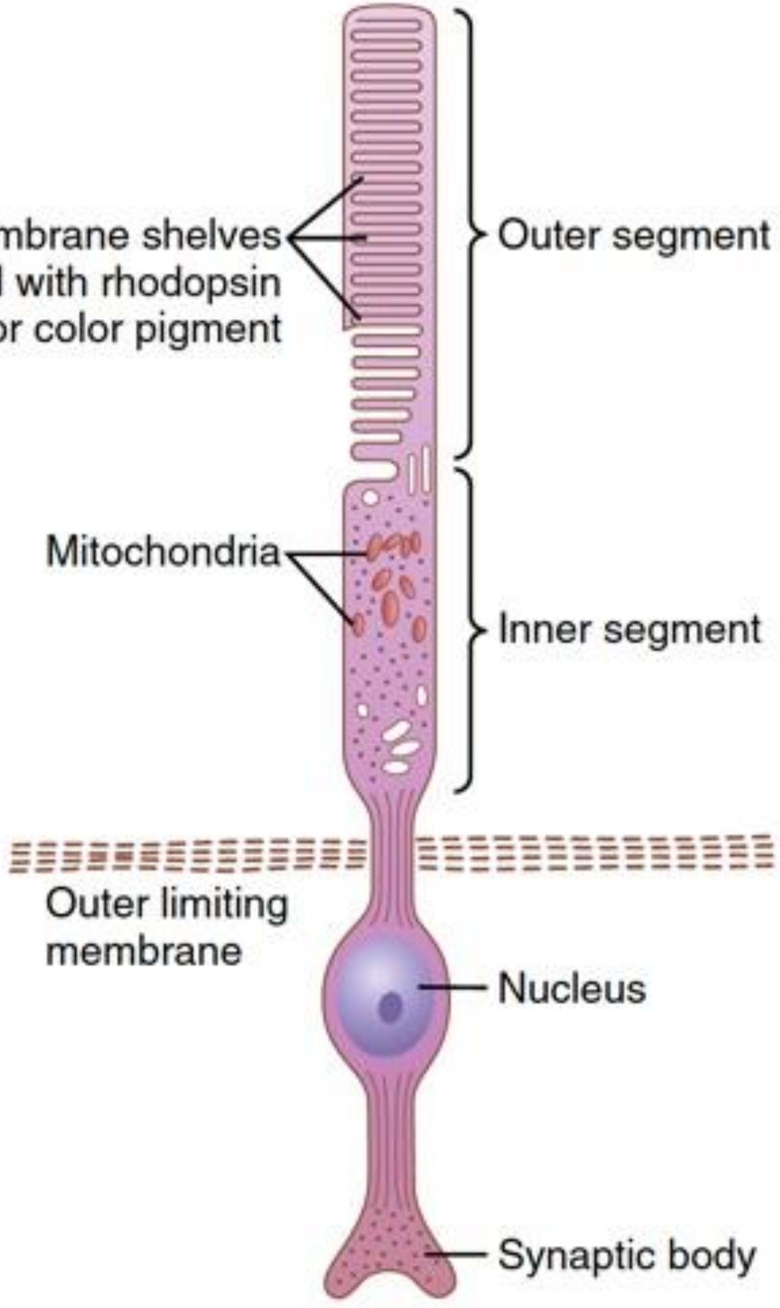


There are two types of photoreceptors (cones and rods) their shapes are just as their names.

-photoreceptor is divided into an outer segment, inner segment and synaptic part. Some people divide the inner segment into nuclear segment and inner part (don't care about it)

The outer segment has photosensitive chemicals that seem like discs on the top of each other
(these chemicals are membranous protein with vitamin A derivative)

-photoreceptor belongs to the specialized cells that will synapse with the first order neuron.



