بسم الله الرحمن الرحيم

DOPAMINE SCIENTIFIC TEAM

Vision (Pt.2)

MID | Lecture 6

﴿إِنِّي تَوَكَّلْتُ عَلَى اللَّهِ رَبِّي وَرَبِّكُمْ ۚ مَّا مِن دَابَّةٍ إِلَّا هُوَ آخِذٌ بِنَاصِيَتِهَا ۚ إِنَّ رَبِّي عَلَىٰ صِرَاطٍ مُّسْتَقِيمٍ﴾

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Saleh Al-Naji

Reviewed by: Omar Ibrahim

PHYSIOLOGY

رحلة اليقين مع سورة يس

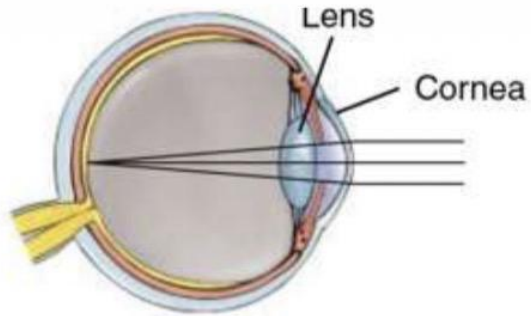
بِسۡمِ ٱللَّهِ ٱلرَّحۡمَٰنِ ٱلرَّحِيمِ

* وَمَآ أَنزَلۡنَا عَلَىٰ قَوۡمِهِۦ مِنۢ بَعۡدِهِۦ مِن جُندٖ مِّنَ ٱلسَّمَآءِ وَمَا كُنَّا مُنزِلِينَ ﴿٢٨﴾ إِن كَانَتۡ إِلَّا صَيۡحَةٗ وَٰحِدَةٗ فَإِذَا هُمۡ خَٰمِدُونَ ﴿٢٩﴾
يَٰحَسۡرَةً عَلَى ٱلۡعِبَادِۚ مَا يَأۡتِيهِم مِّن رَّسُولٍ إِلَّا كَانُواْ بِهِۦ يَسۡتَهۡزِءُونَ ﴿٣٠﴾

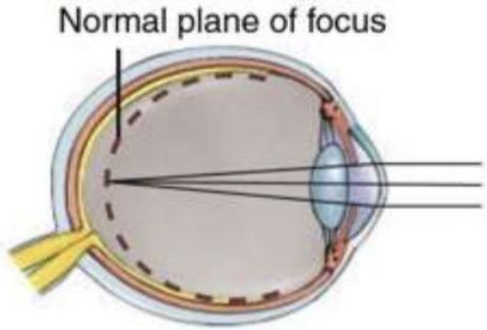
قال الله تعالى في عقوبة أولئك القوم الذين كذبوا الرسل: {وَمَا أَنْزَلْنَا عَلَى قَوْمِهِ مِنْ بَعْدِهِ مِنْ جُنْدٍ مِنَ السَّمَاءِ} أي: ما احتجنا أن نتكلف في عقوبتهم، فننزل جندا من السماء لإتلافهم، {وَمَا كُنَّا مُنْزِلِينَ} لعدم الحاجة إلى ذلك، وعظمة اقتدار الله تعالى، وشدة ضعف بني آدم، وأنهم أدنى شيء يصيبهم من عذاب الله يكفيهم.

{إِنْ كَانَتْ} أي: كانت عقوبتهم {إِلَّا صَيْحَةً وَاحِدَةً} أي: صوتا واحدا، تكلم به بعض ملائكة الله، {فَإِذَا هُمْ خَامِدُونَ} قد تقطعت قلوبهم في أجوافهم، وانزعجوا لتلك الصيحة، فأصبحوا خامدين، لا صوت ولا حركة، ولا حياة بعد ذلك العتو والاستكبار، ومقابلة أشرف الخلق بذلك الكلام القبيح، وتجبرهم عليهم.

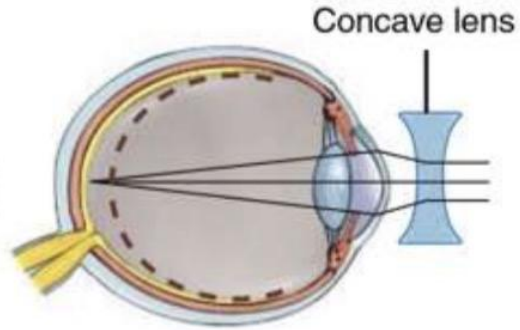
قال الله تعالى: {يَا حَسْرَةً عَلَى الْعِبَادِ مَا يَأْتِيهِمْ مِنْ رَسُولٍ إِلَّا كَانُوا بِهِ يَسْتَهْزِئُونَ} أي: ما أعظم شقاءهم، وأطول عناءهم، وأشد جهلهم، حيث كانوا بهذه الصفة القبيحة، التي هي سبب لكل شقاء وعذاب ونكال.



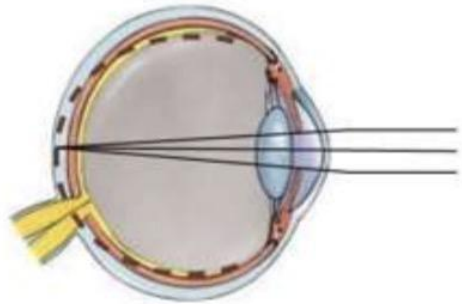
(a) Normal (emmetropic) eye



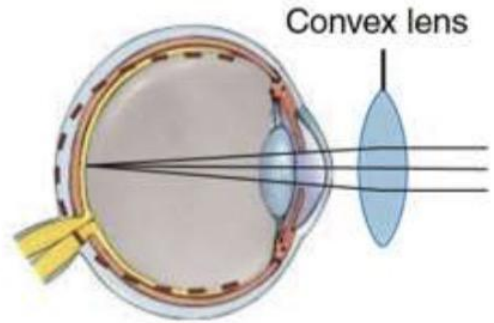
(b) Nearsighted (myopic) eye, uncorrected



(c) Nearsighted (myopic) eye, corrected



(d) Farsighted (hyperopic) eye, uncorrected



(e) Farsighted (hyperopic) eye, corrected

Refractory Abnormalities

- In patients with refractive errors, vision is impaired because the focal point of light does not fall exactly on the retina.

- In uncorrected myopia, the focal point of convergent light falls in front of the retina, often due to a genetically longer eyeball. As a result, patients see distant objects poorly. Concave lenses are prescribed to diverge the light rays, shifting the focal point onto the retina. Lens power is adjusted according to the degree of myopia.

- In uncorrected hyperopia, the focal point of light falls behind the retina, often because the eyeball is shorter than average. With aging, the eye's refractive power may decrease, making distant and near vision worse. Convex lenses are used to converge the light rays, bringing the focal point onto the retina and improving vision.

Near vision

The eye normally undergoes multiple adaptations in order to visualize near objects in the best accuracy and details possible, these include:

- Accommodation
- Pupillary constriction
- Convergence

Near vision response triad: *-To be discussed thoroughly in the upcoming slides-*

- **Accommodation (parasympathetic)** → ciliary muscle contracts → lens curvature increases to focus divergent rays
- **Pupillary constriction (parasympathetic)** → increases depth of focus
- **Convergence** → ensures both eyes fixate on the same near target

Near vision (Accommodation)

- The cornea provides about 75% of the eye's refractive power, while the lens contributes the remaining 25%. Although the lens contributes less overall, it is crucial for adjusting focus on objects at different distances – a process called accommodation. The lens is almost flat at rest and is held by suspensory ligaments (Zonular fibers).

- For distant objects, the light rays are almost parallel, so the lens remains flatter and no major adjustment is needed to focus light on the retina.

- For near objects, the light rays are divergent, so a flat lens cannot focus them. To solve this, the lens increases its curvature (becomes more spherical) by the contraction of the cilliary muscle, increasing its refractive power and converging the light onto the retina, producing a clearer image. A mechanism called **accommodation**.

- Thus, the lens curvature is considered changeble – flatter for far vision and more curved for near vision – to maintain clear vision at all distances.

Decrease in Accommodation

- Unfortunately, this ability decreases with aging because the lens loses elasticity due to protein denaturation and loss of elastic fibers. As a result, the lens cannot change its curvature effectively, leading to a loss of accommodation.

- In children, the lens can change its refractive power by up to 14 diopters, but this capacity declines gradually with age. By around 70 years old, the lens may have no accommodation, meaning the focal point is fixed and cannot adjust for near objects. This is why older adults often require bifocal glasses – the top part for distance vision and the bottom part for near vision. This age-related decrease in accommodation is called **presbyopia**, typically noticeable after 45 years of age.

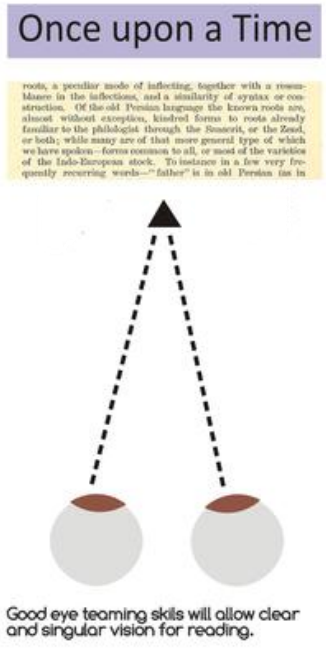
Near vision (Convergence)

- **Binocular vision** occurs because the central visual fields of both eyes overlap. The brain compares the two slightly different images and fuses them, allowing **depth perception** and accurate estimation of object distance for objects located centrally.

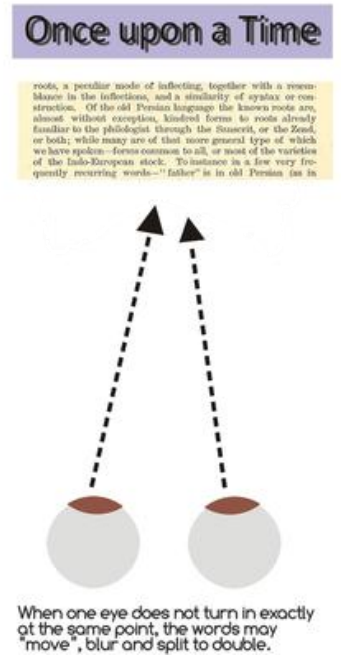
- The **fovea of each retina represents corresponding retinal points.** When light from the same object falls on corresponding points (Foveas) in both eyes, the visual cortex fuses the images into a single perception, yielding a higher resolution of that object.