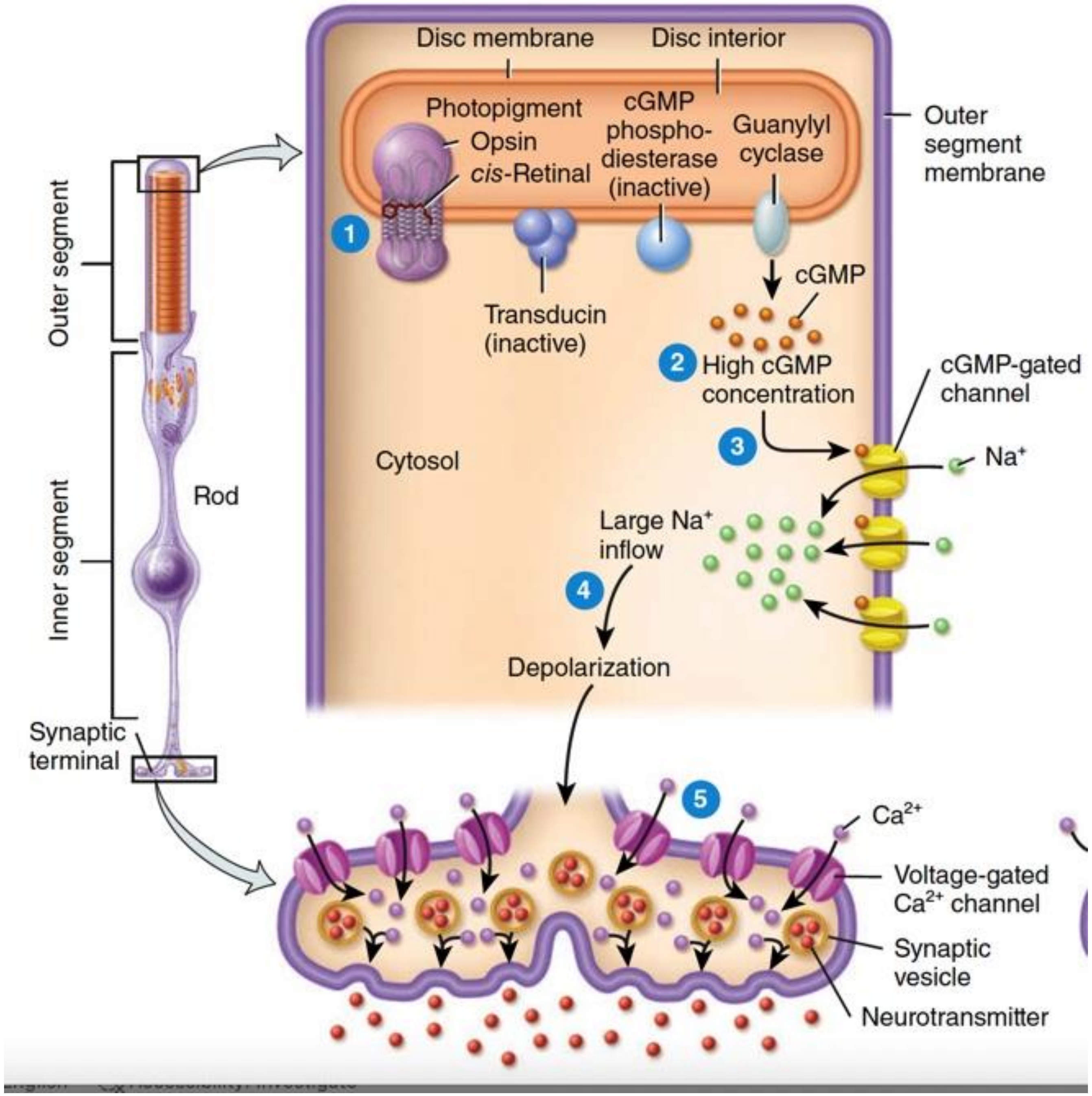
We will talk about rods.

Although cones have the same principle as rods, they have a little bit of difference in names.

*rhodopsin is the photo sensitive structure in reds, it's composed of:

1- scotopsin (trans membrane protein on the disc)

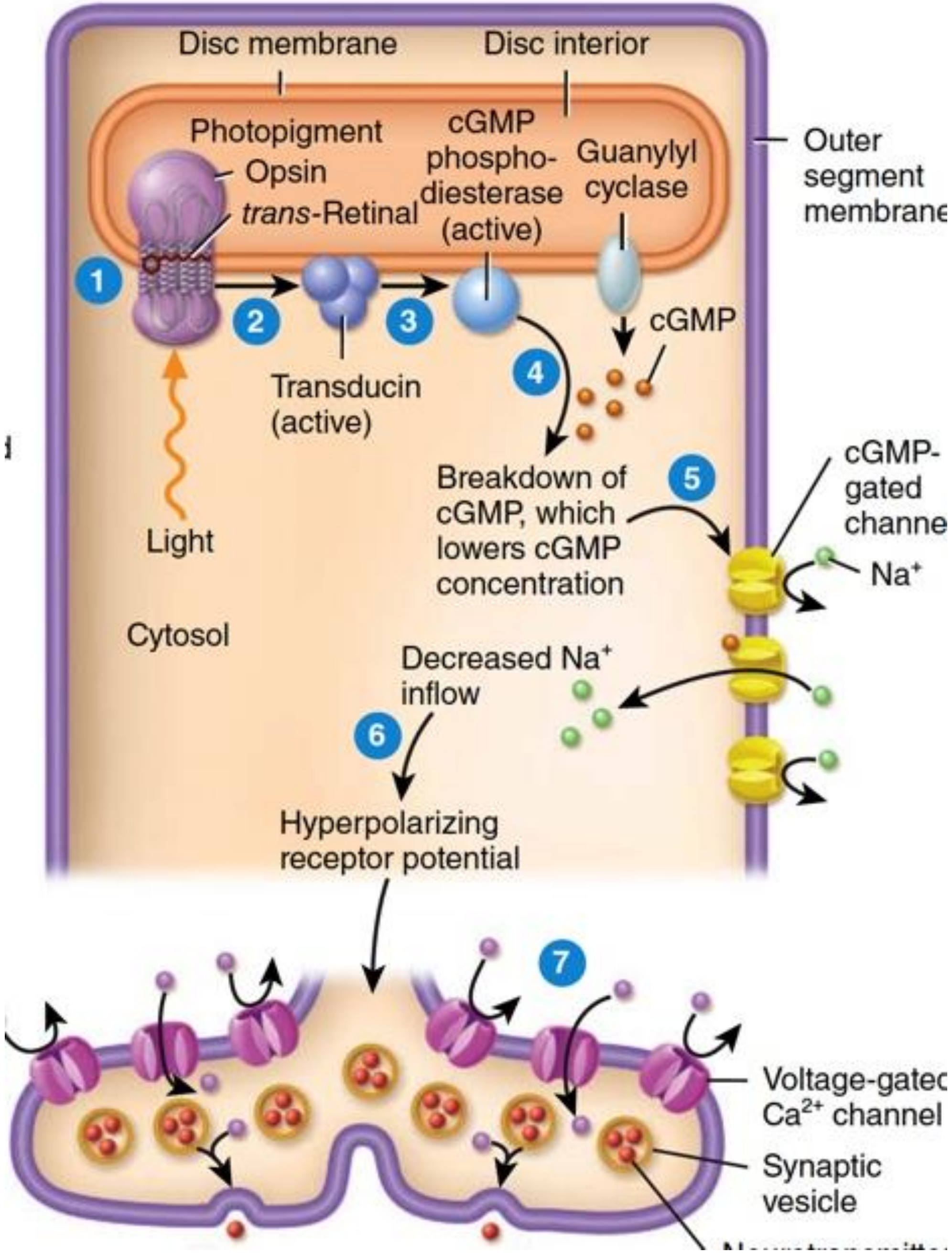
2- cis retinal (vitamin A derivative), cis means has a bent shape.



We will talk about this rod
In the outer segment there are cGMP gated sodium channels.

This cell is in a resting state, it has abundant of cyclic GMP, cGMP activates the gated sodium channels, so Na+ enters and causes depolarization, which activates Ca+2 gated channels in synaptic terminals. Ca+2 gated channels release neurotransmitters from the vesicles that activate first order neurons, then second order, the signal reaches the visual cortex, so action potential happens.

Action potential means no light no stimulus!!



- When there's a stimulus (light) retinal changes from cis to trans configuration (becomes straight), so retinal desperate from scotopsin and activates transducin.

- This activation in different cascades will decrease cGMP, so Na+ channels will be blocked then there is no Ca+2 as well as no action potential, **hyperpolarization happens**, and the cortex recognizes that there's a stimulus/light.

- We said receptor potential isn't the same as action potential. Receptor potential has just two states: depolarization and hyperpolarization not as an action potential.

- The potential of stimulated photoreceptors is hyperpolarization.
- When light exists = no neural signal !!

Pigment

- The black pigment melanin in the pigment layer prevents light reflection throughout the eyeball, which is extremely important for clear vision.
- Why do swe have a pigmented layer ?

For light absorption. We talked previously about transparent structures that refract light, so we need solid-colored structures, which can absorb or refract the light. If there is no pigment as in albinism, there is no absorption and there is just refraction so light is scattered everywhere.

- Patients with albinism have difficulty and get annoyed by the sunlight and images don't reach their cortex acutely because the light is everywhere. Iris is also pigmented to absorb light and prevent entering of excess amount of light to prevent scattering. When the iris is not highly pigmented light scattering happens.