- If images fall on **non-corresponding retinal points (parts of the retina other than the foveas)**, the brain cannot fuse them, resulting in **diplopia (double vision)**.

- For near objects, light rays are highly **divergent**, so without adjustment they would strike non-corresponding retinal areas. To prevent diplopia, the eyes perform **convergence** (bilateral medial rotation via medial rectus muscles) to align the image onto corresponding points.



Good eye teaming skils will allow clear and singular vision for reading.



When one eye does not turn in exactly at the same point, the words may "move", blur and split to double.

Accomodation

- 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.

Accomodation

- 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.

Accomodation

- Also located at the lateral attachments of the lens ligaments to the eyeball is the ciliary muscle.

- Contraction 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.

Accomodation

- Ciliary muscle is controlled almost entirely by parasympathetic nerve signals transmitted to the eye through the third cranial nerve from the third nerve nucleus in the brain stem.

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

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Accomodation

- 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.

Accomodation

- 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**.

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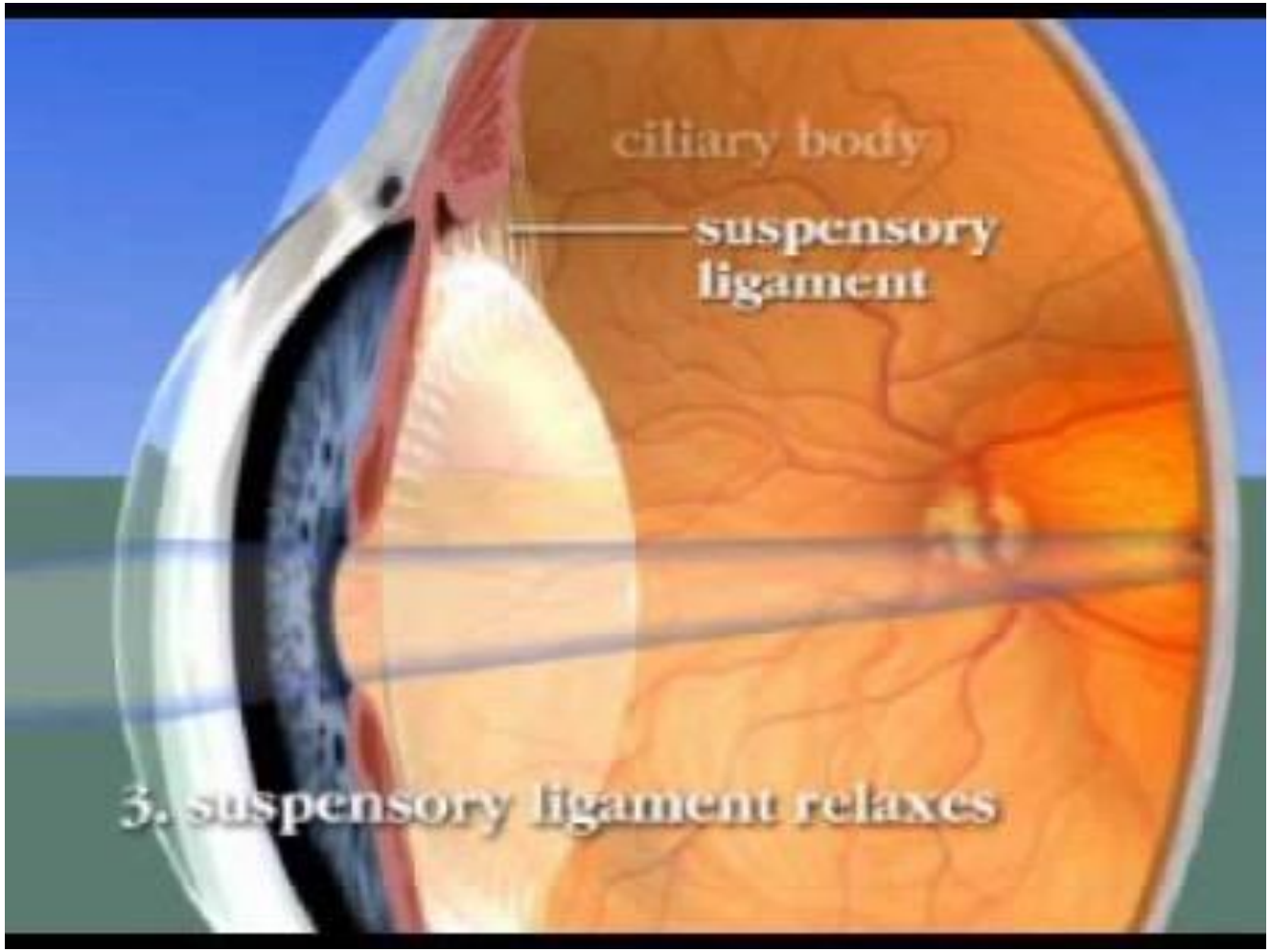
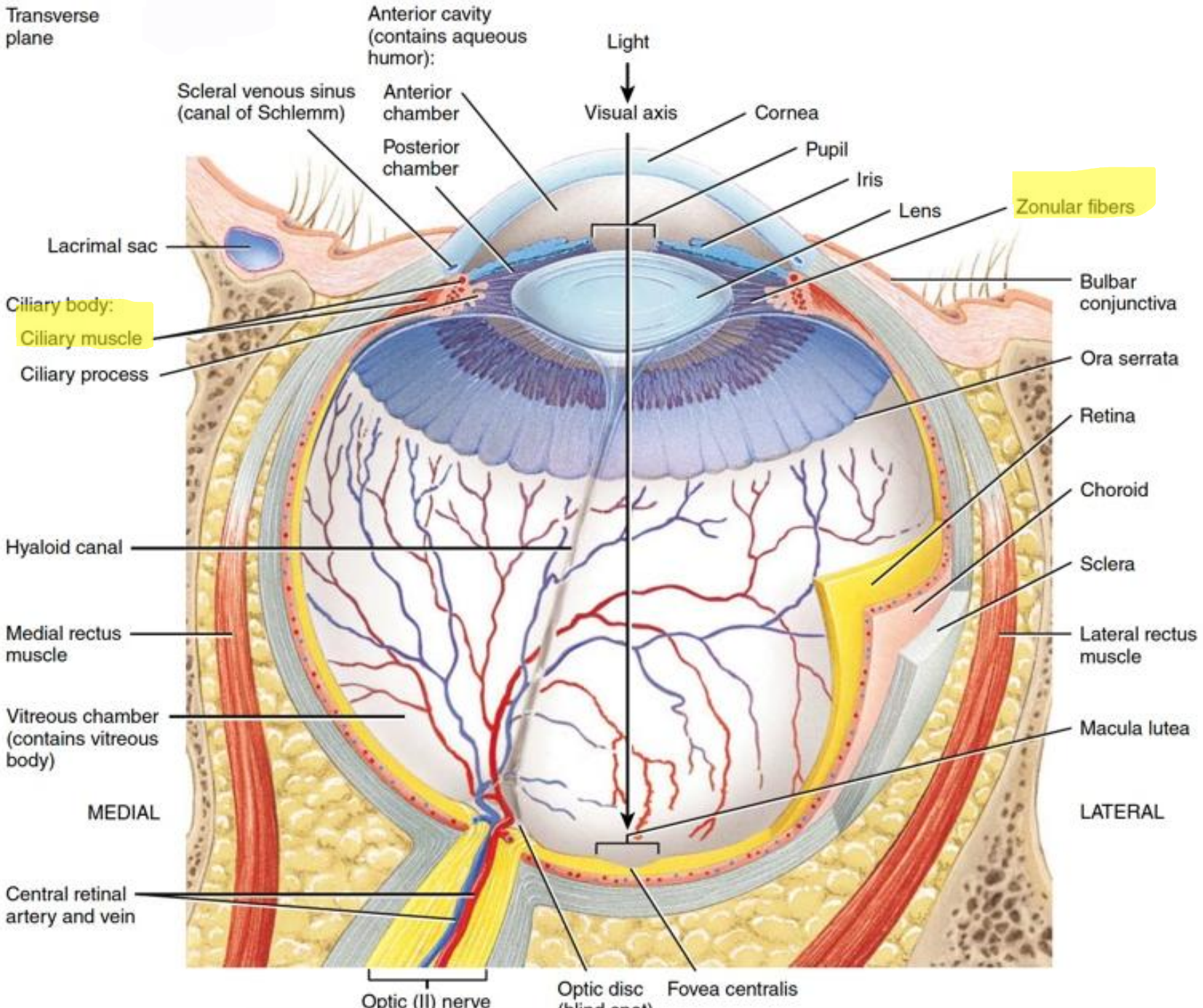
- Once a person has reached the state of presbyopia, each eye remains focused permanently at an almost constant distance; this distance depends on the physical characteristics of each person’s eyes.

- 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).



https://youtu.be/p_xLO7yxgOk

Watch this video to fully understand how the contraction of the ciliary muscles affects the curvature of the lens.