Vitamin A

- The pigment layer also stores large quantities of vitamin A. That is exchanged back and forth through the cell membranes of the outer segments of the rods and cones, which are embedded in the pigment.

- vitamin A is an important precursor of the photosensitive chemicals of the rods and cones. (vitamin A derivative is also important to regenerate photosensitive materials in the pigmented layer)

- Night blindness

Fovea

- Light must pass through the ganglion and bipolar layers before reaching the photoreceptors in all areas of the retina except the fovea, located in the center of the retina.

- Because of this feature, and because only cones (which have greater acuity or discriminative ability than the rods) are found here, the fovea is the point of most distinct vision.

•Let's say the pigments are normal.. when light passes some signals may be lost in this area, so the image is not highly acute.
•This problem doesn't happen at the retina center where retinal thickness decreases, so the image looks highly acute and clear.

Fovea

- The fovea is a minute area in the center of the retina, especially capable of acute and detailed vision.

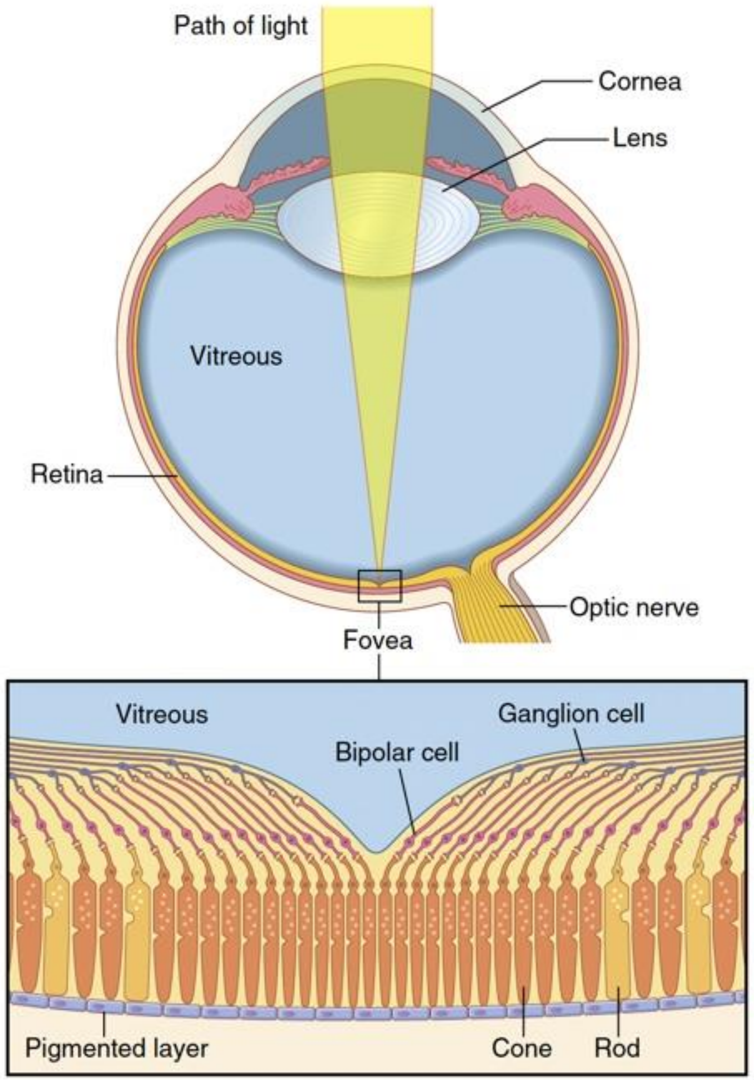
- The central fovea is composed almost entirely of cones. These cones have a special structure that aids their detection of detail in the visual image—that is, the foveal cones have especially long and slender bodies, in contradistinction to the much fatter cones located more peripherally in the retina.

- Also, in the foveal region, the blood vessels, ganglion cells, inner nuclear layer of cells, and plexiform layers are all displaced to one side rather than resting directly on top of the cones, which allows light to pass unimpeded to the cones.

-Cones are specific since it directly contact with light and each single cone spread signal to one single neural cell then reach cortex.
فبقدر أعرف نقطة الرؤية بالزبط

-Rods are sensitive not specific.

Any light in the dark will be detected by rods, and group of rods will synapse with a single neuron.
So, this causes sensitivity.
-In the periphery of the retina there are more rods and less cones
-Cones are more elongated and have smaller size.



The light should cross the neural cells that do synapse until arriving photoreceptors and then transmitted into neural signal.

-In the fovea light goes directly to photoreceptors while other retinal parts are displaced.
-Fovea has just cones not rods.

Cones differ from rods since it's more specific to coloured vision.
-Cones are specialized to bright light while rods concerned about dim light.

-Rods detect black and white light.

Macula

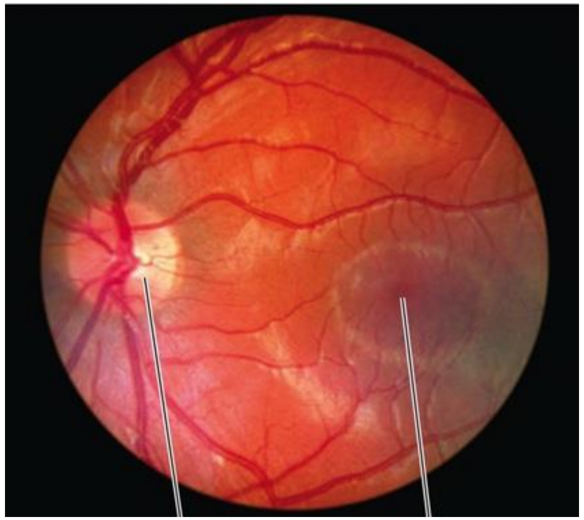
- The area immediately surrounding the fovea is called the macula lutea, has a high concentration of cones and fairly high acuity.

The Image in the center usually has the clearest vision because it's related to the fovea where cones are concentrated.

- Macular acuity is less than that of the fovea because of the overlying ganglion and bipolar cells in the macula.

- Macular degeneration.

The area around the fovea is called macula, but it's degenerated with aging.



This picture represents macular degenerating with age which is loss of vision in the center.

(Donut shape Loss vision with age)

Photoreceptors

- The light-sensitive photochemical is found in the outer segment. In the case of the rods, this photochemical is rhodopsin; in the cones, it is one of three color pigments, that function almost exactly the same as rhodopsin except for differences in spectral sensitivity.
- In the outer segments of the rods and cones, note the large numbers of discs. Each disc is actually an infolded shelf of cell membrane. There are as many as 1000 discs in each rod or cone.

Photoreceptors

- The inner segment of the rod or cone contains the usual cytoplasm, with cytoplasmic organelles. Especially important are the mitochondria, which play the important role of providing energy for function of the photoreceptors.

- The synaptic body is the portion of the rod or cone that connects with subsequent neuronal cells, the horizontal and bipolar cells, which represent the next stages in the vision chain.

Photoreceptors

- Both rhodopsin and the color pigments are conjugated proteins. They are incorporated into the membranes of the discs in the form of transmembrane proteins.

- The concentrations of these photosensitive pigments in the discs are so great that the pigments themselves constitute about 40% of the entire mass of the outer segment.

Photo-transduction

- The outer segment of the rod that projects into the pigment layer of the retina has light-sensitive pigment called rhodopsin.

- This substance is a combination of the protein scotopsin and the carotenoid pigment retinal.

- Furthermore, the retinal is a particular type called 11-cis retinal. This cis form of retinal is important because only this form can bind with scotopsin to synthesize rhodopsin.

Re-formation

- The first stage in re-formation of rhodopsin is to reconvert the all-trans retinal into 11-cis retinal.
- This process requires metabolic energy and is catalyzed by the enzyme retinal isomerase.
- Once the 11-cis retinal is formed, it automatically recombines with the scotopsin to re-form rhodopsin, which then remains stable until its decomposition is again triggered by absorption of light energy.

Cones

- photochemicals in the cones have almost exactly the same chemical composition as that of rhodopsin in the rods.

- The only difference is that the protein portions, or the opsins—called photopsins in the cones—are slightly different from the scotopsin of the rods.

- The retinal portion of all the visual pigments is exactly the same in the cones and rods.

اللهم إنا نسألك أن تفرّج كرب أهل غزة ,اللهم أطعم جائعهم واشف مريضهم وتقبل شهداءهم وانصرهم على من عاداهم.

VERSIONS	SLIDE #	BEFORE CORRECTION	AFTER CORRECTION
V1→ V2			
V2→V3			

امسح الرمز و شاركنا بأفكارك لتحسين أدائنا !!