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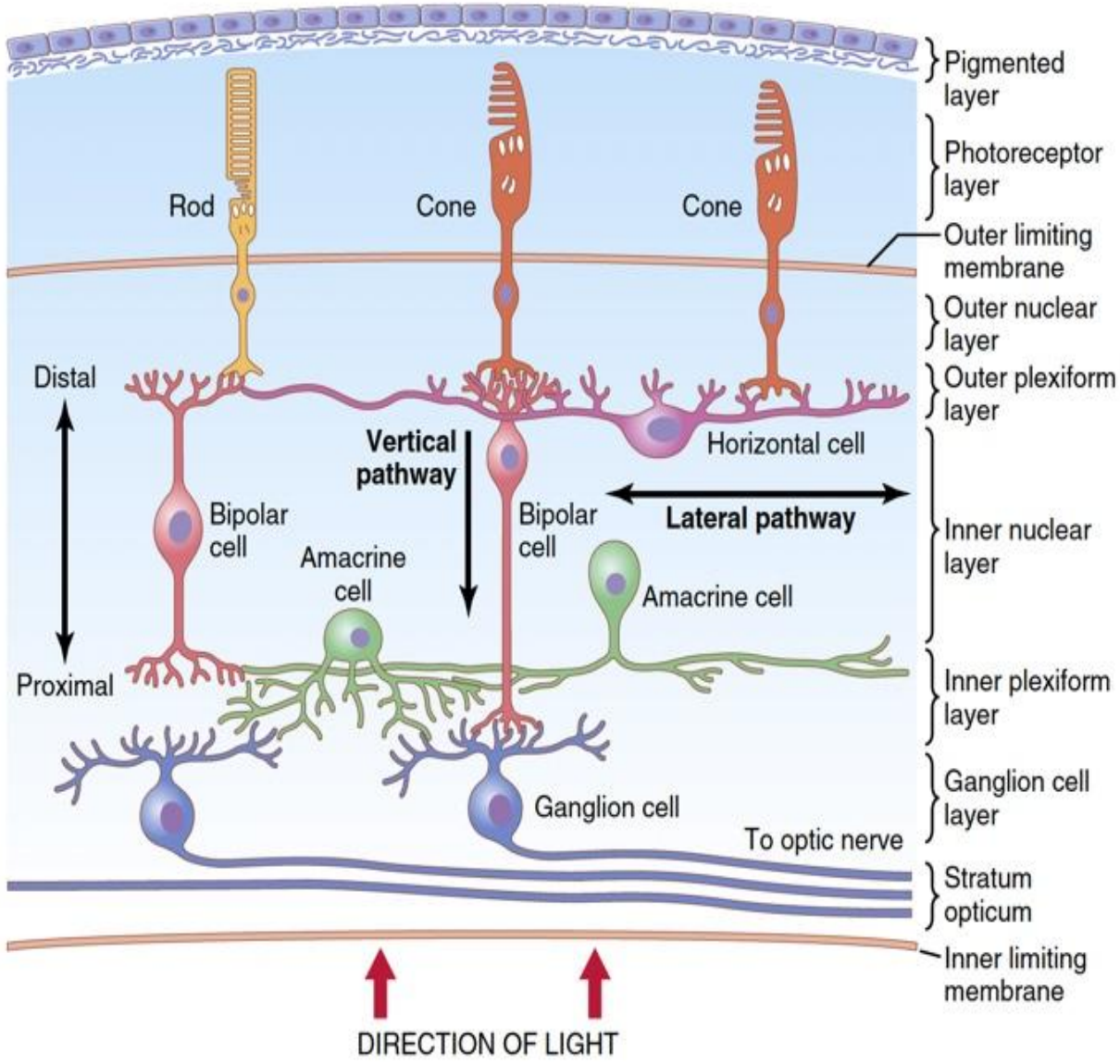
The retina

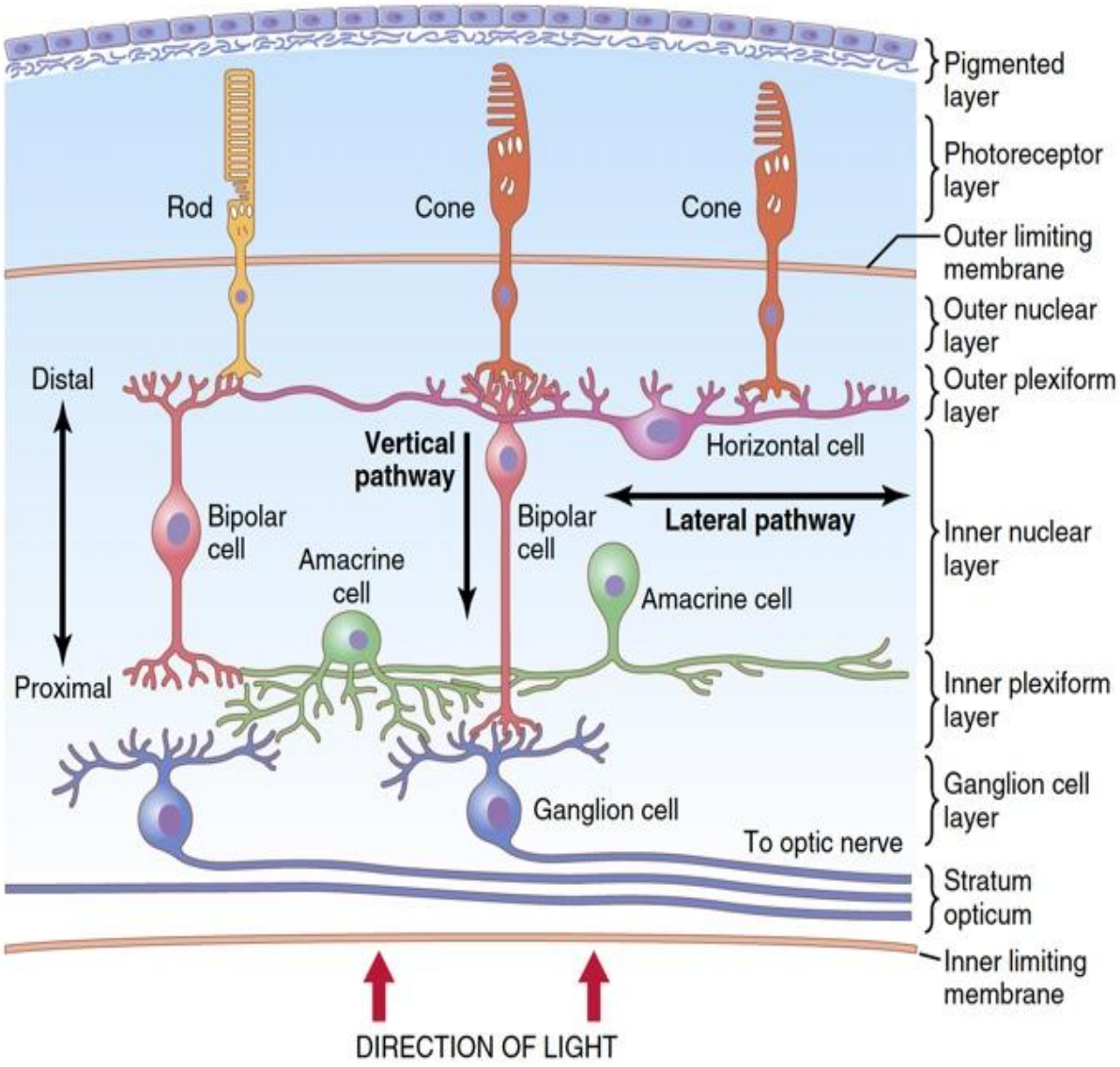
- After the light is refracted, it reaches the retina. The retina is composed of 10 layers with so many types of cells like neuronal cells, epithelial cells, vascular cells and glial cells all play a role in vision.



Layers of the retina

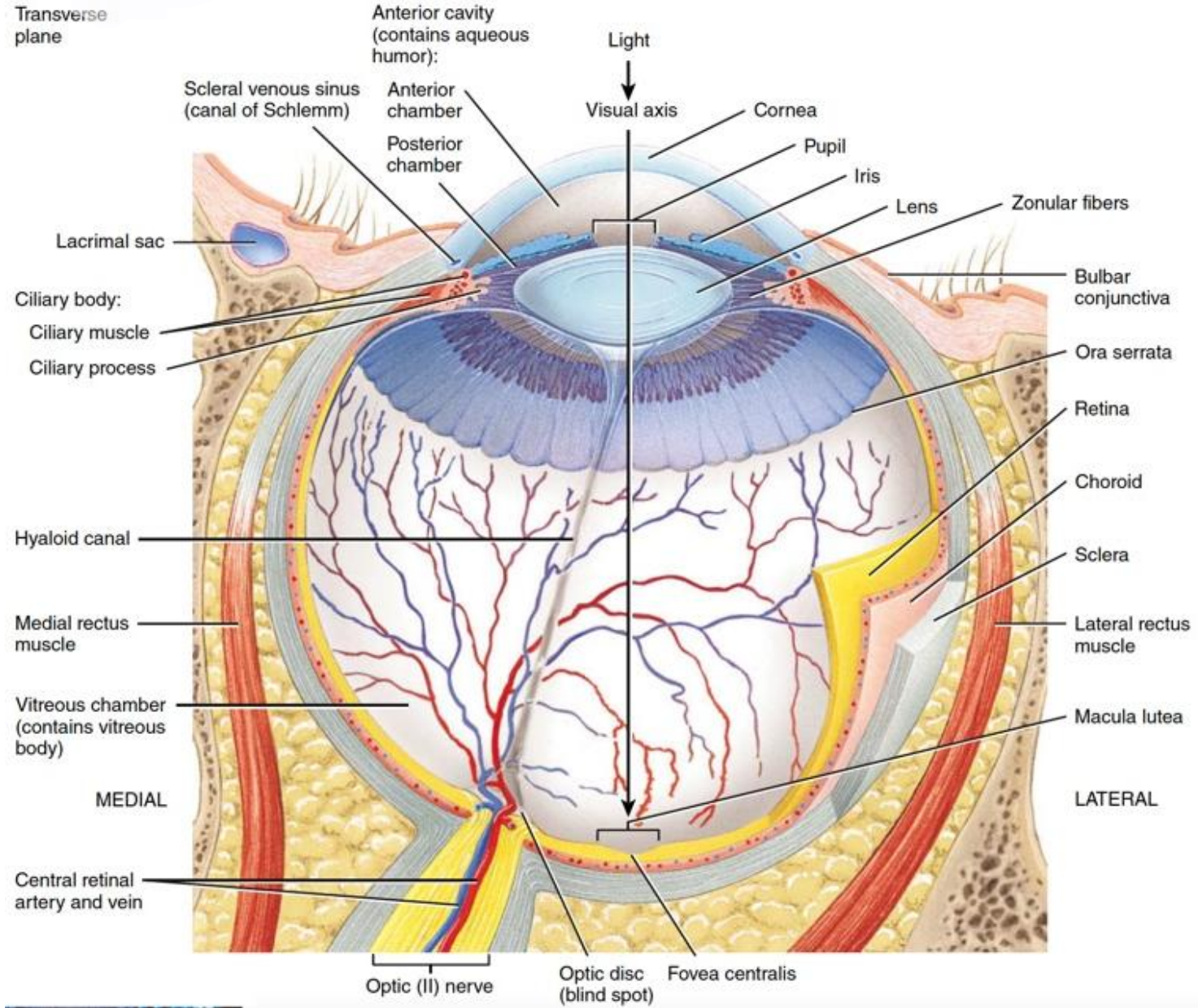
- The outermost layer of the retina is attached to the choroid (highly vascular and pigmented layer) and the innermost layer is in contact with the vitreous humor.
- The outermost layer is the pigmented layer (it is called pigmented since it contains melanin pigment) and it is very close to the photoreceptor layer, the pigmented layer stores vitamin A since inside the photoreceptors there are photopigment molecules which consists of opsin and retinal(vitamin A derivative) so photoreceptors need vitamin A for regeneration.
- The other function of the pigmented layer is to prevent the reflection of the light inside the eye by absorbing the light.
- People with albinism lack the ability to produce melanin, so when light enters their retina it gets reflected many times. This scattering of the light within the eyeball makes it difficult for them to see in bright light.

The Retina



➢ **Doctor's Notes:**

- The light rays passes through all layers of the retina to reach the photoreceptors (from inner -> outer surface of the neural layer); however, the neural signal is transmitted from the photoreceptor to the bipolar cells then to the ganglion cells that ultimately forms the optic nerve (from outer -> inner surface of the neural layer). So, **the light travels opposite to the signal pathway**.
- The nucleus of the photoreceptor is found under the outer limiting membrane that's why it is called outer nuclear layer.
- The synapse between the photoreceptor and the bipolar cell created a plexiform structure that's why it is called the outer plexiform layer.
- The inner nuclear layer where the bipolar cells are found.
- The synapse between the bipolar cells and the ganglion cells occurs in the inner plexiform layer.
- The bipolar cells one process synapse with the photoreceptor the other with the ganglion cell.
- There is horizontal modification of the signal by the horizontal cells found in outer plexiform layer and the amacrine cells in the inner plexiform layer.



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Photoreceptors

- The thickness of the retina is not uniform throughout the retina the thinnest area is called the **fovea**.
- In the human eye rods outnumber cons, there are relatively 100 to 500 million rods and 2 to 5 million cons in the retina.
- Cons are used for colored and detailed vision.
- Rods are used for dark and night vision doesn't give out detailed vision.

Rods vs Cones (Sensitivity vs Precision Systems)

➢ **Distribution difference:**

- Fovea → cone-dominated (detail).
- Periphery → rod-dominated (sensitivity).

➢ **Functional difference:**

- Cones operate in **bright light** and provide **high acuity** and **color vision**.
- Rods operate in **dim light** and **detect minimal illumination**.

➢ **Sensitivity difference:**

- Rods are **extremely sensitive** – even a single photon can trigger a receptor potential.
- Cones **require stronger illumination.**

➢ **Neural wiring difference:**

- Rods show **convergence** (many rods → one bipolar cell), **enhancing sensitivity but reducing spatial precision.**
- Cones have **minimal convergence**, **preserving spatial accuracy** but **lowering sensitivity**.

➢ **Functional trade-off:**

- Cones prioritize **precision and detail**.
- Rods prioritize **detection of faint light**, not image sharpness or details.

Fovea and Macula (Central Vision System)

➢ **The fovea is the point of maximal visual acuity:**

- It contains **almost exclusively cones**, and these cones are **thinner and more cylindrical** to allow extremely dense packing. This structural specialization maximizes spatial resolution.

➢ **Retinal layers are displaced laterally in the fovea:**

- Inner layers (bipolar and ganglion cells) are **pushed aside** so **light reaches the photoreceptors directly without scattering**. This minimizes optical distortion and preserves fine detail.

➢ **Cone-to-bipolar connection is nearly 1:1 :**

- Each cone has an almost independent pathway to the cortex, allowing **precise localization of stimulation. This is why central vision is sharp and detailed** when compared to peripheral vision.

➢ **The macula surrounds the fovea and supports central vision:**

- Age-related degeneration of this region (**macular degeneration**) selectively impairs central vision while peripheral vision is often preserved.

Try this experiment to test your blind spot

To find it, close your left eye, stare at the cross with your right eye, and move closer to the screen until the dot disappears.

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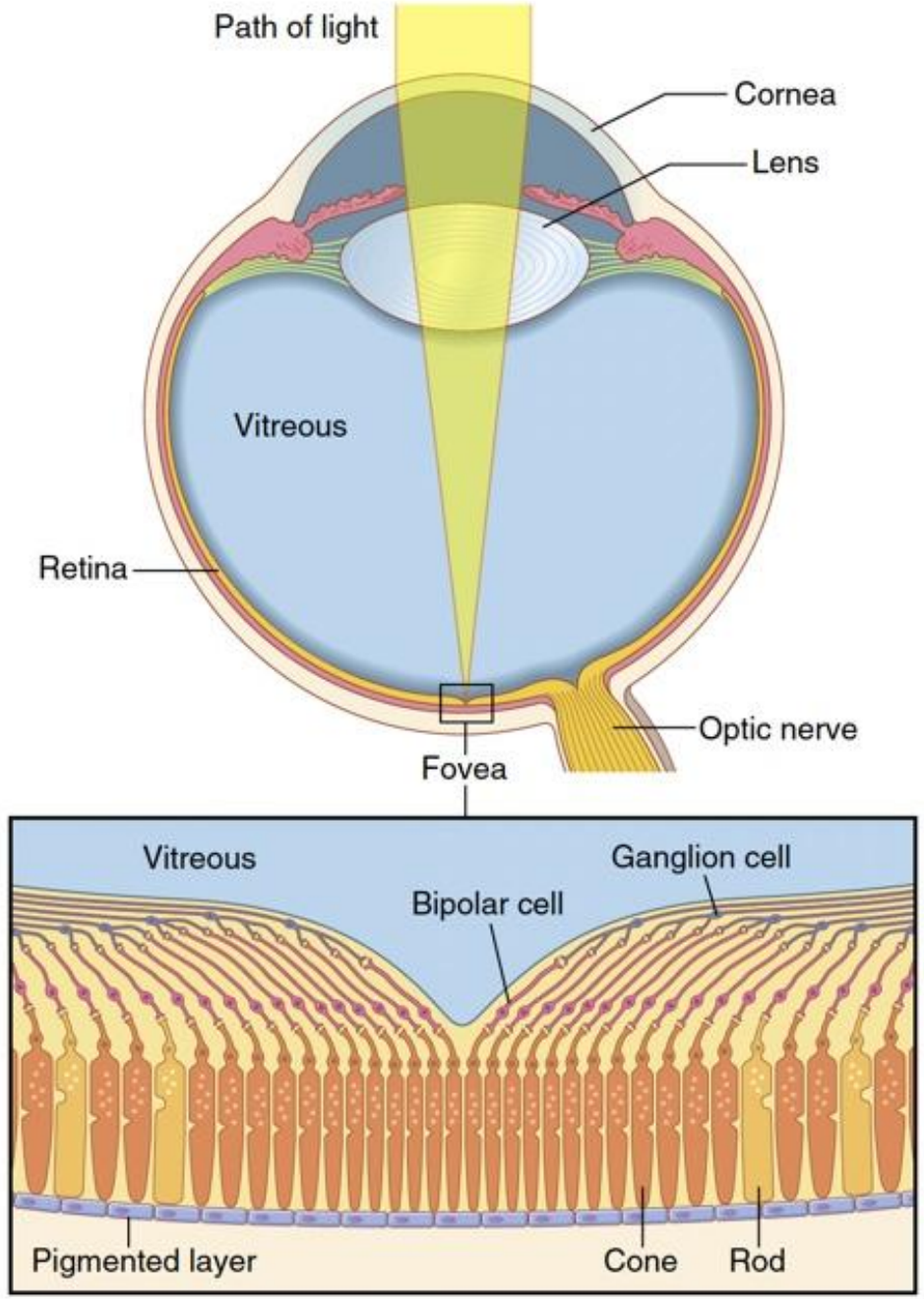

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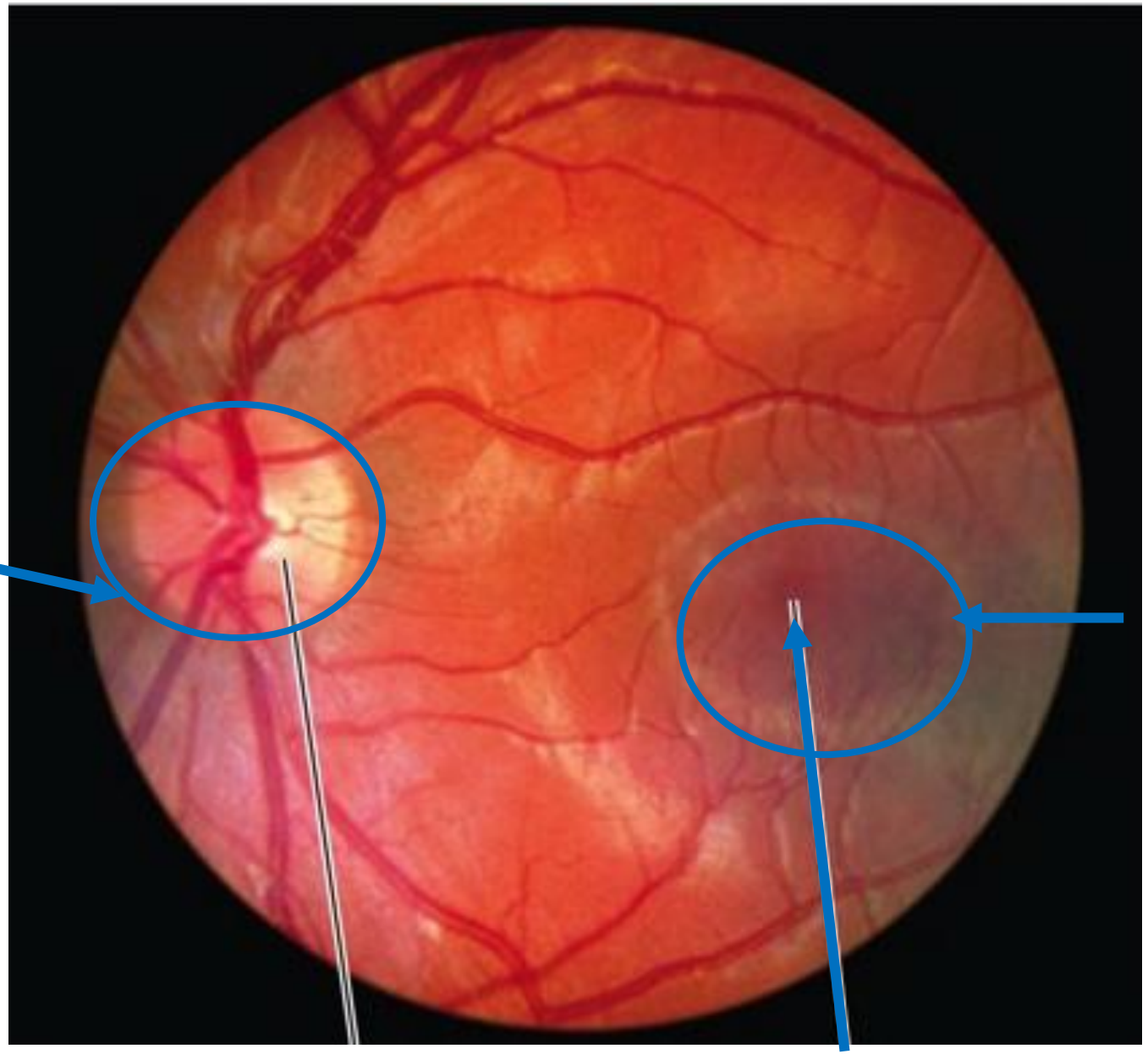


This is what we see through fundoscope.

Optic disc where the optic nerve fiber will pass.

macula

Fovea

الحمد لله الذي عافنا مما ابتلى به غيرنا وفضّلنا على كثيرٍ ممن خلق تفضيلًا

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.

Optic Disc and the Blind Spot

➢ **The optic disc contains no photoreceptors:**

- It is the point where optic nerve fibers exit the retina and where blood vessels enter and leave. Because there are no rods or cones in this region, light falling on it cannot be detected. This creates a physiological **blind spot**.

➢ **Why we normally do not perceive a blind spot:**

- Each eye has its own blind spot, but they are located in different positions in the visual field.
- Because of **binocular vision**, the visual field of one eye covers the blind spot of the other eye.

➢ **Cortical filling-in mechanism:**

- When visual information reaches the visual cortex, the brain integrates input from both eyes and “fills in” the missing area based on surrounding visual information. This creates the perception of a continuous, complete image.

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.

Fovea

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

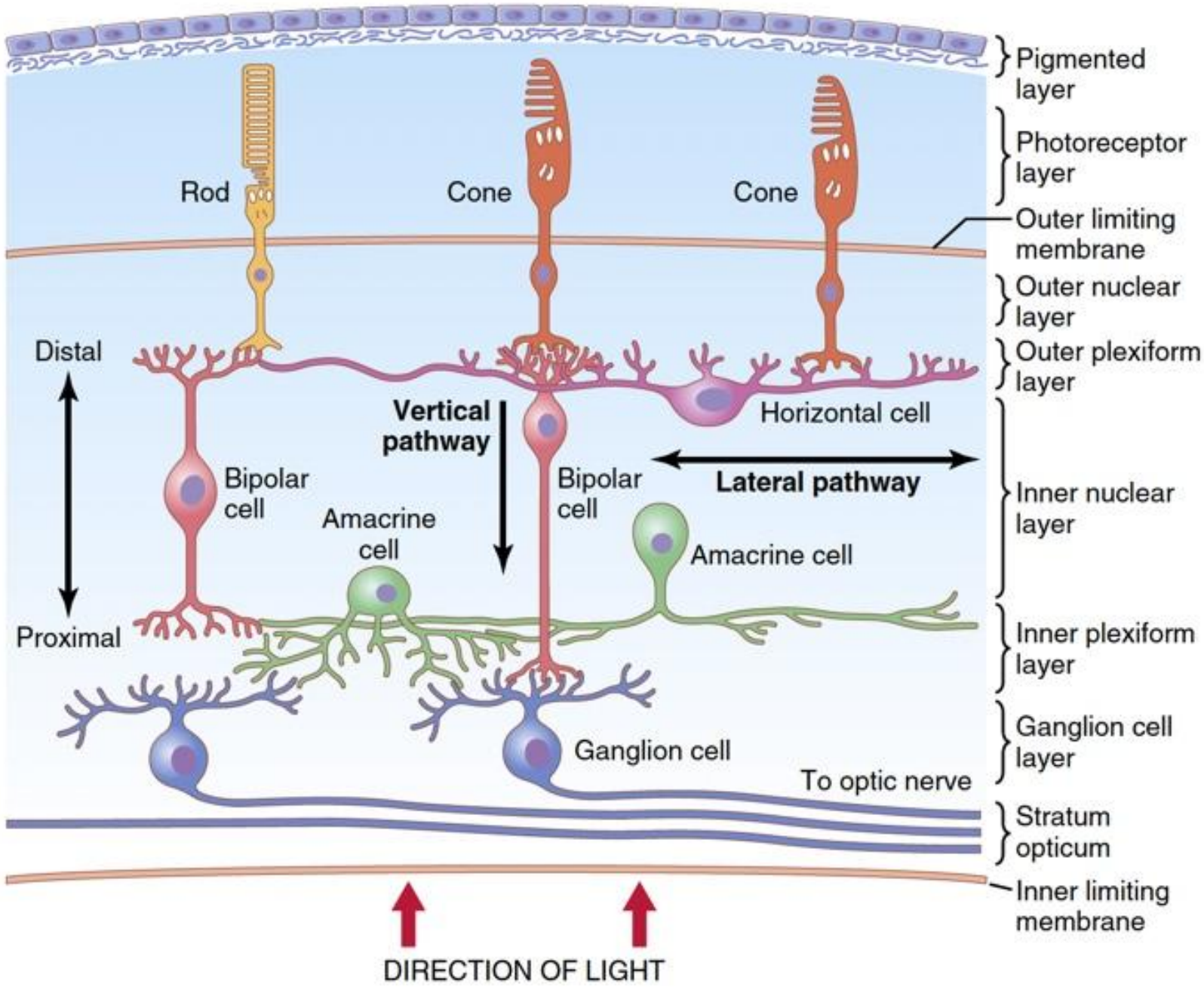
- The central fovea is composed almost entirely of cones. These cones have a special structure that aids their detection of detail in the visual image—that is, the foveal cones have especially long and slender bodies, in contradistinction to the much fatter cones located more peripherally in the retina.

Fovea

- 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.

Macula

- The area immediately surrounding the fovea is called the macula lutea, has a high concentration of cones and fairly high acuity.
- Macular acuity is less than that of the fovea because of the overlying ganglion and bipolar cells in the macula.
- Macular degeneration.


Pigmented layer
Photoreceptor layer
Outer limiting membrane
Outer nuclear layer
Outer plexiform layer
Inner nuclear layer
Inner plexiform layer
Ganglion cell layer
Stratum opticum
Inner limiting membrane
Rod
Cone
Cone
Distal
Proximal
Vertical pathway
Lateral pathway
Horizontal cell
Bipolar cell
Bipolar cell
Amacrine cell
Amacrine cell
Ganglion cell
To optic nerve
DIRECTION OF LIGHT

Pigment

- The black pigment melanin in the pigment layer prevents light reflection throughout the eye ball, which is extremely important for clear vision.

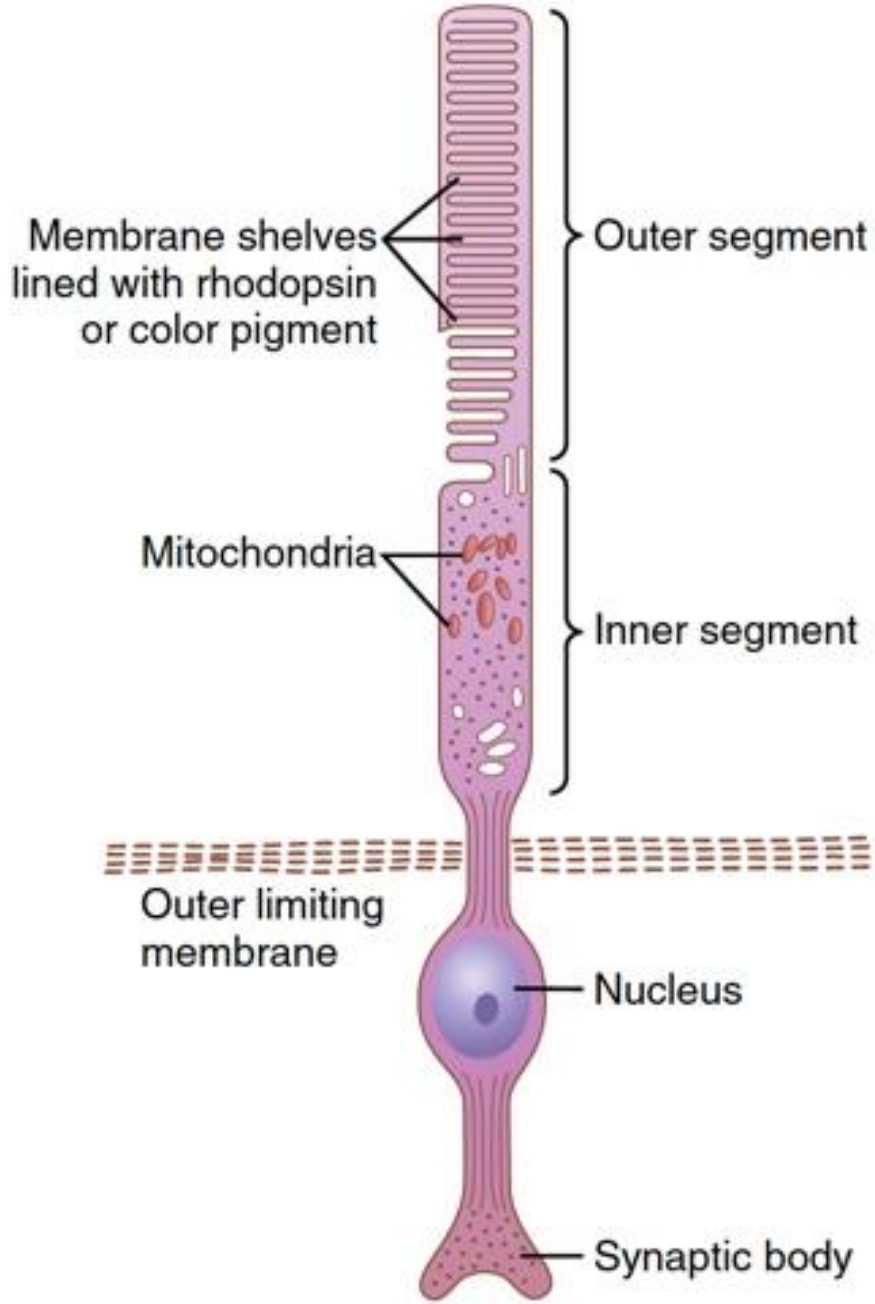
- Albinism

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.

- Night blindness



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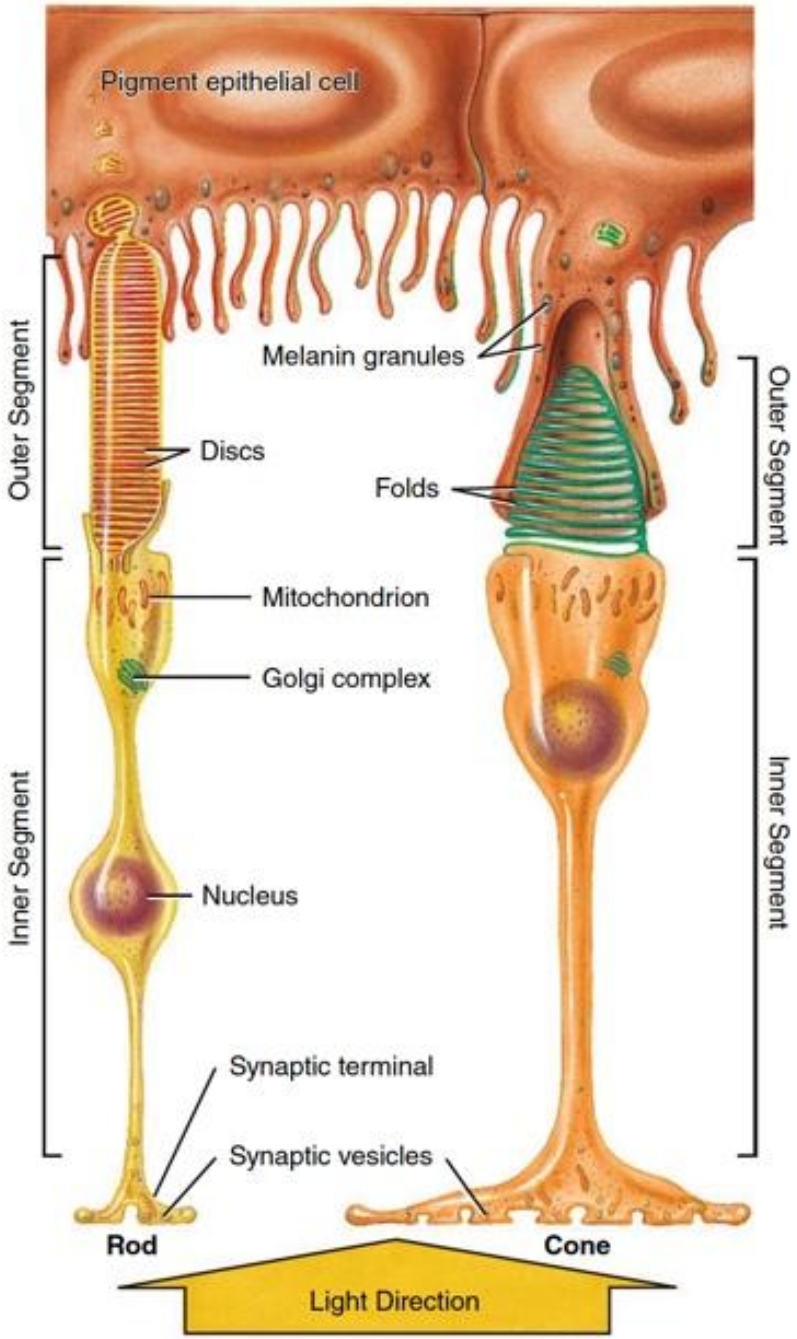
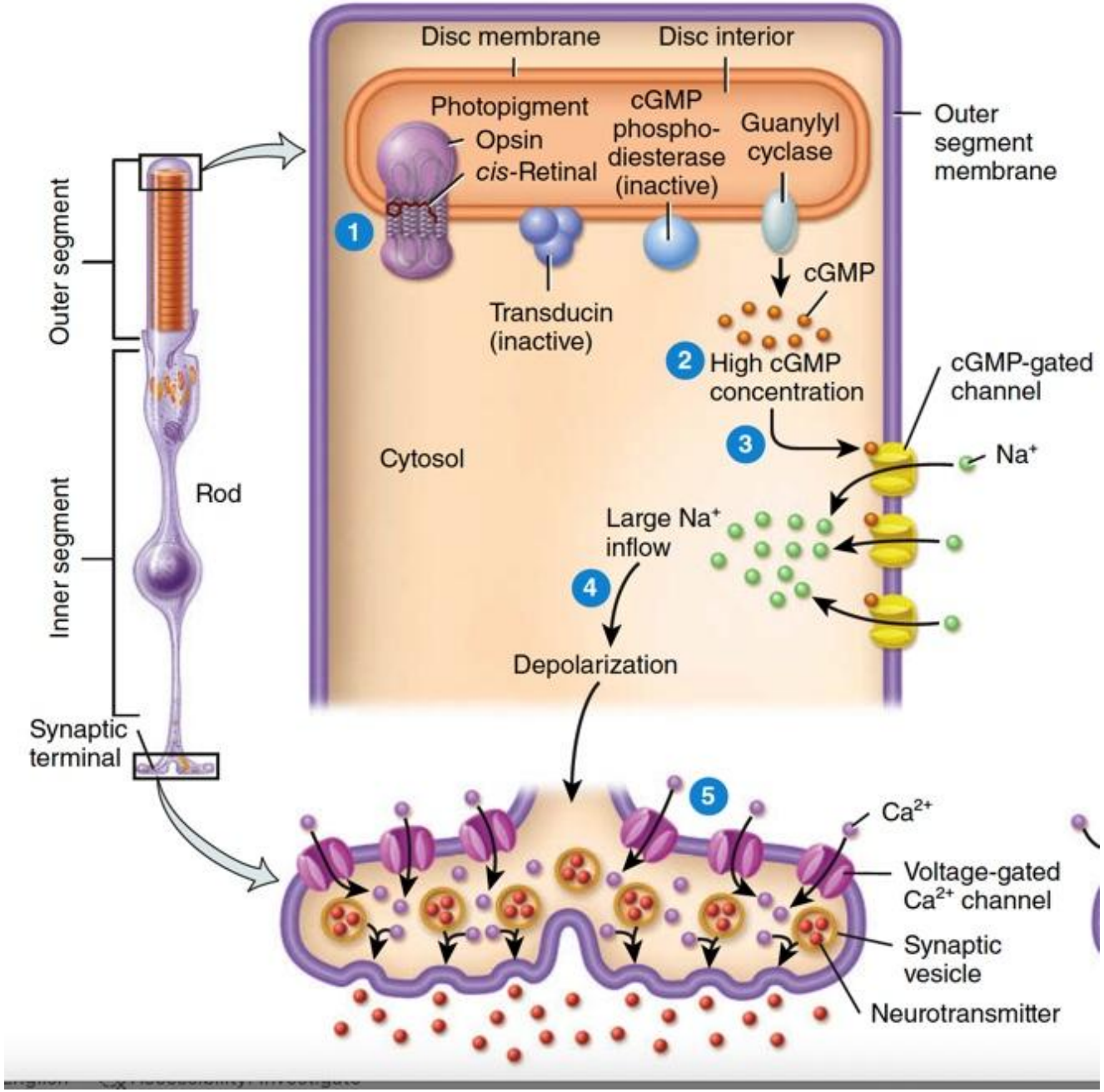
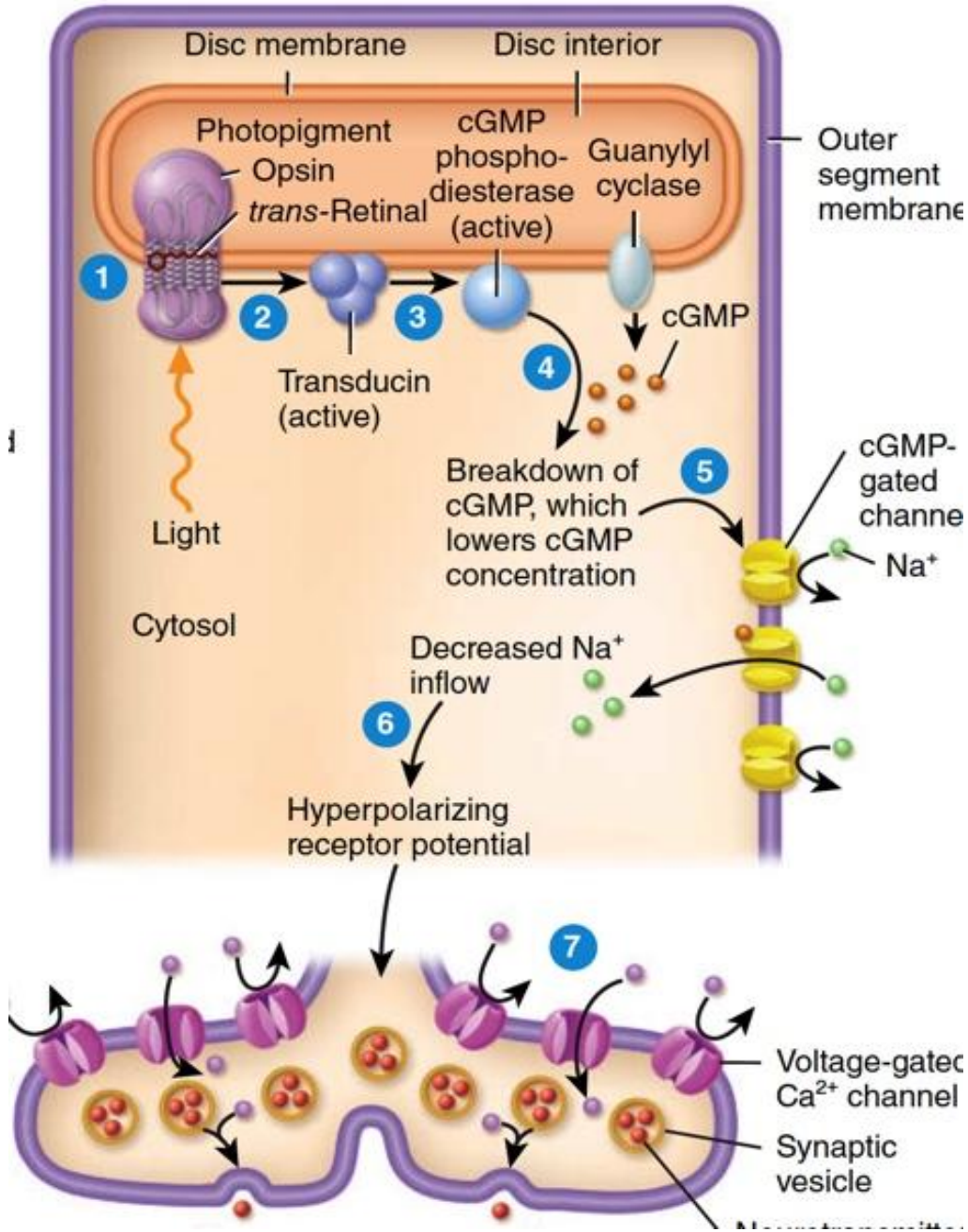


Rods vs cones:

shape
location
number
sensitivity to light
visual acuity
color vision



To be discussed in the upcoming slides



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Receptor Potential in Photoreceptors

➢ **Photoreceptors (rods and cones) have a hyperpolarizing receptor potential:**

- Unlike most sensory receptors, they become **more negative** when stimulated by light.

➢ **In darkness (no light stimulus):**

- cGMP levels are high.
- cGMP-gated Na^+ channels remain open.
- **The cell is relatively depolarized.**
- Glutamate is continuously released.

➢ **When light reaches the photoreceptor:**

- 11-cis retinal converts to all-trans retinal.
- Opsin undergoes a conformational change.
- The phototransduction cascade decreases cGMP.
- Na^+ channels close.
- **The cell becomes hyperpolarized.**
- Glutamate release decreases.

In a nutshell:

➢ Darkness → depolarization → continuous glutamate release

➢ Light → hyperpolarization → decreased glutamate release

Photoreceptor	Sensitivity to Light	Acuity	Dark Adaptation	Color Vision
Rods	Low threshold Sensitive to low-intensity light Night vision	Low acuity Not present on fovea	Adapt late	No
Cones	High threshold Sensitive to high-intensity light Day vision	High acuity Present on fovea	Adapt early	Yes

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.

Color vision

- Each photopigment maximally absorbs a particular wavelength but also absorbs a range of wavelengths shorter and longer than this peak absorption.

- The farther a wavelength is from the peak wavelength absorbed, the less strongly the photopigment responds.

- The absorption curves for the three cone types overlap so that two or three cones may respond to a given wavelength but to a different extent.

Colored vision

➢ **Color vision depends on cones, not rods:**

- Rods function in dim light and do not detect color.
- Color vision occurs in bright light and depends on three types of cones, each containing a different photopigment sensitive to different wavelengths of light.

➢ **Three Types of Cones:**

1) **S-cones (Blue cones)** → most sensitive to **short wavelengths** (~420 nm)
2) **M-cones (Green cones)** → most sensitive to **medium wavelengths** (~530 nm)
3) **L-cones (Red cones)** → most sensitive to **long wavelengths** (~560–590 nm)

- Each cone type responds to a *range* of wavelengths, not just one specific color. for example: L-cones (red cones) respond roughly between 480–680 nm, but their **maximum activation** occurs around ~590 nm.

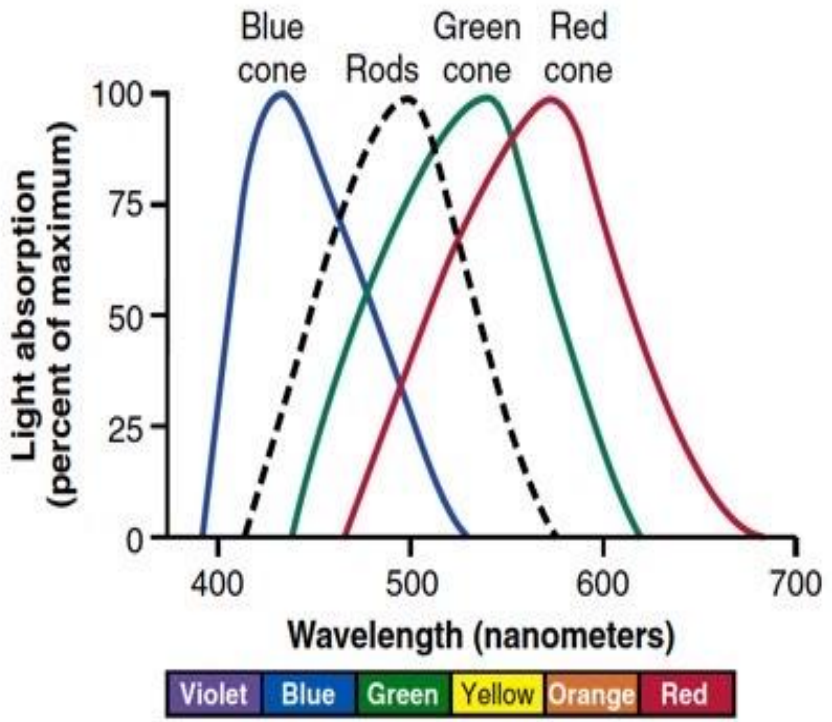
Colored vision

➢ Overlapping Sensitivity:

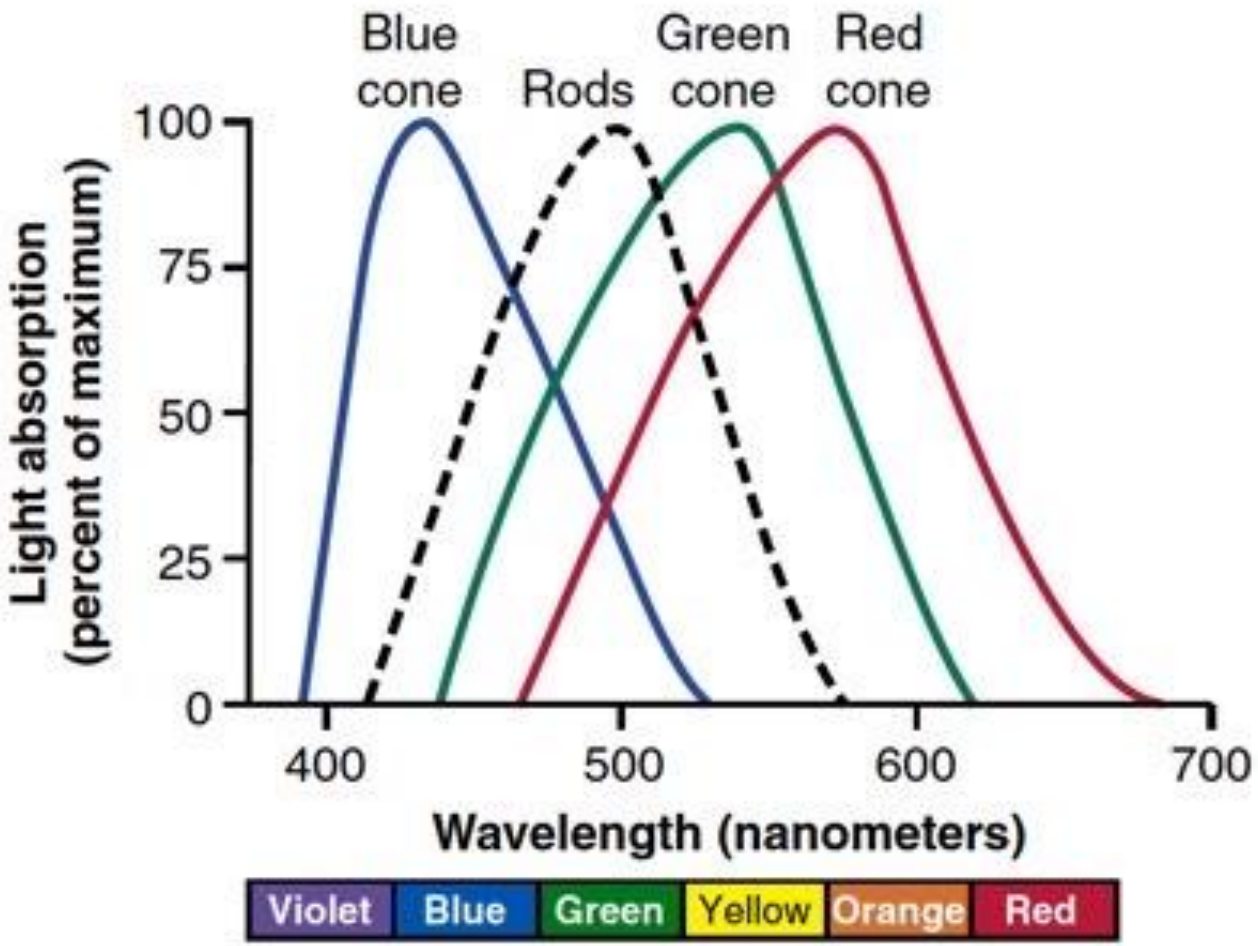
- The **sensitivity curves** of the three cone types **overlap**, this means that:
  - A single wavelength can stimulate more than one cone type
  - The brain does not interpret color based on one cone alone.
  - It compares the relative activation levels of all three cone types.

➢ Color Perception Is Based on Comparison:

- The visual cortex analyzes the ratio of stimulation between S, M, and L cones. For example:
  - Strong L + strong M stimulation → interpreted as **yellow**
  - Strong S stimulation → interpreted as **blue**
  - Equal activation of all three → perceived as **white**
  - Color is therefore determined by the **pattern of activity**, not by a single cone type.

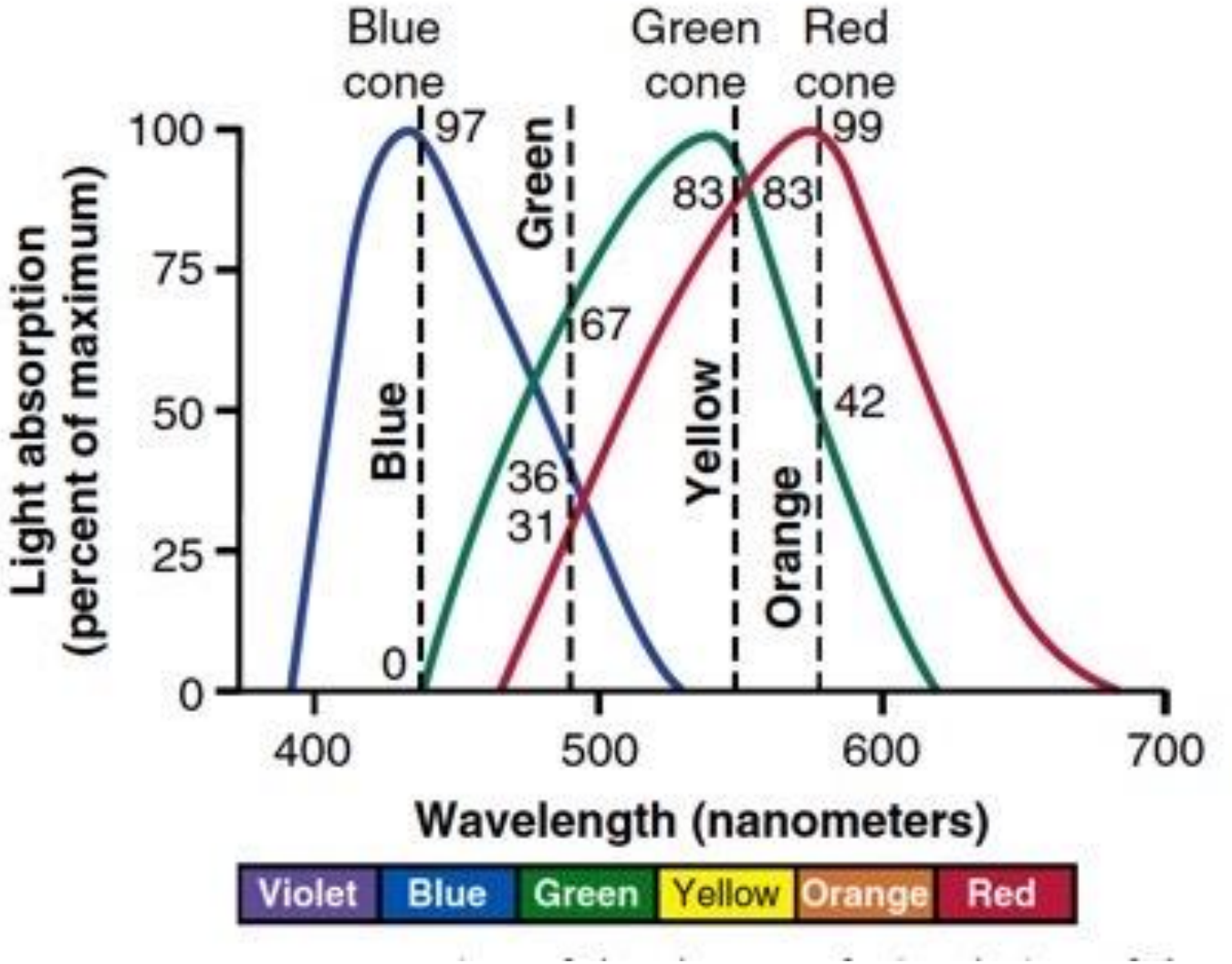


Color vision



Color vision

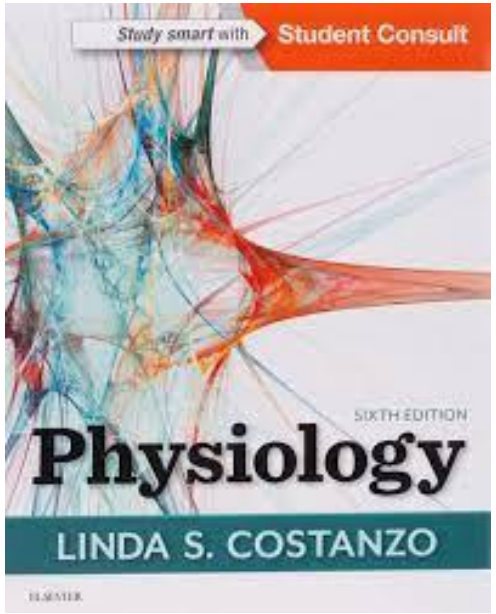
- Each cone type is most effectively activated by a particular wavelength of light in the range of color indicated by its name.
- cones also respond in varying degrees to other wavelengths.
- According to the trichromatic theory of color vision, the perception of the many colors of the world depends on the three cone types' various ratios of stimulation in response to different wavelengths.



the ratios of stimulation of the three types of cones.

About equal stimulation of all the red, green, and blue cones gives one the sensation of seeing white.

References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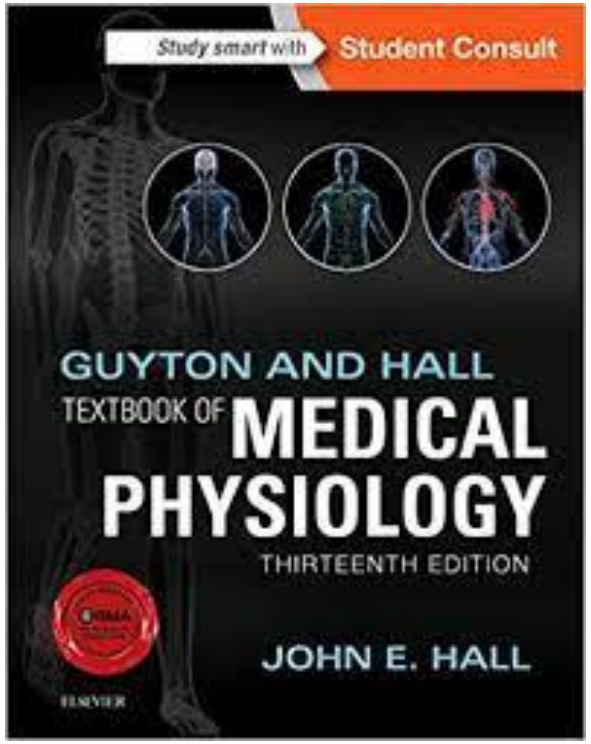
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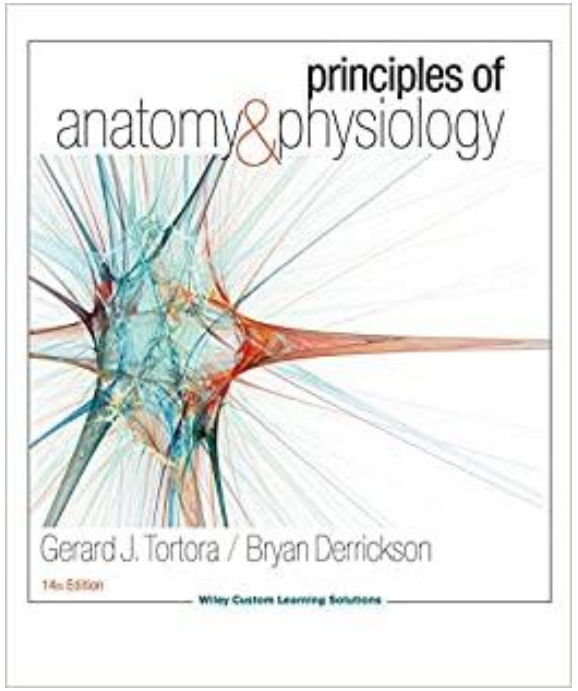
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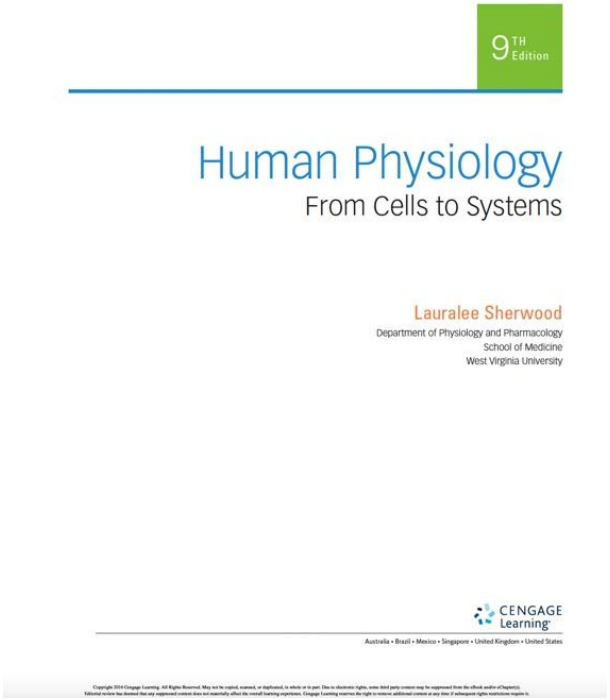
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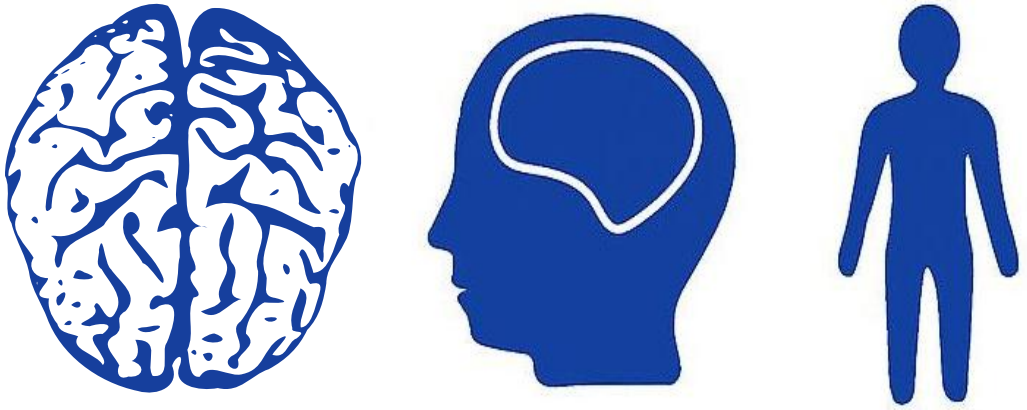

PHYSIOLOGY QUIZ LECTURE 6

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